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18. INTERNATIONAL CONFERENCE ON AGRICULTURE, ANIMAL SCIENCE & RURAL DEVELOPMENT

October 24-26, 2025
Necmettin Erbakan University
Ereğli, Konya, Türkiye

Editors
Prof. Dr. Yaşar KARADAĞ
Assoc. Prof. Dr. Seyithan SEYDOŞOĞLU

CONFERENCE PROCEEDINGS BOOK









18 th INTERNATIONAL CONFERENCE on AGRICULTURE, ANIMAL SCIENCE & RURAL DEVELOPMENT

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adopted by Mariam Rasulan

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(Abstracts & Full Texts)

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EVALUATION PROCESS and POLICIES

All applications have undergone double blind peer review process. In addition, each paper was accepted and the process of publishing in the book was carried out through editorial oversight. The published papers were presented and discussed at the meeting. Full texts and abstracts published in accordance with the Symposium Policy have been prepared in accordance with ethical rules and APA standards. Authors of all papers are both ethically and legally responsible.

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Assoc. Prof. Dr. Khatamov Salimjon Rakhimjon Ugli - Andijan Institute of Agriculture and Agrotechnologies, UZBEKISTAN
Assoc. Prof. Dr. Necati ÇETİN – Ankara University, TÜRKİYE
Assoc. Prof. Dr. İbrahim SAYGILI – Tokat Gaziosmanpaşa University, TÜRKİYE
Assoc. Prof. Dr. Halil ERDEM – Tokat Gaziosmanpaşa University, TÜRKİYE
Assoc. Prof. Dr. Rüveyda YÜZBAŞIOĞLU – Tokat Gaziosmanpaşa University, TÜRKİYE
Assoc. Prof. Dr. Şerife TOPKAYA – Tokat Gaziosmanpaşa University, TÜRKİYE
Assoc. Prof. Dr. Sabriye BELGÜZAR – Tokat Gaziosmanpaşa University, TÜRKİYE
Assoc. Prof. Dr. Hakan POLATÇI – Tokat Gaziosmanpaşa University, TÜRKİYE
Assoc. Prof. Dr. Ayşe YEŞİLAYER – Tokat Gaziosmanpaşa University, TÜRKİYE
Assoc. Prof. Dr. Oya KAÇAR – Bursa Uludağ University, TÜRKİYE

Assoc. Prof. Dr. Yasin Bedrettin KARAN – Tokat Gaziosmanpaşa University, TÜRKİYE
Assoc. Prof. Dr. Adem YAĞCI – Tokat Gaziosmanpaşa University, TÜRKİYE
Assoc. Prof. Dr. Gamze PEKBEY – Yozgat Bozok University, TÜRKİYE
Assoc. Prof. Dr. Nizamettin TURAN – Siirt University, TÜRKİYE
Assoc. Prof. Dr. Mesut BUDAK – Siirt University, TÜRKİYE
Assoc. Prof. Dr. Ertan ATEŞ – Tekirdağ Namık Kemal University, TÜRKİYE
Assoc. Prof. Dr. Gülcan Demiroğlu TOPÇU – Ege University, TÜRKİYE
Assoc. Prof. Dr. Derya KARATAŞ – Necmettin Erbakan University, TÜRKİYE
Assoc. Prof. Dr. ALİ ENDES – Yozgat Bozok University, TÜRKİYE
Assoc. Prof. Dr. Gökçen YAKUPOĞLU – Yozgat Bozok University, TÜRKİYE
Assoc. Prof. Dr. Ömer Süha USLU – Kahramanmaraş Sütçü İmam University, TÜRKİYE
Assoc. Prof. Dr. Serkan ATEŞ – Oregon State University, USA
Assoc. Prof. Dr. Demet ÇEKİN – Rwth Aachen University, GERMANY
Assoc. Prof. Dr. ÖZER ÇALIŞ - Akdeniz University, TÜRKİYE
Assoc. Prof. Dr. Hayriye Sibel Gülse BAL – Tokat Gaziosmanpaşa University, TÜRKİYE
Assoc. Prof. Dr. Gamze PEKBEY – Yozgat Bozok University, TÜRKİYE
Assoc. Prof. Dr. Cennet YAMAN – Yozgat Bozok University, TÜRKİYE
Assoc. Prof. Dr. Güngör KARAKAŞ – Yozgat Bozok University, TÜRKİYE
Assoc. Prof. Dr. Hakan KELES – Yozgat Bozok University, TÜRKİYE
Assoc. Prof. Dr. Kübra YAZICI – Yozgat Bozok University, TÜRKİYE
Assoc. Prof. Dr. Tuğba KILIÇ – Yozgat Bozok University, TÜRKİYE
Assoc. Prof. Dr. Murat GÜNEY – Yozgat Bozok University, TÜRKİYE
Assoc. Prof. Dr. Mehmet Akif BOZ – Yozgat Bozok University, TÜRKİYE
Assoc. Prof. Dr. Musa YAVUZ – İsparta Uygulamalı Bilimler University, TÜRKİYE
Assoc. Prof. Dr. Mehmet Metin ÖZGÜVEN – Ankara University, TÜRKİYE
Assoc. Prof. Dr. Mustafa YAŞAR – Muş Alparslan University, TÜRKİYE
Assoc. Prof. Dr. Mehmet KARAMAN – Muş Alparslan University, TÜRKİYE
Assoc. Prof. Dr. Orhan KARADAĞ – Muş Alparslan University, TÜRKİYE
Assoc. Prof. Dr. Hülya Hanoğlu ORAL – Muş Alparslan University, TÜRKİYE
Assoc. Prof. Dr. İsa YILMAZ – Muş Alparslan University, TÜRKİYE
Assoc. Prof. Dr. Duygu UDUM – Bursa Uludağ University, TÜRKİYE
Assist. Prof. Dr. Orhan ERMETİN – Yozgat Bozok University, TÜRKİYE
Assist. Prof. Dr. Hasan Hüseyin ŞENYÜZ – Necmettin Erbakan University, TÜRKİYE
Assist. Prof. Dr. Mahir ÖZKURT – Muş Alparslan University, TÜRKİYE
Assist. Prof. Dr. Ahmet YENİKALAYCIO – Muş Alparslan University, TÜRKİYE

Assist. Prof. Dr. Onur ŞAHİN – Muş Alparslan University, TÜRKİYE

Assist. Prof. Dr. Dilek KABAKCI – Muş Alparslan University, TÜRKİYE

Assist. Prof. Dr. Mustafa GÜNEŞDOĞDU - Muş Alparslan University, TÜRKİYE

Assist. Prof. Dr. Ayşe Nida KURT – Muş Alparslan University, TÜRKİYE

Assist. Prof. Dr. Muhammet Hanifi SELVİ – Necmettin Erbakan University, TÜRKİYE

Assist. Prof. Dr. Yasin ÖZTÜRK – Necmettin Erbakan University, TÜRKİYE

Assist. Prof. Dr. Gamze BAYRAM – Tokat Gaziosmanpaşa University, TÜRKİYE

Assist. Prof. Dr. Tuba Uzun BAYRAKTAR – Siirt University, TÜRKİYE

Assist. Prof. Dr. Faruk TOHUMCU – Iğdır University, TÜRKİYE

Assist. Prof. Dr. Şaziye DÖKÜLEN – Tokat Gaziosmanpaşa University, TÜRKİYE

Assist. Prof. Dr. Özer KURT – Muş Alparslan University, TÜRKİYE

Assist. Prof. Dr. Hakan KARADAĞ – Tokat Gaziosmanpaşa University, TÜRKİYE

Assist. Prof. Dr. Öznur ÖZ ATASEVER - Tokat Gaziosmanpaşa University, TÜRKİYE

Assist. Prof. Dr. Esra KAPLAN – Tokat Gaziosmanpaşa University, TÜRKİYE

Assist. Prof. Dr. Kübra ÖZDEMİR DİRİK – Tokat Gaziosmanpaşa University, TÜRKİYE

Assist. Prof. Dr. Seda BİCE – Tokat Gaziosmanpaşa University, TÜRKİYE

Assist. Prof. Dr. Onur ŞAHİN – Muş Alparslan University, TÜRKİYE

Assist. Prof. Dr. Feyza Döndü BİLGİN - Aydın Adnan Menderes University, TÜRKİYE

Dr. Kurbonov Abrojon Yorkinovich – Cotton Breeding, Seed Production and Agro Technologies Research Institute, UZBEKISTAN

Dr. Avliyoqulov Mirzoolim Avazovich – Cotton Breeding, Seed Production and Agro Technologies Research Insitute, UZBEKISTAN

Lect. Kuziboev Shukhratjon Tursinaliyevich - Andijan Institute of Agriculture and Agrotechnologies, UZBEKISTAN

Res. Assist. Abdullaev Oybek Shakirjanovich - Andijan Institute of Agriculture and Agrotechnologies, UZBEKISTAN

Assist. Prof. Dr. Zuhair Hashain - Pir Mehr Ali Shah Arid Agriculture University, PAKISTAN

Dr. Ishfaq Ahmad - Asian Development Bank, PAKISTAN

Dr. Asmat Ullah - Agronomic Research Station, PAKISTAN

Dr. Abdul Khaliq (University of Agriculture, Department of Agronomy, Faisalabad, PAKISTAN)

Dr. Adnan Abbas (Nanjing university of information science and technology, nanjing CHINA).

Dr. Ali Mekki (University of Sfax, Biological Engineering-Environmental Bioprocesses and Soil Science, Sfax-TUNISIA)

Dr. Ajar Nath Yadav (Eternal University, Department of Biotechnology, Himachal Pradesh-INDIA)

Dr. Ashokkumar Vallabhbhai Rajani (Junagadh Agricultural University, College of Agricultuew, Dept. of Agril. Chem. & Soil Science, Gujarat-INDIA)

Dr. Barbara Wiśniowska-Kielian (University of Agriculture in Krakow, Faculty of Agriculture and Economics, Department of Agricultural and Environmental Chemistry, Krakow-POLAND)

Dr. Babak SAFAEI (Tsinghua University, CHINA)

Dr. Blend Ibrahim (School of Tourism and Hospitality Management. Department of Tourism Girne American University, CYPRUS)

Dr. hab. Barbara Sawicka (University of Life Sciences in Lublin, Faculty of Agrobioengineering, Department of Plant Production Technology and Commodity Sciences, Lublin-POLAND)

M.Sc. Benjamin Bantchina (Bursa Uludag University, Faculty of Agriculture, Department of Biosystems Engineering, Bursa-TÜRKİYE)

Dr. Brygida Klemens (Opole University of Technology, Faculty of Economics and Management, Opole-POLAND)

Dr. Derya Timuçin, (School of Tourism and Hospitality Management. Department of Tourism Girne American University, CYPRUS)

Dr. Elham Matallebi, Islamic Azad University, Garmsar, IRAN

Dr. Grzegorz Pączka (Rzeszów University, Department of Natural Theories of Agriculture and Environmental Education, Rzeszów, POLAND)

Dr. Fahrurrozi Fahrurrozi (University of Bengkulu, Faculty of Agriculture, Dept. of Crop Production, Bengkulu-INDONESIA)

Dr. Faisal SULTAN (Hazara University, PAKISTAN)

Dr. Francesco Nocera, (University of Catania, ITALY)

Dr. Herák David, (Czech University of Life Sciences Prague, CZECH REPUBLIC)

Dr. Hüseyin Bozdağlar (Girne American University, School of Tourism and Hospitality Cyprus)

Dr. Irshad Bibi (University of Agriculture, Faculty of Agriculture, Institute of Soil and Environmental Sciences, Faisalabad-PAKISTAN)

Dr. Iwan Setiawan, S.P., M.Si. (Department of Agricultural Economics, Agricultural Faculty. Universitas Padjadjaran. Jl. Raya Bandung-Sumedang km 21. Jatinangor. West Java. INDONESIA)

Dr. İsmet Esenyel (Girne American University, School of Tourism and Hospitality, CYPRUS)

Dr. Jam Nazeer Ahmad University of Agriculture, Faculty of Agriculture, Department of Entomology, Faisalabad-PAKISTAN)

Dr. Jasmin Latoviç (Southern Federal Üniversitesi, RUSSIA)

Dr. Khalid Hussain (University of Agriculture, Faculty of Agriculture, Department of Agronomy, Faisalabad-PAKISTAN)

Ph.D. Kusumiyati KUSUMIYATI, SP, M Agr. Sc.,. (Agronomy Department, Faculty of Agriculture, Universitas Padjadjaran Jl. Raya Bandung-Sumedang km 21. Jatinangor. West Java, INDONESIA)

Dr. Mazhar Rafique (University of Haripur, Faculty of Agriculture Sciences, Department of Soil & Climate Sciences-PAKİSTAN)

Dr. Medeuova Galiya (Kazakh National Women's Pedagogical Universty, KAZAKHISTAN)

Dr. Md. Iqbal HOSSAIN (Bangladesh University, BANGLADESH)

Dr. Muhammad Arshad (University of Agriculture, Faculty of Agriculture, Department of Entomology, Faisalabad-PAKISTAN)

Dr. Muhammad Shahbaz Naeem (University of Agriculture, Faculty of Agriculture, Department of Agronomy, Faisalabad-PAKISTAN)

Dr. Mohammad Mehdizadeh (Univesity of Mohaghegh, Department of Agronomy and Plant Breeding, Ardabili-IRAN)

Dr. Muhammad Zahid Ihsan (Islamia Univeristy of Bahawalpur, Cholistan Institute of Desert Studies, Bahawalpur-PAKISTAN)

Dr. Muhammad Adnan (University of Swabi, Department of Agriculture, Swabi-PAKISTAN)

Dr. Muhammad Zubair Siddiqi (Hankyong National University, Department of Biotechnology, SOUTH KOREA)

Dr. Muhammad Nurdin YUSUF (Agribusiness Department. Agricultrural Faculty. University of Galuh. Jl. R.E. Martadinata No. 150. Mekarjaya, Kec. Baregbeg. Kab. Ciamis. West Java 46274. INDONESIA)

Dr. Mushtaque Ahmed Jatoi, (University of Zagreb, Department of Pomology, Zagreb, Croatia, Beijing, CHINA)

Dr. Murat Akkaya (Girne American Universty, Vocatıonal School, CYPRUS)

Dr. Nabeel Khan Niazi (University of Agriculture, Faculty of Agriculture, Institute of Soil and Environmental Sciences, Faisalabad-PAKISTAN)

Dr. Niteesh Kumar Upadhyay (Galgotias University and South Ural State University RUSSIA)

Dr. Rana Nadeem Abbas (University of Agriculture, Faculty of Agriculture, Department of Agronomy, Faisalabad-PAKISTAN)

Dr. Rakesh GUPTA (Delhi University, INDIA)

Dr. Ristina Siti Sundari (University of Perjuangan Tasikmalaya, Faculty of Agriculture, Department of Agribusiness, Wezt Jawa-INDONESİA)

Dr. Safdar Bashir (Ghazi University, Faculty of Agricultural Sciences, Department of Soil and Environmental Sciences, Dera Ghazi Khan-PAKISTAN)

Dr. Sardar Alam Cheema (University of Agriculture, Faculty of Agriculture, Department of Agronomy, Faisalabad-PAKISTAN)

Dr. Shah Fahad (University of Haripur, Department of Agronomy, Haripur-PAKISTAN)

Dr. Saddam Hussain (University of Agriculture, Faculty of Agriculture, Department of Agronomy, Faisalabad-PAKISTAN)

Dr. Somayyeh Razzaghı (Sivas Science and Technology University, Faculty of Agriculture Science and Technology, TÜRKİYE)

Dr. Shitnaan E. Wapmuk (University Of Jos, Plateau State, Nigeria)

M.Sc. Setyo Budi Kurniawan (Universiti Kebangsaan Malaysia, Faculty of Engineering & Built Environment, Department of Chemical and Process Engineering, MALAYSIA)

Dr. Tahir Igbal, (Arid Agriculture University, Rawalpindi, PAKISTAN)

Dr. Wan Taek Im (Hankyong National University, Department of Biotechnology, SOUTH KOREA)

Dr. Viliana Vasileva (Agricultural Academy, Institute of Forage Crops, Forage Production and Livestock Department, Pleven-BULGARIA)

Dr. Yar Zar Chit (Sagaing University MYANMAR)

Dr. Zhongbing Chen (Czech University of Life Sciences Prague, Faculty of Environmental Sciences, Prague-CZECH REPUBLIC)

Dr. Zizis Vryzas (Democritus University, Thrace School of Agricultural & Forestry Sciences, Department of Agricultural Development, Orestiada-GREECE)

Dr. Zulfiqar Ahmad Dasti (University of Agriculture, Faculty of Agriculture, Institute of Soil and Environmental Sciences, Faisalabad-PAKISTAN)

Dr. Zubair Aslam (University of Agriculture, Faculty of Agriculture, Department of Agronomy, Faisalabad-PAKISTAN)

18. INTERNATIONAL CONFERENCE ON AGRICULTURE, ANIMAL SCIENCE & RURAL DEVELOPMENT

OCTOBER 24-26, 2025 / EREGLI, KONYA, TÜRKIYE

Necmettin Erbakan University
Eregli Faculty of Agriculture









Conference Topics

Agricultural Biotechnology, Agricultural Economics, Agricultural Employment, Agricultural Energy Systems, Agricultural Engineering, Agricultural Machinery, Agricultural Policies, Agricultural Structures, Animal Science, Artificial Intelligence in Agriculture, Banking and Agricultural Loans, Bees and Bee Products, Biosystems Engineering, Climate Smart Agriculture, Environment, Food Science and Engineering, Field Crops, Fisheries, Horticulture, Irrigation Systems, Landscape Architecture, Meat and Dairy Technology, Nanotechnology in Agriculture, Occupational Safety and Health in Agriculture, Plant Protection, Precision Farming, Producer Unions and Cooperatives, Regenerative Agriculture, Renewable Energy, Robotic Systems in Agriculture, Rural Development, Seafood, Soil Science and Plant Nutrition, Sustainable Agriculture, Sustainable Resource Allocation, Veterinary Science, Viticulture, Waste Management

CONFERENCE PROGRAM

In-person & Online

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818
https://us02web.zoom.us/j/89707558402?pwd=zPbvq6JR6UGaPJEkDATUrNx53tLu2s.1

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Face to Face / Necmettin Erbakan University, Faculty of Agriculture	
24.10.2025	HALL-1 / SESSION-1
ANKARA LOCAL TIME: 14:30-17:00	

HEAD OF SESSION: Prof. Dr. Mustafa Avcı

Authors	Affiliation	Presentation Title
Yunus Arzik	*Aksaray University*	Machine-learning gwas maps genomic architecture of coccidiosis resistance in sheep
Sedat Behrem Yunus Arzik	*Aksaray University*	Variations in the myostatin (GDF-8) gene and their effects on muscle development
Dr. Öğr. Üyesi Elif Çatıkkaş Said Efe Dost	*Karamanoğlu Mehmetbey University*	Seed nano-priming: a new approach for sustainable agriculture
Said Efe Dost Yilmaz Sesli Dr. Öğr. Üyesi Elif Çatıkkaş	*Karamanoğlu Mehmetbey University*	Effect of drought stress on pink lady and jeromine apple cultivars
Gülten Kaçar Avci	*Potato Research Institute*	Plant-parasitic nematodes in potatoes (*Solanum tuberosum* L.) and control methods
Esengül Demirel	*MORYEM Agricultural R&D Industry and Trade Ltd. Co.*	Seeking solutions to the global protein deficit: preliminary findings from alternative feed formulations and moringa studies
Müjgan Güney Hakan Keles Murat Güney	*Yozgat Bozok University*	Application of chromatographic techniques in the analysis of bioactive compounds in horticultural crops
Müjgan Güney Selcan Özyalin Gökçe Aydöner Çoban Hakan Keles	*Yozgat Bozok University*	Role of volatile compounds in determining aroma and flavor of horticultural crops
Muhammet Tarhan Asiye Sena Çavdar Adnan Gökten Recep İrfan Nazli Hasan Beytullah Dönmez	*Cukurova University*	The effects of different seeding ratios of gelemen clover and barley mixtures on forage yield, quality traits, and weed suppression

(All speakers required to be connected to the session 10 min before the session starts)
Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

Face to Face / Necmettin Erbakan University, Faculty of Agriculture	
24.10.2025	HALL-2 / SESSION-1
ANKARA LOCAL TIME: 14:30-17:00	

HEAD OF SESSION: Prof. Dr. Rüştü HATİPOĞLU

Authors	Affiliation	Presentation Title
İsmail Çinkaya Osman Çağirgan Şafak Ceylan Durmuş Ali Kipritci Sinan Süheri	*Konya Soil, Water and Combating Desertification Research Institute Directorate*	Early wheat yield prediction using multispectral vegetation indices: statistical analysis of variety responses under water stress
Hakan Keles Servet Aras Müjgan Güney Selcan Özyalin	*Yozgat Bozok University*	Humic and fulvic acids in agricultural production: utilization potentials and recent studies
Hakan Keles Selcan Özyalin Servet Aras Müjgan Güney	*Yozgat Bozok University*	Hawthorn (*Crataegus* spp.): potentıals and future perspectıves as an alternatıve specıes
Murat Güney Selcan Özyalin Hakan Keles Servet Aras	*Yozgat Bozok University*	Advances, challenges, and solution strategies in tissue culture applications of fruit species
Murat Güney Hakan Keles Selcan Özyalin Gökçe Aydöner Çoban	*Yozgat Bozok University*	Recent advances in molecular marker-based determination of disease resistance in fruit genotypes
Emine Sema Çetin Nazife Çiğdem Ermiş Berna Keles	*Yozgat Bozok University*	Investigation of the effects of *Ascophyllum nodosum* applications on secondary metabolite accumulation in berries in michele palieri grape variety
Hilmi Yeter Orhan Ermetin	*Yozgat Bozok University*	Investigation of milk yield and reproductive parameters of holstein cattle raised in yozgat province
Orhan Ermetin	*Yozgat Bozok University*	Impact of prepartum body condition management on reproductive performance of dairy cows

(All speakers required to be connected to the session 10 min before the session starts)
Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

Face to Face / Necmettin Erbakan University, Faculty of Agriculture	
24.10.2025	HALL-3 / SESSION-1
ANKARA LOCAL TIME: 14:30-17:00	

HEAD OF SESSION: Prof. Dr. Selahattin ÇINAR

Authors	Affiliation	Presentation Title
Selahattin Çinar	*Kırşehir Ahi Evran University*	Problems and solutions emerging in the applications of range law in türkiye
Melek Kurt Rüştü Hatipoğlu	*Kırşehir Ahi Evran University*	Vegetation studies conducted in the rangelands of the central anatolia region
Aysen Koç Haydar Yilmaz	*Yozgat Bozok University*	Effect of different iba doses and bacterial applications on rooting of black mulberry (*Morus nigra* L.) wood cuttings
Mustafa Alper Savaş Selahattin Çinar	*Kırşehir Ahi Evran University*	Rangeland vegetation survey studies conducted in turkey
Fathimah Azzahra Haydar Haciseferogullari	*Selçuk University*	Biomass potential from agricultural residues in indonesia
Deniz Sevilmiş Ayşe Nuran Çil Y. Ahu A*f*şaban	*Eastern Mediterranean Agricultural Research Institute*	Speed breeding: a current status review
Gülizar Kurtoğlu Akkaya N. Berk Bıtrak Kâmil Ekinci	*Necmettin Erbakan University*	Energy conversion of hemp biomass through anaerobic fermentation: perspectives on biogas and biomethane
Şaban Işik Şükrü Doğan Seydi Aydoğan Murat Küçükçongar	*Bahri Dağdaş International Agricultural Research Institute Directorate*	Determination of growth performances of weaned lambs of different sheep breed on artificial pastures
Korhan Özceylan Özgül Görmüş	*Çukurova University*	Evaluation of agronomic and fiber traits of cotton genotypes (*Gossypium* spp.) for breeding potential in the cukurova region
Ayşegül Faydaci Isa Telci	*Isparta University of Applied Sciences*	Determination of the phenological, agronomic, and quality characteristics of black cumin (*Nigella sativa* L.) genotypes under Isparta conditions

(All speakers required to be connected to the session 10 min before the session starts)
Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

Face to Face / Necmettin Erbakan University, Faculty of Agriculture	
25.10.2025	HALL-1 / SESSION-1
ANKARA LOCAL TIME: 14:00-16:30	

HEAD OF SESSION: Prof. Dr. Yaşar Karadağ

Authors	Affiliation	Presentation Title
Hasan Hüseyin Şenyüz Gökhan Şen Ramazan Ayaş Ali Karapinar Ali Ersin Gümüş	*Necmettin Erbakan University*	Effects of shredlange and conventional methods on nutrient content and in vitro digestibility of corn silage
Sadiye Ayşe Çelik Gülbahar Babaoğlan	*Selçuk University*	Current perspectives on the use of essential oils against root rot disease in peanut
Sadiye Ayşe Çelik Tuba Özkan Ay	*Selçuk University*	Evaluation of the use of essential oils as an alternative to chemical methods in egg disinfection and sterilization
Mehmet Ali Avci Emir Yavaş Melike Mavi	*Selçuk University*	Area coverage performance and ecological turf applications of some wheaten forage crops that can be used in green areas
Seda Günaydın Işıl Kılıç	*Necmettin Erbakan University*	Determination of the influence of different pre-treatments and microwave drying method on co 2 emissions in the drying of red plum (*Prunus domestica*) slices
Sadiye Ayşe Çelik Emir Yavaş Selim Derman Küçükmaraş	*Selçuk University*	Effects of pgpr and mycorrhiza combinations on yield, active compound content, and stress tolerance in medicinal and aromatic plants
Havva Nur Demir Deveci Tahir Külahcı Ramazan Topak	*Necmettin Erbakan University*	A review on the effects of irrigation on lavender (*L. angustifolia* mill.) yield and oil quality
Beyza Yilmaz Ayhan Ceyhan	*Niğde Ömer Halisdemir University*	The effect of climate change on sheep breeding: heat stress, performance, adaptation strategies

(All speakers required to be connected to the session 10 min before the session starts)
Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

25.10.2025 / SESSION-1 / HALL-1

Ankara Local Time: 10:00-12:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Prof. Dr. Metin Armağan

Authors	Affiliation	Presentation Title
Atakan Özalp İsmet Başer Damla Balaban Göcmen	*Tekirdağ Namık Kemal Universitesi*	Effect of different irrigation practices on quality criteria in sorghum and corn
E. Mevliyaoğulları S. Doğan S. Göncü	Başkent *Universitesi*	Changes in blood parameters from birth to weaning in male and female holstein calves
Bekir Demirtaş Fatma Can Alkan	*Hatay Mustafa Kemal Universitesi*	Determination of input utilisation level and agricultural credit needs of olive producers in Hatay-altinözü district
Başak Boztok Özgermen	*Aksaray Universitesi*	Radiographic assessment of cardiac dimensions in healthy dogs: vertebral heart scale (VHS) and vertebral left atrial size (VLAS)
Canan Kop Bozbay Melike Vural Zeynep Geçili Nuri Can Karaoğlu	*Eskisehir Osmangazi University*	Effects of in ovo honey feeding on hatching performance and response to delayed access to feed and water in anadolu-t broiler chicks
Canan Kop Bozbay Berkay Kaya Yiğit Battal Akarsu Kürşat Selman Ovali Miraç Mert Yildirim	*Eskisehir Osmangazi University*	Effects of different doses of in ovo colostrum powder administration on hatching performance and blood parameters of anadolu-t broiler chicks
Mustafa Demirkaya	*Kayseri Universitesi*	Physiological changes occur in white pumpkin seeds during ageing
Mert Acar	*Çukurova Universitesi*	Relationships between aggregate stability and organic matter content in different soil series

(All speakers required to be connected to the session 10 min before the session starts)
Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

25.10.2025 / SESSION-1 / HALL-2

Ankara Local Time: 10:00-12:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Assoc. Prof. Dr. Aras Türkoğlu

Authors	Affiliation	Presentation Title
Şahin Aydin	*Işık University*	Ai-based approaches for regional analysis and forecasting of livestock numbers
Serdar Dizman	*Recep Tayyip Erdogan University*	Detection of natural radioactive isotopes in chestnuts and radiological risk assessment for human health
Ahmet Özden Yusuf Cufadar	*Ministry of Agriculture and Forestry*	Current situation in livestock and new support model
Songül Yildiz Yeşim Öztürk Yilmaz Zeynep Bayramoğlu	*Recep Tayyip Erdoğan University*	Effects of tea vinegar applications on the growth of tea seedlings (*Camellia sinensis* L.)
Songül Yildiz Fatma Kesimal Zeynep Bayramoğlu	*Recep Tayyip Erdoğan University*	Effects of microbial fertilizer and tea waste applications on yield and quality in aronia (*Aronia melanocarpa*) cultivation
Caner Öztürk Neşe Hayat Aksoy Erkan Özkan Ramazan Arslan	*Aksaray University*	Effects of meloxicam on sperm parameters in rats - a preliminary study
Merve Kahraman Abdurrahman Sami Koca	*Bolu Abant İzzet Baysal University*	Seasonal population dynamics of palpita unionalis hubner (lepidoptera: pyralidae) in olive orchards of akhisar district (Manisa, Türkiye)
Arzu Üçtepe Antonios Kominakis	*Isparta University of Applied Sciences*	Estimation of heritability and common environmental effects of egg traits in the blue-breasted quail (*Synoicus chinensis*)
Koray Genç	*Ordu University*	Green business practices focused on the sustainability of agricultural production: a comparative analysis of second wave coffee chains in Turkey

(All speakers required to be connected to the session 10 min before the session starts)
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25.10.2025 / SESSION-1 / HALL-3

Ankara Local Time: 10:00-12:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Assoc. Prof. Dr. Sevim Seda Yamaç

Authors	Affiliation	Presentation Title
Mederbek Zhaanbaev	*Kyrgyz-Turkish Manas University*	Identification of Promising Genotypes Among The Wild Pistachio (Pistacia vera L.) Population Growing in Kazak Uulu Village of Osh Province in Kyrgyzstan
Rotimi-Williams Bello Pius A. Owolawi Chunling Tu Etienne A. van Wyk Mojisola Abosede Oladipo	*Tshwane University of Technology*	Livestock localization using real-time internet-of-things architecture
Oluwadamilola Peace Agoi Moses Adeolu Agoi Solomon Abraham Ukpanah Samuel Olayiwola Ajaga Oluwanifemi Opeyemi Agoi	*Federal University of Agriculture Abeokuta*	Xr-supported decision making in agro-ecosystem design: an evaluative empirical perspective
Saju Abraham	*Newman College*	Climate change and oxidative stress in plants: a phytochemical perspective on resilience
Mederbek Zhaanbaev Aibiike Borubaeva	*Kyrgyz-Turkish Manas University*	Some Fruit Characteristics of Naturally Grown Hawthorns (Crataegus spp.) in Uzgen District, Osh Region, Kyrgyzstan.
Moses Adeolu Agoi Samuel Olayiwola Ajaga Solomon Abraham Ukpanah Oluwadamilola Peace Agoi	*Lagos State University of Education*	Collaborative robots (cobots) for precision pruning and crop management in glass houses
Mamta Sharma Sandeep Kumar Sharma	*University of Delhi*	Integrated Assessment of Desertification, Land-Use Change, and Ecological Degradation – A Case Study of Rewari Industrial Area, Delhi-NCR
Adelmonim Zeroual Mohammed Mitache Bacar Abdallah Abderemane Aziz Baidani Omar Idrissi	*National Institute of Agricultural Research*	Genetic diversity for agronomic traits in a mediterranean lentil collection: towards the development of high yielding climate-change ready cultivars

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25.10.2025 / SESSION-1 / HALL-4

Ankara Local Time: 10:00-12:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Assist. Prof. Dr. Çetin Palta

Authors	Affiliation	Presentation Title
Adelmonim Zeroual Aziz Baidani Bacar Abdallah Abderemane Mohammed Mitache Omar Idrissi	*National Institute of Agricultural Research*	Evaluation of lentil genotypes for mechanical harvesting suitability
Vilma Salkauskiene	*Lietuvos Inzinerijos Kolegija Higher Education Institution*	Assessment of protected and recreational areas in the southwestern part of lithuania relief
S. Kalaiselvan G. Janaki R. Suganya G. Kowsalya R.Sumathi	*Rathinam Technical Campus*	Connecting Advanced Mathematical Applications for Transforming Contemporary Agriculture through Precision, Prediction, and Sustainability
Gunasekar G	*Tamil Nadu Agricultural University*	Life table construction and analysis for evaluating bio-control agents
Jatin Vats, Ajesh Chauhan Chetan Vashisht	*Hindu College of Pharmacy Sonepat*	Revealing the Therapeutic Value of Biodegradable Cellulose Fibers: Novel Developments and Strategies in Skin Tissue Regeneration
Shoumen Dhar Bappy Chowdhury Mehenaj Musa Abdur Rahman Mahima Ranjan Acharjee Sreebash Chandra Bhattacharjee	*Chattogram Veterinary and Animal Sciences University*	Nutritionally Optimized Baby Food from Indigenous Ingredients: Safety, Functionality, and Acceptability for Sustainable Infant Nutrition
Bruno, Ibeabuchi Anwuri Gbara, Uloma Celestine Ogunbayo, Oluwatoyin Glory	*Federal College of Education*	Artificial intelligence and national economic growth: exploring the role of stem education in workforce transformation in nigeria.
Saira Malik Syed Mohsan Raza Shah Uniza Fatima bukhari Tasawar Fatima bukhari Iqra	*University of Education, Lahore*	Leaf structural and functional modification of Ipomoea carnea Jacq. an invasive plant species, under diverse salinity gradient
Giorgi Shtenberg Divagar Muthukumar	*Institute of Agricultural Engineering*	Multiplex pathogenic bacteria detection in milk with the nanoparticle-assisted porous silicon-based sers microarray biosensor

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25.10.2025 / SESSION-1 / HALL-5

Ankara Local Time: 10:00-12:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Assoc. Prof. Dr. Derya KARATAŞ

Authors	Affiliation	Presentation Title
Iram Liaqat	*Government College University*	QS inhibition by algal compounds against marine biofilms
Voroneanu-Popa Rareș-Vasile Richard Constantinescu	*Grigore T. Popa University of Medicine and Pharmacy of Iași*	Possible perspectives of european union policies on the development of the agricultural sector
Bruno, Ibeabuchi Anwuri Ogunbayo, Oluwatoyin Glory Oreke, Obusor Happiness Ajie, Uloma Glory	*Federal College of Education*	Artificial intelligence for individualized remediation of misconceptions in biology concep
Anandhavalli Muniasamy	*King Khalid University*	Plant seedling identification using pretrained deep transfer learning models
Shehu, N.M. Zakari, N. Kabir I.A. Shehu, A.U.	*Federal University*	Flood vulnerability and its impacts on agricultural systems, livestock, and rural development: a comprehensive review
Skender Demaku Muhamet Kiqina Arbnorë Aliu Donika Sylejmani	*University of Prishtina "Hasan Prishtina"*	Chemical analysis of atmospheric dust around the kishnica area in the municipality of gracanica
R. Thiruchelvi	*Vels Vidhyalaya School*	Synthesizing entrepreneurial stem education: a review of theoretical foundations, pedagogical practices, and future directions
Drobchenko N.V.	*Samarkand State University of Architecture and Civil Engineering named after Mirzo Ulugbek*	Ecological rehabilitation of the aral sea region: phytomelioration as a sustainable tool for land restoration
Vijayakumaran Shobana K. Sujatha Tatireddy Omsai Reddy N.P.G. Bhavani	*Institute Chennai*	ECG-based sleep apnea detection using convolutional and long short-term memory networks

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25.10.2025 / SESSION-2 / HALL-1

Ankara Local Time: 12:30-14:30 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Assist. Prof. Dr. Hasan Can

Authors	Affiliation	Presentation Title
İlhan Yandi	*Recep Tayyip Erdoğan University*	In-situ degradation of offshore aquaculture mooring ropes: a depth-wise analysis of plastic emission rates
İlhan Yandi	*Recep Tayyip Erdoğan University*	From experiment to ecosystem: estimating the macro-impact of plastic emissions from black sea offshore aquaculture mooring systems
Tansu Uskutoğlu Rıdvan Uçar	*Pamukkale University*	Clary sage (*Salvia sclarea* L.): cultivation, uses, and potential
Rıdvan Uçar Tansu Uskutoğlu	*Pamukkale University*	Evaluation of the beekeeping potential of denizli oregano
Serpil Aygörmez Mushap Kuru Mustafa Makav	*Kafkas University*	Changes in serum paraoxonase-1 and some oxidative status markers during anoestrus and estrus in abaza and gürcü goats
Sinan Akbal	*Pamukkale University*	Effect of lactic acid bacteria on yeast/mold spoilage in the dairy industry
Sinan Akbal	*Pamukkale University*	Effect of use of plant-based proteases in dairy technology on technological and bioactive properties
Onur Sefa Alkaç	*Tokat Gaziosman Paşa University*	Effects of different planting times and plant density on growth and quality in ornamental sunflowers
Mehmet Ali Dündar Ramazan Topak	*Bahri Dağdaş International Agricultural Research Institute Directorate*	Planning of linear move irrigation systems

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25.10.2025 / SESSION-2 / HALL-2

Ankara Local Time: 12:30-14:30 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Assoc. Prof. Dr. Mahir ÖZKURT

Authors	Affiliation	Presentation Title
Bekir Atar	*Isparta Uygulamalı Bilimler University*	Use of paclobutrazol (pbz) in wheat production
Murat Durmuş	*Cukurova University*	A way to increase marketable milk in goat breeding: use of milk replacers
Orhan Yalçin Recep Gümüş	*Sivas Cumhuriyet Üniversitesi*	The effects of postpartum oral propylene glycol administration on body condition score in dairy cows
Ecenur Aliş Deniz Dinçel	*Bursa Uludağ University*	Genetic basis of heat stress response: novel perspectives on molecular adaptation in cattle
Berna Efe Seçil Candaş Özkan Recep Kirbaş Erol Karakurt	*Central Research Institute for Field Crops*	Morphologic, physiologic and agronomic traits of cold-tolerant common vetch hybrid lines
Şamil Gülaydın Murat Ali Turan	*Bursa Uludağ University*	Effects of nitrogen and sulfur applications on fruit quality in banana plants
Muhammet Cemil Ejderoğlu Murat Ali Turan	*Bursa Uludağ University*	Effect of calcium and boron applications on development of pepper plant
Merve Dilek Karataş	*Van Yüzüncü Yıl University*	Effect of deficit irrigation on the expression of slnced1 and sldreb2 genes in tomato
Mehmet Halil ÖZSÜER Melike OĞUZ Burak TOLU Onur ÖKSÜZ Fatih KARABULUT	*Gübretaş*	Investigation of the effects of microbial fertilizer formulations created with bacterial strains isolated from Turkish soils on grain corn *(zea mays l.)* plants under greenhouse conditions
Mehmet Halil ÖZSÜER Melike OĞUZ Burak TOLU Onur ÖKSÜZ Fatih KARABULUT	*Gübretaş*	Investigation of the effects of microbial fertilizer formulations created wıth bacterial strains isolated from Turkish soils on green pepper *(capsicum annuum l.) Plants* under greenhouse conditions.
Muazzez Yeşilyurt Özgül Gülaydin	*Siirt University*	Chronic respiratory system infection (crd) in poultry

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25.10.2025 / SESSION-2 / HALL-3

Ankara Local Time: 12:30-14:30 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Prof. Dr. Metin Armağan

Authors	Affiliation	Presentation Title
Rawia Nasri Mohamed Faouzi Zid	*University of Tunis El Manar*	Solar light driven photocatalytic degradation of toxic azo dyes using synthesized molybdate catalyst
Mohanapriya P Chamundeeswari M	*St. Joseph's College of Engineering*	Green synthesized iron nanoparticle based detection of microplastics from aqueous environment
Abdullahi Umar	*Ahmadu Bello University*	The use of glutamic acid as a green alternative for corrotion inhibition in HCL solution
Akinleye, Abiodun Olamilekan	*The Federal Polytechnic*	Performance evaluation of wireless sensor networks for smart agriculture using opnet
Ugwuoke Chukwuchebe Obiajulu	*University of Nigeria*	Benefits of agro forestry land use in nsukka local government area, enugu state, nigeria
Y. Sarayu Reddy S. Suji	*R.M.K. Engineering College*	Impact of sustainable agricultural practices on environmental conservation
Chidimma Lilian Asadu Robert Ikechukwu Uroko Stanley Mary Ubenyi	*Esut College of Medicine*	Evaluation of spermatozoa quality, differential sperm morphology and gonadosomatic indices of benign prostatic hyperplasia induced rats treated with polyherbal extract
R.Thiruchelvi P.Saravanan	*St. Joseph's College of Engineering*	Valorization of fruit waste through reutilization approach: a comprehensive review
Sadik Dani Hassane Abd-Dada Aziz Ezzine Ahmed El Annaoui Atman Adiba Abdelmajid Haddioui Said Bouda	*Sultan Moulay Slimane University*	Morphological characterization of the genetic resources of moroccan white mulberry (*Morus alba* L.)

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25.10.2025 / SESSION-2 / HALL-4

Ankara Local Time: 12:30-14:30 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Assoc. Prof. Dr. Aras Türkoğlu

Authors	Affiliation	Presentation Title
Sunil Agrawal	*People's Institute of Management and Research*	A comparative analysis of municipal solid waste management in urban and rural settings
Nesrine Benkhaira Saad Ibnsouda Koraichi Kawtar Fikri-Benbrahim	*Sidi Mohamed Ben Abdellah University*	Exploring the bioactive components and pharmacological benefits of a northern moroccan traditional herb
Faiza Baghida Mourad Boughrara	*Moulay Ismail University*	Structural, electronic, and thermoelectric properties of Cu_2Se were investigated using first-principles calculations within the DFT-PBE framework.
Ghizlane Rahil Imane Rahil Mustapha Oujaoura Walid Bouarifi	*Mathematical Team and Information Processing National school of applied sciences Safi*	Deep motion track: real-time human pose and action recognition using video streams
Emmanuel Ugochukwu Anaso	*Federal University of Agriculture Mubi*	Immunological responses and adaptation of kano brown buckling goats fed diets containing pleurotus ostreatus biodegraded sugarcane scrapings
Jatau T, K. Sani H	*Federal College of Education*	Attitude of the society towards hiv/aids patients in kontagora, niger state, Nigeria
Faisal Nazir	*The University of Agriculture*	Production and characterization of carbon nanotubes from biochar under microwave irradiation
Chlaih Soumaya	*Cadi Ayyad University*	Development and optimization of low-cost clay-based membranes for textile wastewater microfiltration
Sadiq, Mohammed Sanusi Singh, Invinder Paul Ahmad, Muhammad Makarfi Nazifi, Idris Khalid Sani, Bashir Sanyinna	*Department of Agricultural Economics and Agribusiness*	Leaders, laggards, and stalled giants: a typology of frontier technology readiness in selected african economies

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25.10.2025 / SESSION-2 / HALL-5

Ankara Local Time: 12:30-14:30 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Dr. Saida Es-Sanhajy

Authors	Affiliation	Presentation Title
Khatami Salma El Haimeur Bouchra Bouhallaoui Mina Errhif Ahmed	*National Institute of Fisheries Research Casablanca*	From bioassays to sediment quality indices: an integrated approach to assess the environmental status of coastal ecosystems.
Musrat Shaheen Akbar Ali Burhan Khalid Hafiza Zara Saeed	*Government College University Faisalabad*	Mechanistic Understanding of Peptoid Formation from Dithiane Precursors via Multicomponent Reactions: A DFT Study
Rajaa Dianya Said Kerraj Mohamed Kadour Atouailaad Ahmed Arifd Abdelkhalk Aboulouard Mustapha Boulghalat Abdessamad Tounsi Mohammed Salah Mohammed El idrissi	*Sultan Moulay Slimane University*	Enhancing the electronic and optical performance of dye-sensitized solar cells with alizarin-based dyes: DFT/TD-DFT investigations
Felipe Taiti Ukai Gerson Araujo de Medeiros	*São Paulo State University*	Environmental impacts of small-scale interbasin water transfer on the water quality in Southeast Brazil
Saida Es-Sanhajy	*Moulay Ismail University*	Electronic and thermoelectric properties of pure $MgSiO_3$ perovskite: DFT study
Devadharshini.R R. Srinivasan	*Bharath institute of higher education and research*	Animal genetics and breeding
Chokri Bayoudh Hedil Gaaya Afifa Majdoub Taoufik Bettaieb	*IRESA-University of Sousse*	Preliminary trials of optimizing in vitro propagation of the hybrid pistachio rootstock ucb-1 (*Pistacia atlantica* x *Pistacia integerrima*) by bioreactors
A.M.Aliyu U.A.Isa A. Muhammad	*University of Science and Technology Wudil*	Phytochemical screening of different varieties of sweet Pepper (*Capsicum annuum* L.) based on fruit colouration
El Handaoui El Mehdi Abderrahim Jrifi Omar Fanidi	*Hassan II university*	Exploring the Potential of Moringa Oleifera for Sustainable Wastewater Remediation

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25.10.2025 / SESSION-3 / HALL-1

Ankara Local Time: 15:00-17:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Assist. Prof. Dr. Furkan Ömer Kanarya

Authors	Affiliation	Presentation Title
Feyza Döndü Bilgin Ilkay Yavaş	*Aydın Adnan Menderes University*	Phytoremediation: the role of lemongrass, thyme, sage, and dandelion in combating environmental pollution
Figen Kütükoğlu Habil Umur Hülya Hanoğlu Oral	*Central Research Institute for Food and Feed Control*	Use of microscopic method in quality control of fish meals
Güngör Yilmaz Şaziye Dökülen Semra DEMİRLER	*Yozgat Bozok University*	The effect of different nitrogen doses on some yield and quality characteristics in camelina plant [*Camelina sativa* (L.) Crantz]
Ersin Karacabey R. Oğuzhan Soltekin M. Sacit Inan Ahmet Candemir	*Manisa Viticulture Research Institute*	Effects of a low-rate solar energy concentration system on drying kinetics of grape
Nilay Taşdelen Ok M.Eşref Irget	*Ege University*	Determination of the amount of nutrients resolved from the soil by different cherry varieties with their fruit
Volkan Kaydu Eda Keleş Banu Yardimci	*Ondokuz Mayıs University*	The role of liver histology in the evaluation of fish health in cultured rainbow trout (*Oncorhynchus mykiss*)
Hasan Baltaci Seda Sucu Dağ	*Tokat Gaziosmanpaşa University*	Effect of cerium oxide (CEO_2-NP) nanoparticle on physical and physiological parameters in grafted grapevine seedlings under salt stress
Hilmi Kara	*Van Yuzuncu Yıl University*	Foliar application of *Trichoderma viride* Pers. affects the biological traits of *Myzus persicae* Sulz. (Hemiptera: Aphididae) mediated by pepper plants
Servet Sami Ipek Ilknur Alibaş Aysel Arslan	*Uludağ University*	Determination of energy efficiency in pear (*Pyrus communis*) production in Türkiye

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25.10.2025 / SESSION-3 / HALL-2

Ankara Local Time: 15:00-17:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Assoc. Prof. Dr. Tuba Uzun Bayraktar

Authors	Affiliation	Presentation Title
Gözde Engüdar Beyaz Serdar Uğurlu Tahir Yücel Gökhan Boran Emre Bakkalbaşi	*Van Yüzüncü Yıl University*	Effect of different extraction methods on protein content in walnut beverage production
Gözde Engüdar Beyaz Tahir Yücel Gökhan Boran Emre Bakkalbaşi	*Van Yüzüncü Yıl University*	Effect of alcalase enzyme and process conditions on the yield of protein extraction from walnut pomace
Gülcan Tuğçe Vanoğlu Müge U. Kamiloğlu	*Hatay Mustafa Kemal University*	Effects of the application of kaolin on okitsuwase satsuma at various doses and times on some morphological, physiological, efficiency and quality characteristics
Tuba Uzun Bayraktar Aslı Bağlici	*Siirt University*	Geographically indicated grape varieties and grape products in turkey
Önder Volkan Bayraktar	*Siirt University*	Changes in red meat prices in türkiye in recent years and factors affecting producer price formation
Tamer Uysal Funda Yılmaz Baydu Canan Yüksel Özmen Onur Ergönül A. Semih Yaşasın Cengiz Özer Yılmaz Boz Hasan Çelik Gökhan Söylemezoğlu Ali Ergül	*Ankara University*	Molecular characterization of amasya grape genotypes using ssr markers
Hatice Hizli Şerife Ergül	*Eastern Mediterranean Agricultural Research Institute Directorate*	Multivariate assessment of growth and survival traits in turkish hair goats using glm and pca-biplot
Fatih Öner Hacı Şahan	*Ordu University*	Effects of different sowing dates on yield parameters of maize (*Zea mays* L.)
Tülin Güven Gökmen Hatice Yazgan	*Cukurova University*	Quorum quenching: potential applications in veterinary and clinical microbiology

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25.10.2025 / SESSION-3 / HALL-3

Ankara Local Time: 15:00-17:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Dr. R. Surenderkhanna

Authors	Affiliation	Presentation Title
R. Surenderkhanna Rajasekaran. V	*Vellore Institute of Technology*	Reclaiming the Frame: Transgender Self-Representation and the Transformation of Tamil Cinema in Neela Neera Soriyan (2024)
Ivan Pavlović Nada Plavša Aleksandra Tasić Nataša Rajić-Savić	*Scientific Institute of Veterinary Medicine of Serbia*	Arthropode parasites of bee – conopid flies and earwigs
Zainib Razzaq Samreen Gul Khan Fozia Anjum Mehr un Nisa	*Government College University*	Unravelling the anticonvulsant potential of 1,3,4-oxadiazole-carbamothioates: synthesis, in vivo screening, and electrophysiological validation
Amina Teibi Nabila Belyagoubi-Benhammou Abdel Halim Harrath	*Earth And Universe Sciences*	From tradition to science: assessing the reliability of medicinal plants used in fertility treatments
Muhammad Safdar Syed Mohsan Raza Shah	*University of Education*	Unveiling adaptive components for environmental heterogeneity in Ipomoea carnea Jacq
Sumayya Akram Matloob Ahmad Sana Aslam	*Government College University Faisalabad*	Synthesis, in silico and in vitro evaluation of pyridylpiperazine hybrid derivatives as urease inhibitors
U. Das M.A. Bin Hasan T. Hussain A. Rahman A. Mahmood S. Marma J. Tasnia S. Akter S. Barua N.S. Fabia	*Chattogram Veterinary and Animal Sciences University*	Physicochemical, nutritional, and sensory attributes of high fiber fruit leather of red dragon fruit-peel and mango
Chaymae Denden	*National School of Applied Sciences of Oujda*	Hydrogen production from solar energy: a sustainable alternative for rural energy systems
Hasna Jinnou Said Arif Mohamed Achraf Hasnai	*Sultan Moulay Slimane University*	The contribution of multispectral drones to precision agriculture in the tadla plain: efficiency, benefits, and challenges

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25.10.2025 / SESSION-3 / HALL-4

Ankara Local Time: 15:00-17:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Dr. Amina Yahia

Authors	Affiliation	Presentation Title
Tanzeela Asad Syed Mohsan Raza Shah Iqra Arshia Zia Naila Hadayat Muhammad Bedar Bekhat Naseem Zaheer Abbas Farooq Ahmad	*University of Education*	Comparative morphological, anatomical and eco-physiological assessment of moringa oleifera lam. Across dıverse ecologıcal regıons of punjab, Pakıstan
Sunday Olorunlogbon Olorunnipa Olaniyi Habib Aliu	*Quintessential College*	Enhancing public service delivery with artificial intelligence: policy opportunities and challenges in developing nations
Mohammed Denzira Ali Barhoumi Abdessamad Tounsi Mohammed El Idrissi	*Sultan Moulay Slimane University*	Mechanism and stereoselectivity of hydroboration-oxidation reactions of α-trans-himachalene: insights from DFT, molecular docking, and Admet investigations
Amina Yahia	*Oum el Bouaghi University,*	GIS-based multicriteria analysis for optimal Green Hydrogen (GH2) production site selection
Gresa Ahma	*University "Haxhi Zeka"*	Health and nutritional benefits of the mediterranean diet and olive oil consumption
Mustapha Muhammad Imam	*Ahlul-Baity International University*	Agriculture and aminal science development
Amel Zitouni Afaf Oualhaci Faiza Ilyas Amel Belgacem Azzeddine Senouci	*University of Ain Temouchent*	Implementation of a new protocol for cleaning/disinfecting of fruits and vegetables against pesticides
Yegana Ahmadova Tarlan Agayev	*Azerbaycan Devlet Pedagoji Üniversitesi*	The impact of renewable energy technologies and sustainable development on agriculture
Emalisa Emalisa Jhanghiz Syahrivar	*President University*	From refillable to disposable water gallons: a dilemma in eco-friendly water consumption

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25.10.2025 / SESSION-3 / HALL-5

Ankara Local Time: 15:00-17:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Dr. Khalid Boujdi

Authors	Affiliation	Presentation Title
Mithila Sen	*Bangladesh Agricultural University*	Water-based probiotic supplementation improves growth and intestinal morphology in juvenile gulsha tengra (*Mystus cavasius*)
Sujata Dabolkar Kuldeep Sambrekar	*KLS Gogte Institute of Technology*	Integration of artificial intelligence in vertical gardens: a smart approach to sustainable urban greening
Majji M'Hamed Talha A Bdelhak Aouziou Brahim Bounsir Abdelwahed Benkirane Rachid Benyahia Hamid	*Ibn Tofail University*	Influence of plastic mulching on Phytophthora inoculum density in the citrus root zone
Anas Hamdani Rachid Razouk Said Bouda Atman Adiba	*University of Sultan Moulay Slimane*	Agro-physiological and biochemical responses of the 'Angelino' cultivar (*Prunus salicina* L) under conditions of drought and heat stress
H. Mujtaba A.Y. Bazata Y. H. Rambo, A.Y. Bako.,	*Federal University of Agriculture Zuru*	Biofuel production from chlorella species
Khalid Boujdi	*University Hassan II*	Efficient synthesis, structural elucidation, antibacterial screening, and ın silico evaluation of novel ester-functionalized isoxazoles
Saeeda Mubashra Matloob Ahmad Sana Aslam	*Government College University Faisalabad*	Recent advances in multicomponent approaches to the synthesis and bioactivities of piperazine-based mannich bases
E. Praveena S.Rubinthara R.Swathi	*Bharath Institute of higher education and research*	Rural development

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26.10.2025 / SESSION-1 / HALL-1

Ankara Local Time: 10:00-12:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Prof. Dr. Mehmet Okur

Authors	Affiliation	Presentation Title
Tülay Avci	*Selçuk University*	Quality control tests for veterinary medical products
Yezdan Yelken Ismet Çoşkun Hamza Negiş Cevdet Şeker	*Selçuk University*	Effects of mix-bed resins on the water-holding capacity of sandy-calcareous soils
Zühal Gündüz	*Aydin Adnan Menderes University*	Southeastern Türkiye as a crossroad of goat domestication between the fertile crescent and the mediterranean basin
Zühal Gündüz	*Aydin Adnan Menderes University*	Characterization of a 21-bp indel polymorphism in the llgl1 gene among goat breeds in southern türkiye: damascus, kilis and hatay
Fatma Kayacetin Nilüfer Koçak Şahin	*Ankara University*	Current perspectives on erucic acid in brassicaceae seed oils
Fatma Kayacetin Nilüfer Koçak Şahin	*Ankara University*	The sustainable utilization potential of plant growth-promoting rhizobacteria (pgpr) in saffron (*Crocus sativus* L.) Cultivation
Emel Tüten Sevim Sezen Arat	*Tekirdağ Namık Kemal University*	Effects of heat stress on cattle reproductive efficiency
Metin Yağmur Semra Çiçek	*Ataturk University*	Convolutional neural networks and their potential applications in agriculture
Habil Umur Hülya Hanoğlu Oral Erdinç Altinçekiç Serhat Koçer	*Muş Alparslan University*	Determination of urea in oilseed meals using high-performance liquid chromatography with refractive index detection (hplc-rid)
Mehmet Okur	*Karadeniz Teknik University*	Modernization efforts and results in agriculture and in the field of livestock during the early years of the republic

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26.10.2025 / SESSION-1 / HALL-2

Ankara Local Time: 10:00-12:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Assist. Prof. Dr. Hasan Can

Authors	Affiliation	Presentation Title
Osman Inan	*Bağımsız Araştırıcı*	Open-field applied exhibition practices focused on a single crop in agriculture: the example of the potato days türkiye fair
Kemal Çağrı Gökmen Arzu Peker Şükrü Orkan	*Ankara University*	Knowledge and awareness of telemedicine applications in veterinary medicine: the perspective of intern students
Zeynep Karakaya Seval Sevgi Kirdar	*Burdur Mehmet Akif Ersoy University*	Applications of artificial intelligence in agriculture
Zeynep Karakaya Seval Sevgi Kirdar	*Burdur Mehmet Akif Ersoy University*	Artificial intelligence applications in livestock
Adil Tonğa	*Diyarbakir Plant Protection Research Institute*	Assessing the acute toxicity of avermectin and diamide insecticides to the egg parasitoids Trichogramma evanescens AND T. Pintoi
Mansur Hakan Erol	*Çukurova University*	Effects of different doses of feeddha iron source on callus induction and plant regeneration in *Gynura aurantiaca* (Purple Leaf)
Saber Delpasand Khabbazi	*Yozgat Bozok University*	Identification of potential mutation hotspots in the chloroplast dna of hemp (*Cannabis sativa* L.)
Ademtanişman Semih Pamuk Oruç Şahnar Adnan Ayan Fatma Ertaş Oğuz	*Iğdır University*	Investigation of the presence of ascariasis in dogs with symptoms of bloody diarrhea
Şeniz Öziş Altınçekiç Arda Sözcü Ezgi Şenses	*Bursa Uludağ University*	Climatic factors affecting productivity in silkworm (*Bombyx mori* L.)

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26.10.2025 / SESSION-1 / HALL-3

Ankara Local Time: 10:00-12:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Dr. Orjinta, Hope Ifeoma

Authors	Affiliation	Presentation Title
Anwar Mallongi Fajaruddin Natsir Basir Owildan Wisudawan Sarmaliana Nabilah Saffanah Utami Anwar	*Hasanuddin University*	Health and ecological risks assessment due to chromium and iron accumulation in coastal areas of south sulawesi; application of monte carlo simulation model
Nimra Bashir Qureshi Aliza Bashir Qureshi	*University of Chinese Academy of Sciences*	Dirammox and microbial nitrogen cycling: towards sustainable wastewater treatment
Amadi Oko Amadi Eziechina Malachy Amaechi Ifeanyi Moses Iwueze Osita Ngozika Ann Okwa Eyare Nola Ahmed Enesi Abdulrahman	*Akanu Ibiam Federal Polytechnic Unwana*	AI-driven precision agriculture for climate-resilient crop production
Orjinta, Hope Ifeoma	*Chukwuemek A Odumegwu Ojukwu University*	Ownership structure and performance of quoted industrial goods companies in nigeria
Mahesha Madumali	*University of Ruhuna*	Bio fertilizer-based approaches to alleviate salinity stress and improve soil fertility in leguminous crops
Saniya Y. Desai Sanjıvanı A Gavalı Saurabh S Kagne	*Bharati Vidyapeeth College of Pharmacy*	The healing vine: phytopharmacological insights and bioactive wealth of tinospora cordifolia
Karimat I. Aliyu Mashood A. Belewu	*University of Abuja*	Potentials of Kigelia Africana as a natural aphrodisiac and fertility booster in rabbits
Zainab O. Bello	*Al-Hikmah University*	Influence of dietary supplementation of *Celosia argentea* (SOKO) stem oxytetracycline and butylated hydroxyanisole on production indices, blood chemistry, carcass and meat quality of broiler chickens
Dhivya C Arunkumar R	*Tamil Nadu Agricultural University*	Advancing sustainable agriculture through climate-smart technologies: pathways to environmental resilience and rural prosperity

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26.10.2025 / SESSION-1 / HALL-4

Ankara Local Time: 10:00-12:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Dr. Amina Bigzad

Authors	Affiliation	Presentation Title
Rabiul Awal Moniruzzaman Saiful Islam Al-Amin Harunor Rashid Anuradha Bhadra	*Bangladesh Fisheries Research Institute*	Influence of tank coloration in modulating physiological growth, survival and skin pigmentation expression in nursery- reared channa striata
Gheorghe Giurgiu Cristina Fernoaga Manole Cojocaru	*Head of Works at the University of Agronomic Sciences and Veterinary Medicine*	Microbiota modulation as therapeutic approach in the neuropathic pain in dog with spinal cord injury: impact of polenoplasmin
Musa, L. Olaniyi, O.A Ogunkunle, T	*Ladoke Akintola University of Technology Ogbomoso*	Agricultural information usage and the choice of communication channels among poultry farmers in oyo state, Nigeria
S. Shakthi Sree	*Bharath Institute of Higher Education and Research*	Role of biotechnology in animal breeding
Amina Bigzad	*Ahlul bayt international University*	Innovative solutions for supporting affected women
Amina Bigzad	*Ahlul bayt international University*	Rural development and the social role of women in the development process
A. Rajeswari	*G. Venkataswamy Naidu College*	Internet of things (IOT) in smart agriculture: consideration and challenges
Gheorghe Giurgiu Cristina Fernoaga Manole Cojocaru	*Head of Works at the University of Agronomic Sciences and Veterinary Medicine*	Gut dysbiosis in dogs with spinal cord injury: Impact of Polenoplasmin
Obaniyi Kayode Samuel Kayode Pelumi	*Landmark University*	Arable farmers' perception of usage of agricultural technologies in Kwara State, Nigeria

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26.10.2025 / SESSION-1 / HALL-5

Ankara Local Time: 10:00-12:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Prof. Dr. Ramazan Gönenci

Authors	Affiliation	Presentation Title
Nawrin Tamanna Rasha	*Sylhet Agricultural University*	Development of a smart iot-based model to get weather information from rice field
Yalpi Karthik Manoj-Kumar Arthikala Kalpana Nanjareddy Manjula Ishwara Kalyani	*Mangalore University*	Mangrove derived streptomyces viridiostaticus as a source of dual therapeutic bioactives: antimicrobial proteins and tryprostatin b alkaloid with anticancer potency
Dipok Halder Hasan Ali Sanjay Das Humaira Akter Shanta	*Bangladesh Agricultural University Mymensingh-2202*	Evaluating water hyacinth residue as a viable alternative to conventional organic fertilizer
Fettah Abla Mouhir Latifa Hamri Zineb	*Hassan II University of Casablanca*	From waste to climate action: exploring the role of solid waste management in mitigating greenhouse gas emissions - review
Chukwuemeka G. Eme	*National Open University of Nigeria*	Food insecurity in nigeria: an analysis of the impact of climate change, economic development and conflict on food security
Chukwuemeka G. Eme	*National Open University of Nigeria*	Climate change and its effects on the socio-economic development of nigeria
Ogundeji, N. A. Akinlade, O. O. Akinlade, O. O. Sangosina, M. I. Leramo, O. O. Olufayo, O. O. Okusanya, P. O. Irivboje, O. A Olorunsogbon, B. F.	*1 Federal University of Agriculture*	Effects of three phytogenic aqueous blends on nutrient utilisation efficiency of broiler chicken
Usman Samaila Ibrahim Samaila Amina Taneem Hussaini	*1 Umaru Musa Yar'adua University*	Green hybrid nanoparticles for biomedical applications
Vaibhav Kant Singh Kapil Kumar Nagwanshi Samanvay Singh	*A Central University*	Literature review and proposing a wild animal detection CMS using the latest CV and ML technologies for the conservation of tribes of chhattisgarh

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26.10.2025 / SESSION-2 / HALL-1

Ankara Local Time: 12:30-14:30 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Prof. Dr. Nuri Altuğ

Authors	Affiliation	Presentation Title
Nour Baroudi Esra Yüzgeç Özdemir Fatih Özyurt	*Firat University*	Automatic classification of wheat grains using yolo11 architecture for smart agriculture applications
Sakine Ülküm Çizmeci Ayşe Merve Köse	*Selçuk University*	Mammary hyperplasia in feline
Tülay Canatan Şükrü Doğan N.Kürşat Akbulut Emre Bumin Teke Mustafa Kan	*Bahri Dağdaş Uluslararası Tarımsal Araştırma Enstitüsü*	Comparison of fattening performances of central anatolian merino lambs fed in artificial pasture and intensive in karapinar conditions
Ayşe Merve Köse Sakine Ülküm Çizmeci	*Hatay Mustafa Kemal University*	Chemotherapeutic treatment of mammary tumors in bitch
Nigar Anğın Mustafa Özbuldu Volkan Çatalkaya Ahmet Irvem	*Hatay Mustafa Kemal University*	Evaluation of the effect of different sliding window sizes on soil temperature prediction with deep learning model
Hilal Yilmaz Cengiz Sağlam Oğuz Parlakay Hatun Barut Sait Aykanat	*Doğu Akdeniz Tarımsal Araştırma Enstitüsü Müdürlüğü*	Present position and future predictions for some field crops in turkey
Nurver Altun	*Recep Tayyip Erdoğan University*	An overview of the damage and control methods of *Halyomorpha halys* (Stål, 1855) (Hemiptera: Pentatomidae)

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26.10.2025 / SESSION-2 / HALL-2

Ankara Local Time: 12:30-14:30 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Dr. Ali Ilteriş Aykun

Authors	Affiliation	Presentation Title
Ali Ilteriş Aykun Şule Sanal	*Erciyes University*	An ottoman legacy: the meat and fish institution (ebk) and the food provision chain
Ali Ilteriş Aykun Şule Sanal	*Erciyes University*	Meat logistics in türkiye: the strategic role of the meat and fish institution (ebk) in linking production centers to consumption hubs
Ayşe Feyza Yılmaz Senem Kurşun	*Istanbul Technical University*	Flexible soil sensors for smart and sustainable agriculture
Erdem Karakoç Ahmet Kinay	*Yozgat Bozok University*	Pollen harvesting and storage in tobacco
Ahmet Hilmi Gürbüz Hayriye Ibrikçi Hatun Barut Sait Aykanat	*Eastern Mediterranean Agricultural Research Institute Directorate*	Use of geothermal reserves containing silicon and alginic acid in wheat
Aysun Arar Ahmet Eşitken	*Selçuk University*	Effects of pre-culture boron and calcium applications on micropropagation, vitrification, and apical necrosis in apricot
Muhammed Kayalak Mevlüde Beyza Bayhan Sabriye Belgüzar	*Tokat Gaziosmanpaşa Üniversitesi*	Effects of beneficial bacteria on charcoal rot disease caused by macrophomina phaseolina [(Tassi) goid.] And on the growth of common bean
Hasan Çelikyürek Rıdvan Bayram Azat Aras Abdurrahman Yamaç	*Van Yüzüncü Yıl University*	Investigation of before- and after-feeding body bioelectrical activities in simmental crossbred cattle
Seyithan Seydoşoğlu Nizamettin Turan	*Siirt University*	Grasslands and rangelands as carbon sink areas

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26.10.2025 / SESSION-2 / HALL-3

Ankara Local Time: 12:30-14:30 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Dr. Babita Gupta

Authors	Affiliation	Presentation Title
Vaibhav Kant Singh Kapil Kumar Nagwanshi Samanvay Singh	*A Central University*	Literature review and proposing a computer vision based weapon detection system called CMS for the conservation of tribes of chhattisgarh
Ekanem, Ndifreke John Afolabi, Kolawole Daniel Balogun, A. O Muhammad Haroon, Aslam Agwu, Ani Ekwe Essien, Kemfon Friday	*University of Uyo*	Production of designer eggs and its importance in human nutrition: a review
Kishore.R Meenatchi .S Keerthana.V Vaishnavi.K	*Bharath Institute Of Higher Education And Research*	Street food safety and its impact on public health: a cultural and perspective
M. Muthuramlingam R.Ravichandren V.Gowtham	*Bharath Institute Of Higher Education And Research*	Enhancing pharmaceutical outcomes through agricultural knowledge
Ameur Zaghouani Ayoub Hadjeb Sarra Benaissa Mohamed Rami Berbache Chaima Chetioui Amina Hammadi Kawther Bourezzane Yahia Ammari Habiba Hachani	*University of Biskra*	Effect of dietary substitution on some production parameters of red tilapia (*Oreochromis* sp.) in the Biskra region.
Babita Gupta	*Institute of Technology and Management*	Construction feature and regulatory aspects of organ chip for drug delivery application
Aliza Naeem Muhammad Bilal Hussain Marwa Waheed Sawera Asif Mariam Islam Maha Atiq	*Government College University Faisalabad*	Sustainable food packaging technologies: innovation for a greener consumer future
Alexandra Raluca Borșa Andrei Borșa Melinda Fogarasi Floricuţa Ranga Anda Elena Tanislav Vlad Mureșan Cristina Anamaria Semeniuc	*University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca*	Sustainable valorization of rosehip by-products as functional additives in pork sausages: functional and quality perspectives
D.Aravindhan N.Arshad Ahamed K.Dinesh Rajan	*Bharath Institute of Higher Education and Research*	Food safety regulations and consumer awareness

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26.10.2025 / SESSION-2 / HALL-4

Ankara Local Time: 12:30-14:30 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Dr. Wasiu Olatunde Oladapo

Authors	Affiliation	Presentation Title
Boucherdoud Ahmed Abdelkarime Seghier Bendjelloul Meriem	*University of Relizane*	Self-deposited copper oxide on polyaniline nanocomposite catalysts for the photodegradation of organic dyes
Karima Jmaili Khawla Waddi Mohamed Lahrairi Meriem Mahmoudi Bouchaib Bahlaouan Alla Silkina Nadia Boutaleb	*Hassan II University of Casablanca*	From cream to green: unlocking the biostimulant power of whey in sustainable crop growth
Hira Zainab Rimsha Imran Maha Tariq	*Lahore College for Women University*	Threads of escape: adaptive reuse of trains
Akinlade, O. O, Akinlade, O. O. Alausa, O.J. Ojo, R.O. Alabi, S.J.	*Animal Production Technology,*	Reproductive performance of pullet fed oyster mushroom as a replacement to antibiotics
Afshin Tavasoli Farsheh Zahra Masoomi	*Islamic Azad University*	Application of nanomaterials to improve the properties of pet waste bottle sheet: a review
Afshin Tavasoli Farsheh Arezoo Sadat Khafi	*Islamic Azad University*	Recent advances towards the pet environmentally friendly bottles techniques: a review
Wasiu Olatunde Oladapo	*Lagos State University of Education*	AI for agrarian transformation: unlocking the potential of machine learning for crop yield prediction, disease detection, and smart farming
Mohamed Fardouch Rana Choukri Mohamed Faize Mourad Baghour	*University Mohammed I*	Yield, fruit quality, na^+ and k^+ accumulation in tomato fruits grown in intercropping with maize
Thanh-Dung Nguyen Mai-Uyen Nguyen	*Can Tho University*	Evaluation of the antimicrobial activity and characterization of the bioactive secondary meta bolites produced by bacillus velezensis SB4R5 against escherichia coli AND staphylococcus aureus

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26.10.2025 / SESSION-2 / HALL-5

Ankara Local Time: 12:30-14:30 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Dr. Halid Sheriff Adegbusi

Authors	Affiliation	Presentation Title
K. Dinesh Rajan D.Aravindhan N. Arshad Ahamed	*Bharath Institute of Higher Education and Research*	Role of pharmacy in rural development and public healthcare
Rohit Kumar Singh Giorgi Shtenberg	*Institute of Agricultural and Biosystems Engineering ARO*	A nanostructured microarray-based sers sensor targeted at multiplex mycotoxin detection in food and feedstuff using a handheld apparatus
Ajayi, Mercy Adenike Adesanmi, Moses Ademola	*Federal Polytechnic*	A lexical-semantic reading of agricultural terms in two of Niyi Osundare's poems
S Indhu G Priya Murugesan Kamaraj	*SRM Institute of Science and Technology*	A mechanistic multi-omics and ecological risk assessment on ecological safety and non-target effects of biopesticides and microbial inoculants in agroecosystems
Tsegmid N. Zayatogtokh B.	*Mongolian University of Life Sciences*	Sightings of birds in oil production areas (Mongolia)
Biswarup Mukherjee	*Brainware University*	AI-enhanced solar-powered water pumping system for sustainable irrigation in Rural West Bengal
Moniruzzaman Rabiul Awal Moshiur Rahman Harunor Rashid Anuradha Bhadra	*Bangladesh Fisheries Research Institute*	Bottom-clean aquaculture maximizes growth, survival, and profit of high-valued catfish

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26.10.2025 / SESSION-2 / HALL-6

Ankara Local Time: 12:30-14:30 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Dr. Aliyu Hassan

Authors	Affiliation	Presentation Title
Keerthana.V, Meenatchi.S Kishore.R R. Saravanan	*Bharath Institute of Higher Education and Research*	Green pharmacy: a sustainable approach to drug development
Mobarok Hosen Mokarroma Syed Imad Zaman Pias Ahmed Sahadat Hossain Airin Jahan Urmi Upoma Shobnom Raicha Mahbub Alam	*University of Rajshahi*	Unlocking the economic potential of mustard cultivation in bangladesh: profitability, inefficiencies, and institutional gaps
Aliyu Hassan	*Air Force Institute of Technology*	Urban renewal approaches for the revitalization of tudun nupawa neighborhood, Kaduna, Nigeria
Auwal Mohammed Adamu Olufunmilayo Temitope Afolayan	*The Federal Polytechnic*	Leveraging on technical and vocational training (TVET) for achieving food security in nigeria: a study of ogun state
K.Vaishnavi R.Sriarasuvasan V.Keerthana S.Rubinthara R.Kishore K.Deepak	*Bharath Institute of Higher Education and Research*	"Giving voice to the voiceless"— the rise of animal–computer interaction
Boucherdoud Ahmed Douinat Oukacha Bendjelloul Meriem Seghier Abdelkarim Elandaloussi Elhadj.	*University of Relizane*	Synthesis of an activated carbon-nanocomposite for the treatment of pollutants
Yuldashow Bahadir Annamyradow Dowlet Yollyyewa Ayna Yollyyew Hydyrgeldi	*University of Relizane*	Innovation method of the obtainig electric energy from drainage water in Turkmenistan
Ruhul Amin Tasmia Islam Kanta Mosfiq Momtasir Neloy Shahjahan	*Bangladesh Agricultural University*	Combined effects of microplastics and mercury on survivability, hematology, tissue morphology, accumulation, oxidative stress, immune response and GH/IGF axis in Nile tilapia (*Oreochromis niloticus*)
Abdullahi Adamu Kiri Naziru Nura Zaharaddini Haruna Musa Zakari Muhammad	*Jigawa State Polytechnics for Information and Communication Technology*	An artificial fish swarm search algorithm (AFSSA) based on hybrid behavior

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26.10.2025 / SESSION-3 / HALL-1

Ankara Local Time: 15:00-17:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Prof. Dr. Cemal Budağ

Authors	Affiliation	Presentation Title
Tülin Güven Gökmen Hatice Yazgan	*Cukurova University*	Crispr-based rapid diagnostic tests: a new era in microbiology and clinical applications
Mehmet Kulu Alper Döyen Muhammed Emre Keskin	*Konya Teknik University*	Investigation of geothermal greenhouse usage in peri-urban agriculture
Aybike Ayfer Karadağ Demet Demiroğlu	*Düzce University*	An assessment of the potential impacts of the turkish climate law on agricultural landscapes
Demet Demiroğlu Aybike Ayfer Karadağ	*Düzce University*	The legal vulnerability of agricultural areas: turkiye example
Levent Taşeri Ersin Karacabey Gamze Uysal Seçkin	*Tekirdağ Viticulture Research Institute Directorate*	Investigation of drying kinetics of walnut dried with different methods in tekirdağ conditions
Ergül Ay Hüseyin Özpinar Hülya Okkaoğlu Melek Akça Pelen Erseven Ulus Süleyman Çağir Ceylan Büyükkileci	*Aegean Agricultural Research Institute Directorate*	Determination of yield and quality traits of some silage maize (*Zea mays* L.) genotypes in izmir conditions
Cemal Budağ	*Van Yüzüncü Yıl University*	Quality characteristics of drinking water for ruminant animals
Cemal Budağ	*Van Yüzüncü Yıl University*	Current approaches to ruminant drinking water quality: chemical, microbiological and emerging contaminants, digital monitoring and policy perspectives
Mehtap Güney	*Van Yüzüncü Yıl Üniversitesi*	Methane production and rumen microbiotas in ruminants

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26.10.2025 / SESSION-3 / HALL-2

Ankara Local Time: 15:00-17:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Assoc. Prof. Dr. Mehmet Karaman

Authors	Affiliation	Presentation Title
Mehmet Karaman	*Muş Alparslan Üniversitesi*	Evaluation of some bread wheat (*Triticum aestivum* L.) genotypes in terms of yield and quality under supplementary irrigation conditions
Mehmet Karaman	*Muş Alparslan Üniversitesi*	Evaluation of red lentil (*Lens culinaris* Medik.) varieties registered in turkey in terms of yield and some morphological characteristics in conditions of muş province
Zübeyde Albayram Doğan Dr.Tuncay Topdemir Sinan Aras Gülay Yilmaz Gözen Yüceerim Alican Eren Nuri Candan Vural Karagül Şener Özçelik Murat Çağatay Keçeci	*Uluslararası Tarımsal Araştırma ve Eğitim Merkezi Müdürlüğü*	Farmer approach on salinity as a challenge; menemen plain case
Ibrahim Halil Şindak Adem Gökçöl Sıdıka Ekren	*Ege University*	Improving seed germination in *Lavandula angustifolia* Mill. With priming and phytohormone applications
Soner Çolak Oğuz Bilgin Damla Balaban Göcmen	*Tekirdağ Namık Kemal Universitesi*	Examination of mutant lines subjected to salinity stress during germination
Samet Aşkin Yaşar Karadağ Mahir Özkurt	*Muş Alparslan Üniversitesi*	Determination of yield caracteristics of alfalfa (*Medicago sativa* L.) genotype cultured in mus plain
Ece Taşyumru Süzer Umut Süzer Sıdıka Ekren	*Ege University*	Comparison of yield and yield components of two different rapeseed (*Brassica napus* L.) varieties under Kırklareli/Babaeski-Yeniköy conditions
Merve Usal	*Kırklareli University*	Phenolic content and antioxidant activity of honeysuckle flower (*Lonicera japonica*) extracts obtained using different solvents
Mehmet Zeki Koçak	*Igdır University*	Comparative analysis of oil yield and fatty acid composition in local and foreign flax (*Linum usitatissimum* L.) cultivars

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26.10.2025 / SESSION-3 / HALL-3

Ankara Local Time: 15:00-17:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Dr. Murat TURAN

Authors	Affiliation	Presentation Title
Çağrı Melikşah Sakar Burak Artut Hasan Hüseyin Şenyüz	*International Center for Livestock Research and Training*	The relationship between cow activity behaviors and climate
Zeynep Gürbüz Kaçan	*Atatürk University*	Migration of phthalate acid esters from plastic packaging into butter: a literature-based perspective
Erkal Ertem Erhan Akkuzu	*Ege University*	Determination of the relationship between stomatal conductance and tc-ta obtained from thermal images in olive trees
Yavuz Şahin Turgut Yakup Kenan Koca	*Çukurova University*	Long-term analysis of land use changes and establishment of a soil database: the case of yumurtalik
Ilyas Dayan Özlem Çakmakci	*Van Yüzüncü Yıl University*	The effect of nano-silver application under saline water on some growth and yield parameters in tomato seedlings
Murat Turan	*Van Yüzüncü Yıl University*	The effects of behavior in cattle on productivity
Efecan Iştipliler Fikret Öndes	*İzmir Katip Çelebi Üniversitesi*	Effects of hook size, hook type, and bait on catch per unit effort and fish size in recreational fisheries of the aegean sea: implications for fisheries management
Aysel Gülbandilar Barkın Koçer Rumeysa Bozkurt Sıla Gönül	*Eskişehir Osmangazi Üniversitesi*	Determination of the physicochemical and microbiological properties of kefirs enriched with different concentrations of *Spirulina platensis* and P*istachio flavor*
Murat Turan Irfan Inan Halit Deniz Şireli Müzeyyen Buse Karaman	*Van Yüzüncü Yıl University*	Innovative approaches in morphological measurements in cattle and sheep breeding

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26.10.2025 / SESSION-3 / HALL-4

Ankara Local Time: 15:00-17:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Dr. Mezerket Amina

Authors	Affiliation	Presentation Title
Musfiqur Rahman Abdul Baree Bhowmik Shimu Akhi Khatun	*University of Rajshahi*	Effect of planting time and nitrogen dose on growth and yield of cabbage
Ameilia Zuliyanti Siregar Liana Dwi Sri Hastuti Nismah Panjaitan Evawaty Sri Ulina	*University of Sumatera Utara*	Application of salted fish, crab and shrimp variations with organic attractants to control brown plant pests in rice plants in serdang bedagai
Asbai Zakaria Nadia Boutaleb Said El Antri Bouchaib Bahlaouan	*Hassan 2 University of Casablanca*	Valorization of agro-industrial wastes for the sustainable development of controlled-release organomineral fertilizers
Amina Bigzad	*Ahlul bayt international university iran.*	The role of agriculture in the economies of developing countries: a framework of participation, challenges, and pathways to sustainability.
Mezerket Amina	*Ecole Normale Supérieure (ENS) Kouba Algiers*	Impact of phytochemicals on the hatching ability of Meloidogyne incognita
Ali Aguerd Fatima Chegdani Faiza Bennis	*University Hassan II*	Food-based strategies for neurodegenerative disease prevention: an in silico study using parkinson's disease as a model
Bismillah Iftikhar	*Essentials Healthcare Lahore*	Optimizing vitamin d3 bioavailability: development of high-dose oral shot formulation (VOL-D)
Umar Mudi Ahmad Umar Sani Harun Ibrahim Khalil Zakariyya Uba Zango	*Al-Qalam University*	Synthesis, characterization, cytotoxicity and antimicrobial studies on mn(ii) and co(ii) complexes of schiff base derived from Acetophenone and o-Aminophenol

(All speakers required to be connected to the session 10 min before the session starts)
Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

26.10.2025 / SESSION-3 / HALL-5

Ankara Local Time: 15:00-17:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Dr. Halid Sheriff Adegbusi

Authors	Affiliation	Presentation Title
Halid Sheriff Adegbusi	*Nigeria Police Academy Wudil*	Food irradiation for mitigating post-harvest losses in Nigeria
Halid Sheriff Adegbusi	*Nigeria Police Academy Wudil*	Nutritional assessment of complementary foods made from
Aruwa Abdulhafiz Bawa Muhammad Yusuf Muhammad Abdullahi Ubana	*Nasarawa State University*	Biosorption of hexavalent chromium by sulphuric acid modified cucumeropsis manii peel
Jean Richard Jokhu Sulthan Nahrawi Sinurat	*President University*	Analysis of customer loyalty on service quality in lion air airlines
M.A. Dinh Hong Khoa	*Dong Thap University*	Colonial land policies and rural transformation in cochinchina (Late 19th – Early 20th Century)
Ahmed Attahiru Abubakar Umar Birnin-Yauri	*University of Science and Technology*	Natural products as leads for antimicrobial drug discovery
Muhammad Umer Quddoos Munawwar Hussain Tahira Kanwal Kazim Abbas Muhammad Tayyeb Hafeez	*Bahauddin Zakariya University*	Nexus of green innovation and organizational performance: the mediating role of technology transfer
Ourada Haddou Zouhir Hamadi Mourad Boutahire Rahmani Abdelhai	*Universit´e Moulay Ismail*	Thermal conductivity of single-walled carbon nanotubes (SWCNTs)

(All speakers required to be connected to the session 10 min before the session starts)
Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

26.10.2025 / SESSION-3 / HALL-6

Ankara Local Time: 15:00-17:00 Online Session (Zoom Meeting)

Zoom Meeting ID: 897 0755 8402 / Zoom Passcode: 181818

HEAD OF SESSION: Dr. K.r. Padma

Authors	Affiliation	Presentation Title
Sharipah Khadijah S.Hashim	*Politeknik Tuanku Sultanah Bahiyah Malaysia*	Enhancing forecasting competence for value-added agricultural products using forecastify edu: a simulation-based learning approach
K.R. Padma	*Women'sUniversity*	Influence of water treatment methods on zebrafish health: a study of uv-sterilized and groundwater systems
Anas Elharami Issam Forsal Wissal Kotmani	*Sultan moulay slimane university*	Corrosion inhibition of mild steel in 1 m hcl by a green extract: electrochemical and computational study
Jatinkumar Bhimjibhai Kotadiya Dharmendra J. Ambani Hetal Pravinsinh Jadeja	*Atmiya University*	Attention-driven hybrid model for crop disease classification and smart farm management
Endalamaw Yihune Amare Bitew Mekonnen Getahun Yemata	*Bahir Dar University*	The phytoremediation potential of native grass species in ethiopia. systematic review
Ayon Mallick Hasan Ali Abul Bashar Ripon Khalipha	*Gopalganj Science and Technology University*	Computational study of function and structure of uncharacterized gibberella fujikuroi protein
Z. Ait El Caid R. Kellal M. Zertoubi D. Benmessaoud Left	*Hassan II University*	Sustainable mitigation of C38 carbon steel corrosion in aggressive acidic media using bio-derived natural inhibitors: an integrated electrochemical, DFT, and molecular dynamics approach
Anita Pandey V. M. Agrawal	*Govt. Navin college*	Spider diversity in the vicinity of "amakoni reservoir", sarangarh-bilaigarh district, chhattisgarh, India
Granthali P. Shape Pooja Rasal	*JES's SND College of Pharmacy*	Aphaisia:- A comprehensive language disorder

(All speakers required to be connected to the session 10 min before the session starts)

Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

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POLİS


18.ULUSLARARASI TARIM, HAYVANCILIK VE
KIRSAL KALKINMA KONGRESİ
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Dr. Öğr. Üyesi Said Efe DOST
Karamanoğlu Mehmetbey Üniversitesi, Teknik Bil, Bitkisel ve Hayvansal Üretim Bölüm
Email: saidefe.dost@gmail.com
ORCID: 0000-0003-4279-7292
Dr. Öğr. Üyesi. Yılmaz SESLİ
Karamanoğlu Mehmetbey Üniversitesi, Teknik Bil, Bitkisel ve Hayvansal Üretim Bölüm
Email: ysesli@kmu.edu.tr
ORCID: 0000-0002-3150-2180
Öğr. Gör. Dr. Elif ÇATIKKAŞ
Karamanoğlu Mehmetbey Üniversitesi, Teknik Bil, Bitkisel ve Hayvansal Üretim Bölüm
Email: eliffcatikkas@gmail.com
ORCID: 0000-0002-0661-0219

ÖZET

Bu çalışma, yaz ayları sıcak ve kurak geçen, yağış miktarı düşük olan Karaman ili koşullarında, Karamanoğlu Mehmetbey Üniversitesi Elmacılık Araştırma ve Uygulama Merkezi bünyesinde 2019 yılında kurulan deneme parselinde yürütülmüştür. Araştırmada M9 anacı üzerine aşılı Pink Lady ve Jeromine elma çeşitleri 2023–2024 yılları gelişme sezonu boyunca değerlendirilmiştir. Çalışmanın amacı, kuraklık stresinin meyve ve yapraklarda fenolik bileşikler, antioksidan aktivite ve bazı kalite parametreleri üzerine etkilerini belirlemektir. Bu amaçla iki farklı sulama rejimi uygulanmıştır: kontrol ağaçlarına 5 gün aralıklarla 5 L su, stres uygulanan ağaçlara ise 15 gün aralıklarla 5 L su verilmiştir. Sulama öncesinde 15. günün sonunda yaprak ve meyve örnekleri alınarak analiz edilmiştir. Elde edilen tüm veriler istatistiksel olarak anlamlı bulunmuştur. Su stresi altında, suda çözünebilir kuru madde (SÇKM) ve titre edilebilir asitlik (TA) değerleri kontrol ağaçlarına göre daha yüksek kaydedilmiştir. En yüksek SÇKM değerleri Pink Lady çeşidinde 2023'te %14,7 ve 2024'te %15,1, en yüksek TA değerleri ise yine Pink Lady'de %0,74 ve %0,76 olarak belirlenmiştir. Meyve eti ve kabukta toplam fenolik (220,4 mg GAE/100 g) ve antioksidan (159,1 µM Trolox/100 g) değerleri ile yapraklarda toplam fenolik (10,04 mg GAE/g DW), antioksidan (18,21 mg/g TEAC 100 g DW) ve prolin (1,58 µmol/g FW) düzeyleri de Pink Lady çeşidinde en yüksek bulunmuştur. Sonuç olarak, her iki çeşit de kuraklık koşullarına oldukça duyarlı olup, su stresi bitki gelişimi ve ürün kalitesini olumsuz etkilemiştir. Bununla birlikte, fenolik ve antioksidan birikimi, bitkinin su kaybını telafi etmeye yönelik adaptif bir yanıt olarak değerlendirilmektedir.

Anahtar Kelimeler: Elma (Malus domestica), Kuraklık stresi, Prolin, Fenolik ve Antioksidan bileşikler

EFFECT OF DROUGHT STRESS ON PINK LADY AND JEROMINE APPLE CULTİVARS

ABSTRACT

This study was conducted under the hot and dry summer conditions with low precipitation in Karaman, Turkey, at the Apple Research and Application Center of Karamanoğlu Mehmetbey University, in an orchard established in 2019. Pink Lady and Jeromine apple cultivars grafted onto M9 rootstock were evaluated during the 2023–2024 growing seasons. The aim was to determine the effects of drought stress on phenolic compounds, antioxidant activity, and selected fruit quality parameters. Two irrigation regimes were applied: control trees received 5 L of water every 5 days, while stressed trees received 5 L every 15 days. Leaf and fruit samples were collected at the end of each 15-day irrigation cycle. All results were statistically significant. Under drought stress, soluble solid content (SSC) and titratable acidity (TA) values were higher than in control trees. The highest SSC values were obtained in Pink Lady (14.7% in 2023 and 15.1% in 2024), while the highest TA values were also found in Pink Lady (0.74% and 0.76%). In fruit, the highest total phenolic content (220.4 mg GAE/100 g) and antioxidant activity (159.1 µM Trolox/100 g) were recorded in Pink Lady. In leaves, the highest total phenolics (10.04 mg GAE/g DW), antioxidants (18.21 mg/g TEAC 100 g DW), and proline (1.58 µmol/g FW) were also observed in Pink Lady under drought stress. Overall, both cultivars were highly sensitive to water deficit, which negatively affected plant growth and fruit quality. However, the accumulation of phenolic and antioxidant compounds suggests an adaptive response mechanism aimed at mitigating water loss.

Keywords: Apple (Malus domestica), Drought Stress, Proline, Phenolic-Antioxidant Compounds

PATATESTE (*Solanum tuberosum l.*) BİTKİ PARAZİTİ NEMATODLAR VE MÜCADELE YÖNTEMLERİ

Dr. Gülten Kaçar Avcı
Patates Araştırma Enstitüsü
Email: gkacaravci@gmail.com
ORCID: 0009-0002-6859-4792

ÖZET

Patates, ülkemiz tarımı ve ekonomisinde çok önemli bir bitkidir. Türkiye genelinde yetiştirilen patates bitkisinin Doğu Anadolu, Ege ve Marmara Bölgeleri'nde de üretimi yapılmaktadır. Ülkemizde patates üretiminin en yoğun olduğu il Niğde'dir. Ekonomik önem taşıyan patates bitkisinde birim alandan fazla ve kaliteli ürün elde etmek için zararlılar ve hastalıklarla etkin mücadele edilmelidir. Patates bitkisinin yumrularıyla çoğaltılması, hastalık ve zararlılardan daha çok etkilenmesine neden olmaktadır. Bitki paraziti nematodlar, tarımsal üretimde bitkilerde zarar yapan etmenlerdendir ve ciddi verim kayıplarına neden olurlar. Bitki paraziti nematod türlerinin patates bitkisinde verdiği zarar ve mücadele yöntemleri farklılık göstermektedir. Nematodların toprak kökenli patojenler olması ve bazı türlerin dayanıklı yapı olan kistler halinde uzun yıllar toprakta varlığını sürdürmesi nedeniyle birçok türüne karşı etkin kimyasal mücadele yöntemi mevcut değildir. Patates bitkisinde Kök ur nematodları gibi türlerde kimyasal mücadele uygulamaları yapılmaktadır. Kist nematodlarının mücadelesinde dayanıklı çeşitlerin kullanılması tüm dünyada başarı ile uygulanmaktadır. Kist nematodları (Globodera spp.), Kök ur nematodları (Meloidgoyne spp.), Patates çürüklük nematodu (Ditylenchus destructor) Thorne, Soğan-sak nematodu (Ditylenchus dipsaci) Kühn, patates bitkisinde zarar yapan nematodların en önemlileridir. Altın Kist Nematodu (G. rostochiensis) ülkemizde ilk tespiti Bolu ili Dörtdivan ilçesinde patates üretiminin yapıldığı alanda yapılmış ve bölge karantina altına alınmıştır. Son zamanlarda yapılan çalışmalarda Kök lezyon nematodu (Pratylenchus spp.) türlerinin de patates bitkisinde önemli oranda zarar yaptığı tespit edilmiştir. Bu çalışmada patates bitkisinde verim kaybına neden olan nematodlar ve mücadele yöntemleri hakkında bilgi verilmiştir.

Anahtar Kelimeler: Patates, bitki paraziti nematodlar, mücadele, sebze.

PLANT-PARASITIC NEMATODES IN POTATOES (*solanum tuberosum l.)* AND CONTROL METHODS

ABSTRACT

Potato is a very important crop in our country's agriculture and economy. Potato is grown throughout Türkiye, but they are also produced in the Eastern Anatolia, Aegean, and Marmara regions. Niğde is the province with the highest potato production in Turkey. In order to obtain more and higher quality products per unit area in the potato plant, which is economically important in our country, pests and diseases must be effectively combated.

Propagation of potato plants by tubers makes them more susceptible to diseases and pests. Plant-parasitic nematodes are among the factors that cause plant damage in agricultural production and cause significant yield losses. The damage caused by plant parasitic nematode species on potato plants and the control methods vary. Because nematodes are soil-borne pathogens and some species persist in the soil for many years as resistant cysts, there are no effective chemical control methods against many species. Chemical control applications are carried out against species such as root knot nematodes in potato plants. The use of resistant varieties to control cyst nematodes is successfully implemented worldwide.

Cyst nematodes (Globodera spp.), root-knot nematodes (Meloidgoyne spp.), potato rot nematode (Ditylenchus destructor), Thorne, stem and bulb (Ditylenchus dipsaci) Kühn, nematode are the most important nematodes that damage potato plants. The first detection of the Golden Cyst Nematode (G. rostochiensis) in our country was made in the potato production area of Dörtdivan district of Bolu province, and the area was quarantined. Recent studies have also identified root-lesion nematodes (Pratylenchus spp.) as causing significant damage to potato in the field. In this study, information is given about nematodes that cause yield loss in potato plants and their control methods.

Key Words: Potato, plant parasitic nematodes, control, vegetable.

MULTİSPEKTRAL VEJETASYON İNDİSLERİ İLE ERKEN BUĞDAY VERİMİ TAHMİNİ: SU STRESİ ALTINDA ÇEŞİT TEPKİLERİNİN İSTATİSTİKSEL ANALİZİ

Dr. İsmail ÇİNKAYA

Konya Toprak Su ve Çölleşme ile Mücadele Araştırma Enstitüsü Müdürlüğü

Email: ismail.cinkaya@tarimorman.gov.tr

ORCID: 0000-0002-6080-652X

Dr. Osman ÇAĞIRGAN

Konya Toprak Su ve Çölleşme ile Mücadele Araştırma Enstitüsü Müdürlüğü

Email: osman.cagirgan@tarimorman.gov.tr

ORCID: 0000-0001-9979-4098

Şafak CEYLAN

Konya Toprak Su ve Çölleşme ile Mücadele Araştırma Enstitüsü Müdürlüğü

Email: safak.ceylan@tarimorman.gov.tr

ORCID: 0000-0001-8165-2550

Durmuş Ali KİPRİTCİ

Konya Toprak Su ve Çölleşme ile Mücadele Araştırma Enstitüsü Müdürlüğü

Email: durmuşali.kipritci@tarimorman.gov.tr

ORCID: 0000-0001-6622-438X

Doç. Dr. Sinan SÜHERİ

Selçuk Üniversitesi, Ziraat Fakültesi

Email: suheri@sekcuk.edu.tr

ORCID: 0000-0002-6163-0706

ÖZET

Küresel iklim değişikliği ve artan dünya nüfusu, su kaynaklarının etkin yönetimini tarımsal üretimde kritik hale getirmiştir. Bu bağlamda, bitki sağlığı ve gelişimini izleyerek sulama kararlarını destekleyecek hızlı ve doğru yöntemler büyük önem taşımaktadır. Bu çalışmanın amacı, dört farklı buğday çeşidinde uygulanan dört farklı sulama seviyesinin (1.0, 0.70, 0.40 ET0, yağışa bağlı) buğday verimi üzerindeki etkisini incelemek ve bu verimi, deneme süresince periyodik olarak alınan drone tabanlı multispektral görüntülerden elde edilen bitki indisleri (NDVI ve EVI) ile tahmin etmektir. Çalışma, tesadüf blokları deneme desenine göre üç tekerrürlü olarak kurulmuş olup, toplam 48 parselde yürütülmüştür. Elde edilen drone tabanlı indisler, el tipi NDVI ölçümleriyle de karşılaştırılmıştır.

Araştırmada farklı buğday çeşitleri ve sulama uygulamaları arasındaki etkileşimi kapsayacak şekilde tasarlanmıştır. Sulama seviyeleri, bölge için belirlenen referans evapotranspirasyon değerlerine göre ayarlanmıştır. Çalışma süresince, kritik büyüme dönemlerinde multispektral drone görüntüleri alınarak her parsel için NDVI (Normalize Edilmiş Fark Bitki İndeksi) ve EVI (Geliştirilmiş Bitki İndeksi) değerleri hesaplanmıştır. Elde edilen indis değerleri ile hasat sonrası belirlenen buğday verimleri arasındaki ilişki, çeşit ve sulama seviyelerine göre ayrı ayrı ve genel ortalamalar üzerinden regresyon analizleri ile incelenmiştir. Bu analizlerle, verimi en

yüksek doğrulukla tahmin eden indis türü ve optimum ölçüm zamanı tespit edilmeye çalışılmıştır.

Yapılan regresyon analizleri sonucunda, drone tabanlı NDVI'nin buğday verimini tahmin etmede en güçlü ilişkiyi sunduğu tespit edilmiştir. Tüm çeşitlerin ve sulama seviyelerinin ortalamaları dikkate alındığında, drone NDVI, hasattan 30 gün önce alınan ölçümlerle R2 =0.76 gibi yüksek bir belirleme katsayısı ile verimi başarılı bir şekilde açıklamıştır. Sulama seviyeleri özelinde incelendiğinde ise, yağışa bağlı (0.00 Et) sulama koşulundaki verim, daha erken bir tarihte, hasattan 60 gün önce alınan drone NDVI ölçümleriyle yine R2 =0.76 doğrulukla tahmin edilebilmiştir. Bu sonuçlar, drone teknolojisinin ve multispektral bitki indislerinin, farklı buğday çeşitleri ve su stresi koşullarında bile, buğday verimini hasattan önemli ölçüde önce ve yüksek güvenilirlikle tahmin edebilen bir araç olduğunu göstermektedir. Bu erken tahmin yeteneği, çiftçilere ve karar vericilere sulama ve besleme gibi konularda proaktif yönetim stratejileri geliştirme fırsatı sunmaktadır.

Anahtar Kelimeler: NDVI, EVI, verim tahmini, su kısıtı, sulama, multispektral görüntüleme

EARLY WHEAT YIELD PREDICTION USING MULTISPECTRAL VEGETATION INDICES: STATISTICAL ANALYSIS OF VARIETY RESPONSES UNDER WATER STRESS

ABSTRACT

Global climate change and a growing world population have made the efficient management of water resources critical in agricultural production. In this context, rapid and accurate methods to monitor plant health and development, thereby supporting irrigation scheduling decisions, are of paramount importance. The objective of this study was to investigate the effect of four different irrigation levels (1.0, 0.70, 0.40 ET, and rainfed) applied to four different wheat cultivars on wheat yield, and to predict this yield using vegetation indices (NDVI and EVI) derived from drone-based multispectral imagery periodically acquired throughout the growing season. The study was established in a Randomized Complete Block Design (RCBD) with three replications, comprising a total of 48 plots. The derived drone-based indices were also compared with handheld NDVI measurements.

The experiment was designed to capture the interaction between different wheat cultivars and irrigation applications. Irrigation levels were set according to the reference evapotranspiration (ET0) values determined for the region. During the study, multispectral drone images were captured during critical growth stages, and NDVI (Normalized Difference Vegetation Index) and EVI (Enhanced Vegetation Index) values were calculated for each plot. The relationship between the obtained index values and the post-harvest wheat yields was investigated using regression analyses, both separately for each cultivar and irrigation level, and based on overall means. These analyses aimed to identify the index type and the optimum measurement timing that predicted yield with the highest accuracy.

The regression analyses revealed that drone-based NDVI provided the strongest relationship for predicting wheat yield. Considering the overall averages of all cultivars and irrigation levels, the drone NDVI successfully explained the yield with a high coefficient of determination, $R2=0.76$, from measurements taken 30 days before harvest. When focusing specifically on irrigation levels, the yield under rainfed (0.00 ET) conditions could be predicted with the same accuracy, $R2=0.76$, from drone NDVI measurements taken at an earlier date, 60 days before harvest. These results demonstrate that drone technology and multispectral vegetation indices serve as a tool capable of predicting wheat yield significantly earlier and with high reliability, even across different wheat cultivars and under water stress conditions. This early prediction capability offers farmers and decision-makers the opportunity to develop proactive management strategies regarding irrigation and nutrient application.

Keywords: NDVI, EVI, yield estimation, water stress, irrigation, multispectral imaging

TARIMSAL ÜRETİMDE HUMİK VE FULVİK ASİT: KULLANIM OLANAKLARI VE GÜNCEL ÇALIŞMALAR

Doç. Dr. Hakan KELES

Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü

Email: hakan.keles@yobu.edu.tr

ORCID: 0000-0002-8225-931X

Doç. Dr. Servet ARAS

Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü

Email: servet.aras@yobu.edu.tr

ORCID: 0000-0002-0347-6552

Doç. Dr. Müjgan GÜNEY

Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü

Email: mujgan.guney@yobu.edu.tr

ORCID: 0000-0001-5491-1430

Dr. Öğr. Gör. Selcan ÖZYALIN

Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü

Email: selcan.ozyalın@yobu.edu.tr

ORCID: 0000-0003-4831-8600

ÖZET

Tarım, Türkiye gibi gelişmekte olan ülkelerin kalkınmasında önemli bir rol oynayan, gelişmiş ülkelerin ekonomilerinin ise temelini oluşturan bir sektördür. Plansız kentleşme ve nüfus artışı, gün geçtikçe yoğunlaşan sanayileşme ile azalan tarım alanlarına rağmen üretim kaygısı devamlı artış göstermiştir. Artan nüfusun besin ihtiyacını azalan tarımsal alanlarla karşılamak amacıyla tarımsal teknikler gün geçtikçe gelişmiş, bu gelişme ile birlikte özellikle ilaç, gübre gibi kimyasal ürünlerin kullanımı artmıştır. Birim alandan daha yüksek verim kaygısı ile kullanımı kontrolsüz bir şekilde artan kimyasal girdilerin bir süre sonra bazı zararları tespit edilmiştir. Bu girdilerin kullanımı ürün veriminde her ne kadar artış sağlasa da çevreye ve toprağa verdiği zararlar bazı çözümleri zorunlu kılmıştır. Toprak yapısının, organik içeriğinin ve canlı florasının bozulması konularının çözümü amacıyla organik temelli ürünlerin kullanımı çözüm için önemli çıkış kapıları olmuşlardır. Toprak organik maddesinin artırılması, toprakların kimyasal ve fiziksel yapılarının onarılması ve hatta toprakta canlı mevcudiyetinin artırılması için en önemli çözüm yolu olarak yaygınlaşmaya başlamıştır. Ayrıca yapılan bilimsel çalışmaların ışığında tüketiciler ve üreticilerde artan bilinç kimyasal girdilerin dozunda kullanımını ve organik ürünlerin yetiştiricilikte girdi olarak daha fazla yer almasını sağlamıştır.

Son yıllarda artan bilinç organik temelli ürünlerin kullanımında önemli bir artış sağlamıştır. Bu sayede ürün çeşitliliği de artarak devam etmiş ve günümüzde bu ürünler piyasada önemli bir yer almaya başlamışlardır. Humik ve Fulvik Asit içerikli girdiler bu ürünlerin en önemlilerinden birisidir. Bu ürünlerin kullanımı yalnızca toprak yapısının iyileştirilmesini ve bitkilerin besin maddelerinden daha iyi faydalanmasını sağlamaz, aynı zamanda ürün gelişimini de destekleyerek verim ve gelir artışını da önemli oranda destekler. Bu ürünlerin kullanımı ağır metalleri sabitleyebilir ve organik kirleticileri parçalayabilir.

Bu çalışmada, humik ve fulvik asit temelli organik ürünlerin tarımsal amaçla kullanım olanakları sunularak yapılan güncel araştırmalar derlenecektir.

Anahtar Kelimeler: Humik, Fulvik, Organik, Tarım

HUMIC AND FULVIC ACIDS IN AGRICULTURAL PRODUCTION: UTILIZATION POTENTIALS AND RECENT STUDIES

ABSTRACT

Agriculture is a sector that plays a vital role in the development of emerging economies such as Türkiye, while serving as the foundation of the economies of developed nations. Despite declining agricultural lands due to unplanned urbanization, population growth, and accelerating industrialization, the concern for maintaining and increasing agricultural production has persisted. To meet the nutritional demands of a growing population with shrinking agricultural resources, agricultural technologies have steadily advanced. However, this progress has also led to a substantial increase in the use of chemical inputs such as fertilizers and pesticides. Over time, the uncontrolled application of these chemicals, initially aimed at maximizing yield per unit area, has revealed several detrimental effects. Although such inputs contribute to yield enhancement, their adverse impacts on the environment and soil health have necessitated alternative solutions. The degradation of soil structure, organic content, and microbial diversity has prompted the search for sustainable remedies, among which the use of organic-based products has emerged as a promising approach. Increasing soil organic matter, improving the chemical and physical properties of soils, and enhancing microbial activity are now regarded as key strategies for sustainable soil management.

Furthermore, growing awareness among consumers and producers, supported by scientific research, has led to a more measured use of chemical inputs and a rising adoption of organic products in agricultural production systems. In recent years, this increasing awareness has significantly boosted the utilization of organic-based materials, resulting in expanding product diversity and a growing market presence. Among these, inputs containing humic and fulvic acids stand out as particularly important. Their use not only improves soil structure and enhances the uptake of nutrients by plants, but also promotes plant growth, thereby contributing to higher yields and increased economic returns. Additionally, these substances can immobilize heavy metals and decompose organic pollutants, further supporting environmental sustainability.

In this review, recent studies on the agricultural applications and potential uses of humic and fulvic acid–based organic products will be compiled and evaluated.

Keywords: Humic, Fulvic, Organic, Agriculture

ALIÇ (CRATAEGUS SPP.): ALTERNATİF TÜR BAKIMINDAN OLANAKLAR VE GELECEK PERSPEKTİFİ

Doç. Dr. Hakan KELES

Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü

Email: hakan.keles@yobu.edu.tr

ORCID: 0000-0002-8225-931X

Dr. Öğr. Gör. Selcan ÖZYALIN

Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü

Email: selcan.ozyalın@yobu.edu.tr

ORCID: 0000-0003-4831-8600

Doç. Dr. Servet ARAS

Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü

Email: servet.aras@yobu.edu.tr

ORCID: 0000-0002-0347-6552

Doç. Dr. Müjgan GÜNEY

Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü

Email: mujgan.guney@yobu.edu.tr

ORCID: 0000-0001-5491-1430

ÖZET

Gelişmiş toplumlar kalkınma hedeflerine ulaşmak için ekonomilerinin temellerini sağlam bir zemine oturtmuşlardır. Bu temeli oluştururken de ilk adım tarımsal üretim ile başlamıştır. Ekonomilerde genel kalınmanın en önemli yolu kırsal kalkınmadan geçmektedir. Bunu başarabilmek ise doğru planlama sonucunda birim alandan elde edilecek gelirin artırılmasından geçmektedir. Türkiye' de gelişmekte olan ülkeler arasında yer almakla birlikte tarımsal kalkınma sürecini tam anlamıyla tamamlayamamıştır. Özellikle planlamada yaşanan problemler bu sürecin uzamasında önemli bir rol oynamaktadır.

Meyvecilik önemli bir tarımsal faaliyet alanıdır. Tarla ürünlerine oranla birim alandan getirisi yüksek bir üretim koludur. Türkiye bu üretim kolunda önemli bir yerdedir. Ancak karasal iklime sahip bölgelerinde ve uygun olmayan toprak koşullarından bu faaliyet alanından yararlanmak oldukça zordur. Yapılan faaliyetlerden ise başarı elde edilememekle birlikte harcanan zaman ve para da çoğu zaman boşa gitmektedir.

Türkiye bitki gen kaynakları bakımından önemli bir konumdadır. Birçok yabani türün gen merkezidir. Alıç (Crataegus spp.) bu türlerin en önemlilerindendir. Yetiştiricilik özellikleri ve piyasada alıcı bulduğu fiyat düşünüldüğünde yüksek bir potansiyele sahiptir. Alıç meyveleri ülkemizde geleneksel anlamda önemli görülmekle birlikte, son yıllarda alıç meyvelerinden üretilen marmelat, sirke ve turşu gibi ürünler de yoğun talep görmektedir. Farkı türlerinin bulunduğu alıç ayrıca peyzaj bitkisi olarak da değerlendirilebilmektedir. Günümüzde taze olarak 200-300 TL/kg fiyatlara alıcı bulabilmektedir. Ayrıca alıcın farklı bitki kısımları da çay olarak değerlendirilebilmektedir. Alıcın alternatif bir tür olarak potansiyel göstermesinin

yanında akraba türlere (elma, armut, ayva vb.) anaç olma potansiyeli de ayrıca önem arz etmektedir. Sebepler değerlendirildiğinde alıcın mevcut meyve türlerine alternatif bir tür olarak değerlendirilmesi üzerinde durulması gereken bir konu olarak karşımıza çıkmaktadır.

Bu çalışmada, alıcın özellikleri, güncel çalışmalar ve endüstriyel potansiyeli tartışılarak ülkemizin doğal bitkisi olan bu türün mevcut meyve türlerine alternatif bir tür olarak kullanılması üzerine önerilerde bulunulacaktır.

Anahtar Kelimeler: Alıç, Crataegus, Potansiyel, Alternatif

HAWTHORN (CRATAEGUS SPP.): POTENTIALS AND FUTURE PERSPECTIVES AS AN ALTERNATIVE SPECIES

ABSTRACT

Developed societies have established their economies on solid foundations to achieve their development goals, and the first step in building this foundation has traditionally been agricultural production. Sustainable economic development largely depends on rural development, which in turn requires proper planning and the optimization of income obtained per unit area. Although Türkiye is classified among developing countries, it has not yet fully completed its agricultural development process. Problems encountered in agricultural planning have played a major role in prolonging this process.

Fruit growing is an important field of agricultural production and offers higher economic returns per unit area compared to field crops. Türkiye holds a significant position in this sector; however, in regions characterized by a continental climate and unfavorable soil conditions, fruit cultivation faces considerable challenges. As a result, many attempts in these areas have failed to achieve success, leading to significant losses of both time and financial resources.

Türkiye possesses remarkable plant genetic diversity and serves as a gene center for many wild species. Among these, hawthorn (Crataegus spp.) stands out as one of the most important. Considering its cultivation characteristics and the prices it can fetch in the market, hawthorn exhibits high potential as a valuable crop. While hawthorn fruits have traditionally been appreciated in Türkiye, there has been increasing demand in recent years for value-added products such as marmalade, vinegar, and pickles made from hawthorn. In addition, various species of hawthorn can be utilized as ornamental plants in landscaping. Fresh fruits can currently be sold at prices ranging from 200 to 300 TL per kilogram. Moreover, different parts of the plant are also used to produce herbal teas. Beyond its potential as an alternative fruit species, hawthorn's possible use as a rootstock for related species such as apple, pear, and quince further increases its importance. Considering these factors, the evaluation of hawthorn as an alternative fruit species represents a promising area for future agricultural development.

This study aims to discuss the characteristics, recent research findings, and industrial potential of hawthorn (Crataegus spp.), while providing recommendations for its use as an alternative fruit species native to Türkiye.

Keywords: Hawthorn, Crataegus, Potential, Alternative

MICHELE PALIERI ÜZÜM ÇEŞİDİNDE *Ascophyllum nodosum* UYGULAMALARININ TANELERDE SEKONDER METOBOLİT BİRİKİMİ ÜZERİNE ETKİLERİNİN İNCELENMESİ

Prof. Dr. Emine Sema ÇETİN

Yozgat Bozok Üniversitesi, Ziraat Fakültesi

Email: esema.cetin@yobu.edu.tr

ORCID: 0000-0001-7601-8491

Zir. Müh. Nazife Çiğdem ERMİŞ

Yozgat Bozok Üniversitesi, Ziraat Fakültesi

Email: ncigdem.ermis@csb.gov.tr

Arş. Gör. Berna KELES

Yozgat Bozok Üniversitesi, Ziraat Fakültesi

Email: berna.keles@yobu.edu.tr

ORCID: 0000-0002-6723-283X

ÖZET

Sekonder metabolitler bilindiği gibi bitkilerden elde edilen, onların yaşamsal fonksiyonları üzerinde primer metabolitler gibi etkileri bulunmayan bileşiklerdir. Bitkilerin kendilerini savunma amacıyla ürettikleri bu bileşiklerin daha sonra antioksidan, antifungal ve antibakteriyel özelliklerinin ortaya çıkarılmış olması nedeniyle günümüzde kanser, kardivasküler hastalıklar, tip II diyabet gibi pek çok hastalık üzerine olumlu etkiler gösterdiği bilinmektedir. Dolayısıyla başta ilaç sanayi olmak üzere gıda ve kozmetik sektörlerinde de farklı kullanım amaçlarının olması bu bileşiklere duyulan ilgiyi daha da artmıştır.

Bu araştırma ile de Michele Palieri üzüm çeşidinde Ascophyllum nodosum uygulamalarının tanelerde birer sekonder metabolit olan fenolik bileşikler ile yine bitkinin savunma mekanizmasında etkin rol oynayan ve aynı zamanda birer fitohormon olan indol asetik asit, gibberellik asit, zeatin, absisik asit ve salisilik asit birikimi üzerine etkileri incelenmiştir. Uygulamalar fenolojik gözlemler baz alınarak tanelerin koruk safhasında, ben düşme döneminde ve hasattan 10 gün önce olacak şekilde 3 ayrı dönemde yapılmıştır. Uygulamalarda ticari bir firmanın sıvı formdaki A. nodosum solüsyonu kullanılmıştır. Tüm omca pülverizatör ile ıslatılmış, kontrol bitkilerine sadece saf su uygulaması yapılmıştır. A. nodosum, 1/10; 1/15 ve 1/20 dozlarında uygulanmıştır. Araştırma sonucunda spektrofotometrik olarak belirlenen fenolik bileşik miktarları ile HPLC ile belirlenen fenolik bileşenler, bitkisel hormonlar ve organik asit içerikleri değerlendirildiğinde genel olarak A. nodosum uygulamalarının bu bileşenleri artırmada olumlu etkiler gösterdikleri anlaşılmaktadır. Bu durum hem tane kompozisyonunun içeriğinin zenginleştirilmesi hem de bileşenlerin çoğunun doğal savunma bileşenleri olması bakımından önemlidir.

Anahtar Kelimeler: Asma, Üzüm, Sekonder Metabolit, Ascophyllum nodosum, Hormon, Organik Asit

INVESTIGATION OF THE EFFECTS OF *Ascophyllum nodosum* APPLICATIONS ON SECONDARY METABOLITE ACCUMULATION IN BERRIES IN MICHELE PALIERI GRAPE VARIETY

ABSTRACT

Secondary metabolites are compounds derived from plants that do not have the same effects on their vital functions as primary metabolites. These compounds, produced by plants for self-defense, have been later identified for their antioxidant, antifungal, and antibacterial properties, and are now known to have positive effects on many diseases, including cancer, cardiovascular diseases, and type II diabetes. Consequently, their diverse uses, particularly in the pharmaceutical industry, as well as in the food and cosmetic sectors, have further increased interest in these compounds.

This study investigated the effects of Ascophyllum nodosum treatments on the Michele Palieri grape variety on the accumulation of phenolic compounds, which are secondary metabolites, as well as phytohormones such as indole acetic acid, gibberellic acid, zeatin, abscisic acid, and salicylic acid, which play an active role in the plant's defense mechanism. Applications were made at three different times: unripe grape stage, during veraison, and 10 days before harvest, based on phenological observations. A liquid A. nodosum solution from a commercial company was used in the applications. All vines were sprayed, while control plants were treated with pure water only. A. nodosum was applied at doses of 1/10, 1/15, and 1/20. The results of the study indicate that A. nodosum applications generally have positive effects in increasing these compounds, as determined by spectrophotometric methods and by HPLC, as measured by phenolic compounds, plant hormones, and organic acid contents. This is important both for enriching the berry composition and for the fact that many of the components are natural defense components.

Keywords: Grape, Secondary Metabolite, Ascophyllum nodosum, Hormone, Organic Acid

ENDONEZYA'DA TARIMSAL ARTIKLARDAN ELDE EDİLEN BİYOKÜTLE POTANSİYELİ

Fathimah AZZAHRA

Selçuk Üniversitesi, Fen Bilimleri Enstitüsü, Tarım Makineleri ve Teknolojileri Mühendisliği Anabilim Dalı, Konya

Email: 238247001008@ogr.selcuk.edu.tr

ORCID: 0000-0001-6907-1681

Prof. Dr. Haydar HACISEFEROĞULLARI

Selçuk Üniversitesi, Ziraat Fakültesi, Tarım Makineleri ve Teknolojileri Mühendisliği Bölümü, Konya

Email: hhsefer@selcuk.edu.tr

ORCID: 0000-0002-4699-9564

ÖZET

Biyokütle, çevreye ve insan sağlığına önemli ölçüde zarar veren fosil yakıt tüketimine bir alternatif olarak kullanılabilir. Tarım ülkesi olan Endonezya, önemli bir biyokütle enerji potansiyeline sahiptir. Bu çalışma, son beş yıl içinde temel gıda ve plantasyon bitkilerden elde edilen biyokütle potansiyelini tahmin etmeyi ve bu potansiyelin ülkenin 38 eyaletine göre dağılım haritasını sunmayı amaçlamaktadır. Çalışmada pirinç, mısır, şeker kamışı, hindistan cevizi ve yağ palmiyesi artıklarının değerlendirilmesi yapılmıştır. Tarımsal artıkların biyokütle potansiyelinin tahmini, 2020–2024 yıllarına ait ilgili ürünlerin ortalama üretim verileri kullanılarak ve önceki literatürlerde yer alan denklemler temel alınarak hesaplanmıştır. Çalışma sonucunda, söz konusu beş ürünün artıklarından elde edilebilecek toplam tarımsal biyokütle artığı potansiyeli (ABP) 55.79 milyon ton olarak hesaplanmış, toplam ısıl değeri (THV) ise yaklaşık 857.44 PJ olarak bulunmuştur. Pirinç, mısır ve yağ palmiyesi artıklarından elde edilen biyokütle potansiyeli toplam tahmini potansiyelin yaklaşık %98.23'ünü (842.31 PJ) oluşturmaktadır. Gıda ürünleri arasında, pirinç artıklarından en yüksek biyokütle potansiyeline sahip eyaletler Doğu Cava, Orta Cava ve Batı Cava iken; mısır artıklarında Doğu Cava ve Orta Cava öne çıkmaktadır. Plantasyon bitkilerde ise, şeker kamışı artıklarından Doğu Cava ve Lampung; hindistan cevizi artıklarından Riau ve Kuzey Sulawesi; yağ palmiyesi artıklarından ise Riau, Orta Kalimantan ve Batı Kalimantan eyaletleri en yüksek biyokütle potansiyeline sahiptir. Bu çalışmanın, Endonezya'daki her eyalette tarımsal artıkların biyokütle enerji üretiminde değerlendirilmesine katkı sağlaması ve biyokütle kullanılabilirliğinin artırılmasının, ülkede sürdürülebilir tarım ve enerji yönetimini daha da desteklemesi beklenmektedir.

Anahtar Kelimeler: Tarımsal artık, Biyokütle potansiyeli, Yenilenebilir enerji, Endonezya.

BIOMASS POTENTIAL FROM AGRICULTURAL RESIDUES IN INDONESIA

ABSTRACT

Biomass can serve as an alternative to fossil fuel consumption which causes significant harm to the environment and human health. Indonesia, being an agricultural country, possesses a substantial biomass energy potential. This study aimed to estimate the biomass potential derived from major food and plantation crops in over the past five years and present its distribution map across the country's 38 provinces. Residues from paddy, corn, sugarcane, coconut, and oil palm are considered. The estimation of biomass potential from agricultural residues was calculated based on the average of 2020-2024 production data of related crops using equations from previous literatures. As a result of the study, the total available agricultural biomass residue potential (ABP) from these five crops residues was calculated to be 55.79 million tons, with a total heating value (THV) of approximately 857.44 PJ. The biomass potential from paddy, corn, and oil palm residues holds the highest value, approximately 98.23% (842.31 PJ) of the total estimated biomass potential. Among food crops, provinces with the highest biomass potential from paddy residues are East Java, Central Java, and West Java, while from corn residues, East Java and Central Java are prominent. For plantation crops, East Java and Lampung lead in biomass potential from sugarcane residues; Riau and North Sulawesi from coconut residues; also Riau, Central Kalimantan, and West Kalimantan from oil palm residues. It is expected that this study will contribute to the development of biomass energy utilization from agricultural residues in each province in Indonesia and that enhancing biomass availability could further promote sustainable agriculture and energy management in Indonesia.

Keywords: Agricultural residue, Biomass potential, Renewable energy, Indonesia.

ISPARTA KOŞULLARINDA ÇÖREK OTU GENOTİPLERİNİN FENOLOJİK AGRONOMİK VE KALİTE ÖZELLİKLERİNİN BELİRLENMESİ*

Ziraat Yük. Müh. Ayşegül FAYDACI

Isparta Uygulamalı Bilimler Üniversitesi

Lisansüstü Eğitim Enstitüsü

Email: xxxx@gmail.com

ORCID: 0000-0000-0000-0000

Prof. Dr. İsa TELCİ

Isparta Uygulamalı Bilimler Üniversitesi

Ziraat Fakültesi

Email: isatelci@isparta.edu.tr

ORCID: 0000-0002-3651-1641

ÖZET

Bu çalışma Isparta ekolojik koşullarında bazı çörek otu genotiplerinin fenolojik, agronomik ve kalite özelliklerinin belirlenmesi amacıyla yapılmıştır. Çalışmada kullanılan çörek otu genotiplerinden 9 tanesi Nigella sativa, biri ise N. damascena türüne ait olmak üzere 10 farklı çörek otu genotipi araştırılmıştır. Deneme, tesadüf blokları deneme desenine göre yürütülmüştür. Çalışmada; bitki boyu (cm), dal sayısı (adet/bitki), kapsül sayısı (adet/bitki), bin tane ağırlığı (g), tohum verimi (kg/da), biyolojik verim (kg/da) gibi agronomik özellikler ile yağ oranı ve yağ asitleri kompozisyonu (%) gibi kalite özellikleri incelenmiştir. Çalışmada çörek otu genotiplerinin iki yıllık ortalamalarını incelediğimizde fenolojik bakımdan iki (erkenci geçci) farklı gurbun belirlendiği tarımsal özeliklerden bitki boyu 34.5-54.0 cm, dal sayısı 3.5-6.2 adet/bitki, kapsül sayısı 4.8-7.1 adet/bitki, 1000 tane ağırlığı 1.7-3.1 g, biyolojik verim 235.3-341.1 kg/da, tohum verimi 36.0-109.9 kg/da, aralıklarında değiştiği belirleniştir. Çalışmada en yüksek tohum verimleri iki yıl ortalamasına göre Hindistan (109 kg/da) orijinli genotipte elde edilmiş ve bunu Suriye ve Hatay genotipleri izlemiştir. Çörek otunda en fazla bulunan yağ asitleri sırasıyla linoleik, oleik ve palmitik (%42.3-%55.8, %20.1-%26.5, %11.4-%14.7) yağ asitleri olduğu belirlenmiştir. En yüksek linoleik asit oranı Çameli çeşidinden (%55.8) elde edilmiştir. Çalışma sonucunda bölgede kuru koşullarda Hatay, Suriye ve Hindistan orijinli erkenci genotiplerin yüksek verim verdiği ve bölgede üreticilerine tavsiye edilebileceği belirlenmiştir.

Anahtar Kelimeler: Çörek out, Nigella, verim, sabit yağ

* Bu çalışma yüksek lisans tezinden alınmıştır.

DETERMINATION OF THE PHENOLOGICAL, AGRONOMIC, AND QUALITY CHARACTERISTICS OF BLACK CUMIN (NIGELLA SATIVA L.) GENOTYPES UNDER ISPARTA CONDITIONS

ABSTRACT

This study was conducted to determine the phenological, agronomic, and quality characteristics of some black cumin (Nigella sativa L.) genotypes under the ecological conditions of Isparta. A total of ten black cumin genotypes were investigated, nine belonging to Nigella sativa and one to N. damascena. The experiment was carried out according to the randomized complete block design. In the study, agronomic traits such as plant height (cm), number of branches (number/plant), number of capsules (number/plant), thousand-seed weight (g), seed yield (kg/da), and biological yield (kg/da) were examined, along with quality characteristics including oil content and fatty acid composition (%). According to the two-year average data, the genotypes were grouped into two phenological categories (early and late maturing). Among the agronomic traits, plant height ranged from 34.5 to 54.0 cm, number of branches from 3.5 to 6.2 per plant, number of capsules from 4.8 to 7.1 per plant, thousand-seed weight from 1.7 to 3.1 g, biological yield from 235.3 to 341.1 kg/da, and seed yield from 36.0 to 109.9 kg/da. The highest seed yield, according to the two-year average, was obtained from the Indian-origin genotype (109 kg/da), followed by the Syrian and Hatay genotypes. The predominant fatty acids identified in black cumin were linoleic, oleic, and palmitic acids, ranging between 42.3–55.8%, 20.1–26.5%, and 11.4–14.7%, respectively. The highest linoleic acid content (55.8%) was found in the Çameli variety.As a result, it was determined that the early-maturing genotypes originating from Hatay, Syria, and India produced high yields under dry conditions in the region and could be recommended to local farmers.

Keywords: Black cumin, Nigella, yield, seed oil

EFFECTS OF SHREDLANGE AND CONVENTIONAL METHODS ON NUTRIENT CONTENT AND IN VITRO DIGESTIBILITY OF CORN SILAGE

Hasan Hüseyin ŞENYÜZ, Gökhan ŞEN, Ramazan AYAŞ

Necmettin Erbakan University, Faculty of Veterinary Medicine, Department of Animal Nutrition and Nutritional Disease, Konya, Türkiye

Ali KARAPINAR

Kırıkkale University, Faculty of Veterinary Medicine, Department of Animal Nutrition and Nutritional Disease, Kırıkkale, Türkiye

Ali Ersin GÜMÜŞ

Ereğli Municipality, Konya, Türkiye

*Correspond: hasansenyuzvet@yahoo.com

ABSTRACT

Corn silage is the most important roughage in the diet of dairy cattle. Studies on quality improvements are still ongoing. Physical processing techniques of silage during harvest affect its quality. One of these techniques is shredding. During this harvest, the nutrient content of shredded and conventional corn silage was compared, as were those collected by IVTD and fleig. For this purpose, corn silage grown under the same conditions was harvested on the same day and shredded using conventional and shredding machines. Samples were ensiled in 1 L glass jars in a laboratory environment. After 45 days of fermentation, the silages were opened, and their pH properties and flexibility were measured. The pH was lower in conventional silage (3.96±0.02-4.22±0.02). The flexibility values for conventional and shredded silage classes were 111.32±0.22 and 104.79±0.67, respectively ($p<0.05$). DM, CP, NDF and ADF values in silages were determined as 32.36±0.11-33.05±0.13, 7.17±0.13-7.87±0.03 ($p<0.05$), 40.57±0.77-31.17±2.06 ($p<0.05$), 22.19±0.35-16.09±1.27 ($p<0.05$), respectively. IVTD values of silages tend to be high with shredding type ($p=0.06$) (74.03±0.60-79.19±2.14). As a result of the study, it was determined that the shredding method increased the CP value and decreased the NDF and ADF values, resulting in positive improvement in digestibility. The digestibility of shredded corn silage was increased by 5%. It would be beneficial to use the shredding method in corn silage harvest.

Key Words: Corn silage, digestibility, shredlage.

YER FISTIĞINDA KÖK ÇÜRÜKLÜĞÜ HASTALIĞINA KARŞI UÇUCU YAĞLARIN KULLANIMINDA GÜNCEL YAKLAŞIMLAR

Dr. Öğr. Üyesi Sadiye Ayşe ÇELİK
Selçuk Üniversitesi, Ziraat Fakültesi
Email: sacelik@selcuk.edu.tr
ORCID: 0000-0002-0765-642X
Zir. Müh. Gülbahar BABAOĞLAN
Selçuk Üniversitesi, Ziraat Fakültesi
Email: babaoglan.8026@gmail.com
ORCID: 0009-0003-9340-8856

ÖZET

Yer fıstığı (Arachis hypogaea L.), yağ ve protein içeriği açısından önemli bir endüstri bitkisi olup Türkiye'nin özellikle Akdeniz ve Güneydoğu Anadolu bölgelerinde yaygın olarak yetiştirilmektedir. Ancak üretim alanlarında kök çürüklüğü etmenleri, özellikle Rhizoctonia solani ve Sclerotium rolfsii, fide döneminden itibaren bitkide solgunluk, kök sisteminde kahverengileşme ve çürüme gibi belirtiler oluşturarak verim ve kaliteyi önemli ölçüde düşürmektedir. Bu patojenlerin kontrolünde uzun yıllardır kimyasal fungisitler kullanılmakla birlikte, bu uygulamalar çevresel kirlilik, kalıntı sorunları, toprak mikrobiyotasında dengesizlik ve patojenlerde direnç gelişimi gibi ciddi olumsuzluklara yol açmaktadır. Bu nedenle, sürdürülebilir ve çevre dostu alternatif mücadele yöntemlerinin geliştirilmesi önem kazanmıştır.

Son yıllarda tıbbi ve aromatik bitkilerden elde edilen uçucu yağlar, içeriklerindeki biyolojik olarak aktif sekonder metabolitler sayesinde önemli antifungal özellikler göstermekte ve bitki hastalıklarının kontrolünde umut verici biyofungisit adayları olarak değerlendirilmektedir. Yer fıstığında kök çürüklüğü hastalığına karşı en yaygın olarak test edilen uçucu yağlar arasında kekik (Thymus vulgaris), tarçın (Cinnamomum zeylanicum), biberiye (Rosmarinus officinalis), sarımsak (Allium sativum), nane (Mentha spp.) ve okaliptüs (Eucalyptus spp.) yer almaktadır. Bu yağların özellikle timol, karvakrol, eugenol ve 1,8-sineol gibi bileşenleri, misel gelişimini baskılama, hücre zarını bozma ve enzimatik aktiviteleri inhibe etme yoluyla patojenleri etkisiz hale getirmektedir.

Bununla birlikte, defne, karanfil, lemongrass, rezene, anason ve lavanta yağları gibi bazı türlerin yer fıstığı kök çürüklüğü etmenlerine karşı antifungal potansiyelleri henüz yeterince araştırılmamıştır. Bu derlemede, yer fıstığında kök çürüklüğü hastalığına karşı uçucu yağların kullanımına ilişkin güncel literatür sistematik biçimde değerlendirilmekte; mevcut bilgi birikimi, biyolojik etki mekanizmaları ve gelecekteki araştırma alanları bilimsel temeller doğrultusunda tartışılmaktadır.

Anahtar Kelimeler: Yer Fıstığı, Kök Çürüklüğü, Uçucu Yağ, Arachis hypogaea L.

CURRENT PERSPECTIVES ON THE USE OF ESSENTIAL OILS AGAINST ROOT ROT DISEASE IN PEANUT

ABSTRACT

Peanut (Arachis hypogaea L.) is an important industrial crop due to its high oil and protein content and is widely cultivated in the Mediterranean and Southeastern Anatolia regions of Türkiye. However, soil-borne fungal pathogens, particularly Rhizoctonia solani and Sclerotium rolfsii, cause root rot disease, leading to symptoms such as wilting, browning, and decay of the root system from the seedling stage onward, resulting in significant yield and quality losses. Chemical fungicides have long been the primary control strategy against these pathogens. Nevertheless, their extensive and continuous use has raised serious concerns, including environmental pollution, residue accumulation, disruption of soil microbiota, and the emergence of resistant pathogen populations. Consequently, the development of sustainable and eco-friendly alternative control methods has gained increasing importance.

In recent years, essential oils derived from medicinal and aromatic plants have attracted considerable attention as promising biofungicide candidates due to their rich content of biologically active secondary metabolites with strong antifungal properties. Among the essential oils tested against peanut root rot pathogens, thyme (Thymus vulgaris), cinnamon (Cinnamomum zeylanicum), rosemary (Rosmarinus officinalis), garlic (Allium sativum), mint (Mentha spp.), and eucalyptus (Eucalyptus spp.) are the most commonly studied. Active constituents such as thymol, carvacrol, eugenol, and 1,8-cineole have been shown to inhibit mycelial growth and interfere with fungal cell membranes and enzymatic activities.

However, essential oils such as bay laurel (Laurus nobilis), clove (Syzygium aromaticum), lemongrass (Cymbopogon citratus), fennel (Foeniculum vulgare), anise (Pimpinella anisum), and lavender (Lavandula spp.) have not yet been adequately investigated against peanut root rot pathogens, despite their well-documented antifungal activities on other plant pathogens. This review systematically evaluates the current literature on the use of essential oils against peanut root rot disease, discusses their biological modes of action, and highlights future research perspectives within the framework of sustainable plant disease management.

Keywords: Peanut, Root Rot, Essential Oil, Arachis hypogaea L.

YUMURTALARDA STERİLİZASYON VE DEZENFEKSİYON UYGULAMALARINDA KİMYASAL YÖNTEMLER YERİNE UÇUCU YAĞLARIN KULLANIMININ DEĞERLENDİRİLMESİ

Dr. Öğr. Üyesi Sadiye Ayşe ÇELİK

Selçuk Üniversitesi, Ziraat Fakültesi

Email: sacelik@selcuk.edu.tr

ORCID: 0000-0002-0765-642X

Tıbbi Bitkiler Teknikeri Tuba Özkan AY

Selçuk Üniversitesi, Ziraat Fakültesi

Email: ozkanaytuba@gmail.com

ORCID: 0009-0002-6543-4160

ÖZET

Yumurta kabuğu, üretim ve depolama süreçlerinde çevresel mikroorganizmalarla kolaylıkla kontamine olabilmektedir. Salmonella spp., Escherichia coli, küf ve maya türleri gibi patojenler, sofralık yumurtalarda gıda güvenliği açısından ciddi riskler oluştururken, kuluçkalık yumurtalarda embriyonik gelişimi olumsuz etkileyerek ekonomik kayıplara yol açmaktadır. Bu nedenle yumurta kabuğunun etkin bir şekilde dezenfekte edilmesi hem gıda güvenliği hem de kuluçkahane hijyeni açısından kritik bir aşamadır. Günümüzde özellikle kuluçkalık yumurtalarda en yaygın kullanılan yöntem formaldehit fumigasyonudur. Ancak formaldehitin toksik ve kanserojen etkileri hem insan sağlığı hem de çevre açısından önemli riskler taşıdığı için kullanımı birçok ülkede sınırlandırılmış ve daha güvenli, kalıntısız ve çevre dostu alternatif yöntemlere olan ilgi artmıştır.

Son yıllarda tıbbi ve aromatik bitkilerden elde edilen uçucu yağlar, içeriklerindeki timol, karvakrol, eugenol ve 1,8-sineol gibi biyoaktif sekonder metabolitler sayesinde güçlü antimikrobiyal ve antifungal etkilere sahiptir. Yapılan çalışmalar, kekik, karanfil, tarçın, biberiye, nane ve limon otu gibi uçucu yağların hem in vitro koşullarda hem de uygulamalı denemelerde yumurta kabuğu üzerindeki mikrobiyal yükü önemli ölçüde azalttığını ortaya koymuştur. Özellikle karanfil ve kekik yağlarının uygun konsantrasyonlarda ve doğru uygulama yöntemleriyle kullanıldığında formaldehit fumigasyonuna benzer düzeyde mikrobiyal inaktivasyon sağladığı, embriyo gelişimini ya da yumurta kalitesini olumsuz etkilemediği belirtilmektedir. Tarçın ve limon otu gibi diğer uçucu yağlar da dikkate değer antimikrobiyal etkilere sahip olmakla birlikte, uygulama protokollerinin standartlaştırılması ve doz optimizasyonu konularında daha fazla araştırmaya ihtiyaç duyulmaktadır.

Bu derlemede, yumurtalarda sterilizasyon ve dezenfeksiyon amacıyla uçucu yağların kullanımına ilişkin güncel bilgiler sistematik bir şekilde değerlendirilmekte; kullanılan bitki türleri, uygulama yöntemleri, mikrobiyal etkinlikleri, avantajları ve kimyasal yöntemlerle karşılaştırmaları ele alınmaktadır. Ayrıca, uçucu yağ temelli dezenfeksiyon yaklaşımlarının sürdürülebilir, güvenli ve çevre dostu alternatifler olarak gelecekteki uygulamalardaki potansiyelleri vurgulanmaktadır.

Anahtar Kelimeler: Yumurta, Sterlizasyon, Dezenfeksiyon, Uçucu Yağlar

EVALUATION OF THE USE OF ESSENTIAL OILS AS AN ALTERNATIVE TO CHEMICAL METHODS IN EGG DISINFECTION AND STERILIZATION

ABSTRACT

Eggshells are easily contaminated with environmental microorganisms during production and storage. Pathogens such as Salmonella spp., Escherichia coli, molds, and yeasts pose significant risks to food safety in table eggs and can negatively affect embryonic development in hatching eggs, leading to considerable economic losses. Therefore, effective disinfection of the eggshell surface is a critical step for ensuring both food safety and hatchery hygiene. Formaldehyde fumigation has traditionally been the most common disinfection method, particularly for hatching eggs. However, due to its toxic and carcinogenic effects on human health and the environment, the use of formaldehyde has become increasingly restricted, which has intensified the search for safe, residue-free, and environmentally friendly alternatives.

In recent years, essential oils derived from medicinal and aromatic plants have attracted attention as promising natural disinfectants. Their strong antimicrobial and antifungal properties are mainly attributed to bioactive secondary metabolites such as thymol, carvacrol, eugenol, and 1,8-cineole. Studies evaluating the use of essential oils for egg disinfection have reported that thyme, clove, cinnamon, rosemary, mint, and lemongrass oils significantly reduce microbial loads on eggshells under both in vitro and field conditions. Clove and thyme essential oils, when applied at appropriate concentrations and using suitable methods (e.g., spraying, fumigation, nanoemulsion), have demonstrated microbial inactivation levels comparable to formaldehyde without adverse effects on embryo development or egg quality. Other essential oils, including cinnamon and lemongrass, have also shown notable antimicrobial effects, though further research is needed to standardize application protocols and determine optimal dosages.

This review systematically evaluates current knowledge on the use of essential oils in egg disinfection and sterilization. Plant species used, modes of application, antimicrobial efficacy, advantages, and comparisons with conventional chemical methods are discussed. Furthermore, the potential role of essential oil-based approaches as sustainable, safe, and effective alternatives in future disinfection strategies is highlighted.

Keywords: Egg, Sterilization, Disinfection, Essential Oils

YEŞIL ALANLARDA KULLANILABILECEK BAZI BUĞDAYGIL YEM BITKILERININ ALAN KAPLAMA PERFORMANSININ İNCELENMESİ

Prof. Dr. Mehmet Ali AVCI

Selçuk Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü

Email: mavci@selcuk.edu.tr

ORCID: 0000-0003-2448-8779

Ziraat Müh. Emir YAVAŞ

Selçuk Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü

Email: emiryavas361@gmail.com

ORCID: 0009-0002-0827-0462

Ziraat Müh. Öğr. Melike MAVİ

Selçuk Üniversitesi, Ziraat Fakültesi, Tarım Ekonimisi Bölümü

Email: Mavimelike4847@gmail.com

ÖZET

Dünyada ve ülkemizde hızlı nüfus artışı, kentlerin gelişmesine ve buna bağlı olarak yoğun yapılaşmanın artmasına neden olmuştur. Bu durum, doğal alanların tahrip edilerek yok olma tehlikesiyle karşı karşıya kalmasına yol açmıştır. Teknoloji ürünü betonun sert ve soğuk görünümünün yumuşatılması ve yapı çevresi teknolojilerinin insan yaşamı açısından iyileştirilmesi, günümüz kentlerinin temel gereksinimleri arasında yer almıştır. Daha yaşanabilir ortamlar oluşturmak amacıyla kentlerde park ve bahçeler tesis edilmiştir. Park ve bahçelerde en önemli unsurlardan biri de çim alanlardır. Yeşil alanların kullanım amacına uygun çim tohumlarının belirlenmesi, çim tesislerinin uzun ömürlü olması için temel koşullardan biridir. Bu nedenle, kullanılacağı yerin iklimine, zamana ve amaca uygun çim tohumunun seçiminde; hastalık, zararlı ve yabancı otlara karşı dayanıklılık, soğuk, sıcak ve kuraklık toleransı, homojen yapı ve üniform görünüm gibi özelliklere dikkat edilmiştir.

Bu kapsamda, Prof. Dr. Mehmet Ali AVCI tarafından sentetik varyete ıslahı yöntemiyle geliştirilen dört farklı buğdaygil çim bitkisinin hem yalın ekimleri hem de karışımlardaki performansları, mevcut çeşitlerle karşılaştırmalı olarak araştırmada yer almıştır. Deneme alanında materyal olarak çok yıllık çim (Lolium perenne), kamışsı yumak (Festuca arundinacea), çayır salkım otu (Poa pratensis), tavus otu (Agrostis spp.) ve domuz ayrığı (Dactylis glomerata) olmak üzere beş farklı buğdaygil yem bitkisi kullanılmıştır. Araştırma kapsamında, Konya Büyükşehir Stadyumu'nda kullanılan 14 farklı buğdaygil çim çeşidi ile stadyum çimlendirilmesinde kullanılan iki farklı karışımdan oluşan bitki gruplarının ekimi yapılmıştır. Ayrıca, 14 farklı çim çeşidinin yanında ıslah yoluyla geliştirilen dört farklı hattın yalın ekimleri ile bu bitkilerin iki ve üçlü karışımları oluşturularak Orta Anadolu koşullarında en uygun çim karışımları belirlenmiştir. Buna göre deneme, 18 çim bitkisinden oluşan yalın ekim, dörder adet iki ve üçlü karışım ile iki adet beşli karışım olmak üzere üç tekerrürlü olmak üzere toplam 84 parselden oluşmuştur. Araştırma, Selçuk Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü Prof. Dr. Abdulkadir AKÇİN Araştırma ve Uygulama Arazisi'nde yürütülmüştür. Parsel ebatları 1 m × 1 m olacak şekilde dizayn edilmiştir. Denemede, UPOV kriterlerine göre çıkış hızı (gün), alan kaplama hızı (gün), kaplama derecesi (1–9), yaprak rengi

(1–9), yaprak dokusu (mm), yenilenme gücü (1–5), kardeş sayısı (adet), genel görünüm (1–9) ve seyrekleşme derecesi (1–9) gibi özellikler morfolojik olarak değerlendirilmiştir.

Elde edilen veriler sonucunda, alan kaplama hızı, alan kaplama derecesi ve yenilenme gücü gibi kriterlerin yanı sıra su tüketimi açısından da düşük maliyetli ve sürdürülebilir çim alanları oluşturma potansiyeli ortaya konmuştur. Bu özelliklerin incelenmesi, su kaynaklarının etkin kullanımıyla uyumlu çim bitkisi seçimlerine katkı sağlamıştır.

Anahtar Kelimeler: Buğdaygil Yem Bitkileri, UPOV, Yeşil Alan, Sürdürülebilir Tarım

AREA COVERAGE PERFORMANCE AND ECOLOGICAL TURF APPLICATIONS OF SOME WHEATEN FORAGE CROPS THAT CAN BE USED IN GREEN AREAS

ABSTRACT

The rapid population growth in both the world and Turkey has led to the expansion of cities and, consequently, to an increase in urban construction. This process has resulted in the destruction and near extinction of natural areas. Softening the harsh and cold appearance of concrete, a product of modern technology, and improving the built environment in terms of human well-being have become essential requirements of contemporary cities. In order to create more livable environments, parks and gardens have been established in urban areas. One of the most important elements in parks and gardens is turfgrass areas. Determining turfgrass seeds suitable for the intended use of green spaces is one of the key prerequisites for establishing long-lasting lawns. Therefore, in selecting turfgrass seeds appropriate for the climate, time, and purpose of the area, attention has been paid to resistance against diseases, pests, and weeds, tolerance to cold, heat, and drought, as well as homogeneity and uniform appearance.

Within this scope, four different forage grass varieties developed through synthetic variety breeding by Prof. Dr. Mehmet Ali AVCI were included in the study to compare their performance in both pure sowing and mixtures with existing commercial varieties. The experimental materials consisted of five different forage grasses: perennial ryegrass (Lolium perenne), tall fescue (Festuca arundinacea), Kentucky bluegrass (Poa pratensis), bentgrass (Agrostis spp.), and orchardgrass (Dactylis glomerata). In addition, the study included the sowing of 14 different forage grass varieties currently used at Konya Metropolitan Stadium, along with two turf mixtures used for stadium turf establishment. Furthermore, pure sowings of four improved breeding lines and their binary and ternary mixtures with these varieties were evaluated to determine the most suitable turf mixtures under Central Anatolian conditions. Accordingly, the experiment consisted of 18 turfgrass varieties in pure sowings, four binary mixtures, four ternary mixtures, and two quinary mixtures, with three replications, making a total of 84 plots. The study was conducted at the experimental and research fields of the Department of Field Crops, Faculty of Agriculture, Selçuk University (Prof. Dr. Abdulkadir AKÇİN Research and Application Area). Plot dimensions were designed as 1 m × 1 m. The following traits were evaluated morphologically according to UPOV criteria: emergence rate (days), ground coverage rate (days), ground coverage degree (1–9), leaf color (1–9), leaf texture (mm), regeneration capacity (1–5), number of tillers (per plant), general appearance (1–9), and degree of thinning (1–9).

Based on the data obtained, the potential for establishing low-cost and sustainable turf areas was demonstrated, particularly in terms of coverage rate, coverage degree, regeneration capacity, and water consumption. Examination of these traits contributed to the selection of turfgrass species compatible with efficient water use.

Keywords: Forage Grasses, UPOV, Greenfield, Sustainable Agriculture

DETERMINATION OF THE INFLUENCE OF DIFFERENT PRE-TREATMENTS AND MICROWAVE DRYING METHOD ON CO2 EMISSIONS IN THE DRYING OF RED PLUM (*Prunus domestica*) SLICES

Dr. Öğr. Üyesi Seda GÜNAYDIN

Necmettin Erbakan Üniversitesi, Ereğli Ziraat Fakültesi

Email: seda.gunaydin@erbakan.edu.tr

ORCID: 0000-0003-2510-9638

Sorumlu Yazar-Seda GÜNAYDIN

Işıl KILIÇ

Necmettin Erbakan Üniversitesi, Ereğli Ziraat Fakültesi

isilkilic100@gmail.com

ABSTRACT

Red plum (Prunus domestica) is a fruit with numerous health benefits. Due to its high moisture content, it spoils quickly after harvest and becomes inedible. Therefore, preserving it through drying is very important. The aim of this study is to evaluate and compare the effects of various pre-treatment applications and microwave drying methods on CO2 emissions caused by specific energy consumption during the drying process of red plum slices. Microwave drying was performed at power levels of 100, 200, 300, and 600 W, with three different pretreatments (gum arabic, ascorbic acid, and citric acid) and without pretreatment (control). Carbon dioxide (CO_2) emissions from various drying methods were calculated for power plants using wind, solar, hydroelectric, and geothermal energy sources. The wind power plant produced the lowest CO_2 emissions (0.271 g kg-1), while the geothermal power plant produced the highest (260.074 g kg-1). The study also revealed that increasing the microwave level decreased CO2 emissions due to a reduction in the SEC value. Pre-treatment applications reduced the dryer's energy consumption and consequently significantly reduced CO_2 emissions. Therefore, it is recommended to use ascorbic acid, citric acid, and gum arabic pretreatment applications in drying processes to reduce CO_2 emissions caused by drying systems and to develop drying systems that are more environmentally friendly in terms of CO_2 emissions.

Keywords: CO2 emission, microwave drying, red plum, pretreatment

PGPR VE MIKORIZA KOMBİNASYONLARININ TIBBI–AROMATİK BİTKİLERDE VERİM, ETKEN MADDE İÇERİĞİ VE STRES TOLERANSINA ETKİLERİ

Dr. Öğr. Üyesi Sadiye Ayşe ÇELİK
Selçuk Üniversitesi, Ziraat Fakültesi
Email: sacelik@selcuk.edu.tr
ORCID: 0000-0002-0765-642X
Zir. Müh. Emir YAVAŞ
Selçuk Üniversitesi, Ziraat Fakültesi
Email: ozkanaytuba@gmail.com
ORCID: 0009-0002-0827-0462
Zir. Müh. Selim Derman KÜÇÜKMARAŞ
Selçuk Üniversitesi, Ziraat Fakültesi
Email: dermanselim330@gmail.com
ORCID: 0009-0004-0022-0107

ÖZET

Tıbbi ve aromatik bitkiler (TAB), içeriklerinde bulunan uçucu yağlar, fenolik bileşikler, flavonoidler, alkaloidler gibi sekonder metabolitler sayesinde farmasötik, kozmetik, gıda ve aromaterapi endüstrilerinde önemli bir yer tutmaktadır. Artan çevresel stres faktörleri, kuraklık, toprak tuzluluğu ve kimyasal girdi kullanımının yol açtığı sorunlar, bu bitkilerin sürdürülebilir ve kaliteli üretiminde biyolojik çözümlerin önemini artırmıştır. Bu bağlamda, bitki gelişimini teşvik eden rizobakteriler (PGPR) ve arbusküler mikoriza mantarları (AMF), ekolojik üretim sistemlerinde önemli biyolojik girdiler olarak öne çıkmaktadır. PGPR uygulamaları; azot fiksasyonu, fosfor çözündürme, bitki büyüme hormonları (IAA) üretimi, siderofor sentezi ve ACC deaminaz aktivitesi yoluyla kök gelişimini, besin alımını ve stres toleransını artırmaktadır. Mikoriza mantarları ise kök yüzey alanını artırarak özellikle fosfor, çinko ve su alımında avantaj sağlamakta, aynı zamanda bitkilerde sekonder metabolit sentezini uyararak uçucu yağ ve fenolik madde içeriğini yükseltmektedir.

Son yıllarda yapılan araştırmalar, PGPR ve mikorizanın birlikte uygulanmasının, lavanta (Lavandula angustifolia), kekik (Thymus vulgaris), adaçayı (Salvia officinalis), biberiye (Rosmarinus officinalis) ve ekinezya (Echinacea purpurea) gibi tıbbi bitkilerde verim, biyokütle ve kalite parametrelerinde tek başına uygulamalara kıyasla daha üstün sonuçlar verdiğini ortaya koymuştur. Kombinasyon uygulamaları, bitkilerin hem biyotik hem de abiyotik stres koşullarına karşı dayanıklılığını artırmakta, su kullanım etkinliğini yükseltmekte ve kimyasal gübre ihtiyacını azaltarak sürdürülebilir üretime katkı sağlamaktadır. Bu nedenle, PGPR ve mikoriza kombinasyonlarının TAB yetiştiriciliğinde kullanımı, güncel ve geleceğe yönelik yüksek potansiyelli bir araştırma konusudur. Bu bildiride, bu biyolojik ajanların etki mekanizmaları, uygulama yöntemleri ve tıbbi bitkilerde verim–kalite parametreleri üzerine etkileri literatür temelli olarak ele alınmıştır.

Anahtar Kelimeler: PGPR, Mikoriza, Tıbbi Bitkiler, Aromatik Bitkiler.

EFFECTS OF PGPR AND MYCORRHIZA COMBINATIONS ON YIELD, ACTIVE COMPOUND CONTENT, AND STRESS TOLERANCE IN MEDICINAL AND AROMATIC PLANTS

ABSTRACT

Medicinal and aromatic plants (MAPs) play a crucial role in the pharmaceutical, cosmetic, food, and aromatherapy industries due to their rich content of secondary metabolites such as essential oils, phenolic compounds, flavonoids, and alkaloids. Increasing environmental stress factors—including drought, soil salinity, and problems arising from intensive chemical input use—have heightened the importance of biological solutions for the sustainable and high-quality production of MAPs. In this context, Plant Growth Promoting Rhizobacteria (PGPR) and arbuscular mycorrhizal fungi (AMF) have emerged as key biological inputs within ecological production systems. PGPR applications enhance root growth, nutrient uptake, and stress tolerance through mechanisms such as nitrogen fixation, phosphorus solubilization, production of plant growth hormones (IAA), siderophore synthesis, and ACC deaminase activity. Mycorrhizal fungi, by increasing root surface area, improve the uptake of relatively immobile nutrients such as phosphorus and zinc as well as water, while also stimulating the biosynthesis of secondary metabolites, leading to higher levels of essential oils and phenolic compounds.

Recent studies have demonstrated that the combined application of PGPR and AMF produces superior results compared to single applications in terms of yield, biomass, and quality parameters in medicinal plants such as lavender (Lavandula angustifolia), thyme (Thymus vulgaris), sage (Salvia officinalis), rosemary (Rosmarinus officinalis), and echinacea (Echinacea purpurea). The combination improves plant tolerance to both biotic and abiotic stresses, enhances water use efficiency, and contributes to sustainable production by reducing the need for chemical fertilizers. Therefore, the use of PGPR and AMF combinations in MAP cultivation represents a highly relevant and promising research topic for the future. This paper presents a literature-based evaluation of their mechanisms of action, application methods, and impacts on yield and quality parameters in medicinal and aromatic plants.

Keywords: PGPR, Mycorrhiza, Medicinal Plants, Aromatic Plants.

SULAMANIN LAVANTA (*L. angustifolia mill.*) ÜRÜN VERİMİ VE YAĞ KALİTESİNE ETKİLERİ ÜZERİNE BİR İNCELEME

Öğr. Gör. Havva Nur Demir Deveci

Necmettin Erbakan Üniversitesi, Meram Meslek Yüksek Okulu

Email: hndemir@erbakan.edu.tr

ORCID: 0009 0005 6827 7334

Tahir Külahcı

Selçuklu İlçe Tarım ve Orman Müdürlüğü

Email: tahirkulahci@gmail.com

ORCID: 0009-0000-8639-1425

Prof. Dr. Ramazan Topak

Selçuk Üniversitesi, Ziraat Fakültesi

Email: rtopak@selcuk.edu.tr

ORCID: 0000 0003 3748 2720

ÖZET

Tarım kültürüne alınması, tıbbi ve aromatik bitkilerin dünyada varlığını sürdürmesinde çok önemli bir rol oynamıştır. Tıbbi ve aromatik bitkilerin ekseriyeti kuraklığa töleranslı olup, hem yağışa dayalı ve hem de suluda yetiştirilmektedir. Özellikle kurak bölgelerde, yağışa dayalı üretim için bu bitkilerin tarımı tercih edilebilmektedir. Sulama, kurak alanlarda su stresini azaltmak ve ürün verimini artırmak için en etkili önlemdir. Dolayısıyla tıbbi ve aromatik bitkilerde de sulama kaçınılmazdır. Tıbbi ve aromatik bitki olan lavanta, kurağa dayanıklı olup, uçucu yağı için üretilmektedir. Bu çalışma, lavantada sulama üzerine yapılan bazı araştırmaların değerlendirilmesi amacıyla yapılmıştır. Bu kapsamda, bu bildiride, yakın geçmişte yapılan ve farklı sulama programlarının lavantanın ot ve uçucu yağ verimi ile uçucu yağ kalitesi üzerindeki etkisini ortaya koyan bazı çalışmaların bir analizi sunulmuştur. Sonuç olarak, kurak bölgelerde sulama işlemi lavantanın ürün verimini önemli ölçüde artırmaktadır. Dolayısıyla su kıtlığı olan bölgelerde lavanta tarımı için de yüksek sulama suyu üretkenliği sağlayan sulama programlarının geliştirilmesine ihtiyaç duyulmaktadır.

Anahtar Kelimeler: Lavanta; Sulama Yönetimi; Uçucu Yağ Verimi; Yağ Kalitesi

A REVIEW ON THE EFFECTS OF IRRIGATION ON LAVENDER *(l. angustifolia mill.)* YIELD AND OIL QUALITY

ABSTRACT

Their inclusion in agricultural culture has played a very important role in the survival of medicinal and aromatic plants around the world. The majority of medicinal and aromatic plants are drought-tolerant and are grown both rain-fed and irrigated. Especially in arid regions, the cultivation of these plants is preferred for rain-fed production. Irrigation is the most effective measure to reduce water stress and increase crop yields in arid areas. Therefore, irrigation is inevitable for medicinal and aromatic plants as well. Lavender, a medicinal and aromatic plant, is drought-tolerant and is cultivated for its essential oil. This study was conducted to evaluate some research on irrigation in lavender. Within this scope, this paper presents an analysis of recent studies that have demonstrated the effect of different irrigation practices on the herb and essential oil yield and essential oil quality of lavender. Consequently, irrigation significantly increases lavender yield in arid regions. Therefore, there is a need to develop irrigation schedules that provide high irrigation water productivity for lavender cultivation in regions experiencing water scarcity.

Keywords: Lavender; Irrigation Management; Essential Oil Yield; Oil Quality

FARKLI TOPRAK SERİLERİNDE AGREGAT STABİLİTESİ VE ORGANİK MADDE İÇERİĞİ ARASINDAKİ İLİŞKİLER

Dr. Mert Acar

Çukurova Üniversitesi, Ziraat Fakültesi

Email: macar@cu.edu.tr

ORCID: 0000-0002-9971-4470

ÖZET

Agregat stabilitesi ve organik madde, tarımsal üretkenlik ve ekosistem sürdürülebilirliği açısından önemli göstergelerdir. Agregat stabilitesi, erozyona karşı dayanıklılığın ve yapısal bütünlüğün bir göstergesi olup, organik madde ile yakından oldukça ilişkilidir. Agregat oluşumunda ve stabilitesinde organik maddenin bağlayıcı/birleştirici etkisi bulunmakla birlikte organik maddenin korunmasında da mevcut agregatlar önemli bir rol oynamaktadır. Bu bakımdan agregat stabilitesi ile organik madde arasındaki bu ilişki, iki yönlüdür.

Bu çalışmada, farklı arazi kullanımlarına ve karakteristik özelliklere sahip toprak serilerinde (Arık, Balcalı, Baraj, Hurma, Kabaktepe, Karaburun, Kızıltapır, Menzilat ve Mutlu) agregat stabilitesi (AS) ve toprak organik madde (SOM) içeriklerindeki değişimler ile aralarındaki ilişkiler analiz edilmiştir. Bu amaçla, 25 Haziran 2025 tarihinde Çukurova Üniversitesi Kampüsü içerisinde, ilgili serilere ait profillerde veya bu profillere en yakın uygun alanlarda toprak örneklemeleri yapılmıştır. Alınan toprak örneklerinde AS ve OM analiz edilmiştir.

Sonuçlar, toprak serileri arasında hem AS hem de SOM açısından önemli farklılıklar olduğunu ve aralarındaki ilişkinin istatistiksel olarak önemli olduğunu ($p<0.01$) göstermiştir. En yüksek AS değerleri Baraj (%72,6) ve Kızıltapır (%71,2) serilerinde gözlenirken, en düşük değer Arık serisinde (%22,3) belirlenmiştir. SOM içerikleri açısından ise Kızıltapır serisi (%7,83) belirgin şekilde öne çıkarken, en düşük SOM Kabaktepe serisinde (%1,49) belirlenmiştir. Genel olarak, yüksek SOM içeriği olan serilerde AS değerleri de daha yüksek bulunmuş, bu durum organik maddenin agregat oluşumunda ve stabilitesinde kritik rol oynadığını ortaya koymuştur. Ayrıca, en yüksek AS ve SOM değerleri bahçe tarımı yapılan veya orman örtüsü altındaki serilerde belirlenirken, işlemeli tarımın uygulandığı serilerde daha düşük değerler tespit edilmiştir. Bu bulgular, toprak yönetiminde organik madde artırıcı uygulamaların önemini vurgulamaktadır. Ayrıca, düşük SOM ve AS değerlerine sahip serilerin sürdürülebilir kullanım için özel yönetim stratejilerine ihtiyaç duyduğu sonucuna varılmıştır.

Anahtar Kelimeler: Toprak serisi, Agregat, Organik Madde, Sürdürülebilirlik

RELATIONSHIPS BETWEEN AGGREGATE STABILITY AND ORGANIC MATTER CONTENT IN DIFFERENT SOIL SERIES

ABSTRACT

Aggregate stability and soil organic matter are key indicators of agricultural productivity and ecosystem sustainability. Aggregate stability serves as an indicator of resistance to erosion and structural integrity, and it is strongly associated with organic matter. Soil organic matter exerts a binding and aggregating effect in aggregate formation and stability, existing aggregates also play an important role in the protection of organic matter. Therefore, the relationship between aggregate stability and organic matter is bidirectional.

In this study, variations in aggregate stability (AS) and soil organic matter (SOM) content, as well as their interrelationship, were analyzed across soil series with different land uses and distinct characteristics (Arık, Balcalı, Baraj, Hurma, Kabaktepe, Karaburun, Kızıltapır, Menzilat, and Mutlu). For this purpose, on June 25, 2025, soil samples were collected within the Çukurova University Campus from the profiles of the respective soil series or from the nearest appropriate locations to these profiles. The collected soil samples were analyzed for AS and SOM.

The results revealed significant differences among the soil series in terms of both AS and SOM, and their relationship was found to be statistically significant ($p < 0.01$). The highest AS values were observed in Baraj (72.6%) and Kızıltapır (71.2%) series, whereas the lowest value was recorded in the Arık series (22.3%). Kızıltapır series was particularly notable for its high SOM content (7.83%), while the lowest SOM was found in the Kabaktepe series (1.49%). Overall, soil series with higher SOM content showed higher AS values, indicating the critical role of organic matter in aggregate formation and stability. Moreover, the highest AS and SOM values were observed in soil series under horticulture or forest cover, whereas lower values were recorded in series subjected to conventional tillage. These findings highlight the importance of organic matter-enhancing practices in soil management. Furthermore, soil series with low SOM and AS values require specific management strategies to ensure sustainable use.

Keywords: Soil Series, Aggregate, Organic Matter, Sustainability

YAPAY ZEKÂ TABANLI YAKLAŞIMLAR İLE CANLI HAYVAN SAYILARININ BÖLGESEL ANALİZİ VE ÖNGÖRÜLMESİ

Dr. Şahin AYDIN

Işık Üniversitesi, İktisadi, İdari ve Sosyal Bilimler Fakültesi

Email: sahin.aydin@isikun.edu.tr

ORCID: 0000-0001-7355-5339

ÖZET

Hayvancılık, Türkiye tarım ekonomisinin temel taşlarından biri olup gıda güvenliği, kırsal kalkınma ve ulusal ekonomi açısından kritik bir rol oynamaktadır. Talep yapısındaki değişimler, üretim pratiklerindeki dönüşümler ve iklim kaynaklı belirsizlikler karşısında, canlı hayvan sayılarının güvenilir şekilde öngörülmesi her zamankinden daha önemli hale gelmiştir. Ancak geleneksel tahmin yöntemleri, hayvancılığın bölgesel farklılıklarını ve doğrusal olmayan dinamiklerini yakalamada çoğu zaman yetersiz kalmaktadır. Bu çalışmada, Türkiye'de canlı hayvan sayılarının bölgesel analizi ve geleceğe yönelik projeksiyonlarının oluşturulmasında yapay zekâ tabanlı yaklaşımların potansiyeli araştırılmaktadır.

Çalışmada kullanılan veri seti, resmi istatistiklerden elde edilen ve uzun yılları kapsayan bölgesel canlı hayvan sayılarından oluşmaktadır. Öncelikle Exponential Smoothing ve ARIMA gibi klasik zaman serisi modelleri temel senaryo olarak uygulanmış, ardından elde edilen sonuçlar yapay zekâ tabanlı yöntemlerle karşılaştırılmıştır. Random Forest algoritması ile doğrusal olmayan ilişkilerin yakalanması, LSTM (Long Short-Term Memory) modeli ile de zaman serilerindeki uzun dönem bağımlılıkların öğrenilmesi hedeflenmiştir. Tahmin performansı RMSE ve MAPE hata metrikleriyle değerlendirilmiştir.

Bulgular, Türkiye'de canlı hayvan sayılarının bölgeler arasında belirgin farklılıklar gösterdiğini ortaya koymaktadır. Batı bölgelerinde sürekli artış eğilimleri gözlemlenirken, bazı bölgelerde durağanlık öne çıkmıştır. Yapay zekâ tabanlı modeller, kısa, orta ve uzun vadeli öngörülerde geleneksel yöntemlere kıyasla daha yüksek doğruluk sağlamıştır. Çalışma, yapay zekânın öngörü doğruluğunu artırarak sürdürülebilir hayvancılık yönetimine ve kırsal kalkınmaya yönelik kanıta dayalı politika geliştirme süreçlerine katkı sağlayabileceğini göstermektedir.

Anahtar Kelimeler: Yapay Zekâ, Hayvancılık, Zaman Serisi, Bölgesel Analiz, Türkiye

AI-BASED APPROACHES FOR REGIONAL ANALYSIS AND FORECASTING OF LIVESTOCK NUMBERS

ABSTRACT

Livestock production constitutes one of the essential pillars of Türkiye's agricultural sector, with significant contributions to food security, rural livelihoods, and the national economy. Reliable forecasting of livestock numbers is increasingly important in the face of rapid changes in demand, production practices, and climate-related uncertainties. Despite the importance of this field, conventional forecasting approaches often fail to capture the nonlinear dynamics and regional disparities inherent in livestock production. This study therefore aims to explore the potential of artificial intelligence (AI)-based methods for the regional analysis and forecasting of livestock numbers in Türkiye.

The dataset used in this study consists of annual livestock numbers collected from official statistics with a regional breakdown over a multi-decade horizon. Initially, classical time series models such as Exponential Smoothing and ARIMA were employed as baseline forecasting techniques. These models were then compared with AI-based approaches, including Random Forest and Long Short-Term Memory (LSTM) networks, which are well suited to capture nonlinear and temporal dependencies. Forecasting accuracy was evaluated through standard error metrics, including Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE).

The empirical findings reveal pronounced regional disparities in livestock development. While some regions, particularly in western Türkiye, exhibit sustained growth in livestock numbers, others remain relatively stagnant. AI-based models consistently outperformed traditional methods by providing more accurate short-, medium-, and long-term projections. The results highlight the capacity of AI to serve as a decision-support tool for policymakers and producers by offering reliable projections under uncertainty. Ultimately, this study contributes to the literature by demonstrating how AI-based forecasting can strengthen evidence-based strategies for sustainable livestock management and rural development.

Keywords: Artificial Intelligence, Livestock, Time Series Forecasting, Regional Analysis, Türkiye

DETECTION OF NATURAL RADIOACTIVE ISOTOPES IN CHESTNUTS AND RADIOLOGICAL RISK ASSESSMENT FOR HUMAN HEALTH

Doç. Dr. Serdar Dizman

Recep Tayyip Erdogan University, Faculty of Art and Sciences, Department of Physics

Email: serdar.dizman@erdogan.edu.tr

ORCID: 0000-0002-6511-9526

ABSTRACT

Chestnut (Castanea sativa) is an important food source both in our country and worldwide, with its high carbohydrate content, rich mineral composition, and energy-providing properties, making it valuable in human nutrition. The significance of foods lies not only in their nutritional properties but also in their safety, which is critical for public health. Due to environmental factors, nuclear accidents, and the presence of natural radioisotopes, determining radioactivity levels in foods is essential for food safety. Therefore, the determination of radioactivity in chestnuts is important for both protecting consumer health and ensuring the sustainability of food safety. In this study, the background levels of some natural radioisotopes (238U, 232Th and 40K) in some chestnut samples were determined before the operation of the nuclear power plant to be established in Sinop province, and the determined levels were compared with the limit values recommended by international organizations. 238U, 232Th and 40K concentrations in the collected chestnut samples were measured using a High-Purity Germanium detector (HPGe). It was observed that the activity values of 238U were between 1.03 Bq/kg and 3.26 Bq/kg; the activity values of 232Th were between 0.67 Bq/kg and 4.72 Bq/kg; the activity values of 40K were between 25.64 Bq/kg and 67.98 Bq/kg in the chestnut samples. To evaluate the radiological hazards arising from natural radionuclides in the chestnut samples examined, the daily radioactive intake (Dint), the annual effective dose equivalent (AEDE) and lifetime cancer risk (ELCR) values were calculated and compared with world average values. In conclusion, this study demonstrated that the consumption of the chestnut samples examined does not pose a radiological risk to human health.

Keywords: Chestnut, Radioactivity, Radiological Risk, Sinop

ARONYA (*Aronia melanocarpa*) YETİŞTİRİCİLİĞİNDE MİKROBİYAL GÜBRE VE ÇAY ATIĞI UYGULAMALARININ VERİM VE KALİTE ÜZERİNE ETKİSİ

Öğr. Gör. Songül YILDIZ

Recep Tayyip Erdoğan Üniversitesi, Pazar Meslek Yüksekokulu

Email: songul.yildiz@erdogan.edu.tr

ORCID: 0000-0003-4748-6661

Fatma KESİMAL

Recep Tayyip Erdoğan Üniversitesi, Pazar Meslek Yüksekokulu

Email: fatma_kesimal23@erdogan.edu.tr

ORCID: 0009-0005-6757-752X

Doç. Dr. Zeynep BAYRAMOĞLU

Recep Tayyip Erdoğan Üniversitesi, Pazar Meslek Yüksekokulu

Email: zeynep.bayramoglu@erdogan.edu.tr

ORCID: 0000-0001-6994-1106

ÖZET

Aronya *(Aronia melanocarpa),* son yıllarda artan besin değeri ve sağlık üzerindeki olumlu etkileri nedeniyle önemli bir meyve türü haline gelmiştir. Doğu Karadeniz Bölgesinde özellikle Rize ili, aronya yetiştiriciliği için uygun iklim ve ekolojik koşullara sahiptir. Yoğun olarak kullanılan kimyasal gübreler bitki verimini artırmakla birlikte, bilinçsiz ve aşırı uygulamaları insan sağlığı ve çevre üzerinde olumsuz etkiler yaratabilmektedir. Bu nedenle, bitki gelişimini destekleyen mikrobiyal gübrelerin kullanımı çevre dostu tarım uygulamaları açısından kritik öneme sahiptir. Ayrıca, çay lifi gibi tarımsal atıkların değerlendirilmesi, çevresel kirliliğin azaltılmasına katkı sağlarken sürdürülebilir tarım uygulamalarını desteklemektedir.

Bu çalışma, 2024 yılında Recep Tayyip Erdoğan Üniversitesi bünyesindeki seralarda, tesadüf parselleri deneme desenine göre 3 yaşındaki Aronia (Aronia melanocarpa) Viking çeşidi üzerinde yürütülmüştür. Çalışma, yalnızca toprak içeren kontrol grubu (T), sadece çay atığı içeren ortam (Ç), %50 toprak + %50 çay atığı karışımı (T+Ç), toprak ortamına uygulanan mikrobiyal gübre 1 (MG1: Ss-Super Root), ve mikrobiyal gübre 2 (MG2: Biogreen Fabio) olacak şekilde beş farklı uygulamadan oluşmaktadır. Mikrobiyal gübrelerin uygulanması on gün aralıklarla tekrarlanmıştır.

Meyve verimi (g) ve meyve eni (mm) MG2, meyve boyu (mm) MG1, klorofil içeriği (SPAD) T, pH değeri Ç, titre edilebilir asit T+Ç, suda çözünür kuru madde içeriği (%) MG1, toplam fenolik madde (mg GAE/mL) T ve antioksidan aktivitesi (mg/mL) T+Ç uygulamalarında yüksek olarak belirlenmiştir.

Toprak ortamına mikrobiyal gübrenin düzenli olarak uygulanması ve toprak + çay atığı karışımlarının (T+Ç) aronya yetiştiriciliğinde kullanımı, verim ve kalite açısından artış sağlamıştır. Özellikle Doğu Karadeniz Bölgesi'nde, toprak ve çay atığı karışımında yetiştirilen aronya bitkisine düzenli mikrobiyal gübre uygulaması, verim ve kaliteyi artırıcı bir etki gösterebileceği sonucuna ulaşılmıştır.

Anahtar Kelimeler: Aronya, Çay atığı, Mikrobiyal gübre, Küresel ısınma

EFFECTS OF MICROBIAL FERTILIZER AND TEA WASTE APPLICATIONS ON YIELD AND QUALITY IN ARONIA (*Aronia melanocarpa)* CULTIVATION

ABSTRACT

Aronia (*Aronia melanocarpa)* has become an important fruit species in recent years due to its increased nutritional value and positive health effects. Rize province, in particular, in the Eastern Black Sea Region, has the ideal climatic and ecological conditions for aronia cultivation. While intensive use of chemical fertilizers increases plant yields, their indiscriminate and excessive application can have negative effects on human health and the environment. Therefore, the use of microbial fertilizers that support plant growth is critical for environmentally friendly agricultural practices. Furthermore, the utilization of agricultural wastes such as tea fiber contributes to the reduction of environmental pollution and supports sustainable agricultural practices.

This study was conducted in greenhouses at Recep Tayyip Erdoğan University in 2024 using a randomized plot design on 3 year old Aronia (Aronia melanocarpa) Viking. The study consisted of five different treatments: soil-only control (T), tea waste-only medium (C), a 50% soil + 50% tea waste mixture (T+C), microbial fertilizer 1 (MG1: Ss-Super Root), and microbial fertilizer 2 (MG2: Biogreen Fabio) applied to the soil medium. Applications of microbial fertilizers were repeated at ten-day intervals.

Fruit yield (g) and fruit width (mm) were found to be higher in MG2, fruit length (mm) in MG1, chlorophyll content (SPAD) in T, pH value in Ç, titratable acidity in T+Ç, water-soluble solids content (%) in MG1, total phenolic content (mg GAE/mL) in T, and antioxidant activity (mg/mL) in T+Ç treatments.

Regular application of microbial fertilizer to the soil and the use of soil and tea waste mixtures (T+Ç) in aronia cultivation resulted in increased yield and quality. It was concluded that regular application of microbial fertilizer to aronia plants grown in soil and tea waste mixtures, particularly in the Eastern Black Sea Region, could have an increasing effect on yield and quality.

Keywords: Aronia, Tea waste, Microbial fertilizer, Global warming

ÇAY FİDANI (*Camellia sinensis l.)* GELİŞİMİNDE ÇAY SİRKESİ UYGULAMALARININ ETKİLERİ

Öğr. Gör. Songül YILDIZ
Recep Tayyip Erdoğan Üniversitesi, Pazar Meslek Yüksekokulu
Email: songul.yildiz@erdogan.edu.tr
ORCID: 0000-0003-4748-6661
Öğr. Gör. Yeşim ÖZTÜRK YILMAZ
Recep Tayyip Erdoğan Üniversitesi, Pazar Meslek Yüksekokulu
Email: yesim.ozturk@erdogan.edu.tr
ORCID: 0000-0001-6823-707X
Doç. Dr. Zeynep BAYRAMOĞLU
Recep Tayyip Erdoğan Üniversitesi, Pazar Meslek Yüksekokulu
Email: zeynep.bayramoglu@erdogan.edu.tr
ORCID: 0000-0001-6994-1106

ÖZET

Doğu Karadeniz Bölgesi'nde tarımsal üretim açısından stratejik bir öneme sahip olan çay *(Camellia sinensis L.*), bölge üreticileri için temel bir geçim kaynağı olmasının yanı sıra, sanayi sektörü bakımından da kritik bir değer taşımaktadır. Çay işleme süreçleri sonucunda ortaya çıkan atık çay liflerinin odun kömürü üretiminde kullanılmasıyla, piroliz yöntemi aracılığıyla elde edilen önemli yan ürünlerden biri ise odun sirkesidir.

Bu çalışmada amaç, yaş çay üretiminde sentetik gübre kullanımının azaltılmasına katkı sağlayabilecek alternatif bir girdi olarak çay odun sirkesinin çay fidanı gelişiminde en uygun konsantrasyonu belirlemektir. Bu çalışma, 2025 yılında Recep Tayyip Erdoğan Üniversitesi bünyesindeki serada tesadüf parselleri deneme desenine göre üç tekerrürlü olarak yürütülmüştür. Uygulamalar, saksı ortamında (3:1 oranında torf: vermikülit) iki yaşındaki Zihni Derin çeşidi çay fidanlarına 10 gün aralıklarla uygulanarak gerçekleştirilmiştir. Çalışmada kontrol 1 (K1, uygulama yapılmamış), kontrol 2 (K2, ticari odun sirkesi) ve beş farklı çay odunu sirkesi dozu (1/500, 1/1000, 1/1500, 1/2000 ve 1/2500) karşılaştırma yapılmıştır.

Yapılan uygulamalar sonucunda, bitkilerin morfolojik ve fizyolojik özellikleri üzerinde belirgin farklılıklar gözlemlenmiştir. Özellikle sürgün gelişimi açısından, en yüksek sürgün boyu (22,1 cm) ve sürgün çapı (3,3 cm) 1/500 dozunda, yaprak sayısı (15,3 adet) ve yan sürgün sayısı (3,3 adet) 1/1000 dozunda gerçekleştirilen uygulamada belirlenmiştir. Klorofil içeriği 1/2500 dozunda (33,8 SPAD), yaprak alanı ise K2 uygulamasında (14,2 cm^2) ile en yüksek seviyede ölçülmüştür.

Aşırı sentetik gübre kullanımının yol açtığı toprak kirliliği ve biyolojik aktivite kayıplarının azaltılması ile küresel ısınma üzerindeki olumsuz etkilerin hafifletilmesinde, 1/1000 oranında seyreltilmiş odun sirkesi uygulamasının diğer dozlara kıyasla çayda hasat edilecek sürgün miktarını artırmada daha etkili olabileceği sonucuna varılmıştır.

Anahtar Kelimeler: Çay, Odun Sirkesi, Fidan Gelişimi, Küresel ısınma

EFFECTS OF TEA VINEGAR APPLICATIONS ON THE GROWTH OF TEA SEEDLINGS (*Camellia sinensis L.)*

ABSTRACT

Tea (*Camellia sinensis L.),* which holds strategic importance for agricultural production in the Eastern Black Sea Region, is not only a primary source of income for regional producers but also holds critical industrial value. One of the important byproducts of pyrolysis, which utilizes waste tea fibers from tea processing to produce charcoal, is wood vinegar.

The aim of this study was to determine the optimum concentration of tea wood vinegar on tea seedling development as an alternative input that could contribute to reducing the use of synthetic fertilizers in fresh tea production. This study was conducted in the greenhouse of Recep Tayyip Erdoğan University in 2025 using a randomized plot design with three replications. Applications were made at 10-day intervals to two-year-old tea seedlings of the Zihni Derin variety in potted medium (peat:vermiculite ratio of 3:1). Control 1 (K1, untreated), control 2 (K2, commercial wood vinegar), and five different tea wood vinegar doses (1/500, 1/1000, 1/1500, 1/2000, and 1/2500) were compared.

Significant differences were observed in the morphological and physiological characteristics of the plants as a result of the treatments. Specifically, in terms of shoot development, the highest shoot length (22.1 cm) and shoot diameter (3.3 cm) were observed at the 1/500 dose, while the highest leaf count (15.3) and lateral shoot count (3.3) were observed at the 1/1000 dose. Chlorophyll content (33.8 SPAD) was measured at the 1/2500 dose, and leaf area (14.2 cm^2) was measured at the K2 treatment.

It was concluded that the application of 1/1000 diluted wood vinegar may be more effective in increasing the amount of shoots to be harvested in tea compared to other doses in mitigating the negative effects on global warming by reducing soil pollution and biological activity losses caused by excessive use of synthetic fertilizers.

Keywords: Tea, Wood Vinegar, Seedling Development, Global Warming

AKHİSAR (MANİSA, TÜRKİYE) İLÇESİNDEKİ ZEYTİN ALANLARINDA *Palpita unionalis hubner'in* (LEPİDOPTERA: PYRALİDAE) MEVSİMSEL POPÜLASYON DİNAMİKLERİ

Merve KAHRAMAN

Bolu Abant İzzet Baysal Üniversitesi, Lisansüstü Eğitim Enstitüsü

Email: mervekahraman2018@gmail.com

ORCID: 0009-0007-9852-3174

Dr. Öğr. Üyesi Abdurrahman Sami KOCA

Bolu Abant İzzet Baysal Üniversitesi, Ziraat Fakültesi, Bitki Koruma Bölümü

Email: a.samikoca@yahoo.com.tr

ORCID: 0000-0002-7657-5615

ÖZET

Zeytin fidan tırtılı, Palpita unionalis Hübner (Lepidoptera: Pyralidae), birçok bölgede zeytin üretimini tehdit eden önemli bir zararlıdır. Bu tür, larvalarının yaprakları örerek ve tüketerek beslenmesi sonucunda önemli yaprak dökümüne neden olmakta ve meyve kalitesini düşürerek zeytin verimi üzerinde olumsuz etki yapmaktadır. Özellikle Türkiye gibi Akdeniz ülkelerinde zeytinin ekonomik önemi göz önünde bulundurulduğunda, P. unionalis'in neden olduğu bulaşmalar sürdürülebilir zeytin üretimi için ciddi bir tehdit oluşturmaktadır. Bu çalışmada, 2024 yılında Akhisar ilçesindeki üç farklı lokasyonda (Yenice, Kadıdağı ve Hasköy) P. unionalis'in mevsimsel popülasyon dinamikleri belirlenmiştir. Ergin popülasyonları, her bahçeye üç adet yerleştirilen feromon tuzakları ile izlenmiş ve Haziran–Kasım ayları arasında haftalık kontroller yapılmıştır. İlk ergin bireyler 14 Haziran'da Yenice ve Hasköy'de, 17 Haziran'da ise Kadıdağı'nda yakalanmıştır. Zararlının popülasyonları Hasköy'de iki kez tepe noktası oluşturmuş olup sırasıyla 23 Haziran'da 11 adet ergin/tuzak ve 24 Ağustos'ta 8 adet ergin/tuzak tespit edilmiştir. Yenice lokasyonunda da benzer tarihlerde iki kez popülasyonlar tepe noktasına ulaşmış ve her iki tarihte de ortalama 6 adet ergin tuzaklarda yakalanmıştır. Kadıdağı'nda ise 25 Haziran (10 adet ergin/tuzak) ve 18 Ağustos (9 adet ergin/tuzak) tarihlerinde zararlının popülasyonları tepe noktasına ulaşmıştır. Popülasyonların tepe noktalarına ulaşmasının ardından tüm bahçelerde ergin yoğunluğunda kademeli bir azalma gözlenmiştir. Son ergin bireyler 26 Ekim'de zeytin bahçelerinde kaydedilmiştir. Elde edilen sonuçlar, P. unionalis'in mevsimsel dağılımı ve uçuş dönemleri hakkında bilgiler sunmakta ve zararlı ile mücadelede uygun zamanlamanın belirlenmesi için düzenli popülasyon takibin önemini vurgulamaktadır. Bu gözlemler, P. unionalis'in popülasyon dinamiklerinin daha iyi anlaşılmasına katkıda bulunmakta ve bölgede zararlı yönetimi yaklaşımlarının geliştirilmesine yardımcı olabilecek veriler sağlamaktadır.

Anahtar Kelimeler: Zeytin, Popülasyon Takibi, Zeytin Fidan Tırtılı, Akhisar, Manisa

SEASONAL POPULATION DYNAMICS OF *Palpita unionalis hubner* (LEPIDOPTERA: PYRALIDAE) IN OLIVE ORCHARDS OF AKHISAR DISTRICT (MANISA, TURKIYE)

ABSTRACT

The olive leaf moth, Palpita unionalis Hübner (Lepidoptera: Pyralidae), is a significant pest that threatens olive production in many regions. This species has a harmful impact on olive crop yields, causing substantial defoliation and reducing fruit quality through larval feeding habits that involve webbing and consuming leaves. Given the economic importance of olives, particularly in Mediterranean countries such as Türkiye, infestations by P. unionalis pose a serious challenge to sustainable olive production. This study investigated the seasonal population dynamics of P. unionalis in three different locations (Yenice, Kadıdağı, and Hasköy) in the Akhisar district during 2024. Adult populations were monitored using pheromone traps, with three traps per orchard, and weekly inspections conducted between June and November. The first adult captures occurred on 14 June in Yenice and Hasköy, and on 17 June in Kadıdağı. The pest populations in Hasköy exhibited two distinct peaks, with 11 adults per trap recorded on 23 June and 8 adults per trap on 24 August. Similarly, in the Yenice location, population peaks occurred twice around the same periods, with an average of 6 adults per trap detected on both dates. In Kadıdağı, the population reached its peaks on 25 June (10 adults per trap) and 18 August (9 adults per trap). Following these peaks a gradual decline in adult population density was observed across all orchards. The last occurrence of adults was recorded on 26 October in olive orchards. The results provide valuable insights into the temporal distribution and activity patterns of P. unionalis, emphasizing the importance of regular monitoring for the optimal timing of pest management practices. These observations contribute to a better understanding of the population dynamics of P. unionalis and may assist in refining pest management approaches in the region.

Keywords: Olive, Population Dynamics, Olive Leaf Moth, Akhisar, Manisa

MAVİ-GÖĞÜSLÜ BILDIRCINLARDA (*Synoicus chinensis)* YUMURTA ÖZELLİKLERİNİN KALITIM DERECESİ VE ORTAK ÇEVRE ETKİLERİNİN TAHMİNİ

Arş. Gör. Dr. Arzu ÜÇTEPE

Isparta Uygulamalı Bilimler Üniversitesi, Ziraat Fakültesi, Zootekni Bölümü, Isparta, Türkiye

Email: arzuuctepe@isparta.edu.tr

ORCID: 0000-0002-8796-3752

Prof. Dr. Antonios KOMİNAKİS

Atina Tarım Üniversitesi, Zootekni Bölümü, 75 Iera Odos, 11855, Atina, Yunanistan

Email: acom@aua.gr

ORCID: 0009-0009-8398-9750

ÖZET

Mavi-göğüslü bıldırcın (Synoicus chinensis), küçük yapısı ve hızlı üreme döngüsü sayesinde yumurta özelliklerinin genetik analizi için uygun bir modeldir. Yumurta ağırlığı, uzunluğu, genişliği ve bu ölçümlere dayalı diğer özellikler; hem embriyo gelişimi hem de genetik ıslah programlarının başarısı açısından kritik öneme sahiptir. Bu çalışmada, mavi-göğüslü bıldırcınlarda ölçülen ve türetilmiş yumurta özelliklerine ait kalıtım dereceleri ile ortak çevre etkilerinin belirlenmesi amaçlanmıştır. Araştırmada, 49-402 günlük yaş aralığında bulunan 104 dişi bireyden elde edilen toplam 6.602 yumurtaya ait ağırlık, uzunluk ve genişlik kayıtları kullanılmıştır. Türetilmiş özellikler olarak şekil indeksi, hacim, yüzey alanı, yoğunluk ve yüzey-hacim indeksi hesaplanmıştır. Eklemeli genetik, ortak çevresel ve hata etkilerine ilişkin varyans bileşenleri Bayesian tek değişkenli hayvan modelleriyle tahmin edilmiş; jenerasyon, kuluçka grubu, yıl, ay ve yaş sabit etkiler olarak modele dahil edilmiştir. Kalıtım derecesi (h^2) en yüksek yüzey-hacim indeksi (0,54) ve yoğunluk (0,47) için; orta düzeyde (0,23–0,26) ağırlık, genişlik, hacim ve yüzey-hacim indeksi için; en düşük ise uzunluk (0,15) ve şekil indeksi (0,08) için tahmin edilmiştir. Ortak çevre etkilerine (c^2) ait tahminler 0,23 ile 0,43 arasında değişmiş olup, en yüksek varyans payı yüzey-hacim indeksi ve yoğunlukta (0,38) gözlenmiştir. Kısmi korelasyonlar, ağırlık ile uzunluk (r=0,75), genişlik (r=0,85), hacim (r=0,93) ve yüzey alanı (r=0,93) arasında güçlü pozitif ilişkiler olduğunu, şekil indeksinin ise yüzey-hacim indeksi ile neredeyse mükemmel negatif kısmi korelasyona sahip olduğunu (r=−0,99) ortaya koymuştur; ayrıca, yoğunluk, hacim (r=−0,25) ve yüzey-hacim indeksi (r=−0,05) ile zayıf ancak anlamlı negatif kısmi korelasyonlar göstermiştir. Bu bulgular, farklı özellikler için beklenen seleksiyon etkinliği açısından önemli olup, ıslah programlarında güvenilirlik ve uygulanabilirliği artıracak şekilde daha geniş veri setleriyle desteklenmesi büyük katkı sağlayacaktır.

Anahtar Kelimeler: Mavi-Göğüslü Bıldırcın, Yumurta Özellikleri, Kalıtım Derecesi, Eklemeli Genetik Etkiler, Ortak Çevre Etkileri

ESTIMATION OF HERITABILITY AND COMMON ENVIRONMENTAL EFFECTS OF EGG TRAITS IN THE BLUE-BREASTED QUAIL *(synoicus chinensis)*

ABSTRACT

The blue-breasted quail (Synoicus chinensis), owing to its small body size and rapid reproductive cycle, represents a suitable model for the genetic analysis of egg traits. Egg weight, length, width, and other traits derived from these measurements are of critical importance for both embryonic development and the success of genetic improvement programs. This study aimed to estimate heritability and common environmental effects for measured and derived egg traits in blue-breasted quail. A total of 6,602 individual records of egg weight, length, and width were collected from 104 female quails between 49 and 402 days of age. Derived traits included shape index, volume, surface area, density, and surface-volume index. Variance components for additive genetic, common environmental, and residual effects were obtained using Bayesian univariate animal models, with generation, incubation, year, month, and age fitted as fixed effects. Heritability (h^2) estimates were highest for surface-volume index (0.54) and density (0.47), moderate (0.23–0.26) for weight, width, volume, and surface area, and lowest for length (0.15) and shape index (0.08). Estimates of common environmental effects (c^2) varied between 0.23 and 0.43, with the largest contributions observed for surface-volume index and density (0.38). Partial correlations indicated markedly strong positive relationships of weight with length (r=0.75), width (r=0.85), volume (r=0.93), and surface area (r=0.93), while shape index showed an almost perfect negative partial correlation with the surface-volume index (r=−0.99); additionally, density exhibited weak but significant negative partial correlations with volume (r=−0.25) and surface-volume index (r=−0.05). These findings are important for the expected selection efficiency of different traits and will substantially contribute to enhancing the reliability and applicability of breeding programs when supported by larger datasets.

Keywords: Blue-Breasted Quail, Egg Traits, Heritability, Additive Genetic Effects, Common Environmental Effects

IDENTIFICATION OF PROMISING GENOTYPES AMONG THE WILD PISTACHIO *(Pistacia vera l.)* POPULATION GROWING IN KAZAK UULU VILLAGE OF OSH PROVINCE IN KYRGYZSTAN

Instr. Dr. Mederbek Zhaanbaev

Faculty of Agriculture, Kyrgyz-Turkish Manas University, KYRGYZSTAN

Email: mederbek.zhaanbaev@manas.edu.kg

ORCID: 0000-0001-5123-4358

ABSTRACT

There are 11 species in the genus Pistacia. Of these species, Pistacia vera is the only one with edible nuts and economic significance. In Kyrgyzstan, only the Pistacia vera L. species of the Pistacia genus grows naturally on an area of more than 30,000 hectares. Kyrgyzstan's rich genetic diversity provides substantial opportunities for the development of new pistachio cultivars in terms of quality, production, and resistance to pests, diseases, and drought. This study was conducted between 2021 and 2025 in a pistachio orchard near the village of Kazak uulu in the Kara-Suu district of Osh province, Kyrgyzstan, where pistachios were grown from seed without grafting. In the study, 24 trees with large fruit and high cracking rates were selected, and fruit samples were collected in 2021 and 2024 based on periodicity. The collected samples underwent pomological measurements under laboratory conditions. According to the average values of the two years, length was 15.14-18.16 mm, width 8.80-11.21 mm, thickness 7.01-10.89 mm and shell thickness 0.62-1.43 mm. Nut weight ranged between 0.52-0.92 g, while kernel weight ranged between 0.26-0.41 g. Additionally, the splitting rate, which is a very important characteristic of pistachios, ranges from 0.00% to 28.90%, while the kernel rate varies between 35.79-50.74%. As a result of the weighted evaluation, four types of pistachios (K-U 7, K-U 8, K-U 9, K-U 10) received high scores and were determined to be promising. Further phenological measurements were made in the spring of 2025, and it was established that type K-U 9 flowered the later of the different types.

Keywords: Pistacia vera L., Wild pistachio, Selection, Kyrgyzstan

KIRGIZİSTAN'IN OŞ İLİ, ÖZGEN İLÇESİNDE DOĞAL OLARAK YETİŞEN ALIÇLARIN (*crataegus spp.*) BAZI MEYVE ÖZELLİKLERİ

Öğr. Gör. Dr. Mederbek ZHAANBAEV*

Kırgızistan-Türkiye Manas Üniversitesi, Ziraat Fakültesi, Kırgızistan

Email: mederbek.zhaanbaev@manas.edu.kg,

ORCID: 0000-0001-5123-4358

Aibiike BORUBAEVA

Kırgızistan-Türkiye Manas Üniversitesi, Ziraat Fakültesi, Kırgızistan

Email: alibekovnaibiike@gmail.com

ORCID: 0009-0001-6994-7169

ÖZET

Bu araştırma 2024-2025 yıllar arasında Kırgızistan'ın Oş iline bağlı Özgen ilçesinde kurak ve yarı-kurak koşullarda doğal olarak yetişen bazı alıç türlerinde verimli ve iri meyveli tipleri seçmek amacıyla gerçekleştirilmiştir. Yürütülen bu çalışmada 500 civarında ağaç gözden geçirilmiştir ve onların içerisinden 5'i sarı 8'i ise kırmızı renkli meyveye sahip toplamda 13 alıç tipinden meyve örnekleri toplanmıştır. Alınan meyve örnekleri laboratuvara getirilerek ölçümler yapılmıştır. Çalışmada meyve ve çekirdek ağırlığı (g), meyve eni ve meyve boyu (mm), 100 dane meyve ağırlığı, meyve et oranı (%), meyve şekil indeksi, sap uzunluğu (mm), sap kalınlığı (mm), çekirdek sayısı (adet), meyvenin dış ve iç renk özellikleri (L*, a*, b*) incelenmiştir. Ayrıca, bu tiplerde tomurcuk kabarma ve tomurcuk patlama tarihi, ilk çiçeklenme gibi fenolojik özellikler de incelenmiştir. Sonuç olarak tiplerinin meyve ağırlığı 0.69-5.61 g, meyve boyu 10.23-23.88 mm, meyve eni 10.92- 21.49 mm, çekirdek sayısı 1-2.5 adet, çekirdek ağırlığı 0.15-0.97 g, 100 dane meyve ağırlığı 56-556 g, meyve et oranı %63.76-88.44, meyve şekil indeksi 0.94-1.12 arasında değişim göstermiştir. Sap uzunluğu 9.34-16.38 mm, sap kalınlığı 0.44-0.69 mm, dış meyve rengi L, a, b değerleri sırasıyla 13.22-59.62, 15.21-32.55, 5.09-40.88, iç meyve rengi L, a, b değerleri sırasıyla 15.88-44.06, 3.87-21.51, 2.43-26.12 arasında değişim gösterdiği tespit edilmiştir. Meyve özellikleri bakımından Tip-13 diğer tiplere kıyasla daha üstün özelliklere sahip olduğu belirlenmiştir. Özgen iklim şartlarında sarı meyve rengine sahip alıçların kırmızı meyvelilerden yaklaşık 10 gün geç uyandığı tespit edilmiştir. Sonuçlardaki geniş varyasyonun sebebi meyve örneklerinin farklı alıç türlerinden toplanmasından kaynaklı olduğu düşünülmektedir ve bu alanın daha detaylı araştırmaların yapılması önerilmektedir.

Anahtar kelimeler: Kırgızistan, Alıç, Crataegus spp., Pomoloji

SOME FRUIT CHARACTERISTICS OF NATURALLY GROWN HAWTHORNS (*crataegus spp.)* IN UZGEN DISTRICT, OSH REGION, KYRGYZSTAN.

Mederbek Zhaanbaev

Aibiike Borubaeva

ABSTRACT

This research was conducted between 2024 and 2025 in the Uzgen District of Osh Region, Kyrgyzstan, under arid and semi-arid conditions, with the aim of selecting high-yielding and large-fruited types among naturally growing hawthorn (Crataegus spp.) species. Approximately 500 trees were surveyed during the study, and a total of 13 hawthorn types were selected, with 5 having yellow and 8 having red fruit color, from which fruit samples were collected. The collected fruit samples were brought to the laboratory for measurements. The characteristics examined in this study included fruit weight and seed weight (g), fruit width and fruit length (mm), 100-fruit weight (g), fruit flesh ratio (%), fruit shape index, pedicel length (mm), pedicel thickness (mm), number of seeds (count), and the external and internal color characteristics (L^*, a^*, b^*) of the fruit. Furthermore, phenological characteristics such as bud swell, bud burst dates, and the date of first flowering were also investigated for these types. The results showed that fruit weight ranged from 0.69 to 5.61 g, fruit length from 10.23 to 23.88 mm, fruit width from 10.92 to 21.49 mm, seed count from 1 to 2.5, seed weight from 0.15 to 0.97 g, 100-fruit weight from 56 to 556 g, fruit flesh ratio from 63.76% to 88.44%, and fruit shape index from 0.94 to 1.12. Pedicel length varied between 9.34 and 16.38 mm, pedicel thickness between 0.44 and 0.69 mm. The external fruit color L, a, b values ranged from 13.22–59.62, 15.21–32.55, and 5.09–40.88, respectively, while the internal fruit color L, a, b values ranged from 15.88–44.06, 3.87–21.51, and 2.43–26.12, respectively. In terms of fruit characteristics, Type-13 was identified as having superior traits compared to the other types. It was determined that yellow-fruited hawthorns in the climate conditions of Uzgen wake up approximately 10 days later than the red-fruited ones. The wide variation observed in the results is thought to be due to the fruit samples being collected from different Crataegus species, and more detailed research in this area is recommended.

Keywords: Kyrgyzstan, Hawthorn, Crataegus spp., Pomology

GENETIC DIVERSITY FOR AGRONOMIC TRAITS IN A MEDITERRANEAN LENTIL COLLECTION: TOWARDS THE DEVELOPMENT OF HIGH YIELDING CLIMATE-CHANGE READY CULTIVARS

Adelmonim Zeroual

Laboratory of Food Legumes Breeding, Regional Center of Agricultural Research of Settat, National Institute of Agricultural Research, Avenue Ennasr, BP 415 Rabat Principale, Rabat 10090, Morocco

Email: Abdelmonimzeroual@gmail.com

ORCID: 0000-0003-3028-5468

Mohammed Mitache

Laboratory of Food Legumes Breeding, Regional Center of Agricultural Research of Settat, National Institute of Agricultural Research, Avenue Ennasr, BP 415 Rabat Principale, Rabat 10090, Morocco

Bacar Abdallah Abderemane

Laboratory of Food Legumes Breeding, Regional Center of Agricultural Research of Settat, National Institute of Agricultural Research, Avenue Ennasr, BP 415 Rabat Principale, Rabat 10090, Morocco

Aziz Baidani

Laboratory of Laboratory of Agrifood and Health, Faculty of Sciences and Techniques, Hassan First University of Settat, BP 577, Settat 26000, Morocco

Omar Idrissi

Laboratory of Food Legumes Breeding, Regional Center of Agricultural Research of Settat, National Institute of Agricultural Research, Avenue Ennasr, BP 415 Rabat Principale, Rabat 10090, Morocco

ABSTRACT

Lentil is an essential legume crop in the Mediterranean region, valued for its nutritional benefits and role in sustainable agriculture. However, climate change, particularly increasing drought and heat stress, poses significant challenges to its productivity. This study aimed to assess genetic variation for key agronomic traits in a Mediterranean lentil collection and identify promising genotypes for breeding climate-resilient cultivars. A total of 120 accessions—comprising improved varieties, landraces, local cultivars, and advanced breeding lines—were evaluated under conventional and no-till tillage systems. Agronomic traits including days to 50% flowering, grain yield, and 100-seed weight were recorded. Significant genetic variation was observed across accessions. High heritability estimates were obtained for flowering time (89.76%) and 100-seed weight (85.49%) under conventional tillage, and for 100-seed weight (73.61%) and grain yield (67.36%) under no-till. Several genotypes showed superior performance across systems, representing valuable material for breeding high-yielding, climate-adapted lentil cultivars for Mediterranean environments.

Keywords: Lentil, climate change, conservation agriculture, drought stress, heat stress, genetic variability.

EVALUATION OF LENTIL GENOTYPES FOR MECHANICAL HARVESTING SUITABILITY

Adelmonim Zeroual

Laboratory of Food Legumes Breeding, Regional Center of Agricultural Research of Settat, National Institute of Agricultural Research, Rabat 10090, Morocco

Email: Abdelmonimzeroual@gmail.com

ORCID: 0000-0003-3028-5468

Aziz Baidani

Laboratory of Laboratory of Agrifood and Health, Faculty of Sciences and Techniques, Hassan First University of Settat, Morocco

Bacar Abdallah Abderemane

Laboratory of Food Legumes Breeding, Regional Center of Agricultural Research of Settat, National Institute of Agricultural Research, Morocco

Mohammed Mitache

Laboratory of Food Legumes Breeding, Regional Center of Agricultural Research of Settat, National Institute of Agricultural Research, Morocco

Omar Idrissi

Laboratory of Food Legumes Breeding, Regional Center of Agricultural Research of Settat, National Institute of Agricultural Research, Morocco

Email: Omar.idrissi@inra.ma; ORCID: 0000-0002-9706-7388

ABSTRACT

Lentil is a nutritionally-rich staple crop that provides high-quality protein (20–35 g/100 g), slowly digestible carbohydrates, and essential micronutrients. It is naturally low in fat and rich in lysine, with moderate levels of methionine and cysteine, making it a valuable protein source in plant-based diets. Additionally, lentil contributes to sustainable agriculture through its capacity to fix atmospheric nitrogen in symbiosis with rhizobia, reducing dependence on synthetic nitrogen fertilizers.

Despite its nutritional and agro-ecological benefits, lentil production remains limited by several challenges. In many lentil-producing countries, the lack of varieties suitable for mechanical harvesting increases labor costs and reduces profitability. Lodging, a major constraint to mechanization, is particularly problematic. Breeding for lodging resistance and other traits that facilitate mechanical harvesting is essential for improving productivity and reducing production costs.

In this study, 50 lentil genotypes were evaluated across diverse Moroccan environments for lodging resistance and agro-morphological traits. Significant genotypic variation was observed, and high heritability was recorded for lodging resistance (70%), indicating strong potential for genetic improvement. Several promising genotypes suitable for mechanical harvesting were identified, offering valuable options to enhance lentil production and profitability in systems currently dependent on manual harvesting.

Keywords: Lentil, lodging resistance, mechanical harvesting, genetic variability.

CONNECTING ADVANCED MATHEMATICAL APPLICATIONS FOR TRANSFORMING CONTEMPORARY AGRICULTURE THROUGH PRECISION, PREDICTION, AND SUSTAINABILITY

Dr. S. Kalaiselvan[1*], G. Janaki[2], R. Suganya[3], G. Kowsalya[4] & R.Sumathi[5]

[2,3,4,5]Assistant Professor, Department Mathematics, Rathinam Technical Campus, Coimbatore, Tamilnadu, India

[1*]Associate Professor, Department of Chemistry, Rathinam Technical Campus, Coimbatore, Tamilnadu, India

[*]Corresponding Author: kalaichem82@gmail.com,

ABSTRACT

Advanced mathematical applications have become integral to modern agriculture, driving efficiency, sustainability, and data-driven decision-making. Mathematical modeling, statistical analysis, and computational simulations are used to optimize crop growth, irrigation scheduling, pest control, and nutrient management. Predictive algorithms enable accurate forecasting of weather patterns, soil moisture dynamics, and crop yield, supporting precision farming practices. Differential equations and optimization models assist in understanding plant–environment interactions and resource allocation. Furthermore, machine learning–integrated mathematical frameworks enhance disease prediction and real-time monitoring through sensor and satellite data analysis. These quantitative approaches contribute to minimizing waste, improving productivity, and ensuring environmental sustainability. The convergence of mathematics, agronomy, and technology is reshaping agriculture into a more predictive and adaptive science, ensuring food security and efficient resource utilization in the face of global challenges.

Keywords:
Mathematical modeling, Precision agriculture, Crop yield prediction, Optimization, Computational simulation, Predictive analytics, Resource management, Sustainable farming, Agrometeorology, Data-driven agriculture.

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LIFE TABLE CONSTRUCTION AND ANALYSIS FOR EVALUATING BIO-CONTROL AGENTS

Gunasekar G

Ph. D Scholar, Department of Agricultural Entomology

Tamil Nadu Agricultural University

ORCID: 0009-0007-2566-8348

Email: gunaselanbschonorsagri07@gmail.com[1]

ABSTRACT

Life table construction and analysis is a fundamental demographic technique used in applied ecology to rigorously evaluate the efficacy and ecological fitness of biological control agents (BCAs). The method involves meticulously tracking the age-specific survival (lx) and age-specific fecundity (mx) of a BCA population, typically a parasitoid or predator, under controlled or semi-field conditions. From these raw data, researchers calculate key demographic parameters crucial for predicting biocontrol success: the Net Reproductive Rate (R0), which indicates the potential for population growth; the Generation Time (T); and, most importantly, the Intrinsic Rate of Increase (rm). The rm is the most robust measure of an agent's performance, summarizing its ability to increase its population size per unit of time. A higher rm suggests a more promising candidate for successful field establishment and pest suppression. This quantitative approach is invaluable for selecting the best BCA species or strain, determining optimal mass-rearing conditions, assessing potential non-target impacts, and providing solid parameters for predictive population dynamics models, ultimately serving as the scientific backbone for effective Integrated Pest Management (IPM) programs.

Keywords: Life table, biocontrol, net reproductive rate, population

REVEALING THE THERAPEUTIC VALUE OF BIODEGRADABLE CELLULOSE FIBERS: NOVEL DEVELOPMENTS AND STRATEGIES IN SKIN TISSUE REGENERATION

Jatin Vats, Ajesh Chauhan*, Chetan Vashisht

Author of Correspondence- Ajesh Chauhan, Assistant Professor, Hindu College of Pharmacy Sonepat, Haryana, India

Email: ajeshchauhan1996@gmail.com

ABSTRACT

Biodegradable cellulose has garnered significant attention in the past several years since it has its exceptional attributes, including hydrophilicity, mechanical durability, degradability, biocompatibility, availability, and low cytotoxicity. Biodegradable cellulose (BC), a cellulose obtained from biodegradable sources, is a versatile biomaterial with considerable potential in tissue regeneration, owing to its favourable mechanical properties, enhanced hydrophilicity, crystallinity, and integrity of structure. Tissue regeneration is a multiple disciplines domain focused on the repair, augmentation, and substitution of damaged tissues. The objective is to reinstate the inherent useful characteristics of the cellular tissues by the integration of scaffolds, viable cells, and growth factors. The rising desire for efficient repairing damaged tissue has led to a notable surge in interest in tissue regeneration techniques for both flexible and stiff cellular tissues during the last two decades. Skin tissue regeneration is a critical field that facilitates the repair of skin abnormalities utilizing scaffolds. This study examines current studies designed to evaluate and investigate the possible uses of cellulose and its derived substances in tissue biological regeneration. The current paper examines the tissue regeneration technique, the therapeutic management of various skin abnormalities, and the experiences of tissue regeneration in several organ components alongside the application of biodegradable cellulose. The conclusion here focused on biodegradable cellulose-based polymer suitable for tissue regeneration and repair.

Keywords: Biodegradable cellulose, Hydrophilicity, Biocompatibility, Tissue regeneration, Polymer, Crystallinity.

NUTRITIONALLY OPTIMIZED BABY FOOD FROM INDIGENOUS INGREDIENTS: SAFETY, FUNCTIONALITY, AND ACCEPTABILITY FOR SUSTAINABLE INFANT NUTRITION

Shoumen Dhar[1], Bappy Chowdhury[1], Mehenaj Musa[2], Abdur Rahman[3], Mahima Ranjan Acharjee[4*], Sreebash Chandra Bhattacharjee[5]

[1] Department of Applied Food Science and Nutrition, Faculty of Food Science and Technology, Chattogram Veterinary and Animal Sciences University, Chattogram 4225, Bangladesh

[2] Department of Physiology, Biochemistry, and Pharmacology, Chattogram Veterinary and Animal Sciences University, Chattogram 4225, Bangladesh

[3] One Health Institute, Chattogram Veterinary and Animal Sciences University, Chattogram 4225, Bangladesh

[4] Department of Aquaculture, Faculty of Fisheries, Chattogram Veterinary and Animal Sciences University, Chattogram 4225, Bangladesh

[5] BCSIR Chattogram Laboratories, Chattogram- 4220

*Email: shoumen1600@my.cvasu.ac.bd

N.B.: Author 1 and 2 are Contributed Equally

ABSTRACT

In low-income countries like Bangladesh, malnutrition remains a significant challenge for infants, as conventional foods often fail to meet their nutritional needs after six months of age. This study developed and assessed three baby food formulations (F1, F2, F3) containing indigenous raw materials- broken rice, carrot, soybean, peanuts, cowpea, and skim milk powder to confront this issue. The proximate analysis demonstrated F2 as the most nutrient-dense, with 19.92± 1.58 %protein and 9.01 ± 0.10 % fat, while F3 delivered the highest carbohydrate content 63.55 ± 1.79 % for energy. Furthermore, based on the minerals and vitamins profiles of the formulations, F2 contained elevated level of iron (4.86 ± 0.03 mg/100 g), calcium (270.26 ± 0.03 mg/100 g), and vitamin A (0.92 ± 0.02 mg/100 g) which are essential for resisting deficiencies and supporting immune and skeletal health. Additionally, the absence of heavy metal in the formulations, ensuring the safety for consumption. Moreover,functional tests indicated F2's superior water absorption (3.27 ± 0.06 g/g) and viscosity (2103.33 ± 5.77 cP), increasing feeding suitability, whereas F3 scored highest in sensory appeal (overall acceptability: 8.5/9). Microbial stability was confirmed respectively, remaining within permissible limits, while no coliforms, *Salmonella* spp., and*Listeria monocytogenes* were detected in any formulation.These findings contribute to tackling infant malnutrition in low-resource settings and support global nutrition initiatives. Overall, this approach offers a promising strategy for improving infant nutrition and reducing the burden of malnutrition in vulnerable populations.

Keyword: Infant Nutrition, Malnutrition, Baby Food Formulation, Sustainable Nutrition, Indigenous Raw Materials, Low-Income Countries.

ARTIFICIAL INTELLIGENCE AND NATIONAL ECONOMIC GROWTH: EXPLORING THE ROLE OF STEM EDUCATION IN WORKFORCE TRANSFORMATION IN NIGERIA.

Bruno, Ibeabuchı Anwurı, Gbara, Uloma Celestıne, & Ogunbayo, Oluwatoyın Glory.

1&3. Department of Biology education, Federal College of Education (Technical) Omoku ,
2, Department of Mathematics education , Federal College of Education (Technical)Omoku.

Email address: anwuribruno@gmail.com

ABSTRACT

Artificial Intelligence (AI) is rapidly transforming global economies, reshaping labor markets, and redefining national competitiveness. Nations that strategically integrate AI into Science, Technology, Engineering, and Mathematics (STEM) education systems are better positioned to foster innovation, create jobs, and achieve sustainable economic growth. In Nigeria, where unemployment and underemployment remain persistent challenges, AI adoption represents a potential pathway to economic diversification and workforce transformation. However, the country faces significant barriers, including weak STEM curricula, inadequate infrastructure, limited AI literacy, and poor industry-academia collaboration.

This study investigates the relationship between AI adoption, STEM education, and economic growth in Nigeria using an empirical approach. The objectives were to: (1) examine how AI adoption influences economic growth through STEM-driven sectors, (2) evaluate the role of STEM education in preparing Nigeria's workforce for AI-driven transformations, and (3) analyze the challenges and opportunities of integrating AI into STEM education for sustainable development. Three research questions guided the study, with statistical analysis conducted using descriptive and inferential methods to assess the relationship between variables.

Findings reveal that AI adoption significantly contributes to national productivity in agriculture, healthcare, and manufacturing, with a reported increase of up to **25% in sectoral efficiency** when combined with STEM-driven innovations. The study also finds that Nigeria's current STEM education framework remains insufficient in preparing graduates for AI-related labor markets, leading to skill mismatches and heightened unemployment. Nevertheless, opportunities exist in policy reforms, teacher retraining, digital literacy programs, and investment in research and development to strengthen the AI-STEM nexus.

The study concludes that AI adoption, when strategically aligned with STEM education, has the potential to transform Nigeria's workforce and accelerate economic growth. Recommendations include strengthening STEM curricula with AI components, fostering industry-academia partnerships, and implementing targeted government policies to support AI-driven innovation. By addressing these gaps, Nigeria can harness AI not only as a technological tool but also as an engine for sustainable national development.

Keywords: Artificial Intelligence, STEM Education, Economic Growth, Workforce Transformation, Nigeria

LEAF STRUCTURAL AND FUNCTIONAL MODIFICATION OF *IPOMOEA CARNEA* JACQ. AN INVASIVE PLANT SPECIES, UNDER DIVERSE SALINITY GRADIENT

Saira Malik[1], Syed Mohsan Raza Shah[1], Uniza Fatima bukhari[1], Tasawar Fatima bukhari[1], Iqra

[1]Department of Botany, Division of Science and Technology, University of Education, Lahore, Pakistan

*authors e-mails: Sairamalik.dgk12@gmail.com

ABSTRACT

The role of structural and functional plasticity of *Ipomoea carnea* for invasion in diverse saline environments was investigated. The populations were collected from 30 different habitats of Pakistan. The populations were divided into 3 groups based on the extent of salinity in their natural habitat. The non-saline habitats (ECe>4 dS m^{-1}) were Kohala, Islamabad, Pahari Nala, Pir Kot, Nerian Sharif, Daska, Dhir Kot, Namal, Lower Jhelum and Majuhan. Moderately saline habitats (ECe 4-8 dS m^{-1}) were Mong Depo, Pasrur, Layyah, Mana Wala, Phularwan Roadside, Kharian Wala, Phulrwan canal, Rasool, Puran and Shah Kot. Highly saline habitats (<8 dS m^{-1}) included Gunjal, Gutwala, Skindar Pura, Choa Sadien Shah, Phid, Buchal, Kallar Kahar, Cholistan Desert, Sangla Hills and Sahian Wala. The hyper-saline population accumulated more compatible solutes like total soluble sugars, phenolics and flavonoids linked to osmoprotection. Increased sclerifcation and phloem thickness in hyper-saline and moderately saline populations. Increased density of trichomes and salt excretory glands prevented water loss and excreted toxic ions through leaf surface. In conclusion, *I. carnea* populations adopted different strategies like water conservation via water storage in parenchymatous tissues, accumulation of compatible solutes (total soluble sugars) and allelochemicals (flavonoids and phenolics) for chemical defense. All these aspects were key factors for survival and invasive success in a variety of habitat types and environmental conditions.

Keywords: Environmental heterogeneity, Invasive species, *Ipomoea carnea*, Sclerifcation, Trichomes.

MULTIPLEX PATHOGENIC BACTERIA DETECTION IN MILK WITH THE NANOPARTICLE-ASSISTED POROUS SILICON-BASED SERS MICROARRAY BIOSENSOR

Giorgi Shtenberg

Institute of Agricultural Engineering, ARO, Volcani Institute, Rishon LeZion, Israel

Email: giorgi@agri.gov.il

ORCID: 0000-0003-1234-1104

Divagar Muthukumar

Institute of Agricultural Engineering, ARO, Volcani Institute, Rishon LeZion, Israel

Email: divagar.ooty@gmail.com

ORCID: 0000-0001-5682-4488

ABSTRACT

The ongoing threat of milk-related pathogens poses a substantial risk to human health, necessitating the development of efficient detection methods. This study explores the creation of a SERS-based multiplex biosensor to meet the demand for simultaneous detection of multiple pathogens, thereby reducing measurement time and enhancing food safety. The biosensor utilizes an indirect immunoassay, leveraging gold nanoparticles as selective Raman reporters and a silver nanoparticle-modified porous silicon microarray (Ag-pSi) as the SERS substrate. In the initial phase, experiments focused on optimizing physical parameters and conditions, leading to the successful construction of an assay capable of detecting bacterial cells, specifically E. coli, S. aureus, and B. cereus, within the concentration range of log 1 to log 5 CFU/mL, with detection limits of 5 CFU/mL, respectively. The assay's selectivity was validated through experiments involving common interfering pathogens. Subsequently, the developed assay was applied to detect specified bacterial cells spiked in various milk qualities and presented recovery values ranging from 85% to 105%. Notably, the overall assay timing was maintained under 90 minutes. These findings underscore the efficacy of the multiplex detection approach for bacterial pathogens in diverse samples, representing a significant advancement toward the realization of a portable SERS biosensor.

Keywords: Multiplex bacteria detection; SERS biosensor; foodborne pathogen; food safety

POSSIBLE PERSPECTIVES OF EUROPEAN UNION POLICIES ON THE DEVELOPMENT OF THE AGRICULTURAL SECTOR

Voroneanu-Popa Rareș-Vasile

Grigore T. Popa University of Medicine and Pharmacy of Iași

Richard Constantinescu

Grigore T. Popa University of Medicine and Pharmacy of Iași

ABSTRACT

The agricultural sector represents an area of major interest for the European Union. In recent years, a series of comprehensive plans have been designed with the aim of increasing production within the agricultural sphere. Moreover, programs such as the “Green Deal–driven CAP” and the “Recalibrated CAP” establish important frameworks for the sustainable development of agriculture.

In addition, a significant number of citizens within the European Community are actively engaged in agricultural work on a daily basis. Consequently, this sector constitutes a vital pillar for ensuring the material well-being of the population.

Other strategies proposed by the European Union are grounded in key priorities such as biodiversity, the preservation of natural ecosystems, and soil health. Likewise, specific agreements and frameworks have been introduced to monitor soil quality and to manage contaminated sites in an efficient and sustainable manner.

ARTIFICIAL INTELLIGENCE FOR INDIVIDUALIZED REMEDIATION OF MISCONCEPTIONS IN BIOLOGY CONCEP

Bruno, Ibeabuchi Anwuri, Ogunbayo, Oluwatoyin Glory, Oreke, Obusor Happiness, & Ajıe, Uloma Glory.

Department of Biology Education, Federal College of Education (Technical) Omoku, Rivers State, Nigeria.

Email: anwuribruno@gmail.com, orekehappiness@gmail.com, Wilsonglory18@gmail.com

ABSTRACT

Persistent misconceptions remain a major barrier to effective learning in biology education. Traditional teaching approaches often fail to address these misconceptions, leading to poor conceptual understanding and performance. This study investigates the role of Artificial Intelligence (AI) in individualized remediation of biology misconceptions among secondary school students. A quasi-experimental design was adopted using 120 Senior Secondary II students in Rivers State, Nigeria, divided into experimental and control groups. Data were collected using the Biology Misconception Diagnostic Test (BMDT) and analyzed with descriptive and inferential statistics. Findings revealed that AI-powered interventions significantly improved students' conceptual understanding ($p < 0.05$) compared to conventional instruction. Teachers and students also perceived AI as effective for individualized learning support. The study recommends integrating AI-based tools into biology education, enhancing teacher training in AI applications, and investing in AI infrastructure for schools.

Keywords: Artificial Intelligence, biology education, misconceptions, individualized learning, remediation

PLANT SEEDLING IDENTIFICATION USING PRETRAINED DEEP TRANSFER LEARNING MODELS

Anandhavalli Muniasamy

Department of Informatics and Computer Systems

College of Computer Science, King Khalid University, Saudi Arabia

Email: anandhavalli.dr@gmail.com

ABSTRACT

For biodiversity conservation, it is highly important to define plant seedlings accurately. Additionally, traditional methods for the identification of plant seedlings are relatively complicated, time-consuming, and error prone. Consequently, one should address these problems and present automatic identification methodologies based on deep-learning techniques to enhance recognition precision and efficiency. This study mainly focused on the effective identification of various plan seedlings using the various CNN based transfer learning models—including SqueezeNet, EfficientNetB0, ResNet50, InceptionV3, and MobileNetV2. This study employed a systematic approach to detect and categorize plant seedlings. The dataset was initially loaded, and thereafter, preprocessing was conducted to eliminate noisy data. Data augmentation then was used to improve model accuracy. Five pretrained models were utilized to train the CNN model, taking advantage of their learning capabilities, and subsequently. The support vector machine (SVM) has been utilized to extract only the pertinent information for the subsequent classification of plant seedlings. The EfficientNetB0 CNN model achieved a very good accuracy of 99.9%.

Keywords: Plant Seedling, SqueezeNet, EfficientNetB0, ResNet50, InceptionV3, MobileNetV2.

FLOOD VULNERABILITY AND ITS IMPACTS ON AGRICULTURAL SYSTEMS, LIVESTOCK, AND RURAL DEVELOPMENT: A COMPREHENSIVE REVIEW

Shehu, N. M., Zakari, N., Kabir I. A. Shehu, A. U.

Department of Environmental Sciences

Federal University, Dutse Jigawa State, Nigeria

Email: otels445@gmail.com, nurudeen.s@fud.edu.ng

ABSTRACT

Flood Vulnerability and its Impacts on Agricultural Systems, Livestock, and Rural Development: A Comprehensive Review Abstract Flooding poses a catastrophic threat not just to urban centers but profoundly to the backbone of many economies: the agricultural sector and rural communities. This literature review synthesizes current research on flood vulnerability, recasting its implications specifically for agriculture, animal science, and rural development. It explores how floods devastate crops, endanger livestock, and erode the livelihoods of rural populations, thereby undermining food security and sustainable development. The review highlights integrated assessment methodologies, including Geographic Information Systems (GIS) and multi-criteria decision-making, as vital tools for identifying vulnerable agricultural zones and rural systems. The findings emphasized the urgent need for adaptive, climate-resilient farming practices, robust veterinary infrastructure, and rural development policies that prioritize flood risk management to safeguard food systems and strengthen community resilience.

Keywords: Flood vulnerability, Agriculture, Livestock, Rural Development

CHEMICAL ANALYSIS OF ATMOSPHERIC DUST AROUND THE KISHNICA AREA IN THE MUNICIPALITY OF GRACANICA

Prof. Assoc. Skender Demaku

Msc. Muhamet Kiqina

Msc. Arbnorë Aliu

Msc. Donika Sylejmani

Faculty of Natural and Mathematical Science, University of Prishtina "Hasan Prishtina"
Department of Chemistry and Biology, Prishtina -Kosovo

ABSTRACT

Kosovo is a very specific country, geographically, surrounded by all sides with the range, which is fundamentally protected, however, from The influence of the global climate, but in fact, how can this be defined when in many cases we encounter Pristina, as a city that has the primate. In the world, of the day-to-day pollution of the environment, what is it that causes all this contamination, with a weak economy, why all this contamination, we have them, they are too weak filters (or have not installed them at all), then old vehicles, forest cutting, lakes contamination, Above all, our awareness of a clean environment is lacking, almost `will be ours. Therefore, in this project, we will present our findings, based on Chemical analysis, in the cities; Prishtina, Gracanica, the cities considered as the most polluted, therefore, the impact on the health of residents and many other environmental impacts, in the areas analyzed will bring a realistic picture of environmental pollution, a perimeter of approximately 30km, including a triangle of the three cities analyzed.

Keywords: Heavy metals; Air, Cars, Households, Thermal power plants

SYNTHESIZING ENTREPRENEURIAL STEM EDUCATION: A REVIEW OF THEORETICAL FOUNDATIONS, PEDAGOGICAL PRACTICES, AND FUTURE DIRECTIONS

R.Thıruchelvı

Bıology Teacher, Vels Vıdhyalaya School, Indıa

Email: thiruchelvi13892gmail.com

ORCID: 0000-0001-5532-8597

ABSTRACT

This review article synthesizes current research and discourse on Entrepreneurial STEM (E-STEM) education, a burgeoning field that integrates entrepreneurial mindsets and capabilities into Science, Technology, Engineering, and Mathematics learning. Drawing from a special issue editorial that outlines the field's conceptual landscape and an empirical study investigating skill development in students, this paper examines the core tenets of E-STEM. We explore the foundational concepts of values and risk as central to the entrepreneurial dimension, arguing that E-STEM moves beyond utilitarian economics to foster broad human capabilities. The review highlights key entrepreneurial frameworks, such as the QAA guidelines and the EntreComp model, which outline skills, behaviors, and competencies like resourcefulness, problem-solving, resilience, and strategic thinking. Empirical evidence demonstrates that while short-term E-STEM interventions can significantly enhance specific sub-skills—such as emotional control, behavioral planning, and a proactive approach to problems—long-term, systemic implementation is crucial for holistic development. The article also addresses critical implementation challenges, including teacher professional development, curriculum design, and strategies for fostering inclusive participation, particularly for women in STEM. We conclude that E-STEM education represents a paradigm shift, positioning STEM not merely as disciplines of knowledge but as a vehicle for developing agile, value-driven individuals capable of navigating and innovating within a complex, risk-filled society. Recommendations for future research and practice are discussed

Keywords: Entrepreneurial STEM Education, Enterprise Capabilities, Problem-Solving, Resourcefulness, Risk Society, Values, Teacher Development, Curriculum Integration

ECOLOGICAL REHABILITATION OF THE ARAL SEA REGION: PHYTOMELIORATION AS A SUSTAINABLE TOOL FOR LAND RESTORATION

Drobchenko N.V.
Samarkand State University of Architecture and Civil Engineering named after Mirzo Ulugbek, Samarkand, Uzbekistan

Email: drobchenko.natalya@samdaqu.edu.uz

ABSTRACT

The Aral Sea region is among the most severely degraded ecological zones in Central Asia, where extensive landscape transformation, water scarcity, and soil salinization have produced profound environmental, social, and economic impacts. The dramatic shrinkage of the Aral Sea has led to the formation of vast areas of dry seabed, accelerating desertification processes, intensifying dust storms, and creating transboundary environmental challenges. These processes have directly affected agricultural productivity, human health, and biodiversity conservation. Under conditions of climate change, the development and implementation of nature-based solutions aimed at restoring degraded landscapes and supporting local livelihoods are becoming increasingly urgent.

The aim of this study is to evaluate and demonstrate the effectiveness of phytomelioration techniques based on native, climate-resilient plant species for soil stabilization, dust reduction, and ecosystem restoration in the Aral Sea region. The research focuses on developing an adaptive ecological rehabilitation model that integrates traditional land management practices with modern environmental technologies.

The methodological framework combines field observations, geobotanical assessments, remote sensing and GIS analysis, and comparative evaluation of sites with different degradation levels. These methods make it possible to track vegetation dynamics, assess soil properties, and identify the most effective species and planting schemes for sustainable restoration of degraded lands.

Expected results include an increase in vegetation cover, improvement of soil quality indicators, reduction of airborne dust emissions, and the establishment of ecological buffer zones that strengthen the region's green infrastructure. These outcomes are expected to contribute to long-term ecological stability, support sustainable agriculture, and enhance climate change adaptation. The findings can be used by policymakers, environmental organizations, and local communities to implement cost-effective and environmentally sound restoration strategies.

Keywords: Aral Sea region, phytomelioration, land degradation, ecosystem restoration, sustainable agriculture, climate adaptation.

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ECG-BASED SLEEP APNEA DETECTION USING CONVOLUTIONAL AND LONG SHORT-TERM MEMORY NETWORKS

Vijayakumaran

EEE dept., Dr. M.G.R. Educational and Research Institute Chennai, India.

Shobana

EEE dept., Dr. M.G.R. Educational and Research Institute

Chennai, India.

K. Sujatha

EEE dept., Dr. M.G.R. Educational and Research Institute

Chennai, India

Tatireddy

Dept. of ECE, Saveetha Institute of Medical and Technical Sciences, India

Omsai Reddy

Dept. of ECE, Saveetha Institute of Medical and Technical Sciences, India

N.P.G. Bhavani

Dept. of ECE, Saveetha Institute of Medical and Technical Sciences, India

ABSTRACT

Sleep apnea, which is one of the most common sleep disorders that can lead to undesirable health outcomes if not treated and requires PSG as a standard diagnostic test forthe diagnosis. Among the physiological parameters monitored by PSG during sleep are brain activity eye movement muscle activities heart rate and airflow. All of this makes it possible to identify apnea periods in sleep, which is a key symptom for sleep apnea diagnosis. Although PSG is acknowledged as a gold standard, there are other research interests in non-invasive diagnostic tools. One of such methods focuses on the possible role as single-signal ECG may play in sleep apnea diagnosis. One of the most important tools for measuring heart activity is ECG, giving useful information on what happens in a human being's heart. The suggested method is the segmentation of ECG signals and then features extraction from them. This means that we might even be able to find sleep apnea markers without the intense long-term PSG monitoring. Lastly, the accuracy of our model at testing phase was determined to be 86.18% that suggests it an easy-to-use and effective diagnostic tool for sleep apnea cases.

***Index Terms*—**Sleep apnea, Convolutional neural network (CNN), Long short-term memory (LSTM), Electrocardiogram (ECG), Deep learning, ECG classification

OFFSHORE BALIK YETİŞTİRİCİLİĞİ MOORİNG HALATLARININ IN-SITU BOZUNMASI: DERİNLİĞE GÖRE PLASTİK SALINIM ORANLARININ ANALİZİ

Doç. Dr. İlhan YANDI

Recep Tayyip Erdoğan Üniversitesi, Turgut Kıran Denizcilik Fakültesi

Email: ilhan.yandi@erdogan.edu.tr

ORCID: 0000-0003-1780-3654

ÖZET

Mevcut araştırmalar, su ürünleri yetiştiriciliğine özgü yüzer halatların sistematik incelenmesi ve özellikle deniz ortamında in-situ koşullar altında plastik salınım oranlarının nicel olarak belirlenmesi konusunda belirgin bir bilgi boşluğunu ortaya koymaktadır. Bu eksiklik, hidrolojik dolaşımın sınırlı olduğu ve dolayısıyla kirleticilerin kalış süresinin uzadığı kapalı veya yarı kapalı deniz sistemleri açısından özellikle önem taşımaktadır. Bu çalışmada, Batı Karadeniz'de yürütülen ve gerçek saha koşullarında polipropilen (PP) ile polietilen (PE) su ürünleri yetiştiriciliği yüzer halatlarının bozunma süreçlerini doğrudan ölçmeyi amaçlayan kapsamlı bir yıllık saha deneyi sunulmaktadır.

Yöntem kapsamında, özenle hazırlanmış halat örnekleri yüzeyden 40 metre derinliğe kadar farklı seviyelere asılmış ve dalga, akıntı ile sıcaklık, tuzluluk ve ışık şiddeti gibi değişken fiziko-kimyasal koşullara on iki ay boyunca maruz bırakılmıştır. Bu süreçte belirli aralıklarla yapılan ayrıntılı ağırlık ölçümleri ile kümülatif kütle kaybı değerlendirilmiştir. Ayrıca, su kolonundaki mevsimsel tabakalaşma değişimlerini izleyen çevresel ölçümler, bozunma oranlarının yorumlanmasına bağlamsal bir temel sağlamıştır.

Elde edilen bulgular, derinliğe bağlı belirgin bir bozunma eğilimine işaret etmektedir: Ağırlık kaybı yüzeyde en yüksek düzeyde gerçekleşmiş (PP için %1,81; PE için %1,73) ve derinlikle birlikte azalarak 30–40 metre aralığında yaklaşık %0,30'a düşmüştür. Bu eğilim, özellikle üst su kolonundaki yüksek sıcaklık, güçlü türbülans ve daha yoğun ışık penetrasyonu ile güçlü biçimde korelasyon göstermektedir. Sonuç olarak, ultraviyole (UV) radyasyonu, mekanik aşınma ve sıcaklık dalgalanmalarının sinerjik etkisinin ilk 10 metreyi yüzer halatlardan mikroplastik üretiminin temel odağı hâline getirdiği ortaya konmuş ve su ürünleri yetiştiriciliği kaynaklı plastik kirliliğinin azaltılmasına yönelik politika ve stratejiler için kritik nicel veriler sağlanmıştır.

Anahtar Kelimeler: Halat Bozunmasi, Kütle Kaybi, Polipropilen (Pp), Polietilen (Pe), Plastic Emisyonu, Uv Radyasyonu, Mekanik Bozunma

IN-SITU DEGRADATION OF OFFSHORE AQUACULTURE MOORING ROPES: A DEPTH-WISE ANALYSIS OF PLASTIC EMISSION RATES

ABSTRACT

The current body of research exhibits a pronounced knowledge gap regarding the systematic study of aquaculture-specific mooring ropes, particularly in quantifying their plastic release rates under true in-situ marine conditions. This shortcoming is especially relevant for enclosed or semi-enclosed marine systems, which are characterized by limited hydrological circulation and, therefore, extended pollutant residence times that can amplify ecological impacts. Addressing this gap, the present study reports on a comprehensive year-long field experiment conducted in the western Black Sea to directly measure the degradation of polypropylene (PP) and polyethylene (PE) aquaculture mooring ropes under real-world operational conditions.

Our methodology involved suspending carefully prepared rope segments at multiple depths ranging from the surface to 40 meters and performing meticulous, periodic weight measurements to determine cumulative loss after 12 months of exposure to natural waves, currents, and variable physicochemical factors such as temperature, salinity, and light intensity. Complementary environmental monitoring captured seasonal changes in water column stratification, providing context for interpreting degradation rates.

The key finding reveals a clear depth-dependent pattern of rope deterioration: weight loss was greatest near the surface (1.81 % for PP and 1.73 % for PE) and declined steadily with depth, reaching a minimum of roughly 0.30 % at 30–40 meters. This trend correlates strongly with environmental parameters, particularly higher temperature, stronger turbulence, and greater light penetration in the upper water column. We conclude that the combined influence of ultraviolet radiation, mechanical abrasion, and fluctuating thermal conditions within the top ten meters creates the primary hotspot for microplastic generation from mooring ropes, offering critical, quantitative evidence to guide mitigation strategies and policy development aimed at reducing plastic pollution in aquaculture operations.

Keywords: Rope Degradation, Weight Loss, Polypropylene (PP), Polyethylene (PE), Plastic Emission, UV Radiation, Mechanical Abrasion

DENEYDEN EKOSİSTEME: KARADENİZ AÇIK DENİZ SU ÜRÜNLERİ YETİŞTİRİCİLİĞİ MOORİNG HALAT SİSTEMLERİNDEN PLASTİK SALINIMININ MAKRO DÜZEYDE BELİRLENMESİ

Doç. Dr. İlhan YANDI

Recep Tayyip Erdoğan Üniversitesi, Turgut Kıran Denizcilik Fakültesi

Email: ilhan.yandi@erdogan.edu.tr

ORCID: 0000-0003-1780-3654

ÖZET

Avrupa Komisyonu'nun son raporları, Karadeniz'in Avrupa'nın kayıt altına alınmış en yüksek yüzer plastik atık yoğunluğuna sahip olduğunu tespit etmekte ve bu durum kritik bir çevre sorununa işaret etmektedir. Bu tespite ve ayrıca Türkiye Karadenizi'ndeki yüzey suları, sedimentler ve yabani deniz organizmalarında mikroplastik kirliliğini değerlendiren çok sayıda çalışmaya rağmen, mevcut araştırmalar bu yaygın kirliliğin belirli bölümlerini henüz net bir şekilde su ürünleri yetiştiriciliğinden kaynaklanan emisyonlara atfedememiştir. Bu sunum, bu nedenle, Türkiye'nin Karadeniz'deki offshore su ürünleri yetiştiricilik sektöründen kaynaklanan toplam plastik kirliliğini tespit etmek amacıyla ayrıntılı deneysel verilerimizin ölçeğini belirlemektedir. Derinliğe özgü bozunma oranlarımızı, yaklaşık 1.392 km bağlama halatı kullanan 97 açık deniz çiftliğini belgeleyen kapsamlı bir bölgesel envanter ile entegre ettik. Geliştirdiğimiz kütle dengesi modeli, bu altyapıdan gerçekçi deniz koşullarında salınan plastik atığın yıllık kütlesini hesaplamaktadır.

Yalnızca halat bozunmasından yıllık 22,1 ton plastik salındığını ve bu miktarın diğer kaynaklardan bağımsız önemli bir değer olduğunu tahmin etmekteyiz. Kirliliğin dikey dağılımına ilişkin çarpıcı bir bulgu ise şudur: Ekolojik açıdan hayati önem taşıyan 0-10 metre tabakası, plastiğin ezici çoğunluğunu (%73,2 veya 16.180 kg) içerirken, doğrudan yüzey katmanı yalnızca %2,6'lık bir paya sahiptir. Polipropilen (PP) halatlar, toplam salımın %88,5'ini (19.577 kg) oluşturarak sektördeki baskınlıklarını ve çevre üzerindeki özel etkilerini yansıtmaktadır.

Bu çalışma, bölgedeki su ürünleri yetiştiriciliği bağlama sistemlerinden kaynaklanan plastik emisyonlarına yönelik ilk kesin atfı ve hassas niceliğini sağlamakta, onları daha önce hesaba katılmamış büyük bir deniz kirliliği kaynağı olarak tespit etmektedir. Elde edilen bu bulgular, politika yapıcılar ve sektör paydaşları için, bu önemli emisyon kaynağını AB Deniz Stratejisi Çerçeve Direktifi gibi çevresel izleme programlarına ve düzenleyici çerçevelere entegre etmek, böylece doğru kirlilik bütçeleri oluşturmak ve ekosistem koruması için sürdürülebilir uygulamaların geliştirilmesine rehberlik etmek konusunda güçlü bir zorunluluk oluşturmaktadır.

Anahtar Kelimeler: Plastik Kirlilik Yükü, Bölgesel Ölçeklendirme, Deniz Çöpleri, Çevresel Etki Değerlendirmesi, Karadeniz, Plastic Envanteri

FROM EXPERIMENT TO ECOSYSTEM: ESTIMATING THE MACRO-IMPACT OF PLASTIC EMISSIONS FROM BLACK SEA OFFSHORE AQUACULTURE MOORING SYSTEMS

ABSTRACT

Recent European Commission reports identify the Black Sea as holding Europe's highest recorded density of floating plastic debris, highlighting a critical environmental challenge. Notwithstanding this finding, and despite numerous studies assessing microplastic contamination in the Turkish Black Sea across surface waters, sediments, and wild marine organisms, research has yet to clearly attribute specific portions of this widespread pollution to aquaculture-derived emissions. This presentation therefore scales our detailed experimental data to quantify the total plastic pollution originating from Türkiye's Black Sea offshore aquaculture sector. We integrated our depth-specific degradation rates with a comprehensive regional inventory, documenting 97 offshore farms using approximately 1,392 km of mooring ropes. Our mass-balance model calculates the annual mass of plastic debris released from this infrastructure under real-world marine conditions.

We estimate that 22.1 metric tons of plastic are emitted annually from rope degradation alone, a substantial quantity independent of other sources. A crucial finding is the vertical distribution of this pollution: the ecologically vital 0-10 meter layer contains the overwhelming majority, 73.2% (16,180 kg), while the immediate surface holds only 2.6%. Polypropylene (PP) ropes constitute 88.5% of this release (19,577 kg), reflecting their industry dominance and particular environmental impact.

This study provides the first conclusive attribution and precise quantification of plastic emissions from aquaculture mooring systems in the region, establishing them as a major, previously unaccounted source of marine pollution. These findings create a strong imperative for policymakers and industry stakeholders to integrate this significant emission vector into environmental monitoring programs and regulatory frameworks like the EU Marine Strategy Framework Directive, thereby ensuring accurate pollution budgets and guiding the development of sustainable practices for ecosystem protection.

Keywords: Plastic Pollution Load, Regional Upscaling, Marine Litter, Environmental Impact Assessment, Black Sea, Plastic Inventory.

PACLOBUTRAZOL'UN (PBZ) BUĞDAY ÜRETİMİNDE KULLANIMI

Doç. Dr. Bekir ATAR

Isparta Uygulamalı Bilimler Üniversitesi, Atabey Meslek Yüksekokulu, Bitkisel Ve Hayvansal Üretim Bölümü, Atabey, Isparta

Email: bekiratar@isparta.edu.tr

ORCID: 0000-0002-1446-5699

ÖZET

Paclobutrazol (PBZ), triazol grubu bir bitki büyüme düzenleyicisi olup büyümeyi geciktirici özellik göstermektedir. Ticari olarak Bonzi, Clipper, Cultar ve Parsley isimleriyle bilinmektedir. Triazol bileşikleri, gibberellinler ve oksinler üzerinde antagonistik etki göstererek GA_3 biyosentezini inhibe eder; böylece hücre uzaması ve bölünmesi azalır. Gibberellin sentezinin engellenmesi, terpenoid yolunda daha fazla öncü madde birikimine neden olur ve bu durum absisik asit (ABA) üretimini artırır. Ayrıca PBZ'nin ABA'nın normal katabolizmasını (parçalanmasını) inhibe ettiği bildirilmiştir. Stres koşullara dayanıklılığı ABA sentezini artırarak gerçekleştiriyor olabilir.

PBZ, sitokinin sentezini de teşvik eder; bu durum kloroplast farklılaşmasını ve klorofil biyosentezini artırırken klorofil bozulmasını geciktirir. Aynı zamanda etilen sentezini azaltarak senesensi (yaşlanma sürecini) yavaşlatır. Prolin içeriğini artırarak kuraklık stresine karşı koruyucu etki sağlar. PBZ uygulamaları, klorofil içeriği ve antioksidan enzim seviyelerini yükseltmekte; aktif oksijen türlerinin detoksifikasyonunu destekleyerek oksidatif stresin azaltılmasına yardımcı olmaktadır. Sterol biyosentezini inhibe eden bir triazol olarak, PBZ fungusit olarak yaygın şekilde kullanılmaktadır.

Genel olarak triazol bileşikleri, bitkilerin çeşitli abiyotik stres faktörlerine (soğuk, kuraklık, yüksek sıcaklık, su baskını, tuzluluk, hava kirleticileri ve ağır metaller) ve biyotik stres etmenlerine (fungal patojenler ve diğer hastalık etmenleri) karşı toleransını artırmaktadır.

Morfolojik ve fizyolojik etkileri; bitki boyunun ve ağırlık merkezinin azalmasına (internod uzunluğunun kısalması) neden olurken, sap çapı ile sap duvar kalınlığını artırmaktadır. Ayrıca kök uzunluğunda ve lateral kök sayısında artışa yol açmakta, kök biyokütlesini yükseltmektedir. Bu yapısal değişiklikler, sap kırılma direncini ve yatmaya karşı dayanıklılığı önemli ölçüde artırmaktadır. Ayrıca fotosentetik kapasitede (klorofil içeriğinin) artış, yaprak alanında azalma, yaprak kalınlığında artış, kardeşlenmeyi teşvik, kök-gövde oranında ve fide kuru ağırlığında artış, CO_2 asimilasyon fizyolojisinde iyileşme sayılabilir. Ek olarak toprağa uygulandığında besin alım dinamiklerinde ve rizosferdeki toprak bakteri yoğunluklarında değişikliklere yol açmaktadır.

Potansiyel olumsuz etkileri arasında; yüksek doz uygulamalarında toksik etki göstererek çimlenme oranında azalmaya neden olması, çıkış sürecinde gecikmelere yol açması ve birincil yaprakların uzamasını olumsuz yönde etkilemesi yer almaktadır.

Uygulama yöntemleri arasında tohum ön işlemesi (priming), sulama yoluyla uygulama ve yapraktan sprey şeklinde uygulama yer almaktadır. Paclobutrazol (PBZ), floemde sınırlı hareket kabiliyetine sahipken, esas olarak ksilem üzerinden taşınmaktadır. Bu nedenle, uygulama yöntemi PBZ'nin bitki üzerindeki etkilerini önemli ölçüde belirlemekte ve fizyolojik yanıtlar uygulama şekline göre farklılık gösterebilmektedir..

Uygulama dozu açısından, tohumdan uygulamalarda oldukça farklı konsantrasyonlar denenmiştir. Ancak 200 ppm'in üzerindeki dozlar toksik etki göstererek çimlenme ve gelişim üzerinde olumsuz sonuçlara yol açabilmekte, dolayısıyla verimi azaltabilmektedir. Paclobutrazol (PBZ), düşük dozlarda dahi etkili olabilen bir büyüme düzenleyicidir. Buğday için 22–100 mg L^{-1} aralığı uygun görünmektedir.

Buğday üretiminde, tohum uygulamaları ile sap kalkma veya başaklanma dönemlerinde yapraktan uygulamalar, verimin korunmasına ve artırılmasına önemli katkılar sağlamaktadır. Paclobutrazol (PBZ), yüksek dozlar kullanılmadığı sürece toksik etki göstermemekte ve ürün üzerinde kalıntı bırakmamaktadır. Bu yönüyle, uygun doz ve zamanlamayla yapılan uygulamalar, bitki gelişimini düzenleyerek agronomik performansı iyileştirmektedir.

Anahtar Kelimeler: Buğday, Paclobutrazol (PBZ), Priming

USE OF PACLOBUTRAZOL (PBZ) IN WHEAT PRODUCTION

ABSTRACT

Paclobutrazol (PBZ) is a plant growth regulator belonging to the triazole group, known for its growth-retarding properties. It is commercially available under the names Bonzi, Clipper, Cultar, and Parsley. Triazole compounds exhibit antagonistic effects on gibberellins and auxins by inhibiting GA_3 biosynthesis, thereby reducing cell elongation and division. Inhibition of gibberellin synthesis leads to the accumulation of precursor molecules in the terpenoid pathway, which in turn enhances abscisic acid (ABA) production. Additionally, PBZ has been reported to inhibit the normal catabolism of ABA, suggesting that its role in stress tolerance may be mediated through increased ABA synthesis.

PBZ also promotes cytokinin synthesis, which enhances chloroplast differentiation and chlorophyll biosynthesis while delaying chlorophyll degradation. It reduces ethylene synthesis, thereby delaying senescence. By increasing proline content, PBZ contributes to drought stress tolerance. Applications of PBZ have been shown to elevate chlorophyll content and antioxidant enzyme levels, supporting the detoxification of reactive oxygen species and mitigating oxidative stress. As a triazole that inhibits sterol biosynthesis, PBZ also exhibits fungicidal activity.

In general, triazole compounds improve plant tolerance to various abiotic stress factors (cold, drought, high temperature, flooding, salinity, air pollutants, and heavy metals) as well as biotic stress agents (fungal pathogens and other disease-causing organisms).

Morphological and physiological effects of PBZ include reduced plant height and center of gravity (due to shortened internodes), increased stem diameter and wall thickness, enhanced root length and lateral root number, and elevated root biomass. These structural changes significantly improve stem strength and lodging resistance. Additional effects include increased photosynthetic capacity (chlorophyll content), reduced leaf area, increased leaf thickness, stimulated tillering, improved root-to-shoot ratio, and higher seedling dry weight. PBZ also enhances CO_2 assimilation physiology. When applied to soil, it alters nutrient uptake dynamics and affects rhizosphere bacterial density.

Potential adverse effects include toxicity at high doses, leading to reduced germination rates, delayed emergence, and inhibited elongation of primary leaves.

Application methods include seed priming, soil drenching, and foliar spraying. PBZ exhibits limited mobility in the phloem and is primarily transported via the xylem. Therefore, the physiological responses to PBZ vary significantly depending on the method of application.

Regarding dosage, a wide range of concentrations has been tested for seed treatments. However, doses exceeding 200 ppm may induce toxicity and negatively affect germination and growth, ultimately reducing yield. PBZ is effective even at low concentrations, and for wheat, seed treatments in the range of 22–100 mg L^{-1} appear to be suitable.

In wheat production, seed applications and foliar treatments during stem elongation or heading stages contribute significantly to yield preservation and enhancement. PBZ does not exhibit toxicity or leave residues when applied at appropriate doses and timings. Thus, it serves as a valuable tool for regulating plant growth and improving agronomic performance.

Keywords: Wheat, Paclobutrazol (PBZ), Priming

SICAK STRESİNE YANITIN GENETİK TEMELLERİ: SIĞIRLARDA MOLEKÜLER ADAPTASYONA YÖNELİK YENİ YAKLAŞIMLAR

Ecenur ALIŞ

[1]Bursa Uludağ Üniversitesi, Sağlık Bilimleri Enstütüsü,Veteriner- Genetik A.D., Bursa, Tükiye

Email: ecenuralis70@gmail.com

ORCID:0009-0007-7329-4168

Doç. Dr. Deniz DİNÇEL

[2]Bursa Uludağ Üniversitesi,Veteriner Falüktesi,Genetik A.D., Bursa, Türkiye

Email: deniz@uludag.edu.tr

ORCID: 0000-0002-8015-9032

ÖZET

Ruminantlar, zorlu çevre koşullarına belirli bir adaptasyon kabiliyeti göstermelerine rağmen, bu süreçte ortaya çıkan fizyolojik stres tepkileri genellikle hayvan refahı ve verimliliğini olumsuz etkilemektedir. Küresel iklim değişikliği ve artan sıcaklık öngörüleri, sıcak stresini özellikle sığır yetiştiriciliği başta olmak üzere hayvancılık sektöründe büyüyen bir tehdit haline getirmiştir. Bu çalışmanın amacı, sığırlarda sıcak stresine karşı oluşan moleküler yanıtların değerlendirilmesi, bu yanıtlarda rol oynayan temel genetik mekanizmalar ile güncel bilgilerin derlenmesi ve termal stresle başa çıkmak için geliştirilen stratejilerin sürdürülebilirlik açısından irdelenmesidir. Bu kapsamda; gen ekspresyon analizleri, GWAS çalışmaları ve genetik varyantların işlevsel açıklamaları incelenerek termal toleransla ilişkili genler ve biyolojik süreçler değerlendirilmiştir.

Sıcak stresine maruz kalan sığırlarda; süt verimi, döl verimi, embriyonik gelişim, bağışıklık yanıtı ve genel sağlık durumu ciddi şekilde etkilemektedir. Fizyolojik süreçte ve verim özelliklerinde meydana gelen bu etkinin moleküler mekanizmaların etkisi altında olduğu ve bu mekanizmaların bireysel farklar ortaya çıkardığı bilinmektedir. Büyük ölçekli GWAS analizleri de rektal sıcaklık, solunum skoru ve süt bileşenleri gibi fenotiplerle ilişkili gen bölgelerini ortaya çıkararak termotoleransla bağlantılı genetik çeşitliliğin haritalanmasına olanak sağlarken; SNP analizleriyle de sıcaklığa duyarlı ya da dirençli genetik varyantlar tanımlanmıştır.

Moleküler düzeyde, sıcak stresine yanıt olarak *HSP70*, *HSP90*, *HSF1* gibi ısı şoku proteinleri ön plandadır. Gerek kültür gerekse yerli ırklarda yapılan çalışmalarda, sıcak stresine karşı yanıtta *DNAJB1, HSPA1A, EIF2A, HIF1A, PAEP, FASN, ITPR2, HSP90AB1, SNORA19, RFWD2, SCARNA3, GOT1, KBTBD2, RFWD12, IL6, IL10, TNF-α, NOS2, LSM5* ve *U1* genlerinin önemli bir rol üstlendiği tespit edilmiştir.

Sıcak stresinin hayvan refahı, sağlık ve verimlilik üzerindeki olumsuz etkileri göz önüne alındığında, çevresel müdahale yöntemlerinin (gölgelik, fan, su püskürtme, rasyon düzenlemeleri) geçici fayda sağladığı, uzun vadede ekonomik olmamakla birlikte mücadelede sınırlı kaldığı görülmüştür. Buna karşılık ıslah programlarında genetik belirteçler ile termal toleransı yüksek bireylerin seçilmesi ruminant yetiştiriciliği açısından kalıcı ve sürdürülebilir bir çözüm sunmaktadır. Bu yaklaşım, iklim değişikliğine adaptif hayvancılık sistemlerinin oluşturulması açısından oldukça stratejiktir. Gelecekte genetik / epigenetik faktörler ile

bağırsak mikrobiyotası gibi fizyolojik bulguların entegrasyonunun ve CRISPR/Cas9 gibi rekombinant teknolojiler ile moleküler çalışmaların derinleştirilmesinin gerekliliği açıktır. Sıcak stresine dirençli, sürdürülebilir bir hayvancılık için bu doğrultuda yapılacak olan bilimsel temelli genetik araştırmaların kilit rol oynayacağı öngörülmektedir.

Anahtar Kelimeler: Sığır, iklim değişikliği, sıcak stresi, genomik seleksiyon, termotolerans genleri*, HSP70/90*, *HSF1, DNAJB1*

GENETIC BASIS OF HEAT STRESS RESPONSE: NOVEL PERSPECTIVES ON MOLECULAR ADAPTATION IN CATTLE

ABSTRACT

Although ruminants exhibit a certain capacity for adaptation to harsh environmental conditions, the physiological stress responses arising during this process often have negative effects on animal welfare and productivity. Global climate change and rising temperature projections have made heat stress an increasing threat to the livestock sector, particularly in cattle farming. The aim of this study is to evaluate the molecular responses to heat stress in cattle, to review current knowledge on the key genetic mechanisms involved in these responses, and to assess strategies developed to cope with thermal stress in terms of sustainability. In this context, gene expression analyses, GWAS studies, and functional interpretations of genetic variants were reviewed to identify genes and biological processes associated with thermal tolerance.

In cattle exposed to heat stress, milk yield, fertility, embryonic development, immune responses, and overall health status are severely affected. It is known that the impacts on physiological processes and production traits are driven by molecular mechanisms, which also account for individual differences. Large-scale GWAS analyses have identified genomic regions associated with phenotypes such as rectal temperature, respiration score, and milk components, thereby enabling the mapping of genetic diversity linked to thermotolerance. Moreover, SNP analyses have allowed the identification of genetic variants that are either sensitive or resistant to elevated temperatures.

At the molecular level, heat shock proteins such as *HSP70, HSP90*, and *HSF1* play a crucial role in the response to heat stress. Studies conducted in both commercial and indigenous breeds have demonstrated that genes including *DNAJB1, HSPA1A, EIF2A, HIF1A, PAEP, FASN, ITPR2, HSP90AB1, SNORA19, RFWD2, SCARNA3, GOT1, KBTBD2, RFWD12, IL6, IL10, TNF-α, NOS2, LSM5,* and *U1* are significantly involved in the adaptive response to elevated temperatures.

Considering the adverse effects of heat stress on animal welfare, health, and productivity, environmental intervention methods (such as shading, fans, sprinklers, and dietary adjustments) provide only temporary benefits, are not economically sustainable in the long term, and remain limited in their effectiveness. In contrast, the use of genetic markers in breeding programs to select individuals with high thermal tolerance offers a permanent and sustainable solution for ruminant production. This approach is highly strategic in establishing climate-adaptive livestock systems. In the future, the necessity of integrating genetic and epigenetic factors with physiological findings such as the gut microbiota, as well as advancing molecular studies through recombinant technologies such as CRISPR/Cas9, is clear. Scientific, genetics-based research carried out in this direction is expected to play a key role in developing sustainable livestock systems resistant to heat stress.

Keywords: Cattle, climate change, heat stress, genomic selection, thermotolerant genes, *HSP70/90, HSF1, DNAJB1.*

SOĞUĞA TOLERANSLI YAYGIN FİĞ MELEZ HATLARININ MORFOLOJİK, FİZYOLOJİK VE AGRONOMİK ÖZELLİKLERİ

Dr. Berna EFE

Department of Meadow-Rangeland and Forage Crops, Central Research Institute for Field Crops, Ankara, Türkiye

Email: berna.efe@tarimorman.gov.tr

ORCID: 0000-0003-2207-6543

MSc. Seçil CANDAŞ ÖZKAN

Department of Meadow-Rangeland and Forage Crops, Central Research Institute for Field Crops, Ankara, Türkiye

Email: seçil.candas@tarimorman.gov.tr

ORCID: 0009-0006-7623-1878

Dr. Recep KIRBAŞ

Department of Meadow-Rangeland and Forage Crops, Central Research Institute for Field Crops, Ankara, Türkiye

Email: recep.kirbas@tarimorman.gov.tr

ORCID: 0000-0001-9153-2456

Dr. Erol KARAKURT

Department of Meadow-Rangeland and Forage Crops, Central Research Institute for Field Crops, Ankara, Türkiye

Email: erol.karakurt@tarimorman.gov.tr

ORCID: 0000-0002-0977-3419

ÖZET

Yaygın fiğ (*Vicia sativa* L.), Türkiye'nin Orta Anadolu Bölgesi'nde yaygın olarak yetiştirilen bir baklagil yem bitkisidir. Bu bölge, yarı kurak, kurak iklim ve zayıf toprak yapısı ile karakterize edilmektedir. Bu zorlu ortamda, yaygın fiğ yetiştiriciliği genellikle yazlık olarak gerçekleştirilir, ancak bölgeye uyumlu kışlık çeşitler de geliştirilmiştir. Ancak, bu çeşitlerin yazlık çeşitlere kıyasla nispeten daha düşük tane verimi sergilediği gözlemlenmiştir. Bu dezavantajı aşmanın en etkili yöntemi, kışa toleranslı, biyolojik verimi ve tane verimi yüksek yeni çeşitler üretmektir. İstenilen özelliklere sahip bu yeni çeşitleri elde etmek için şimdiye kadar yapılan araştırmalarda çeşitli genetik kaynaklar kullanılmıştır. Ayaz-08 çeşidi soğuğa toleranslı, erken olgunlaşan ve biyolojik verimi yüksek bir çeşittir. Mutant Toplesa çeşidi, soğuğa hassas, geç olgunlaşan ve yüksek tane verimine sahip bir çeşittir. Ayaz-08'de, baklalar bitkinin tabanından tepesine doğru dizilmiş olup, alt baklalar önce olgunlaşır. Buna karşılık, Toplesa, baklaların bitkinin tepesinde kümelenmiş olduğu bir mutant özelliği sergiler. Bu nedenle, hasat sırasında verim kaybı azaldığından, Toplesa'nın tane verimi yüksektir. Toplesa ile ıslah çalışmaları, Ayaz-08'in tane verimini artırmak amacıyla 2014 yılında Tarla Bitkileri Merkezi Araştırma Enstitüsü'nde başlatılmıştır. Yüksek verim potansiyeline sahip, soğuğa toleranslı, erken olgunlaşan bir çeşit elde etmek için 2014-2023 yılları arasında bir dizi ıslah ve seleksiyon prosedürü uygulanmıştır. 2024 yılında, yaygın fiğ melez hatları, iki kontrol çeşidi

(Ayaz-08 ve Toplesa) ile 2 m²'lik parsellere, augmented deneme deseni kullanılarak ekildi. Elde edilen veriler daha sonra aşağıdaki parametreler kullanılarak kapsamlı bir değerlendirmeye tabi tutulmuştur: çiçeklenme zamanı (FT), bitki boyu (PH), sap kalınlığı (SD), sap sayısı (NS), ilk bakla yüksekliği (FPH), bitkideki bakla sayısı (PPP), bakladaki tane sayısı (SPP), 1000 tane ağırlığı (SW), biyolojik verim (BY) ve tane verimi (GY). Korelasyon analizi, FPH'nin BY ve GY ile yüksek korelasyon gösterdiğini ortaya koymuştur. FT, FPH, BY ve GY'ye dayalı temel bileşen analizinde (PCA), genotipler gruplandırılmıştır. Analiz, toplam varyasyonun %79.7'sinin ilk temel bileşen (PC1) tarafından %50.4'ünün, ikinci temel bileşen (PC2) tarafından %29.3'ünün açıklandığını ortaya koymuştur. AT-23, AT-25, AT-31, AT-32, AT-33, AT-53, AT-54, AT-55, AT-56, AT-57, AT-61, AT-63, AT-64 ve AT-68 hatlarının hem BY hem de GY açısından potansiyel öneme sahip olduğu belirlenmiştir.

Anahtar Kelimeler: Melezleme, İlk Bakla Yüksekliği, Biyolojik Verim, Tane Verimi, PCA.

MORPHOLOGIC, PHYSIOLOGIC AND AGRONOMIC TRAITS OF COLD-TOLERANT COMMON VETCH HYBRID LINES

ABSTRACT

Common vetch (*Vicia sativa* L.) is a forage legume widely cultivated in the Central Anatolia Region of Türkiye. This region is characterized by a semi-arid, arid climate and poor soil structure. In this harsh environment, common vetch cultivation is generally carried out as a summer crop, although winter cultivars adapted to the region have also been developed. However, these cultivars have been observed to exhibit a comparatively lower grain yield in comparison to those classified as summer cultivars. The most effective method of overcoming this disadvantage is to breed new cultivars with high winter hardiness, biological and grain yield. Various genetic resources have been used during the research conducted so far in order to obtain these new cultivars with the desired characteristics. Ayaz-08 cultivar is cold-tolerant, early maturing, and has high biological yield. The mutant Toplesa cultivar is a cold-sensitive, late-maturing cultivar with high grain yield. In the Ayaz-08, the pods are arranged from the base to the apex of the plant, with the lower pods maturing first. In contrast, the Toplesa exhibits a mutant characteristic wherein the pods are observed to be clustered at the apex of the plant. Therefore, as yield loss is reduced during harvesting, the grain yield of the Toplesa is high. Breeding studies with the Toplesa were initiated in 2014 at the Central Research Institute for Field Crops with the objective of enhancing the grain yield of the Ayaz-08. A series of breeding and selection procedures were conducted from 2014 to 2023 to obtain a cold-tolerant, early-maturing cultivar with high yield potential. In 2024, the common vetch hybrid lines were sown in 2 m² plots with two check cultivars (Ayaz-08 and Toplesa) using an augmented experimental design. The resulting data were then subjected to a comprehensive evaluation, using the following parameters: flowering time (FT), plant height (PH), stem diameter (SD), stem number (NS), first pod height (FPH), number of pods per plant (PPP), number of seeds per pod (SPP), seed weight (SW), biological yield (BY), and grain yield (GY). Correlation analysis showed that FPH was highly correlated with BY and GY. In the principal component analysis (PCA) based on FT, FPH, BY and GY, genotypes were grouped. The analysis explained that 79.7% of the total variation, 50.4% by the first principal component (PC1) and 29.3% by the second principal component (PC2). It has been determined that the AT-23, AT-25, AT-31, AT-32, AT-33, AT-53, AT-54, AT-55, AT-56, AT-57, AT-61, AT-63, AT-64 and AT-68 lines have potential significance in terms of both BY and GY.

Keywords: Crossbreeding, First Pod Height, Biological Yield, Grain Yield, PCA.

MUZ BİTKİSİNDE AZOT VE KÜKÜRT UYGULAMALARININ MEYVE KALİTESİ ÜZERİNE ETKİLERİ

Şamil Gülaydın
Bursa Uludağ Üniversitesi Ziraat Fakültesi
Toprak Bilimi ve Bitki Besleme
Email: 502318012@ogr.uludag.edu.tr
ORCID: 0009-0002-4444-8176
Prof. Dr. Murat Ali Turan
Bursa Uludağ Üniversitesi Ziraat Fakültesi
Email: maturan@uludag.edu.tr
ORCID: 0000-0002-7936-1663

ÖZET

Bu çalışma, sera koşullarında yetiştirilen muz bitkilerinde (Musa spp.) elementel kükürt (ES) uygulamalarının bazı kalite parametreleri üzerine etkilerini belirlemek amacıyla yürütülmüştür. Araştırma, Antalya ili Manavgat ilçesi Sağırin mevkiinde yer alan ticari bir muz serasında gerçekleştirilmiştir. Araştırma kapsamında kurulan sera denemesinde elementel kükürt artan oranlarda uygulanmıştır. Uygulamalar fide dikiminden bir ay sonra ve dört ay sonra olmak üzere iki kez tekrarlanmış, topraktan elemental kükürt uygulamaları ES_1: 0g/ağaç, ES_2: 50 g/ağaç, ES_3: 100 g/ağaç, ES_4: 200 g/ağaç ve ES_5: 400 g/ağaç dozlarında yapılmıştır. Toprağa uygulanacak elementel kükürt miktarları hesaplanarak ağaç etrafına çapa yardımı ile karıştırılmıştır. Çalışma boyunca, elementel kükürdün etkilerini belirleyebilmek için kükürt içeren gübreler kullanılmamıştır. Elde edilen bulgular, elementel kükürdün muzun kalite parametreleri üzerine önemli etkilerinin olduğunu göstermiştir. Artan kükürt dozlarıyla birlikte bitkide kükürt birikiminin arttığı belirlenmiştir. Bitki kükürt içerikleri ES1 uygulamasında %0,24, ES2 ve ES3 uygulamalarında %0,29, ES4 uygulamasında %0,32 ve ES5 uygulamasında %0,34 olarak tespit edilmiştir. Kontrol uygulamasıyla (ES1) karşılaştırıldığında ES5 dozu, bitki kükürt içeriğinde %41,66 oranında bir artış sağlamıştır. Bunun yanı sıra, meyve kalite parametreleri de uygulamalardan etkilenmiştir. Kontrol uygulamasında (ES1) hevenk başına parmak sayısı sırasıyla üst, orta ve alt kısımlarda 19–20–18 adet, hevenk ağırlığı ise 21,3 kg olarak belirlenmiştir. Buna karşın ES5 uygulamasında parmak sayısı 18–18–17 adet olarak belirlenmiş, hevenk ağırlığı ise 24,8 kg'a yükselmiştir. Genel değerlendirme sonucunda, elementel kükürt uygulamalarının tüm dozlarda hevenk ağırlığını artırdığı belirlenmiştir. En yüksek artış, %7,98 ile ES5 dozunda elde edilmiştir. Bulgular, elementel kükürdün yalnızca kükürt alımını artırmakla kalmayıp aynı zamanda meyve ağırlığına doğrudan katkı sağladığını ortaya koymaktadır.

Anahtar Kelimeler: Muz, elementel kükürt, kalite, verim

EFFECTS OF NITROGEN AND SULFUR APPLICATIONS ON FRUIT QUALITY IN BANANA PLANTS

ABSTRACT

This study was conducted to determine the effects of elemental sulfur (ES) applications on some quality parameters in banana plants (Musa spp) grown under greenhouse conditions. The study was conducted in a commercial banana greenhouse located in the Sağırin area of the Manavgat district of Antalya province. In the greenhouse trial established for the study, elemental sulfur was applied at increasing rates. Applications were repeated twice, one month and four months after seedling planting. The soil application doses were ES1: 0g/tree, ES2: 50g/tree, ES3: 100g/tree, ES4: 200g/tree, and ES5: 400g/tree. The amount of elemental sulfur to be applied to the soil was calculated and mixed around the trees using a hoe. Sulfur-containing fertilizers were not used throughout the study to determine the effects of elemental sulfur. The results showed that elemental sulfur has significant effects on banana quality parameters. It was determined that sulfur accumulation in the plant samples increased with increasing sulfur doses. Plant sulfur (S) contents were determined as 0.24% in ES1 treatment, 0.29% in ES2 and ES3 treatments, 0.32% in ES4 treatment, and 0.34% in ES5 treatment. Compared to the control treatment (ES1), the ES5 dose caused a 41.66% increase in plant sulfur content. In addition, fruit quality parameters were also affected by the treatments. In the control treatment (ES1), the number of fingers per bunch was determined as 19–20–18 in the upper, middle, and lower parts respectively, and bunch weight was 21.3 kg. In contrast, in the ES5 treatment, the number of fingers was determined as 18–18–17, and bunch weight increased to 24.8 kg. The results showed that elemental sulfur applications increased bunch weight at all doses. The highest increase, 7.98% was achieved at the ES5 dose. The findings indicate that elemental sulfur not only increases sulfur uptake but also directly contributes to fruit weight.

Keywords: Banana, Sulfur, Elemental Sulfur, Quality, Yield

KALSİYUM VE BOR UYGULAMALARININ BİBER BİTKİSİNİN GELİŞİMİ ÜZERİNE ETKİSİ

Muhammet Cemil Ejderoğlu
Bursa Uludağ Üniversitesi, Ziraat Fakültesi,
Toprak Bilimi ve Bitki Besleme Bölümü
Email: 502318007@ogr.uludag.edu.tr,
ORCID: 0009-0007-8777-4437
Prof. Dr. Murat Ali Turan
Bursa Uludağ Üniversitesi, Ziraat Fakültesi,
Toprak Bilimi ve Bitki Besleme Bölümü
Email: maturan@uludag.edu.tr,
ORCID: 0000-0002-7936-1663

ÖZET

Bu çalışmada topraktan artan dozlarda uygulanan kalsiyum (Ca) ve borun (B) biber bitkisinin gelişimi ve kimi bitki besin elementlerinin alınımı üzerine etkileri araştırılmıştır. Denemede biber bitkisinin gelişimi ve bitki besin elementi içeriğini araştırmak amacıyla bir sera denemesi kurulmuştur. Üç burun biber çeşidinin kullanıldığı denemede kalsiyum kaynağı olarak kalsiyum nitrat ($CaNO_3$) ve bor kaynağı olarak borik asit (H_3BO_3) kullanılmıştır. Denemede iki kalsiyum dozu (Ca_1 0 mg Ca kg^{-1} ve Ca_2 1000 mg Ca kg^{-1}) ve beş bor dozu (B_1 0 mg B kg^{-1}, B_2 2,5 mg B kg^{-1}, B_3 5 mg B kg^{-1}, B_4 7,5 mg B kg^{-1}, B_5 10 mg B kg^{-1}) kullanılmıştır. Bitki örneklerinde yapılan analizler sonucunda toprak üstü aksamda $CaNO_3$ uygulamaları sonucu, bitkilerin Ca içeriklerinde (Ca_1: % 2,06 ve Ca_2: % 2,38) ortalama % 15,53 oranında bir artış belirlenirken, bu artış kökte (Ca_1: % 2,80 ve Ca_2: % 4,47) ortalama % 59,64 oranında gerçekleşmiştir. Artan konsantrasyonlarda uygulanan borun (B) etkisi ile bitki örneklerinin B içerikleri toprak üstü aksamda Ca_1'de sırasıyla 11,70, 14,05, 17,38, 24,62 ve 34,47 mg B kg^{-1} ve Ca_2'de sırasıyla 16,48, 20,17, 25,96, 29,27 ve 41,39 mg B kg^{-1} olarak belirlenmiştir. Bitki kök aksamında ise bu durum Ca_1'de sırasıyla 0,30, 1,15, 3,53, 4,43, 8,61 mg B kg^{-1} ve Ca_2'de sırasıyla 0,32, 3,29, 4,85, 6,51, 8,43 mg B kg^{-1} olarak belirlenmiştir. Topraktan artan oranlarda H_3BO_3 ve $CaNO_3$ uygulaması bitkilerin kök ve toprak üstü aksamında B konsantrasyonunun artmasına neden olmuştur. Bunun sonucunda bitkilerin kök kuru madde içeriklerinde % 29,03 ve toprak üstü aksamında ise % 20,71 oranında bir azalmanın gerçekleştiği belirlenmiştir.

Anahtar Kelimeler: Biber, kalsiyum, bor

EFFECT OF CALCIUM AND BORON APPLICATIONS ON DEVELOPMENT OF PEPPER PLANT

ABSTRACT

In this study, the effects of increasing soil doses of calcium (Ca) and boron (B) on pepper plant development and the uptake of some plant nutrients were investigated. A greenhouse experiment was conducted to investigate pepper plant development and plant nutrient content. In the experiment calcium nitrate ($CaNO_3$) was used as the calcium source, and boric acid (H_3BO_3) was used as the boron source. Two calcium doses (Ca_1 0 mg Ca kg^{-1} and Ca_2 1000 mg Ca kg^{-1}) and five boron doses (B_1 0 mg B kg^{-1}, B_2 2.5 mg B kg^{-1}, B_3 5 mg B kg^{-1}, B_4 7.5 mg B kg^{-1}, B_5 10 mg B kg^{-1}) were used in the experiment. It was determined that an increase of 15.53% was determined in the Ca contents of shoot in $CaNO_3$ application (Ca_1: 2.06% and Ca_2: 2.38%), while this increase was realized as of 59.64% in the root (Ca_1: 2.80% and Ca_2: 4.47%). In boron applications, B contents of the plant samples were determined as 11.70, 14.05, 17.38, 24.62 and 34.47 mg B kg^{-1} for Ca_1 in the shoot and 16.48, 20.17, 25.96, 29.27 and 41.39 mg B kg^{-1} for Ca_2 respectively. In plant root, this situation was determined as 0.30, 1.15, 3.53, 4.43, 8.61 mg B kg^{-1} for Ca_1 and 0.32, 3.29, 4.85, 6.51, 8.43 mg B kg^{-1} for Ca_2, respectively. Applications of H_3BO_3 and $CaNO_3$ in the soil caused an increase in B concentration in the root and shoot of the plants. As a result, it was determined that a decrease of 29.03% in the root dry matter content of the plants and a decrease of 20.71% in the shoot occurred.

Keywords: Paper, calcium, boron

GREEN SYNTHESIZED IRON NANOPARTICLE BASED DETECTION OF MICROPLASTICS FROM AQUEOUS ENVIRONMENT

Mohanapriya P*

Research Fellow, Department of Biotechnology, St. Joseph's College of Engineering, India

Chamundeeswari M

Associate Professor, Department of Biotechnology, St. Joseph's College of Engineering, India.

*Email: priyam22995@gmail.com

ABSTRACT

Disposable polypropylene (PP) face masks pose substantial ecological risks due to their persistence and contribution to microplastic pollution. This study investigates a novel approach to accelerate PP biodegradation by combining soil-isolated plastic-degrading microorganisms with green-synthesized iron nanoparticles (FeNPs) as degradation enhancers. The FeNPs were synthesized via a green chemistry approach, using agro-friendly plant *Sesbania bispinosa* aqueous extract to control nanoparticle size through optimized parameters. The researchers have demonstrated that such biosynthesized FeNPs stimulate bacterial proliferation, organic matter mineralization, humidification, and compost maturation. Plastic-degrading strains were isolated from agricultural soil and screened for degradation activity. Laboratory-scale biodegradation assays were conducted using face mask films, degradation efficiency was quantified based on weight loss, and molecular changes were confirmed by FTIR, which revealed emergence of acetaldehyde and carbonyl peaks compared to untreated films. Biofilm formation by the microbial strains on the mask surfaces confirmed microbial colonization and attachment. The results indicate that the synergistic application of isolated soil microorganisms and green-synthesized FeNPs markedly improves the biodegradation of PP masks. This integrated strategy shows strong potential as an environmentally sustainable method for managing PP waste.

Key Words: Microplastics, soil microorganisms, biodegradation, Sustainability approach, Face mask

THE USE OF GLUTAMIC ACID AS A GREEN ALTERNATIVE FOR CORROTION INHIBITION IN HCL SOLUTION

ABDULLAHİ UMAR

ABSTRACT

The corrosion of aluminium in acidic environments, such as hydrochloric acid (HCl), poses significant challenges in various industrial applications. This study investigates the potential use of glutamic acid as a green corrosion inhibitor for aluminum in HCl solution through theoretical and computational approaches. Using Spartan software (Students version), the 3D structures of glutamic acid, aluminum, and HCl were constructed, and the geometry optimization was performed using the DFT method. Subsequent adsorption studies focused on the interactions between aluminum and the molecules, with both length calculations used to assess interaction strengths. Also, the energy ban gap (E-Gap) between the HOMO and LUMO of the adsorption complexes was evaluated to determine the stability and reactivity of the inhibitor. The results indicates that glutamic acid forms a more stable adsorption complex with aluminum, characterized by a smaller energy ban gap and stronger chemisorption compared to HCl. These findings suggest that glutamicacid exhibits a higher affinity for the aluminum surface, providing an effective barrier against corrosion. This study offers valuable insights into the potential application of glutamic acid as an eco-friendly corrosion inhibitor in acidic environments, contributing to sustainable corrosion management strategies.

PERFORMANCE EVALUATION OF WIRELESS SENSOR NETWORKS FOR SMART AGRICULTURE USING OPNET

AKINLEYE, Abiodun Olamilekan

Department of Computer Engineering

The Federal Polytechnic, Ilaro. Ogun State.

Email: akinleyeao@gmail.com

ORCID: 0009-0004-2939-5066

ABSTRACT

The fast advancement of technology in the agricultural systems has resulted in adopting smart farming practices where the use of wireless communication network plays a significant role in data collection and analysis. This paper concentrates on the Performance Analysis of the Wireless Sensor Networks (WSNs) with Smart Agriculture with OPNET Modeler 14.5. The study will evaluate the efficiency of WSNs in measuring vital agronomical parameters like soil moisture, temperature and humidity that are vital in achieving best crop productions and environmental resource conservation. The sensor nodes, in the simulation, have been placed in a virtual farmland to gather and send the environmental data to a sink node in the middle, to be analyzed. The vital key performance indicators like network throughput, end-to-end delay, packet delivery ratio, and the energy consumption are tested with variations on the node densities and communication ranges. It is assumed the results will demonstrate the effects of network design on communication efficiency and reliability of data in smart agriculture systems. The results of this research will be used in creating the energy efficient and cost-effective network models to develop precision agriculture, hence, assist with sustainable agriculture and better environmental management. The study helps to address the gap between the agricultural production and the recent communication technologies.

Keywords: Wireless Sensor Networks, Smart Agriculture, OPNET Modeler, Precision Farming, Environmental Monitoring.

IMPACT OF SUSTAINABLE AGRICULTURAL PRACTICES ON ENVIRONMENTAL CONSERVATION

Y. Sarayu Reddy

Department of Electronics & Communication EngineeringR.M.K. Engineering College Thiruvallur,

Email: India240875.ec@rmkec.ac.in

S. Suji

Department of Electronics & Communication EngineeringR.M.K. Engineering College Thiruvallur, India

Email: 240761.ec@rmkec.ac.in

ABSTRACT

Sustainable agriculture plays a crucial role in promoting environmental conservation while ensuring long-term food security. This study focuses on the impact of sustainable farming practices such as crop rotation, organic fertilization, integrated pest management, and efficient irrigation systems. These methods help maintain soil fertility, reduce greenhouse gas emissions, and preserve biodiversity. The paper highlights how sustainable practices minimize the overuse of chemical inputs and promote ecological balance. By adopting eco-friendly approaches, farmers can achieve productive yields while protecting natural resources. The study concludes that sustainable agricultural practices are essential for achieving a balance between productivity and environmental health, contributing significantly to global sustainability goals.

Keywords: Sustainable Agriculture, Environmental Conservation, Organic Farming, Biodiversity, Eco-friendly Practices

BENEFITS OF AGRO FORESTRY LAND USE IN NSUKKA LOCAL GOVERNMENT AREA, ENUGU STATE, NIGERIA

Ugwuoke Chukwuchebe Obiajulu

Department of Agricultural Economics, Faculty of Agriculture

University of Nigeria, Nsukka

ABSTRACT

The study analyzed benefits of Agro Forestry Land Use in Nsukka Local Government Area, Enugu State, Nigeria. Sampling was done using two stage random sampling technique. Data for this study was obtained from both primary and secondary sources. Data collected was analyzed using simple statistical description. Results showed that the farmer's perceived benefits include: all year round income (M=3.76), enrich soil with manure (M=3.74), fight soil erosion (M=3.38), increase land productivity (M=3.42), maintenance of gen diversity (M=3.34), ensure better land management (M=3.54),), provision of shade (M=3.48). The result also showed that farmers participate in agro forestry due to economic reasons (100%), more productivity (100%), as a source of income (100%), enriches the soil (100%), and encourages afforestation (100%). The identified major constraints of agro forestry land use were poor road/transport (M=3.64), theft (M=3.62), poor/hazardous working condition (M=3.54), poor harvest lost (M=3.49), inadequate storage facilities (M=3.48) poor access to capital (M=3.46), poor extension contact (M=3.44 etc. The land tenure system of the entire study area is largely (84%) by inheritance, and land use is determined by the male head which formed (60%) of the respondents and, on whom the right of usage is vested. Government should therefore investigate the possibilities of facilitating access to farm lands by reviewing the land tenure act. The government and concerned agencies should provide incentives to increase their adoption of agroforestry practices.

Key words: Benefits of Agro Forestry; Land Use

EVALUATION OF SPERMATOZOA QUALITY, DIFFERENTIAL SPERM MORPHOLOGY AND GONADOSOMATIC INDICES OF BENIGN PROSTATIC HYPERPLASIA INDUCED RATS TREATED WITH POLYHERBAL EXTRACT.

Chidimma Lilian Asadu[1*], Robert Ikechukwu Uroko[2*], Stanley Mary Ubenyi[1*]

[1] Department of Medical Biochemistry, Esut College of Medicine, Parklane Nigeria.

[2] Department of Biochemistry, College of Natural Sciences, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria

Corresponding Author**:** chidinma.asadu@esut.edu.ng

ABSTRACT

Introduction: The study of benign prostatic hyperplasia (BPH) is intricate and its complete understanding is yet to be achieved. The hormones testosterone and dihydrotestosterone have a permissive and important role in male fertility. Growth factors and other hormones like estrogens and factors that may contribute to the development of BPH.This study investigated the ameliorating potential of polyherbal leave extract of Stinging nesttle, Vernonia amygdalina, Milk thistle and roots of Musa Paradisiaca (SVMM) on Testosterone Propionate-Induced Benign prostatic hyperplasia in male wistar rats. Methods: A total of 36 male rats were used in this study. They were grouped into 6 groups of 6 rats each. Benign prostate hyperplasia was induced in the rats using the intraperitoneal administration of 5 mg/kg testosterone propionate injection subcutaneously and 1 hour later treated with polyherbal extract for 28 consecutive days. Semen sample was collected for spermatozoa quality, morphology and gonadosomatic indices using standard protocols. The study showed that the induction of BPH brought about some adverse effect on spermatozoa proportion, quality, normal spermatozoa and testicular and prostate weight relative to normal control. Sperm abnormalities like those with bent mid-piece were seen. The findings showed that the administration of SVMM extract had a significant positive impact on the sperm cell abnormalities, significant reduction in testicular and prostate weight thus, leading to the restoration of the sperm cell morphology and potentially improving fertility. These findings demonstrated that the use of SVMM can reduce the harmful effects of Testosterone Propionate-Induced Benign prostatic hyperplasia (BPH) and enhance fertility by restoring the quality semen and sperm morphology to their normal state in rats.

Keywords: Benign prostatic hyperplasia, *Milk thistle, Musa paradisiacal, Stinging nettle,* Testosterone Propionate, *Vernonia amygdalina*

VALORIZATION OF FRUIT WASTE THROUGH REUTILIZATION APPROACH: A COMPREHENSIVE REVIEW

R.Thiruchelvi

Research Scholar, Biotechnology, St. Joseph's College of Engineering, Chennai, India

Email: thiruchelvi13892gmail.com

ORCID: 0000-0001-5532-8597

Dr.P.Saravanan[2]

Head & Associate Professor, Chemistry, St. Joseph's College of Engineering, Chennai, India.

ABSTRACT

The shift towards a circular economy presents opportunities to minimize waste and maximize resource efficiency, particularly in the context of fruit waste. This review explores the innovative utilization of fruit waste globally, highlighting its potential to enhance sustainability. It discusses the types, quantities, and compositions of waste generated by the fruit industry. Current waste management practices, such as composting, biogas production, and their use as animal feed, are examined as important strategies for reducing environmental impact. The potential for fruit waste to create value-added products is explored in depth,

including applications in food packaging, agriculture, water purification, and the extraction of bioactive compounds for pharmaceutical and nutraceutical uses. The role of fruit waste in the food sector is also discussed, with particular attention to the utilization of bioactive compounds and incorporation into bakery products, illustrating its potential to improve food quality and sustainability. It further discusses emerging technologies, challenges, and policy frameworks in waste management. The importance of fruit waste utilization in fostering a sustainable future is highlighted, aligning with global efforts to reduce waste and promote resource circularity. By integrating innovative solutions and cross-sector collaborations, fruit waste can be transformed into a valuable resource in the circular economy.

Keywords: bioactive compounds, circular economy, environmental sustainability, fruit waste management , sustainable development

MORPHOLOGICAL CHARACTERIZATION OF THE GENETIC RESOURCES OF MOROCCAN WHITE MULBERRY (MORUS ALBA L.)

Sadik DANI[1*], Hassane ABD-DADA [1*], Aziz EZZINE [1*], Ahmed El Annaoui[1*], Atman ADIBA[2*], Abdelmajid HADDIOUI[1*], Said BOUDA[1*]

[1*] Laboratory of Agro-Industrial and Medical Biotechnologies, Faculty of Sciences and Techniques, Sultan Moulay Slimane University, Beni Mellal, Morocco

[2*] Agro-food Technology and Quality Laboratory Regional Center of Agricultural Research of Tadla National Institute of Agricultural Research Ennasr Avenue, BP 415 Rabat Principale 10090 Rabat, Morocco

Corresponding author: Sadik DANI

Email: sadik.dani@usms.ma

ABSTRACT

The White mulberry (*Morus alba L.*), also known as "Toot" in Arabic, is a member of the *Moraceae* family. The leaves of the white mulberry, which is widely grown all over the world, are the main food source for silkworms. It is cultivated for its fruit in North African nations, and it is also eaten as a vegetable in some European countries. The leaves are used to make tea and powdered juice in Japan. The plant's fruits, leaves, roots, branches, and bark are all used in traditional medical systems, for their potential to promote health and provide antioxidants.

White mulberry is abundant in bioactive compounds, including phenolic acids, flavonoids, flavanols, anthocyanins, as well as essential macronutrients, vitamins, minerals, and aromatic volatile compounds. These naturally occurring substances exhibit potent biological activity and provide notable pharmacological benefits in the prevention and treatment of various diseases.

This work characterised and assessed phenotypic variation within this species. Forty-Two qualitative and quantitative morphological characters pertaining to the tree, flowers, and fruit were evaluated across thirteen natural accessions sampled throughout its native Moroccan range. Significant intraspecific phenotypic variability was indicated by the analysis of variance, which showed significant variations between accessions for most characteristics. Moreover, the principal component analysis allowed for the classification of *M. alba* accessions into three distinct morphological categories. These observations reveal a great phenotypic diversity among the natural specimens of this species in Morocco. The study highlighted the phenotypic diversity that could serve as an attractive approach to consider the valorisation of this species in Morocco.

Key words: *Morus alba*; Morocco; Phenotypic diversity; Variability; Pomology

ATTITUDE OF THE SOCIETY TOWARDS HIV/AIDS PATIENTS IN KONTAGORA, NIGER STATE, NIGERIA

Jatau T, K.,

School of Sciences, Department of Biology Education/ Integrated Science, Federal College of Education,

Kontagora Niger State, Nigeria.

Sani H

School of Sciences, Department of Biology Education/ Integrated Science, Federal College of Education,

Kontagora Niger State, Nigeria.

ABSTRACT

The research was conducted on the attitude of the Society Towards HIV/AIDS Patients in Kontagora, Niger state, Nigeria. Fifty (50) questionnaires were distributed randomly and fifteen (15) respondents were interviewed. Five (5) areas were sampled; General Hospital, Federal Low-cost Kontagora, Sabon-Gari, Tudun Wada and Dadin-Kowa Kontagora. Ten (10) questionnaires were distributed to each sampled area. The methods used in analyzing the data collected from these areas are Simple Percentage (%) and Chi-square ($\times^2$) test. From the results, 4 (82%) of the respondents are HIV/AIDS negative and 9 (18%) are HIV/AIDS positive. 50 (100%) of the respondent disagree with the discrimination as the best way of caring for HIV/AIDS victims, while 1 (2%) agreed. It also showed that 49(98%) agreed that HIV/AIDS victims should be treated equally in the society and 1 (2%) of the respondent disagree. From the Chi-square ($\times^2$) test analysis, the $\times^2$ - cal = 169.9 and the $\times^2$ – tab = 221.7, also $\times^2$ =23.59 at probability level of 0.5 and degree of freedom (df) of 9. Since $\times^2$ – cal > $\times^2$ – tab, then there is significant difference in the attitude of the society towards HIV/AIDS patients. The study then recommends that; doctors should be educated on the interactions between social lives and health care as it would level out bias attitude towards HIV/AIDS patients. Hospitals should provide free access for counselling and test for HIV/AIDS among others.

Keywords: HIV, AIDS, Immune, Patient, Symptom, Treatment.

"A COMPARATIVE ANALYSIS OF MUNICIPAL SOLID WASTE MANAGEMENT IN URBAN AND RURAL SETTINGS"

Prof. (Dr.) Sunil Agrawal

Professor, People's Institute of Management & Research

People's University, Bhopal, MP, INDIA

Email: drsuagrawal@gmail.com

ORCID: 0000-0002-2130-9694

ABSTRACT

Effective municipal solid waste management (MSWM) is essential for maintaining public health, environmental sustainability, and economic stability. However, significant disparities exist between urban and rural waste management systems due to differences in population density, infrastructure, financial resources, and governance capacity. This study presents a comparative analysis of MSWM practices in urban and rural settings, focusing on waste generation rates, collection efficiency, treatment methods, and community participation. Data were collected through field surveys, stakeholder interviews, and secondary reports from selected municipalities representing both settings. The findings reveal that urban areas generate substantially higher volumes of waste, dominated by plastics, paper, and packaging materials, while rural regions produce more organic and agricultural residues. Urban MSWM systems tend to rely on centralized collection and disposal methods, often involving engineered landfills and limited recycling initiatives. In contrast, rural communities depend on informal or community-based waste handling practices, with lower collection coverage but higher rates of organic waste reuse and composting. The study identifies critical challenges, including inadequate funding, weak policy enforcement, and low public awareness, which impede efficient waste management in both contexts. Comparative analysis underscores the need for context-specific strategies—such as decentralized composting in rural areas and enhanced recycling infrastructure in urban zones. The paper concludes by proposing an integrated MSWM framework that combines technological innovation, stakeholder engagement, and policy reform to promote sustainable waste management across diverse geographic and socio-economic settings.

Keywords: Municipal Solid Waste, Urban-Rural Comparison, Sustainability, Waste Management Practices, Environmental Policy.

EXPLORING THE BIOACTIVE COMPONENTS AND PHARMACOLOGICAL BENEFITS OF A NORTHERN MOROCCAN TRADITIONAL HERB

Nesrine Benkhaira[1,*] Saad Ibnsouda Koraichi[1], Kawtar Fikri-Benbrahim[1]

[1]Laboratory of Microbial Biotechnology and Bioactive Molecules, Faculty of Sciences and Technologies Faculty, Sidi Mohamed Ben Abdellah University, Fes, Morocco

Abstract

Ruta montana L., a medicinal herb in Moroccan folk medicine, has been used to treat infections, hyperglycemia, spasms, and fever. This study uses GC-MS to examine the bioactive constituents of RMEO and analyzes its antibacterial, antioxidant, and antidiabetic actions *in vitro* and using molecular docking approaches.

GC-MS identified 2-undecanone as the main compound of the essential oil. RMEO inhibited α-amylase (IC_{50} = 0.365 ± 0.11 mg/mL) and α-glucosidase (IC_{50} = 0.311 mg/mL), had significant antioxidant potential (FRAP EC_{50} = 188.61 ± 1.12 µg/mL; beta-carotene IC_{50} = 149.21 ± 1.12 µg/mL), and had potent antibacterial effects, particularly against *Micrococcus luteus* and *Staphylococcus aureus* (20.05 ± 0.98 and 18.11 ± 1.11 mm).

It demonstrated modest efficacy against *Candida albicans* (13.05 ± 0.5 mm), with MIC/MBC values ranging from 0.25 to 8% (v/v). Molecular docking and ADME tests confirmed these findings.
Overall, DVEO exhibits remarkable antioxidant, antibacterial, anticandidal, and antidiabetic effects, indicating a potential for natural therapeutic uses.

Keywords: volatile oil, *Ruta montana,* GC-MS, antibacterial, antiradical.

STRUCTURAL, ELECTRONIC, AND THERMOELECTRIC PROPERTIES OF CU_2SE WERE INVESTIGATED USING FIRST-PRINCIPLES CALCULATIONS WITHIN THE DFT-PBE FRAMEWORK.

Faiza Baghida

Physics,Moulay Ismail University Faculty of Sciences

Email: ba.faiza@edu.umi.ac.ma,

Pr. Mourad Boughrara

Physics,Moulay Ismail University Faculty of Sciences

Meknes, Morocco

ABSTRACT

The copper selenide is now being looked at as a possible way to meet the energy needs. Therefore, in this study, the structural and thermoelectric properties of Cu_2Se were investigated using both density functional and classical Boltzmann transport models. The structural. The Perdew-Burke-Ernzerhof (PBE) was utilised to determine the band gaps.We demonstrate a prototype thermal evolution path for liquid thermal conductivity in solids. Thermal evolution of b-Cu2Se shows large interstitial displacement of constituent atoms marked by glass-like transitions and an asymptotic liquid thermal transport. Using LAMMPS, we identify these transitions, and confirm them with in situ transmission electron microscopy and electron energy loss spectros copy. The thermal disorder of the Cu+ ions forms homopolar Cu–Cu bonds under a rigid Se framework, and at yet higher temperatures the Se framework undergoes thermal distortion. The non-equilibrium AIMD prediction of lattice thermal conductivity shows significant suppression of the phonon transport, in agreement with experiments and molecular behavior.

Keywords: DFT, Thermoelectric properties ,Electronic properties.

PRODUCTION AND CHARACTERIZATION OF CARBON NANOTUBES FROM BIOCHAR UNDER MICROWAVE IRRADIATION.

Faisal Nazir

ABSTRACT

Carbon nanotubes (CNTs) are widely used in a variety of fields to produce a diversity of products, including hydrogen storage systems, and field emitters. In the proposed study, CNTs synthesized via biochar under the microwave irradiation method. In this method, the combination of charcoal and ferrocene are used to synthesize CNTs from the biochar approach. Biochar samples for CNTs synthesis are made from pyrolyzed agro-industrial waste such as rapeseed cake, hazelnut hulls, wheat straw, and oat hulls at different temperatures. The biochar was produced from agro-industrial biomass. During experiments, 100g of biomass was placed in a microwave reactor. The samples were pyrolyzed at 400 °C to 600°C. SEM analysis was used to confirm the morphology of CNTs. SEM micrographs revealed the perfect structure of multiwall carbon nanotubes, while interlayers spacing was changed due to variation of catalysts and measured about 0.34nm. Further, the optical properties were examined by UV-visible spectroscopy. In the UV, one band is clear at 240 nm region due to resonance of nanotubes pi(π) electrons of carbon nanotubes. XRD was used to analyze the glassy structure of prepared CNTs under microwave revealed that the creation and growth of CNTs were mostly influenced by microwave irradiation and the ferrocene catalyst. The structure of CNTs was developed under microwave heating and in the presence of ferrocene catalyst. To research how nitrogen impurities adhere to CNTs, FTIR experiments were conducted in the 400–4000 cm^{-1} range. The sample's FTIR spectra exhibit prominent peaks that correspond to C-H and C=C, respectively.

DEVELOPMENT AND OPTIMIZATION OF LOW-COST CLAY-BASED MEMBRANES FOR TEXTILE WASTEWATER MICROFILTRATION

Chlaih Soumaya

Cadi Ayyad University, UCA, Faculty of Science Semlalia, FSSM, Laboratory of Physical Chemistry of Materials and Environment (LPCME)

Marrakech, Morocco

ABSTRACT

This study focuses on the development of a sustainable flat ceramic microfiltration membrane produced from low-cost and environmentally friendly raw materials. The membrane was synthesized and optimized using a statistical design approach to determine the most suitable processing conditions. The obtained material exhibited good mechanical strength, adequate porosity, and high filtration performance, demonstrating effective removal of turbidity and organic pollutants from industrial wastewater. These results confirm the potential of the proposed clay-based membrane as an efficient and eco-friendly solution for wastewater treatment applications.

Keywords: clay, membrane, microfiltration

FROM BIOASSAYS TO SEDIMENT QUALITY INDICES: AN INTEGRATED APPROACH TO ASSESS THE ENVIRONMENTAL STATUS OF COASTAL ECOSYSTEMS.

Khatamı Salma [1,2], El Haımeur Bouchra [2], Bouhallaouı Mına [2], Errhıf Ahmed [1*]

[1] Faculty of Sciences Ain Chock Casablanca.

[2] National Institute of Fisheries Research Casablanca.

ABSTRACT:

Discharging anthropogenic activities into aquatic environments raises significant environmental and health concerns, as they can lead to long-lasting degradation of these critical resources. Industrial effluents often contain a mix of contaminants and pollutants, necessitating a thorough assessment of their potential dangers and risks before release into aquatic ecosystems. However, the ecotoxicological approach is used to determine the toxic effects on organisms pertaining to various ecosystems and supplies information about the contaminants' bioavailability in different matrices, such as sediments.

The use of a single species for a correct evaluation of the toxicity levels can be reductive, concerning the complexity of the ecosystem. In this work, a bioassay battery consisting of three different species representing different trophic levels, algae *Tetraselmis suecica*, crustacean *Artemia salina*, and echinoids *Paracentrotus lividus*, has been used to assess the toxicity of sediment elutriate, porewater, and whole sediment. The sediment samples were collected from four sampling stations along the North Atlantic Coast of Morocco. The test battery used in this study allowed us to screen the ecotoxicological toxicity of the studied area. The species utilized for toxicity tests responded differently to the investigated samples, showing different sensitivity.

However, a difference in sediment toxicity is registered in different studied areas depending on the sedimentary phases. Indeed, the S3 recorded the maximum effect of embryo-larval malformation in the pore water phase. For the whole sediment, S2 recorded the maximum effect, while for the algal growth inhibition bioassay, S1 showed the most pronounced effect.

Keywords: Pollution; sediment; bioassays; elutriate; pore water.

MECHANISTIC UNDERSTANDING OF PEPTOID FORMATION FROM DITHIANE PRECURSORS VIA MULTICOMPONENT REACTIONS: A DFT STUDY

Musrat Shaheen[1]*, Akbar Ali[1], Burhan Khalid[2], Hafiza Zara Saeed[3]

[1]Department of Chemistry, Government College University, Faisalabad, Pakistan

[2]College of Plant Science and Technology, Huazhong Agricultural University, Wuhan, China

[3]Department of Botany, Government College University Faisalabad, Pakistan

ABSTRACT

Peptoids are a type of peptidomimetic where the side chain is linked to the nitrogen atom of the amide group instead of the α-carbon. This modification in the backbone structure is highly prized because it imparts advantageous properties such as increased resistance to proteolysis, enhanced immunogenicity, improved biostability, and better bioavailability. In this study, we concentrated on synthesizing peptoids using a Ugi-4CR-based one-pot method, employing 1,4-dithiane-2,5-diol as the carbonyl component along with amine, carboxylic acid, and isocyanides. We successfully designed and synthesized four new peptoids in good chemical yields, and conducted DFT studies to explore their electronic properties. TD-DFT calculations were used to predict the electronic excitation and orbital contributions of four compounds. A natural bond order (NBO) analysis was performed to examine the electronic transitions of the newly synthesized peptoids, focusing on their charge distribution patterns. Additionally, MEP and NPA analyses were conducted to predict charge distribution in these compounds. The reactivity and stability of the targeted peptoids were assessed using global reactivity descriptors, determined through frontier molecular orbital analysis.

ENHANCING THE ELECTRONIC AND OPTICAL PERFORMANCE OF DYE-SENSITIZED SOLAR CELLS WITH ALIZARIN-BASED DYES: DFT/TD-DFT INVESTIGATIONS

Rajaa Dianya,[b], Said Kerraj[c], Mohamed Kadour Atouailaad,[e], Ahmed Arifd,[e], Abdelkhalk Aboulouard[f,g,h], Mustapha Boulghalat[e], Abdessamad Tounsi[a], Mohammed Salah[b] and Mohammed El idrissi[d]

a: Faculty of Science and Techniques, Sultan Moulay Slimane University, Beni Mellal, Morocco

b: Faculty of Sciences, Chouaïb Doukkali University, El Jadida, Morocco

c: Faculty of Sciences Ben M'Sik, University Hassan II, Casablanca, Morocco

d: TCPA, Faculty Polydisciplinary Sultan Moulay Slimane University, Beni-Mellal, Morocco

e: LC2MCFaculty of Sciences and Technologies, Sultan Moulay Slimane University, Beni-Mellal, Morocco

f: Research Laboratory in Physics and Engineering Sciences, Polydisciplinary Faculty, Beni-Mellal, Morocco

g: Science and Engineering Lab for Energy, National School of Applied Sciences, El Jadida, Morocco

h: Higher School of Education and Training, Beni-Mellal, Morocco

ABSTRACT.

Dye-sensitized solar cells (DSSCs) offer several advantages over traditional silicon-based solar cells, such as lower cost, versatility, and transparency. Titanium dioxide (TiO_2) is widely used as a photocatalyst in DSSCs due to its chemical stability, high photocatalytic activity, photostability, and non-toxicity. This study provides a computational analysis of the geometric, electronic, optical, and photovoltaic properties of ten novel dyes using Density Functional Theory (DFT) and Time-Dependent DFT (TD-DFT). To our knowledge, these dyes have not been previously explored in the literature. Our findings indicate that structural modifications can significantly enhance the electronic, optical, and photovoltaic properties of these dyes. The B3LYP functional was identified as the most effective for predicting the geometric and electronic properties, while TD-DFT calculations with the CAM-B3LYP functional and the 6-31G(d,p) basis set accurately predicted the absorption properties. The absorption maxima of the dyes ranged from 427.82 nm to 755.93 nm, with strong UV-Vis absorption attributed to delocalized π-π* transitions. The calculated band gaps varied from 1.928 eV to 2.425 eV, showing that increased conjugation leads to reduced band gaps and improved dye performance. Open-circuit voltage (Voc) values for TiO_2 ranged from 0.893 eV to 1.38 eV, suggesting good potential for efficient electron injection into the TiO2 conduction band. In conclusion, the ten novel dyes studied exhibit significant potential for use in DSSCs, and the theoretical methods employed here offer a reliable framework for predicting the properties of other materials. This approach can guide the development of new materials designed to improve the performance of DSSCs.

Keywords: Alizarin-based dyes, Dye-sensitized solar cells, DFT, TD-DFT, Photovoltaic materials, Optical properties and Electronic properties

ENVIRONMENTAL IMPACTS OF SMALL-SCALE INTERBASIN WATER TRANSFER ON THE WATER QUALITY IN SOUTHEAST BRAZIL

Felipe Taiti Ukai

São Paulo State University (Unesp), Address: Sorocaba, São Paulo state, Brazil

Email: felipe.ukai@unesp.br,

Gerson Araujo de Medeiros

São Paulo State University (Unesp), Address: Sorocaba, São Paulo state, Brazil

Email: gerson.medeiros@unesp.br

ABSTRACT

Large-scale water transfer projects is an important alternative to face the water scarcity and adopted worldwide. Nevertheless, investments in massive infrastructure, negative environmental impacts and restrictive legislation have required from water managers to adopt new approaches, as small-scale interbasin water transfer (SSIWT), mainly in industrial and urbanized regions. Yet, there is a dearth of research addressing to environmental impacts assessment of SSIWT to support decision-making, especially in developing countries, like Brazil. The main goal of this research was to assess the environmental impacts of water transfer on the quality of surface water in Jundiaí-Mirim river basin, Southeast Brazil. Data from water quality reports carried out by Environmental Company of the State of São Paulo (CETESB) were analysed in the period from 2017 to 2024. During this period, the dates on which there was the water transfer were separated from those on which there was no transposition. The following total metals were analyzed: (Al, Cr, Cu, Fe, Mg, and Mn). Descriptive statistics were performed to test the hypothesis that there was an effect of SSWIT on water quality. The results showed impacts regarding to introducing of ions from Atibaia river in Jundiaí Mirim river and the degradation of banks which influenced significantly on Al, Fe, and Mg concentrations. Our findings give important information of environmental performance of small-scale hydraulic facilities to help the decision makers to establish strategies to reduce negative environmental impacts.

Keywords: Environmental Management; Metals, Water Resources; Sustainable Development.

PRELIMINARY TRIALS OF OPTIMIZING *IN VITRO* PROPAGATION OF THE HYBRID PISTACHIO ROOTSTOCK UCB-1 (*pistacia atlantica* x *pistacia integerrima*) BY BIOREACTORS

Dr. Chokri BAYOUDH[1]

[1]LR21AGR03-Production and Protection for a Sustainable Horticulture, Regional Research Centre on Horticulture and Organic Agriculture (CRRHAB), Tunisia

Email: chokribayoudh@gmail.com

ORCID: 0000-0002-7531-2979

Mrs Hedil GAAYA[2]

[2]Higher Agronomic Institute (ISA), 4042 Chott-Mariem, IRESA-University of Sousse, Tunisia.

Mrs Afifa MAJDOUB[3]

[3]Regional Research Centre on Horticulture and Organic Agriculture (CRRHAB), 4042 Chott-Mariem, IRESA, Tunisia.

Pr. Taoufik BETTAIEB[4]

[4]Laboratory of Horticultural Sciences, National Agronomic Institute of Tunisia, University of Carthage, 43 Avenue Charles Nicolle, 1082 Tunis, Tunisia.

ABSTRACT

The hybrid pistachio rootstock UCB-1 (*Pistacia atlantica* × *P. integerima*) is a considerable commercial rootstock mostly used for the production of pistachio plants because of its greater growth, large productivity and high soil performance. *In vitro* propagation protocols of this rootstock were recently established for the rapid multiplication of high quality plants. Via these protocols, the multiplication step of vitroshoots was mainly performed on solid media (POM, MS and WPM basal media). The use of liquid media, with bioreactors or TIS (Temporary Immersion Systems) containers applied for the multiplication of many crops (Banana, date palm, eucalyptus, etc.) was with great benefits and has highly optimized this micropropagation step. Thus, trials to optimize the *in vitro* multiplication of UCB-1 rootstock by bioreactor was applied on liquid POM medium, enriched with 1 mg/l mT (metatopolin) and 0.2 mg/l IBA (Indole Butyric Acid). Preliminary results show that bioreactors have greatly increased the multiplication rate (MR) of UCB-1 shoots leading to a MR of 2.7, higher than that obtained on solid medium and optimized the vitroplants quality. The micropropagated shoots were with important vigor and height, increasing 2.0 mm in tall during two weeks. Furthermore, these apparatus regenerate vitroplants with less necrosis and are so practical for the professionals since they produce massively high quality plants with reduced costs.

Keyword: Bioreactors, liquid medium, multiplication rate, UCB-1, vitroshoots.

EXPLORING THE POTENTIAL OF *Moringa oleifera* FOR SUSTAINABLE WASTEWATER REMEDIATION

El HANDAOUI El Mehdi[1], Abderrahim JRIFI[1], Omar FANIDI[1]

[1] Laboratory of Intelligent Systems, Industrial and Mechanical Engineering (LISIME) – ENSAM Hassan II university, Casablanca, Morocco.

ABSTRACT

Water pollution by heavy metals such as lead (Pb^{2+}), cadmium (Cd^{2+}), and hexavalent chromium (Cr^{6+}), along with organic pollutants, is a major environmental and public health challenge. Conventional wastewater treatments, although effective, often require high costs, advanced infrastructure, and cause secondary impacts. This study explores the potential of Moringa oleifera seeds as a natural, low-cost, and eco-friendly bioadsorbent and coagulant. Seeds were dried, ground, and applied as powder to contaminated water. Heavy metal removal was evaluated using atomic absorption spectroscopy (AAS), while organic pollution was measured via biochemical oxygen demand over five days (BOD_5). Results showed removal efficiency above 85% for Pb^{2+} and Cd^{2+}, with significant reductions in Cr^{6+} and organic load. These findings confirm the effectiveness of Moringa seeds in improving water quality. Their abundance, biodegradability, and low cost make them suitable for resource-limited areas. This study supports the integration of plant-based materials into sustainable wastewater strategies. Further research is needed to optimize treatment parameters, assess long-term performance, and validate field applicability.

Key words: *Moringa oleifera,* bioadsorbent, Heavy metals, Wastewater, Natural coagulant, Organic pollutants.

KETENCİK BİTKİSİNDE [*Camelina sativa (l.) crantz*] FARKLI AZOT DOZLARININ BAZI VERİM VE KALİTE ÖZELLİKLERİNE ETKİSİ

Prof. Dr.Güngör YILMAZ

Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü Yozgat

Email: gungor.yilmaz@bozok.edu.tr

ORCID: 0000-0003-0070-5484

Dr. Öğr. Üyesi Şaziye DÖKÜLEN*

Tokat Gaziosmanpaşa Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü Tokat

Email: saziye.dokulen@gop.edu.tr

ORCID:0000-0003-2767-7604

Ziraat Yüksek Mühendisi Semra DEMİRLER

Email: semray_demirler@hotmail.com

ORCID: 0009-0007-1576-7246

*Sorumlu yazar: saziye.dokulen@gop.edu.tr

ÖZET

Ketencik (*Camelina sativa* L. Crantz), Brassicaceae familyasına ait tek yıllık yağlı tohumlu bir bitkidir. Ketencik bitkisi yazlık ve kışlık olarak ekilebilmekte ve belli ölçüde kuraklığı toleransı yüksek olan bir bitki olarak bilinmektedir. Bu araştırma, farklı azot dozlarının ketencik bitkisinin verim ve kalite özelliklerine etkilerini belirlenmek amacıyla yapılmıştır. Çalışma, 2017-2018 ve 2018-2019 vejetasyon dönemlerinde Tokat-Kazova şartlarında kışlık ekilerek yürütülmüştür. Araştırma Tesadüf Blokları Deneme Desenine göre üç tekerrürlü olarak düzenlenmiştir. Çalışmada hektara 10 kg tohum hesabıyla Ames 26680 ketencik genotipi kullanılmış, 6 farklı azot (N) dozu (kontrol (0), 40, 80, 120, 160 ve 200 kg/ha) bulguları karşılaştırılmıştır.

Denemede; bitki boyu, bitki başına dal sayısı, bitki başına kapsül sayısı, kapsül başına tohum sayısı, bin tohum ağırlığı, tohum verimi, yağ oranı ve yağ verimi parametreleri incelenmiştir. Çalışmada incelenen özelliklerden kapsül başına tohum sayısı, bin tohum ağırlığı ve yağ oranı hariç diğer özelliklerde gübre dozları arasındaki farklılıklar istatistiki olarak önemli bulunmuştur. Araştırmadan elde edilen iki yıllık sonuçlara göre, bitki boyu 88.3-97.2 cm, dal sayısı 3.9-5.8 adet, bitkideki kapsül sayısı 147.9-187.1 adet, kapsül başına tohum sayısı 13.5-14.2 adet, bin tohum ağırlığı 0.863-0.918 g, tohum verimi 1208.5-1590.8 kg/ha, yağ oranı %32.5-34.4 ve yağ verimi 401.3-524.2 kg/ha arasında değişmiştir.

Tokat-Kazova'da sulama yapmaksızın ketencikte azot dozlarının etkisinin araştırıldığı bu çalışma sonucunda; dekara tohum ve yağ verimi bakımından 120-160 kg/ha azot dozlarının uygun olduğu, gübre tasarrufu dikkate alındığında 120 kg/ha azot dozunun ketencik yetiştiriciliği için yeterli bulunduğu sonucuna varılmıştır.

Anahtar Kelimeler: Azot, Ketencik, Tohum verimi, Yağ oranı

THE EFFECT OF DIFFERENT NITROGEN DOSES ON SOME YIELD AND QUALITY CHARACTERISTICS IN CAMELINA PLANT [*Camelina sativa (l.) crantz*]

ABSTRACT

Camelina (*Camelina sativa* L. Crantz) is an annual oilseed plant belonging to the Brassicaceae family. It can be cultivated both in spring and winter, and is known for its relatively high tolerance to drought. This study was carried out to determine the effects of different nitrogen doses on the yield and quality characteristics of camelina. The study was conducted in Tokat-Kazova during the 2017–2018 and 2018–2019 growing seasons under winter sowing conditions. The experiment was arranged in a Randomized Complete Block Design with three replications. In the study, the Ames 26680 camelina genotype was used with a seeding rate of 10 kg of seed per hectare, and six different nitrogen (N) doses (control (0), 40, 80, 120, 160, and 200 kg/ha) were compared.

The parameters evaluated in the experiment included plant height, number of branches per plant, number of capsules per plant, number of seeds per capsule, thousand seed weight, seed yield, oil content, and oil yield. Among the investigated traits, all parameters except the number of seeds per capsule, thousand seed weight, and oil content showed statistically significant differences between nitrogen doses. According to the two-year results obtained from the study, plant height ranged from 88.3 to 97.2 cm, number of branches per plant from 3.9 to 5.8, number of capsules per plant from 147.8 to 187.1, number of seeds per capsule from 13.5 to 14.2, thousand seed weight from 0.863 to 0.918 g, seed yield from 1208.5 to 1590.8 kg/ha, oil content from 32.5% to 34.4%, and oil yield from 401.3 to 524.2 kg/ha.

As a result of this study, which investigated the effect of nitrogen doses on camelina without irrigation in Tokat-Kazova conditions, it was concluded that nitrogen doses of 120-160 kg/ha were suitable in terms of seed and oil yield per decare, and considering fertilizer efficiency, a nitrogen dose of 120 kg/ha was found to be sufficient for camelina cultivation.

Keywords: Nitrogen, Camelina, Seed yield, Oil ratio

DÜŞÜK ORANLI BİR GÜNEŞ ENERJİSİ YOĞUNLAŞTIRMA SİSTEMİNİN ÜZÜMDE KURUTMA KİNETİĞİNE ETKİLERİ

Dr. Ersin KARACABEY
Manisa Bağcılık Araştırma Enstitüsü
Email: ersin.karacabey@tarimorman.gov.tr
ORCID: 0000-0003-4166-1553
Dr. R. Oğuzhan SOLTEKİN
Manisa Bağcılık Araştırma Enstitüsü
Email: oguz.soltekin@tarimorman.gov.tr
ORCID: 0000-0001-7886-6531
M. Sacit İNAN
Manisa Bağcılık Araştırma Enstitüsü
Email: mustafasacit.inan@tarimorman.gov.tr
ORCID: 0000-0001-8335-4725
Dr. Ahmet CANDEMİR
Manisa Bağcılık Araştırma Enstitüsü
ahmet.candemir@tarimorman.gov.tr
ORCID: 0000-0001-8738-9933

ÖZET

Açık alanda yapılan üzüm kurutma işleminde kuruma süresinin uzaması ürün kalitesi açısından birçok olumsuz etkiye sebep olmaktadır. Bu çalışmada açık alanda üzüm kurutma işleminde kuruma süresini kısaltma amacıyla bir düşük oranlı güneş enerjisi yoğunlaştırma sisteminin farklı çalışma pozisyonlarında nem içeriğine etkileri araştırılmıştır. Yoğunlaştırılmış güneş enerjisi sistemleri güneş ışığının akı yoğunluğunu artırma yolu ile yüksek sıcaklık ve yüksek enerji dönüşüm verimlerine ulaşmak ve bu şekilde ısıl enerji elde etmek için kullanılan bir enerji üretim yöntemidir. Güneş odaklama sistemlerinde güneş ışığı, çeşitli aynalar ve aynalara bağlı güneşi izleme sistemleri vasıtasıyla alıcıya yansıtılarak yüksek sıcaklıklarda ısı enerjisine farklı oranlarda çevrilebilmektedir. Bu çalışmada ise düşük oranlı yoğunlaştırıcı yüzey olarak üründe kararma bozulma vb. etkilere sebep olmamak amacıyla eloksal kaplamalı alüminyum malzeme kullanılmıştır. Eloksal elektrolitik yöntemle alüminyumun oksidasyonu işlemidir. Bu işlem aynı zamanda anodik oksidasyon veya anodizasyon olarak da tanımlanmaktadır. Kaplamanın amacı alüminyumun korozyon direncini arttırmak ve ona hem estetik hem de fonksiyonel değerler katmaktır. Otomotivden inşaat sektörüne kadar farklı alanlarda kullanılabilen eloksallı alüminyum yüzey bazı dalga boylarını emerken bazı dalga boylarını yansıtabilen niteliğe sahiptir. Bu çalışmada malzemenin bu özelliğinden tarımsal kurutmada yararlanılması hedeflenmiştir.

Denemeler Manisa İlinde Ekim ayında yoğunlaştırmalı sistemde 6 kg ve yoğunlaştırma olmayan kontrol grubunda 6 kg “Sultani Çekirdeksiz” üzüm çeşidi kullanılarak yürütülmüştür. Deneme sırasında yöney, yansıtıcı yüzeyin yatay olan açısı, ürünün yerden yüksekliği, yüzeyler

arası mesafe gibi varyasyonlar denenerek optimum çalışma noktası elde edilmeye çalışılmıştır. Yapılan denemeler sonucunda en etkili kurutmanın doğu-batı çift yöneyli, yatayla 47^{o} açı ve yüzeyler arasında 1,40 m mesafenin olduğu sistem ve güneye bakan tek yüzeyli, 47^{o} eğim açılı, ürünün yerden 30-40 cm yerden yukarıda olduğu sistemde gerçekleştiği belirlenmiştir. Tüm ölçümler sonunda Ekim ayı şartlarında %18 son nem değeri baz kabul edildiğinde yoğunlaştırma sisteminin kurutma süresinde %33 oranında kısalma sağladığı tespit edilmiştir.

Anahtar Kelimeler: Kurutma, Üzüm, Güneş Enerjisi, Yoğunlaştırma

EFFECTS OF A LOW-RATE SOLAR ENERGY CONCENTRATION SYSTEM ON DRYING KINETICS OF GRAPE

ABSTRACT

Prolongation of the drying time in open sun drying of grapes causes many negative effects in terms of product quality. In this study, the effects of a low-rate solar energy concentration system on moisture content under different operating positions were investigated in order to shorten the drying time in the open field drying process of grapes. Concentrated solar power systems are a method of energy production used to achieve high temperatures and high energy conversion efficiencies by increasing the flux density of sunlight, thereby generating thermal energy. In solar focusing systems, sunlight is reflected to a receiver by various mirrors and sun-tracking systems connected to the mirrors, which convert it into heat energy at different rates at high temperatures. In this study, anodized aluminum material was used to prevent the product from adverse effects such as darkening, deterioration as reflective surface. Anodizing is the electrolytic oxidation of aluminum. This process is also known as anodic oxidation or anodization. The purpose of the coating is to increase the aluminum's corrosion resistance and add both aesthetic and functional value. Anodized aluminum surfaces, which can be used in a variety of applications from the automotive to the construction industry, have the ability to absorb some wavelengths while reflecting others. This study aimed to utilize this property of the material in agricultural drying.

The experiments were carried out in Manisa Province in October, using 6 kg of Thompson seedless grape variety in the concentration system and 6 kg in the control group without concentrator. During the trial, variations such as direction, angle of the reflective surface with horizontal, height of the product from the ground, and distance between surfaces were tried to obtain the optimum operating point. As a result of the experiments, it was determined that the most effective drying occured in the system with an east-west bidirectional, 47o angle to the horizontal and a distance of 1.40 m between the surfaces, and in the system with a single surface facing south, with a 47o inclination angle, where the product is 30-40 cm above the ground. At the end of all measurements, it was determined that the concentration system provided a 33% reduction in drying time, considering the final moisture value of 18% in October conditions.

Keywords: Drying, Grape, Solar Energy, Concentration

TÜRKİYE ARMUT ÜRETİMİNDE ENERJİ ETKİNLİĞİNİN BELİRLENMESİ

DETERMINATION OF ENERGY EFFICIENCY IN PEAR(*Pyrus Communis)* PRODUCTION IN TÜRKİYE

Servet Sami İPEK

Uludağ Üniversitesi Biyosistem Mühendisliği Ana Bilim Dalı Bursa Türkiye

Email: sservet2023@gmail.com

ORCID: 0000-0002-8371-0416

Prof. Dr.İlknur ALİBAŞ

Uludağ Üniversitesi Ziraat Fakültesi Biyosistem Mühendisliği Bursa Türkiye

Email: ialibas@uludag.edu.tr

ORCID: 0000-0002-1898-8390

PhD Aysel ARSLAN

Malatya Turgut Özal University, Ziraat Fakültesi Biyosistem Mühendisliği Malatya Türkiye

Email: aysel.arslan@ozal.edu.tr

ORCID: 0000-0002-0060-0263.

ÖZET

Türkiye'de armut (*P. communis)* üretimi TÜİK (Türkiye İstatistik Kurumu) 2014 ve 2024 yılları ortalama verilerine göre Bursa İli ve İnegöl İlçesinin Türkiye genelinde karşılaştırmalı armut üretim oranları , İnegöl İlçesi Türkiye'nin % 5,75'i, Bursa İlinin % 14,34'ü, Bursa İli ise Türkiye'nin % 40.20'sini karşılamaktadır. Armut insan sağlığı açısından düşük kalorili, besin değeri zengin, yüksek C ve K vitamin içeriği ile antioksidan özelliği gösteren, lifli bir yapıya sahip, kalp sağlığına pozitif etki eden özellikli bir meyvedir. Dünyada ve Türkiye'de armut tüketimi sırasıyla kişi başına yıllık yaklaşık 2021 yılı TÜİK verisinde 4,4 kg, FAO (Birleşmiş Milletler Gıda ve Tarım Örgütü) verisinde 2,2 kilogram olarak açıklanmıştır. Süregelen tarım uygulamaları enerji tüketim değerlerinin yüksek seviyelerde hesaplanması, üretimin tüm dallarında olduğu gibi armutta da enerji verimliliğinin önemli olduğunu göstermektedir. Bu araştırma; Türkiye genelinde armut üretiminde söz sahibi olan Bursa İli , İnegöl İlçesinde yürütülmüş, enerji bileşenlerinin ,tüm hatları ile ortaya çıkarılması amaçlanmıştır. Basit tesadüfi örnekleme yöntemiyle belirlenen 48 adet armut üreticisiyle 2024 ve 2025 yılları üretim sezonunda yapılan anket verileri değerlendirilmiştir. Armud'un enerji girdi ve çıktıları sırasıyla 114.113,225 MJ ha^{-1}, 291.227,491 MJ ha^{-1} dır. Enerji girdilerinin oransal değişimi büyükten küçüğe sırasıyla makine % 41, fungusit ve insektisitler % 26, dizel yakıt % 13 ve kimyasal gübreler % 11 olarak hesaplanmıştır. Enerji çıktıları sırasıyla meyve % 39,88, budanan dallar % 33,13, yapraklar % 26,98 oranında hesaplanmıştır. Doğrudan enerji ile yenilenebilir enerji sırasıyla % 55, % 56, dolaylı enerji ve yenilenemeyen enerji sırasıyla % 43, % 44 seviyelerinde oransal benzerlik göstermiştir. Enerji verimliliği, özgül enerji değerleri sırasıyla, 1,01, 2,55 ' dir. Enerji verimliliğinin 1,01 olması armut üretiminde enerji kazancının var olduğunu göstermektedir. Türkiye meyveciliğinde ortaya çıkan biyokütle çıktılarının oluşturduğu yenilenebilir enerji miktarları litaratür kaynaklarında ve bu çalışmada görüldüğü gibi dikkatle incelenmeli ve değerlendirilmelidir. Bu çalışma sonuçlarına göre Türkiye'de amut üretiminde belirlenen enerji etkinliği sonuçları, sürdürülebilir tarım için halihazırda ve gelecekte tavsiye edilmesi öngörülen bir meyve çeşiti olduğunu göstermektedir.

Anahtar Kelimeler: Armut,*Pyrus Communis,* Enerji Etkinliği, Biyokütle,Yenilenebilir Enerji

CHANGES IN RED MEAT PRICES IN TÜRKİYE IN RECENT YEARS AND FACTORS AFFECTING PRODUCER PRICE FORMATION

Dr. Öğr. Üyesi Önder Volkan BAYRAKTAR

Siirt Üniversitesi, Ziraat Fakültesi, Tarım Ekonomisi Bölümü, Siirt

Email: onder.bayraktar@siirt.edu.tr

ORCID: 0000-0001-5560-386X

ÖZET

Bu çalışma, Türkiye'de son yıllarda kırmızı et fiyatlarındaki değişimlerin incelenmesi ve bu fiyat değişimlerini etkileyen faktörlerin belirlenmesi üzerine odaklanmaktadır. Kırmızı et, insan beslenmesinin temel bir bileşenlerinden olup, tüketici ve üreticiler için ekonomik ve sosyal öneme sahiptir. Bu nedenle, kırmızı et fiyatlarındaki değişimlerin nedenleri ve sonuçları, tüketicilerin ve üreticilerin yaşamları üzerinde önemli etkilere sahip olabilir. Kırmızı et fiyatlarındaki dalgalanmaların nedenlerini anlamak için çeşitli faktörler dikkate alınmalıdır. Nüfus artışı, gelir seviyelerindeki değişimler, tarım politikaları, hayvancılık sektöründeki gelişmeler ve dış etkiler gibi faktörler, fiyat oluşumunu etkileyebilecek potansiyele sahiptir. Bu çalışmanın amacı, Türkiye'deki kırmızı et fiyatlarındaki değişimleri ve üretici fiyat oluşumunu etkileyen faktörleri sistemli bir şekilde analiz etmektir. Elde edilen bulgular, kırmızı et sektörünün önemli bir bileşeni olan fiyatların zaman içinde önemli ölçüde değiştiğini göstermektedir. Türkiye'de kırmızı et fiyatlarının değişimine etki eden faktörler arasında arz ve talep dengesi, tarım politikaları, döviz kurları, uluslararası ticaret, hayvancılık sektöründeki yapısal değişiklikler ve tüketici tercihleri gibi unsurlar belirlenmiştir. Çalışmanın bulguları, kırmızı et sektöründeki paydaşlara, fiyat değişimlerini daha iyi anlama ve gelecekteki fiyat dalgalanmalarına hazırlıklı olma konusunda fikir sağlamaktadır. Özellikle tarım politikalarının kırmızı et fiyatları üzerindeki etkisi göz önünde bulundurularak, politika yapıcılar ve karar vericiler, sektörde istikrarı sağlamak ve tüketicilere uygun fiyatlar sunmak için stratejiler geliştirmelidir. Bununla birlikte, bu çalışma kırmızı et fiyatlarındaki değişimlerin tüm etkilerini kapsamamaktadır. Gelecekteki araştırmalar, daha derinlemesine analizlerle fiyat değişimlerini daha iyi anlamak için yapılabilir. Bu konuda tüketici davranışı ve tercihlerinin kırmızı et fiyatları üzerindeki etkisini daha detaylı inceleyen çalışmalara da ihtiyaç vardır. Bu çalışmanın sonuçları, kırmızı et sektöründeki paydaşlara, politika yapıcılara ve araştırmacılara önemli bir perspektif sunacaktır. Ayrıca, kırmızı et piyasasının sürdürülebilirliği için öneriler sunulacak ve ileriki çalışmalara ışık tutulacaktır.

Anahtar Kelimeler: Fiyat değişimi, kırmızı et, Türkiye, üretici fiyatı

SON YILLARDA TÜRKİYE'DE KIRMIZI ET FİYATLARINDA MEYDANA GELEN DEĞİŞİMLER VE ÜRETİCİ FİYATI OLUŞUMUNDA ETKİLİ OLAN FAKTÖRLER

ABSTRACT

This study focuses on examining the changes in red meat prices in Turkey in recent years and determining the factors affecting these price changes. Red meat is an essential component of human nutrition and has economic and social importance for both consumers and producers. Therefore, the causes and consequences of changes in red meat prices can significantly impact the lives of consumers and producers. Several factors must be considered to understand the reasons for fluctuations in red meat prices. Factors such as population growth, changes in income levels, agricultural policies, livestock sector developments, and external influences can influence price formation. This study aimed to systematically analyze the changes in red meat prices in Turkey and the factors affecting producer price formation. The findings show that prices, which are an important component of the red meat sector, change considerably over time. Among the factors affecting the change in red meat prices in Turkey, factors such as the supply and demand balance, agricultural policies, exchange rates, international trade, structural changes in the livestock sector, and consumer preferences have been determined. The study's findings provide insights for stakeholders in the red meat sector to better understand price changes and prepare for future price fluctuations. Considering the impact of agricultural policies on red meat prices, policymakers and decision-makers must develop strategies to ensure stability in the sector and offer affordable prices to consumers. However, this study did not cover all the effects of changes in red meat prices. Future research should be conducted to better understand price variations through more in-depth analyses. In this regard, studies that examine the effect of consumer behavior and preferences on red meat prices in more detail are needed. The results of this study will provide an important perspective for stakeholders, policymakers, and researchers in the red meat industry. In addition, suggestions for the sustainability of the red meat market and future studies are presented.

Keywords: Price change, red meat, Türkiye, producer price

AMASYA ÜZÜM GENOTİPLERİNİN SSR MARKÖRLER İLE MOLEKÜLER KARAKTERİZASYONU

Ziraat Yüksek Mühendis Tamer Uysal

Tarım ve Orman Bakanlığı, Tarımsal Araştırmalar ve Politikalar Genel Müdürlüğü, Bağcılık Araştırma Enstitüsü, Tekirdağ, Türkiye

Email: tamer.uysal@tarimorman.gov.tr

ORCID: 0000-0003-0171-0605

Dr. Öğr. Üyesi Funda Yılmaz Baydu

Ankara Üniversitesi Ziraat Fakültesi Bahçe Bitkileri Bölümü, Ankara, Türkiye

Email: fbaydu@ankara.edu.tr

ORCID: 0000-0002-2128-573

Dr. Canan Yüksel Özmen

Ankara Üniversitesi Biyoteknoloji Enstitüsü, Ankara, Türkiye

Email: cananyuksel555@gmail.com

ORCID: 0000-0002-4421-1358

Dr. Onur Ergönül

Tarım ve Orman Bakanlığı, Tarımsal Araştırmalar ve Politikalar Genel Müdürlüğü, Bağcılık Araştırma Enstitüsü, Tekirdağ, Türkiye

Email: onur.ergonul@tarimorman.gov.tr

ORCID: 0000-0002-2251-426X

Semih Yaşasın

Tarım ve Orman Bakanlığı, Tarımsal Araştırmalar ve Politikalar Genel Müdürlüğü, Bağcılık Araştırma Enstitüsü, Tekirdağ, Türkiye

Email: ahmetsemih.yasasin@tarimorman.gov.tr

ORCID: 0000-0003-0693-5432

Dr. Cengiz Özer

Tarım ve Orman Bakanlığı, Tarımsal Araştırmalar ve Politikalar Genel Müdürlüğü, Bağcılık Araştırma Enstitüsü, Tekirdağ, Türkiye

Email: ozercengiz59@gmail.com

ORCID: 0000-0002-9833-3975

Dr. Yılmaz Boz

Tarım ve Orman Bakanlığı, Tarımsal Araştırmalar ve Politikalar Genel Müdürlüğü, Atatürk Bahçe Bitkileri Merkez Araştırma Enstitüsü, Yalova, Türkiye

Email: yilmaz_boz@hotmail.com

ORCID: 0000-0002-2908-7029

Prof. Dr. Hasan Çelik

Ankara Üniversitesi Ziraat Fakültesi Bahçe Bitkileri Bölümü, Ankara, Türkiye

Email: celikh@agri.ankara.edu.tr

ORCID: 0000-0002-8618-9531

Prof. Dr. Gökhan Söylemezoğlu

Ankara Üniversitesi Ziraat Fakültesi Bahçe Bitkileri Bölümü, Ankara, Türkiye

Email: gokhan.Soylemezoglu@agri.ankara.edu.tr

ORCID: 0000-0002-7959-0407

Prof. Dr. Ali Ergül*

Ankara Üniversitesi Biyoteknoloji Enstitüsü, Ankara, Türkiye

Email: ergul@ankara.edu.tr

ORCID:0000-0002-1205-268X

ÖZET

Asmanın anavatanı olan Anadolu'da binlerce yıldır yapılan bağcılık, zengin bir asma genetik çeşitliliğinin oluşmasını sağlamıştır. Hem yerli hem de yabancı birçok üzüm çeşidinin yetiştirildiği ülkemizde, üzüm genetik kaynakları materyalinin muhafazasından 1. derecede sorumlu olan kuruluş Tekirdağ Bağcılık Araştırma Enstitüsü'dür.

TÜBİTAK-TAGEM tarafından desteklenmiş olan (KAMAG Proje no:105G078) bu çalışmada, Tekirdağ Bağcılık Araştırma Enstitüsü Milli Koleksiyon Bağı'nda bulunan toplam 13 adet Amasya üzüm genotipi (2 adet referans: Cabernet Sauvignon (CS) ve Merlot (M) ile birlikte), kullanılmıştır. 19 adet SSR (simple sequence repeats-basit dizi tekrarları) lokusu kullanılarak, Amasya üzüm genotipleri arası genetik ilişkiler değerlendirilmiştir. Her bir SSR lokusuna ait primerler ile gerçekleştirilen PCR sonrası, amplifikasyon ürünlerinin Beckman CEQ TM 8800 Genetik Analiz Sistemi'nde kapiller elektroforezleri gerçekleştirilmiştir. Her bir SSR lokusundan elde edilen allel profillerine göre, genetik parametreler, Identity 1.0, benzerlik oranı indeksi Microsat, genetik ilişki dendogramı ise UPGMA yöntemi kullanılarak NTSYS (versiyon 2.02g, Exeter Software, Setauket, NY) programı ile oluşturulmuştur.

Analizler sonucunda, toplamda allel sayısı 110 olarak belirlenmiş olup, en yüksek allel, VVS2 ve VMC2h4 (9 allel) lokuslarından elde edilmiştir. Tüm lokuslardaki beklenen heterozigotluk (*He*) değerleri 0.275 ile 0.849, gözlenen heterozigotluk (*Ho*) değerleri ise; 0.230 ile 1.000 arasında belirlenmiş olup, en yüksek *He* değeri VVS2, en yüksek *Ho* değeri ise VVS2, VVMD27, VrZAG47 ve VMC2h4 SSR lokuslarında görülmüştür.

13 adet Amasya üzüm genotipinden, 2 adet grup aynı (identical) [(1. grup: 1-6-7 no'lu genotipler (Amasya), 2. grup: 2 ve 3 no'lu genotipler (Amasya)] olarak bulunmuştur. Diğer taraftan, 2 ve 3 no'lu genotipler (Amasya), 11 no'lu genotip (İstanbul Amasya) ile sinonim olurken, 9-10 no'lu genotipler (Beyaz Amasya) ve 4 no'lu genotip (Amasya), 1-2-3-6-7 no'lu genotipler (Amasya) ile birlikte homonimdir.

Amasya üzüm genotiplerinin genetik olarak birbirleri ile ilişkilendirilmesine yönelik elde edilen bu verilerin, yürütülecek çeşit tayini, bitki ıslahı, gen kaynaklarının kontrol ve yetiştiriciliği gibi alanlarda önemli katkılar sağlayacağı düşünülmektedir.

Anahtar Kelimeler: *Vitis vinifera* L., Amasya üzüm genotipleri, SSR markör, genetik karakterizasyon, Türkiye

MOLECULAR CHARACTERIZATION OF AMASYA GRAPE GENOTYPES USING SSR MARKERS

ABSTRACT

Viticulture, practised for thousands of years in Anatolia, the homeland of the grapevine, has led to the development of a rich genetic diversity of grapevines. In our country, where many local and foreign grape varieties are cultivated, the Tekirdağ Viticulture Research Institute is primarily responsible for the preservation of grape genetic resources.

This study, supported by TUBITAK-TAGEM (KAMAG Project No: 105G078), was conducted using a total of 13 Amasya grape genotypes (together with 2 reference varieties: Cabernet Sauvignon (CS) and Merlot (M)) from the National Grapevine Collection Vineyard of the Tekirdağ Viticulture Research Institute. Genetic relationships among the genotypes were evaluated using 19 SSR (simple sequence repeats) loci. Following PCR performed with specific primers to each SSR locus, the amplification products were subjected to capillary electrophoresis using the Beckman CEQ™ 8800 Genetic Analysis System. Based on the allele profiles obtained from each locus, genetic parameters were calculated using Identity 1.0, the similarity index was determined with Microsat, and the genetic relationship dendrogram was constructed by the UPGMA method using the NTSYS software (version 2.02g, Exeter Software, Setauket, NY).

As a result of the analyses, a total of 110 alleles were identified, with the highest number of alleles (9) obtained from the loci VVS2 and VMC2h4. The expected heterozygosity (*He*) values across all loci ranged from 0.275 to 0.849, while the observed heterozygosity (*Ho*) values ranged from 0.230 to 1.000. The highest *He* value was detected at the VVS2 locus, whereas the highest Ho values were observed at the VVS2, VVMD27, VrZAG47, and VMC2h4 SSR loci.

13 Amasya grape genotypes were identified, with two groups being identical [(Group 1: genotypes 1, 6, and 7 (Amasya); Group 2: genotypes 2 and 3 (Amasya)]. On the other hand, genotypes 2 and 3 (Amasya) are synonymous with genotype 11 (İstanbul Amasya), Genotypes 9, and 10 (Beyaz Amasya) and genotype 4 (Amasya) are homonymous with genotypes 1, 2, 3, 6, and 7 (Amasya).

It is considered that the data obtained for the genetic characterization and relationship of Amasya grape genotypes will provide significant contributions to areas such as varietal identification, plant breeding, the management of genetic resources, and cultivation.

Keywords: *Vitis vinifera* L., ‘Amasya’ grape cultivar, SSR marker, genetic characterisation, Türkiye

TÜRK KIL KEÇİLERİNDE BÜYÜME VE YAŞAMA ÖZELLİKLERİNİN GLM VE PCA-BİPLOT İLE ÇOK DEĞİŞKENLİ DEĞERLENDİRİLMESİ

Doç. Dr. Hatice HIZLI

Doğu Akdeniz Tarımsal Araştırma Enstitüsü Müdürlüğü Adana

Email: haticehizli@gmail.com

ORCID: 000-0002-5451-1397

Dr. Şerife ERGÜL

Doğu Akdeniz Tarımsal Araştırma Enstitüsü Müdürlüğü Adana

Email: serife01i@gmail.com,

ORCID: 0000-0002-6516-8942

ÖZET

Bu çalışma, Kıl keçilerinde büyüme performans özelliklerinin klasik ve çok değişkenli istatistiksel yaklaşımlar kullanılarak değerlendirilmesini amaçlamıştır. Veriler, Osmaniye ilinde yürütülen Halk Elinde Küçükbaş Hayvan Islahı Projesi kapsamında 2019-2022 yılları arasında doğan 22.122 oğlaktan elde edilmiştir. Doğum ağırlığı (BW), sütten kesim ağırlığı (WW), günlük canlı ağırlık artışı (ADG) ve yaşama oranı (SR) gibi büyüme ile ilişkili özellikler; yıl, mevsim, cinsiyet, doğum tipi, ana yaşı, sürü büyüklüğü, sürü tipi ve rakım olmak üzere sekiz çevresel ve biyolojik faktörün etkisi altında incelenmiştir.

BW, WW ve ADG özellikleri için Genel Doğrusal Model (GLM), SR için ise ikili lojistik regresyon kullanılmıştır. Ayrıca, değişkenler ile faktör düzeyleri arasındaki çok boyutlu ilişkilerin görselleştirilmesi amacıyla Temel Bileşenler Analizi (PCA) Biplot yöntemi uygulanmıştır. GLM sonuçları, incelenen tüm faktörlerin BW, WW ve ADG üzerinde istatistiksel olarak anlamlı etkiler yarattığını göstermiştir ($p < 0.001$). Elit sürülerde, tek doğan, yaşlı analardan doğan ve erkek cinsiyete sahip oğlakların yaşama olasılıklarının daha yüksek olduğu belirlenmiştir ($p < 0.05$). Yıl, mevsim ve rakım özellikle erken dönem büyüme performansı üzerinde etkili bulunmuş; orta rakımlı bölgelerde ve ilkbaharda doğan oğlakların daha iyi performans gösterdiği tespit edilmiştir.

PCA Biplot analizi, çevresel koşullar, biyolojik özellikler ve büyüme sonuçları arasındaki ilişkileri başarılı bir şekilde görselleştirerek GLM bulgularını desteklemiştir. GLM ve PCA Biplot'un birlikte kullanımı, istatistiksel modelleme ile çok değişkenli grafiksel yorumun tamamlayıcı gücünü ortaya koymuş ve küçükbaş hayvan yetiştiriciliğinde büyüme ve yaşama performansının daha bütüncül biçimde anlaşılmasına katkı sağlamıştır.

Anahtar Kelimeler: Kıl keçisi, Büyüme performansı, Biplot

MULTIVARIATE ASSESSMENT OF GROWTH AND SURVIVAL TRAITS IN TURKISH HAIR GOATS USING GLM AND PCA-BIPLOT

ABSTRACT

This study aimed to evaluate growth performance traits in Turkish Hair goats using both classical and multivariate statistical approaches. Data were obtained from 22,122 kids born between 2019 and 2022 within the National Small Ruminant Breeding Project in Farmers' Hands conducted in Osmaniye, Türkiye. Growth-related traits including birth weight (BW), weaning weight (WW), average daily gain (ADG), and survival rate (SR) were analyzed to assess the effects of eight environmental and biological factors: year, season, gender, birth type, dam age, herd size, herd type, and altitude.

General Linear Models (GLM) were used for BW, WW, and ADG, while binary logistic regression was applied to SR. In addition, a Principal Component Analysis (PCA) Biplot was employed to visualize multivariate relationships among traits and factor levels. The GLM results showed that all examined factors significantly influenced BW, WW, and ADG ($p < 0.001$). Kids born in elite herds, as singletons, from older dams, and of male gender exhibited higher survival probabilities ($p < 0.05$). Year, season, and altitude were particularly influential on early growth traits, with kids raised at mid-altitude regions and born in spring demonstrating superior performance.

The PCA Biplot successfully illustrated associations between environmental conditions, biological characteristics, and growth outcomes, revealing underlying patterns consistent with GLM findings. The combined use of GLM and PCA Biplot emphasizes the value of integrating statistical modeling and graphical multivariate interpretation for animal breeding research.

This comprehensive evaluation contributes to the optimization of breeding and management strategies aimed at improving growth efficiency and kid survivability in small ruminant production systems.

Keywords: Hair goat, Growth performance, Biplot

RECLAIMING THE FRAME: TRANSGENDER SELF-REPRESENTATION AND THE TRANSFORMATION OF TAMIL CINEMA IN *Neela neera soriyan* (2024)

R. Surenderkhanna

Research Scholar, Vellore Institute of Technology, Chennai. Ü

Email: surenderkhanna.r2022@vitstudent.ac.in

Dr. Rajasekaran. V

Associate Professor Sr., Vellore Institute of Technology, Chennai

Email: rajasekaran.v@vit.ac.in

ABSTRACT:

Neela Neera Soriyan (2024) marks a significant moment in Tamil cinema's evolving queer landscape by featuring real transgender individuals performing transgender roles, breaking away from the long-standing tradition of cisgender actors portraying transgender identities in comedic or marginal capacities. Through close textual analysis grounded in performance studies, this paper examines how the film redefines authenticity and self-representation by foregrounding trans bodies, voices, and lived experiences within the cinematic frame. The study explores how *Neela Neera Soriyan* visualises transformation not as a medicalised spectacle or physical transition, but as ongoing processes of emotional resilience, social belonging, and cultural affirmation. Drawing upon Judith Butler's theory of performativity and Susan Stryker's discourse on Tran's embodiment, the paper argues that the film constructs a space for visibility, resistance, and dignity. It further investigates how cinematic acknowledgement of real transgender actors destabilises the cisgender gaze and contributes to broader societal recognition of Trans lives in contemporary Tamil society. The film thus functions as both aesthetic intervention and political praxis, transforming cinematic representation into an instrument of Tran's empowerment and social inclusion.

Keywords: Real Transgender representation, Tamil cinema, performativity, queer embodiment, cisgender gaze, visibility.

ARTHROPODE PARASITES OF BEE – CONOPID FLIES AND EARWIGS

Academician prof Dr Ivan Pavlović
Scientific Institute of Veterinary Medicine of Serbia, Belgrade, Serbia
Email: dripavlovic58@gmail.com
ORCID: 0000-0003-4751-6760
prof dr Nada Plavša
Faculty of Agriculture, Department of Veterinary Medicine, University of Novi Sad, Serbia
Email: plavsa.nada@gmail.com
ORCID: 0000-0001-6745-1218
PhD Aleksandra Tasıć
Scientific Institute of Veterinary Medicine of Serbia, Belgrade, Serbia
Email: alekstasic79@gmail.com
ORCID: 0000-0002-8361-569
PhD Nataša Rajıć-Savıć
Veterinary Ambulance "Minic", Belgrade, Serbia
Email: mrajicsavic@yahoo.com
ORCID: 0009-0003-1675-5643

ABSTRACT

Conopid Flies also known as the thick-headed flie are endoparasitoids of bees. The females rest on flowers, awaiting passing bumble bees or honey bees. They then attack passing bees in flight or sometimes catch bees as they forage on flowers. Upon landing on the bee, the fly prises open a space between two of the bee's body segments, and inserts an egg into the soft body beneath the harder body cuticle. The egg hatches quite quickly inside the bee, and the emerging larvae feeds on the victim, eating it from the inside. Before dies the bee's behavior changes. It spends less time in the nest, and ultimately will no longer return at night, instead seeking cooler locations away from the nest. Whilst still able to forage, research has shown that bees parasitized by conopid flies have a reduced capacity to carry nectar. The conopid fly then overwinters under ground in the body of the host bee, and emerges the following year, now an adult conopid fly, ready to attack more bees and begin the cycle again.

Honey bees are harmed by common earwigs *Forficula auricularia*, garden earwigs *Forficula tomis* and coastal earwigs *Labidura riparia*. In bee colonies, these insects can occur throughout the beekeeping period, but active penetration into hives is observed in the second half of summer and autumn, especially in cool and rainy weather. A mass cluster of earwigs can be observed at the bottom of the hive from the outside, as well as on the inside of the hive cover, in the insulation material, crevices, and on honeycomb, where they feed on honey and perg, contaminating their surface with the products of vital activity, attack sick adult bees, spoil brood. Earwigs bring pathogens of American and European foulbrood into bee colonies and five types of viruses BQCV, DWV, IAPV, KBV and SBV.

Keywords: honey bee, conopid flies, earwigs

UNRAVELLING THE ANTICONVULSANT POTENTIAL OF 1,3,4-OXADIAZOLE-CARBAMOTHIOATES: SYNTHESIS, *IN VIVO* SCREENING, AND ELECTROPHYSIOLOGICAL VALIDATION"

Zainib Razzaq

Department of Chemistry, Drug Design and Medicinal Chemistry Laboratory, Faculty of Physical Science, Government College University, Pakistan

Email: zainibgood@gmail.com

Samreen Gul Khan

Department of Chemistry, Drug Design and Medicinal Chemistry Laboratory, Faculty of Physical Science, Government College University, Pakistan

Email: samreengul@gcuf.edu

Fozia Anjum

Department of Chemistry, Drug Design and Medicinal Chemistry Laboratory, Faculty of Physical Science, Government College University, Pakistan

Email: foziaanjum2008@yahoo.com

Mehr un Nisa

Department of Chemistry, University of Lahore, Lahore 40100, Pakistan

Email: mehr.nisa@chem.uol.edu.pk

ABSTRACT

Epilepsy is a widespread neurological disorder characterized by frequent seizures and affects millions of individuals worldwide. Despite the primary role of antiseizure drugs (ASDs) as therapeutics, about 30% of patients develop drug-resistant epilepsy (DRE). In DRE, seizures are not sufficiently controlled by the existing medications. This highlights the urgent need to develop new ASDs with greater efficacy and tolerability. The moieties 1,3,4-oxadiazole and carboxamide serve as significant pharmacological scaffolds, particularly in antiseizure drugs. In this pursuit, iso-nicotinic acid **(1)** was chemically modified to synthesize 1,3,4-oxadiazole coupled carbamothioate hybrid structures. A series of *N*-Arylated 5-(pyridin-4-yl)-1,3,4-oxadiazole-2-yl-2 sulfanyl carbamide compounds **(6a-6e)** were synthesized in significant yields (74-88%) by substituting the hydrogen atom in the SH group of the oxadiazole moiety **4** with different electrophiles under diverse reaction conditions. The resulting compound structures were verified using spectroscopic techniques such as ^{1}H & ^{13}C-NMR, FTIR, and EI-MS analysis. Later, the synthesized compounds **(6a-6e)** were tested for anticonvulsant potential through *in vivo* experimentation in 6 Hz (32 Hz) and PTZ (80 mg/kg)-induced seizure models. The neuroprotective effects observed in the acute PTZ test were further validated through video-encephalographic (vEEG) analysis. Among the series, compounds **6a** and **6e**, with electron-donating methoxy and ethoxy groups at para positions on the phenyl ring of *N*-substituted carbamides, demonstrated marked protection against seizure onset and progression in both models. Furthermore, pre-treatment with **6a** and **6e** led to a substantial reduction in the development of epileptiform spiking activity, revealing robust anticonvulsive potential.

Keywords: 1,3,4-Oxadiazole, Carbamothioate, Iso-nicotinic acid, Epilepsy, PTZ-induced seizures, 6 Hz, Electroencephalography

UNVEILING ADAPTIVE COMPONENTS FOR ENVIRONMENTAL HETEROGENEITY IN *Ipomoea carnea* JACQ.

Muhammad Safdar[1], Syed Mohsan Raza Shah[1]

[1]Department of Botany, Division of Science and Technology, University of Education, Lahore, Pakistan

ABSTRACT

Environmental heterogeneity is an important factor that affects species richness and provides conditions for adaptation of existing species. Factors affecting the diversity gradient are climatic variation, biotic interactions, territory, ambient vigor, productivity, available water resources and some other factors that direct the historical process by the evaluation of climatic history and phylogeny of niche conversation. Naturally adapted populations of *Ipomoea carnea* Jacq. were collected from various ecological regions of Punjab province to investigate their adaptive components that have been developed under heterogeneous environmental conditions. Multivariate redundancy analysis (RDA) and correlation analysis were done to evaluate the association of soil physiochemical features with different morpho-anatomical and physiological characteristics. *I. carnea* is an invasive species that can rapidly grow, spread and adapt from xerophytic to aquatic habitats. This species showed better growth and biomass production near water bodies. Additionally, it also exhibited some specific anatomical modifications such as aerenchyma formation, sclerification, xylem ray thickness, leaf thickness and large metaxylem area that enable it to survive under harsh environmental conditions. Populations from highly saline habitats showed higher value of osmolytes and ionic contents (K^+ and Ca^{2+}). Furthermore, the populations from highly saline areas also exhibited the maximum uptake of Na^+ content and the lowest uptake of K^+ and Ca^{2+} content. In conclusion, *I. carnea* showed very specific modifications in morpho-anatomical and physiological traits that reveal its ecological success from aquatic to xerophytic habitats.

SYNTHESIS, *IN SILICO* AND *IN VITRO* EVALUATION OF PYRIDYLPIPERAZINE HYBRID DERIVATIVES AS UREASE INHIBITORS

Sumayya Akram

PhD Scholar, Department of Chemistry, Government College University Faisalabad, Pakistan

Email: sumayya.201002384@gcuf.edu.pk

Prof. Dr. Matloob Ahmad

Department of Chemistry, Government College University Faisalabad, Pakistan

Email: matloob.ahmad@gcuf.edu.pk

Dr. Sana Aslam

Department of Chemistry, Government College Women University Faisalabad, Pakistan

Email: dr.sana@gcwuf.edu.pk

ABSTRACT:

Urease, a nickel-dependent enzyme presents in various organisms, facilitate the decomposition of urea, executing nitrogen metabolism by producing ammonia and carbamate. This process increases pH levels, promotes pathogen survival, and may result in infections, including gastric issues like ulcers and cancer in humans. *Helicobacter pylori* utilizes urease to endure the acidic conditions in stomach and facilitates in protein synthesis. To address these infections and prevent the growth of pathogens, it is essential to inhibit urease activity; thus, derivatives of 1-(3-nitropyridin-2-yl)piperazine were synthesized. All of these newly synthesized compounds were examined for their urease inhibition potential by *in vitro* inhibition protocols. The results showed that two compounds are the potent inhibitors, having IC_{50} values of 2.0 ± 0.73 and 2.24 ± 1.63µM, respectively that are lower than the IC_{50} value of the standard thiourea, 23.2 ± 11.0 µM. The hemolysis potential of all the synthesized compounds was also determined; two compounds demonstrated good biocompatibility in human blood cells. Both these potent inhibitors exhibited feasible interactions with the active site of urease, having binding energies of −8.0 and −8.1 kcal/mol, determined by *in silico* analysis. The binding energy of thiourea was −2.8kcal/mol. Consequently, both compounds can act as important inhibitors of urease.

PHYSICOCHEMICAL, NUTRITIONAL, AND SENSORY ATTRIBUTES OF HIGH FIBER FRUIT LEATHER OF RED DRAGON FRUIT-PEEL AND MANGO

U. Das [1*], M.A. Bin Hasan [1], T. Hussain [2], A. Rahman [2], A. Mahmood [3], S. Marma [1], J. Tasnia [2], S. Akter [1], S. Barua [1], N.S. Fabia [1]

1. Department of Applied Food Science and Nutrition, Chattogram Veterinary and Animal Sciences University, Bangladesh

2. One Health Institute, Chattogram Veterinary and Animal Sciences University, Bangladesh

3. Faculty of Fisheries and Food Science, Universiti Malaysia Terengganu, 21300 Kuala Nerus Terengganu, Malaysia

ABSTRACT

Background: The growing demand for sustainable and health-conscious foods has led to innovative uses of fruit by-products. Dragon fruit peel, often discarded, is high in fiber and antioxidants, while mango pulp enhances taste and nutritional value. This study focused on developing a fiber-rich, sustainable fruit leather, assessing its physicochemical, nutritional, and sensory properties to evaluate its potential for commercialization.

Methods: Two fruit leather formulations were prepared: one with spices and one without. Their physicochemical properties including pH, total soluble solids (°Brix), water activity, and ascorbic acid content along with proximate composition (protein, fiber, fat, ash, and carbohydrate content) were assessed using standard methods. Sensory evaluation was conducted with 30 untrained panelists (15 male and 15 female) using a seven-point hedonic scale to assess appearance, odor, texture, taste, spiciness, chewiness, and overall acceptability. Quality parameters such as color, flavor, texture, and taste were also evaluated at 30-day intervals for four months by five trained panelists. Statistical analysis was performed using one-way ANOVA, with results reported as mean±Standard Deviation, using Minitab v21, with statistical significance set at $p<0.05$.

Results: The spiced formulation showed a pH of 4.03, total soluble solids of 35.2 °Brix, water activity of 0.641, and ascorbic acid content of 58.5 mg/100 g. Proximate analysis revealed moisture content of 13.76%, crude protein of 2.74%, crude fiber of 33.91%, crude fat of 0.54%, ash of 3.74%, and carbohydrate content of 20.58%, with an energy value of 98.14 kcal/100 g. Sensory evaluation indicated a preference for the spiced version due to enhanced flavor and aroma, achieving higher acceptability scores.

Conclusion: This research highlights the potential of repurposing dragon fruit peel into a commercially viable, high-fiber snack, contributing to waste reduction and functional food innovation. Additionally, mango further enhances the product's sensory appeal and nutritional profile.

HIGHLIGHTS

High fiber, low energy entirely organic fruit leather as synthetic ingredients were absent.

Honey slightly reduced the total soluble solids due to its water content, affecting texture.

Spices significantly influenced the taste and aroma of the fruit leather.

HYDROGEN PRODUCTION FROM SOLAR ENERGY: A SUSTAINABLE ALTERNATIVE FOR RURAL ENERGY SYSTEMS

Chaymae Denden

National School of Applied Sciences of Oujda(ENSAO),UMP

Email: chaymae.denden@ump.ac.ma

ORCID: 0009-0004-3739-862X

ABSTRACT

The growing global demand for clean and sustainable energy sources has accelerated the search for efficient alternatives to fossil fuels. Among these, hydrogen stands out as a promising energy carrier due to its high energy density and zero carbon emissions at the point of use. This study presents an overview of hydrogen production through water electrolysis powered by photovoltaic (PV) solar energy. The proposed approach highlights the potential of integrating solar PV systems with electrolyzers to generate green hydrogen for rural and agricultural applications. Such systems can provide a stable and renewable energy supply for irrigation, water pumping, and storage, especially in remote or off-grid areas. The paper emphasizes the environmental and economic benefits of solar hydrogen production as a key solution for sustainable rural development and the global energy transition.

Keywords: Hydrogen production, Solar energy, Photovoltaic systems, Electrolysis, Rural development, Sustainability.

THE CONTRIBUTION OF MULTISPECTRAL DRONES TO PRECISION AGRICULTURE IN THE TADLA PLAIN : EFFICIENCY, BENEFITS, AND CHALLENGES

Hasna JINNOU*, Said ARIF and Mohamed Achraf HASNAI*****

*Research Laboratory (Landscape Dynamics, Risks, and Heritage), Faculty of Letters and Human Sciences, Sultan Moulay Slimane University, Béni Mellal, Morocco.
**Professor of Geography at the Faculty of Letters and Human Sciences, Béni Mellal.
***Manager of Farmassist, an agricultural company specializing in agricultural service provision.

ABSTRACT

This study evaluates the use of multispectral drones in agricultural management, highlighting their contribution to optimizing agronomic practices. The experiment, conducted in the Tadla Plain, focused on various crops, including cereals, olive groves, and citrus orchards, to assess the effectiveness of multispectral imaging in detecting water stress, nutrient deficiencies, and pest infestations. The integration of multispectral sensors mounted on drones enabled the early identification of anomalies and targeted interventions through vegetation indices such as the Green Chlorophyll Index (GCI), thereby reducing yield losses and optimizing the use of agricultural inputs.

The results confirm the numerous advantages of this technology: rapid and precise crop monitoring, more efficient use of water resources and fertilizers, and a reduction in the environmental impact of phytosanitary treatments. Compared to conventional approaches, multispectral imaging enhances agronomic decision-making and promotes more sustainable and efficient agriculture. However, certain technical constraints remain and may limit its large-scale deployment.

Despite these challenges, the integration of drones into agronomic monitoring represents a significant step forward in precision agriculture, offering better risk anticipation and more effective crop management.

Keywords : Precision Agriculture, Multispectral Drones, GCI, Crop Management, Tadla Plain.

MECHANISM AND STEREOSELECTIVITY OF HYDROBORATION-OXIDATION REACTIONS OF A-TRANS-HIMACHALENE: INSIGHTS FROM DFT, MOLECULAR DOCKING, AND ADMET INVESTIGATIONS

Mohammed Denzira1*, Ali Barhoumi, Abdessamad Tounsi1, Mohammed El idrissi2

1Team of Chemical Processes and Applied Materials, Sultan Moulay Slimane University, Polydisciplinary Faculty, Beni Mellal, 23000, Morocco.

Email: mohamed.denzira@usms.ma

ABSTRACT

The alcohol C15H26O was synthesized by hydroboration-oxidation of α-transhimachalene (R) with 9-BBN and H2O2/OH- in tetrahydrofuran. The chemoselectivity of the reaction was studied theoretically using molecular density theory (MEDT). Experimental chemoselectivity with optimal interaction was determined appropriately, as predicted by Parr's functions, analysis of the electron localization function (ELF) of the reactants, and energy studies. Furthermore, the hydroboration-oxidation reaction of α-trans-himachalene (R) by 9-BBN and H2O2/OH- exhibits lower activation energy in water and ethanol, demonstrating that this reaction can be carried out in environmentally friendly solvents. The mechanistic study indicates that this hydroboration-oxidation reaction follows a concerted mechanism with asynchronous bond formation. In addition, a docking study was performed by docking α-trans-himachalen (R), alcohol P"1, and alcohol P"2 with the main protease Topoisomerase II (1ZXM) relative to etoposide, and in the main protease of Tubulin (1SA0) relative to taxol. This study showed that alcohols could be candidates for cancer drugs.

Keywords: hydroboration-oxidation, MEDT, ELF, α-trans-himachalene, activation energy.

GIS-BASED MULTICRITERIA ANALYSIS FOR OPTIMAL GREEN HYDROGEN (GH2) PRODUCTION SITE SELECTION

1Amina Yahia

1Amina Yahia : Institute of Urban Management Techniques, Oum el Bouaghi University, Algeria.

Email: yahia.amina@univ-oeb.dz.

ORCID: 0000-0002-3782-1713

ABSTRACT:

The viability of a green hydrogen economy in Algeria depends on successfully exploiting its green energy production, water availability, and its potential to convert to hydrogen. Identifying optimal production sites should encompass the entire hydrogen value chain, while considering all elements influencing the levelized cost of hydrogen (LCOH). This comprehensive approach can ensure the sustainable development of a hydrogen economy in Algeria, while providing insight into potential synergies between the actors involved. This would improve the efficiency of the value chain and potentially reduce the LCOH.

Stable production of green hydrogen requires a constant supply of sustainable energy. Fortunately, Algeria has abundant solar and wind resources suitable for large-scale green hydrogen production. The strategic approach of harnessing both solar and wind sources offers significant benefits. This synergy enhances the stability of sustainable energy supply by mitigating the production fluctuations inherent in variable renewable resources. [1]

This article has been developed to document and deepen knowledge on green hydrogen (GH2) from existing research and policy documents. The demonstrated knowledge is expected to contribute to a better understanding of the factors relevant to the optimal location of GH2 production facilities.

The second objective is to use the knowledge developed under the first objective to identify optimal locations and regions for GH2 production using wind and solar energy. This includes the process and methodology used to leverage geographic information systems (GIS) to identify optimal locations for Algeria's GH2 production facilities. The document details the factors incorporated into the evaluation process, fully explaining the logic behind the importance or weighting assigned to each factor. The analysis results are discussed, and relevant questions to improve the process in future evaluations are presented.

As part of this study, three green hydrogen production scenarios are established:

Scenario 1: Large-scale pilot sites with an electrolyser capacity of 20 to 50 MW,

Scenario 2: Industrial sites with an electrolyzer capacity of 200 to 400 MW,

Scenario 3: Giga-sites with an electrolyzer capacity of 2 GW.

For each of the three GH2 production scenarios, typical configurations including electrolyzers, wind, and solar energy were established. The analysis starts with a 1 MW electrolyzer as a reference. Using current technological data, the potential production of hydrogen is calculated based on different capacity factors (CFs).

Keywords: Green Hydrogen (GH2), Hydrogen Economy in Algeria, Optimal Production Sites, Solar Energy in Algeria, Wind Energy in Algeria, Geographic Information Systems (GIS), Site Selection Methodology.

HEALTH AND NUTRITIONAL BENEFITS OF THE MEDITERRANEAN DIET AND OLIVE OIL CONSUMPTION

Gresa Ahma

University "Haxhi Zeka", Faculty of Agribussines, Food Technology, Peje, Kosovo.

ORCID: 0009-0001-3167-4257

Email: gresa.ahma@unhz.eu

ABSTRACT

The Mediterranean Diet (MedDiet) is widely acknowledged for its significant role in enhancing health and preventing chronic diseases. Characterized by a high intake of plant-based foods such as fruits, vegetables, legumes, whole grains, and nuts, it also emphasizes olive oil as the primary source of dietary fat. While extra virgin olive oil (EVOO) is particularly noted for its rich polyphenol content and antioxidant properties, all forms of olive oil virgin or refined remain essential components of the MedDiet, contributing substantially to its overall health benefits. Although extensive research has demonstrated the MedDiet's positive effects on cardiovascular, metabolic, and cognitive health, current investigations continue to explore the specific mechanisms underlying olive oil's contribution to these outcomes. This paper explores the association between adherence to the MedDiet especially olive oil consumption and improvements in nutritional status as well as the prevention of non-communicable diseases (NCDs). A comprehensive review of recent clinical trials and systematic reviews was conducted, synthesizing data from various populations and study designs. The evidence consistently indicates that regular olive oil consumption within the MedDiet framework is linked to reduced systemic inflammation, improved lipid profiles, lower obesity rates, and enhanced cognitive performance. The high concentration of monounsaturated fatty acids (MUFA) and bioactive compounds in olive oil plays a crucial role in these beneficial effects. Overall, these findings reinforce the value of incorporating olive oil into daily dietary practices and underscore the MedDiet as a sustainable and effective approach to long-term health promotion.

Keywords: Mediterranean Diet, Olive Oil, Nutritional Health, Chronic Disease Prevention, Longevity

AGRICULTURE AND AMINAL SCIENCE DEVELOPMENT

Mustapha Muhammad Imam

Ahlul-Baıty Internatıonal Unıversıty (Abu Tehran)

Department: Archıtecture

ABSTRACT

This article explores the transformative convergence of modern agriculture and animal science, outlining a path toward a more sustainable and efficient global food system. It argues that the integration of digital technologies, genetic advancements, and circular economic models is revolutionizing traditional practices. Key developments discussed include the application of precision agriculture and precision livestock farming (PLF) for data-driven management, the use of genetic tools like CRISPR for developing resilient crops and livestock, and the implementation of integrated crop-livestock systems that minimize waste. The article concludes that this synergistic approach, grounded in the "One Health" principle, is essential for enhancing productivity, improving animal welfare, and ensuring environmental sustainability to meet the challenges of the future.

IMPLEMENTATION OF A NEW PROTOCOL FOR CLEANING/DISINFECTING OF FRUITS AND VEGETABLES AGAINST PESTICIDES

Amel ZITOUNI1, Afaf Oualhaci1, Faiza Ilyas1, Amel BELGACEM1, Azzeddine SENOUCI1.

1Department Of Agri-Food, Faculty Of Science And Technology, University Of Ain Temouchent , ALGERIA;

ABSTRACT

Food safety and human health are closely linked. Unsafe or contaminated food creates a vicious cycle of diseases and poisonings, which can be caused by the presence of pathogens on the surface of agricultural products, as well as their chemical contamination by pesticides and fertilizers. In light of this situation, it is necessary to implement good hygiene protocols aimed at disinfecting fruits and vegetables before consumption.

Our study aligns with this dynamic and aims to achieve two main objectives:

The first is to contribute to improving knowledge of the incidence of food poisoning from pesticide residues and microorganisms. We conducted a survey of 200 university students from various universities in Western Algeria and 50 public health employees in the Aïn Temouchent province (west of Algeria). Of those consulted, 65.2% believe that raw fruits and vegetables contain contaminants, 71.6% have experienced food poisoning from consuming these agricultural products, and 91.2% wish for an appropriate industrial disinfectant/cleaner for fruits and vegetables to be available in the Algerian market. Therefore, we conducted another small survey of 50 people living abroad, where 98% recommended using this product for its effectiveness.

In the second part, our study is dedicated to experimenting with and establishing a good protocol for disinfecting and cleaning fruits and vegetables. The objective is to provide a new depollutant composed of two different products: a disinfectant based on sodium hypochlorite and a cleaner made from citrus lemon essential oil and some natural components, marking the originality of our study.

Key words: Fruits- Vegetables- Contaminants- Pesticides- Microorganisms- Food poisoning.

FROM REFILLABLE TO DISPOSABLE WATER GALLONS: A DILEMMA IN ECO-FRIENDLY WATER CONSUMPTION

Emalisa Emalisa

Faculty of Business, President University – Indonesia

Jhanghiz Syahrivar

Faculty of Business, President University – Indonesia

Corresponding Author: jhanghiz@president.ac.id

ABSTRACT

The transition from refillable to disposable water gallons presents a critical sustainability dilemma. While disposables are promoted as practical, they generate substantially more plastic waste and pose greater environmental and health risks than refillable options, which remain the eco-friendly option. This study investigates the psychological and perceptual factors that may encourage consumer adoption of disposable gallons, with the aim of informing strategies to reinforce refillable systems. Drawing primarily on the Theory of Reasoned Action (TRA), the research examines how perceptions of price fairness, environmental awareness, and health consciousness influence consumer attitudes, and how these attitudes shape purchase intention toward disposable gallons. Data were collected from 300 refillable water gallon users familiar with disposable gallons through an online survey and analyzed using Structural Equation Modeling (SEM). The results show that price fairness, environmental awareness, and health consciousness have a significant impact on attitudes, which in turn predict purchase intention for disposable products. Notably, the positive effect of environmental awareness on attitudes reveals a misalignment between perceived and actual sustainability, suggesting that some consumers mistakenly view disposables as environmentally friendly. This counterintuitive finding underscores the importance of education, communication, and policy interventions to correct misconceptions, discourage reliance on disposables, and promote refillable systems as the more sustainable choice in water consumption.

Keywords: Refillable water gallons; Disposable water gallons; Environmental sustainability; Consumer attitudes; Sustainable water consumption

Discipline/Topic: Environmental Studies

WATER-BASED PROBIOTIC SUPPLEMENTATION IMPROVES GROWTH AND INTESTINAL MORPHOLOGY IN JUVENILE GULSHA TENGRA (*mystus cavasius)*

Mithila Sen

Laboratory of Fish Disease, Department of Aquaculture, Bangladesh Agricultural University, Bangladesh

Email: mithila.1906025@student.bau.edu.bd

ABSTRACT

Probiotics, particularly Bacillus-based formulations, are increasingly used in aquaculture to enhance fish growth. However, their water application methods and optimal dosing for indigenous species like Gulsha Tengra (Mystus cavasius) remain poorly understood. This study evaluated the effects of water-based probiotics on the growth performance and intestinal morphology of M. cavasius. Four treatments were administered: T1 (Control; 0 mg/L B. subtilis), T2 (1 mg/L B. subtilis), T3 (5 mg/L B. subtilis), and T4 (10 mg/L B. subtilis) for 60 days. Results demonstrated that T3 showed significantly better performance compared to others by exhibiting the highest weight gain (WG), specific growth rate (SGR), and the lowest feed conversion ratio (FCR). Moreover, the intestinal morphology was also improved significantly in T3. These findings demonstrate that water-applied B. subtilis probiotic at 5 mg/L significantly enhances growth performance and intestinal health in M. cavasius, providing a practical protocol for small-scale farmers.

Keywords– Probiotics, intestinal morphology, aquaculture, Mystus cavasius

INFLUENCE OF PLASTIC MULCHING ON PHYTOPHTHORA INOCULUM DENSITY IN THE CITRUS ROOT ZONE

MAJJI M'hamed [1,2], TALHA Abdelhak[1], AOUZIOU Brahim[1], BOUNSIR Abdelwahed[1,2], BENKIRANE Rachid[2], BENYAHIA Hamid[1,*]

[1] Research Unit in Plant Breeding and Germplasm Conservation, National Institute for Agricultural Research (INRA), Kenitra, Morocco

[2] Laboratory of Botany, Biotechnology, and Plant Protection, Ibn Tofail University, Kenitra, Morocco

ABSTRACT

Phytophthora root rot is among the most damaging diseases affecting citrus production in Morocco, causing root decay, trunk gummosis, and fruit brown rot. This study evaluated the effect of plastic mulching on the density of Phytophthora inoculum in the rhizosphere of citrus rootstocks. The trial was conducted for one year on new citrus varieties at the El-Menzeh experimental field (INRA, Kenitra). Composite soil samples were collected around the base of trees (15–20 cm depth, four directions) and processed using the dilution plating technique on BARPHY72 selective medium. Results revealed significant variation in inoculum density depending on both rootstock and mulching treatment. Plastic mulching consistently reduced Phytophthora propagule density, with a stronger effect observed in Citrange carrizo compared to Citrus volkameriana. These findings highlight mulching as an effective strategy to limit Phytophthora infection in citrus orchards.

Keywords: Soilborne pathogens, Propagule density, Disease management, Cultural practices, Sustainable agriculture.

AGRO-PHYSIOLOGICAL AND BIOCHEMICAL RESPONSES OF THE 'ANGELINO' CULTIVAR (*prunus salicina l*) UNDER CONDITIONS OF DROUGHT AND HEAT STRESS

Anas Hamdani [1,2*], Rachid Razouk[1], Said Bouda[2], Atman Adiba[1]

[1]National Institute of Agricultural Research (INRA), BO 415, Rabat, Morocco,

[2]Laboratory of Agro-Industrial and Medical Biotechnologies, Faculty of Sciences and Techniques, University of Sultan Moulay Slimane, BP 523, Beni Mellal, Morocco,

Corresponding author: hamdanianasse@gmail.com

ABSTRACT

This study examines the impact of deficient irrigation and high temperatures on the levels of growth, production and physico-chemical quality of the plum cultivar 'Angelino' (Prunus salicina L). The study was conducted in the field of the National Agricultural Research Institute (INRA) experimental estate at 'Ain Taoujdate'. Two stress treatments were applied, namely a drought stress (DS) level of 50% of crop evapotranspiration (ETc), and exposure to a heat stress (HS) of 2.5°C, were compared with on-demand irrigation (100% of ETc) not under thermal stress, during the fruit development period from the fruit set stage until harvest time. Observations were made on various traits that could be stress descriptors, including fruit yield, certain vegetative growth characteristics including shoot length, number of leaves and leaf area, as well as physiological characteristics such as stomatal characteristics, leaf proline, cuticular wax and chlorophyll a and b pigment content, with some chemical and biochemical components of plum quality. The results obtained showed that the effect of drought and heat stress reduced plum productivity by a general average of 61%, vegetative growth also declined by 49% and physiological characteristics decreased by 48% except proline and cuticular wax, although the taste quality of plums has been improved thanks to increases in the content of sugars, amino acids and polyphenols. This illustrates the need for agriculture in the study area to adapt to the conditions imposed and predicted by climate change in terms of water resources and high temperatures.

Keywords: Prunus salicina L, Drought stress, Temperature, Production, Growth, Quality.

BIOFUEL PRODUCTION FROM CHLORELLA SPECIES

[1]H. MUJTABA, A.Y. Bazata, [1]Y. H. RAMBO, [2]A.Y. BAKO

[1]Department of Biology, Collage of Sciences, Federal University of Agriculture Zuru, Kebbi State Nigeria.

[2]Department of Chemistry, Collage of Science Federal university of Agriculture Zuru, Kebbi State, Nigeria

[3]Department of Microbiology, Faculty of Science, Federal University Birnin Kebbi.

Corresponding Author's email; - mujtabaharuna20@gmail.com

ABSTRACT

Biofuels are considered a more sustainable alternative to fossil fuels because they are produced from biomass sources, making them renewable and biodegradabl. This study was carried out to investigate the potential of Chlorella species for biodiesel production. Here is a concise summary of the provided study. This study investigated the potential of Chlorella species for biodiesel production using samples collected from ponds, stagnant water, and drainage sources. Microalgae were identified through microscopic and molecular methods, with Chlorella sorokiniana confirmed via molecular analysis. Cultivation was optimized by adjusting pH, temperature, and light, using three different growth media: BG11, NPK, and Biomark Algal Broth. Among the identified species were Chlorella spp., Spirogyra spp., Chlamydomonas spp., Oedogonium spp., and Microspora spp. BG11 medium supported the highest growth rate (0.140 mg/day), biomass productivity (0.842 mg/ml/day), and oil yield (0.028 ml, 24%). In contrast, NPK medium had the lowest values in all categories. Biodiesel was extracted via mechanical pressing and transesterified using ethanol and sodium hydroxide. BG11-grown microalgae produced the highest biodiesel yield (0.021 ml), while NPK-grown yielded the least (0.00723 ml). The study recommends the use of microalgae, especially Chlorella, as a sustainable and eco-friendly biofuel source.

Keywords: Biofuels, Algae, renewable energy.

RECENT ADVANCES IN MULTICOMPONENT APPROACHES TO THE SYNTHESIS AND BIOACTIVITIES OF PIPERAZINE-BASED MANNICH BASES

Saeeda Mubashra

Department of Chemistry, Government College University Faisalabad, 38000, Pakistan

Matloob Ahmad

Department of Chemistry, Government College University Faisalabad, 38000, Pakistan

Sana Aslam

Department of Chemistry, Government College Women University Faisalabad, 38000, Pakistan

ABSTRACT

Piperazine-based Mannich bases have attracted significant attention in recent years due to their broad range of biological and agricultural applications. These compounds display notable antifungal, antibacterial, antiviral, antioxidant, anti-inflammatory, and anticancer properties, making them valuable candidates for developing new agents against crop and animal pathogens. Their ease of synthesis, structural diversity, and tunable physicochemical properties further enhance their potential as sustainable bioactive molecules.This review summarizes the recent (2020–2025) progress in multicomponent Mannich-type methodologies for constructing functionalized piperazine scaffolds. Key advances in reaction design, catalyst systems, and substrate scope are discussed alongside correlations between structure and biological activity. The relevance of these synthetic strategies to agricultural, environmental, and veterinary research is emphasized, highlighting their contribution to sustainable rural development. Overall, this review provides an updated perspective on piperazine-based Mannich bases, underscoring their growing significance across chemical and life sciences.

VETERİNER TIBBİ ÜRÜNLERİN KALİTE KONTROL TESTLERİ

Dr. Tülay AVCI
Selçuk Üniversitesi Veteriner Fakültesi
Email: tulay.avci@selcuk.edu.tr
ORCID 0009-0005-0817-8182

ÖZET

Veteriner tıbbî ürün, hayvan hastalıklarının teşhisi, önlenmesi, tedavisi veya fizyolojik fonksiyonların düzenlenmesi amacıyla hedef türe uygulanan ya da hedef tür için kullanılmak üzere tüm üretim aşamalarından geçerek kullanıma hazır hâle getirilmiş etkin madde içeren ürünlerdir. Resmi otoriteler tarafından yayımlanan kılavuzlarda, farmasötik ürün, bitmiş ürün, müstahzar ve ilaç gibi farklı şekillerde de ifade edilmektedir. Veteriner ilaç endüstrisi, hayvan sağlığının korunması, antimikrobiyal dirençle mücadele ve gıda güvenliğinin sağlanması açısından veteriner tıbbi ürünün yaşamsal döngüsünün kritik öneme sahip olduğu, sürekli olarak istenilen kalitede ürün üretebilme becerisinin olduğu bir endüstridir. Veteriner tıbbi ürünlerin hedeflenen kalitede üretildiklerinin güvence altına alınmasında resmi otoriteler tarafından gerçekleştirilen denetimler ve konuya ilişkin yapılan düzenlemeler de oldukça önemlidir. Ülkemizde veteriner tıbbi ürünlerin üretimi, ithalatı, ihracatı, kullanımı, reçeteli ya da reçetesiz satışı, izin, kontrol ve teminine ilişkin uygulamaların belirlenmesine yönelik otorite Tarım ve Orman Bakanlığı'dır. İlaç endüstrisinde özellikle son on yılda, farmasötik ürün kalitesinin güvence altına alınmasında yenilikçi yaklaşımların kullanılmaya başlandığı görülmektedir. İyi Üretim Uygulamaları (GMP) çerçevesinde, ulusal ve uluslararası düzenleyici otoritelerin belirlediği kalite, güvenlik ve etkin standartlarına uygun olarak üretilen veteriner tıbbi ürünlerin kalite bütünlüğü, lojistik ve dağıtım süreçlerinin herhangi bir aşamasında bozulma riski taşımaktadır. Veteriner tıbbi ürünlerde yaşanacak bozulmaların ortaya konmasında piyasaya arzı sonrası mevzuat kapsamında yapılan denetlemelerde alınan numunelerin üretici firma tarafından beyan edilen spesifikasyonlara uygunluğunun araştırılması ile mümkündür. Spesifikasyonlar etkin madde miktarı tayini, fiziksel-kimyasal analizler (pH, yoğunluk, çözünürlük vb.), mikrobiyolojik kontroller (sterilite testleri, bakteriyel endotoksinler vb.) ve ambalaj uygunluğu gibi parametreler içermektedir. Bu kapsamda bu derlemede; Veteriner tıbbi ürünlerin piyasaya arz edilirken sunulan raf ömrü spesifikasyon parametreleri kapsamında kalite kontrol testleri hakkında bilgi verilmiştir.

Anahtar Kelimeler: Veteriner Tıbbi Ürün, Kalite Kontrol Testleri, Antimikrobiyal Direnç

QUALITY CONTROL TESTS FOR VETERINARY MEDICAL PRODUCTS

ABSTRACT

Veterinary medicinal products are products containing active substances that have undergone all stages of production to be ready for use, applied to the target species or intended for use on the target species for the diagnosis, prevention, treatment or regulation of physiological functions of animal diseases. In guidelines published by official authorities, they are also referred to in different ways, such as pharmaceutical products, finished products, preparations, and medicines. The veterinary drug industry is one in which the life cycle of veterinary medicinal products is of critical importance in terms of protecting animal health, combating antimicrobial resistance and ensuring food safety, and which has the ability to continuously produce products of the desired quality. Inspections carried out by official authorities and regulations on the subject are also very important in ensuring that veterinary medicinal products are produced to the targeted quality. In our country, the Ministry of Agriculture and Forestry is the authority responsible for determining the practices related to the production, import, export, use, prescription or non-prescription sale, licensing, control and supply of veterinary medicinal products. In the pharmaceutical industry, particularly in the last decade, innovative approaches have been adopted to ensure the quality of pharmaceutical products. Within the framework of Good Manufacturing Practices (GMP), the quality integrity of veterinary medicinal products manufactured in accordance with the quality, safety and efficacy standards set by national and international regulatory authorities is at risk of deterioration at any stage of the logistics and distribution processes. The occurrence of deterioration in veterinary medicinal products can be identified by examining the compliance of samples taken during post-market inspections with the specifications declared by the manufacturing company. Specifications include parameters such as active ingredient quantity determination, physical-chemical analyses (pH, density, solubility, etc.), microbiological controls (sterility tests, bacterial endotoxins, etc.), and packaging suitability. In this context, this review provides information on quality control tests within the scope of shelf life specification parameters presented when veterinary medicinal products are placed on the market.

Keywords: Veterinary Medicinal Product, Control Tests, Antimicrobial Resistance

ISI STRESİNİN SIĞIR ÜREME VERİMİ ÜZERİNE ETKİLERİ

Arş. Gör. Dr. Emel TÜTEN SEVİM
Akdeniz Üniversitesi, Ziraat Fakültesi
Email: tutensevim@akdeniz.edu.tr
ORCID: 0000-0002-3105-6416
Prof. Dr. Sezen ARAT
Tekirdağ Namık Kemal Üniversitesi, Ziraat Fakültesi
Email: sarat@nku.edu.tr
ORCID: 0000-0002-2789-0635

ÖZET

Isı stresi, hayvanların termal konfor bölgesinin üzerinde kalan sıcaklık ve neme maruz kalması sonucunda fizyolojik, metabolik ve davranışsal adaptasyon mekanizmalarının yetersiz kaldığı bir durum olarak tanımlanmaktadır. Isı stresi, hayvan yetiştiriciliğinde verimi etkileyen en önemli çevresel faktörlerden biri olup hayvanların verim performanslarını, sağlıklarını ve refahlarını olumsuz etkileyerek doğrudan veya dolaylı olarak hayvan yetiştiriciliğinde zorluklar yaşanmasına yol açmasından dolayı hayvancılık sektörün de kritik bir sorundur. Küresel iklim değişikliğiyle birlikte artan sıcaklıklar, Türkiye'nin de yer aldığı Akdeniz iklim kuşağındaki bölgelerde hayvancılık için daha da kritik bir sorun haline gelmiştir. Son raporlar da küresel sıcaklığın son 10 yılda 0,25 °C artacağı bildirilmiş ve bu artışın 2100 yılına kadar 1,9 ila 8,5 °C'ye ulaşabileceğini öngörülmüştür. Bu durum göz önünde bulundurulduğunda ısı stresinin önemli ölçüde artacağı ve sürdürülebilir hayvancılığın sağlanmasında daha ciddi zorluklar yaşanmasına neden olacağı söylenebilir.

Sığırlar, yüksek vücut kütlesine sahip olmaları ve sınırlı terleme kapasitelerinden dolayı ısı stresine karşı oldukça hassastır. Sığırlarda ısı stresi; özellikle sıcak ve nemli iklimlerde yaygın olarak görülür ve sığırların vücut ısısını düzenleme yeteneklerini sınırlamaktadır. Hayvanların fizyolojisinde ve genel performansında baskı oluşturarak üreme verimini olumsuz etkilemektedir. Sıcaklık-nem indeksi (SNİ) sığırlarda ısı stresinin şiddetini belirlemede kritik bir rol oynamaktadır ve SNİ'nin 72'nin üzerine çıkması, üreme performansında belirgin düşüşlerle ilişkilendirilmiştir.

Sığır yetiştiriciliğinde üreme verimi, sürünün sürdürülebilirliğinin sağlanması ve dolayısıyla ekonomik kazanç elde edilmesi açısından önemlidir. Ancak ısı stresi, hem dişi hemde erkek sığırlarda üreme fonksiyonlarını doğrudan etkileyerek gebelik oranlarında düşüşe yol açmaktadır. Dişi sığırlarda ısı stresi; hormonel dengesizliklere, zayıf östrus davranışına, ovulasyonun gecikmesine ve oosit kalitesinin düşmesi gibi olumsuzluklar oluşturmaktadır. Ayrıca, ısı stresi sonucunda ineklerde uterus içi sıcaklığındaki artış, embriyonun gelişimini olumsuz etkileyerek, implantasyonda başarısızlıklara dolayısıyla erken gebelik kayıplarına neden olmaktadır. Erkek sığırlarda ise testis dokusundaki oluşan hipertermi, spermatogenez sürecinde aksamalara, sperm kalitesinde bozulmalara neden olarak anormal sperm sayısını artırmaktadır.

Bu çalışmanın amacı, ısı stresinin sığır üreme verimi üzerindeki etkilerini detaylı bir şekilde ele almaktır. Hem dişi hem de erkek sığırlarda ısı stresine maruz kalma sonucu ortaya çıkan fizyolojik ve hücresel değişiklikler, hormonel bozulmalar ve bunun sonucunda ortaya çıkan

embriyo gelişimi ile gebelik oranlarında yaşanan düşüşler değerlendirilecektir. Bunların yanı sıra bu olumsuz etkileri azaltmaya yönelik geliştirilen stratejiler kapsamlı bir şekilde ele alınacaktır.

Anahtar Kelimeler: Sığır, Isı Stresi, Üreme Verimi

EFFECTS OF HEAT STRESS ON CATTLE REPRODUCTIVE EFFICIENCY

ABSTRACT

Heat stress is defined as a condition in which animals' physiological, metabolic, and behavioral adaptation mechanisms fail due to exposure to temperatures and humidity above their thermal comfort zone. Heat stress is one of the most significant environmental factors affecting productivity in animal husbandry and poses a critical problem in the livestock sector because it negatively impacts animals' performance, health, and welfare, directly or indirectly leading to difficulties in animal husbandry. Rising temperatures due to global climate change have become an even more critical problem for husbandry in regions within the Mediterranean climate zone, which includes Turkey. Recent reports have predicted that global temperatures will increase by 0.25°C in the last 10 years, and this increase could reach 1.9 to 8.5°C by 2100. Considering this situation, it can be predicted that heat stress will increase significantly, causing more serious challenges to sustainable animal husbandry.

Cattle are highly susceptible to heat stress due to their high body mass and limited sweating capacity. Heat stress in cattle: It is particularly common in hot and humid climates and limits cattle's ability to regulate body temperature. It negatively impacts reproductive efficiency by putting pressure on animals' physiology and overall performance. The Heat-Humidity Index (THI) plays a critical role in determining the severity of heat stress in cattle, and THI exceeding 72 has been associated with significant decreases in reproductive performance.

In cattle farming, reproductive efficiency is crucial for ensuring herd sustainability and, consequently, economic profit. However, heat stress directly affects reproductive functions in both cow and bull, leading to decreased pregnancy rates. In cow, heat stress causes adverse effects such as hormonal imbalances, poor estrus behavior, delayed ovulation, and decreased oocyte quality. Furthermore, increased intrauterine temperature in cows resulting from heat stress negatively impacts embryo development, leading to implantation failure and, consequently, early pregnancy loss. In bulls, hyperthermia in the testicular tissue disrupts spermatogenesis, impairs sperm quality, and increases abnormal sperm counts.

The aim of this study is to examine in detail the effects of heat stress on cattle reproductive performance. The physiological and cellular changes, hormonal disruptions, and resulting decreases in embryo development and pregnancy rates resulting from exposure to heat stress in both female and male cattle will be evaluated. Furthermore, strategies developed to mitigate these adverse effects will be comprehensively discussed.

Keywords: Cattle, Heat Stress, Reproductive Efficiency

YAĞLI TOHUM KÜSPELERİNDE ÜRENİN REFRAKTİF İNDEKS DEDEKTÖRLÜ YÜKSEK PERFORMANSLI SIVI KROMATOGRAFİ (HPLC-RID) KULLANILARAK BELİRLENMESİ)

Ziraat Yüksek Mühendisi Habil UMUR

Gıda ve Yem Kontrol Merkez Araştırma Enstitüsü

Email: habil.umur@tarimorman.gov.tr

ORCID: 0000-0002-9824-1165

Dr. Öğretim Üyesi Hülya HANOĞLU ORAL

Muş Alparslan Üniversitesi, Uygulamalı Bilimler Fakültesi, Hayvansal Üretim ve Teknolojileri Bölümü

Email: h.hanoglu@alparslan.edu.tr

ORCID: 0000-0003-3626-9637

Ziraat Yüksek Mühendisi Dr. Erdinç ALTINÇEKİÇ

Gıda ve Yem Kontrol Merkez Araştırma Enstitüsü

Email: erdinc.altincekic@tarimorman.gov.tr

ORCID: 0000-0002-8728-3044

Gıda Yüksek Mühendisi Dr. Serhat KOÇER

Gıda ve Yem Kontrol Merkez Araştırma Enstitüsü

Email: serhat.kocer@tarimorman.gov.tr

ORCID: 0000-0003-1926-5167

ÖZET

Yağlı tohum küspeleri, yem sanayinde yaygın olarak kullanılan önemli bir protein kaynağıdır. Yağlı tohum küspelerinin maliyetini düşürmek için protein olmayan nitrojen (NPN) kaynaklarından birisi olan üre eklenebilmektedir. Ancak, yem katkı maddesi olarak eklenen üre miktarının kontrolü hem hayvan sağlığı hem de yasal düzenlemelere uyum açısından büyük önem taşımaktadır. Üre, günümüzde ruminant yemlerinde NPN kaynağı olarak kullanımı Avrupa Komisyonu Uygulama Yönetmeliği (AB) No 839/2012 (EU, 2012) ile yetkilendirilmiş, bitkisel ve hayvansal protein kaynaklarının yerine ikame edilebilen ucuz bir yem katkı maddesi olarak yaygınlaşmıştır.Laboratuvarlarda yemlerde üre olup olmadığı, var yok testleri ile kalitatif olarak belirlendiği gibi, kantitatif olarak da üre miktarı belirlenmektedir. Kantitatif üre tayini çalışmalarında ulusal ve uluslararası kuruluşlar tarafından yayınlanan standartlara uyulmaktadır. Ülkemizde ve AB ülkelerinde üre miktarı, spektrofotometrik yöntemle belirlenmekte, ancak yem içerisinde serbest amino asitlerin olması durumunda yanlış/pozitif sonuçlar alınabilmektedir. Bu araştırmada, sığır süt yemlerinde ürenin kantitatif olarak belirlenmesi için geliştirilen Refraktif İndeks Dedektörlü (RID) Yüksek Performanlı Likit Kromatagrafisi (HPLC) yönteminin, yağlı tohum küspelerindeki etkilerinnin belirlenmesi amaçlanmıştır. Araştırmada piyasada satışa sunulan 3'er adet ayçiçeği tohumu küspesi, kolza tohumu küspesi, pamuk tohumu küspesi ve soya fasulyesi küspelerinin her birine %0.2 ve %2.0 düzeylerinde yemlik granül üre deneysel olarak katılarak spektrofotometrik yöntem ile sonuçları karşılaştırılmıştır. Araştırma sonucunda; HPLC- (RID) yöntemi ile ayçiçeği tohumu

küspesi, kolza tohumu küspesi ve pamuk tohumu küspesine katılan yemlik granül ürenin rutin analiz laboratuvarları tarafından belirlenebileceği kanıtlanmıştır. Bu yöntem ile analiz sonuçlarının güvenirliğini sağlamak için validasyonun yapılması gerektiği sonucuna varılmıştır. Ayrıca bu yöntemin yağlı tohum küspelerinde ürenin belirlenmesi için uygun bir yöntem olma potansiyeline sahiptir.

Anahtar Kelimeler: Yağlı Tohum Küspesi, Üre Analizi, Yüksek Performanslı Sıvı Kromatografi (HPLC), Refraktif İndeks Dedektörü (RID)

DETERMINATION OF UREA IN OILSEED MEALS USİNG HİGH-PERFORMANCE LİQUİD CHROMATOGRAPHY WİTH REFRACTİVE INDEX DETECTİON (HPLC-RID

ABSTRACT

Oilseed meals are an important protein source widely used in the feed industry. To reduce the cost of oilseed meals, non-protein nitrogen (NPN) sources such as urea can be added. However, the control of the amount of urea added as a feed additive is of great importance both for animal health and compliance with legal regulations. Urea is currently authorized for use in ruminant feeds as an NPN source under Commission Implementing Regulation (EU) No 839/2012, and it has become a common feed additive due to its affordability and ability to substitute plant- and animal-based protein sources. In laboratories, the presence of urea in feed can be determined both qualitatively (presence/absence tests) and quantitatively. Quantitative determination of urea is performed according to standards published by national and international organizations. In Türkiye and EU countries, urea levels in feed are generally determined using spectrophotometric methods. However, the presence of free amino acids in feed can lead to false-positive results with these methods. This study aimed to evaluate the applicability of a High-Performance Liquid Chromatography method with Refractive Index Detection (HPLC-RID), developed for the quantitative determination of urea in dairy cattle feeds, to various oilseed meals. For this purpose, three commercial samples each of sunflower seed meal, rapeseed meal, cottonseed meal, and soybean meal were experimentally spiked with feed-grade granular urea at concentrations of 0.2% and 2.0%. The results obtained were compared with those from the spectrophotometric method. The findings of the study demonstrated that the HPLC-RID method can be used by routine analytical laboratories to accurately determine the amount of feed-grade urea added to sunflower seed meal, rapeseed meal, and cottonseed meal. It was concluded that validation of the method is essential to ensure the reliability of the analytical results. Furthermore, this method has significant potential as a suitable tool for the determination of urea in oilseed meals.

Keywords: Oilseed Meal, Urea Analysis, High-Performance Liquid Chromatography (HPLC), Refractive Index Detector (RID)

VETERİNER HEKİMLİKTE TELE-TIP UYGULAMALARININ BİLGİ VE FARKINDALIĞININ ÖLÇÜLMESİ: İNTÖRN ÖĞRENCİLERİ BAKIŞ AÇISI

Doktora Öğrencisi Kemal Çağrı GÖKMEN

Ankara University Institute of Health Sciences, Department of Animal Health Economics and Management, Ankara-Türkiye

ORCID: 0009-0007-6748-7772

Email: kemalcagrigokmen@gmail.com

Dr. Öğr. Üyesi Arzu PEKER

Ankara University, Faculty of Veterinary Medicine, Department of Animal Health Economics and Management, Ankara-Türkiye

ORCID: 0000-0002-5509-2171

Email: agokdai@ankara.edu.tr

Arş. Gör. Şükrü ORKAN

Ankara University, Faculty of Veterinary Medicine, Department of Animal Health Economics and Management, Ankara-Türkiye

ORCID: 0009-0008-5452-9432

Email: orkan@ankara.edu.tr

ÖZET

Tele-Tıp, veteriner hizmetlerinin sunumunda her geçen gün daha belirgin bir dönüşüm sağlamaktadır. Uzaktan ön muayene, danışmanlık ve eğitim gibi alanlarda dijital teknolojiler aracılığıyla yeni olanaklar sunmaktadır. Bu dönüşüm devam ederken; geleceğin veteriner hekimlerinin Tele-Tıp'a nasıl yaklaştığını ve bu teknolojiyi nasıl benimsediğini anlamak, klinik ve akademik uygulamalara başarılı bir şekilde entegre edilmesi açısından büyük önem taşımaktadır. Bu çalışma, mesleğin geleceğini şekillendirecek kilit bir grup olan veteriner fakültesi intörn öğrencilerinin tele-tıp konusundaki bilgi düzeylerini, tutumlarını ve eğitim beklentilerini araştırmaktadır.

2024-2025 eğitim-öğretim yılında Ankara Üniversitesi Veteriner Fakültesi'nde öğrenim görmekte olan 60 intörn öğrenciyle bir anket çalışması yürütülmüştür. Öğrencilerin Tele-Tıp konusundaki başlangıç düzeydeki farkındalıkları düşük olarak belirlenmiş yalnızca %25'i bu kavramı önceden duymuştur. Ancak anket sürecine entegre edilen bilgilendirmeler sonrasında %97'si farkındalıklarının arttığını belirtmiş, %87'si ise çalışma sonrasında daha fazla bilgi edinmek istediğini ifade etmiştir.

Katılımcıların %85'i Tele-Tıp'ın veteriner hekimliği müfredatına entegre edilmesini desteklemektedir. Aynı zamanda %87'si bu teknolojinin klinik vaka çeşitliliğini artıracağına inanmaktadır. Öğrencilerin %91'i Tele-Tıp'ın özellikle uzaktan vaka tartışmalarında, %77'si ise uzman eğitimlerine erişimde kullanılması gerektiğini belirtmiştir. Ayrıca öğrencilerin %78'i, Tele-Tıp'ı gelecekteki mesleki uygulamalarında çeşitli alanlarda kullanmayı düşündüklerini ifade etmiş; bu bağlamda, uzman danışmanlıklarını %65, laboratuvar sonuçlarının uzaktan değerlendirilmesini %70 ve genel klinik rehberlik gibi alanları %70 oranında faydalı

bulmuşlardır. Ayrıca, kırsal bölgelerdeki hayvan sahiplerine erişim sağlama ve yoğun klinik ortamlarında zaman yönetimini kolaylaştırma potansiyeli de vurgulanmıştır.

Bu olumlu yaklaşıma rağmen, bazı engeller de belirlenmiştir. Öğrencilerin %100'ü güvenli ve etik kullanım için yasal düzenlemelere ihtiyaç duyulduğunu vurgulamıştır. Katılımcıların %85'i yanlış tanı riskini, %75'i fiziksel muayene eksikliği ve yetersiz uygulamalı eğitim gibi konularda endişelerini dile getirmiştir. Tele-Tıp'ın klinik yoğunluğu azaltma ve operasyon sonrası izlem süreçlerindeki rolü konusunda ise görüşler farklılık göstermiştir. Bu da yüz yüze bakımın ve fiziki klinik ziyaretlerinin bazı yönlerinin vazgeçilmez olduğunu göstermektedir.

Sonuç olarak, veteriner fakültesi intörn öğrencileri Tele-Tıp'a karşı güçlü bir ilgi ve potansiyel benimseme eğilimi göstermektedir. Bu teknolojinin uygun ve etkili bir şekilde benimsenebilmesi için yapılandırılmış müfredatlara, uygulamaya dayalı eğitimlere ve destekleyici yasal çerçevelere ihtiyaç duyulmaktadır.

Anahtar Kelimeler: Dijital Teknolojiler, Müfredat Entegrasyonu, Tele-Tıp, Veteriner Hekimliği Eğitimi

KNOWLEDGE AND AWARENESS OF TELEMEDICINE APPLICATIONS IN VETERINARY MEDICINE: THE PERSPECTIVE OF INTERN STUDENTS

ABSTRACT

Telemedicine is increasingly driving a more profound transformation in the delivery of veterinary services. Through digital technologies, it offers new opportunities in areas such as remote pre-examination, consultation, and education. As this transformation continues, understanding how future veterinarians perceive and adopt telemedicine is of great importance for its successful integration into both clinical and academic practices. This study investigates the knowledge levels, attitudes, and educational expectations of veterinary faculty intern students who represent a key group shaping the future of the profession regarding telemedicine.

A survey was conducted with 60 intern students enrolled at the Faculty of Veterinary Medicine, Ankara University, during the 2024–2025 academic year. The initial awareness of students on telemedicine was found to be low, with only 25% having previously heard of the concept. However, after the information provided during the survey, 97% reported an increase in their awareness, and 87% expressed a desire to further improve their knowledge on the subject.

A majority of participants (85%) supported the integration of telemedicine into veterinary curriculum, while 87% believed that this technology would enrich the diversity of clinical cases. Moreover, 91% stated that telemedicine should particularly be used in remote case discussions, and 77% emphasized its role in access to expert training. Additionally, 78% indicated that they plan to apply telemedicine in various aspects of their future professional practice; among these, 65% highlighted expert consultations, 70% the remote evaluation of laboratory results, and 70% general clinical guidance as particularly beneficial. The potential of telemedicine to improve access for animal owners in rural areas and to facilitate time management in busy clinical environments was also underlined.

Despite these positive perspectives, some barriers were identified. All students (100%) emphasized the need for legal regulations to ensure safe and ethical use. Concerns were raised by 85% of participants regarding the risk of misdiagnosis, and by 75% regarding the lack of physical examination and insufficient hands-on training. Opinions diverged on the role of telemedicine in reducing clinical workload and in post-operative follow-up processes, indicating that certain aspects of face-to-face care and physical clinical visits remain indispensable.

In conclusion, veterinary intern students demonstrated strong interest and potential willingness to adopt telemedicine. For proper and effective adoption, there is a clear need for structured curriculum, practice-based training, and supportive legal frameworks.

Keywords: Curriculum Integration, Digital Technologies, Telemedicine, Veterinary Education

Gynura aurantiaca (MOR YAPRAK) BİTKİSİNDE FeEDDHA DEMİR KAYNAĞININ FARKLI DOZLARININ KALLUS İNDÜKSİYONU VE BİTKİ REJENERASYONU ÜZERİNDEKİ ETKİLERİ

Dr. Mansur Hakan EROL

Çukurova Üniversitesi, Biyoteknoloji Araştırma ve Uygulama Merkezi, Adana, Türkiye

Email: hknmnsr@gmail.com

ORCID: 0000-0003-2424-5670

ÖZET

Gynura aurantiaca, yaygın adıyla mor yaprak veya mor kadife bitkisi, Asteraceae familyasına ait, dikkat çekici morumsu yapraklarıyla tanınan bir süs bitkisidir. Yaprak yüzeyindeki kadifemsi tüyler, bitkiye hem estetik hem de ayırt edici bir görünüm kazandırır. Genellikle iç mekân süs bitkisi olarak değerlendirilmekle birlikte, içerdiği antosiyanin bileşikleri sayesinde yüksek antioksidan potansiyeli ile biyoteknolojik uygulamalarda da dikkat çekmektedir.

Bu çalışmada, mor yaprak bitkisinin *in vitro* koşullarda yaprak eksplantlarından kallus oluşumu ve bitkiye dönüşüm süreçlerinde alternatif demir kaynağı olan FeEDDHA'nın farklı dozlarının etkisi araştırılmıştır. Standart demir kaynağı olarak kullanılan FeEDTA (100 µM) kontrol grubu olarak değerlendirilmiştir. Kültür ortamı olarak Murashige ve Skoog (MS) besin ortamı kullanılmış ve FeEDDHA demir kaynağı 100, 200, 400 ve 800 µM dozlarında uygulanmıştır. Kallus oluşumu yüzdesi, kallus ağırlığı, kallus alanı, elde edilen bitki sayısı ve bitkiye dönüşüm yüzdesi parametreleri değerlendirilmiştir.

FeEDDHA'nın 200 µM dozunda kallus ağırlığı ve kallus alanı en yüksek düzeyde gözlenmiştir. Bitkiye dönüşüm yüzdesi açısından 100 µM FeEDDHA uygulaması, FeEDTA kontrol grubuna göre anlamlı şekilde daha yüksek bulunmuştur. 800 µM dozda ise kallus oluşumu ve bitkiye dönüşüm belirgin şekilde azalmış, bazı tekrarlar tamamen inhibe olmuştur. LSD analizine göre dozlar arasında istatistiksel olarak anlamlı farklılıklar saptanmıştır ($p < 0.01$).

FeEDDHA demir kaynağı, uygun dozlarda kullanıldığında mor yaprak bitkisinin in vitro rejenerasyonunu FeEDTA kontrolüne kıyasla daha etkin şekilde desteklemektedir. Özellikle 100–200 µM aralığı, kallus verimliliği ve bitkiye dönüşüm açısından optimal doz aralığı olarak öne çıkmaktadır. Bu sonuçlar, mikropropagasyon protokollerinde demir kaynağı seçiminin kritik rolünü vurgulamaktadır.

Anahtar Kelimeler: Mor kadife bitkisi, FeEDDHA, in vitro, Kallus indüksiyonu, Bitki rejenerasyonu

EFFECTS OF DIFFERENT DOSES OF FEEDDHA IRON SOURCE ON CALLUS INDUCTION AND PLANT REGENERATION IN *Gynura aurantiaca* (PURPLE LEAF)

ABSTRACT

Gynura aurantiaca, commonly known as purple leaf or purple velvet plant, is an ornamental species belonging to the Asteraceae family, recognized for its striking purplish foliage. The velvety trichomes on the leaf surface not only enhance its aesthetic appeal but also contribute to its distinct identity. While primarily cultivated as an indoor ornamental plant, its high antioxidant potential, attributed to anthocyanin compounds, has drawn attention in biotechnological applications.

In this study, the effects of different doses of the alternative iron source FeEDDHA on callus induction and plant regeneration from leaf explants of Gynura aurantiaca under *in vitro* conditions were investigated. The standard iron source FeEDTA (100 µM) was used as the control group. Murashige and Skoog (MS) medium was supplemented with FeEDDHA at concentrations of 100, 200, 400, and 800 µM. Parameters including callus formation percentage, callus weight, callus area, number of regenerated plants, and plant conversion percentage were evaluated.

The highest callus weight and area were observed at 200 µM FeEDDHA. In terms of plant conversion percentage, the 100 µM FeEDDHA treatment showed significantly higher values compared to the FeEDTA control. At 800 µM, both callus formation and plant regeneration were markedly reduced, with some replicates showing complete inhibition. LSD analysis revealed statistically significant differences among the tested doses ($p < 0.01$).

FeEDDHA, when applied at appropriate concentrations, enhanced the in vitro regeneration of Gynura aurantiaca more effectively than the FeEDTA control. Particularly, the 100–200 µM range emerged as the optimal dose window for promoting callus productivity and plant regeneration. These findings underscore the critical role of iron source selection in micropropagation protocols.

Keywords: Purple velvet plant, FeEDDHA, in vitro, Callus induction, Plant regeneration

AVERMEKTİN VE DİAMİD GRUBU İNSEKTİSİTLERİN YUMURTA PARAZİTOİDLERİ TRICHOGRAMMA EVANESCENS VE T. PINTOI'YE AKUT TOKSİSİTELERİNİN DEĞERLENDİRİLMESİ

Dr. Adil Tonğa

Diyarbakır Zirai Mücadele Araştırma Enstitüsü, Entomoloji Bölümü, 21110, Sur, Diyarbakır

Email: adton21@gmail.com

ORCID: 0000-0001-7485-8411

ÖZET

Yumurta parazitoitleri, özellikle Trichogramma türleri, Lepidopter zararlılar da dahil olmak üzere ekonomik olarak önemli, geniş bir herbivor böcek kitlesinin kontrolündeki etkinlikleri sayesinde tarımsal ekosistemlerde büyük öneme sahiptir. Ancak, hedef dışı akut insektisit maruziyeti dahil olmak üzere birçok faktör, parazitoitlerin ekolojik fonksiyonunu parazitleme potansiyelini azaltarak ve davranışsal tepkilerini değiştirerek olumsuz etkileyebilir. Bu çalışma, generalist yumurta parazitoitleri Trichogramma evanescens ve T. pintoi üzerinde iki avermektin (abamectin ve emamectin benzoate), iki diamid (chlorantraniliprole ve flubendiamide) ve hazır kullanıma yönelik bir karışım (chlorantraniliprole + abamektin) insektisidinin akut toksisitesini değerlendirmektedir. İlk deneyler, her insektisidin her iki türde %10-90 ölüm oranına yol açan konsantrasyon aralıklarını belirlemek amacıyla yapılmıştır. Buna göre, her insektisid için LC30 ve LC50 konsantrasyonlarını hesaplamak üzere probit analizi uygulanmıştır. Avermektinler her iki parazitoit için benzer toksisite göstermiş, flubendiamid değişken toksisite göstermiş ve chlorantraniliprole her iki parazitoit türü için toksik bulunmamıştır. Risk katsayısı analizleri, her iki diamidin güvenli olduğunu, abamektin ve karışımının tehlikeli olduğunu ve emamektin benzoatın parazitoitler için hafiften orta derecede güvenli olduğunu göstermiştir. Bundan sonraki denemelerde, insektisitlerin LC30 ve LC50 konsantrasyonlarının her iki türün beslenme performansı ve çeşitli davranışsal parametreleri üzerindeki etkileri incelenecektir. Son olarak, bu bulgular, avermektin ve diamid insektisitlerinin Trichogramma parazitoitleri üzerindeki akut etkilerine ilişkin önemli bilgiler sağlayarak toksikolojik ve davranışsal değerlendirmeleri birleştirecek ve doğal zararlı kontrol etkinlikleri üzerindeki potansiyel sonuçların daha iyi değerlendirilmesine olanak tanıyacaktır.

Anahtar kelimeler: probit analizi, davranışsal değerlendirmeler, parazitlenme performansı, risk katsayısı

ASSESSING THE ACUTE TOXICITY OF AVERMECTIN AND DIAMIDE INSECTICIDES TO THE EGG PARASITOIDS TRICHOGRAMMA EVANESCENS AND T. PINTOI

ABSTRACT

Egg parasitoids, particularly those from the genus Trichogramma, are of great importance in agricultural ecosystems thanks to their efficiency in controlling a wide range of herbivorous insects including economically significant Lepidopteran pests. However, numerous factors including non-target acute insecticide exposure, can compromise their ecological function by reducing parasitism potential and altering behavioral responses. This study evaluates the acute toxicity of two avermectins (abamectin and emamectin benzoate), two diamides (chlorantraniliprole and flubendiamide), and one ready-to-use mixture of chlorantraniliprole + abamectin on the generalist egg parasitoids Trichogramma evanescens and T. pintoi. Initial experiments were conducted to determine the concentration ranges of each insecticide that caused 10-90% mortality in both species. Probit analysis was accordingly employed to calculate LC30 and LC50 concentrations for each insecticide. Avermectins were similarly toxic to both parasitoids, flubendiamide showed variable toxicity, and chlorantraniliprole was not toxic to both parasitoid species. Risk quotient indicated that both diamides are safe, abamectin and its mixture are dangerous and emamectin benzoate is slightly to moderate safe to the parasitoids. Future experiments will investigate the effects of LC30 and LC50 concentrations on feeding performance and several behavioral parameters of both species. Finally, these findings will provide significant insights into the acute effects of avermectin and diamide insecticides on Trichogramma parasitoids, integrating toxicological and behavioral assessments to better evaluate potential consequences for their natural pest control efficiency.

Keywords: probit analysis, behavioral assessments, parasitism performance, risk quotient,

KENEVİR (*Cannabis sativa l.)* CPDNA'SINDA POTANSİYEL MUTASYON BÖLGELERİNİN TANIMLANMASI

Dr. Öğr. Üyesi Saber DELPASAND KHABBAZI

Yozgat Bozok Üniversitesi, Kenevir Araştırmaları Enstitüsü

Email: saber.d.khabbazi@yobu.edu.tr

ORCID: 0000-0002-1697-9327

ÖZET

Kenevir (Cannabis sativa L.), Cannabaceae familyasına ait, kökeni Orta Asya'ya dayanan ekonomik ve biyoteknolojik açıdan büyük öneme sahip bir bitkidir. Lif, tohum ve kannabinoid içeriği sayesinde hem endüstriyel hem de tıbbi alanlarda geniş kullanım potansiyeline sahiptir. Lifleri tekstil, kağıt ve kompozit malzeme üretiminde değerlendirilirken; tohumları gıda, besin takviyesi ve yağ üretimi için kullanılmaktadır. Kannabinoid bileşikleri ise farmasötik ve terapötik uygulamalarda giderek artan bir şekilde değerlendirilmektedir. Ancak bitkinin yüksek tetrahidrokannabinol (THC) içeriği ve psikoaktif etkileri, birçok ülkede yetiştiriciliğini sıkı yasal düzenlemelere tabi kılmaktadır. Cannabis cinsinin tür düzeyindeki sınıflandırması bilimsel olarak tartışmalıdır. Bazı araştırmacılar cinsi yüksek polimorfizme sahip tek bir tür olarak değerlendirirken, bazıları morfolojik ve kimyasal farklılıklara dayanarak birden fazla türden oluşan bir cins olarak sınıflandırmaktadır. Geleneksel sınıflandırma yöntemleri çoğu zaman çevresel koşullardan etkilenmekte ve kesin sonuçlar vermemektedir. Bu bağlamda, DNA temelli genetik belirteçlerin kullanımı, bitki türleri ve çeşitlerinin doğru, hızlı ve maliyet etkin biçimde tanımlanmasını sağlayan güvenilir bir yöntem olarak öne çıkmaktadır. Bu belirteçler ayrıca endüstriyel kenevir ile yasa dışı esrar türlerinin ayırt edilmesinde ve uyuşturucu ticaretinin izlenmesinde de etkili araçlardır. Bu çalışmada, kenevir kloroplast DNA'sında (cpDNA) mutasyon yoğunluğunun yüksek olduğu bölgeler detaylı olarak incelenmiştir. Farklı genotipler arasında tespit edilen dizi varyasyonları ve kısa ardışık tekrarların (SSR) birikimi, CLPP genik ve ndhF–rpl32 intergenik bölgelerinin potansiyel moleküler belirteçler olarak kullanılabileceğini göstermektedir. Bu bölgeler, genotipe özgü markörlerin geliştirilmesi için uygun hedeflerdir. Elde edilen sonuçlar, kenevirde çeşit ayrımı, popülasyon genetiği ve markör destekli ıslah programları için sağlam bir bilimsel temel oluşturmakta ve genetik kaynakların korunmasına yönelik stratejilerin geliştirilmesine katkı sağlamaktadır.

Anahtar Kelimeler: cpDNA, Genetik varyasyon, Kenevir, SSR

IDENTIFICATION OF POTENTIAL MUTATION HOTSPOTS IN THE CHLOROPLAST DNA OF HEMP (CANNABIS SATIVA L.)

ABSTRACT

Hemp (Cannabis sativa L.) is an economically and biotechnologically significant plant of the Cannabaceae family, with origins traceable to Central Asia. Owing to its fibre, seed and cannabinoid content, it holds substantial potential for both industrial and medicinal applications. Its fibres are employed in textile production and composite materials, its seeds serve as a source of food and oil, and its cannabinoid compounds are increasingly utilised in pharmaceutical and therapeutic contexts. Nevertheless, the elevated concentrations of tetrahydrocannabinol (THC) and the associated psychoactive properties of the species have resulted in legal restrictions on its cultivation in numerous jurisdictions. The species-level taxonomy of the Cannabis genus has been a subject of longstanding debate. Some researchers treat the genus as a single, highly polymorphic species, whereas others recognise multiple distinct species based on morphological and chemical differences. Conventional classification methods are often influenced by environmental conditions and consequently may produce ambiguous or non-definitive results. In this context, DNA-based genetic markers have emerged as a reliable, rapid and cost-effective alternative for the accurate identification of plant species and cultivars. In the present study, regions of the hemp chloroplast genome (cpDNA) exhibiting elevated mutation density were investigated. Sequence variation detected among diverse C. sativa genotypes particularly the accumulation of simple sequence repeats (SSRs) indicates that the CLPP genic region and the ndhF–rpl32 intergenic region represent promising candidates as molecular markers. These loci appear suitable targets for the development of genotype-specific markers in hemp. The findings contribute a solid scientific basis for cultivar discrimination, population genetic analyses and marker-assisted breeding programmes. Moreover, the data generated herein are pertinent to the conservation of hemp genetic resources and the formulation of sustainable breeding strategies.

Keywords: cpDNA, Genetic variation, Hemp, SSR

KANLI İSHAL BELİRTİLİ KÖPEKLERDE ASKARİDİOZİS VARLIĞININ ARAŞTIRILMASI

AdemTANIŞMAN

Yüksek Lisans Öğrencisi**,** Iğdır Üniversitesi, Biyomühendislik ve Bilimleri Anabilim Dalı

Semih PAMUK

Yüksek Lisans Öğrencisi**,** Iğdır Üniversitesi, Zootekni Anabilim dalı

Oruç ŞAHNAR

Yüksek Lisans Öğrencisi**,** Iğdır Üniversitesi, Zootekni Anabilim dalı

Doç. Dr. ADNAN AYAN

Aksaray Üniversitesi, Veteriner Fakültesi, Veterinerlik Parazitolojisi

ORCID: 0000-0002-6564-3416

Dr. Öğr. Üyesi FATMA ERTAŞ OĞUZ

Iğdır Üniversitesi Tuzluca MYO Tıbbi Hizmetler ve Teknikler Bölümü.

Email: Fatmaertas.@igdir.edu.tr

ORCID: 0000-0001-5289-071X

ÖZET

Köpeklerde görülen paraziter enfeksiyonlardan askaridiozis, hem hayvan sağlığını hem de halk sağlığını tehdit eden önemli zoonotik bir hastalıktır. Bu hastalık özellikle genç köpeklerde sık rastlanan, gastrointestinal sisteme yerleşir. Hastalığın etkeni genellikle Toxocara canis olup, nadiren Toxascaris leonina türü de köpeklerde görülmektedir. Askaridlerin yaşam döngüsü karmaşık olup, transplasental, laktasyonel ve oral yollarla bulaşma görülebilir. Bu durum, özellikle yavru köpeklerin erken dönemde enfekte olmasına neden olmaktadır. Askarid larvaları, konağın ince bağırsağında gelişim gösterirken mekanik irritasyon, mukozal hasar ve besin emiliminde bozulmaya yol açar. Yoğun enfeksiyonlarda kusma, karın şişkinliği, kilo kaybı, iştahsızlık ve kanlı ishal gibi belirgin klinik semptomlar ortaya çıkabilir. Parazitin neden olduğu mukozal zedelenme ve sekonder bakteriyel enfeksiyonlar, hastalığın seyrini daha da ağırlaştırabilir. Özellikle yavru köpeklerde yüksek parazit yükü, gelişme geriliği ve hatta ölüme kadar ilerleyebilen ciddi komplikasyonlara yol açabilmektedir. Bu çalışma, kanlı ishal belirtileri gösteren köpeklerde askaridiozis enfeksiyonunun varlığını belirlemek ve bu paraziter enfeksiyonun klinik bulgularla ilişkisini ortaya koymak amacıyla yürütülmüştür. Araştırma, farklı yaş, cinsiyet ve ırka sahip toplam 50 adet köpek üzerinde gerçekleştirilmiştir. Hayvanlardan alınan taze dışkı örnekleri, laboratuvar ortamında makroskobik ve mikroskobik olarak değerlendirilmiştir. Makroskobik incelemede dışkının kıvamı, rengi, kan ve mukus varlığı kaydedilmiştir. Mikroskobik incelemelerde ise özellikle Toxocara canis ve Toxascaris leonina yumurtalarının tanımlanması amacıyla flotasyon (şeker çözeltisi yöntemi) ve sedimantasyon teknikleri kullanılmıştır. Sonuçlar, incelenen köpeklerin %30'unda askarid yumurtalarının tespit edildiğini göstermiştir. Enfeksiyon oranının özellikle 6 aydan küçük yavru köpeklerde ve dış ortamda yaşayan hayvanlarda daha yüksek olduğu belirlenmiştir. Pozitif olguların büyük bir kısmında dışkıda taze veya pıhtılaşmış kan, mukus, karın şişkinliği ve kilo kaybı gibi belirtiler gözlemlenmiştir. Ayrıca bazı köpeklerde anemi, iştahsızlık ve halsizlik gibi sistemik bulgular da rapor edilmiştir. Elde edilen veriler, kanlı ishal olgularında askaridiozisin

göz ardı edilmemesi gereken önemli bir etken olduğunu göstermektedir. Sonuç olarak, köpeklerde görülen kanlı ishal vakalarının değerlendirilmesinde paraziter nedenlerin, özellikle askarid enfeksiyonlarının mutlaka dikkate alınması gerektiği sonucuna varılmıştır. Düzenli antiparaziter tedavi programlarının uygulanması, dışkı muayenelerinin periyodik olarak yapılması ve çevresel hijyenin sağlanması, hem bireysel hayvan sağlığı hem de zoonotik riskin azaltılması açısından büyük önem taşımaktadır.

Anahtar Kelimeler: Köpek, Askaridiozis, Kanlı ishal, Toxocara canis

INVESTIGATION OF THE PRESENCE OF ASCARIASIS IN DOGS WITH SYMPTOMS OF BLOODY DIARRHEA

ABSTRACT

Askaridiosis, a parasitic infection seen in dogs, is an important zoonotic disease that threatens both animal and public health. This disease is particularly common in young dogs and affects the gastrointestinal system. The causative agent is usually Toxocara canis, although the species Toxascaris leonina is also rarely seen in dogs. The life cycle of ascarids is complex, and transmission can occur through transplacental, lactational, and oral routes. This situation causes puppies to become infected early on. Ascarid larvae develop in the host's small intestine, causing mechanical irritation, mucosal damage, and impaired nutrient absorption. In heavy infections, pronounced clinical symptoms such as vomiting, abdominal distension, weight loss, loss of appetite, and bloody diarrhea may occur. Mucosal damage caused by the parasite and secondary bacterial infections can further aggravate the course of the disease. High parasite load, especially in puppies, can lead to serious complications, including growth retardation and even death. This study was conducted to determine the presence of ascariasis infection in dogs showing symptoms of bloody diarrhea and to reveal the relationship between this parasitic infection and clinical findings. The study was conducted on a total of 50 dogs of different ages, genders, and breeds. Fresh fecal samples collected from the animals were evaluated macroscopically and microscopically in a laboratory setting. Macroscopic examination recorded the consistency, color, and presence of blood and mucus in the feces. Microscopic examination used flotation (sugar solution method) and sedimentation techniques, particularly for the identification of Toxocara canis and Toxascaris leonina eggs. The results showed that ascarid eggs were detected in 30% of the dogs examined. The infection rate was found to be higher, especially in puppies younger than 6 months and in animals living outdoors. In most of the positive cases, symptoms such as fresh or clotted blood in the stool, mucus, abdominal distension, and weight loss were observed. In addition, systemic findings such as anemia, loss of appetite, and lethargy were also reported in some dogs. The data obtained indicate that ascariasis is an important factor that should not be overlooked in cases of bloody diarrhea. Consequently, it has been concluded that parasitic causes, particularly ascariasis infections, must be considered in the evaluation of bloody diarrhea cases in dogs. The implementation of regular antiparasitic treatment programs, periodic fecal examinations, and ensuring environmental hygiene are crucial for both individual animal health and reducing zoonotic risk.

Keywords: Dog, Ascariasis, Bloody diarrhea, Toxocara canis

DIRAMMOX AND MICROBIAL NITROGEN CYCLING: TOWARDS SUSTAINABLE WASTEWATER TREATMENT

Nimra Bashir Qureshi 1

University of Chinese Academy of Sciences, State Key Laboratory of Microbial Resources Institute of Microbiology, Chinese Academy of Sciences, Beijing, China

Email: nimbas9304@mails.ucas.ac.cn

ORCID: 0009-0009-2419-8625

Aliza Bashir Qureshi 2

Government Graduate Collage, Department of Botany, Jampur, district Rajanpur, Pakistan

bashiraliza751@gmail.com

ORCID: 0009-0001-4136-3698

ABSTRACT

Ammonia microbial transformation is essential for wastewater treatment and environmental sustainability. Despite their effectiveness, conventional nitrification–denitrification systems utilize a lot of energy and release the powerful greenhouse gas nitrous oxide.

A revolutionary development in biological nitrogen removal is the direct ammonia oxidation (DIRAMMOX) technique. By using hydroxylamine as a crucial intermediary, DIRAMMOX permits the direct aerobic conversion of ammonia (NH_3) to dinitrogen gas (N_2), in contrast to traditional nitrification–denitrification and anammox procedures that call for sequential redox reactions. The DnfABC enzyme complex, which was found in Alcaligenes species, is responsible for this action. DnfA catalyzes the oxidation of hydroxylamine to nitrogen gas, while DnfB and DnfC facilitate electron transfer and substrate regeneration. By removing nitrite and nitrate intermediates, the process functions effectively in aerobic environments, lowering nitrous oxide emissions, carbon source dependence, and aeration energy.

Its potential integration with microbial electrochemical systems to improve reactor performance and redox balance has been emphasized by recent investigations. In addition to making nitrogen transformation easier, DIRAMMOX provides a low-carbon, scalable wastewater treatment method. Optimizing reactor design and process management requires an understanding of its environmental adaptability, enzyme kinetics, and genetic modulation.

DIRAMMOX, which connects applied environmental biotechnology and microbial physiology, has the potential to become a key tool in sustainable nitrogen management as research advances.

Keywords: DIRAMMOX, Nitrogen removal, Wastewater treatment

OWNERSHIP STRUCTURE AND PERFORMANCE OF QUOTED INDUSTRIAL GOODS COMPANIES IN NIGERIA

Orjınta, Hope Ifeoma (Ph.D)

Department Of Accountancy, Faculty Of Management Scıences,

Chukwuemek A Odumegwu Ojukwu Unıversıty, Igbarıam Campus, Anambra State

Email: Ifyorjinta@Gmail.Com

ORCID: 0000-0002-0531-8056

ABSTRACT:

This study examines the effects of ownership structure on performance of quoted industrial goods firms in Nigeria. The study relies on secondary data derived from various companies' financial statements and the Nigerian Exchange fact book to determine and measure the level of ownership holdings of various firms in corporate financial statements, applying an all-inclusive multivariate analysis. Samples of 10 industrial goods firms quoted in Nigeria Exchange Group were used for the period of ten years spanning 2015 to 2024. The study employed ex-post facto and longitudinal research design. The secondary sources of data were collected from annual reports of the selected industrial goods companies and five (5) specific objectives and hypotheses were subjected to some preliminary data tests using descriptive statistics, Pearson correlation analysis and variance Inflation Factor and were tested and analyzed using panel regression analysis. The empirical analysis using a total of 100 company-year observations, shows that foreign ownership has negative but significant effect on performance of quoted industrial goods companies in Nigeria which was statistically significant at 5% level of significance while a positive and significant effect were documented for family ownership at 95% confidence level. Institutional ownership and block ownership were found to have positive but insignificant effect on performance of quoted industrial goods companies in Nigeria. In line with the above findings, this study therefore recommends among others that, family members should be encouraged to have shareholding in their respective businesses as this helps in maintaining high performance of firms in Nigeria industrial goods sector while emphasis on foreign shareholding in the firms should be minimized since it was found to have negative and insignificant effect on performance of industrial goods firms in Nigeria.

Keywords: Foreign, Institutional, family, block ownership, performance, and Nigeria industrial goods firms

BIO FERTILIZER-BASED APPROACHES TO ALLEVIATE SALINITY STRESS AND IMPROVE SOIL FERTILITY IN LEGUMINOUS CROPS

Mahesha MADUMALI

Department of Agricultural Biology, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya

maheshamadumali5@gmail.com

ABSTRACT

Salinity stress poses a significant threat to crop productivity, affecting physiological, biochemical, and yield parameters. This review highlights the potential of bio fertilizers particularly Azolla concentrates, and algal bio fertilizers in mitigating salinity induced damage and improving nutrient uptake in leguminous crops such as mung bean and cowpea. The continuous demand for food crops, coupled with declining productivity from the excessive use of chemical fertilizers, has caused reduced yields, soil fertility loss, and land degradation, thereby hindering progress toward sustainable agriculture. Azolla effectively reduce ethylene levels and alleviate salinity stress, enhancing photosynthetic traits and grain quality. Similarly, the use of Azolla pinnata concentrates as a bio stimulant has shown to increase soil fertility, nutrient uptake, and economic returns, though its effect on seed yield remained insignificant. Furthermore, the application of green and brown algae, especially cyanobacteria (blue-green algae), demonstrates promising improvements in plant growth, antioxidant activity, soil aggregation, nitrogen fixation, and stress tolerance. The review concludes that these bio-based inputs offer sustainable alternatives to synthetic fertilizers, promoting eco-friendly agriculture and resilience to salinity stress.

THE HEALING VINE: PHYTOPHARMACOLOGICAL INSIGHTS AND BIOACTIVE WEALTH OF TINOSPORA CORDIFOLIA

Saniya Y. Desai *

*1 Department of Pharmaceutical Quality Assurance., Bharati Vidyapeeth College of Pharmacy, Kolhapur -416013 Maharashtra, India

*Corresponding Author Email: saniyadesai001@gmail.com

ORCID: 0009-0007-7458-8491

Sanjıvanı A Gavalı and Saurabh S Kagne

Department of Pharmaceutıcal Chemıstry, Dr. Rajendra Gode Instıtute of Pharmacy, Amravatı - 444 602 Maharashtra, Indıa.

ABSTRACT

According to the World Health Organization, nearly 80% of the global population depends primarily on traditional medicine, which often involves plant-based remedies or their bioactive constituents. India, with its vast biodiversity and long-standing heritage of traditional healing systems such as Ayurveda, Siddha, Unani, Amchi, and various local practices, provides a strong basis for the use of numerous medicinal plants in both preventive healthcare and the management of common ailments. One such important plant is Tinospora cordifolia, a deciduous climbing shrub distributed across India, China, and Africa, belonging to the Menispermaceae family. Its medicinal value lies mainly in the roots, stems, and leaves, which are rich in bioactive compounds like alkaloids, steroids, glycosides, lactones, and polysaccharides. Almost all parts of the plant are known for their immunomodulatory properties, making it a vital herb in Ayurvedic medicine for the treatment of conditions such as fever, common cold, diabetes, and rheumatoid arthritis.

Keywords: Tinospora Cordifoli; Medicinal Plants; Guduchi; Medicinal; Ayurveda; Giloy

INFLUENCE OF DIETARY SUPPLEMENTATION OF *celosia argentea* (SOKO) STEM OXYTETRACYCLINE AND BUTYLATED HYDROXYANISOLE ON PRODUCTION INDICES, BLOOD CHEMISTRY, CARCASS AND MEAT QUALITY OF BROILER CHICKENS

ZAİNAB O. BELLO

ABSTRACT

This study investigated the influence of dietary supplementation of Celosia argentea (soko) stem, oxytetracycline and butylated hydroxyanisole (BHA) on production indices, blood chemistry, carcass and meat quality of broiler chickens. A total of 240 day-old Ross 308 broilers were randomly assigned to four dietary treatments with six replicates and ten birds per replicate for a period of six weeks: Basal diet (T1), Basal diet with BHA and Oxytetracycline (T2), and two experimental groups with 0.25g/kg (T1) and 0.5g/kg (T2) of Celosia argentea stem powder, respectively.

The phytochemical analysis indicated the presence of flavonoids, coumarins, glycosides, terpenoids, and phytic acid. Production indices were not significantly different ($p > 0.05$) with weight gain, feed intake and best FCR recorded in supplemented birds. Blood chemistry results showed hypocholesterolemic effect of celosia argentea due to reduced values of cholesterol and LDL. ALT, AST were reduced reflecting hepatoprotective effect of the feed additive. Haematological indices were not significantly affected by the supplemented diet. Carcass and meat quality showed no significant differences ($p > 0.05$) across treatments, with dressing percentage ranging from 69.81% (T2) to 74.89% (T1), suggesting that supplementation of Celosia argentea (soko) stem powder at up to 0.5g/kg diet may be a potential alternative to synthetic feed additive such as Butylated hydroxyanisole and oxytetracycline in broiler diets.

Keywords: Ross 308, treatment, alternative, replicate, significant

ADVANCING SUSTAINABLE AGRICULTURE THROUGH CLIMATE-SMART TECHNOLOGIES: PATHWAYS TO ENVIRONMENTAL RESILIENCE AND RURAL PROSPERITY

Dhivya C

Research Scholar (Agricultural Extension Education), Department of Agricultural Extension and Rural Sociology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

ORCID: 0009-0004-8984-1812

Arunkumar R

Assistant Professor (Agricultural Extension), Department of Agricultural Extension and C0mmunication, RVS Agricultural College, Thanjavur, Tamil Nadu, India

ORCID: 0000-0001-5580-5170

*Corresponding author mail ID: dhivya2908@gmail.com

ABSTRACT

The agricultural sector is undergoing a critical transformation as it confronts the intertwined challenges of climate change, environmental degradation, and food insecurity. Climate-Smart Agriculture (CSA) has emerged as a comprehensive approach that enhances productivity, strengthens resilience and reduces emissions simultaneously. By integrating innovative technologies such as precision agriculture, remote sensing, renewable energy systems and water-efficient irrigation, CSA enables the sustainable use of natural resources and supports climate adaptation. It not only improves farm-level productivity but also contributes to soil health, biodiversity conservation and sustainable livelihoods. Furthermore, adopting climate-smart practices promotes rural prosperity by enhancing market access, reducing input costs and fostering income stability among smallholder farmers. Successful implementation of CSA requires strong institutional support, effective extension services and policies that encourage innovation, capacity building and financial inclusion. Equally important is the participation of farmers, researchers and policymakers in co-developing context-specific solutions that balance environmental and economic objectives. As global food systems transition towards sustainability, CSA provides a viable framework to align agricultural growth with environmental stewardship. By fostering technological innovation and resource efficiency, climate-smart technologies offer a clear pathway toward achieving food security, ecological balance and inclusive rural development in an era of climate uncertainty.

Keywords: Climate-Smart Agriculture, Sustainable Farming, Environmental Resilience, Rural Development, Agricultural Innovation

INFLUENCE OF TANK COLORATION IN MODULATING PHYSIOLOGICAL GROWTH, SURVIVAL AND SKIN PIGMENTATION EXPRESSION IN NURSERY-REARED CHANNA STRIATA

Md. Rabiul Awal[1], Md. Moniruzzaman[1], Md. Saiful Islam[1], Al-amin[1], Md. Harunor Rashid[2], Anuradha Bhadra[3]

[1] Scientific Officer, Bangladesh Fisheries Research Institute, Freshwater Station, Mymensingh -2201

[2] Chief Scientific Officer, Bangladesh Fisheries Research Institute, Freshwater Station Mymensingh -2201

[3]Director General, Bangladesh Fisheries Research Institute, Mymensingh-2201

ABSTRACT:

Tank background coloration was tested for its influence on growth, survival, cannibalism, and pigmentation of striped snakehead (Channa striata) larvae under nursery conditions. A 35-day rearing trial was conducted using five treatments: control (T0), white (T1), black (T2), blue (T3), and red (T4), each in triplicate. Water quality remained within optimal ranges. Growth and survival differed significantly ($p < 0.05$) among treatments. Larvae reared in blue (T3) and white (T1) tanks achieved the greatest final length (7.57 ± 0.88 cm and 7.32 ± 0.52 cm) and weight gain (3.40 ± 0.19 g and 3.18 ± 0.21 g), with efficient feed conversion ratios (1.19 ± 0.07 and 1.17 ± 0.07). Survival was also highest in T1 (95.11 ± 5.09%) and T3 (94.89 ± 5.11%), while the lowest occurred in T0 (70.77 ± 4.49%). Cannibalism was markedly reduced in blue (2.21%) and white (2.12%) tanks but elevated in black (9.24%) and control (10.77%). Pigmentation analysis showed tank color altered CIELAB parameters, with T3 yielding the highest hue angle (140.57°) and T4 the greatest chroma (23.26 ± 0.11). Correlation analysis confirmed positive relationships of tank color with growth and survival and negative with cannibalism. These results demonstrate that blue and white backgrounds markedly enhance larval performance, offering a low-cost, scalable strategy to improve seed quality and productivity in snakehead aquaculture.

Keywords: Channa striata, Larval Rearing, Tank Background Color, Growth, Survival, Cannibalism, Pigmentation

AGRICULTURAL INFORMATION USAGE AND THE CHOICE OF COMMUNICATION CHANNELS AMONG POULTRY FARMERS IN OYO STATE, NIGERIA

MR. MUSA, L

Department of Agricultural Extension and Rural Development, Ladoke Akintola University of Technology Ogbomoso, Nigeria

PROFESSOR OLANIYI, O.A

Department of Agricultural Education and Extension, University of Eswatini, M205, Eswatini

ORCID: 0000-0003-0262-5293

DR. OGUNKUNLE, T

Bioresouces Development Centre, National Biotechnology Research and Development Agency Owode-Yewa South, Ogun State, , Nigeria

ORCID: 0000-0002-9391-1043

*Corresponding Author's Email: ogunkunletajudeen@gmail.com

ABSTRACT

The study examined the use of communication channels for accessing agricultural information among poultry farmers in Oyo State, Nigeria. A multi-stage sampling technique was used in the selection of 156 respondents for the study. Data were collected with the use of structured face-to-face interview schedule and analyzed with the use of descriptive statistics such as; frequency counts, means, percentages, while Chi-square test was employed as inferential statistical tool at 5 percent level of probability. The results revealed that the major available and most utilized communication channels for accessing agricultural information were: Mobile phone (98.7%, WMS=4.65), Radio (91.7%, WMS=4.19) and fellow farmers (91.0%, WMS=4.17) respectively. Agricultural information accessed through the available channels include information on handling of chicks (100%), brooding and lighting management of day old chicks (98.1%) and breeds of birds (97.4%). The result of Chi-Square revealed that significant relationship existed between Sex (X2 =28.88; p=0.000), Marital Status (X2 =74.40: p=0.000), Education (X2 =40.24; p=0.000), Religion (X2=3.92; p=0.048); Household size (X2=14.44; p=0.071), Primary occupation (X2=64.80: p=0.000); Secondary occupation (X2 =39.20; p=0.000) and the extent of communication channels usage. The study concluded that both modern digital and interpersonal channel were mostly explored for accessing information especially during early production stage. It was therefore recommended that agricultural information could be disseminated through the identified channels for easy and timely access for improved productivity among poultry farmers in the state..

Key words: Agricultural information, Communication channels, poultry (Chicken) farmers, information usage

ROLE OF BIOTECHNOLOGY IN ANIMAL BREEDING

S. Shakthi Sree

Bharath Institute of Higher Education and Research, Selaiyur, Chennai -73.

ABSTRACT

Biotechnology has revolutionized animal breeding by providing advanced tools to enhance genetic improvement, reproductive efficiency, and disease resistance. Traditional breeding methods are now complemented by modern biotechnological techniques such as artificial insemination, embryo transfer, in vitro fertilization, and cloning, which enable faster propagation of superior traits. Molecular technologies like marker-assisted selection and genomic selection allow precise identification and selection of animals with desirable genetic characteristics. Furthermore, gene editing tools such as CRISPR-Cas9 facilitate targeted genetic modifications to improve productivity and health traits. The use of transgenic and cloned animals also contributes to the development of high-yielding and disease-resistant breeds. Additionally, cryopreservation techniques help conserve valuable and endangered genetic resources for future use. Overall, biotechnology plays a crucial role in accelerating genetic progress, improving livestock performance, and ensuring sustainable animal production systems.

Keywords : Biotechnology, animal breeding, reproductive efficiency, genetic characteristics, genetic modifications.

INNOVATİVE SOLUTİONS FOR SUPPORTİNG AFFECTED WOMEN

Amina Bigzad

Masters Student of Department of Womens Studies, Ahlul Bayt İnternational University İran.

Email: aminabigzad2@gmail.com

ABSTRACT

This article examines innovative and effective strategies for supporting women affected by violence and discrimination, particularly in vulnerable societies. In complex and crisis-ridden conditions like Afghanistan, women, especially, face various forms of social, economic, and .physical violence, situations that require serious and practical attention

In this study, we analyze traditional methods of support for women and explore their limitations. Instead, this article introduces new and innovative approaches, particularly those developed through the use of information technology and social media. The use of online platforms as effective tools for providing psychological counseling, organizing educational .programs, and fundraising is one such strategy

Additionally, the article investigates the critical role of non-governmental organizations, social activists, and governments in creating support networks

facilitating access to health and legal services. It emphasizes how collaboration among these .entities can significantly contribute to positive changes in the lives of affected women

Finally, the importance of active community participation and synergy between various organizations in successfully implementing these strategies is highlighted, along with .recommendations for improving and expanding these initiatives.

Keywords : Inovative solution , supporting effeted womens.

RURAL DEVELOPMENT AND THE SOCIAL ROLE OF WOMEN IN THE DEVELOPMENT PROCESS

Amina Bigzad

Masters student of department of womens studies, Ahlul bayt international university iran.

Email: aminabigzad@gmail.com

ABSTRACT

This article investigates the social role of women in the rural development process and aims to demonstrate how active participation of women at the village level can lead to improvements .in economic-social development indicators, social cohesion, and the sustainability of projects The theoretical framework combines culture-economy theories and gender-focused approaches to development to explain the relationship between values, local institutions, and women's participation opportunities. The main research question is: how can women's social power and —resources—including education, health, entrepreneurship, and social-political participation alter the path of rural development? Key hypotheses are: (1) the active presence of women in ,the management of development projects and village councils improves transparency accountability, and project efficiency; (2) equal access to education, health, and employment ;opportunities for women strengthens local value creation and rural labor force development balancing traditional roles with modern opportunities for women leads to cultural (3) ,sustainability and acceptance of innovation in rural areas. The methodology is mixed combining a systematic literature review, comparative case studies in villages with diverse cultural contexts, and qualitative-quantitative analysis through in-depth interviews, focus groups, and indicators of women's participation in decision-making and rural development indicators. Preliminary findings indicate that: (1) women's participation in local decision-making, with better access to resources, increases entrepreneurship and the delivery of public services; (2) practical training and skill-building opportunities for women facilitate home-based entrepreneurship and enhance rural production capabilities; (3) institutional and structural barriers such as gender gaps in leadership in villages are obstacles requiring policy interventions and institutional change. Ultimately, the article recommends that rural development policymaking adopt a gender mainstreaming approach at all levels, with emphasis on equal participation, transparency in resource distribution, and support for women's supportive networks

INTERNET OF THINGS (IOT) IN SMART AGRICULTURE: CONSIDERATION AND CHALLENGES

Mrs.A.Rajeswari

G.Venkataswamy Naidu College, Kovilpatti, Tamilnadu, India.

Email: rajeswari@gvncollege.edu.in

ORCID: 0005-7906-5089

ABSTRACT

The modern society is constantly evolving in terms of technology and there are numerous tools and approaches to use in the agricultural industry. Also, the IoT preference in the agricultural division is knowledge processing. Newly installed sensors will be useful in collecting all the information. The Internet-of-things (IoT)-based technology of risk mitigation, industry mechanization, production improvement, livestock inspection, environmental condition monitoring, greenhouse roboticization, and crop monitoring has transformed virtually every business including smart agriculture and has led into a shift in methods of operation being quantitative, rather than factual. The concepts help the Internet of Things (IoT) to link real things that contain sensors, actuators, and processing capabilities such that they can collaborate on a project and yet remain connected online. Internet of Things (IoT) is a collection of computers, software, and sensors, among other devices, which are connected to the Internet according to the Worldwide Guidelines Operation by the World Telecommunication Union. The resource is highly susceptible to the consequences of its smart agriculture.

Keywords: Smart Farming, Smart Agriculture, Application of IOT, Implications of implementation.

ARABLE FARMERS' PERCEPTION OF USAGE OF AGRICULTURAL TECHNOLOGIES IN KWARA STATE , NIGERIA

Obaniyi Kayode Samuel

Department of Agricultural extension and Rural Development, Landmark University, Omu-Aran Affiliation: Landmark University

Email:obaniyi.kayode@lmu.edu.ng

Kayode Pelumi

Department of Agricultural extension and Rural Development, Landmark University, Omu-Aran Affiliation: Landmark University

ABSTRACT

This study examines the perceived effects of agricultural technology usage on the level of production among arable crop farmers in, Kwara State, Nigeria. The study adopted a survey-based approach and collects data through use of well structured questionnaire. The study used multistage sampling procedure to select a sample size of 120 respondents, The result were analyzed with percentages, frequency , mean and correlation analysis. The findings of the study revealed that farmers, male arable crop farmers dominated the sample, making up 62.5% of the respondents, Regarding agricultural technologies, fertilizers were the most commonly used technology with a usage rate of 95.8%, followed by irrigation materials at 91.7%. In terms of the perceived effects of using agricultural technologies, increased income received the highest mean score of 2.61, indicating its significant impact. Increase in food production and improvement in food consumption level both had mean scores of 2.476 The study also identified constraints to the usage of agricultural technologies, with inadequate capital and high implementation costs perceived as the most significant challenges (mean scores of 3.13 out of 5). The findings further shows that sex, marital status, year of schooling, household size, occupation, crop yield, income from the last season, and credit access were statistically significant with the extent of technology usage.. Therefore, it is recommended that the usage of fertilizer, irrigation, pesticide and extension information technologies should be encouraged among farmers in Sub-Sharan Africa.

Keywords : Arable crop farmers, agricultural technology, perception ,

DEVELOPMENT OF A SMART IOT-BASED MODEL TO GET WEATHER INFORMATION FROM RICE FIELD

Nawrin Tamanna Rasha

Laboratory of Agricultural Machinery, Department of Farm Power and Machinery, Sylhet Agricultural University, Sylhet 3100, Bangladesh

Email: nawrinrasha@gmail.com

ABSTRACT

Half of the agricultural GDP and one-sixth of the total income in Bangladesh is derived from the rice industry. In the country, rice is grown by almost 13 million agricultural families. Human error, delays, and inconsistent data collection are common when gathering weather data manually (rainfall, humidity, soil moisture, and wind speed). Automated systems and sensors typically capture real-time meteorological data more accurately and efficiently. The foundation of this study's Internet of Things (IoT) idea is a real-time environmental monitoring system. The Internet of Things (IoT) is a key component of today's world through an extensive and enduring network of sensors that monitor the surroundings and their parameters. By using sensors, this system keeps track of and stores critical environmental information like temperature, humidity, soil moisture, and wind speed. Data is subsequently transferred to the cloud. Through the internet, this data is accessible from any location, and the sensor data is then displayed graphically. The setup and outcomes of an environmental monitoring system that uses sensors to gauge the local temperature, humidity, and other environmental parameters are covered in this study.

Keywords– IoT, Meteorological data, Cloud, Sensor

MANGROVE DERIVED *streptomyces viridiostaticus* AS A SOURCE OF DUAL THERAPEUTIC BIOACTIVES: ANTIMICROBIAL PROTEINS AND TRYPROSTATIN B ALKALOID WITH ANTICANCER POTENCY

Yalpi Karthik [a,b]

[a] Department of Studies and Research in Microbiology, Mangalore University, Kodagu, India

[b] Agrogenomic Sciences, National School of Advanced Studies, León Unit, National Autonomous University of Mexico (UNAM), León, Guanajuato, Mexico.

Manoj-Kumar Arthikala [b]

[b] Agrogenomic Sciences, National School of Advanced Studies, León Unit, National Autonomous University of Mexico (UNAM), León, Guanajuato, Mexico.

Kalpana Nanjareddy [b,]

[b] Agrogenomic Sciences, National School of Advanced Studies, León Unit, National Autonomous University of Mexico (UNAM), León, Guanajuato, Mexico.

Manjula Ishwara Kalyani[a]*

[a] Department of Studies and Research in Microbiology, Mangalore University, India

ABSTRACT

Actinomycetes are prolific producers of secondary metabolites with therapeutic potential, particularly in antimicrobial and anticancer domains. Mangrove ecosystems represent underexplored reservoirs for novel bioactive strains. This study reports the cultural characteristics, and bioactivity assessment of *Streptomyces viridiostaticus* recovered from mangrove soil sample of the Mangalore coastal region, India. Morphological and biochemical characterization was performed on SCNA and additional selective media. Antibacterial activity of crude proteins was tested against Gram-positive and Gram-negative pathogens. Protein purification was carried out using Sephadex G-10 column chromatography, Cytotoxic activity was determined via MTT assay using the PC3 prostate cancer cell line. Metabolite profiling through mass spectrometry, identifies Tryprostatin B. S24 was confirmed as *Streptomyces viridiostaticus* by 16S rRNA sequencing (Accession: MZ021336.1). The isolate displayed robust growth across different media, with distinct brown aerial and substrate pigmentation. Crude protein extracts exhibited antibacterial activity against *Bacillus cereus*, *Proteus vulgaris*, *Salmonella typhimurium*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*, with inhibition zones up to 24 mm. Protein purification yielded a 10.75-fold increase in specific activity, though with reduced recovery (9.25%). Cytotoxic assays revealed dose-dependent inhibition of PC3 cells, achieving 51.85% growth inhibition at 200 µg/mL. Mass spectrometry confirmed the presence of Tryprostatin B, a known indole alkaloid with anticancer potential. The study demonstrates that *Streptomyces viridiostaticus* is a promising source of bioactive proteins and metabolites with antibacterial and anticancer properties. Its discovery from mangrove soil highlights the ecological and pharmaceutical significance of marine-derived *Actinomycetes* as reservoirs of novel therapeutic compounds.

Keywords: *Actinomycetes*; anticancer activity; antimicrobial peptides; mangrove soil; protein purification; *Streptomyces viridiostaticus*; Tryprostatin

EVALUATING WATER HYACINTH RESIDUE AS A VIABLE ALTERNATIVE TO CONVENTIONAL ORGANIC FERTILIZER

Dipok Halder

[1]Department of Agronomy, Bangladesh Agricultural University Mymensingh-2202, Bangladesh.

[2]Bangladesh Agricultural Research Institute (BARI), Gopalganj-8100, Bangladesh.

Email: dipokkumar006@gmail.com

Md. Hasan Ali

[3]Department of Agriculture, Gopalganj Science and Technology University, Gopalganj-8105, Bangladesh.

Email: hasan.19agr019@gstu.edu.bd

Sanjay Das

[3]Department of Agriculture, Gopalganj Science and Technology University, Gopalganj-8105, Bangladesh.

Email: sanjay.19agr042@gstu.edu.bd

Humaira Akter Shanta

[3]Department of Agriculture, Gopalganj Science and Technology University, Gopalganj-8105, Bangladesh.

Email: humairashanta355@gmail.com

ABSTRACT

Sustainable soil fertility management is vital for crop productivity in Bangladesh, particularly for smallholder farmers dependent on organic inputs. This study assessed the potential of composted water hyacinth (*Eichhornia crassipes*), an invasive aquatic weed, as an alternative to cowdung in cauliflower (*Brassica oleracea* var. botrytis subvar. cauliflora L.) cultivation under AEZ-14 (Gopalganj-Khulna Beels). A field trial was conducted using a randomized complete block design (RCBD) with four treatments: cowdung (5 t/ha), water hyacinth compost at 5, 8, and 11 t/ha. Agronomic parameters, yield, and soil nutrient dynamics were evaluated. Results revealed that water hyacinth compost at 11 t/ha significantly improved curd length (23.50 cm), diameter (50.13 cm), weight (534 g), and yield (22.25 t/ha) compared to cowdung (15.25 t/ha). Soil nutrient status post-harvest showed increased potassium and micronutrient availability, demonstrating water hyacinth's high nutrient content and its role in soil enrichment. The findings suggest water hyacinth compost is a cost-effective, eco-friendly alternative to conventional organic fertilizers, supporting sustainable crop production in nutrient-depleted soils.

FROM WASTE TO CLIMATE ACTION: EXPLORING THE ROLE OF SOLID WASTE MANAGEMENT IN MITIGATING GREENHOUSE GAS EMISSIONS – REVIEW

FETTAH Abla*

[1]Process Engineering and Environment Laboratory, Faculty of Science and Technology of Mohammedia, Hassan II University of Casablanca

Email: abla.fettah-etu@etu.univh2c.ma

MOUHIR Latifa

[1]Process Engineering and Environment Laboratory, Faculty of Science and Technology of Mohammedia, Hassan II University of Casablanca

HAMRI Zineb

[1]Process Engineering and Environment Laboratory, Faculty of Science and Technology of Mohammedia, Hassan II University of Casablanca

ABSTRACT

Human activities generate large amounts of solid waste, which represent a significant source of greenhouse gases (GHGs) and contribute directly to climate change. Globally, the waste sector is estimated to account for about 3.2% of total GHG emissions, including nearly 11% of global methane (CH_4) emissions, a gas with a much higher warming potential than carbon dioxide. This presentation provides a literature review on the impacts of solid and organic waste on the global carbon balance, highlighting their main sources, environmental consequences, and the mechanisms through which they exacerbate global warming.
The study also explores sustainable waste valorization strategies, such as energy recovery, composting, industrial reuse, and integrated approaches within a circular economy framework. These practices not only reduce GHG emissions but also promote more efficient resource use and support sustainable development.

Finally, the presentation discusses future perspectives for optimizing waste management, emphasizing the importance of innovative technologies and policies tailored to local contexts. It demonstrates that well-designed waste valorization can play a key role in mitigating climate change while fostering sustainable practices at the global level.

Keywords: Solid waste management ; Climate change mitigation ; Environmental sustainability ; Waste reduction; Greenhouse gas emissions

Corresponding Author Bio:

Abla Fettah is a second-year Ph.D. student specializing in climate change mitigation through waste valorization. She holds a Master's degree in Environmental Science and Management, graduating as the top of her class. Her research focuses on sustainable waste management strategies to reduce greenhouse gas emissions and promote environmental protection. Passionate about integrating science and practical solutions, Abla aims to contribute to the global fight against climate change. She is committed to advancing knowledge in environmental sustainability and developing innovative approaches for waste valorization that align with circular economy principles, benefiting both society and the planet.

EFFECTS OF THREE PHYTOGENIC AQUEOUS BLENDS ON NUTRIENT UTILISATION EFFICIENCY OF BROILER CHICKEN

Ogundeji, N. A.

Federal University of Agriculture, Abeokuta, Nigeria

***Akinlade, O. O.**

Federal University of Agriculture, Abeokuta, Nigeria; [2]The Federal Polytechnic, Ilaro, Nigeria

Email: akinlade.olamilekano@pg.funaab.edu.ng (*Corresponding author)

Akinlade, O. O.

Federal College of Agriculture, Moor Plantation, Ibadan, Nigeria

Sangosina, M. I.

The Federal Polytechnic, Ilaro, Nigeria

Leramo, O. O.

The Federal Polytechnic, Ilaro, Nigeria

Olufayo, O. O.

The Federal Polytechnic, Ilaro, Nigeria

Okusanya, P. O.

The Federal Polytechnic, Ilaro, Nigeria

Irivboje, O. A.

The Federal Polytechnic, Ilaro, Nigeria

Olorunsogbon, B. F.

Federal University of Agriculture, Abeokuta, Nigeria

ABSTRACT

The poultry industry faces increasing demand for natural feed additives that enhance nutrient utilization while reducing reliance on synthetic growth promoters. Phytogenic plants such as garlic (*Allium sativum*), ginger (*Zingiber officinale*), and onion (*Allium cepa*) possess bioactive compounds with antioxidant, and digestive-stimulant properties that may improve feed utilisation efficiency in broiler production. This study was conducted to evaluate the effect of aqueous extracts of garlic, ginger, and onion on the nutrient digestibility of broiler chickens. A total of 120-day-old broilers were allocated into four treatment groups with three replicates each. Treatments consisted of aqueous blend prepared at 20 g, 30 g, and 40 g of each spice per litre of water, administered at 1 ml/litre (T1, T2, and T3), while the control group (T4) received plain water with antibiotics. Faecal samples were collected for proximate composition to determine nutrient excretion and digestibility in the laboratory. The results were subjected to one way analysis of variance. The results revealed significant differences ($p < 0.05$) among treatments in crude-protein, fat, ash, and nitrogen-free extract. Broilers in T1 exhibited the lowest faecal NFE (65.94%) and moderate crude protein excretion (10.46%), indicating superior carbohydrate and protein digestibility. T2 and T3 had higher crude protein excretion, suggesting reduced nitrogen retention, while the control group recorded the highest NFE

(73.39%) and lowest protein utilization. Although T1 showed higher fat excretion, its overall balance in nutrient utilization was superior. It was concluded that moderate inclusion of aqueous extracts of garlic, ginger, and onion at 40g/L is optimal for improving nutrient digestibility in broilers. The study recommends the adoption of phytogenic extracts in poultry production to enhance feed efficiency, reduce nutrient losses, and support sustainable, residue-free poultry farming.

KEYWORDS: feed, garlic, ginger, onion, water

LITERATURE REVIEW AND PROPOSING A WILD ANIMAL DETECTION CMS USING THE LATEST CV AND ML TECHNOLOGIES FOR THE CONSERVATION OF TRIBES OF CHHATTISGARH

Vaibhav Kant Singh

Guru Ghasidas Vishwavidyalaya, A Central University, India

Email: vibhu200427@gmail.com

ORCID: 0000-0002-6776-9573

Kapil Kumar Nagwanshi

Guru Ghasidas Vishwavidyalaya, A Central University, India

ORCID: 0000-0003-3133-978X

Samanvay Singh

Guru Ghasidas Vishwavidyalaya, A Central University, India

ORCID: 0009-0007-2551-8884

ABSTRACT

In the current paper the authors had presented a way that the Tribes of Chhattisgarh may use to safeguard their lives from dangerous wild animals. A big region of the state chhattisgarh a state of India is under forest region. In the current paper the author had proposed the usage of AI based technology that is ML for the identification of dangerous wild animals arriving in the residential area and to take preventive measures to safeguard their lives. The prototype proposed is going to be handed over to the Government officials that is the Forest Service people generally Forest Ranger to keep track of the arrival of dangerous animals and safeguard the Tribes of Chhattisgarh. The developed prototype using Computer Vision technology equipped with CCTV coverage will go for Government approval and after the approval the Forest rangers can take preventive measures for the Tribes of Chhattisgarh.

Keywords: AI, ML, Animal, CV, Disease.

KARAPINAR ŞARTLARINDA YAPAY MERA VE YOĞUN BESLENMEYE TABİ TUTULMUŞ ORTA ANADOLU MERİNOSU KUZULARIN BESİ PERFORMANSLARININ KARŞILAŞTIRILMASI

Zir.Yük.Müh. Tülay CANATAN

Bahri Dağdaş Uluslararası Tarımsal Araştırma Enstitüsü, Konya / Türkiye

Email: tulay.canatanyilmaz@tarimorman.gov.tr

ORCID: 0009-0009-3004-3435

Dr. Şükrü DOĞAN

Bahri Dağdaş Uluslararası Tarımsal Araştırma Enstitüsü, Konya / Türkiye

Email: sukru.dogan@tarimorman.gov.tr

ORCID: 0000-0001-8673-2904

Dr. N.Kürşat AKBULUT

Necmettin Erbakan Üniversitesi Ereğli Veteriner Fakültesi, Konya, Türkiye

ORCID: 0000-0003-3853-9960

Email: nkakbulut@erbakan.edu.tr

Dr. Emre Bumin TEKE

Bahri Dağdaş Uluslararası Tarımsal Araştırma Enstitüsü, Konya / Türkiye

Email: bumin.emreteke@tarimorman.gov.tr

ORCID: 0000-0002-4632-0953

Prof.Dr. Mustafa KAN

Ahi Evran Üniversitesi Ziraat Fakültesi Tarım Ekonomisi Bölümü, Kırşehir / Türkiye

Email: mustafa.kan@ahievran.edu.tr

ORCID: 0000-0001-9198-5906

ÖZET

Araştırmanın amacı, Konya ili Karapınar ilçesi şartlarında Orta Anadolu Merinosu kuzuların yapay mera ve yoğun besleme altında besi performanslarının karşılaştırılmasıdır. Araştırma Konya ili Karapınar ilçesinde bir koyun işletmesinde yürütülmüştür. İşletmede 60 baş Orta Anadolu Merinosu kuzu kullanılmıştır. Çalışmada 3 farklı besi grubu oluşturulmuş ve deneme 60 gün sürdürülmüştür. Deneme grupları 1.grup Mera+ süt (20 baş), 2.grup Mera+ süt+ ilave yem (20 baş), 3.grup entansif besleme (20 baş) şeklinde dizayn edilmiştir. Mera çalışması için 24 da mera alanı kurulmuştur. Mera 3 buğdaygil + 3 baklagil karışımından oluşmuştur. Mera karışımları % 30 çok yıllık çim, % 20 kamışsı yumak, % 20 domuz ayrığı, % 10 korunga, % 5 yonca ve % 15 ak üçgülden oluşmuştur. Deneme parselleri eşit olarak 4 alt parsele bölünmüş ve parsellerde rotasyonlu otlatma yapılmıştır. Araştırma sonucunda yapay meradan farklı tarihlerde biçilen meranın yeşil ot verimi 6.640, 4.075, 3.400 ve 1.620 kg/da, kuru ot verimi, 2.603, 1.970, 1.505 ve 625 kg/da ($p<0.001$) bulunmuştur. Denemeden elde edilen otların kuru madde içerikleri sırasıyla % 93.38, 93.58, 93.65, 94.28; ADF değerleri % 32.36, 35.66, 36.28, 34.87; NDF değerleri % 53.75, 56.94, 55.25, 57.13; Ham Selüloz değerleri % 35.05, 32.87,

31.83, 27.92; Ham protein değerleri ise % 17.25, 16.91, 15.73 ve 15.51 olarak bulunmuştur ($p<0.001$). Deneme gruplarındaki kuzularının değişik dönemlerdeki canlı ağırlıkları incelendiğinde entansif, mera + süt ve mera + süt + ilave yem grubunun besi başı ağırlıkları sırasıyla 22.84, 20.69, 21.79 kg; besi sonu ağırlıkları sırasıyla; 41.64, 36.59, 39.23 kg ($p<0.001$) tespit edilmiştir. Besi sonu ortalama canlı ağırlık artışları; 313.3, 264.9 ve 290.8 g/gün olarak ($p<0.001$) hesaplanmıştır. Entansif ve mera + süt +yem grubundaki kuzuların besi sonu yem tüketimleri ve yemden yararlanma değerleri sırasıyla; 1.18, 1.07 kg; 5.94, 4.02 olarak ($p<0.001$) tespit edilmiştir.

Sonuç olarak, yüksek üretim ve ot tüketimi için tahıl ekimi yapılamayan arazilerin yapay mera alanına dönüştürülmesi akılcı bir çözüm olduğu ve Merinos kuzularında sadece entansif yemleme dayalı bir besleme sisteminin ekonomik olmadığı belirlenmiştir.

Anahtar kelimeler: Orta Anadolu Merinosu, kuzu, yapay mera, besi performansı

COMPARISON OF FATTENING PERFORMANCES OF CENTRAL ANATOLIAN MERINO LAMBS FED IN ARTIFICIAL PASTURE AND INTENSIVE IN KARAPINAR CONDITIONS

ABSTRACT

The primary objective of this study was to compare the fattening performance of Central Anatolian Merino lambs under conditions of artificial pasture and intensive feeding in the Karapınar district of Konya Province. The research was conducted in a commercial sheep farm located in Karapınar, utilizing a total of 60 Central Anatolian Merino lambs. The study was designed with three experimental groups and lasted for 60 days. The treatment groups were organized as follows: Group 1 – Pasture + milk (20 lambs), Group 2 – Pasture + milk + supplementary feed (20 lambs), and Group 3 – Intensive feeding (20 lambs). For the pasture component, a 24-decare artificial pasture area was established. The pasture mixture was composed of three grasses and three legumes, specifically 30% perennial ryegrass, 20% tall fescue, 20% cocksfoot, 10% sainfoin, 5% alfalfa, and 15% white clover. "The experimental plots were equally divided into four sub-plots, and rotational grazing was implemented within these plots. The green forage yields from different cutting periods of the artificial pasture were determined as 6,640, 4,075, 3,400, and 1,620 kg/da, while dry matter yields were recorded as 2,603, 1,970, 1,505, and 625 kg/da, respectively ($p<0.001$). The chemical composition of the harvested forages revealed dry matter contents of 93.38%, 93.58%, 93.65%, and 94.28%; ADF values of 32.36%, 35.66%, 36.28%, and 34.87%; NDF values of 53.75%, 56.94%, 55.25%, and 57.13%; crude fiber contents of 35.05%, 32.87%, 31.83%, and 27.92%; and crude protein values of 17.25%, 16.91%, 15.73%, and 15.51%, respectively ($p<0.001$). When the body weights of lambs in the different feeding groups were examined, the initial live weights were determined as 22.84 kg, 20.69 kg, and 21.79 kg in the intensive, pasture + milk, and pasture + milk + supplementary feed groups, respectively. At the end of the fattening period, the final live weights were 41.64 kg, 36.59 kg, and 39.23 kg, respectively ($p<0.001$). The average daily live weight gains were calculated as 313.3 g/day, 264.9 g/day, and 290.8 g/day, respectively ($p<0.001$). Feed intake and feed conversion ratios of lambs in the intensive, pasture + milk and pasture + milk + supplementary feed groups were recorded as 1.18 kg and 1.07 kg, and 5.94 and 4.02, respectively ($p<0.001$).

In conclusion, the findings indicate that transforming non-arable lands—where grain cultivation is not feasible—into artificial pastures provides a rational solution for enhancing forage production and utilization. Furthermore, it was determined that a feeding system based solely on intensive concentrate feeding in Merino lambs is not economically viable.

Keywords: Central Anatolian Merino, lamb, artificial pasture, fattening performance

DERİN ÖĞRENME MODELİ İLE TOPRAK SICAKLIĞI TAHMİNİNDE FARKLI KAYAN PENCERE BOYUTLARININ ETKİSİNİN DEĞERLENDİRİLMESİ

Zir. Yük. Müh. Nigar Anğın,

Doğu Akdeniz Tarımsal Araştırma Enstitüsü Müdürlüğü, Adana.

Email: nangin2006@gmail.com,

ORCID : 0000-0002-9827-6245

Dr.Öğr. Üyesi Mustafa Özbuldu,

Hatay Mustafa Kemal Üniversitesi, Ziraat Fakültesi Biyosistem Mühendisliği Bölümü,

Email: mustafaozbuldu@mku.edu.tr ,

ORCID : 0000-0002-5359-8750

Zir. Yük.Müh. Volkan Çatalkaya,

Doğu Akdeniz Tarımsal Araştırma Enstitüsü Müdürlüğü, Adana.

Email: catalkayavolkan@gmail.com,

ORCID : 0000-0002-8078-3548

Prof.Dr. Ahmet İrvem,

Hatay Mustafa Kemal Üniversitesi, Ziraat Fakültesi Biyosistem Mühendisliği Bölümü,

Email: airvem@mku.edu.tr,

ORCID : 0000-0002-3838-1924

ÖZET

Bu çalışmada, 18054 nolu Yüreğir/Çukurova Tarımsal Araştırma Otomatik Meteoroloji Gözlem İstasyonunu 2016–2025 yılları arasındaki meteorolojik verileri kullanılarak 5 cm derinlikteki günlük toprak sıcaklığı derin öğrenme modeli olan Uzun Kısa Süreli Bellek (LSTM) kullanılarak tahmin edilmesi amaçlanmıştır. Model giriş değişkenleri olarak ortalama rüzgâr hızı, toplam yağış, ortalama sıcaklık, maksimum sıcaklık, minimum sıcaklık, bağıl nem ve günlük evapotranspirasyon değerleri kullanılmıştır. Veri setlerindeki eksik veriler doğrusal interpolasyon yöntemi ile tamamlanmıştır. Modelin girdi değişkenleri min-max normalizasyonu ile ölçeklendirilmiştir. Model geliştirme sürecinde, farklı kayan pencere (sliding window) boyutları (3, 5, 7, 10, 14, 21 ve 30 gün) test edilerek her bir boyutun tahmin doğruluğuna etkisi araştırılmıştır. Model performansı, Ortalama Mutlak Hata (MAE), Kök Ortalamaları Kare Hatası (RMSE) ve Belirleme Katsayısı (R^2) ölçütleri ile değerlendirilmiştir. Değerlendirme sonucunda en yüksek doğruluk 7 günlük kayan pencere kullanılarak elde edilmiş ve MAE, RMSE ve R^2 değerleri sırasıyla 1.565 °C, 1.890 °C ve 0.943 olarak belirlenmiştir. Kısa günlük kayan pencerelere (3 ve 5 gün) sahip modeller, yetersiz geçmiş bilgi nedeniyle daha düşük doğruluk sağlamıştır ($R^2 \approx 0.885$). Daha uzun günlük kayan pencerelerde (21 ve 30 günlük) ise bilgi güncelliği kaybı nedeniyle model performansının düştüğü gözlemlenmiştir ($R^2 \approx 0.916$–0.921). Elde edilen bulgular, toprak sıcaklığının kısa vadeli iklim dinamiklerine gecikmeli tepkiler verdiğini ve zaman serisi tahminlerinde kayan pencere boyutunun model başarımında belirleyici bir faktör olduğunu göstermektedir.

Anahtar Kelimeler: LSTM, RMSE, Sliding window, Toprak Sıcaklığı Tahmini

EVALUATION OF THE EFFECT OF DIFFERENT SLIDING WINDOW SIZES ON SOIL TEMPERATURE PREDICTION WITH DEEP LEARNING MODEL

ABSTRACT

In this study, the aim was to predict daily soil temperature at a depth of 5 cm using a deep learning model, Long Short-Term Memory (LSTM), based on meteorological data from the Yüreğir/Çukurova Agricultural Research Automatic Meteorological Observation Station (station no. 18054) for the period between 2016 and 2025. The input variables of the model included average wind speed, total precipitation, average temperature, maximum temperature, minimum temperature, relative humidity, and daily evapotranspiration values. Missing data in the dataset were completed using the linear interpolation method. The input variables of the model were scaled using min-max normalization. During model development, various sliding window sizes (3, 5, 7, 10, 14, 21, and 30 days) were tested to examine their effect on prediction accuracy. The model performance was evaluated using Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and the Coefficient of Determination (R^2) metrics. As a result of the evaluation, the highest accuracy was achieved using a 7-day sliding window, with MAE, RMSE, and R^2 values determined as 1.565 °C, 1.890 °C and 0.943 respectively. Models with shorter sliding windows (3 and 5 days) yielded lower accuracy due to insufficient historical information ($R^2 \approx 0.885$). On the other hand, in models with longer sliding windows (21 and 30 days), a decrease in performance was observed due to the loss of information timeliness ($R^2 \approx$ 0.916–0.921). The findings indicate that soil temperature responds with a delay to short-term climate dynamics, and the sliding window size is a determining factor in the performance of time series predicting models.

Keywords: LSTM, RMSE, Sliding Window, Soil Temperature Prediction

TÜRKİYE'DE BAZI TARLA ÜRÜNLERİNİN MEVCUT DURUMU VE GELECEĞE YÖNELİK TAHMİNLER

Dr. Hilal YILMAZ
Doğu Akdeniz Tarımsal Araştırma Enstitüsü Müdürlüğü-Tarım Ekonomisi Birimi
Email: htarim01@gmail.com
ORCID: 0000-0003-0449-7432
Z.Y.M. Cengiz SAĞLAM
Doğu Akdeniz Tarımsal Araştırma Enstitüsü Müdürlüğü-Tarım Ekonomisi Birimi
Email: cengizsağlam@hotmail.com
ORCID: 0000-0001-7455-1364
Prof. Dr. Oğuz PARLAKAY
Mustafa Kemal Üniversitesi- Ziraat Fakültesi-Tarım Ekonomisi Bölümü
Email: oparlakay@mku.edu.tr
ORCID: 0000-0001-6012-0723
Doç. Dr. Hatun BARUT
Doğu Akdeniz Tarımsal Araştırma Enstitüsü Müdürlüğü-Toprak ve Su Kaynakları Bölümü
Email: baruthatun@yahoo.com
ORCID: 0000-0003-2482-6715
Dr. Sait AYKANAT
Doğu Akdeniz Tarımsal Araştırma Enstitüsü Müdürlüğü- Üretim ve Tohumluk Birimi
Email: saitaykanat@hotmail.com
ORCID: 0000-0002-5690-408X

ÖZET

Türkiye'de bitkisel ürün deseni içerisinde tarla bitkileri kapsamında yetiştirilen ürünler gerek insan beslenmesinde gerekse hayvan yemi olarak önemli yer tutmaktadır. Bu çalışmanın amacı, Türkiye'de üretilen bazı tarla ürünlerinin mevcut durumlarının incelenmesi ve istatistiksel verilerden yararlanarak geleceğe yönelik tahminlerde bulunulmasıdır. Bu kapsamda tarla bitkilerinden sıcak iklim tahılı olarak mısır, yağlı tohumlu bitkilerden de soya, ayçiçeği ve yer fıstığına ait veriler kullanılmıştır. Mısır, günümüzde ekonomik değeri büyük ve enerji değeri yüksek olan dünyada ve ülkemizde insan beslenmesinde büyük öneme sahip bir bitkidir. Mısır, son yıllarda silaj tekniklerinin gelişmesiyle geviş getiren hayvanlar için dünyada en önemli silaj bitkilerinden birisi olmuştur. Yüksek besin değerine sahip olan mısır, insan gıdası olarak ön plana çıkarken, mısır silajı hayvan yemi ve sanayi ham maddesi olarak da kullanılarak önemini bir kez daha arttırmaktadır. Yağlı tohumlu bitkiler de insan ve hayvan beslenmesinin yanı sıra enerji sektöründe kullanılması ve yoğunlukla dış ticarete konu olması bakımından stratejik ürünlerdir. Türkiye'de yağlı tohumlu bitkilerin üretimi yurt içi kullanıma yetmemekte ve ihtiyaç duyulan ürünler ithalat yoluyla karşılanmaktadır. Çalışmanın ana materyalini, Türkiye İstatistik Kurumundan (TÜİK) alınan istatiksel veriler oluşturmaktadır. Çalışmada 2006 ile 2024 yılları

arasını kapsayan dönem verileri analiz edilmiştir. Ayrıca değerlendirme ve yorumlama aşamasında konu ile ilgili daha önceden yapılan çalışmalardan faydalanılmıştır. Yöntem olarak zaman serileri analiz yöntemlerinden Trend Analizi kullanılmıştır. Yapılan analiz sonucu 2006 yılında 5.360.000 da olan mısır ekim alanı 2030 yılında 9.215.680 da, 2006 yılında 119.186 da olan soya ekim alanı 2030 yılında 550.576 da, 2006 yılında 226.900 da olan yerfıstığı ekim alanı 2030 yılında 663.464 da ve 2006 yılında 5.100.000 da olan ayçiçeği ekim alanı 2030 yılında 9.580.006 da olacağı tahmin edilmektedir. İncelenen dönemde özellikle soya ekim alanındaki artış dikkat çekmektedir. Elde edilen bulgular üretim deseninde yer alan ürünlerin ileriki dönemlerde nasıl bir eğilim içerisinde olacağı ve bu ürünlerin iç talebi karşılayabilme durumunu göstermesi açısından önemlidir. Bu bulgulara dayalı sonuçlar karar vericilere politika üretme konusunda yararlı bilgiler sunmaktadır. Ayrıca çalışmada ele alınan ürünlerin ekonomideki yeri ve önemi göz önüne alındığında bu ve benzeri çalışmaların, yeni yayınların yapılmasına zemin oluşturacağı değerlendirilebilir.

Anahtar kelimeler: Tarla ürünleri, Tahmin, Beklenti, Trend Analizi

PRESENT POSITION AND FUTURE PREDICTIONS FOR SOME FIELD CROPS IN TURKEY

ABSTRACT

In Turkey, crops cultivated within the field crop category of plant cropping systems have important roles both in human nutrition and as animal feed. The aim of this study is to examine the current status of some field crops produced in Turkey and to make projections for the future using statistical data. In this context, data on corn as a warm climate grain crop and on soybeans, sunflowers, and peanuts as oilseed crops were used. Corn is a plant of great economic value and high energy value today, and it is of great importance in human nutrition both globally and in our country. With the development of silage techniques in recent years, maize has become one of the most important silage crops in the world for ruminants. Maize, which has high nutritional value, is prominent as human food, while maize silage is also used as animal feed and industrial raw material, further increasing its importance. Oilseed crops are strategic products in terms of their use in human and animal nutrition, their use in the energy sector, and their heavy involvement in foreign trade. In Turkey, the production of oilseed crops is insufficient for domestic consumption, and the required products are met through imports. The main material of the study consists of statistical data obtained from the Turkish Statistical Institute (TÜİK). Data covering the period between 2006 and 2024 were analyzed in the study. In addition, previous studies on the subject were utilized during the evaluation and interpretation phase. The Trend Analysis method from time series analysis methods was used. The analysis results show that the corn cultivation area, which was 5,360,000 da in 2006, will be 9,215,680 da in 2030, the soybean cultivation area, which was 119,186 da in 2006, will be 550,576 da in 2030, the peanut cultivation area, which was 226,900 da in 2006, is estimated to be 663,464 da in 2030, and the sunflower cultivation area, which was 5,100,000 da in 2006, is estimated to be 9,580,006 da in 2030. The increase in soybean cultivation areas during the period under review is particularly noteworthy. The findings obtained are important in terms of showing the future trends of the products included in the production pattern and their ability to meet domestic demand. The findings provide decision-makers with useful information for policy-making. Furthermore, considering the place and importance of the products examined in this study in the economy, it can be argued that this and similar studies will pave the way for new publications.

Keywords: Field crops, Forecast, Expectation, Trend Analysis

BİR OSMANLI MİRASI: ET BALIK KURUMU VE GIDA TEDARİK ZİNCİRİ*

Arş. Gör. Ali İlteriş AYKUN
Erciyes Üniversitesi, Veteriner Fakültesi
Email: aliaykun@erciyes.edu.tr
ORCID: 0000-0002-1986-1519
Prof. Dr. Şule SANAL
Ondokuz Mayıs Üniversitesi, Veteriner Fakültesi
Email: suleo@omu.edu.tr
ORCID: 0000-0002-5703-5752

ÖZET

Bu çalışma, Et ve Balık Kurumu'nun (EBK) 1952'deki kuruluş amaç ve görevlerini, kurumun sadece ekonomik bir Kamu İktisadi Teşebbüsü (KİT) olmanın ötesinde, Osmanlı'dan süre gelen iaşe misyonunu üstlendiğini ve kurumsal devamı olarak analiz etmektedir. Tarihsel olarak Osmanlı İmparatorluğu'nun başkenti İstanbul'da Celebkeşan, Celeb, Koyun Emini ve Kasapbaşı gibi isimler aracılığıyla yürütülen et iaşesi, orduya sürekli bir tedarik ve narh uygulaması ve beraberindeki kurallar ile halkın temel gıdaya erişimini sağlama olmak üzere çeşitli görevler üstlenmiştir. Zaman İçerisinde Osmanlı'nın son dönemlerine doğru bu geleneksel yapılar zayıflasa da, iaşe görevi bir devlet politikası olarak varlığını korumuştur.

Cumhuriyet döneminde, özellikle II. Dünya Savaşı sonrasında ortaya çıkan İstanbul'da hayat pahalılığı krizi, et tedariki sorununu ulusal güvenlik meselesine dönüştürmüştür. Bu konunun önemi 1936 yılında Sanayi Kongresi'nde konuşulmuştur. Ama kurumsal olarak bu kararların faaliyete geçmesi 1949 yılını bulmuştur. Hükümet, bu görevi Marshall yardımları aracılığıyla 1949 yılında görevi ilk olarak Toprak Mahsulleri Ofisi'ne (TMO) devretmiş, ancak bu girişim TMO'nun görev çeşitliliği dolayısıyla yetersiz kalmıştır. Bu durum tamamen özel bir konu olarak, EBK'nın 1952'de Milli Korunma Kanunu'na dayanarak kurulmasını zorunlu kılmıştır.

EBK, kuruluş amaçları ile bağlantılı olarak Osmanlı dönemindeki piyasanın düzenlenmesi ve orduya ve halka et tedariği ve süreklilik gibi benzer görevleri sürdürmüştür. Çalışma, EBK'nın maliyetlerinin ve oluşan zararın yönetimsel verimsizlikten ziyade, kurumun üstlendiği kamu yükümlülüğünün sonucu olduğunu savunmaktadır. Sonuç olarak, 1992 yılında özelleştirilen kurumun, 2005 yılında özelleştirme kapsamından çıkarılması ve yeniden kamu kurumu haline gelmesi, iaşe görevinin özele bırakılmayacak şekilde devlet için vazgeçilemez bir stratejik görev olduğunu göstermektedir. Bu analiz, EBK'yı sadece bir KİT olmaktan çıkarıp, iaşe görevinin devlet için bir zorunluluk olduğunu tanımlayarak literatüre katkı sağlamaktadır.

Anahtar Kelimeler: Et ve Balık Kurumu (EBK), Et ve Et Ürünleri, Osmanlı İaşesi, Toprak Mahsulleri Ofisi (TMO)

***Bu çalışma henüz sunulmamış "Et ve Balık Kurumunun Kuruluşu ve Tarihsel Gelişiminden Bir Kesit (1952-2013)" isimli doktora tez çalışmasından üretilmiştir.**

AN OTTOMAN LEGACY: THE MEAT AND FISH INSTITUTION (EBK) AND THE FOOD PROVISION CHAIN

ABSTRACT

This study analyzes the foundation objectives and duties of the Meat and Fish Institution (Et ve Balık Kurumu - EBK) in 1952, arguing that the institution was not merely an economic State Economic Enterprise (SEE), but undertook the provision mission (iaşe) sustained from the Ottoman period, serving as its institutional continuation. Historically, the meat provisioning (iaşe) system in the Ottoman capital of Istanbul, managed through officials such as Celebkeşan, Celeb, Koyun Emini, and Kasapbaşı, assumed diverse responsibilities. These included ensuring a constant supply for the military and securing public access to essential foodstuffs through narh (price control) and associated regulations. Although these traditional structures weakened towards the final periods of the Ottoman Empire, the provision mission persisted as a paramount state policy.

During the Republican era, the cost of living crisis that emerged in Istanbul, particularly following World War II, transformed the meat supply problem into a matter of national security. The significance of this issue was first discussed at the Industry Congress in 1936. However, the institutional activation of these decisions only occurred in 1949. Utilizing Marshall Plan aid, the government initially assigned this duty to the Turkish Grain Board (TMO) in 1949. However, this endeavor proved inadequate due to TMO's diverse range of functions. This inadequacy, relating to a highly specialized matter, necessitated the establishment of the EBK in 1952, founded upon the National Protection Law (Milli Korunma Kanunu).

In connection with its founding objectives, the EBK sustained analogous duties from the Ottoman period, such as market regulation and ensuring the provision and continuity of meat supply to the military and the public. The study posits that the EBK's costs and resulting financial losses originated not from managerial inefficiency, but rather from the public obligation assumed by the institution. Consequently, the removal of the institution from the scope of privatization in 2005—having been privatized in 1992—and its subsequent return to a public entity status, demonstrates that the iaşe mission is an indispensable strategic function for the state, one that cannot be entrusted to the private sector. This analysis contributes to the literature by reframing the EBK, moving it beyond the definition of a mere SEE and defining the iaşe duty as a fundamental state imperative.

Keywords: Meat and Fish Institution, Meat and Meat Products, Ottoman Food, Turkish Grain Board (TMO)

TÜRKİYE'DE ET SEVKİYATI: ET VE BALIK KURUMU'NUN ÜRETİM MERKEZLERİNİ TÜKETİM MERKEZLERİNE BAĞLAYAN STRATEJİK ROLÜ*

Arş. Gör. Ali İlteriş AYKUN

Erciyes Üniversitesi, Veteriner Fakültesi

Email: aliaykun@erciyes.edu.tr

ORCID: 0000-0002-1986-1519

Prof. Dr. Şule SANAL

Ondokuz Mayıs Üniversitesi, Veteriner Fakültesi

Email: suleo@omu.edu.tr

ORCID: 0000-0002-5703-5752

ÖZET

Bu çalışma, Et ve Balık Kurumu'nun (EBK) 1952'deki kuruluşu, gelişme sürecini ve günümüz arasındaki süreci, Türkiye'nin et üretim ve tüketim merkezleri arasında gıda tedarik ve bölgesel kalkınma misyonu ve sürekliliği üzerinden incelemektedir. Ülkemizde hayvancılığın merkezi olan Doğu Anadolu'dan, nüfusun ve tüketimin yoğun olduğu batı merkezlerine yapılan canlı hayvan naklinden kaynaklanan yüksek fire ve maliyetler, ulusal et tedarik zincirinin kronik bir sorunu olmuştur. Bu konu, 1936 Sanayi Kongresi'nde gündeme gelmiş ve hayvanların yoğun olarak yetiştirildiği yerde kesilip, ürün haline getirildikten sonra batıda yer alan tüketim merkezlerine daha düşük maliyet ve fire ile nakledilmesi temel strateji olarak benimsenmiştir.

EBK, Milli Korunma Kanunu temelinde, bu kamusal zorunluluğu hayata geçirmek üzere kurulmuştur. Kurumun kurulmasından önce bu görevi üstlenen Toprak Mahsulleri Ofisi Marshall yardımları ile Amerika'dan gelen uzmanların katkıları ile ilk girişimi Erzurum Kombinası ile gerçekleştirmiştir. EBK, bu girişim ve sonrasında gelişen süreç ile doğu ve batı bölgesi arasındaki gelişmişlik ve kalkınma farkını ve iç göçü en aza indirmek amacıyla bölgesel kalkınmada ve Doğu Anadolu Bölgesi'nin hayvancılığını desteklemede hayati bir rol üstlenmiştir.

Özelleştirme sürecinde ve özelleştirme kapsamından çıktığı tarihte de çalışmaya devam eden kombinaların çoğu doğu ve güneydoğu illerinde bulunmaktaydı ve bölge hayvancılığının devam etmesine fayda sağlamaktaydı. Ancak 1992 yılında özelleştirme kapsamına alınan kurumun bu süreçte hükümetin teşviklerine karşın Doğu ve Güneydoğu Anadolu Bölgesi'ne yeterince yatırım yapmadığı görülmüştür. Bu durum, stratejik gıda transferi ve bölgenin kalkındırılması misyonunun özel sektör tarafından sürdürülemeyecek bir kamu yükümlülüğü olduğunu kanıtlamıştır. Sonuç olarak, EBK'nın 2005 yılında özelleştirme kapsamından çıkarılması ve TAR-ET Projesi gibi programlarla yeniden bölge hayvancılığını destekleme görevini üstlenmesi, devletin Doğu'dan Batı'ya güvenli ve düzenli gıda tedarik misyonunu geri aldığını göstermektedir. Mevcut durumda misyonuna Et ve Süt Kurumu olarak devam eden kurumun mevcutta yer alan kombinalarının da doğu, güney doğu ve iç Anadolu bölgelerinde bulunması da bu görevin önemini vurgulamakta ve günümüzde devam ettiğini göstermektedir. Bu analiz, EBK'nın kuruluş misyonu ve günümüzdeki durumu ile bölgesel kalkınma ile et ve et ürünlerinin üretim merkezinden tüketim merkezine bir düzen içerisinde ulaştırılması ile stratejik bir kurum olarak tanımlayarak literatüre katkı sağlamaktadır.

Anahtar Kelimeler: Et Balık Kurumu (EBK), Et ve Süt Kurumu, Bölgesel Kalkınma, Gıda Transferi.

*****Bu çalışma henüz sunulmamış "Et ve Balık Kurumunun Kuruluşu ve Tarihsel Gelişiminden Bir Kesit (1952-2013)" isimli doktora tez çalışmasından üretilmiştir**.**

MEAT LOGISTICS IN TÜRKIYE: THE STRATEGIC ROLE OF THE MEAT AND FISH INSTITUTION (EBK) IN LINKING PRODUCTION CENTERS TO CONSUMPTION HUBS

ABSTRACT

This study examines the foundation, development process, and current status of the Meat and Fish Institution (Et ve Balık Kurumu - EBK) since 1952, focusing on its mission continuity related to food provision and regional development between Turkey's meat production and consumption centers. High wastage and costs arising from the transport of live animals from Eastern Anatolia (the center of animal husbandry) to the densely populated consumption centers in the West have been a chronic problem for the national meat supply chain. This issue was brought to the agenda at the 1936 Industry Congress, where the core strategy was adopted: animals should be slaughtered and processed where they are intensively raised and then transported as finished products to Western consumption centers at lower cost and with minimal wastage.

The EBK was founded on the basis of the National Protection Law (Milli Korunma Kanunu) to execute this public imperative. The first institutional attempt was realized with the Erzurum Meat Processing Plant (Erzurum Kombinası), an initiative supported by Marshall Plan aid and American experts, prior to the official establishment of EBK by the Turkish Grain Board (TMO). Through this initiative and subsequent development, EBK assumed a vital role in regional development and supporting animal husbandry in Eastern Anatolia, aiming to minimize the disparity in development and internal migration between the East and West.

During the privatization process and at the time of its removal from the scope of privatization, most operating Meat Processing Plants were located in the Eastern and Southeastern provinces, contributing significantly to the continuation of regional livestock farming. However, the private sector, despite government incentives, was observed to have not invested adequately in the Eastern and Southeastern Anatolia Regions. This proved that the strategic mission of food transfer and regional development was a public obligation that could not be sustained by the private sector. Consequently, the removal of the EBK from the privatization scope in 2005 and its re-assuming the duty of supporting regional animal husbandry through programs like the TAR-ET Project, signified the state’s reclaim of the mission for a secure and regulated food supply from East to West. The fact that the Meat Processing Plants of the successor institution, the Meat and Milk Board (Et ve Süt Kurumu, ESK), are currently located in the Eastern, Southeastern, and Central Anatolia regions further emphasizes the continued importance of this mission. This analysis contributes to the literature by defining the EBK—from its founding mission and present status—as a strategic institution responsible for regional development and the regulated conveyance of meat and meat products from production to consumption centers.

Keywords: Meat and Fish Institution (EBK), Meat and Milk Board (ESK), Regional Development, Food Transfer, Public Obligation.

FLEXIBLE SOIL SENSORS FOR SMART AND SUSTAINABLE AGRICULTURE

Dr. Ayşe Feyza Yılmaz
Istanbul Technical University, Faculty of Mechanical Engineering
Email: yilmazaysef@itu.edu.tr
ORCID: 0000-0002-3507-2624
Prof. Dr. Senem Kurşun
Istanbul Technical University, Faculty of Mechanical Engineering
Email: kursuns@itu.edu.tr
ORCID: 0000-0003-1537-2475

ABSTRACT

In conventional agriculture, soil condition is evaluated based on experience and subjective observations of farmers. For instance, soil moisture is generally checked manually to determine irrigation timing, while planting seasons are determined based on seasonal temperature changes. However, these methods lead to inefficient use of resources such as water, fertilizer, pesticides, and labor, which in turn increases costs and causes greater environmental damage.

Soil sensor technologies, developed as a solution to these problems, provide measurable and real-time data, ensuring that agricultural production processes are more efficient, sustainable, and controlled. These sensors detect moisture, temperature, pH, etc., converting physical and chemical signals into electrical outputs and making them measurable. Rigid soil sensors, manufactured from ceramic or metal bodies, are inserted into the soil and can only measure data at their specific location. When the soil dries out, swells, or compacts, gaps form between the sensor and the soil, leading to measurement errors. Furthermore, it is costly to use multiple rigid sensors to detect the conditions of a field.

This study investigates flexible soil sensors developed to overcome the limitations of rigid sensors. Fabricated from flexible substrate materials, these sensors can be placed without damaging the root zone of plants; and their thin, lightweight, and low-cost nature enhances applicability. By adapting to the physical properties of the soil, flexible sensors can monitor critical parameters such as moisture, temperature, pH, and nutrient levels, offering an innovative solution that both optimizes resource use and increases crop productivity. This approach enables the transition from conventional to smart and sustainable agriculture.

Keywords: Precision Agriculture, Resource Optimization, Soil Monitoring, Rigid Sensor, Flexible Soil Sensor

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SİLİSYUM VE ALJİNİK ASİT İÇERİKLİ JEOTERMAL REZERVLERİN BUĞDAY TARIMINDA KULLANILMASI

Z.Y.M. Ahmet Hilmi GÜRBÜZ

Çukurova Üniversitesi-Ziraat Fakültesi-Toprak Bilimi ve Bitki Besleme Bölümü

Email: ahmethilmigurbuz@gmail.com

ORCID: 0009-0009-9757-5540

Prof. Dr. Hayriye İBRİKÇİ

Çukurova Üniversitesi-Ziraat Fakültesi-Toprak Bilimi ve Bitki Besleme Bölümü

Email: hibrikci@cu.edu.tr

ORCID: 0009-0003-0501-0403

Doç. Dr. Hatun BARUT

Doğu Akdeniz Tarımsal Araştırma Enstitüsü Müdürlüğü-Toprak ve Su Kaynakları Bölümü

Email: baruthatun@yahoo.com

ORCID: 0000-0003-2482-6715

Dr. Sait AYKANAT

Doğu Akdeniz Tarımsal Araştırma Enstitüsü Müdürlüğü- Üretim ve Tohumluk Birimi

Email: saitaykanat@hotmail.com

ORCID: 0000-0002-5690-408X

ÖZET

Silisyum ve aljinik asit bitkide büyüme ve gelişme üzerinde olumlu etkileri olan maddelerdir. Bu çalışmada, silisyum ve aljinik asit içerikli toprak düzenleyicinin buğday bitkisinin verim ve verim parametreleri üzerine etkisi araştırılmıştır. Bu amaçla kurulan deneme, Doğu Akdeniz Tarımsal Araştırma Enstitüsü arazilerinden Doğankent lokasyonunda tarla koşullarında yürütülmüştür. Söz konusu deneme 450 adet m^2 ekim normunda, tesadüf blokları deneme desenine göre üç tekerrürlü olarak kurulmuştur. Deneme parselinin büyüklüğü 1.4 m eninde 5 m boyunda olacak şekilde 7 m^2 olarak ayarlanmıştır. Denemede bitkisel materyal olarak Adana-99 ekmeklik buğday çeşidi kullanılmıştır. Ekim zamanında taban gübresi olarak DAP (18-46-0) ile birlikte toprak düzenleyicinin 0, 10, 20, 30, 40, 50 kg da^{-1} dozları, uygulanmıştır. Kardeşlenme döneminde üst gübre olarak üre (%46 N) gübresi kullanılmıştır.

Araştırma sonucunda, kullanılan toprak düzenleyici materyalin buğday verim ve verim parametreleri üzerine etkisi olumlu bulunmuştur. Uygulamaların buğdayın bitki boyu (cm), başak sayısı (adet m^{-2}), 1000 tane ağırlığı (g), biyolojik verim (kg da^{-1}) üzerine etkisi istatistiki olarak önemli bulunmuştur. En yüksek değer, kontrol uygulaması konusuna göre dekara 40 ve 50 kg toprak düzenleyici uygulamalarından elde edilmiştir. Yapılan araştırmada verim ve toprak düzenleyici arasında quadratik bir ilişki ($y= 438.838+24.409x-0.334x^2$) bulunmuştur. Bu eşitliğe göre, buğday bitkisinde uygulanabilecek toprak düzenleyicinin optimum dozu 36.54 kg da^{-1} olarak tespit edilmiştir. Tek yıllık bir araştırma sonucunda, denemeye konu olan jeotermal biyomineral kompozisyonun buğdayın verim ve verim kriterleri üzerine etkileri incelendiğinde, buğday tarımında kullanılmasının olumlu etkisinin olabileceği gözlemlenmiştir.

Anahtar kelimeler: Silisyum, aljinik asit, buğday, toprak düzenleyici, jeotermal biyomineral rezerv

USE OF GEOTHERMAL RESERVES CONTAİNİNG SİLİCON AND ALGİNİC ACİD İN WHEAT

ABSTRACT

As a result of a one-year research, when the effects of the geothermal biomineral composition, which was the subject of the experiment, on the yield and yield criteria of wheat were examined, it was observed that its use in wheat agriculture could have a positive effect. As a result of a one-year research, when the effects of the geothermal biomineral composition, which was the subject of the experiment, on the yield and yield criteria of wheat were examined, it was observed that its use in wheat agriculture could have a positive effect. Silicon and alginic acid are substances that have positive effects on plant growth and development. This is possible, an investigation was made on the yield and yield of wheat plants compatible with soil containing silicon and alginic acid. For this purpose, the experiment was carried out under field conditions in Doğankent location, one of the lands of the Eastern Mediterranean Agricultural Research Institute. The experiment was conducted with three replications, according to the randomized block trial design, with a planting norm of 450 m^2. The size of the trial plot was adjusted to 7 m^2, with a width of 1.4 m and a length of 5 m. Adana-99 bread wheat variety was used as plant material in the experiment. DAP (18-46-0) as base fertilizer and 0, 10, 20, 30, 40, 50 kg da^{-1} doses of soil conditioner were applied together at the time of planting. Urea (46% N) fertilizer was used as top fertilizer during the tillering period.

As a result of the research, the effect of the soil amendment material used on wheat yield and yield parameters was found to be positive. The effects of the treatments on plant height (cm), number of ears (number m^{-2}), 1000 grain weight (g), biological yield (kg da^{-1}) of wheat were found to be statistically significant. The highest value was obtained from 40 and 50 kg soil conditioner applications per decare, depending on the control application subject. In the research, a quadratic relationship ($y= 438.838+24.409x-0.334x^2$) was found between yield and soil conditioner. According to this equation, the optimum dose of soil conditioner that can be applied to wheat plants was determined as 36.54 kg da^{-1}. As a result of a one-year research, when the effects of the geothermal biomineral composition, which was the subject of the experiment, on the yield and yield criteria of wheat were examined, it was observed that its use in wheat agriculture could have a positive effect

Keywords: Silicon, alginic acid, wheat, soil conditioner, geothermal biomineral reserve.

KAYISIDA KÜLTÜR ÖNCESI BOR VE KALSIYUM UYGULAMALARININ MIKROÇOĞALTIM, CAMLAŞMA VE APİKAL NEKROZA ETKISI

Öğr. Aysun ARAR

Selçuk Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü

Email: aysunarar1@gmail.com

ORCID: 0009-0002-1350-4825

Prof. Dr. Ahmet EŞİTKEN

Selçuk Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü

Email: aesitken@selcuk.edu.tr

ORCID: 0000-0002-6140-7782

ÖZET

Bu çalışmada materyal olarak, Konya'da yapılan önceki çalışmalar sonucunda anaçlık özellikleri bakımından üstün bulunan 42-25 zerdali kayısı genotipine ait, Selçuk Üniversitesi Bahçe Bitkileri Bölümü'nde mikroçoğaltma ile elde edilmiş 3 yaşındaki fidanlar kullanılmıştır. Kayısı genotipinde eksplant alınacak bitkilere kültür öncesi uygulanan bor (150 ve 300 ppm), kalsiyum (%1 ve %2 $CaCl_2$) ve bunların kombinasyonlarının *in vitro* mikroçoğaltma ve köklendirme başarısına etkilerini belirlemek amacıyla yürütülmüştür.

Kültür öncesinde belirlenen dozlarda Ca ve B püskürtülen bitkiden alınan çelikler, sterilizasyon işlemlerinden geçirilmiş ve MS besi ortamına aktarılmıştır. Çoğaltma aşamasında eksplantlar, yeterli sayıya ulaşıncaya kadar düzenli olarak alt kültüre alınmış ve bu süreç toplam yedi alt kültür boyunca devam etmiştir. Her alt kültürde sağlıklı gelişim gösteren sürgünler bir sonraki ortama aktarılmıştır. Bu aşamada bitki canlılığı, sürgün sayısı, sürgün uzunluğu ve camlaşma oranı değerlendirilmiştir. Köklendirme aşamasında ise köklenme oranı, kök sayısı, kök uzunluğu ve apikal nekroz oranları incelenmiştir. Sonuç olarak, toplam dokuz uygulamanın beşinde başarılı veriler elde edilmiş (Kontrol, %1 $CaCl_2$, %1 $CaCl_2$ + 150 ppm B ve %1 $CaCl_2$ + 300 ppm B ve 300 ppm B); apikal nekrozdaki artış ve yüksek dozlara bağlı fitotoksisite nedeniyle diğer uygulamalarda bitkilerin yaşamını yitirdiği tespit edilmiştir.

Elde edilen bulgulara göre sürgün sayısı en fazla kontrol grubunda (9,40 adet/eksplant) belirlenmiştir. Sürgün uzunluğu ise en yüksek 300 ppm B uygulamasında kaydedilmiştir. Camlaşma oranı en yüksek yine 300 ppm B'de gözlenmiş ancak %1 $CaCl_2$ ve bazı kombinasyonlarda tamamen engellenmiştir. Köklenme oranı kontrol dahil tüm uygulamalarda %100 gerçekleşirken, kök sayısı özellikle %1 $CaCl_2$ ve kontrol'de öne çıkmıştır. Kök uzunluğu %1 $CaCl_2$ ve kombinasyonlarında en yüksek seviyelere ulaşmıştır. Ayrıca apikal nekroz oranı en düşük %1 $CaCl_2$ uygulamasında kaydedilmiş ve bu uygulamanın önemli bir baskılama etkisi yaptığı belirlenmiştir.

Anahtar Kelimeler: Kayısı, bor, kalsiyum, mikroçoğaltım başarısı

EFFECTS OF PRE-CULTURE BORON AND CALCIUM APPLICATIONS ON MICROPROPAGATION, VITRIFICATION, AND APICAL NECROSIS IN APRICOT

ABSTRACT

In this study, three-year-old seedlings of the 42-25 apricot (Prunus armeniaca L.) genotype, previously identified in field studies conducted in Konya as superior in terms of rootstock characteristics and obtained through micropropagation at the Department of Horticulture, Selçuk University, were used as plant material. The study aimed to determine the effects of pre-culture applications of boron (150 and 300 ppm), calcium (1% and 2% $CaCl_2$), and their combinations on *in vitro* micropropagation and rooting success in this apricot genotype.

Cuttings taken from plants sprayed with predetermined doses of Ca and B before culture were sterilized and transferred to MS nutrient medium. During the propagation phase, explants were subcultured regularly until a sufficient number was reached, continuing for a total of seven subcultures. Shoots showing healthy growth in each subculture were transferred to fresh medium. At this stage, plant viability, shoot number, shoot length, and vitrification rate were evaluated. In the rooting phase, rooting rate, root number, root length, and apical necrosis rate were examined. As a result, successful outcomes were obtained in five of the nine treatments (Control, 1% $CaCl_2$, 1% $CaCl_2$ + 150 ppm B, 1% $CaCl_2$ + 300 ppm B, and 300 ppm B), while increased apical necrosis and phytotoxicity caused by higher doses led to plant death in the remaining treatments.

According to the findings, the highest shoot number was recorded in the control group (9.40 shoots/explant), whereas the longest shoots were obtained from the 300 ppm B treatment. The highest vitrification rate was also observed in the 300 ppm B treatment; however, vitrification was completely prevented in 1% $CaCl_2$ and some combination treatments. Rooting rate reached 100% in all treatments, including the control, while root number was particularly higher in 1% $CaCl_2$ and control treatments. Root length reached its maximum levels in 1% $CaCl_2$ and its combinations. Additionally, the lowest apical necrosis rate was recorded in the 1% $CaCl_2$ treatment, indicating a strong suppressive effect.

Keywords: Apricot, boron, calcium, micropropagation success.

FAYDALI BAKTERİLERİN FASULYEDE *Macrophomına phaseolına* [(tassı) goıd.]'NIN NEDEN OLDUĞU KÖMÜR ÇÜRÜKLÜĞÜ HASTALIĞI VE BİTKİ GELİŞİMİ ÜZERİNE ETKİLERİ

Muhammed KAYALAK

Tokat Gaziosmanpaşa Üniversitesi, Ziraat Fakültesi

Email: muhammedkayalak01@gmail.com

ORCID NO: 0000-0002-8264-4744

Araş. Gör. Mevlüde Beyza BAYHAN

Tokat Gaziosmanpaşa Üniversitesi, Ziraat Fakültesi

Email: mevludebeyza.bayhan@gop.edu.tr

ORCID: 0009-0005-9267-6298

Doç. Dr. Sabriye BELGÜZAR

Tokat Gaziosmanpaşa Üniversitesi, Ziraat Fakültesi

Email: sabriye.yazici@gop.edu.tr

ORCID: 0000-0002-8892-0017

ÖZET

Bu çalışma bazı faydalı bakterilerin fasulyede kömür çürüklüğü hastalık etmeni *Macrophomina phaseolina* [(Tassi) Goid.]'ya karşı biyokontrol potansiyellerini belirlemek ve bu bakterilerin fide gelişimi üzerindeki etkilerini araştırmak amacıyla yapılmıştır. Çalışmada çeşitli kaynaklardan izole edilen bakteri izolatları, fasulyeden izole edilen *M. phaseolina* izolatı ve Gina çeşidi fasulye tohumları kullanılmıştır. Çalışma, *in vitro* ve iklim odası koşullarında yürütülmüştür. *In vitro* koşullarda Triptik Soy Agar besi yerinde ikili kültür testi ile yapılmış ve uygulama yapılan petrilerde fungus miselyum çapları ölçülerek bakteri izolatlarının fungus üzerindeki etkisi belirlenmiştir. İkili kültür testinde fungus üzerinde etkili olan altı adet izolat ile saksı denemesi kurulmuştur. Saksı denemesinde, fasulye tohumları her bir izolattan hazırlanan bakteri süspansiyonu ile muamele edilmiştir. Tohum ekimi esnasında *M. phaseolina*'dan hazırlanan mikrosklerot süspansiyonu tohum çevresine uygulanmış ve bu uygulamadan yedi gün sonra ikinci bir bakteri uygulaması topraktan sulama şeklinde tohumlara verilmiştir. Negatif kontrol olarak saf su uygulanan tohumlar, pozitif kontrol olarak sadece patojen fungus uygulanan tohumlar kullanılmıştır. Yaklaşık 30 gün sonra bitkilerdeki çökme sayısına göre değerlendirme yapılmıştır. Çalışmada ayrıca bakterilerin fasulyede fide gelişimine olan etkisi de araştırılmıştır. Patojen uygulaması dışında bakteri uygulanan tohumlardan oluşan fidelerde farklı parametrelerle değerlendirme yapılmıştır. İkili kültür testlerinde bakterilerin %37,6-86,5 arasında değişen oranlarda *M. phaseolina* miselyum gelişimini baskıladığı belirlenmiştir. Saksı denemesinde ise kontrol (2,4) ile kıyaslandığında MBB1 (0,2) en yüksek biyokontrol potansiyeline sahip izolat olarak belirlenmiştir. Kullanılan bakterilerin çeşitli parametrelerde fide gelişimini de olumlu yönde etkilediği görülmüştür. Çalışmada bazı faydalı bakterilerin kömür çürüklüğü hastalığı üzerine etkisi belirlenmiş olup, sera ve tarla koşullarında yürütülecek çalışmalar ile baskılama özelliklerinin ortaya konulması mücadelesi zor olan bu hastalık için oldukça önem arz etmektedir. Kullanılan bakterilerin etki mekanizmalarının ve biyogübre potansiyellerinin detaylı bir şekilde belirlenmesi çalışmayı daha anlamlı kılacaktır.

Anahtar Kelime: *Macrophomina phaseolina,* Faydalı bakteriler, Biyolojik mücadele

EFFECTS OF BENEFICIAL BACTERIA ON CHARCOAL ROT DISEASE CAUSED BY *Macrophomına phaseolına* [(tassı) goıd.] AND ON THE GROWTH OF COMMON BEAN

ABSTRACT

This study was conducted to determine the biocontrol potential of certain beneficial bacteria against the charcoal rot pathogen *Macrophomina phaseolina* [(Tassi) Goid.] in bean (*Phaseolus vulgaris* L.) and to investigate their effects on seedling growth. Bacterial isolates obtained from various sources, an *M. phaseolina* isolate collected from bean, and seeds of the Gina bean variety were used in the study. The experiments were carried out under both *in vitro* and climate chamber conditions. Under *in vitro* conditions, a dual culture test was performed on Tryptic Soy Agar medium. The mycelial diameter of the fungus was measured to determine the inhibitory effect of the bacterial isolates. Based on the *in vitro* results, six isolates that showed high antifungal activity were selected for pot experiments. In the pot experiment, bean seeds were treated with bacterial suspensions prepared from each isolate. During sowing, a microsclerotial suspension of *M. phaseolina* was applied around the seeds, and seven days later, a second bacterial treatment was administered to the soil as irrigation. Sterile distilled water-treated seeds served as the negative control, while seeds inoculated only with the pathogen constituted the positive control. Approximately 30 days after sowing, disease incidence was evaluated based on the number of collapsed seedlings. In addition, the effects of the bacterial treatments on seedling growth were evaluated. In treatments without pathogen inoculation, seedlings derived from bacterium-treated seeds were assessed using various growth parameters. The dual culture tests revealed that bacterial isolates inhibited *M. phaseolina* mycelial growth by 37.6–86.5%. In the pot experiment, when compared with the control (2.4), isolate MBB1 (0.2) exhibited the highest biocontrol potential. The tested bacterial isolates also positively affected seedling growth parameters. Overall, the study demonstrated that some beneficial bacteria can suppress charcoal rot disease in beans. Future greenhouse and field experiments will be crucial to confirm their disease-suppressive potential against this difficult-to-control pathogen. Moreover, detailed investigation of the mechanisms of action and biofertilizer potential of these bacteria will further enhance the significance of this research.

Keywords: *Macrophomina phaseolina,* Beneficial bacteria, Biological control

SİMMENTAL MELEZİ SIĞIRLARDA YEMLEME ÖNCESİ VE SONRASI VÜCUT BİYOELEKTRİK AKTİVİTELERİNİN İNCELENMESİ

Dr.Öğr. Üyesi Hasan ÇELİKYÜREK

Van Yüzüncü Yıl Üniversitesi, Ziraat Fakültesi, Zootekni Bölümü

Email: hasancy@yyu.edu.tr

ORCID: 0000-0001-5154-7979

Öğr. Gör. Rıdvan BAYRAM

Hakkâri Üniversitesi, Yüksekova MYO, Bitkisel ve Hayvansal Üretim Bölümü

Email: ridvanbayram@hakkari.edu.tr

ORCID: 0000-0003-1624-6753

Azat ARAS

Van Yüzüncü Yıl Üniversitesi/ Zootekni Bölümü

Email: azataraszootekni@gmail.com

ORCID: 0009-0008-2635-433X

Abdurrahman YAMAÇ

Van Yüzüncü Yıl Üniversitesi/ Zootekni Bölümü

Email: by_yamac@hotmail.com

ORCID: 0000-0000-0000-0000

ÖZET

Bu çalışma, sığırlarda yemleme öncesi ve sonrası biyoelektrik aktivitede meydana gelen değişiklikleri tespit etmek ve bu durumun fizyolojik sebeplerini ortaya koymak amacıyla yapılmıştır. Doğru tasarlanmış in vitro simülasyon teknolojileri biyolojik araştırmalarda tamamlayıcı bir araçtır. Bu nedenle canlının vücudunda üretilen ve sürekli var olan biyoelektrik aktivitenin de üretim mekanizmasında etkili bir faktör olarak değerlendirilmesi gerektiğini düşünmekteyiz.

Çalışmada, Van ilinden 16 dişi ve Kars ilinden 14 erkek Simmental Melezi sığır kullanılmıştır. Hayvanların biyoelektrik aktivitesi, 35 gün boyunca her gün akşam yemleme öncesi ve sonrasında Avometre cihazı ile yalıtkan bir platform üzerinde ölçülmüştür. Elde edilen veriler, hayvanların cinsiyet, yaş, ağırlık ve şehir gibi faktörlere göre istatistiksel analizleri yapılmıştır.

Ölçümler sonucu; yemleme öncesi 0.517±0.011v ve yemleme sonrası 0.507±0.010v biyoelektrik aktivite bulundurdukları tespit edilmiştir. Yemleme öncesi ve sonrası ölçülen biyoelektrik aktivite değerlerinin cinsiyet, yaş, durum, ağırlık ve şehir bakımından önemli bir fark oluşturdukları tespit edilmiştir.

Vücuttaki elektriksel iletkenlik, iyonların (sodyum, potasyum, kalsiyum) dengesi ve su miktarı ile doğrudan ilişkilidir. Özellikle kan damarlarındaki sıvı dengesi ve hormonal etkiler, biyoelektrik aktivite ölçümlerinde geçici dalgalanmalara neden olmaktadır. Bu durum, sindirimle birlikte metabolik süreçlerin hızlanması ve vücudun yeni bir denge durumuna geçmesiyle açıklanabilir.

Sonuç olarak, sığırlardaki biyoelektrik aktivitenin yemlemeden önce yüksek, yemlemeden sonra ise önemli oranda düştüğü tespit edilmiştir. Bu bulgular, yapılacak çalışmalarda biyoelektrik aktivite ölçümlerinin dinamik bir süreç olarak ele alınması gerektiğini ortaya koymaktadır. Bu çalışma, hayvanlardaki biyoelektrik aktivitenin günlük yaşam döngüsü içindeki değişimlerini anlamak için önemli bir ilk adımdır ve gelecekte bu konuda yapılacak araştırmalar için bir temel oluşturabilir.

Anahtar Kelimeler: Biyoelektrik aktivite, Simmental, Yemleme öncesi, Yemleme sonrası

Vücut elektriği

INVESTIGATION OF BEFORE- AND AFTER-FEEDING BODY BIOELECTRICAL ACTIVITIES IN SIMMENTAL CROSSBRED CATTLE

ABSTRACT

This study was conducted to determine the changes in bioelectric activity that occur in cattle before and after feeding and to reveal the physiological reasons for these changes. We believe that bioelectric activity, which is produced continuously in a living organism's body, should be considered an effective factor in its production mechanism. In vitro simulation technologies, when designed correctly, are a complementary tool in biological research.

For the study, 16 female and 14 male Simmental Crossbred cattle from Van and Kars provinces, respectively, were used. The animals' body electricity was measured

for 35 days, both before and after their evening feeding, using an Avometer on an insulating platform. The data obtained from the measurements were statistically analyzed based on factors such as the animals' sex, age, weight, and city.

The measurements revealed that the animals' bioelectric activity was 0.517±0.011v before feeding and 0.507±0.010v after feeding. It was also determined that the bioelectric activity values measured before and after feeding showed a significant difference based on gender, age, physiological status, weight, and city.

Electrical conductivity within the body is directly related to the balance of ions (sodium, potassium, calcium, etc.) and water content. The fluid balance in blood vessels and hormonal effects, in particular, cause temporary fluctuations in bioelectric activity measurements. This can be explained by the acceleration of metabolic processes and the body's transition to a new state of equilibrium during digestion.

In conclusion, it was determined that the bioelectric activity in cattle is high before feeding and decreases significantly after feeding. These findings suggest that bioelectric activity measurements in future studies should be treated as a dynamic process. This study is an important first step toward understanding the daily variations in bioelectric activity in animals and can provide a basis for future research in this area.

Keywords: Bioelectrical activity, Simmental, Pre-feeding, Post-feeding, Body electricity

LITERATURE REVIEW AND PROPOSING A COMPUTER VISION BASED WEAPON DETECTION SYSTEM CALLED CMS FOR THE CONSERVATION OF TRIBES OF CHHATTISGARH

Vaibhav Kant Singh

Guru Ghasidas Vishwavidyalaya, A Central University, India

Email: vibhu200427@gmail.com

ORCID: 0000-0002-6776-9573

Kapil Kumar Nagwanshi

ORCID: 0000-0003-3133-978X

Guru Ghasidas Vishwavidyalaya, A Central University, India

Samanvay Singh

ORCID: 0009-0007-2551-8884

Guru Ghasidas Vishwavidyalaya, A Central University, India

ABSTRACT

Chhattisgarh a state of India is suffering from naxal problem. The identification whether a person is belonging to Naxal domain or not is a very difficult problem. Government of India and Chhattisgarh has made commendable progress in maintaining the catastrophic situation in some parts of chhattisgarh. In the current paper the authors knowing that the naxal people are generally located in dense forest area will take help of the proposed prototype of the current article. In the current article with the advancement of CNN based drone technology and CCTV based CNN technologies could be used for the detection of people having weapon and send an alert to the respective officer in-charge that government has appointed to take care of the problem. In the current work we will be performing a Training Operation where all the individuals from the Government who carry weapons will be detected and afterwards whenever a new person carrying weapon is detected in the suspected region will send an alert in terms of Email or Message. The prototype is what is conveyed in the paper using the CNN based technology and the conservation of Tribes which is the majority population near the dense forest area are going to have the help.

Keywords: AI, ML, Naxal, CV, CCTV.

PRODUCTION OF DESIGNER EGGS AND ITS IMPORTANCE IN HUMAN NUTRITION : A REVIEW

Ekanem, Ndifreke John

Department of Animal Science, Faculty of Agriculture, University of Uyo, Uyo, Nigeria

Email: ekanemndi@gmail.com (Corresponding author)

Afolabi, Kolawole Daniel

Department of Animal Science, Faculty of Agriculture, University of Uyo, Uyo, Nigeria

Balogun, A. O

Department of Agricultural Biochemistry and Nutrition, University of Ibadan, Nigeria

Muhammad Haroon, Aslam;

Institute of Animal and Dairy Sciences, Faculty of Animal Husbandry, University of Agriculture Faisalabad, Faisalabad, Pakistan

Agwu, Ani Ekwe

Department of Animal Health and Production Technology, Federal Polytechnic Ngodo-Isuochi, Abia State, Nigeria.

Essien, Kemfon Friday

Department of Animal Science, Bayero University Kano, Kano State, Nigeria

ABSTRACT

Designer eggs are one of the significant improvements in poultry egg production, driven by the increasing need for nutritionally dense foods. They are enriched eggs that are produced by modifying the diet of laying hens to improve the nutritional profile of eggs with superior makeup/composition to their original. As designer eggs are laid by hens whose diets have been infused with certain feed additives which includes antioxidants, vitamins, minerals, omega-3-rich sources, and the likes, they can also be considered as nutritionally enhanced eggs. By means of genetic selection and beneficial modifications, designer eggs can also be produced to provide advantageous health benefits. This review explores the different techniques of producing designer eggs, with an emphasis on feed-based approaches including adding flaxseed, fish oil, microalgae, selenium, and carotenoids to hens' diet. These dietary changes produce eggs that are highly metabolized. The paper further examines the use of designer eggs to prevent chronic diseases, such as cardiovascular ailments, cognitive decline, and vitamin deficiencies, in addition to detailing compositional enhancements. Within the larger framework of nutrition-sensitive agriculture, the function of designer eggs to promote public health is assessed with a focus on alleviating undetected malnutrition and non-communicable diseases in both industrialized and developing nations. Even though, there are still issues with production costs, safety standards, and nutritional stability, designer or enhance eggs present a viable pathway for the development of functional foods. They offer a practical, long-term approach to enhancing population health by combining focused dietary modifications with farming methods.

Keywords: Designer eggs, Nutrition, Importance, Additives, Supplementation laying hens

STREET FOOD SAFETY AND ITS IMPACT ON PUBLIC HEALTH: A CULTURAL AND PERSPECTIVE

Kishore.R

Faculty Of Pharmacy , Bharath Institute Of Higher Education And Research ,chennai India

Meenatchi .S

Faculty Of Pharmacy , Bharath Institute Of Higher Education And Research ,chennai India

Keerthana.V

Faculty Of Pharmacy , Bharath Institute Of Higher Education And Research ,chennai India

Vaishnavi.k

Faculty Of Pharmacy , Bharath Institute Of Higher Education And Research ,chennai India

ABSTRACT

Street food plays a vital role in urban food culture, offering affordable and accessible meals to millions worldwide. However, despite its cultural and economic significance, street food often poses major public health challenges due to inadequate hygiene practices, lack of proper storage facilities, and limited regulatory oversight. This study aims to explore the relationship between street food consumption, food safety standards, and public health outcomes. Emphasis is placed on understanding the social importance of street food vendors, consumer behavior, and awareness regarding food hygiene. Findings suggest that while street food supports local economies and preserves traditional culinary practices, it also contributes to foodborne diseases when safety measures are neglected. Strengthening food safety education, implementing hygiene regulations, and promoting awareness among vendors and consumers are essential for ensuring safe street food practices. The study highlights the need for integrated policy approaches that balance cultural preservation with public health protection

Keywords: Street food, food safety, public health, hygiene, consumer behavior, cultural practices

ENHANCING PHARMACEUTICAL OUTCOMES THROUGH AGRICULTURAL KNOWLEDGE

M. Muthuramlingam

Faculty of pharmacy, Bharath institute of higher education and research, chennai, India

R.Ravichandren

Faculty of pharmacy, Bharath institute of higher education and research, chennai, India

VGowtham

Faculty of pharmacy, Bharath institute of higher education and research, chennai, India

ABSTRACT:

Agriculture serves as a vital pillar in pharmaceutical sciences, especially in the sourcing and development of plant-based medicines. Many essential drugs originate from medicinal plants cultivated through agricultural practices, making knowledge of cultivation, harvesting, and post-harvest handling critical to ensuring drug quality and consistency. Agricultural studies in pharmacy focus on medicinal plant identification, soil and climate requirements, pest management, and sustainable farming techniques to optimize the yield of pharmacologically active compounds. .Understanding agriculture is not only important for herbal drug production but also for ensuring the authenticity, safety, and efficacy of natural products. With the growing global demand for phytopharmaceuticals and traditional medicines, pharmacists must be equipped with agricultural insights to ensure ethical sourcing and promote conservation of medicinal plant biodiversity Integrating agricultural knowledge into pharmacy strengthens the link between nature and medicine, supporting innovation, sustainability, and global health.

Keywords: Agriculture in pharmacy, medicinal plants, herbal drug production, phytopharmaceuticals, sustainable farming, medicinal plant cultivation, pharmacognosy, natural product sourcing, traditional medicine, plant-based medicines, biodiversity conservation, post-harvest handling, agricultural practices in pharmacy.

EFFECT OF DIETARY SUBSTITUTION ON SOME PRODUCTION PARAMETERS OF RED TILAPIA (*oreochromis sp.*) IN THE BISKRA REGION.

Ameur ZAGHOUANI*

Laboratory of Ecosystem Diversity and Agricultural Production System Dynamics in Arid Zones (DESDPAZA), University of Biskra, Biskra 07000 Algeria.

Email: ameur.zaghouani@univ-biskra.dz

Ayoub HADJEB[1]

Laboratory of Ecosystem Diversity and Agricultural Production System Dynamics in Arid Zones (DESDPAZA), University of Biskra, Biskra 07000 Algeria.

Sarra BENAISSA

Laboratory of Ecosystem Diversity and Agricultural Production System Dynamics in Arid Zones (DESDPAZA), University of Biskra, Biskra 07000 Algeria.

Mohamed Rami BERBACHE

Laboratory of Ecosystem Diversity and Agricultural Production System Dynamics in Arid Zones (DESDPAZA), University of Biskra, Biskra 07000 Algeria.

Chaima CHETIOUI

Department of Agriculture Sciences, Laboratory of Improvement and Development of Plant and Animal Production, University of Sétif 1, Algeria

Amina HAMMADI

Department of Agriculture Sciences, Laboratory of Improvement and Development of Plant and Animal Production, University of Sétif 1, Algeria

Kawther BOUREZZANE

Laboratory of Ecosystem Diversity and Agricultural Production System Dynamics in Arid Zones (DESDPAZA), University of Biskra, Biskra 07000 Algeria.

Yahia AMMARI

University of Kasdi Merbah Ouargla, Laboratory of Saharan Bioresources Preservation and Valorisation

Habiba HACHANI

Laboratory of Ecosystem Diversity and Agricultural Production System Dynamics in Arid Zones (DESDPAZA), University of Biskra, Biskra 07000 Algeria.

ABSTRACT

The experiment was carried out in an experimental greenhouse at the Department of Agronomic Sciences, University of Biskra. Two 1 m³ tanks, each housing 30 fish, were utilized with a mechanical filtration system and weekly water replenishment. In the evaluated diet, soybean meal was substituted with peanut meal in equivalent quantities The control feed comprised 41% soybean meal, 14% fish meal, 35% corn, 8% oil, and 2% multivitamin supplement (MVS). The fish were nourished bi-daily, and the assessed parameters included weight, length, width, and growth coefficient. The primary aim of this study is to compare the weight and growth of hybrid

tilapia (Oreochromis sp.) fed a diet consisting of readily available vegetable materials (peanuts) with those nourished on commercial feed. The proposed methodology involves weekly measurements of the weights and sizes of hybrid tilapia over a two-month duration. The mean weight at the conclusion of the experiment was 33.54 grams. The average dimensions measured were 12.22 cm in length and 4.5 cm in width. The results gathered in this study indicates that food derived from plant products warrants our utmost attention and should be broadly valued.

Keywords: Red tilapia, weight, dimensions, peanuts, processed food, commercial food.

CONSTRUCTION FEATURE AND REGULATORY ASPECTS OF ORGAN CHIP FOR DRUG DELIVERY APPLICATION

Babita Gupta

Assistant Professor, Institute of Technology and Management

Email: guptababita2001@gmail.com

ABSTRACT

Organ-on-chip is an innovative technique, that emerged from tissue engineering and microfluidic technologies. Organ-on-chip devices (OoCs) are anticipated to provide efficient resolutions to dealing with challenges in pharmaceutical advancement and individualized illness therapies. Organ-on-chip is an advanced technology that simulates the physiological processes of human organs on a silicon chip. The main objective of the organ-on-chip technique is to replicate three essential aspects of human physiology: the complex cellular interfaces found in organs such as blood vessels, lungs, and the gut, which act as barriers in tissues. The article aims to explore the detailed design factors that contribute to the biomimetic character of Organ-on-Chip devices, focusing on their construction aspects primarily for drug delivery applications. Three-dimensional organ-on-a-chip models can contract and secrete albumin like genuine tissues. Several scientific fields employ microfluidic devices to construct basic humanoid model systems. Effective integration of this advanced technical platform with common pharmaceutical and medical contexts is still a challenge. subsequently, it summarizes tumor-on-a-chip technologies and indicates their application in anti-cancer drug assessment. Microfluidic technology, a micro-level technique, has become a potent tool for biomedical engineering research. As a result, it has revolutionized disciplines including physiological material interpreting, compound detection, cell-based assay, tissue engineering, biological diagnostics, and pharmaceutical identification. The review provides a comprehensive analysis of the regulatory dimensions related to the application of OOC technology in the field of drug delivery. The article explores how Organ-on-Chip medication delivery technology must improve the connection between experimental models and clinical applications.

Keywords: Organ-on-chip, Microfluidic technology, Bioengineering, Tissue engineering

SUSTAINABLE FOOD PACKAGING TECHNOLOGIES: INNOVATION FOR A GREENER CONSUMER FUTURE

Aliza Naeem

Department of Food Sciences, Government College University Faisalabad, Pakistan

Muhammad Bilal Hussain

Department of Food Sciences, Government College University Faisalabad, Pakistan

Marwa Waheed

Department of Food Science Technology, Riphah International University , Faisalabad, Pakistan

Sawera Asif

Department of Food Sciences, Government College University Faisalabad, Pakistan

Mariam Islam

Department of Food Sciences, Government College University Faisalabad, Pakistan

Maha Atiq

Department of Food Sciences, Government College University Faisalabad, Pakistan

ABSTRACT

The need for friendly and sustainable solution from consumers is causing a major shift in the food packaging sector. Innovation in food packaging are focused on reducing waste, increasing recyclability, and promoting environmentally responsible practices. Recent development in the edible packaging, biodegradable material, and smart packaging technologies are highlighted in this abstract as example of sustainable of food packaging. Redesigning food packaging options to be more sustainable is necessary, but evaluating which option is more optimal while taking into account the full value chain of food products is a highly challenging issue. Although earlier research cleared the path for a definition of sustainable food packaging, it is still far from widely used or widely accepted in the felid of food system, which leads to all parties involved in the value chain producer, distribution, practitioners, and consumer making ignorant decisions about sustainable food packaging.

Biodegradable material, such as plant-based bioplastics and compostable packaging, offer a promising alternative to traditional plastics. Packaging waste is completely eliminated with edible packaging, which is produced from natural substances like cornstarch or seaweed. Smart packaging technologies, including intelligent labels and sensor, enable real-time monitoring of food freshness and quality. In general, it is expected that more countries and regions would implement laws to reduce waste and promote a circular economy, continuing the trend toward sustainable food packaging regulation. This is likely to encourage the creation of new eco-friendly packaging materials and encourage businesses to adopt more sustainable practices. As consumer become more aware of the environmental impact of their purchasing decisions, the demand for sustainable food packaging will continuous to grow, driving further innovation and adoption of eco-friendly practices.

Keywords: Eco-friendly materials, **Biodegradable packaging, Circular economy,** Green technolog

SUSTAINABLE VALORIZATION OF ROSEHIP BY-PRODUCTS AS FUNCTIONAL ADDITIVES IN PORK SAUSAGES: FUNCTIONAL AND QUALITY PERSPECTIVES

Alexandra Raluca Borşa (Bogdan)

University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Food Science and Technology, Department of Food Engineering, Cluj-Napoca, Romania

Email: raluca.borsa@usamvcluj.ro

ORCID: 0001-6343-4082

Lect. Andrei Borșa*

University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Food Science and Technology, Department of Food Engineering, Cluj-Napoca, Romania

Email: andrei.borsa@usamvcluj.ro

ORCID: 001-7887-8639

Melinda Fogarasi

University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Food Science and Technology, Department of Food Engineering, Cluj-Napoca, Romania

Email: melinda.fogarasi@usamvcluj.ro

ORCID: 0000-0002-9561-1183

Floricuţa RANGA

University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Food Science and Technology, Department of Food Science, Cluj-Napoca, Romania

Email: floricutza_ro@yahoo.com

ORCID: 0002-4694-7932

Anda Elena TANISLAV

University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Food Science and Technology, Department of Food Science, Cluj-Napoca, Romania

Email: anda.tanislav@usamvcluj.ro

ORCID: 0000-0002-9136-4832

Vlad MUREŞAN

University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Food Science and Technology, Department of Food Engineering, Cluj-Napoca, Romania

Email: vlad.muresan@usamvcluj.ro

ORCID: 0000-0003-2113-422X

Cristina Anamaria SEMENIUC*

University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Food Science and Technology, Department of Food Engineering, Cluj-Napoca, Romania

Email: cristina.semeniuc@usamvcluj.ro

ORCID: ORCID: 0000-0002-9721-4560

ABSTRACT

Introduction:

Rosehip by-products represent a sustainable source of fibers, polyphenols, and carotenoids (Borşa et al., 2025) with strong antioxidant and coloring potential. Their inclusion in meat products may reduce synthetic additives while enhancing quality and stability. This study explores their valorization as natural functional additives for pork sausage reformulation. Exploring their incorporation into meat systems offers an opportunity to improve both product quality and circular economy outcomes in the food sector.

The objective of this study was to investigate the feasibility of incorporating rosehip by-product powder into pork sausages and to evaluate its influence on their technological, physicochemical, and sensory characteristics within a sustainability-oriented framework.

Three pork sausage formulations were prepared: a control sample without rosehip powder and two experimental variants containing 2.7% and 5.5% rosehip by-product powder. The sausages were analyzed to determine the influence of the ingredient on color, texture, and general quality attributes throughout storage. Physicochemical parameters, including pH, moisture, and lipid oxidation, were measured, alongside colorimetric and textural profile analyses. Furthermore, total polyphenol and carotenoid contents were quantified to assess the functional contribution of the powder. Sensory evaluation was carried out with consumer panels to determine acceptance and perceived quality differences among the samples.

The inclusion of rosehip by-product powder in pork sausage formulations resulted in measurable changes to their composition and quality parameters. Moisture and protein contents showed a significant decrease, while total carbohydrates, polyphenol, and carotenoid levels increased proportionally to the amount of powder added. The powder also contributed to a lower pH and reduced easily hydrolysable nitrogen, indicating potential preservative effects. In terms of appearance, reformulated sausages exhibited enhanced red and yellow tones, reflecting improved visual quality. Texture profile analysis revealed reductions in gumminess and chewiness, while sensory evaluation showed only minor differences in taste and mouthfeel compared to the control. Overall consumer acceptance remained high across all treatments, indicating good market potential.

Rosehip by-products represent a promising functional ingredient for pork sausage reformulation, offering both technological and nutritional benefits while supporting sustainable waste valorization and clean-label product development.

Keywords: carotenoids, polyphenols, physicochemical properties, functional meat products

FOOD SAFETY REGULATIONS AND CONSUMER AWARENESS

D.Aravindhan

Faculty of Pharmacy, Bharath Institute of Higher Education and Research, Chennai, India

N.Arshad Ahamed

Faculty of Pharmacy, Bharath Institute of Higher Education and Research, Chennai, India

K.Dinesh Rajan

Faculty of Pharmacy, Bharath Institute of Higher Education and Research, Chennai, India

ABSTRACT

Food safety is a critical component of public health that ensures the protection of consumers from foodborne diseases, contamination, and adulteration. With globalization and the expansion of food supply chains, the role of food safety regulations has become increasingly important in maintaining quality standards from production to consumption. Effective regulations, such as the Hazard Analysis and Critical Control Points (HACCP), Food Safety and Standards Authority of India (FSSAI) guidelines, and Codex Alimentarius standards, provide a framework for controlling hazards and ensuring safe practices. However, the effectiveness of these regulations depends largely on consumer awareness and participation. Educated consumers are more likely to read food labels, demand compliance, and report unsafe practices, thereby encouraging industries to adhere to regulatory norms. In many developing countries, limited awareness leads to weak enforcement and higher risks of foodborne illnesses. Public health campaigns, digital platforms, and community-based interventions play a crucial role in bridging this gap. The integration of regulatory frameworks with consumer education creates a sustainable system where both industry and consumers contribute to food safety. Therefore, enhancing consumer awareness alongside strengthening regulations is essential to safeguard health, promote trust, and ensure sustainable development in the food sector.

Keywords:

Food Safety, Regulations, Consumer Awareness, Foodborne Diseases, HACCP, FSSAI, Codex Alimentarius, Food Supply Chain, Labeling, Adulteration, Public Health, Risk Management, Compliance, Sustainability.

FROM CREAM TO GREEN: UNLOCKING THE BIOSTIMULANT POWER OF WHEY IN SUSTAINABLE CROP GROWTH

Karima JMAILI

Hassan II University of Casablanca, Faculty of sciences and techniques Mohammedia, Morocco

Email: karima.jmaili@etu.fstm.ac.ma

ORCID: 0009-3153-0825

Khawla WADDI

Hassan II University of Casablanca, Faculty of sciences and techniques Mohammedia, Morocco

Email: khawla.waddi@etu.fstm.ac.ma

ORCID: 0000-0001-9820-2265

Mohamed LAHRAIRI

Hassan II University of Casablanca, Faculty of sciences and techniques Mohammedia, Morocco

Email: mohamed.lahrairi@gmail.com

ORCID: 0009-0006-9408-9190

Meriem MAHMOUDI

Hassan II University of Casablanca, Faculty of sciences and techniques Mohammedia, Morocco

Email: mahmoudimeriem17@gmail.com

ORCID: 0009-0002-2682-2478

Bouchaib BAHLAOUAN

Higher Institutes of the Nursing Professions and Techniques of Health ISPITS Casablanca 22500, Morocco

Email: b.bahlaouan@ispitscasa.ac.ma

ORCID: 0000-0002-0976-1274

Alla SILKINA

Algal Research Group, Bioscience Department, College of Science, Swansea University, Singleton Park, Swansea, SA2 8PP, UK

Email: a.silkina@swansea.ac.uk

ORCID: 0000-0002-1804-8083

Nadia BOUTALEB

Hassan II University of Casablanca, Faculty of sciences and techniques Mohammedia, Morocco

Email: nadia.boutaleb@fstm.ac.ma

ORCID: 0000-0003-1628-4311

ABSTRACT

The dairy industry produces large volumes of whey, a by-product with a high organic and nutrient load that poses serious environmental challenges when discarded untreated. Transforming this effluent into a useful agricultural input aligns with the principles of circular economy and sustainable production. This study investigates the potential of whey-derived digestate as a natural biostimulant to improve seed germination and early growth of two major crops, tomato (*Solanum lycopersicum*) and wheat (*Triticum aestivum*).

Synthetic whey was prepared by heating to 80 °C and adding 2% citric acid for coagulation and filtration. Anaerobic digestion was then carried out under mesophilic conditions (35–40 °C), producing a nutrient-rich digestate containing nitrogen, phosphorus, potassium, and calcium. The digestate was diluted to four concentrations (0%, 25%, 50%, and 75%) and applied to plants under controlled conditions. Germination rate, root and shoot length, and total biomass were measured and statistically analyzed to determine dose–response effects.

Results showed that moderate digestate concentrations (25–50%) significantly enhanced germination rate, root elongation, and shoot biomass, particularly in tomato, while excessive concentrations (≥ 75%) inhibited growth due to high organic and mineral loads.

These findings demonstrate that whey-derived digestate can serve as an effective and sustainable biostimulant, improving crop establishment while contributing to the valorization of dairy waste. Optimizing dilution and application protocols could further enhance its agronomic benefits and reduce the environmental footprint of the dairy sector.

Keywords: Whey, Biostimulant, Sustainable agriculture, Germination, Tomato, Wheat.

THREADS OF ESCAPE: ADAPTIVE REUSE OF TRAINS

Hira Zainab

Interior Designer

Email: hirazainab2003@gmail.com

Rimsha Imran

Ph.D. Architecture (Scholar) University of Engineering & Technology, Lahore, Pakistan, Faculty of Interior Design Department, Lahore College for Women University, Lahore, Pakistan.

Maha Tariq

Masters In interior design National College of Arts, Lahore, Pakistan, Faculty of Interior Design Department, Lahore College for Women University, Lahore, Pakistan.

Email: rimsha.imran@Icwu.edu.pk

ORCID: 0009-0008-0917-6981

ABSTRACT

Old train carriages are often left to rust and decay, even though they're built to last and could be repurposed in creative ways. This project repurposes these forgotten carriages into immersive escape rooms, creating interactive environments that engage visitors both intellectually and physically. By building on the existing structure, the design reduces environmental impact and revives forgotten infrastructure with a fresh purpose. The "Threads of Escape" concept links several carriages into one seamless journey, creating a stronger sense of exploration and keeping the experience engaging throughout. Preserving the original form of the trains, the project blends history with innovation, offering a unique recreational attraction that local tourism and public engagement. It demonstrates how adaptive reuse can turn outdated spaces into vibrant, experience-focused destinations, reimagining abandonment as a chance for creativity and innovation.

Keywords: Abandoned Trains, Adaptive Use, Adventure, Escape, Environments, Experiential Design, Interactive Space.

REPRODUCTIVE PERFORMANCE OF PULLET FED OYSTER MUSHROOM AS A REPLACEMENT TO ANTIBIOTICS

Akinlade, O. O

Animal Production Technology, The Federal Polytechnic, Ilaro

Akinlade, O. O

Animal Production Technology, Federal College of Agriculture, Moor Plantation, Ibadan.

Alausa, O.J.

Animal Health and Production Technology, The Federal Polytechnic, Ilaro

Ojo, R.O.

Animal Health and Production Technology, The Federal Polytechnic, Ilaro

Alabi, S.J.

Animal Production and health, Federal University of Agriculture, Abeokuta

Email: Oluwadamilare.alausa@federalpolyilaro.edu.ng (Corresponding author)

ABSTRACT

The use of Antibiotic for reproductive performance and disease prevention does not only impair livestock's natural physiological processes, it also encourages the development of resistant infections pathogens that people can contract through food chains. In this study feed forms (mash and pellets) and two inclusion levels of oyster mushroom were tested on three hundred and twenty (320), fourteen (14) weeks old pullets that were divided into four treatments containing 80 birds in a treatment with 10 replicates of 8 birds each. The study was arranged in a 2 × 2 factorial laid out in a completely randomized design consisting of two feed forms (mash and pellets) and two inclusion levels of oyster mushroom (0 or 1 g/kg). After six weeks of administering the treatments, two birds per replicate were randomly selected and eviscerated to determine the reproductive organ development at 20^{th} week of age. The length of the oviduct, number of follicles, follicle weight, number of ovary and weight of the ovary were evaluated. Data collected were subjected to two ways analysis of variance. The result of the study showed that the effect of feed form and the interaction between the feed forms and oyster mushroom inclusion did not significantly ($p>0.05$) affect the reproductive organs parts of the pullets. However, the inclusion of 1 g/kg (1.00g) of oyster mushroom in the diet of the birds significantly ($p>0.05$) decreased the follicle weight relative to the control (1.75g). The study concluded that the inclusion of 1 g/kg significantly reduced the follicle weight of the birds.

Keywords: Microbiota, Oyster mushroom, Ovaries, and pullets

APPLICATION OF NANOMATERIALS TO IMPROVE THE PROPERTIES OF PET 215WASTE BOTTLE SHEET: A REVIEW

Afshin Tavasoli Farsheh

Department of Agriculture, Mashhad Branch, Islamic Azad University, Mashhad, Iran

Email: tavasoliaf@gmail.com

Zahra Masoomi

Department of Industrial Design, Mashhad Branch, Islamic Azad University, Mashhad, Iran

ABSTRACT

The growing accumulation of polyethylene terephthalate (PET) waste, primarily from discarded beverage bottles, has become a major environmental and resource management concern. Mechanical recycling of PET into sheets is a promising strategy for waste valorization; however, the resulting recycled PET (rPET) often suffers from poor mechanical, thermal, and barrier properties compared with its virgin counterpart. In recent years, the integration of nanomaterials has emerged as a powerful approach to overcome these limitations. This review critically examines recent advances in the application of nanomaterials—including nano clays, carbon nanotubes, graphene derivatives, metal oxide nanoparticles, and bio-based nanofillers—to enhance the structural and functional performance of rPET sheets. The discussion emphasizes the influence of nanoparticle type, surface modification, dispersion techniques, and processing routes on the final properties of PET-based nanocomposites. Particular attention is given to the interfacial interactions between the PET matrix and nanofillers, which govern crystallinity, rheology, and barrier behavior. Moreover, this review highlights the potential of hybrid nanofiller systems and green synthesis methods to achieve both performance improvement and environmental sustainability. Finally, key challenges and future perspectives—such as nanoparticle dispersion control, recyclability, and industrial-scale processing—are outlined to guide further research toward circular and high-performance PET nanocomposite materials.

Key words: Polyethylene Terephthalate, nanomaterials, nano clays, carbon nanotubes, graphene

RECENT ADVANCES TOWARDS THE PET ENVIRONMENTALLY FRIENDLY BOTTLES TECHNIQUES : A REVIEW

Afshin Tavasoli Farsheh

Department of Agriculture, Mashhad Branch, Islamic Azad University, Mashhad, Iran

Email: tavasoliaf@gmail.com

Arezoo Sadat Khafi

Department of Biology, Mashhad Branch, Islamic Azad University, Mashhad, Iran

ABSTRACT

Polyethylene terephthalate (PET) has long dominated the beverage packaging industry due to its transparency, strength, and low cost; however, the environmental burden associated with its fossil-based origin and poor degradability has prompted extensive research into more sustainable alternatives. This review highlights recent progress in developing environmentally friendly PET bottles through innovations in material design, recycling technologies, and bio-based feedstocks. Advances in chemical and enzymatic recycling have enabled the recovery of high-purity monomers such as terephthalic acid and ethylene glycol, facilitating the production of high-quality recycled PET (rPET) suitable for food-grade applications. Parallel efforts in bio-based PET synthesis—using renewable precursors such as bio-ethylene glycol and 2,5-furandicarboxylic acid (FDCA)—have demonstrated comparable performance to conventional PET while reducing carbon footprint. Additionally, the incorporation of biodegradable copolymers, nanofillers, and green additives has improved the degradability, mechanical integrity, and barrier properties of PET bottles. Emerging technologies such as reactive extrusion, advanced catalysis, and life-cycle optimization further support a closed-loop circular economy for PET packaging. This review concludes that integrating bio-based chemistry, nanotechnology, and smart recycling systems offers a realistic pathway toward fully sustainable PET bottles that balance performance, recyclability, and environmental impact

Key words: Polyethylene terephthalate, environmentally friendly, enzymatic recycling, green additives

AI FOR AGRARIAN TRANSFORMATION: UNLOCKING THE POTENTIAL OF MACHINE LEARNING FOR CROP YIELD PREDICTION, DISEASE DETECTION, AND SMART FARMING

Wasiu Olatunde OLADAPO

Lagos State University of Education

Email: wasiuoladapo19@gmail.com

ABSTRACT

The food security and economic development of the countries rely on agriculture which is becoming more and more challenged by the climate change, resource availability, and population growth. The recent development in the Artificial Intelligence (AI) and the Machine Learning (ML) is reshaping the agrarian environment, making it possible to use data-driven decision-making, predictive analytics, and automation. The paper will discuss how AI is changing the agrarian systems and emphasize three relevant areas of crop yield prediction, disease detection, and smart farming. Internet of things (IoT) sensors, remote sensing data, the combination of ML algorithms allow farmers make more accurate predictions about yields, real-time disease detection in crop, optimization of the input, such as water, fertilizers, and pesticides. It presents cases of practical applications of deep learning and predictive modeling, which are enhancing productivity and sustainability in developed and developing regions. It also covers the barriers to adoption including the absence of data, infrastructural barriers and the need to have digital literacy training that targets farmers. The results highlight that AI use in agriculture could have huge potentials in attaining agrarian transformation in a sustainable approach, enhancing food chains and facilitating the global food security ambitions.

Keywords:-Artificial Intelligence, Machine Learning, Crop Yield Prediction, Disease Detection, Smart Farming, Agrarian Transformation, Precision Agriculture, Sustainability.

YİELD, FRUİT QUALİTY, NA+ AND K+ ACCUMULATİON İN TOMATO FRUİTS GROWN İN İNTERCROPPİNG WİTH MAİZE

MSc. Mohamed Fardouch

University Mohammed I, Faculty of Nador, Department of Biology, Nador, Morocco

Email: medfardouch@gmail.com

ORCID: 0009-0001-0991-1471

MSc. Rana CHOUKRI

University Mohammed I, Faculty of Nador, Department of Biology, Nador, Morocco

Email: rana.choukridoc@gmail.com

ORCID: 0009-0006-4920-951X

Prof. Dr. Mohamed FAIZE

University Chouaïb Doukkali, Faculty of Sciences, Dept of Biology, El Jadida, Morocco.

Email: faizemohamed@yahoo.fr

ORCID: 0000-0001-5718-1787

Prof. Dr. Mourad Baghour

University Mohammed I, Faculty of Nador, Department of Biology, Nador, Morocco

Email: mbaghour@hotmail.com

ORCID: 0000-0001-8976-7731

ABSTRACT

Climate change intensifies these stresses, emphasizing the need for resilient agricultural systems. Intercropping has emerged as a sustainable strategy to mitigate these impacts by enhancing soil moisture retention, regulating root-zone temperatures, and optimizing nutrient acquisition under salinity stress. Salinity is considered as one of the most serious factors limiting plant growth and crop productivity by affecting various physiological and biochemical parameters of plants. Salt stress can negatively influence plant development and efficiency of numerous crops, particularly in arid and semi-arid zones. Different strategies and techniques can be applied to moderate the negative effects of high NaCl concentrations within the soil. In the present study, we have evaluated the salinity tolerance of two tomato varieties grown in an intercropping system with maize by analysing fruit production, lycopene content, pH, total soluble solids (TSS), Na^+ and K^+ in fruits. Our results show that chlorophyll a was higher in the intercropping tomato than in the monoculture plants in both control (T0 = 0 mM NaCl) and NaCl-treated varieties (T1 = 125 mM NaCl). Moreover, in intercropping systems, the variety of Karima was less affected by NaCl treatment. Regarding fruit quality, pH value of Karima was higher in intercropped plants under NaCl treatment, while the Brix value was less affected by NaCl and intercropping conditions. Finally, intercropping practices significantly influenced Na^+ and K^+ accumulation and Karima variety showed the capacity to accumulate more K^+ and less Na^+

Keywords: Intercropping, salinity tolerance, tomato, fruit quality, yield

ABSTRACT

In the past decade, there have been significant advancements in agricultural technologies, which have revolutionized the agricultural industry. The use of modern technology has led to the development of more efficient, precise, and versatile machinery that can optimize crop yield while reducing labor costs, workload and environmental impact. The success of the planting phase in agriculture can affect the success of all plant production at the very beginning. The aim of this paper is to review the advancements in seeders over the past decade. In recent years, there has been a focus on developing seed flow and in-row seed distribution of seeders. To achieve this there have been conducted several research to produce prediction models that provide improvement on arrangements of present seeders. Development of no-till seeders reduce soil erosion and improve soil health, as well as reducing the time and energy required for tillage. Thus, farmers save money by reducing the need for fuel and labor costs. Additionally, planting multiple crops simultaneously have been achieved and that provide time and resource saving where farmers need to maximize their yield on a limited space while maximizing crop diversity. Precision agriculture, which includes GPS-guided seeders that can provide accurate and consistent seed placement, has significantly reduced seed waste and increased crop yield by ensuring planting at right depth and spacing. Precision technology has paved the way for development of robotic seeders as well. In conclusion, the advancements in seeders over the last decade have had a significant impact on the agricultural industry. Theoretical an practical imprevements have contributed to the development of more efficient and sustainable seeders. These advancements have helped farmers increase crop yield, reduce labor costs, and minimize environmental impact. As technology continues to advance, it is likely to see further improvements to ensure food security for future generations.

Keywords: Precision agriculture, no-till, multi-crop seeding, seed distribution, sustainable agriculture

ROLE OF PHARMACY IN RURAL DEVELOPMENT AND PUBLIC HEALTHCARE

K. Dinesh Rajan

Faculty of pharmacy, Bharath institute of higher education and research, Chennai, India

D.Aravindhan

Faculty of pharmacy, Bharath institute of higher education and research, Chennai, India

N.Arshad Ahamed

Faculty of pharmacy, Bharath institute of higher education and research, Chennai, India

ABSTRACT

Rural development and pharmacy are deeply interconnected in improving the overall health and well-being of rural communities. Access to quality healthcare and essential medicines remains a major challenge in many rural areas due to limited healthcare infrastructure, shortage of qualified professionals, and lack of health awareness. Pharmacists play a vital role in bridging this gap by providing primary healthcare services, ensuring rational drug use, and promoting health education. Community pharmacies act as accessible centers for dispensing medicines, offering counseling, and spreading awareness about disease prevention, hygiene, and nutrition. Moreover, pharmacists contribute to national health programs such as immunization, maternal and child health, and the control of communicable diseases. Through mobile pharmacy services and telepharmacy, pharmaceutical care can reach even the most remote villages, improving treatment adherence and reducing medication errors. Encouraging local production and distribution of essential drugs also supports rural economic development. Integrating pharmacy practice with rural health initiatives not only strengthens healthcare delivery but also empowers communities toward a healthier and more sustainable future.

Keywords: Rural pharmacy, Public health, Community pharmacist, Primary healthcare, Health awareness, Telepharmacy, Drug accessibility, Rural development, Preventive healthcare, Sustainable health system.

A NANOSTRUCTURED MICROARRAY-BASED SERS SENSOR TARGETED AT MULTIPLEX MYCOTOXIN DETECTION IN FOOD AND FEEDSTUFF USING A HANDHELD APPARATUS

Dr. Rohit Kumar Singh

Institute of Agricultural and Biosystems Engineering ARO, Volcani Institute, Rishon, Israel

Email: singhroh2711@gmail.com,

ORCID:0000-0001-6252-2005

Dr. Giorgi Shtenberg

Institute of Agricultural and Biosystems Engineering ARO, Volcani Institute, Rishon, Israel

Email: giorgi@volcani.agri.gov.il

ORCID:0000-0003-1234-1104

ABSTRACT

In food and agricultural commodities, toxic mold contamination impacts 25% of global crops, resulting in significant financial losses and associated health hazards. Here, we introduce a nanostructured microarray that uses silver-coated porous silicon (Ag-pSi) as a transducer for surface-enhanced Raman scattering (SERS). The internal porous void and pore morphology were optimized to amplify the SERS effect, achieving an enhancement factor of 1.75×10^7. A portable Raman equipment was utilized to assess three target mycotoxins using the microarray features. When the anti-target mycotoxin aptamer-modified scaffold demonstrated selective biorecognition, the optical output was inversely proportional to the analyte concentration. In the 0.001–1000 ppb range, the Ag-pSi SERS substrate showed low limits of detection (0.922, 0.547, and 0.008 ppb for ochratoxin A, fumonisin B1, and aflatoxin B1, respectively). Additionally, three weeks of stability, four regeneration cycles, and no interference with competing mycotoxins were among the good performance values that were shown by the careful evaluation of selectivity, reusability, and overall shelf life. Finally, the SERS microarray that was built was tested on rice, maize, and wheat. The results showed recovery rates of 95–104% and an RSD of less than 6.6%. To monitor food and feed safety, the integrated approach provides a reliable, field-deployable solution for a real-time multi-analyte screening platform.

Keywords: Microarray, SERS, Aptamer, Mycotoxin.

A LEXICAL-SEMANTIC READING OF AGRICULTURAL TERMS IN TWO OF NIYI OSUNDARE'S POEMS

Ajayi, Mercy Adenike

General Studies Department, Federal Polytechnic, Ilaro, Nigeria

Adesanmi, Moses Ademola

General Studies Department, Federal Polytechnic, Ilaro, Nigeria

Email: moses.adesanmi@federalpolyilaro.edu.ng

ABSTRACT

This study focuses on the interrogation of the lexical-semantic deployment of agricultural terms in two of Niyi Osundare's poems, with an intent to expatiate how agrarian lexicon functions beyond its denotative meanings to convey deeper socio-political and ecological messages. Using a qualitative textual analysis, and from the lenses of lexical semantics and systemic functional linguistics as its theoretical framework, the paper investigates how Osundare's choice of agricultural vocabulary contributes to thematic development and socio-political commentary. The analysis reveals that Osundare deploys agricultural terms not merely to depict rural life but as metaphors to encapsulate broader societal issues, such as exploitation, resistance, and environmental degradation. It is oblivious that in "The Hoe," the hoe is a symbol both the tool of labour and at the same time the burden of the oppressed. In the same vein, in "Harvestcall," the harvest represents both agricultural yield and the fruits of collective struggle. These findings underscore the poet's strategic use of agrarian language to engage readers in critical reflection on societal structures and ecological concerns. The study concludes that tactical integration of agricultural lexicon by Osundare serves as a powerful tool for socio-political critique and ecological consciousness, thereby enriching the interpretive possibilities of his poetry.

Keywords: Agrarian Lexicon, Exploitation, Ecocritical, Lexical-Semantic, Metaphor

A MECHANISTIC MULTI-OMICS AND ECOLOGICAL RISK ASSESSMENT ON ECOLOGICAL SAFETY AND NON-TARGET EFFECTS OF BIOPESTICIDES AND MICROBIAL INOCULANTS IN AGROECOSYSTEMS

S Indhu

Department of Biotechnology, Faculty of Science and Humanities, SRM Institute of Science and Technology, Ramapuram Campus, Chennai- 600089, Tamil Nadu, India.

Email: 21indhu@gmail.com

G Priya

Department of Biotechnology, Faculty of Science and Humanities, SRM Institute of Science and Technology, Ramapuram Campus, Chennai- 600089, Tamil Nadu, India.

ORCID:0000-000229711792

Email: priyag3@srmist.edu.in

Murugesan Kamaraj

Department of Biotechnology, Faculty of Science and Humanities, SRM Institute of Science and Technology, Ramapuram Campus, Chennai- 600089, Tamil Nadu, India.

ORCID:0000-0002-0111-8524

Email: drkamarajm@gmail.com

ABSTRACT

Since ancient times, synthetic pesticides formulated with chemical compounds and carriers such as polymers have been used to target specific pests and improve crop yields.The pesticides can be clasified based on the active ingredients and function. Despite synthetic pesticides have positive effects on crop yield and productivity, they do have negative impacts on soil biodiversity, animals, aquatic life, and human life .Therafter biopesticides and microbial inoculants have been very useful in the control of pests with lot of merits such as its being cheap, ecosafe and specific mode of action by the inhibition and destruction of the plasma membrane and protein translation of pathogens/pests. Repeated application of these biopesticides may alter resident soil microbial communities, affect beneficial arthropods (pollinators, natural enemies), and change ecosystem functions in ways that are poorly characterized under realistic agricultural conditions. Few setbacks of biopesticides are short shelf life, wherein it can completely eliminate the existing pests and prevent the growth of the pests that will come after the application of the biopesticides. The critical assessment of these merits and demerits, and the possible measures to improve on these seeming drawbacks has become very important. The research will systematically evaluate the non-target ecological effects of representative biopesticides (e.g., azadirachtin / neem formulations) and microbial inoculants (e.g., *Trichoderma spp.*, *Pseudomonas* / biofertilizer consortia) across controlled greenhouse experiments and multi-season field trials using a combination of (i) soil physicochemical assays, (ii) amplicon and shotgun metagenomics, (iii) soil and plant metabolomics (LC-HRMS), (iv) enzyme and nutrient-cycling assays, and (v) insect bioassays (pollinators & beneficial predators). By integration of results from product application , soil microbiome shifts , changes in ecosystem functions and impacts on non-target organisms including isolation, tracking of introduced strains (barcoded/marker strains where allowed), gnotobiotic reconstitution experiments which involve germ-free host plants colonized with a

defined, known community of microbes to study how these specific microorganisms influence the host's health, development, and metabolism. These experiments will investigate the specific roles of individual microbes or entire microbial communities by controlling the entire microbial composition of the system. The study identifies safe application doses and formulations. This integrated approach will fill a major knowledge gap and support policies for scaling up biobased agricultural inputs safely.

Keywords: Biopesticides, microbial inoculants, soil microbiome shifts, gnotobiotic

SIGHTINGS OF BIRDS IN OIL PRODUCTION AREAS (MONGOLIA)

Tsegmid N. And Zayatogtokh B.

Mongolian University of Life Sciences.

Email: Tsegmid@muls.edu.mn

ABSTRACT

The surveyed area is located in the East Mongolian Plain Steppe subregion [1, 3]. The landscape of this subregion approximates ideal plains. Their absolute elevation is 600-800 m, with only the highest points in the west barely reaching 1000 m. Steppe vegetation predominates throughout the chestnut soils [2].The field study area is located in the steppes of the Matad soums of Dornod Province, where oil is produced.

The primary research method was foot-based route surveys, covering a total of over 80 km. The total area covered was 213.92 km2. Birds were collected on June 8 and September 8, 2024, and June 8 and August 24, 2025. Bird counts were conducted using a ZESS CONQUEST HD 8*32 binoculars and a SONY DSC-HX400 digital camera with 20.4 megapixels. Bird names in the list are based on the summary by S. Gombobaatar, 2019, and the faunal genetic structure by Stegmann, 1938.

In Eastern Mongolia, including the oil production area, 47 bird species belonging to 12 orders, 24 families, and 38 genera have been recorded. They inhabit various ecological environments (steppes, structures, and wetlands) in the adjacent steppes of the Matad soum of Dornod aimag. Of these, 14 species are sedentary, and 33 species pass through during spring and autumn migration. Of the total number of recorded bird species, 25 (53.2%) belong to the order Passeriformes. During the observation, 10 species of birds (*Buteo hemilasius, Columba livia, Pyrrhocorax pyrrhocorax, Hirundo rustica, Alauda arvensis, Eremophila alpestris, Melanocorpha mongolica, Oenanthe isabelline, Passer montanus, Anthus godlewskii*) were frequently encountered.

During spring migration, 7 species of birds (*Tadorna tadorna, Grus virgo, Charadrius dubius, Charadrius veredus, Sterna hirundo, Apus apus, Apus pacificus, Oenanthe oenanthe*) were noted.

During autumn migration, 18 species of birds were encountered (*Coturnix japonica, Anas zonorhyncha, Otis tarda, Vanellus vanellus, Gallinago gallinago, Upupa epops, Phylloscopus borealis, Phylloscopus proregulus, Saxicola maurus, Ficedula narcissina, Ficedula albicilla, Muscicapa striata, Muscicapa sibirica, Muscicapa dauurica, Motacilla cinerea, Motacilla alba, Carpodacus erythrinus, Emberiza yessoensis*). Of these, seven bird species (*Phylloscopus borealis, Phylloscopus proregulus, Ficedula albicilla, Muscicapa striata, Muscicapa sibirica, and Muscicapa dauurica*) were actively migrating in the dry steppe where oil is extracted on August 24. After 14 days (September 8), nine bird species (*Coturnix japonica, Anas zonorhyncha, Vanellus vanellus, Gallinago gallinago, Saxicola maurus, Motacilla cinerea, Motacilla alba, Carpodacus erythrinus, and Emberiza yessoensis*) were observed migrating, but their migration was not intense, with 1-16 individuals observed.

Oil production is underway in this steppe region, but this also indicates that many bird species are still feeding and resting during migration. The summer of 2025 was dry and arid. Therefore, the waterbirds recorded in 2024 were not observed. However, migration of arboreal birds, which feed primarily on insects, was observed.

The avifauna of Matad soum, Dornod province, where the oil extraction region is located, is widely represented by mid-latitude species. According to the ornithogeographic division of B.K. Stegman (1938), they belong to the following fauna types: Mongolian 34% (n=16), Transpalearctic 25.5% (n=12), Siberian 12.8% (n=6), Chinese 10.7% (n=5), European 8.5% (n=4), Mediterranean 6.4% (n=3), and Arctic 2.1% (n=1).

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FOOD IRRADIATION FOR MITIGATING POST-HARVEST LOSSES IN NIGERIA

Dr. Halid Sheriff Adegbusi

Department of Biological Sciences, Nigeria Police Academy Wudil, Kano Nigeria

Email: Khalidadegbusi@yahoo.com

ORCID: 0000-0003-0038-9776

ABSTRACT

This paper is a contributory advocacy on the commercial usage of food irradiation for food preservation for reducing postharvest losses of agricultural produce in Nigeria. Postharvest losses were found to cause a loss of about 13 million metric tons of agricultural crops in Nigeria, especially for perishable crops, grains, and fish. About 0.7 million metric tons of tomatoes were found lost annually. Resulting in the annual economy loss of about 3.7 trillion and 72 billion Nigeria Naira, in respect of agricultural produce and especially of tomato. Comparatively food irradiation offers a better method for food preservation, but does not serve for the replacement of others. Food irradiation was used to preserved yam, water yam, onions, tomatoes, potatoes, cowpea seeds and other crops without reported toxic effect and deteriorated nutritional qualities. Cobalt-60, electron beam and X-rays are commonly used for food irradiation. Over 70 countries have legislated its usage, and has been endorsed by reputable world regulatory bodies for the propensity of food and nutritional, health, economic and export securities. The only one irradiation facility available in Nigeria is Gamma Irradiation Facility operated on Cobalt-60 source, and currently under laboratory use. Putting the facility under commercial usage can help reducing postharvest losses of agricultural crops, thus strengthening food security for achieving sustainable development goal 2 in Nigeria. Commercial usage of the technology may also stimulate agricultural productivity for gross domestic product (GDP), safe exportation for Nigeria currency growth, global market is increasing for irradiated foods. Factors hindering its commercial adsorption can be surmounted by government craftiness. It is therefore recommended, for quick commercial operation of food irradiation, that positively adequate education about the technique is disseminated among relevant stakeholders, and that government should establish more accessible irradiation facilities at strategic areas in Nigeria for both farmers and marketers of perishable food crops, and interested individuals.

Keywords: Food irradiation and preservation, postharvest losses, perishable foods, food security, SDG 2, GDP, Nigeria

BOTTOM-CLEAN AQUACULTURE MAXIMIZES GROWTH, SURVIVAL, AND PROFIT OF HIGH-VALUED CATFISH

Md. Moniruzzaman

Scientific Officer, Bangladesh Fisheries Research Institute, Freshwater Station,

Md. Rabiul Awal

Scientific Officer, Bangladesh Fisheries Research Institute, Freshwater Station

Md. Moshiur Rahman

Senior Scientific Officer, Bangladesh Fisheries Research Institute, Freshwater Station

Md. Harunor Rashid

Chief Scientific Officer, Bangladesh Fisheries Research Institute, Freshwater Station

Anuradha Bhadra

Director General, Bangladesh Fisheries Research Institute

ABSTRACT

A 150-day study was conducted at the Bangladesh Fisheries Research Institute, Mymensingh, to evaluate the growth, survival, and economic performance of Butter Catfish (*Ompok pabda*) and Walking Catfish (*Clarias batrachus*) cultured in an 8,000 L bottom-clean indoor tank system. Three stocking densities (1200, 1500, and 1800 ind./m³) were tested, with fish fed a commercial diet containing 37% crude protein twice daily. Water quality parameters remained within optimal ranges throughout the culture period. For *O. pabda*, the lowest density (1200 ind./m³) yielded the highest final weight (22.35 ± 4.06 g), weight gain (18.85 ± 0.26 g), survival rate (90.23 ± 1.81%), feed conversion ratio (1.13 ± 0.09), and specific growth rate (2.67 ± 0.04% day⁻¹), respectively. *Walking Catfish* exhibited a similar trend, attaining maximum growth (final weight 40.33 ± 5.03 g; weight gain 34.76 ± 0.03 g), survival (82.55 ± 2.32%), and feed efficiency (FCR 1.21 ± 0.04) at the same density. Increasing density reduced individual growth and survival; nevertheless, biomass yield per unit volume remained comparable across culture period. Furthermore, economic analysis confirmed that the moderate density (1200 ind./m³) achieved the greatest net profit and benefit–cost ratio for both species. Albeit higher densities provided equivalent biomass output, they compromised survival and feed efficiency. Overall, the findings demonstrate that bottom-clean aquaculture is an effective and economically viable system for intensive indoor production of high-value catfish, offering a sustainable strategy for small- and medium-scale aquaculture enterprises in Bangladesh.

Keywords: Butter Catfish, Walking Catfish, Bottom-Clean Aquaculture, Stocking Density, Growth, Survival, Economic Performance

GREEN PHARMACY: A SUSTAINABLE APPROACH TO DRUG DEVELOPMENT

Keerthana.V

Faculty of pharmacy, Bharath Institute of Higher Education and Research,Chennai,India-600073

Meenatchi.S,Kishore.R

Faculty of pharmacy, Bharath Institute of Higher Education and Research,Chennai,India-600073

Dr.R.Saravanan

Faculty of pharmacy, Bharath Institute of Higher Education and Research,Chennai,India-600073

ABSTRACT

Green Pharmacy is an emerging concept that emphasizes the design, manufacture, use, and disposal of pharmaceutical products in an environmentally responsible manner. Traditional drug production often generates significant chemical waste, consumes large amounts of energy, and leads to pharmaceutical pollutants entering the environment. Green Pharmacy seeks to minimize these impacts by integrating eco-friendly principles into every stage of the drug life cycle—from discovery and synthesis to packaging and disposal. Sustainable drug development involves the use of biodegradable excipients, renewable resources, green chemistry techniques, and energy-efficient manufacturing processes. It also encourages proper waste management, recycling of pharmaceutical materials, and public education on safe drug disposal. By adopting sustainable practices, the pharmaceutical industry can protect both human health and the environment, contributing to global goals such as pollution reduction, biodiversity preservation, and sustainable healthcare systems. The integrated GREENER approach can be used to accelerate discussions about future innovations in drug discovery and development.

Keywords: Green Pharmacy, Sustainable Drug Development, Environmental Impact, Green Chemistry, Pharmaceutical Waste, Eco-friendly Drugs, Biodegradable Materials, Pollution Control, Sustainable Healthcare, Environmental Protection.

UNLOCKING THE ECONOMIC POTENTIAL OF MUSTARD CULTIVATION IN BANGLADESH: PROFITABILITY, INEFFICIENCIES, AND INSTITUTIONAL GAP

Md. Mobarok Hosen

Departmebt: Crop science and technology, University of Rajshahi, Rajshahi, Bangladesh

Email : mobarok10102002@gmail.com

ORCID: 0009-0004-9316-0480

Most. Mokarroma

Department: Crop Science and Technology, University of Rajshahi, Rajshah, Bangladesh

Email: s2112169103@ru.ac.bd

ORCID: 0009-0001-8350-0670

Syed Imad Zaman

Department: Crop Science and technology, University of Rajshahi, Rajshahi, Bangladesh

Email: syedimadzaman@gmail.com

ORCID: 0009-0007-3900-2707

Pias Ahmed

Department: Crop Science and technology, University of Rajshahi, Rajshahi, Bangladesh

Email: s2210869121@ru.ac.bd

ORCID: 0009-0000-8360-7884

Md. Sahadat Hossain

Department: Crop Science and technology, University of Rajshahi, Rajshahi, Bangladesh

Email: fdbsahadath962@gmail.com

ORCID: 0009-0001-8099-3457

Airin Jahan Urmi

Department: Crop Science and technology, University of Rajshahi, Rajshahi, Bangladesh

Email: airinjahanurmi20@gmail.com

ORCID: 0009-0000-3561-1440

Mst.Upoma Shobnom Raicha

Department: Crop Science and technology, University of Rajshahi, Rajshahi, Bangladesh

Email: upoma9045@gmail.com

ORCID: 0009-0008-2611-1856

Md. Mahbub Alam

Department: Crop Science and technology, University of Rajshahi, Rajshahi, Bangladesh

Email: mahbubalamsaddam120220@gmail.com

ORCID: 0009-0001-5204-0018

ABSTRACT

Mustard has long been an important crop in Bangladesh, valued both for its role in crop rotation and the steady demand for mustard oil. Yet, the full economic promise of mustard farming often remains out of reach for many farmers. This study explores how profitability, input management, and institutional support shape the realities of mustard cultivation across the country. The analysis showed that simply expanding the cultivated area brings only modest income gains ($r = 0.236$, $p = 0.024$). Surprisingly, higher spending on inputs does not always lead to better yields ($r = –0.273$, $p = 0.009$), pointing to mismanagement in fertilizer use and other practices. At the same time, investment still plays a strong role in overall earnings ($R^2 = 0.714$, $p < 0.001$), suggesting that mustard can be a profitable venture when resources are used wisely. Training programs do not seem to improve yields in any meaningful way, and more than 90% of farmers report receiving no institutional help. Even so, 72% believe mustard is more profitable than rice, wheat, or maize, thanks to lower input needs and strong market demand. For the remaining 26%, risks like climate shocks, pests, and input shortages keep profitability uncertain. Together, these findings reveal a crop with strong potential, but one that needs smarter training, better input management, and stronger institutional backing to truly deliver for farmers.

Keywords: Mustard cultivation; Profitability; Input efficiency; Agricultural extension; Bangladesh

URBAN RENEWAL APPROACHES FOR THE REVITALIZATION OF TUDUN NUPAWA NEIGHBORHOOD, KADUNA, NIGERIA

Aliyu Hassan

Department of Civil and Environmental Engineering, Air Force Institute of Technology,

Nigerian Air Force, Kaduna-Nigeria

Email: aliyuhassan13@yahoo.com

ABSTRACT

Urban renewal has emerged as a vital strategy for addressing the challenges of physical decay, environmental degradation, and socioeconomic decline in many inner-city neighborhoods. This study examines the strategies for urban renewal aimed at revitalizing the Tudun Nupawa neighborhood in Kaduna, Nigeria. The research assesses the existing physical, social, and economic conditions of the area and identifies the key factors contributing to urban deterioration, such as inadequate infrastructure, poor housing quality, and ineffective land-use management. Using a mixed-method approach that integrates field surveys, spatial analysis, and stakeholder interviews, the study evaluates current renewal initiatives and explores sustainable models applicable to the local context. Findings reveal that effective urban renewal in Tudun Nupawa requires an integrated framework involving community participation, public–private partnership, improved infrastructure provision, and inclusive planning policies. The study concludes that revitalizing Tudun Nupawa through context-specific and participatory renewal strategies will enhance the neighborhood's livability, economic productivity, and environmental resilience. Recommendations are made for urban policymakers and planning authorities to adopt inclusive, sustainable, and adaptive renewal approaches to transform Tudun Nupawa into a functional and vibrant urban community.

Keywords: Urban renewal, Neighborhood revitalization, Tudun Nupawa, Kaduna, Sustainable urban development, Urban planning, Public–private partnership, Community participation.

LEVERAGING ON TECHNICAL AND VOCATIONAL TRAINING (TVET) FOR ACHIEVING FOOD SECURITY IN NIGERIA: A STUDY OF OGUN STATE

Auwal Mohammed ADAMU

General Studies Department, The Federal Polytechnic, Ilaro, Ogun State. Nigeria

Email: auwal.adamu@federalpolyilaro.edu.ng

Olufunmilayo Temitope AFOLAYAN

General Studies Department, The Federal Polytechnic, Ilaro, Ogun State. Nigeria

Email: afolayan.olufunmilayo@yahoo.com

ABSTRACT

The greater numbers of the youth, who have the potential to change the Agricultural landscape of the country, are enrolled in the tertiary institutional system. Therefore, there is need to leverage on TVET to increase agricultural productivity as a means of ensuring food security in the country. This study attempts to investigate the role of TVET in ensuring food sufficiency in the country. *The study* adopted descriptive statistics to analyze data obtained using Multi-stage sampling techniques. Responses were drawn from questionnaires administered to 250 students of Agricultural technology from Federal Polytechnic, Ilaro and Moshood Abiola Polytechnic situated in Ogun State. The findings from the study shows that majority of the respondents are young and energetic for farm work. The study also revealed that most of the students are ready to engage in agriculture after graduation if adequate facilities are available. The findings from the regression analysis revealed that agricultural technology education and training have positive significant impact on agricultural productivity in Nigeria. on this note, the study the paper suggests, inter-alia, increase in government expenditure on technical institution, and encourage the participation of youth into agriculture after graduation through free interest agricultural loan facilities.

Keywords: Food Security, Agricultural productivity, technical and vocational training

"GIVING VOICE TO THE VOICELESS"— THE RISE OF ANIMAL–COMPUTER INTERACTION

K.Vaishnavi

Faculty of Pharmacy, Bharath Institute of Higher Education and Research, Chennai, India-600073

R.Sriarasuvasan

Faculty of Pharmacy, Bharath Institute of Higher Education and Research, Chennai, India-600073

V.Keerthana

Faculty of Pharmacy, Bharath Institute of Higher Education and Research, Chennai, India-600073

S.Rubinthara

Faculty of Pharmacy, Bharath Institute of Higher Education and Research, Chennai, India-600073

R.Kishore

Faculty of Pharmacy, Bharath Institute of Higher Education and Research, Chennai, India-600073

K.Deepak

Faculty of Pharmacy, Bharath Institute of Higher Education and Research, Chennai, India-600073

ABSTRACT

Animal–Computer Interaction (ACI) is an emerging interdisciplinary field that explores how animals engage with digital technologies designed specifically for their needs, welfare, and communication. Moving beyond traditional human-centric design, ACI seeks to create interfaces and systems that enable animals to express choices, control aspects of their environment, and even communicate across species barriers. From touchscreens for parrots and video-call devices for dogs to AI-based systems that interpret animal emotions and behavior, ACI integrates principles from computer science, animal behavior, cognitive science, and ethics. It promotes animal welfare through enrichment, mental stimulation, and improved monitoring of health and stress levels. With advancements in artificial intelligence, wearable sensors, and interactive robotics, the future of ACI lies in developing adaptive, non-invasive, and ethical interfaces that empower animals to become active participants rather than passive subjects. This innovative field not only enhances animal well-being but also reshapes our understanding of interspecies communication and co-existence in the digital era.

Keywords:

Touchscreen and smart devices for animals, Ethical interface design, Animal cognition, Robotics and automation, Digital enrichment systems, Machine learning in animal studies, Human–animal interaction.

SYNTHESIS OF AN ACTIVATED CARBON-NANOCOMPOSITE FOR THE TREATMENT OF POLLUTANTS.

BOUCHERDOUD Ahmed

Laboratory of Environment and Sustainable Development , Department of Chemistry, Faculty of science and engineering, University of Relizane.

DOUINAT Oukacha

Laboratory of Environment and Sustainable Development , Department of Chemistry, Faculty of science and engineering, University of Relizane.

BENDJELLOUL Meriem

Laboratory of Environment and Sustainable Development , Department of Chemistry, Faculty of science and engineering, University of Relizane.

SEGHIER Abdelkarim

Laboratory of Environment and Sustainable Development , Department of Chemistry, Faculty of science and engineering, University of Relizane.

ELANDALOUSSI Elhadj

Laboratory of Environment and Sustainable Development , Department of Chemistry, Faculty of science and engineering, University of Relizane.

TABTI Senouci

Laboratory of Environment and Sustainable Development , Department of Chemistry, Faculty of science and engineering, University of Relizane.

Email: senouc.tabti@univ-Relizane.dz

ABSTRACT

The study aims to treat polluted water using adsorption technology, a proven and efficient method for removing contaminants from wastewater. Methylamine, a common organic pollutant found in industrial effluents, was selected as the model contaminant to assess the efficacy of the treatment method. The adsorbent material chosen for the study was a wood- derived activated carbon nanocomposite, known for its high surface area and porosity, which enhances its adsorption capabilities. The impact of various operational parameters—including contaminant concentration, pH levels, temperature, contact time, and the amount of adsorbent used—was systematically studied to optimize the process and understand the dynamics influencing adsorption. The study also included an analysis of adsorption kinetics and isotherm models to characterize the interaction between the adsorbent and the adsorbate. Results indicated that the adsorption process followed the Langmuir isotherm model, suggesting monolayer adsorption on a homogeneous surface with a maximum methylamine adsorption capacity of 46.37 mg/g. Kinetic studies demonstrated that the process adhered to a pseudo-second-order model, indicating chemisorption as the rate-limiting step. The adsorption efficiency was found to be significantly influenced by the pH of the solution, with optimal uptake observed at a specific pH range. The findings of this study underscore the potential of biomass-derived activated carbon nanocomposites as an effective, sustainable solution for the treatment of organic pollutants in wastewater. This approach offers significant advantages over traditional treatment methods due to its simplicity, cost-effectiveness, and potential for scalability, making it an attractive option for large-scale industrial applications aimed at improving water quality and ensuring environmental safety.

Keywords : Active carbons,Adsorption,wastewater treatment ,nanocomposite.

COMBINED EFFECTS OF MICROPLASTICS AND MERCURY ON SURVIVABILITY, HEMATOLOGY, TISSUE MORPHOLOGY, ACCUMULATION, OXIDATIVE STRESS, IMMUNE RESPONSE AND GH/IGF AXIS IN NILE TILAPIA (*Oreochromis niloticus*)

Md Ruhul Amin

Laboratory of Fish Ecophysiology, Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

Email: ru.amin98@gmail.com (*Corresponding author)

Tasmia Islam Kanta

Laboratory of Fish Ecophysiology, Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

Mosfiq Momtasir Neloy

Laboratory of Fish Ecophysiology, Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

Md Shahjahan

Laboratory of Fish Ecophysiology, Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

ABSTRACT

Microplastics (MPs) and the heavy metal mercury (Hg) have drawn increasing global scrutiny as major aquatic contaminants due to their significant toxic effects on aquatic organisms. Individually, their effects on aquatic organisms are well documented; however, their combined effects remain poorly elucidated. In today's environmental context, aquatic organisms experience concurrent exposure to multiple pollutants, underscoring the need to investigate their integrative effects. Here, we investigated the effects of polyamide microplastic (PA-MP), mercury (Hg) and their combination on Nile tilapia (*Oreochromis niloticus*) fingerlings in relation to survival, growth metrics, hematology, tissue morphology, antioxidant defense, immune function and the GH/IGF axis. Fingerlings were subjected to sub-lethal concentrations of PA-MP (10 mg/L), Hg (0.03 mg/L), a combination of both stressors or maintained under control conditions for six weeks, with 20 individuals per tank in triplicate. The co-exposure group showed increased MP accumulation and mortality, suppressed growth performance (e.g., weigh gain, specific growth rate and feed efficiency); substantial shifts in blood physiology including elevated glucose (126.83 ± 2.40 mg/dL) and lowered hemoglobin level (9.45 ± 0.85 g/dL) as well as pronounced cellular and nuclear irregularities. The histo-architectural assessment identified significant tissue damage in gills, intestine, liver and kidney of fish under co-exposure. At transcriptional level, co-exposure exerted oxidative damage in fish liver by influencing the activities of antioxidant genes (*sod* and *cat*) and significantly upregulated immune-related genes *ifn-γ* and *tnf-α* as well as suppressed the expression of *il-1β*, indicating an inflammatory response. Besides, the expression level of growth hormone-secreting gene (*gh*) in the pituitary gland, along with the expression levels of insulin-like growth factors (*igf-1* and *igf-2*) in liver showed a significant downregulation ($p < 0.05$) under co-exposure. Collectively, these findings underscore that co-exposure to MP and Hg aggravates systemic and molecular impairments in Nile tilapia, reducing physiological performance and survivability.

Keywords: Microplastics, mercury, blood biomarkers, bioaccumulation, environmental risk

JEOTERMAL SERACILIĞIN KENT ÇEVRESEL TARIMDA KULLANIMININ ARAŞTIRILMASI

Mehmet Kulu

Konya Teknik Üniversitesi, Lisansüstü Eğitim Enstitüsü

Email: mehmetkulu@gmail.com

ORCID: 0000-0003-3077-4763

Alper Döyen

Konya Teknik Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, Endüstri Mühendisliği Bölümü

Email: alperdoyen@ktun.edu.tr

ORCID: 0000-0001-9671-9105

Muhammed Emre Keskin

Atatürk Üniversitesi, Mühendislik Fakültesi, Endüstri Mühendisliği Bölümü

Email: emre.keskin@atauni.edu.tr

ORCID: 0000-0001-9381-123X

ÖZET

Dünya nüfusu ve bunun paralelinde sosyo-ekonomik gerekçelerle kent nüfusu hızlı bir şekilde artmaktadır. Bu durum geniş kitlelerin sınırsız ihtiyaçlarının belirli merkezlerde odaklanması yol açmıştır. Bu ağırlık merkezleri, yarattıkları taleple tedarik zincirlerini zorlamakta; politika yapıcılarını ve endüstriyi yeni çözümler araştırmaya itmektedir.

Üretim, depolama, dağıtım ve nihai tüketiciye sunumu içeren bu tedarik zinciri yapısının doğru planlanması bulunabilirlik, ulaşabilirlik, maliyet, kalite gibi parametreleri doğrudan etkileyecektir. Gıda üretiminin de hem artan talebi karşılayacak şekilde genişlemesi hem de üretim noktalarından tüketim bölgelerine verimli bir şekilde aktarılması gerekmektedir. Bu bağlamda, kent ve kent çevresel tarım, gıda arz güvenliği ile başa çıkmada kaldıraç noktalarından biri olarak karşımıza çıkmaktadır. Kent ve kent çevresel tarım, kentlerin tarım ürünü ihtiyaçlarını karşılamak üzere, bu ürünlerin üretildiği nispeten uzak bölgelerden şehirlere taşınmasının yerine kent çevresinde yetiştirilmesi olarak ifade edilebilir.

Bu bağlamda; önerilen konsept yapı ile kaynakların daha etkin kullanılacağı, yüksek taşıma maliyetlerinin ortadan kaldırılacağı bir sistem öngörülmektedir. Mevcut tedarik zincirinin kısaltılıp taşıma maliyetlerin düşürülmesi, gıda arz güvenliğine katkı sunması, yeşil enerji kaynaklarının kullanılarak ekonomiye kazandırılması olmak üzere doğrudan ve ayrıca bölgesel üretim havzaları ile yatırım, istihdam ve sair ekonomik faaliyetlere imkan verecek olması, toplumsal refah artışına katkı sunması gibi de dolaylı pozitif etkilerinin olması beklenmektedir.

Anahtar Kelimeler: Kent Çevresel Tarım, Jeotermal Seracılık, Gıda Arz Güvenliği.

INVESTIGATION OF GEOTHERMAL GREENHOUSE USAGE IN PERI-URBAN AGRICULTURE

ABSTRACT

The world's population, and in parallel, the urban population driven by socio-economic factors, is rapidly increasing. This situation has led to the concentration of the unlimited needs of large masses in specific centers. These centers of gravity, through the demand they generate, strain supply chains and push policymakers and industries to seek new solutions.

The proper planning of this supply chain structure encompassing production, storage, distribution, and delivery to the final consumer, will directly affect parameters such as availability, accessibility, cost, and quality. Food production must also increase to meet the growing demand, and the goods should be efficiently transferred from production sites to consumption areas. In this context, urban and peri-urban agriculture emerges as one of the leverage points in addressing food security. Urban and peri-urban agriculture can be defined as the cultivation of agricultural products in and around cities rather than transporting them from relatively distant rural areas to urban centers.

In this context, the proposed conceptual structure envisions a system that utilizes resources more efficiently and eliminates high transportation costs. It is expected to have direct positive effects, such as shortening the current supply chain, reducing transportation costs, contributing to food supply security, and integrating green energy resources into the economy. It also has indirect positive effects, such as facilitating investment, employment, and other economic activities within regional production basins, and contributing to increased social welfare.

Keywords: Peri-Urban Agriculture, Geothermal Greenhouse Cultivation, Food Security.

TARIM ALANLARININ HUKUKİ KIRILGANLIĞI: TÜRKİYE ÖRNEĞİ

Prof. Dr. Demet Demiroğlu*
Kilis 7 Aralık Üniversitesi, Ziraat Fakültesi
Email: ddemiroglu@kilis.edu.tr
ORCID: 0000-0002-3934-5319
Prof. Dr. Aybike Ayfer Karadağ
Düzce Üniversitesi, Orman Fakültesi
Email: ayferkaradag@duzce.edu.tr
ORCID: 0000-0002-7726-8756

ÖZET

Türkiye'de tarım alanlarının korunması, temel olarak 5403 sayılı Toprak Koruma ve Arazi Kullanımı Kanunu ile düzenlenmiştir. Ancak yerel yönetim ölçeğindeki dönüşümlerde ve özellikle ülkedeki afetler sonrası yeniden yapılanma süreçlerinde ve bu koruma mekanizmalarının etkinliği önemli ölçüde azalmaktadır.

Bu çalışma, Türkiye'de tarım alanlarının hukuki kırılganlık dinamiklerini mevzuat perspektifinden incelemektedir. Analiz, 5403 (Toprak Koruma ve Arazi Kullanımı Yasası), 3194 (İmar Kanunu), 6306 (Afet Riski Altındaki Alanların Dönüştürülmesi Kanunu) ve 6360 sayılı (On Dört İlde Büyükşehir Belediyesi ve Yirmi Yedi İlçe Kurulmasi İle Bazı Kanun ve Kanun Hükmünde Kararnamelerde Değişiklik Yapılmasına Dair Kanun-Bütünşehir Yasası) yasalar arasındaki etkileşimleri karşılaştırmalı biçimde değerlendirmektedir. Bulgular, özellikle afet sonrası yeniden yapılanma sürecinde kamu yararı ve imar kolaylıkları gerekçesiyle tarım dışı kullanım baskısının arttığını; ayrıca 6360 Sayılı Yasa ile Türkiye'de kırsal alan statüsünün ortadan kalkmasının, tarım topraklarının belediye imar yetkileri altında daha korunmasız hale gelmesine yol açtığını göstermektedir. Yasa sonrasında köylerin mahalleye dönüştürülmesi, tarım alanlarının planlama süreçlerinde kentleşme baskısına açılmasına ve tarımsal üretim haklarının zayıflamasına neden olmuştur. Bu durum, özellikle afet sonrası dönemde arazi kullanımında çok katmanlı bir hukuki kırılganlık üretmektedir.

Sonuç olarak, tarım alanlarının korunabilmesi için afet yönetimi, imar ve yerel yönetim mevzuatının tarımsal arazi koruma ilkeleriyle bütünleştirilmesi, yetki çatışmalarının giderilmesi ve iklim dayanıklılığı odaklı yasal reformların hayata geçirilmesi gerekmektedir.

Anahtar Kelimeler: Tarım Alanları, Hukuki Kırılganlık, Afet Yönetimi, Arazi Kullanımı

THE LEGAL VULNERABILITY OF AGRICULTURAL AREAS: TURKIYE EXAMPLE

ABSTRACT

The protection of agricultural lands in Turkey is primarily regulated under Law No. 5403 on Soil Conservation and Land Use. However, its effectiveness is significantly reduced during post-disaster reconstruction and local governance transformations. In particular, Law No. 6306 on the Transformation of Areas under Disaster Risk and Law No. 6360 (Metropolitan Municipality Law) indirectly weaken the legal status of agricultural lands.

This study examines the legal vulnerability dynamics of agricultural lands in Turkey from a legislative perspective. It analyzes interactions between Law No. 5403, Law No. 3194, Law No. 6306, and Law No. 6360. Findings indicate that post-disaster reconstruction often prioritizes "public interest" and facilitates zoning changes, increasing pressure for non-agricultural land use. The Metropolitan Municipality Law, which converted villages into urban neighborhoods, exposes agricultural lands to urban planning pressures and weakens their protection.

As a result, agricultural lands face multi-layered legal vulnerability, compounded by overlapping authorities, inconsistent regulations, and rapid policy decisions during post-disaster recovery. Safeguarding agricultural lands requires harmonizing legislation on disaster management, zoning, and local governance with agricultural land protection principles, resolving jurisdictional conflicts, and developing climate-resilient, food-security-oriented legal reforms.

Keywords: Agricultural Lands, Legal Vulnerability, Disaster Management, Land Use Policy

TÜRKIYE İKLİM KANUNU'NUN TARIMSAL PEYZAJLAR ÜZERINDEKİ OLASI ETKİLERİNİN DEĞERLENDİRİLMESİ

Prof. Dr. Aybike Ayfer Karadağ
Düzce Üniversitesi, Orman Fakültesi
Email: ayferkaradag@duzce.edu.tr
ORCID: 0000-0002-7726-8756
Prof. Dr. Demet Demiroğlu*
Kilis 7 Aralık Üniversitesi, Ziraat Fakültesi
Email: ddemiroglu@kilis.edu.tr
ORCID: 0000-0002-3934-5319

ÖZET

2025 yılında yürürlüğe giren 7552 sayılı Türkiye İklim Kanunu, net sıfır emisyon hedefleri, yeşil büyüme vizyonu ve iklim değişikliğine uyum ilkeleri çerçevesinde tarımsal üretim, arazi kullanımı ve kırsal alan yönetimini doğrudan ve dolaylı olarak etkileyen kritik bir düzenlemedir. Bu çalışma, Kanunun tarımsal peyzajlar üzerindeki fırsat, risk ve tehditlerini değerlendirmeyi amaçlamaktadır.

Kanun, karbon yutaklarının korunması, ekosistem temelli yaklaşımlar ve sürdürülebilirlik ilkeleri aracılığıyla tarımsal peyzajların direncini ve uyum kapasitesini güçlendirme potansiyeline sahiptir. Kanun kapsamında tarımsal peyzajlar için öne çıkan fırsatlar; karbon depolama ve sera gazı azaltımı, iklim dirençli ürün desenleri, agroekoloji ve agroforestry uygulamaları, örtü bitkileri ve sulak alan yönetimi ile toprak sağlığının iyileştirilmesi, arazi kullanım planlaması, yeşil alan ve su havzalarının korunması, erozyon ve çölleşmeyle mücadele ile ekosistem hizmetlerinin sürdürülmesidir. Yeşil finansman ve karbon piyasalarına erişim, biyolojik çeşitlilik ile uyumlu tarımsal uygulamaları güçlendirmektedir. Öte yandan, küçük üreticilerin finansman ve teknolojiye erişim güçlükleri, üretim maliyetleri, bölgesel farklılıkların yönetimi, karbon fiyatlandırması, arazi kullanım kısıtlamaları, geleneksel su-yoğun ve monokültür tarım uygulamaları ve tarım arazilerinin kentsel genişleme ile kaybı risk ve tehditler arasında yer almaktadır. Ayrıca Kanunun mevcut ulusal mevzuatla entegrasyonu ve tarım teşvikleriyle uyumu konusundaki belirsizlikler, uygulamadaki etkinliği sınırlayabilecek yapısal riskler olarak öne çıkmaktadır.

Sonuç olarak, Türkiye İklim Kanunu, tarımsal peyzajları hem iklim değişikliğinin yükünü taşıyan hem de çözümün merkezinde yer alan alanlar hâline getirme potansiyeline sahiptir ve bu potansiyelin gerçekleşmesi uygulamadaki bütüncüllük, yerel uyarlama ve küçük üreticiyi gözeten politikalarla mümkün olacaktır. Ayrıca Kanunun tarımsal peyzaj ölçeğinde etkin uygulanması; toprak karbonu yönetimi, biyolojik çeşitlilik entegrasyonu, su bütçesi gözetimi, kırsal kalkınma, bölgesel adaptasyon planları, çiftçi eğitim ve destek programları, adil geçiş mekanizmaları ve ekosistem temelli planlama ile mümkündür.

Anahtar Kelimeler: Türkiye İklim Kanunu, Tarımsal Peyzaj, İklim Değişikliğine Uyum, Sürdürülebilir Tarım.

AN ASSESSMENT OF THE POTENTIAL IMPACTS OF THE TURKISH CLIMATE LAW ON AGRICULTURAL LANDSCAPES

ABSTRACT

Enacted in 2025, Türkiye's Climate Law (Law No. 7552) represents a pivotal framework shaping agricultural production, land use, and rural landscape management within the pursuit of net-zero emissions, green growth, and climate adaptation. This study assesses the opportunities and challenges the Law introduces for agricultural landscapes.

The Law offers significant potential to strengthen resilience and adaptive capacity by protecting carbon sinks, promoting ecosystem-based approaches, and embedding sustainability principles. Key opportunities include advancing carbon sequestration and greenhouse gas mitigation, encouraging climate-resilient cropping systems, and supporting agroecology and agroforestry practices. Measures such as cover cropping, wetland restoration, improved soil management, and integrated land-use planning further enhance ecosystem services. Protection of water basins, erosion control, and desertification prevention are also central to achieving long-term sustainability. Access to green financing and participation in carbon markets create additional incentives for biodiversity-friendly practices.

Nevertheless, the Law entails notable risks and challenges. Smallholders may face barriers in accessing finance and technology, while rising production costs and regional disparities could exacerbate inequalities. Carbon pricing, land-use restrictions, reliance on water-intensive monocultures, and the ongoing conversion of farmland to urban uses present further constraints. Moreover, uncertainties in aligning the law with existing national legislation and agricultural subsidy schemes pose structural obstacles to effective implementation.

In conclusion, the Climate Law positions agricultural landscapes both as vulnerable domains affected by climate change and as critical levers for mitigation and adaptation. Unlocking this dual potential requires holistic and locally adapted implementation, policies supportive of small-scale farmers, and integration with broader rural development agendas. Effective landscape-level action depends on soil carbon management, biodiversity mainstreaming, water budget monitoring, regional adaptation planning, farmer capacity-building, just transition mechanisms, and ecosystem-based land-use strategies.

Keywords: Türkiye's Climate Law, Agricultural Landscapes, Climate Change Adaptation, Sustainable Agriculture

TEKİRDAĞ KOŞULLARINDA FARKLI YÖNTEMLERLE KURUTULAN CEVİZLERİN KURUTMA KİNETİKLERİNİN İNCELENMESİ

Levent TAŞERİ

Dr., Tekirdağ Bağcılık Araştırma Enstitüsü Müdürlüğü, Gıda Teknolojileri Bölümü, Tekirdağ-Türkiye

Email: levent.taseri@tarimorman.gov.tr (Responsible Author)

ORCID : 0000-0002-4494-9125

Ersin KARACABEY

Dr., Manisa Bağcılık Araştırma Enstitüsü Müdürlüğü Manisa-Türkiye

Email: karacabey.ersin@tarimorman.gov.tr

ORCID : 0000-0003-4166-1553

Gamze UYSAL SEÇKİN

Dr., Tekirdağ Bağcılık Araştırma Enstitüsü Müdürlüğü, Gıda Teknolojileri Bölümü, Tekirdağ-Türkiye

Email: gamze.uysalseckin@tarimorman.gov.tr

ORCID : 0000-0002-2117-075X

ÖZET

Ceviz yetiştiriciliğinde yaşanılan en büyük sorunlardan birisi hasat sonu işlemlerden olan kurutma işlemidir. Cevizlerin sarsmayla yere düşürüldükten sonra uzun süre bekletilmesi; meyvede kararma, ısıdan zarar görme, kurtlanma ve küflenme gibi kalite kayıplarını oluşturabilmektedir. Bu sebeple, yere düşürülen meyvelerin zaman kaybetmeden toplanması, yeşil kabuklarının soyulması ve kurutulması gerekmektedir. Bu projede cevizler, 32 ºC ve 37 ºC'de güneş enerjisi-biyokütle hibrit kurutucusunda, 35 ºC ve 40 ºC'de laboratuvar tipi elektrikli fırında ve açık alanda gölgede kurutulmuştur. Kurutma denemeleri 19 Ekim tarihinde başlamış ve 28 Ekim tarihinde sona ermiştir. Denemede elde edilen verilere göre; açık alanda gölgede kurutulan örneklerin ortalama nem değeri, 193.5 saatin sonunda %31.21'den %11.8'e düşmüştür. Güneş-biyokütle hibrit kurutucuda 32 ºC derecede kurutulan örneklerin %26.9 olan nem oranı, 23.5 saat sonunda ortalama %9.07'ye düşmüştür. Güneş-biyokütle hibrit kurutucuda 37 ºC derecede kurutulan örneklerin %31.9 olan nem oranı, 26 saat sonunda ortalama %7.8'e düşmüştür. 35 ºC derecede elektrikli fırında kurutulan örneklerin %25.36 olan nem oranı ise 39 saat sonunda %3.62'ye düşmüştür. 40 °C derecede elektrikli fırında kurutulan örneklerin %30.76 olan nem oranı ise 16 saat sonunda %7.22'ye düşmüştür. Tekirdağ ilinde Ekim ayı iklim verilerine göre yağışlı bulutlu günlerin olması ve yüksek nem içeriğinden dolayı, cevizlerin açık alanda gölgede kurutulması mikrobiyolojik risk taşımaktadır. Bundan dolayı, Tekirdağ ilinde açık alanda gölgede kurutma yöntemi önerilmemektedir. Güneş-biyokütle yöntemleri, kurutma kinetikleri ve kalite kriterlerine göre karşılaştırıldığında kurutma havası sıcaklığının 37°C'de olmasının 32 °C'ye göre tercih edilmesi önerilmektedir. Elektrikli fırında kurutma yönteminde ise değerlendirme kriterlerine göre kurutma havası sıcaklığının 40 °C olması 35 °C'ye göre önerilmektedir.

Anahtar Kelimeler: Chandler Cevizi, Güneş Enerjisi, Biyokütle Enerjisi, Elektrikli Fırın, Kurutma Özellikleri

INVESTIGATION OF DRYING KINETICS OF WALNUT DRIED WITH DIFFERENT METHODS IN TEKIRDAĞ CONDITIONS

ABSTRACT

One of the biggest problems experienced in walnut cultivation is the drying process of the walnut, which is one of the post-harvest processes. Keeping the walnuts waiting for a long time after being dropped to the ground by shaking; It can cause quality losses such as darkening of the fruit, damage from heat, worming and molding. For this reason, it is necessary to collect the fallen fruits without losing time, peel the green skins and dry them. In this project, walnuts were dried in a solar-biomass hybrid dryer at 32 °C and 37 °C, in a laboratory electric oven at 35 °C and 40 °C, and in the open area in the shade. Drying trials started on October 19, 2021 and ended on October 28, 2021. The average moisture value of samples dried in the open area decreased from 31.21% to 11.8% after 193.5 hours. The moisture content of the samples, which was 26.9% in a solar-biomass hybrid dryer at 32 °C, decreased to an average of 9.07% at the end of 23.5 hours. The humidity of 31.9% of the samples dried in a solar-biomass dryer at 37 °C decreased to an average of 7.8% at the end of 26 hours. The moisture content of the samples dried at 35 °C in an electric oven, which was 25.36%, decreased to 3.62% at the end of 39 hours. The moisture content of the samples dried in an electric oven at 40 °C, which was 30.76%, decreased to 7.22% at the end of 16 hours. According to climate data for October, drying walnuts in the open area carries a microbiological risk due to the rainy, cloudy days and high moisture content. Therefore, open area drying method is not recommended in Tekirdağ province. When the methods in solar-biomass are compared in terms of quality criteria and drying kinetics, solar-biomass (37°C) drying method is more preferable than solar-biomass (32°C) drying method. In electric oven drying, when compared in terms of quality criteria and drying kinetics, the electric oven drying method at 40°C is more preferable than the 35°C drying method.

Key words: Chandler Walnuts, Solar Energy, Biomass Energy, Electric Oven, Drying Properties

İZMİR KOŞULLARINDA BAZI SİLAJLIK MISIR (*Zea mays* L.) GENOTİPLERİNİN VERİM VE KALİTE ÖZELLİKLERİNİN BELİRLENMESİ

Ergül AY*

Ege Tarımsal Araştırma Enstitüsü Müdürlüğü

Email: ergul.ay@tarimorman.gov.tr (*Sorumlu yazar)

ORCID: 0000-0002-8591-3508

Dr. Hüseyin ÖZPINAR

Emekli Araştırmacı, T.C. Tarım ve Orman Bakanlığı

Email: huseyin_ozpinar@hotmail.com

ORCID: 0000-0002-3351-3908

Dr. Hülya OKKAOĞLU

Ege Tarımsal Araştırma Enstitüsü Müdürlüğü

Email: hulya.okkaoglu@tarimorman.gov.tr

ORCID: 0000-0003-3830-3878

Melek AKÇA PELEN

Ege Tarımsal Araştırma Enstitüsü Müdürlüğü

Email: melek.akcapelen@tarimorman.gov.tr,

ORCID: 0000-0003-4704-7677

Erseven ULUS

Ege Tarımsal Araştırma Enstitüsü Müdürlüğü

Email: erseven.ulus@tarimorman.gov.tr

ORCID: 0009-0003-5800-5939

Süleyman ÇAĞIR

Ege Tarımsal Araştırma Enstitüsü Müdürlüğü

Email: suleyman.cagir@tarimorman.gov.tr

ORCID: 0000-0001-9466-7786

Dr. Ceylan BÜYÜKKİLECİ

Ege Tarımsal Araştırma Enstitüsü Müdürlüğü

Email: ceylan.buyukkileci@tarimorman.gov.tr

ORCID: 0000-0003-1247-4193

ÖZET

Amaç:

Silajlık mısır ülkemiz için önemli bir kaba yem kaynağıdır. İzmir, Türkiye'de silajlık mısır üretiminde yaklaşık %12'lik payı ile ilk sırada yer almaktadır. Bölgede yaygın olan süt ve besi

sığırcılığı faaliyetleri kaliteli kaba yeme olan talebi artırmış bu da silajlık mısır ekim alanlarının genişlemesinde etkili olmuştur. Bu çalışma Ege Bölgesi Silajlık Mısır Islah projesi sonucunda geliştirilen hibritler ile bölgemiz koşullarında üretimi yapılan ticari çeşitlerin verim ve kalite özelliklerini belirlemek amacıyla yürütülmüştür.

Materyal ve Yöntem:

Deneme İzmir koşullarında, Ege Tarımsal Araştırma Enstitüsü deneme alanlarında 2023 ve 2024 yılı ana ürün yetiştirme sezonunda iki yıl süre ile tesadüf blokları deneme desenine göre 3 tekerrürlü olarak yürütülmüştür. Denemede materyal olarak Enstitümüzde yürütülen mısır ıslah çalışmaları sonucunda geliştirilen Ege F1 95, Ege F1 98 ve Ege F1 100 genotipleri ve 8 adet ticari çeşit (Aga, Samada 07, Pehlivan 07, Kilowatt, PR31Y43, DKC 6777, LG.30685, LG.30709) kullanılmıştır.

Bulgular:

Çalışmanın 2 yıllık sonuçları değerlendirildiğinde; genotipler arasında bitki boyu, yeşil bitki ve kuru madde verimleri, ham protein, ADF ve NDF oranları açısından farklılıklar istatistiksel olarak önemli bulunmuştur. Genotiplerin ortalama bitki boyları 246,7-296,2 cm arasında ölçülmüştür. Genotiplerin ortalama yeşil bitki verimleri 6300-8581 kg/da olarak belirlenmiş, ıslah çalışmaları sonucunda geliştirilen Ege F1 100 ilk verim grubunda yer almıştır. Genotipler kuru madde verimi açısından değerlendirildiğinde Kilowatt (2765 kg/da), Ege F1 100 (2761 kg/da) ve LG 30.685 (2749 kg/da) ilk verim grubunda yer almışlardır. Yine Ege F1 100 genotipi ortalama % 10,4 ham protein oranı ile ilk grubu oluşturmuştur. Genotiplerin ortalama ADF oranları %22,13-31,05 arasında değişiklik göstermiştir. NDF oranları ise %38,88-50,39 olarak saptanmıştır.

Sonuç:

Verim ve bazı kalite değerleri kontrol çeşitlerin üzerinde olan Ege F1 100 genotipinin bölgemiz için ümit var olduğu ve tescil olması halinde bölge çiftçisine tavsiye edilebileceği düşünülmektedir.

Anahtar Kelimeler: Silajlık mısır, yeşil bitki verimi, kuru madde verimi, kalite, ham protein, ADF, NDF

DETERMINATION OF YIELD AND QUALITY TRAITS OF SOME SILAGE MAIZE (Zea mays L.) GENOTYPES IN İZMİR CONDITIONS

ABSTRACT

Objective:

Silage corn is an important source of forage for our country. İzmir ranks first in Türkiye's silage corn production, accounting for approximately 12%. The widespread dairy and beef cattle farming activities in the region have increased the demand for high-quality forage, which has contributed to the expansion of silage corn acreage. This study was conducted to determine the yield and quality characteristics of hybrids developed as a result of the Aegean Region Silage Corn Breeding Project and commercial varieties cultivated in our region.

Materials and Methods:

The experiment was conducted in Izmir conditions at the trial areas of the Aegean Agricultural Research Institute using a randomized complete block design with three replications for two years during the 2023 and 2024 main crop growing seasons. Ege F1 95, Ege F1 98 and Ege F1 100 genotypes developed as a result of corn breeding studies carried out in our Institute and 8 commercial cultivars (Aga, Samada 07, Pehlivan 07, Kilowatt, PR31Y43, DKC 6777, LG.30685, LG.30709) were used as the experimental material.

Conclusion:

When the two-year results of the study were evaluated, the differences among genotypes in terms of plant height, green plant and dry matter yields, crude protein, ADF and NDF ratios were found to be statistically significant. The average plant heights of the genotypes ranged between 246.7 and 296.2 cm. The average green plant yields of the genotypes were determined to range from 6300 to 8581 kg/da, with the Ege F1 100 genotype developed through breeding studies being placed in the highest yield group. When evaluated in terms of dry matter yield, Kilowatt (2765 kg/da), Ege F1 100 (2761 kg/da), and LG 30.685 (2749 kg/da) were included in the highest yield group. Additionally, the Ege F1 100 genotype formed the first group with an average crude protein ratio of 10.4%. The average ADF ratios of the genotypes ranged from 22.13% to 31.05%, while the NDF ratios were determined to range from 38.88% to 50.39%.

Results:

It is thought that the Ege F1 100 genotype, which has yield and some quality values above the control varieties, is hopeful for our region and can be recommended to farmers in the region if it is registered.

Keywords: Silage corn, green plant yield, dry matter yield, quality, crude protein, ADF, NDF

RUMİNANTLARDA METAN ÜRETİMİ VE RUMEN MİKROBİYOTASI

Doç. Dr. Mehtap GÜNEY,
Van Yüzüncü Yıl Üniversitesi, Ziraat Fakültesi
Email: mguney@yyu.edu.tr
ORCID: 0000-0002-0613-3600

ÖZET

Geviş getiren hayvanların sindirim sistemi karmaşık, zengin bir mikrobiyal topluluğa sahiptir. Burada yaşayan mikrobiyota; bakteriler, arkealar, protozoalar ve mantarlardan oluşmaktadır. Söz konusu mikroorganizmalar, ruminantlar tarafından tüketilen lignoselülolitik yapısal karbonhidratları parçalayarak bu hayvanların sindirebileceği asetik, propiyonik ve bütirik asit gibi uçucu yağ asitlerinin üretilmesini sağlamaktadırlar. Bazı mikroorganizma türleri, rumende fermantasyon sırasında doğal olarak oluşan hidrojen ve karbondioksitten metan üretmektedirler. Metanogenez adı verilen bu süreçte, anaerobik ortamda açığa çıkan metan, metanojenik arkealar ve kimi diğer mikroorganizmalar tarafından üretilmektedir. Metan, ruminant hayvanlarda enerji kaybına neden olarak hem verim kayıplarına hem de çevre kirliliğine neden olabilmektedir. Son yıllarda kamuoyunun odağı haline gelen metan üretiminin azaltılması konusu dikkat çekmekte olup çeşitli metan azaltma stratejileri geliştirilmektedir. Bu çalışmada rumende fermantasyon sırasında oluşan metan ve rumen mikrobiotası arasındaki ilişki tartışılacaktır.

Anahtar Kelimeler: Ruminant, Metan, Mikrobiyom

METHANE PRODUCTION AND RUMEN MICROBIOTAS IN RUMINANTS

ABSTRACT

The digestive system of ruminants possesses a complex and rich microbial community. The microbiota living there consists of bacteria, archaea, protozoa, and fungi. These microorganisms break down lignocellulolytic structural carbohydrates consumed by ruminants, enabling the production of volatile fatty acids such as acetic, propionic, and butyric acids that these animals can digest. Some microorganisms produce methane from the naturally occurring hydrogen and carbon dioxide during fermentation in the rumen. In this process, called methanogenesis, methane released in an anaerobic environment is produced by methanogenic archaea and some other microorganisms. Methane causes energy loss in ruminants, which can lead to both productivity losses and environmental pollution. The reduction of methane production, a topic that has become a public focus in recent years, has attracted attention, and various methane reduction strategies are being developed. This study will discuss the relationship between methane produced during rumen fermentation and the rumen microbiota.

Keywords: Ruminant, Methane, Microbiome

TUZLULUK SORUNUNA ÇİFTÇİ YAKLAŞIMI; MENEMEN ÖRNEĞİ

Dr. Zübeyde ALBAYRAM DOĞAN
Uluslararası Tarımsal Araştırma ve Eğitim Merkezi Müdürlüğü
Email: zubeyde.albayram@gmail.com
ORCID: 0000-0001-8314-9262
Dr.Tuncay TOPDEMİR
Uluslararası Tarımsal Araştırma ve Eğitim Merkezi Müdürlüğü
Email: ttopdemir26@gmail.com
ORCID: 0000-0001-7425-2110
Dr. Sinan ARAS
Uluslararası Tarımsal Araştırma ve Eğitim Merkezi Müdürlüğü
Email: arasssinan@gmail.com
ORCID: 0000-0002-7935-9205
Dr. Gülay YILMAZ
Uluslararası Tarımsal Araştırma ve Eğitim Merkezi Müdürlüğü
Email: ylmaz73@gmail.com
ORCID: 0000-0002-7932-1565
Dr. Gözen YÜCEERİM
Uluslararası Tarımsal Araştırma ve Eğitim Merkezi Müdürlüğü
Email: gozenyuceerim@gmail.com
ORCID: 0000-0002-8769-3422
Alican EREN
Uluslararası Tarımsal Araştırma ve Eğitim Merkezi Müdürlüğü
Email: alcnern@gmail.com
ORCID: 0000-0002-2089-7594
Nuri CANDAN
Uluslararası Tarımsal Araştırma ve Eğitim Merkezi Müdürlüğü
Email: nuricandan09@gmail.com
ORCID: 0000-0001-8654-6036
Vural KARAGÜL
Uluslararası Tarımsal Araştırma ve Eğitim Merkezi Müdürlüğü
Email: vuralkaragul@gmail.com
ORCID: 0000-0001-8654-6036

Şener ÖZÇELİK
Uluslararası Tarımsal Araştırma ve Eğitim Merkezi Müdürlüğü
Email: sener.ozcelik@tarimorman.gov.tr
ORCID: 0000-0002-1470-6827
Murat Çağatay KEÇECİ
Karadeniz Tarımsal Araştırma Enstitüsü Müdürlüğü
Email: muratcagatay.kececi@tarimorman.gov.tr
ORCID: 0000-0002-1482-695X

ÖZET

Menemen Ovası tarımsal üretim potansiyeli açısından stratejik öneme sahip bölgeler içerisinde yer almaktadır. Ovada karşılaşılan sorunların tespitine yönelik yapılan çalışmalardan elde edilen verilere göre Menemen Ovası'nın toplamda yaklaşık üçte birinde tuzluluk probleminin farklı seviyelerde gözlendiği ortaya çıkmıştır. Tuzluluk kaynaklı ihtiyaç duyulan su miktarının bitki tarafından alınamaması ve beraberinde verim kaybı ile elde edilen gelirin olumsuz etkilenmesi üreticiler açısından önemli bir problem olarak değerlendirilmektedir. Tuzluluğun bölgesel olarak karşılaşılan alanlarda denize yakın olmasının ve delta etkisinin etkili olduğu ancak çiftçi kaynaklı bilinçsiz uygulamalar sonucunda da bu etkinin arttığı düşünülmektedir. Bu çalışma ile üreticinin tuzluluk ile karşı karşıya kaldığı bu alanlarda hangi tarımsal uygulamaların olumlu etkisi olabileceği, alınabilecek önlemler ya da bu problemin çözümü noktasında üreticilerin davranışsal yaklaşımı ve istekliliği değerlendirilmiştir. Ayrıca, Menemen Ovası'nda tuzluluğun oluşmasında etkili olabilecek sebeplerin çeşitli yönlerden değerlendirmesi üretici yaklaşımı ile ortaya koyularak üreticilerin ne şekilde etkilendiği ele alınmıştır. Anket yolu ile Menemen Ovası'nda görüşülen 30 üreticinin %57'si tuzluluk problemi ile çeşitli düzeylerde karşılaştığını belirtmiş ve tuzluluğa sebep olan en önemli etkenin kuraklık olduğu ve bunun beraberinde sulama suyu kalitesinin de önemli derecede etkili olduğu belirtilmiştir. Bölgedeki tuzluluğu önlemek için alınabilecek önlemler açısından üreticilerin yaklaşımı değerlendirildiğinde karar verici ilgili birimler tarafından altyapısal rehabilitasyonun yapılmasının etkili olabileceği ve tarımsal sulamada kullanılan sulama suyu kalitesinin iyileştirilmesi yönünde alınabilecek önlemlerin çözüm getirebileceği ortaya çıkmıştır. Tuzluluk sebebi ile tarımsal üretim dışına çıkarılan tarım arazilerinin olduğunu belirten üreticilerin sürdürülebilir üretim kapsamında kalabilmeleri için hem altyapısal önlemlerin alınması hem de üretici uygulamalarından kaynaklı olumsuz etkilerin en aza indirgenmesi önem taşımaktadır. Çiftçilerin yanlış uygulamalarından kaynaklı etkilerin azaltımı yönünde ise bilinç düzeyinin arttırılarak doğa temelli çözümlerin benimsetilmesi gerekmektedir.

Anahtar Kelimeler: Tuzluluk, Üretici davranışı, Menemen Ovası

FARMER APPROACH ON SALINITY AS A CHALLENGE; MENEMEN PLAIN CASE

ABSTRACT

Menemen Plain is located in a region of strategic importance in terms of its agricultural production potential. According to data obtained from studies investigating problems in the plain, it has been revealed that salinity is present at various levels in around a third of Menemen Plain. The inability of plants to absorb the required amount of water due to salinity, coupled with the subsequent loss of yield and its negative impact on income, is considered a significant problem for producers. It is thought that salinity is encountered regionally in areas close to the sea, and that the delta effect is influential. However, this effect is also increased as a result of unconscious farming practices. This study evaluated the potential positive impact of agricultural practices in areas where producers face salinity, the measures that could be taken and the behavioural approach and willingness of producers to solve this problem. Furthermore, a producer approach was considered to evaluate the various factors that could contribute to salinity formation in the Menemen Plain, examining how producers are affected. A survey of 30 producers in the Menemen Plain revealed that 57% had encountered salinity problems to varying degrees. The survey indicated that drought was the most significant cause of salinity and that the quality of irrigation water also had a significant impact. When evaluating the approaches of producers to measures that could prevent salinization in the region, it was determined that rehabilitation of infrastructure by the relevant decision-making bodies could be effective, as could improving the quality of irrigation water used in agriculture. It is important that both infrastructure measures are taken and negative effects arising from producer practices are minimized so that producers who indicate that agricultural land has been excluded from agricultural production due to salinity can remain within the scope of sustainable production. In order to reduce the effects caused by farmers' incorrect practices, it is necessary to raise awareness and promote nature-based solutions.

Keywords: Salinity, Producer Behaviour, Menemen Plain

EXAMINATION OF MUTANT LINES SUBJECTED TO SALINITY STRESS DURING GERMINATION

Soner ÇOLAK

Tekirdağ Namık Kemal Universitesi Agricultural Faculty

Prof. Dr. Oğuz BİLGİN

Tekirdağ Namık Kemal Universitesi Agricultural Faculty

Email: obilgin@nku.edu.t

ORCID: 0000-0002-4338-9912

Res. Ass. Dr. Damla Balaban GÖCMEN

Tekirdağ Namık Kemal Universitesi Agricultural Faculty

Email: dgocmen@nku.edu.tr.

ABSTRACT

A total of 3 different bread wheat varieties were used as rootstocks, including a variety developed by Tekirdağ Namık Kemal University Tekirdağ Faculty of Agriculture Department of Field Crops (NKÜ Lider) and 2 old bread wheat varieties (Sagittario and Flamura 85) cultivated in the Thrace Region in different periods. 12 mutant advanced lines and their rootstocks, selected among the mutant advanced lines developed from M4 populations of these varieties, which were developed by gamma irradiation from a 60Co source, were used as standard materials in this study.

In this study, germination and early seedlings of mutant advanced lines developed from different commercial varieties by gamma irradiation. It was aimed to contribute to the literature knowledge on this subject by examining their responses to salinity stress during development periods and identifying promising lines.

Keywords Triticum aestivum L., Mutant, Stress, Salinity, Germination, Seedling Growth

UZUN YILLAR ARAZI KULLANIM DEGISIMLERININ INCELENMESI ve TOPRAK VERITABANI OLUSTURULMASI: YUMURTALIK ORNEGI

Arş. Gör. Dr. Yavuz Şahin TURGUT

Çukurova Üniversitesi, Ziraat Fakültesi, Toprak Bilimi ve Bitki Besleme Bölümü.

Email: ysturgut@cu.edu.tr

ORCID: 0000-0002-8566-6375

Doç. Dr. Yakup Kenan KOCA

Çukurova Üniversitesi, Ziraat Fakültesi, Toprak Bilimi ve Bitki Besleme Bölümü.

Email: ykkoca@cu.edu.tr

ORCID: 0000-0001-9285-1416

ÖZET

Uzun yıllar boyunca gerçekleşen arazi kullanım değişimleri, özellikle tarım alanlarının genişlemesi, kentleşme ve sanayileşme süreçlerinin hızlanmasıyla birlikte doğal ekosistemler üzerinde önemli baskılar oluşturmuştur. Bu süreçler, orman ve mera alanlarının giderek daralmasına, karbon depolama kapasitesinin azalmasına ve ekosistem hizmetlerinde ciddi kayıplara yol açmıştır. Özellikle tarımsal üretim amacıyla doğal alanların dönüştürülmesi, toprak organik karbon stoklarının azalmasına, toprak yapısının bozulmasına ve arazi bozulumunun hızlanmasına neden olmaktadır. Bu durum, bölgesel ölçekte karbon döngüsünün dengesini bozarak iklim değişikliğinin etkilerini daha belirgin hale getirmektedir. Bu çalışmada, Sentinel-2A ve Sentinel-2B uydularına ait 10 m spektral çözünürlüklü veriler kullanılarak 2017–2024 yılları arasında Adana ili Yumurtalık ilçesindeki arazi kullanım ve arazi örtüsü değişimleri (LULC) analiz edilmiştir. Coğrafi bilgi sistemleri ile değişimler incelenerek uydu görüntülerinin sınıflandırılmasıyla tarım, mera, orman ve diğer (yerleşim ve su yüzeyleri) arazi kullanımları olmak üzere arazi kullanım sınıfı belirlenmiş, bu sınıflar üzerinden zamansal değişim oranları hesaplanmıştır. Bu sonuçlara göre, incelenen dönemde tarım alanlarında yaklaşık 437,7 hektarlık artış, mera alanlarında ise 563,8 hektarlık azalma meydana gelmiştir. Ayrıca, alanın genelinde tarım arazilerinin toplam arazi kullanımının yaklaşık %80–90'ını, ormanlık alanların ise yalnızca %0,1–0,3'ünü oluşturduğu belirlenmiştir. Elde edilen sonuçlar, Yumurtalık bölgesinde mera alanlarının giderek tarım alanına dönüştüğünü ve bu dönüşümün toprak bozunumu riskini artırdığını göstermektedir. Bu durum, uzun vadede hem toprak verimliliği hem de karbon stoklama kapasitesi üzerinde olumsuz etkiler yaratabilir. Dolayısıyla, gelecekteki araştırmaların daha geniş alanları kapsayacak şekilde arazi kullanım değişimlerinin toprak karbon dinamikleri üzerindeki etkilerine odaklanması ve sadece uydu görüntüleri ile değil aynı zamanda açılan toprak profilleri ile derinlikteki değişimin incelenmesi hem sürdürülebilir arazi yönetimi hem de iklim değişikliğiyle mücadele açısından büyük önem taşımaktadır.

Anahtar Kelimeler: Arazi Kullanımı, Arazi Bozunumu, Uzaktan Algılama, Yumurtalık.

LONG-TERM ANALYSIS OF LAND USE CHANGES AND ESTABLISHMENT OF A SOIL DATABASE: THE CASE OF YUMURTALIK

ABSTRACT

Land use changes that have occurred over many years, particularly the expansion of agricultural areas, have created significant pressures on natural ecosystems, especially with the acceleration of urbanization and industrialization processes. These processes have led to the gradual reduction of forest and pasture areas, a decrease in carbon storage capacity, and serious losses in ecosystem services. The conversion of natural areas for agricultural production, in particular, has caused a decrease in soil organic carbon stocks, soil structure degradation, and accelerated land degradation. This situation disrupts the balance of the carbon cycle at the regional scale, making the effects of climate change more pronounced. In this study, land use and land cover (LULC) changes in the Yumurtalık district of Adana province between 2017 and 2024 were analyzed using 10 m spectral resolution data from the Sentinel-2A and Sentinel-2B satellites. Changes were examined using geographic information systems, and land use classes were determined by classifying satellite images into agricultural, pasture, forest, and other (settlements and water surfaces) land uses. Temporal change rates were calculated for these classes. According to these results, there was an increase of approximately 437.7 hectares in agricultural areas and a decrease of 563.8 hectares in pasture areas during the period under consideration. Furthermore, it was determined that agricultural lands constituted approximately 80–90% of the total land use in the area, while forested areas constituted only 0.1–0.3%. The results obtained show that pasture areas in the Yumurtalık region are gradually being converted into agricultural areas and that this conversion increases the risk of soil degradation. This situation may have negative effects on both soil fertility and carbon storage capacity in the long term. Therefore, it is crucial for future research to focus on the effects of land use changes on soil carbon dynamics, covering larger areas, and to examine changes at depth not only with satellite images but also with soil profiles. This is of great importance for both sustainable land management and combating climate change.

Keywords: Landuse, land degradation, remote sensing, Yumurtalik

BÜYÜKBAŞ HAYVANLARDA DAVRANIŞIN VERİM ÜZERİNE ETKİLERİ

Arş. Gör. Dr. Murat TURAN
Van Yüzüncü Yıl Üniversitesi, Ziraat Fakültesi, Zootekni
Email: muratturan@yyu.edu.tr
ORCID: 0000-0001-9286-3046

ÖZET

Büyükbaş hayvanlarda davranış özellikleri, hayvan refahını ve üretim verimliliğini doğrudan etkileyen temel bir unsurlardan biridir. Büyükbaş hayvanların sergiledikleri davranışsal tepkiler; çevresel faktörler, sürü içi sosyal etkileşimler, yönetim uygulamaları ve genetik yapı gibi birçok unsur tarafından etkilenmektedir. Hayvan davranışların sistematik biçimde gözlemlenmesi, refah düzeyinin belirlenmesinde ve uygun sürü yönetim stratejilerinin geliştirilmesinde önemli bir araç olarak değerlendirilmektedir. Son yıllarda büyükbaş hayvancılık işletmelerinde uygulanan davranış testleri ile sürü içerisindeki bireysel davranış farklılıklarının erken dönemde tespiti mümkün hale gelmiştir. Büyükbaş işletmelerinde uygulanan davranış testleri aracılığıyla hayvanların çevresel uyum yetenekleri, stres düzeyleri, sosyal etkileşim biçimleri ve insanla iletişim dereceleri objektif olarak değerlendirilebilmektedir. Bu uygulamalar, sürü içerisinde hayvan refahı düzeyinin yükselmesine, stres faktörlerinin azaltılmasına ve ekonomik kayıpların önlenmesine katkı sağlamış; aynı zamanda davranış özelliklerinin damızlık hayvan seçiminde bir kriter olarak kullanılmasına olanak tanımıştır. Son yıllarda büyükbaş hayvanlarda davranış özellikleri üzerine yapılan araştırmalar, büyükbaş hayvanlarda davranış özelliklerinin süt verimi, büyüme hızı, döl verimi ve et kalitesi üzerinde belirgin etkiler oluşturduğunu göstermektedir. Uygulanan davranış testleri, bireysel farklılıkların, stres tepkilerinin ve çevresel uyum yeteneklerinin değerlendirilmesinde önemli bir araç olarak kullanılmaktadır. Bu testlerde genellikle fizyolojik parametreler (kalp atım hızı, nabız, vücut sıcaklığı ve kortizol düzeyi) ile davranışsal veriler birlikte değerlendirilmekte ve hayvanın genel refah durumu hakkında kapsamlı değerlendirmeler yapılabilmektedir.

Son dönemlerde geliştirilen yapay zekâ tabanlı görüntüleme sistemleri, sensör teknolojileri ve otomatik hayvan davranış izleme araçları sayesinde büyükbaş hayvan davranışlarının tespiti daha kolay, hızlı ve objektif hale gelmiştir. Bu teknolojilerin yaygınlaşması ve davranış testlerinin uygulanması hem bireysel hem de sürü düzeyinde refah ve verim düzeylerinin artırılmasına katkı sağlayarak modern büyükbaş hayvancılıkta sürdürülebilir üretim hedeflerinin gerçekleştirilmesini desteklemektedir.

Anahtar Kelimeler: Büyükbaş hayvan, Davranış testleri, Refah, Verim, Stres, Kortizol

THE EFFECTS OF BEHAVIOR IN CATTLE ON PRODUCTIVITY

ABSTRACT

Behavioral characteristics in cattle are one of the fundamental elements that directly affect animal welfare and production efficiency. Animal behavioral responses are influenced by numerous factors, including environmental factors, social interactions within the herd, management practices, and genetic makeup. Systematic observation of animal behavior is considered an important tool in determining welfare levels and developing appropriate herd management strategies. In recent years, behavioral tests implemented in cattle farms have made it possible to identify individual behavioral differences within the herd at an early stage. Through behavioral tests implemented in cattle farms, animals' environmental adaptation abilities, stress levels, social interaction patterns, and levels of human interaction can be objectively assessed. These practices have contributed to improving animal welfare within the herd, reducing stress factors, and preventing economic losses; they have also enabled the use of behavioral traits as a criterion for breeding animal selection. Recent research on behavioral traits in cattle has shown that behavioral traits have significant effects on milk yield, growth rate, fertility, and meat quality. Applied behavioral tests are used as an important tool in assessing individual differences, stress responses, and environmental adaptation abilities. These tests generally evaluate physiological parameters (heart rate, pulse, body temperature, and cortisol levels) along with behavioral data, allowing for comprehensive assessments of the animal's overall well-being.

Recently developed artificial intelligence-based imaging systems, sensor technologies, and automated animal behavior monitoring tools have made identifying cattle behavior easier, faster, and more objective. The widespread adoption of these technologies contributes to improving welfare and productivity at both the individual and herd levels, supporting the achievement of sustainable production goals in modern cattle farming.

Keywords: Cattle, Behavioral tests, Welfare, Productivity, Stress, Cortisol

EGE DENİZİ AMATÖR BALIKÇILIĞINDA İĞNE BOYU, İĞNE TİPİ VE YEM TÜRÜNÜN BİRİM ÇABAYA DÜŞEN AV MİKTARI VE BALIK BOYU ÜZERİNDEKİ ETKİLERİ: BALIKÇILIK YÖNETİMİ AÇISINDAN ÇIKARIMLAR

Efecan İŞTİPLİLER*

İzmir Katip Çelebi Üniversitesi, Fen Bilimleri Enstitüsü, Su Ürünleri A.B.D.

Email: efeistipliler@gmail.com

ORCID: 0009-0003-2944-0616

Doç. Dr. Fikret ÖNDES

İzmir Katip Çelebi Üniversitesi, Su Ürünleri Fakültesi

Email: fikret.ondes@ikcu.edu.tr

ORCID: 0000-0002-9522-7050

ÖZET

Bu çalışma, amatör balıkçılıkta kullanılan farklı iğne tipleri, iğne boyutları ve yem türlerinin birim çaba başına av miktarı (CPUE) ile yakalanan türlerin boy seçiciliği üzerindeki etkilerini belirlemeyi amaçlamıştır. Veriler, 2025 yılında İzmir'de (Ege Denizi) kıyıdan ve tekneden yapılan gözlemlerle toplanmıştır. Çalışmada üç farklı yem türü (sülünez, mamun ve sardalya), üç farklı iğne boyutu ve iki iğne tipi (Circle ve J tipi) kullanılmıştır. Ortalama birim çaba başına av miktarı (CPUE), en yüksek sülünez kullanılan iğnelerde, ardından mamun ve sardalya ile kullanılanlarda elde edilmiştir. Ortalama CPUE, Circle iğnelere kıyasla J tipi iğnelerde daha yüksek bulunmuştur. Genel olarak iğne boyu ile balık boyu arasında istatistiksel olarak anlamlı bir fark bulunmamış, ancak bazı türlerde anlamlı farklılıklar tespit edilmiştir. Yem tipi yakalanan balıkların boyunu anlamlı düzeyde etkilemiştir; mamun ile yakalanan bireylerin ortalama boyu en yüksek, sülünez ile yakalananlarınki orta, sardalya ile yakalananlarınki ise en düşük bulunmuştur. Gözlenen oranlara göre, iğne hasarı Circle iğnelerde J iğnelere kıyasla daha düşük görünmekle birlikte, bu fark istatistiksel olarak anlamlı değildir. İğne ve yemlerin boy seçiciliği ile hasar düzeylerine ilişkin elde edilen sonuçlar doğrultusunda balıkçılık yönetimi için bazı öneriler tartışılmıştır.

Anahtar Kelimeler: Balıkçılık, Seçicilik, Av Özellikleri, Türkiye

EFFECTS OF HOOK SIZE, HOOK TYPE, AND BAIT ON CATCH PER UNIT EFFORT AND FISH SIZE IN RECREATIONAL FISHERIES OF THE AEGEAN SEA: IMPLICATIONS FOR FISHERIES MANAGEMENT

ABSTRACT

This study aimed to determine the effects of different hook types, hook sizes, and bait types used in recreational fishing on catch per unit effort (CPUE) and the size selectivity of the caught species. The data were collected in 2025 in İzmir (Aegean Sea) through observations conducted both from shore and by boat, using three bait types (razor shell, mud shrimp, and sardine), three hook sizes, and two hook types (Circle and J type). The mean catch per unit effort (CPUE) was highest on hooks used for razor shell, followed by those used for mud shrimp and sardine. The mean CPUE was found to be higher on J-type hooks compared to Circle hooks. Overall, there was no statistically significant difference between hook size and fish size; however, for certain species, a significant difference was detected. Bait type significantly affected the size of the caught fish; individuals caught with mud shrimp had the largest average size, those caught with razor shell were intermediate, and those caught with sardine had the smallest average size. Based on the observed proportions, the incidence of hooking damage appears lower with Circle hooks compared to J hooks; however, this difference is not statistically significant. Based on the results regarding hook and bait size selectivity and levels of damage, we discussed some recommendations for fisheries management.

Keywords: Fisheries, Selectivity, Catch characteristics, Türkiye

APPLICATION OF SALTED FISH, CRAB AND SHRIMP VARIATIONS WITH ORGANIC ATTRACTANTS TO CONTROL BROWN PLANT PESTS IN RICE PLANTS IN SERDANG BEDAGAI

Ameilia Zuliyanti Siregar

Faculty of Agriculture, University of Sumatera Utara, Jl. Dr. A. Sofyan No 3 Medan, 20154, Sumatera Utara, Indonesia

Email: ameilia@usu.ac.id (Corresponding)

Liana Dwi Sri Hastuti

Department Biology, Faculty of Mathematic and Natural Sciences, University of Sumatera Utara, Jl. Biotechnology No 1 Medan, 20154, Sumatera Utara, Indonesia

Nismah Panjaitan

Industrial Engineering, Faculty of Engineering, University of Sumatra, Jl. Almamater Medan, 20154, Sumatera Utara, Indonesia

Evawaty Sri Ulina

Kawasan Sains dan Teknologi (KST) Soekarno, Jl. Raya Jakarta-Bogor KM 46, Cibinong, Kabupaten Bogor, Jawa Barat 16911, Indonesia.

ABSTRACT

Leptocorisa oratorius, rice ear bug is a dominant pest that has the potential to suck ripe rice grains, so that the rice grains will not be fully filled or even empty. The compilation of the use of carcasses with organic attractant enrichment is one alternative for controlling rice ear bug (*L. oratorius*) pests. The aim of this study was to determine the preference of the brown planthopper for the compilation of carcasses and organic attractants and to determine the most effective organic attractants for controlling the brown planthopper. This study was conducted from July 2025 to September 2025, in organic rice fields in Lubuk Bayak Village, Perbaungan District, Serdang Bedagai Regency, Sumatera Utara. This study used an experimental method with attractant treatments of salted fish, crab, and shrimp. Data were analysed using the Kruskal-Wallis test. Quantitative and qualitative descriptive data will be displayed in the form of scores and images. The number and mortality index of the brown planthopper on the salted fish attractant showed the highest, but not significant, difference with the shrimp attractant. The number of brown planthoppers collected from each treatment using salted fish, crab, and shrimp was twenty-four, six, and twelve individuals.

Keyword: Application, rice ear bug, organic paddy, Lubuk Bayas, Northern Sumatera

VALORIZATION OF AGRO-INDUSTRIAL WASTES FOR THE SUSTAINABLE DEVELOPMENT OF CONTROLLED-RELEASE ORGANOMINERAL FERTILIZERS

Asbai Zakaria *

1Hassan University of Casablanca, Laboratory of Biochemistry, Environment and Agri-Food, LBEA URAC36, 20650 Morocco.

Email: zakaria.asbai@etu.fstm.ac.ma (Corresponding author)

Nadia Boutaleb

Hassan University of Casablanca, Laboratory of Biochemistry, Environment and Agri-Food, LBEA URAC36, 20650 Morocco.

Said El Antri

Hassan University of Casablanca, Laboratory of Biochemistry, Environment and Agri-Food, LBEA URAC36, 20650 Morocco.

Bouchaib Bahlaouan

Higher Institutes of the Nursing Professions and Techniques of Health ISPITS Casablanca 22500, Morocco.

ABSTRACT

Fertilizers are essential for increasing crop yield, maintaining soil fertility, and ensuring nutrient supply. However, excessive use can lead to environmental issues such as nutrient loss and pollution. Eco-friendly organomineral fertilizers with slow and controlled release offer a sustainable alternative, enhancing nutrient use efficiency while reducing environmental impact.

This study examines the formulation effects of organomineral fertilizers and sustainable biological coating material: pectin extracted from orange peels for its gelling, thickening, and stabilizing properties, as a barrier for controlled-release fertilizers (CRFs). By valorizing agro-industrial waste through aerobic and anaerobic biotransformation, nutrient-rich materials are converted into biofertilizers and combined with phosphogypsum (PG) to produce organomineral fertilizers with slow and controlled nutrient release. FTIR, SEM, pH analysis, NPK release, germination, and fertilization tests were conducted to assess the effectiveness of coated and uncoated fertilizers compared to conventional fertilizers.

The best performing mixtures demonstrated optimal nutrient release profiles: M2-coated (compost) released only 22.05 (±1.43) % of nitrogen over 28 days, M5- coated (50% compost–50% PG) displayed a sustained phosphorus release profile with 33.17(±2.16) % over 28 days, and M5-coated exhibited a controlled potassium release, reaching just 25 (±1.45) % within 28 days, meeting CRF standards for nutrient release over time.

Results highlight the potential of these CRFs to enhance nutrient release efficiency, reduce leaching, and improve soil health, supporting climate-smart agriculture. This approach aligns with Conservation Agriculture principles and contributes to Sustainable Development Goals 2, 12, and 13 by promoting sustainable agriculture and minimizing environmental impact.

Keywords: Controlled-release systems, Pectin, Liquid digestate, Nutrient use efficiency (NUE), Phosphogypsum

THE ROLE OF AGRICULTURE IN THE ECONOMIES OF DEVELOPING COUNTRIES: A FRAMEWORK OF PARTICIPATION, CHALLENGES, AND PATHWAYS TO SUSTAINABILITY.

Amina Bigzad

Masters student of department of womens studies, Ahlul bayt international university iran.

Email: aminabigzad@gmail.com

ABSTRACT

Agriculture, as a key sector in the economies of developing countries, has historically played a dual ;role: on the one hand, it is the main driver of rural economic growth, job creation, and food security on the other hand, it constitutes a source of development challenges such as income inequality, pressure on natural resources, and dependence on climatic factors. This article deeply examines the ,multidimensional role of agriculture in these countries and, drawing on international and case evidence analyzes the direct and indirect impacts of agriculture on gross domestic product (GDP) growth, per :capita income, employment, food security, and sustainable poverty. The key axes are

Growth of production and value-adding processes: How agriculture can contribute to GDP growth and - ,the development of related industries by improving input efficiency (water, fertilizer, energy) :addressing market distortions, and developing value chains.- Employment and rural poverty reduction ,Agriculture's role in creating sustainable job opportunities, moving from informal to formal economies and reducing poverty through farm incomes and ancillary services such as local trade, processing .industries, and rural tourism

Food security and market autonomy: How farm-level flexibility and crop diversity, access to domestic - and export markets, and supportive policies can strengthen food security and elevate a country's role in global markets- Climate resilience and resource management: Designing and implementing strategies to reduce climate-related risks, managing water and land resources, preserving biodiversity, and -transferring sustainable technologies to minimize damages from hydro meteorological events ,Innovation and efficient technologies: Adoption of smart agriculture, data-driven approaches, drones production forecasting models, and access to financial services and product insurance to reduce agricultural risks and increase investment.- Supportive and institutional policies: The role of market-oriented policies, value-chain contracts, access to credit, product insurance, and advisory services in improving efficiency and sustainability of agriculture, considering institutional and input constraints of ,countries.- Gender equality and social participation: Increasing women's participation in agriculture improving access to resources and technologies, and reducing poverty by strengthening the capacities .of rural households

,Applied Framework for Countries- Optimizing investment in rural infrastructure: Water, electricity :market-access roads, and product storage systes- Strengthening human and institutional capacities Technical training for farmers, promoting crop diversification, and improving farm management capabilities.- Developing value chains with emphasis on value addition: Processing units, modern packaging, access to domestic and global markets- Climate-risk financial instruments: Product insurance, forward-looking market tools, and credit schemes, especially for smallholders.- Sustainable ,and balanced policy support: Balancing short-term supports with long-term investments in research .innovation, and supportive services

For developing countries, agriculture is not only a source of food security but also a hub of rur economic growth and a driver of overall national economic development. By adopting a comprehensive approach …that

IMPACT OF PHYTOCHEMICALS ON THE HATCHING ABILITY OF *MELOIDOGYNE INCOGNITA*

MEZERKET Amina

Laboratoire d'ethnobotanique et de substances naturelles. Ecole Normale Supérieure (ENS) Kouba Algiers, Algeria

Email: amina.mezerket@g.ens-kouba.dz

ABSTRACT

In Algeria, the *Meloidogyne* genus of root- knot nematodes represents the most destructive pests affecting vegetable crops. These sedentary endoparasites are prevalent in nearly all market garden plots, inflicting significant harm, especially to tomato crops. To mitigate the use of chemical nematicides and their adverse effects on the environment and plant health, various methods have been developed, including the application of phytochemicals such as essential oils. In their natural state, essential oils are biodegradable, non-toxic to the environment, and considerate of consumer health. Our research focused on assessing the nematicidal efficacy of the essential oil derived from white mugwort *Artemisia herba alba* Asso (Asteraceae) on the potential hatching of *Meloidogyne incognita* eggs. One egg mass of *M. incognita* was placed in each hatcher, which contained the essential oil of mugwort at concentrations of 50, 100, 200, 400, and 800 µl/l, along with a control and a fenamiphos chemical solution. The percentage of inhibition of *M. incognita* larvae hatching was evaluated after 12 days. The findings indicated that the essential oil of *Artemisia herba alba* possesses considerable nematicidal activity. The rates of hatching inhibition increased with the concentrations tested. At the highest concentration (800 µl/l) of essential oil, the inhibition rate of *M. incognita* hatching reached 62.79%. In comparison, the chemical treatment yielded an inhibition rate of 63.54%. Additionally, a chemical screening was conducted to identify the secondary metabolites present in this plant, concluding that this oil is primarily composed of tannins, saponosides, and flavonoids. Therefore, it would be beneficial to conduct tests using various plants from different families as potential nematicides.

Key words: *Artemisia herba alba* , essential oil , hatching inhibition, *Meloidogyne incognita*, eggs.

FOOD-BASED STRATEGIES FOR NEURODEGENERATIVE DISEASE PREVENTION: AN IN SILICO STUDY USING PARKINSON'S DISEASE AS A MODEL

Ali Aguerd

Laboratory of Integrative Biology, Faculty of Science Ain Chock, University Hassan II, Casablanca, Morocco.

Email: Ali Aguerd - aliagu97ninety@gmail.com (Corresponding author)

ORCID: 0009-0004-6819-2130

Fatima Chegdani

Laboratory of Integrative Biology, Faculty of Science Ain Chock, University Hassan II, Casablanca, Morocco.

Faiza Bennis

Laboratory of Integrative Biology, Faculty of Science Ain Chock, University Hassan II, Casablanca, Morocco.

ABSTRACT

Food-based preventive strategies are increasingly recognized as a promising approach to reduce the risk of neurodegenerative disorders such as Parkinson's disease (PD), a progressive condition with limited curative options. Bioactive compounds derived from dietary sources can modulate gene expression through epigenetic mechanisms, offering a pathway for nutrition-oriented disease prevention. In this study, we performed an *in silico* analysis to identify nutritional epigenetic modulators targeting genes implicated in PD. Using the Genome-Wide Association Studies (GWAS) catalog, we selected the most significant PD-associated single nucleotide polymorphisms (SNPs) (rs356182-A/G, rs356203-T, rs34637584-A, rs76763715-G, rs1372518-A, rs35682329-A, rs34311866-T) and identified their corresponding genes: *SNCA*, *LRRK2*, *GBA1*, *HMGN2P18*, and *TMEM175*. Gene interaction networks were constructed and enriched via the STRING database to elucidate functional relationships. Subsequently, bioactive compounds with nutritional origins were identified from the PubChem database, including dopamine precursors (bananas, avocados, chocolate), gallic acid (green tea, berries), lactic acid (fermented foods), resveratrol (grapes, peanuts), alpha-lipoic acid (spinach, broccoli, tomatoes), and phloretin (apples, pears). These compounds demonstrated potential epigenetic influence on PD-related genes, linking dietary diversity directly to molecular pathways involved in neuroprotection. Our findings suggest that food-based epigenetic interventions, explored through *in silico* tools, can contribute to the development of preventive nutritional strategies against neurodegenerative diseases, bridging agriculture, food sciences, and molecular biology.

Keywords:

Food-based prevention; Epigenetic modulation; Nutrition; Parkinson's disease; in silico analysis; SNP

OPTIMIZING VITAMIN D3 BIOAVAILABILITY: DEVELOPMENT OF HIGH-DOSE ORAL SHOT FORMULATION (VOL-D)

Bismillah Iftikhar

Essentials Healthcare Lahore , Pakistan

Email: Bismillahiftikhar12@gmail.com

ABSTRACT

Background: Vitamin D3 (cholecalciferol) deficiency is a prevalent global health concern associated with skeletal, cardiovascular, and immune dysfunctions. Despite widespread supplementation, poor bioavailability and low patient adherence to conventional oral tablets or capsules remain major limitations. This study focuses on the formulation and evaluation of VOL-D, a high-dose (200,000 IU) oral shot designed to enhance Vitamin D3 absorption and improve compliance.

Objective: To develop and assess a high-strength, single-dose oral shot formulation of Vitamin D3 (VOL-D) for optimized bioavailability, ease of administration, and improved patient adherence.

Methods: A lipid-based emulsion system was optimized to enhance the solubility and intestinal absorption of cholecalciferol. The formulation was evaluated for physicochemical stability, uniformity, and palatability. Comparative in vitro dissolution and simulated intestinal absorption studies were conducted against conventional tablet forms. Additionally, sensory acceptability and compliance potential were assessed through pilot consumer feedback.

Results: VOL-D demonstrated superior dispersion and dissolution characteristics compared to standard Vitamin D3 tablets, indicating improved bioavailability potential. The formulation remained physically and chemically stable over accelerated storage conditions. Participant feedback reflected enhanced convenience, taste acceptability, and willingness for continued use, supporting improved adherence potential.

Conclusion: The VOL-D oral shot offers an innovative, patient-friendly, and effective nutraceutical approach to address Vitamin D3 deficiency. By combining high-dose efficacy with superior absorption and convenience, this formulation can contribute to global preventive healthcare strategies against hypovitaminosis D.

Keywords: Vitamin D3, Cholecalciferol, Bioavailability, Oral Shot, Nutraceutical, VOL-D, Supplementation, Innovation, Immunity, Formulation Development

SYNTHESIS, CHARACTERIZATION, CYTOTOXICITY AND ANTIMICROBIAL STUDIES ON Mn(II) and Co(II) COMPLEXES OF SCHIFF BASE DERIVED FROM ACETOPHENONE AND o-AMINOPHENOL

Umar Mudi Ahmad

Department of Chemistry, School of Sciences, Kano State College of Education and Preliminary Studies, Kano, Nigeria

Email: umarwaru3@gmail.com

Umar Sani

Department of Pure and Industrial Chemistry, Bayero University, Kano, Nigeria

Harun Ibrahim Khalil

Department of Pure and Industrial Chemistry, Bayero University, Kano, Nigeria

Zakariyya Uba Zango

Department of Chemistry, College of Natural and Applied Scinces, Al-Qalam University, Katsina, Nigeria

ABSTRACT

Schiff base derived from acetophenone and o-aminophenol was synthesized as well as its Mn(II) and Co(II) complexes. The compounds were characterized based on melting/decomposition temperature, solubility, magnetic susceptibility, infrared analysis, Atomic Absorption Spectroscopy and Elemental Analysis. The azomethine bond was formed at 1685cm^{-1} and that of metal(II) complexes are 1596 cm^{-1} and 1626 cm^{-1}. The melting point of the Schiff base was found to be 186^{o}C and the decomposition temperature of the metal(II) complexes was found to range from 240^{o}C - 286^{o}C. The magnetic moment value (5.93 and 4.85B.M) shows that all metal ions in the complexes are paramagnetic in nature. The two complexes have low conductance value (19.6 and 18.3 ohm^{-1}cm-1mol^{-1}), indicating that they were non-electrolyte. Atomic Absorption Spectroscopy and Elemental Analysis reveal that all metal complexes are in 1:2 metal-ligand ratio, analytical data suggest that the Schiff base act as bidentate ligand towards metal ions. The synthesized ligand and the metal complexes were screened for their antibacterial against *Staphylococcus aureau, Eschericia coli* and *Salmonella typhi* bacterial strains and antifungal activity against *Aspergillus niger, Aspergillus flavus* and *Candida albicans* . The results of these studies revealed that all the compounds and their metal complexes showed significant antibacterial and antifungal strength at highest concentration. Cytotoxicity analysis results reveals that both ligand and metal (II) complexes were toxic with LC_{50} values range from 91.861 to 171.226µg/ml.

Keywords: Schiff base, Acetophenone, o-aminophenol, Complexes

FOOD IRRADIATION FOR MITIGATING POST-HARVEST LOSSES IN NIGERIA

Dr. Halid Sheriff Adegbusi

Department of Biological Sciences, Nigeria Police Academy Wudil, Kano Nigeria

Email: Khalidadegbusi@yahoo.com

ORCID: 0000-0003-0038-9776

ABSTRACT

This paper is a contributory advocacy on the commercial usage of food irradiation for food preservation for reducing postharvest losses of agricultural produce in Nigeria. Postharvest losses were found to cause a loss of about 13 million metric tons of agricultural crops in Nigeria, especially for perishable crops, grains, and fish. About 0.7 million metric tons of tomatoes were found lost annually. Resulting in the annual economy loss of about 3.7 trillion and 72 billion Nigeria Naira, in respect of agricultural produce and especially of tomato. Comparatively food irradiation offers a better method for food preservation, but does not serve for the replacement of others. Food irradiation was used to preserved yam, water yam, onions, tomatoes, potatoes, cowpea seeds and other crops without reported toxic effect and deteriorated nutritional qualities. Cobalt-60, electron beam and X-rays are commonly used for food irradiation. Over 70 countries have legislated its usage, and has been endorsed by reputable world regulatory bodies for the propensity of food and nutritional, health, economic and export securities. The only one irradiation facility available in Nigeria is Gamma Irradiation Facility operated on Cobalt-60 source, and currently under laboratory use. Putting the facility under commercial usage can help reducing postharvest losses of agricultural crops, thus strengthening food security for achieving sustainable development goal 2 in Nigeria. Commercial usage of the technology may also stimulate agricultural productivity for gross domestic product (GDP), safe exportation for Nigeria currency growth, global market is increasing for irradiated foods. Factors hindering its commercial adsorption can be surmounted by government craftiness. It is therefore recommended, for quick commercial operation of food irradiation, that positively adequate education about the technique is disseminated among relevant stakeholders, and that government should establish more accessible irradiation facilities at strategic areas in Nigeria for both farmers and marketers of perishable food crops, and interested individuals.

Keywords: Food irradiation and preservation, postharvest losses, perishable foods, food security, SDG 2, GDP, Nigeria

NUTRITIONAL ASSESSMENT OF COMPLEMENTARY FOODS MADE FROM NIGERIAN YELLOW MAIZE, SOYBEAN, AND CRAYFISH BLENDS

Dr. Halid Sheriff Adegbusi

Department of Biological Sciences, Nigeria Police Academy Wudil, Kano Nigeria

Email: Khalidadegbusi@yahoo.com

ORCID: 0000-0003-0038-9776

ABSTRACT

Plant-based complementary foods (CFs) generally supply insufficient amount of nutrients to meet recommended nutrient intakes for 6–23 months old children. This study determined the nutritional quality of CFs formulated from Nigerian yellow maize (*Zea mays*), soybean (*Glycine max*) and crayfish (*Procambarus clarkii*). Three CFs were formulated, namely; maize-only flour (MF, 100 g), blends of maize and soybean flour (MSF, 72:28 g) and maize, soybean and crayfish flour (MSCF, 80:10:10 g). Nutritional quality was evaluated using analyses of chemical composition of CFs, and biology quality of complementary food diets (CFDs) fed to weaned Sprague Dawley rats fed. Data were compared by Multivariate Analysis of Variance and significantly differentiated at $P \leq 0.05$. Nine selected nutritional criteria were used to determine CF that possessed optimal nutritional characteristic on comparison with MF and fortified wheat flour (FWMF). Total scores obtained from selected fifteen (15) nutritional criteria ranked MSCF, having total score of 30, the lowest and thus considered to possess the most desirable nutritional characteristics compared to MF, MSF and commercial CF (FWMF) that had the respective total score of 55, 39 and 24. Conclusively, MSCF may serve as a better alternative CF for MF and MSC, which compared favourably with FWMF. This study has produced a potential alternative cost-effective and adequate CF, formulated from crayfish (*Procambarus clarkii*) supplementation of locally available blend of yellow maize (*Zea mays*) and soybean (*Glycine max*), for the poor human population, in order to encourage the consumption of animal-sourced CF for alleviating the prevalence of childhood undernutrition.

Keywords: Maize, soybean, crayfish, complementary food, nutritional quality, Nigeria, Africa.

BIOSORPTION OF HEXAVALENT CHROMIUM BY SULPHURIC ACID MODIFIED *CUCUMEROPSIS MANII* PEEL

Aruwa Abdulhafiz

Department of Biochemistry, Faculty of Natural and Applied Sciences, Nasarawa State University, Keffi, Nigeria

Bawa Muhammad Yusuf

Department of Biochemistry, Faculty of Natural and Applied Sciences, Nasarawa State University, Keffi, Nigeria

Muhammad Abdullahi Ubana

Department of Biochemistry, Faculty of Natural and Applied Sciences, Nasarawa State University, Keffi, Nigeria

Department of Biochemistry, Faculty of Biotechnology and Biomolecular Science Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, D.E, Malaysia

ABSTRACT

Hexavalent chromium is widely used in industries such as leather tanning, electroplating, mining, paint production, and wood preservation, with wastewater discharges posing serious risks to the environment and human health. This study investigated the use of sulphuric acid modified *Cucumeropsis mannii* peel as a cost-effective biosorbent for the removal of hexavalent chromium from aqueous solution. Batch adsorption experiments were carried out to examine the effects of pH, contact time, adsorbent dosage, and initial chromium concentration. The biosorbent exhibited optimum performance at pH 2, with maximum chromium removal achieved using 1.0 g of adsorbent at an initial concentration of 50 ppm without agitation (0 rpm). Equilibrium was attained within 60 minutes of contact time. The point of zero charge (pHpzc) was determined to evaluate the influence of surface charge on adsorption behavior. Fourier Transform Infrared Spectroscopy (FTIR) analysis confirmed the involvement of hydroxyl, carboxyl, and carbonyl functional groups in chromium binding. The results demonstrate that sulphuric acid modified *Cucumeropsis mannii* peel is an efficient, eco-friendly biosorbent with strong potential for treating chromium-contaminated water.

KEYWORDS: Biosorption, chromium, *Cucumeropsis mannii*, sulphuric acid modification, point of zero charge.

NEXUS OF GREEN INNOVATION AND ORGANIZATIONAL PERFORMANCE: THE MEDIATING ROLE OF TECHNOLOGY TRANSFER

Muhammad Umer Quddoos

Associate Professor, Department of Commerce, Bahauddin Zakariya University Multan, Pakistan

Email: umerattari@bzu.edu.pk

Munawwar Hussain

M.Phil. Commerce, Department of Commerce, Bahauddin Zakariya University Multan, Pakistan

Email: hmunawar574@gmail.com

Ms. Tahira Kanwal

Ph.D. Scholar, Department of Commerce, Bahauddin Zakariya University Multan, Pakistan

Email: tahirasalman6@gmail.com

Kazim Abbas

Ph.D. Scholar, Department of Commerce, Bahauddin Zakariya University Multan, Pakistan

Email: Kazimabbas160@gmail.com

Muhammad Tayyeb Hafeez

M.Phil. Scholar, Department of Commerce, Bahauddin Zakariya University, Multan, Pakistan.

Email: tybhafeez@gmail.con

ABSTRACT

This study investigates the role of green innovation in enhancing organizational performance in Pakistan's textile manufacturing sector and examines how technology transfer mediates this relationship. Drawing on Signaling Theory and the Resource-Based View (RBV), green innovation is conceptualized as a higher-order construct comprising product and process innovation. Product innovation focuses on eco-friendly design, recyclable materials, and reduced environmental impact, while process innovation emphasizes sustainable production, energy efficiency, and waste minimization. Technology transfer enables firms to acquire and integrate advanced environmental technologies from external sources, bridging capability gaps and accelerating sustainability adoption.

A quantitative, cross-sectional research design was employed, surveying 230 senior managers from medium-to-large textile firms. Partial Least Squares Structural Equation Modelling (PLS-SEM) was used to assess the measurement and structural models. Results confirm that both product and process innovations significantly contribute to green innovation, which, in turn, positively influences organizational performance. Technology transfer further enhances this relationship, underscoring its strategic value in accelerating environmental technology adoption.

The findings extend Signaling Theory by demonstrating how technology transfer strengthens the credibility of sustainability commitments, and they reinforce RBV by framing green innovation and external technologies as valuable, rare, and inimitable resources. Practically, the study offers actionable insights for managers to integrate internal innovation efforts with

strategic technology partnerships, while policymakers can design incentives to promote technology-sharing collaborations. This integrated approach positions firms for sustainable competitiveness in increasingly environmentally conscious markets.

Keywords: Green Innovation, Technology Transfer, Organizational Performance, Signaling Theory, Resource-Based View

INFLUENCE OF WATER TREATMENT METHODS ON ZEBRAFISH HEALTH: A STUDY OF UV-STERILIZED AND GROUNDWATER SYSTEMS

K.R.Padma

Assistant Professor, Department of Biotechnology, Sri Padmavati Mahila Visvavidyalayam (Women'sUniversity) , Tirupati, AP.

Email: thulasipadi@gmail.com (Corresponding author)

ORCID: 0000-0002-6783-3248

ABSTRACT

Zebrafish (Danio rerio) are widely acknowledged as an important model organism for the investigation of environmental and biomedical processes, owing to their genetic resemblance to humans, transparent embryonic development, and sensitivity to water quality. This study examines the potential impacts of UV-sterilized drinking water and natural groundwater on the health of zebrafish, with a specific focus on the generation of Reactive Oxygen Species (ROS) and responses to oxidative stress. Parameters of water quality, including pH, temperature, dissolved oxygen, and mineral content, can significantly affect physiological and cellular functions in aquatic organisms. UV-sterilized water, which is commonly utilized for human consumption, undergoes ultraviolet disinfection that removes microbial contaminants but may also modify essential trace minerals and organic compounds. Conversely, groundwater, while naturally filtered, may contain varying concentrations of dissolved minerals and possible pollutants. The comparative analysis aims to understand whether variations in the chemical composition of these water sources influence ROS production, antioxidant enzyme activity, and tissue integrity in zebrafish. Increased levels of ROS can disturb cellular homeostasis, resulting in oxidative damage and compromised metabolic processes. The outcomes of this research are anticipated to underscore the impact of water treatment methods on aquatic model organisms and offer insights into the connection between water quality and oxidative stress. Future investigations will broaden these findings to include long-term exposure effects, gene expression profiling, and behavioral evaluations. The results could guide the advancement of enhanced water management and bioassay systems for assessing the safety of treated and natural water sources, ultimately benefiting both aquatic ecosystems and human health.

Keywords: Zebrafish, UV-sterilized, Groundwater, Pollutants, Reactive Oxygen Species, Water management.

CORROSION INHIBITION OF MILD STEEL IN 1 M HCL BY A GREEN EXTRACT: ELECTROCHEMICAL AND COMPUTATIONAL STUDY

ANAS ELHARAMI

Sultan moulay slimane university, School of Technology, Laboratory of Engineering and Applied Technologies, Beni Mellal, Morocco

Email: anaselharami@gmail.com

ORCID: 0009-0005-6254-2950

ISSAM FORSAL

Sultan moulay slimane university, School of Technology, Laboratory of Engineering and Applied Technologies, Beni Mellal, Morocco

Email: forsalissam@yahoo.fr

ORCID: 0000-0003-2769-8499

WISSAL KOTMANI

Sultan moulay slimane university, School of Technology, Laboratory of Engineering and Applied Technologies, Beni Mellal, Morocco

Email: wissalkotmani@gmail.com

ORCID: 0009-0004-5706-2007

ABSTRACT

This research investigates the efficacy of an acetonic extract obtained from OM leaves as a natural corrosion inhibitor for carbon steel (CS) in a 1M HCl medium. With a growing emphasis on environmentally friendly corrosion mitigation strategies, natural inhibitors have gained prominence. OM leaves, were selected as a potential source of corrosion inhibition. Results indicate a substantial influence of the OM leaf acetonic extract on corrosion inhibition. The extract's inhibition efficiency (IE%) was evaluated using various experimental techniques, including Potentiodynamic Polarization (PDP) and Electrochemical Impedance Spectroscopy (EIS), across five concentrations ranging from 0.125 to 1 g/L. The results indicated that the inhibitory effect escalated as the concentration of OM extract increased up to 1 g/L (94%). Fourier-transform infrared spectroscopy identified the characteristic functional groups present in the extract, while scanning electron microscopy of the mild-steel surface evidenced the formation of a coherent protective layer. Adsorption of the inhibitory species followed the Langmuir isotherm, and the thermodynamic parameters confirmed that the process was spontaneous and predominantly governed by physisorption. Density functional theory (DFT) calculations revealed strong interactions between the inhibitor molecules and the steel surface, reflected by a lowered frontier-orbital energy gap (ΔE), which corroborates the observed molecular-level inhibition efficiency.

Keywords: Carbon steel; Extract of OM; OCP; EIS; PDP; Immersion time

THE PHYTOREMEDIATION POTENTIAL OF NATIVE GRASS SPECIES IN ETHIOPIA. SYSTEMATIC REVIEW

Endalamaw Yihune

Department of Biology, Faculty of Sciences, Bahir Dar University, Bahir Dar, Ethiopia.

Email: 2007endalamaw@gmail.com (Corresponding author)

Amare Bitew Mekonnen

Department of Biology, Faculty of Sciences, Bahir Dar University, Bahir Dar, Ethiopia.

Getahun Yemata

Department of Biology, Faculty of Sciences, Bahir Dar University, Bahir Dar, Ethiopia.

ABSTRACT

Phytoremediation is the use of plants to remove and degrade environmental pollutants and has gained international attention as an inexpensive and eco-friendly approach to soil, water, and air contamination. Heavy metal-contaminated soil, water, and air pollution and increased soil salinity are a serious risk to the industrializing and agricultural economies of Ethiopia. The phytoremediation of toxins is economical and environmentally sound relative to conventional remediation technology, and native grasses are excellent themes because they naturally adapt to native climatic and soil conditions. This review attempts to gather the articles of indigenous grass and plants used for Phytoremediation in Ethiopia (2000-2024). Following PRISMA guidance, relevant keywords were used to search PubMed, Scopus, Web of Science, and Google Scholar. A total of 17 indigenous grass and plant species have been recognized for their phytoremediation potential use. The results that record native grass species are *Chrysopogon zizanioides* (Vetiver grass), *Rumex nepalensis, Chloris gayana,* and *Cyperus* spp. with high potential towards phytoremediation. This review confirms that indigenous grass vegetation of Ethiopia is a precious and still relatively under-exploited resource for developing effective and cost-effective environmental improvement practices. Thus, it is highly recommended that future efforts need to be aimed at large-scale, in-situ field trials using ingenious grass species and explore methods for maximizing remediation effectiveness.

Keywords: Phytoremediation, Native Grasses, Heavy Metals, Phytoextraction, Ethiopia

SUSTAINABLE MITIGATION OF C38 CARBON STEEL CORROSION IN AGGRESSIVE ACIDIC MEDIA USING BIO-DERIVED NATURAL INHIBITORS: AN INTEGRATED ELECTROCHEMICAL, DFT, AND MOLECULAR DYNAMICS APPROACH

Z. AIT EL CAID

Laboratory of Interface Materials and Environment, Faculty of Sciences Ain Chock, Hassan II University, B.P. 5366 Maârif, Casablanca, Morocco

Email: zakaria.aitcaid@gmail.com

R. Kellal

Laboratory of Interface Materials and Environment, Faculty of Sciences Ain Chock, Hassan II University, B.P. 5366 Maârif, Casablanca, Morocco

M. Zertoubi

Laboratory of Interface Materials and Environment, Faculty of Sciences Ain Chock, Hassan II University, B.P. 5366 Maârif, Casablanca, Morocco

D. Benmessaoud left

Laboratory of Interface Materials and Environment, Faculty of Sciences Ain Chock, Hassan II University, B.P. 5366 Maârif, Casablanca, Morocco

ABSTRACT

Corrosion remains a persistent industrial and environmental challenge, leading to significant economic losses and safety concerns worldwide. It is one of the primary causes of degradation and premature failure of metallic structures and equipment exposed to aggressive conditions. Factors such as material composition, temperature, flow dynamics, microbial activity, and mechanical stress collectively influence the corrosion process and its kinetics.

In this study, a bioactive molecule extracted from a natural plant source is investigated as an eco-friendly corrosion inhibitor for C38 carbon steel immersed in a 1 M hydrochloric acid solution. The inhibition performance of the compound was evaluated using electrochemical techniques, including electrochemical impedance spectroscopy (EIS), chronoamperometry, and potentiodynamic polarization (PDP). The impact of inhibitor concentration and temperature on the protection efficiency was also examined to establish optimal operating conditions.

Complementary theoretical investigations based on **Density Functional Theory (DFT)** and **Molecular Dynamics Simulations (MDS)** were carried out to gain deeper insight into the adsorption mechanism and electronic interactions governing the inhibition process. The strong agreement between experimental and theoretical results confirms the high efficiency and environmentally sustainable potential of the selected natural compound.

Keywords: Corrosion inhibition, Carbon steel, Electrochemistry, DFT, MDS

APHAISIA :- A COMPREHENSIVE LANGUAGE DISORDER

Granthali P. Shape

Department of Pharmacology, JES's SND College of Pharmacy, Babhulgaon, Dist. Nashik, India.

Email: grantha.shape@gmail.com

Pooja Rasal *

Department of Pharmacology, JES's SND College of Pharmacy, Babhulgaon, Dist. Nashik, India.

Email: poojarasal2000@gmail.com

ABSTRACT

Aphaisia is the language disorder which mostly occurs in the left hemisphere of posterior and inferior frontal gyrus of Brodmann Area. It is basically the language impairment in which there is a loss of communication. Patient with this disorder are unable to communicate properly and they faces a lots of problems while speaking. It can be worse while it can cure through various assesments and methods and mainly this disorder can be cured by communicating continuously. This mostly occurs after stroke which damages the part of language namely (Broca's And Wernicke's Area) which are responsible for language producing. Apopharygis is an important field of study, which it's studies included in many basic and clinical sciences such as speech-language pathology; psycology ; neurology and linguistics. In this review we discuss about the neuroanatomy,and there clinical assesments methods through which aphaisia can be controlled and also the speech therapy which remains unchanged. The method used to do transcranial is innovative repetitive transcranial magnetic stimulation and direct current stimulation, which are used to regulate cortical excitability by delivering cortical brain stimulation and are only now being investigated.

Keywords: Aphaisia , Broca area , Wernicke area , neurology, Speech-language pathology , Clinical assessment methods, Apopharygis

ASSESSMENT OF PROTECTED AND RECREATIONAL AREAS IN THE SOUTHWESTERN PART OF LITHUANIA

Vilma Salkauskiene

Lietuvos Inzinerijos Kolegija Higher Education Institution

vilma.salkauskiene@lik.tech

ORCID NO: 0000-0002-1042-8591

ABSTRACT

In recent decades, increasing attention has been devoted to environmental protection and sustainable land development, aiming to balance human activities with the preservation of natural resources. Protected and recreational areas form an essential part of environmental and regional development systems – they not only maintain ecological and biological diversity but also play a significant social and economic role. These territories contribute to the well-being of local communities, promote sustainable tourism, and strengthen regional identity.

The southwestern part of Lithuania is characterized by highly valuable natural and recreational resources, distinguished by landscape diversity and cultural heritage. However, the management and utilization of their potential remain insufficiently analyzed. Limited attention has been given to territorial planning, protection regimes, and sustainable recreational use, which constrains opportunities to ensure their long-term sustainability.

The relevance of this research is further emphasized by the growing public interest in ecological sustainability and nature-based recreation. As visitor numbers increase, challenges related to inadequate infrastructure, territory adaptation, and the protection of natural assets become more evident. These trends highlight the need for balanced solutions that would harmonize nature conservation with recreational activities and economic potential.

In Lithuania, the ecological, social, and economic value of protected and recreational areas, as well as their management efficiency, have not been sufficiently studied. There is a lack of consistent research and methodologies to determine the optimal use of these territories while maintaining ecological balance. To ensure sustainable development, a comprehensive approach to territorial planning is required—integrating environmental, social, and economic interests and implementing sustainable management principles.

After analyzing the protected and recreational areas of the selected territory in Lithuania, it was determined that the region is characterized by high recreational and ecological diversity. A comprehensive evaluation of these areas allows proposing solutions to optimize the management of protected and recreational territories, promote sustainable development, and ensure the long-term preservation of natural and recreational resources. This research is significant both scientifically and practically, providing a foundation for further studies.

Keywords: protected areas, recreational areas, evaluation.

ANIMAL GENETICS AND BREEDING

Devadharshini.R

Dr.R.Srinivasan

Faculty of pharmacy, Bharath institute of higher education and research, Chennai-600073,India

ABSTRACT

Animal genetics and breeding play a fundamental role in improving livestock productivity, disease resistance, and adaptability to diverse environmental conditions. This scientific field focuses on understanding the genetic basis of traits such as growth rate, milk yield, fertility, and disease resistance, enabling the selection and propagation of superior animals. Traditional breeding techniques, including selective breeding and crossbreeding, have long been used to enhance desirable traits. However, recent advances in molecular biology and biotechnology, such as genomic selection, DNA sequencing, and CRISPR gene editing, have revolutionised the field by allowing precise identification and manipulation of genes. These innovations accelerate genetic improvement programs, leading to enhanced production efficiency and improved animal health. Additionally, genetic research supports the conservation of indigenous and endangered breeds, ensuring biodiversity and long-term sustainability in livestock systems. Ethical considerations, including animal welfare and responsible genetic modification, remain essential in modern breeding practices. Overall, animal genetics and breeding contribute significantly to global food security, sustainable agriculture, and the development of resilient livestock suited to future challenges such as climate change and population growth.

Keywords: Animal genetics, Animal breeding, Selective breeding, Crossbreeding, Genomic selection, CRISPR Cas9 , Genetic improvement, Livestock productivity, Molecular genetics, DNA sequencing, Artificial insemination, Gene editing, Heritability, Trait selection, Biotechnology, Disease resistance, Breed conservation, Reproductive technology, Genetic diversity, Sustainable livestock production.

FARKLI KİRAZ ÇEŞİTLERİNİN TOPRAKTAN MEYVE İLE KALDIRDIĞI BESİN ELEMENTİ MİKTARLARININ SAPTANMASI

Zir. Y. Müh. Nilay TAŞDELEN OK

Ege Üniversitesi, Ziraat Fakültesi

Email: nilay.tasdelen@tarimorman.gov.tr

ORCID: 0009-0000-2430-2853

Prof. Dr. M.Eşref İRGET

Ege Üniversitesi, Ziraat Fakültesi

Email: esref.irget@ege.edu.tr

ORCID: 0000-0001-9109-0299

ÖZET

Türkiye coğrafi konumu ve iklim özellikleri nedeniyle birçok tarım ürününün yetiştirilebildiği bir ülkedir. Bu ürünlerin birçoğu her kıtaya ihraç edilmekte ayrıca tarım ürünlerinin işlenmesiyle de ülke gıda sanayi gelişim göstermektedir. Türkiye'nin coğrafik koşulları hemen hemen tüm bölgelerde kiraz üretimine olanak sağlamaktadır. Bununla birlikte ticari ölçekte ele alındığında Ege bölgesi özellikle İzmir ve Manisa listenin başını çekmektir. Bu çalışmada ülkemiz için büyük bir üretim ve ihracat değerine sahip kiraz meyvesi taze meyve olarak ele alınmıştır. Türkiye dünya kiraz üretiminin yaklaşık % 27'sini tek başına gerçekleştirmektedir.

Diğer kültür bitkilerinde olduğu gibi kirazda da verim ve kalite son derece önemlidir. Hatta ihracaat sözkonusu olduğunda kalite çoğu zaman verimden de daha önemli bir konuma yükselebilmektedir. Bu nedenle, yüksek verim ve kalite için, üretim koşullarının düzenlenmesi ve verim-kaliteyi etkileyen koşulların optimize edilmesi gerekir. Bu bağlamda çeşit, anaç, budama, gübreleme, sulama ve bitki koruma gibi verim ve kaliteyi etkileyen etmenlerin kontrolü son derece önem taşımaktadır.Kültür bitkileri için gübreleme programlarının hazırlanması için 3 önemli veri grubuna gereksinim duyulmaktadır. Bunlar; 1-Toprakta bitkilerin yararlanabileceği durumda bulunuan besin elementi miktarları; 2-Farklı bitki kısımları (meyve+dal+sürgün+kök) ile bir vejetasyon döneminde topraktan kaldırılan besin maddesi miktarları; 3- Farklı bitki kısımları ile topraktan uzaklaştırılan besin maddelerinin, vejetasyon periyoduna göre gösterdiği değişimdir.

Bu çalışmada, İzmir'in Kemalpaşa ilçesinde kiraz yetiştiriciliğinin yoğun yapıldığı 11 farklı bahçeden, 3 farklı kiraz çeşidi olan Early Burlat, Napolyon ve Salihli çeşitlerine ait meyve örnekleri alınmıştır.Meyvelerin et,çekirdek ve meyve sapı kısımlarında toplam, N,P,K,Ca ve Mg analizleri yapılmıştır.Araştırma sonuçlarına göre incelenen çeşitlerde 100 kg meyve ile topraktan 164.3-416.8 g N;42.2-116.7 g P_2O_5; 148.3-476.9 g K_2O; 37.4-80.9 g CaO; 7.4-53.7 g MgO arasında değişen miktarlarda besin elementi kaldırıldığı saptanmıştır.

Anahtar Kelimeler: Kiraz, Çeşit, Meyve, Besin Elementi, Alınım, Miktar

ABSTRACT

Turkey, due to its geographical location and climate, is a country capable of growing a wide variety of agricultural products. Many of these products are exported to every continent, and the country's food industry is developing through the processing of agricultural products. Turkey's geographical conditions allow for cherry production in almost all regions. However, on a commercial scale, the Aegean region, particularly Izmir and Manisa, leads the list. This study examines cherries, which hold significant production and export value for our country, as fresh fruit. Türkiye alone accounts for approximately 27% of global cherry production.

As with other cultivated plants, yield and quality are crucial for cherries. In fact, when it comes to export, quality can often outweigh yield. Therefore, to achieve high yield and quality, production conditions must be adjusted and the conditions affecting yield and quality optimized. In this context, controlling factors affecting yield and quality, such as variety, rootstock, pruning, fertilization, irrigation, and plant protection, is crucial. Three important data sets are needed to develop fertilization programs for cultivated plants. These are: 1. The amount of nutrients available to plants in the soil; 2. The amount of nutrients removed from the soil by different plant parts (fruit, branch, shoot, and root) during a single vegetation period; and 3. The variation in nutrients removed from the soil by different plant parts over the vegetation period.

In this study, fruit samples of 3 different cherry varieties, Early Burlat, Napoleon and Salihli, were taken from 11 different orchards where cherry cultivation is intensive in the Kemalpaşa district of İzmir. Total, N, P, K, Ca and Mg analyses were carried out in the flesh, seed and fruit stalk parts of the fruits. According to the results of the research, it was determined that nutrient elements were removed from the soil with 100 kg of fruit in the examined varieties, ranging from 164.3-416.8 g N; 42.2-116.7 g P2O5; 148.3-476.9 g K2O; 37.4-80.9 g CaO; 7.4-53.7 g MgO.

Keywords: Cherry, Variety, Fruit, Nutrient, Intake, Amount

FROM TRADITION TO SCIENCE: ASSESSING THE RELIABILITY OF MEDICINAL PLANTS USED IN FERTILITY TREATMENTS.

Amina Teibi[1]*, Nabila Belyagoubi-Benhammou [2], Abdel Halim Harrath

Laboratory Of Natural Products, Department Of Biology, Faculty Of Natural And Life Sciences, Earth And Universe Sciences, University

Abou-Bekr Belkaïd, Algeria.

*Corresponding author: aminateibi.13@gmail.com

Abstract

Infertility remains a major global reproductive health concern, prompting the search for effective and affordable therapeutic alternatives. This review evaluates the reliability of seventeen medicinal plants traditionally used for fertility enhancement. Literature analysis revealed varied outcomes: six plants (*Ajuga iva, Anacyclus pyrethrum, Prunus amygdalus, Grewia tenax, Punica granatum,* and *Salvia officinalis*) showed consistent pro-fertility and androgenic effects, while two (*Cuminum cyminum* and *Marrubium vulgare*) demonstrated mechanisms supporting fertility improvement. Three species (*Artemisia absinthium, A. herba-alba,* and *Peganum harmala*) exhibited dose-dependent or contradictory actions. Conversely, six plants (*Mentha pulegium, Ricinus communis, Carlina gummifera, Trigonella foenum-graecum, Salvadora persica,* and *Ruta chalepensis*) displayed anti-fertility or toxic properties. These findings highlight both the therapeutic promise and safety concerns surrounding fertility-enhancing plants and emphasize the need for rigorous pharmacological validation to ensure their informed and safe incorporation into modern fertility care.

Keywords: Medicinal Plants, Reproductive Health, fertility enhancement, Scientific reliability, Traditional medicine, Phytotherapy.

EVALUATION OF THE ANTIMICROBIAL ACTIVITY AND CHARACTERIZATION OF THE BIOACTIVE SECONDARY METABOLITES PRODUCED BY *Bacillus velezensis* SB4R5 AGAINST *Escherichia coli* AND *Staphylococcus aureus*

Thanh-Dung Nguyen*

Can Tho University, Can Tho, Vietnam

* Email: nguyenthanhdung.vietnam@gmail.com

ORCID: 0009-0003-2417-0012

Mai-Uyen Nguyen

Hong Bang International University, Ho Chi Minh city, Vietnam

ABSTRACT

Endophytic bacteria, which are linked or associated with medicinal plants, employ unique strategies that enhance the growth and survival of their host plants, often through the mediation of distinctive secondary metabolites. These bacteria and their secondary metabolites constitute crucial subjects for fundamental and applied research focused on sustainable agriculture. In this study, an endogenous bacterial strain originating from a medicinal plant (*Adenosma bracteosum* Bonati) stored at the Institute of Biotechnology and Food, Can Tho University, was assessed for its *in vitro* antibacterial activities against common pathogenic bacteria, including *Escherichia coli* and *Staphylococcus aureus.*

The SB4R5 strain exhibited high resistance to two pathogenic bacterial strains. It demonstrated simultaneous production of siderophores and four types of lytic enzymes (such as protease, cellulase, amylase, and chitinase), which are potentially important mediators of antagonistic activity against pathogens. Based on 16S rDNA sequences, the SB4R5 strain showed the closest genetic relationship to *Bacillus velezensis* (Named *Bacillus velezensis* SB4R5). Gas chromatography/mass-spectrometry (GC-MS) analysis of cell-free extracts of the SB4R5 strain showed that at least 4 compounds were produced, including putative compounds known to have antimicrobial activity. Our discoveries offer fresh insights into the antibacterial capabilities of natural endophytes. These findings suggest that this particular species could be a promising candidate as an antibacterial agent, potentially providing resistance against other pathogens.

Keywords: Antibacterial activities, *Bacillus velezensis*, endophytic bacteria, GC-MS.

EFFECT OF PLANTING TIME AND NITROGEN DOSE ON GROWTH AND YIELD OF CABBAGE.

Md. Musfiqur Rahman

Department of Crop Science and Technology, Faculty of Agriculture,

University of Rajshahi,

Rajshahi 6205, Bangladesh

Dr. Md. Abdul Baree

Professor, Department of Crop Science and Technology, Faculty of Agriculture,

University of Rajshahi,

Rajshahi 6205, Bangladesh

Bhowmik Shimu

Department of Crop Science and Technology, Faculty of agriculture,

University of Rajshahi,

Rajshahi 6205, Bangladesh

Akhi Khatun

Department of Crop Science and Technology, Faculty of Agriculture,

University of Rajshahi,

Rajshahi 6205, Bangladesh

ABSTRACT:

A field experiment was carried out at Horticulture Farm of the Department of Crop Science and Technology, University of Rajshahi, during the period from November 2018 to February 2019. The experiment consisted of two factors: Factor A: Planting time (three levels) as T1= 10 November; T2= 25 November and T3= 10 December and Factor B: Nitrogen (four levels) as No= 0 kg per ha (control); N1=180 kg per ha; N2= 240 kg per ha and N3= 300 kg per ha nitrogen, respectively. The two factors experiment were laid out in Randomized Complete Block Design with three replications. The variety of cabbage was Atlas-70. Due to different planting time, the maximum thickness of head (14.5 cm) and the highest marketable yield (46.5 ton per ha) was obtained from T2 and the minimum thickness of head (13.2 cm) and the lowest marketable yield (40.01 ton per ha) was obtained from T3. For nitrogen, the maximum thickness of head (15.4 cm) and the highest marketable yield (50.06 ton per ha) was found from N2 and the minimum thickness of head (12.4 cm) and the lowest marketable yield (37.5 ton per ha) were found from No. For combined effect, the maximum thickness of head(16.4 cm) and the highest marketable yield (51.7 ton per ha) were found from T2N2 and the minimum thickness of head (11.5 cm) and the lowest marketable yield (34.04 ton per ha) were found from T3No.Economic analysis revealed that T2N2 gave the maximum benefit cost ratio (2.33). So, 25 November planting along with 240 kg per ha nitrogen was the best for growth and yield of cabbage.

EFFICIENT SYNTHESIS, STRUCTURAL ELUCIDATION, ANTIBACTERIAL SCREENING, AND IN SILICO EVALUATION OF NOVEL ESTER-FUNCTIONALIZED ISOXAZOLES

Khalid Boujdi

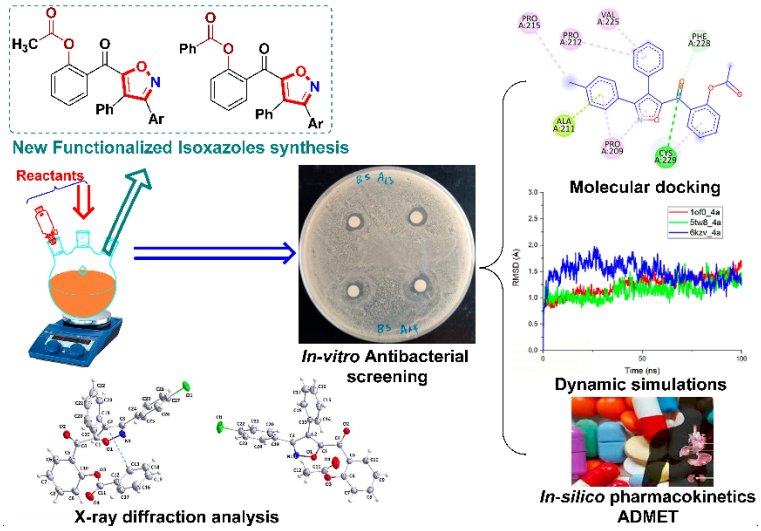
Faculty of Sciences and Technologies Mohammedia, University Hassan II, B.P. 146, Mohammedia 28800, Morocco

ABSTRACT

In response to the growing threat of antimicrobial resistance, we synthesized and evaluated a new series of ester-functionalized isoxazole derivatives as potential antibacterial agents. These compounds were obtained through a 1,3-dipolar cycloaddition of (Z)-2-benzylidenebenzofuran-3(2H)-one with in situ-generated arylnitrile oxide dipoles, followed by esterification. The final products were fully characterized using IR, ^{1}H and ^{13}C NMR, high-resolution mass spectrometry, and, for compounds 4c and 4f, single-crystal X-ray diffraction.

Their antibacterial activities were assessed in vitro against Escherichia coli, Bacillus subtilis, and Staphylococcus aureus. Compound 4a showed strong inhibition against E. coli (17.5 ± 1.2 mm), while compound 4f exhibited significant activity against S. aureus (15.5 ± 1.6 mm), comparable to reference antibiotics. Molecular docking studies revealed favorable binding affinities and interaction profiles with key bacterial proteins. Molecular dynamics simulations further confirmed the stability of the ligand–protein complexes, especially for compound 4a.

In silico ADME-Tox predictions indicated excellent intestinal absorption, no Ames toxicity, and favorable pharmacokinetic profiles for all compounds. These findings suggest that this family of isoxazole derivatives holds promise as a scaffold for the development of new multi-target antibacterial agents.



Keywords: Isoxazoles, antibacterial agents, molecular docking, ADME-Tox, molecular dynamics, heterocycles.

RURAL DEVELOPMENT

E. Praveena, S.rubinthara, R.swathi .

Bharath Institute of higher education and research. Chennai India.

ABSTRACT

The rapid development of China's economy, greatly improved the living standards of rural residents, and also caused the destruction of the rural ecological environment. government to formulate rural development planning and can also be used as a reference for the evaluation of rural ecological environment in developed and underdeveloped areas. Diets are not static and indeed are changing due to globalization, urbanization and demographic and rural development are central to the diversity of global food systems and diets, Challenges include natural resource declines, climate change .this article constructs an evaluation index system for URI from five dimensions: economic integration, social integration, ecological integration, element integration, and spatial integration. the dynamic urban-rural integration level (URIL) of 373 counties from 2000 to 2019.Urban-rural integration development (URID) is the solution to the excessive urban-rural gap, unequal and insufficient development in urban-rural areas, along with the process of dynamic and balanced urban-rural growth. The URI indicator system is built using the new development philosophy, and 94 cities in the YRB are used as samples .the construction of URIs should be promoted at a more microscopic city and county level; and strong support is provided to achieve high-quality sustainable development of the YRB .Rural development is , including economic, , environmental, and cultural aspects of rural life .many areas and particularly in mountainous countries, forest depletion, largely from uncontrolled agricultural expansion, is leading to a loss of environmental protection of the forest, resulting in floods, droughts, erosion, desertification and loss of agricultural body of knowledge by examining the asymmetric link between rural development and pro-environmental in rural China. Rural development is assessed via rural income and digital financial . The article has applied the Augmented Dickey-Fuller (ADF) test to examine and quantile autoregressive distributed lag (QARDL) model to investigate the association among variables. The results revealed that the construction industry revenue, growth, construction policy GDP, and industrialization positively link sustainable rural development in China. the policy development authorities to develop effective policies related to improvement in the construction industry that will enhance sustainable rural development.

Keywords: Sustainable rural development, yellow river basin ,food safety, ecological environment.

FULL TEXTS

MACHINE-LEARNING GWAS REVEALS CANDIDATE GENES UNDERLYING COCCIDIOSIS RESISTANCE IN CENTRAL ANATOLIAN MERINO SHEEP

Yunus Arzık

Department of Animal Science, Faculty of Veterinary Medicine, Aksaray University, Türkiye

ORCID: 0000-0002-3068-8155

Email: yunus.arzik@aksaray.edu.tr

ÖZET

Eimeria türlerinin neden olduğu koksidiyoz, küçük ruminantlarda önemli ekonomik kayıplara ve refah sorunlarına yol açan en ciddi bağırsak paraziter hastalıklardan biridir. Klasik genom çapında ilişki analizleri (GWAS), parazit direncine ilişkin bazı genomik bölgeleri belirlemiş olsa da, bu yöntemler karmaşık özelliklerin doğrusal olmayan ve çok genli doğasını modellemede sınırlıdır. Bu çalışmada, Orta Anadolu Merinosu (CAM) koyunlarında koksidiyoz direncinin genetik yapısını incelemek için iki aşamalı makine öğrenmesi (ML) tabanlı bir GWAS yaklaşımı uygulanmıştır. Toplam 228 kuzuda gram başına ookist (OPG) sayıları kaydedilmiş ve log(OPG + 1) dönüşümüne tabi tutulmuştur. Genotipleme, Illumina OvineSNP50 BeadChip kullanılarak gerçekleştirilmiştir. Birinci aşamada, bilgi içeriği yüksek SNP'leri belirlemek için *LASSO*, *Ridge Regression* ve *Elastic Net* modelleriyle öznitelik seçimi yapılmıştır. İkinci aşamada, *Destek Vektör Regresyonu (SVR)*, *Rastgele Orman (RF)* ve *XGBoost* modelleri tekrarlı çapraz doğrulama altında ilişki modellemesi için kullanılmıştır. SVR modeli en yüksek tahmin performansını (R^2 = 0.440; RMSE = 0.865) göstermiş, RF modeli ise bunu (R^2 = 0.407; RMSE = 0.890) ile takip etmiştir. Anlamlı SNP'lere yakın konumlanan aday genlerin anotasyonu, epitel bariyer bütünlüğü (*SCN7A*, *SCN9A*, *AQP4*), mukozal koruma (*CHST9*, *GALNT5*) ve immün-sinirsel düzenleme (*PDE10A*, *DRD3*) ile ilişkili lokusları ortaya koymuştur. Ayrıca *PCOLCE2*, *WASHC3* ve *ATP6V1A* gibi genlerin, mukozal savunmada kilit rol oynayan hücre dışı matriks yeniden yapılanması, endozomal taşınma ve asitlenme süreçlerinde görev aldığı belirlenmiştir. Makine öğrenmesinin GWAS ile bütünleştirilmesi, *Eimeria* enfeksiyonuna karşı dirençteki varyasyonun altında yatan biyolojik olarak anlamlı aday bölgelerin belirlenmesini sağlamıştır. Bu bulgular, yerli koyunlarda parazit direncinin genomik seleksiyon programlarına dahil edilmesinin uygulanabilirliğini desteklemektedir.

Anahtar Kelimeler: *Eimeria spp*., ookist sayısı, makine öğrenmesi, GWAS, SVR, intestinal bağışıklığı, genomik seleksiyon, Orta Anadolu Merinosu.

ABSTRACT

Coccidiosis, caused by *Eimeria* species, remains one of the most important enteric parasitic diseases in small ruminants, resulting in significant economic and welfare losses. Conventional genome-wide association studies (GWAS) have identified relevant genomic regions for parasite resistance, yet they are limited in modeling the non-linear and polygenic nature of complex traits. This study employed a two-stage machine-learning (ML) GWAS approach to dissect the genetic architecture of resistance to coccidiosis in Central Anatolian Merino (CAM) sheep. Oocyst per gram (OPG) counts were recorded for 228 lambs and log-transformed as log(OPG + 1). Genotyping was performed using the Illumina OvineSNP50 BeadChip. In Stage 1, LASSO, Ridge Regression, and Elastic Net models were applied for feature selection to derive a consensus set of informative SNPs. In Stage 2, Support Vector Regression (SVR), Random Forest (RF), and XGBoost were used for association modeling under repeated cross-validation. SVR achieved the highest predictive performance (R^2 = 0.440; RMSE = 0.865), followed by RF (R^2 = 0.407; RMSE = 0.890). Candidate genes proximal to significant SNPs were annotated, revealing loci related to epithelial barrier integrity (SCN7A, SCN9A, AQP4), mucosal protection (CHST9, GALNT5), and immune-neural regulation (PDE10A, DRD3). Additional genes such as PCOLCE2, WASHC3, and ATP6V1A were involved in extracellular matrix remodeling, endosomal trafficking, and acidification—key processes in mucosal defense. The integration of ML with GWAS enabled the identification of biologically meaningful candidate regions potentially underlying variation in resistance to *Eimeria* infection. These findings support the feasibility of incorporating parasite resistance into genomic selection programs for indigenous sheep.

Keywords: *Eimeria spp.*, oocyst count, machine learning, GWAS, SVR, intestinal immunity, genomic selection, Central Anatolian Merino.

INTRODUCTION

Coccidiosis, caused by protozoan parasites of the genus *Eimeria*, represents a major enteric disease in sheep flocks worldwide (Chartier & Paraud, 2012). Clinical and subclinical infections result in reduced growth rates, feed conversion efficiency, and overall productivity, leading to substantial economic losses in the sheep industry (Taylor et al., 2016). The disease is particularly relevant in intensive and semi-intensive production systems, where environmental conditions facilitate oocyst accumulation and reinfection. In Türkiye, *Eimeria ovinoidalis*, *E. parva*, and *E. crandallis* are the most common species affecting lambs, especially during the weaning transition period (Arslan et al., 1999).

The host's response to *Eimeria* infection is complex, involving mucosal immune mechanisms, epithelial integrity, and metabolic adjustments that mitigate intestinal damage (Yun et al., 2000; Rose et al., 2012). Genetic variation in resistance has been demonstrated in several sheep populations, suggesting the potential for selection-based control strategies (Bishop & Stear, 2003). However, coccidiosis resistance is a polygenic trait, governed by multiple loci each exerting small effects, often involving non-linear interactions among genetic, physiological, and environmental factors (). Consequently, conventional linear GWAS approaches may fail to capture these non-additive genomic signals (Hu et al., 2016).

Machine learning (ML) has emerged as a promising complement to classical GWAS for dissecting complex traits (Pérez-Enciso & Zingaretti, 2019). Unlike linear models, ML algorithms can accommodate non-linearity, multicollinearity, and high-dimensional data structures (Cortes & Vapnik, 1995; Kuhn & Johnson, 2013). Recent advances in livestock genomics have demonstrated the value of ML-based GWAS in uncovering subtle genotype–phenotype associations for growth, wool, and disease resistance traits in sheep and cattle ().

The Central Anatolian Merino (CAM) is a native Turkish composite breed derived from Karacabey Merino × Akkaraman crosses, selected for dual-purpose production under semi-arid conditions (Keskin et al., 2021). Understanding the genetic mechanisms of disease resistance in this population is pivotal for sustainable breeding strategies that reduce reliance on chemoprophylaxis and contribute to the One Health agenda on antimicrobial stewardship (FAO, 2022).

This study therefore aimed to (i) apply a two-stage ML-GWAS to identify genomic regions associated with resistance to *Eimeria* spp. infection in CAM lambs; (ii) evaluate and compare model predictive performances; and (iii) annotate and biologically interpret the most informative SNPs and genes linked to intestinal defense and immune regulation.

MATERIALS AND METHODS

Animals and Phenotypic Data

A total of 228 Central Anatolian Merino (CAM) lambs were sampled from the Aksaray region of Türkiye. All animals were reared under semi-intensive management conditions with standardized feeding and vaccination programs. Fresh fecal samples were collected directly from the rectum at 90–120 days of age, coinciding with the post-weaning period when *Eimeria* infection pressure is typically high (Taylor et al., 2016). Oocyst counts were determined using the McMaster technique and expressed as oocysts per gram (OPG) of feces (Foreyt, 2013). To normalize data distribution and reduce skewness, values were log-transformed as log(OPG + 1) prior to analysis (Sallé et al., 2012).

Genotyping and Quality Control

Genomic DNA was extracted from whole blood and genotyping was performed with the Illumina OvineSNP50 BeadChip (approximately 54,000 SNPs) (Kijas et al., 2014). SNPs with

a minor allele frequency (MAF) < 0.05, call rate < 0.95, or deviation from Hardy–Weinberg equilibrium ($p < 1\times10^{-6}$) were removed (Purcell et al., 2007). After quality control, approximately 48,000 high-quality SNPs and all 228 individuals were retained for analysis.

Two-Stage Machine Learning GWAS Framework

A two-stage ML framework was implemented to integrate feature selection and predictive association modeling (Pérez-Enciso & Zingaretti, 2019). Stage 1 involved regularization-based methods—LASSO, Ridge Regression, and Elastic Net—applied independently using tenfold cross-validation (Tibshirani, 1996; Zou & Hastie, 2005). A consensus SNP panel was constructed by intersecting the top 5 % of SNPs from each model, retaining markers that consistently contributed to variance across methods. Stage 2 employed Random Forest (Breiman, 2001), Support Vector Regression (Cortes & Vapnik, 1995), and eXtreme Gradient Boosting (Chen & Guestrin, 2016). Hyperparameters were tuned via grid search, and each model was evaluated under repeated fivefold cross-validation (Varma & Simon, 2006).

Candidate Gene Annotation and Functional Enrichment

Significant SNPs were mapped to the *Oar_v4.0* sheep reference genome (Jiang et al., 2014). Genes located within ±100 kb of significant loci were retrieved using Ensembl BioMart (Kinsella et al., 2011). Functional annotation was based on Gene Ontology and KEGG pathway databases (Kanehisa et al., 2023).

Statistical and Visualization Tools

All analyses were conducted in R (version 4.3). Feature selection used the **glmnet** package , ensemble learning used **randomForest**, **e1071**, and **xgboost**, and visualization employed **ggplot2** and **VennDiagram**.

RESULTS

3.1. Model Performance and Comparative Evaluation

In the first stage of analysis, feature selection using LASSO, Ridge, and Elastic Net regularization models revealed a highly polygenic architecture underlying resistance to coccidiosis. Each algorithm identified distinct but partially overlapping sets of influential SNPs (Figure 1). Specifically, LASSO selected 58 unique markers, Ridge 55, and Elastic Net 48, with 16 SNPs consistently retained across all three methods. These shared loci were prioritized for subsequent modeling as they represented the most stable predictors under different regularization penalties.

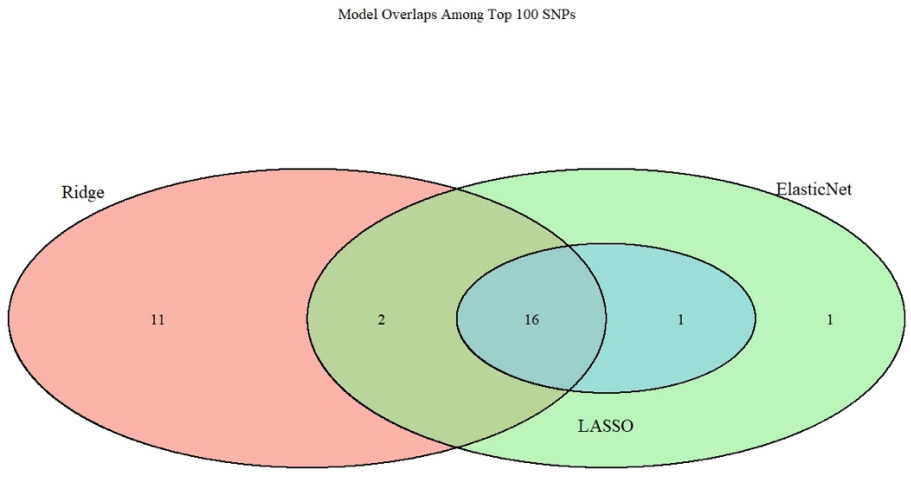


Figure 1. Venn diagram showing overlap of selected SNPs across feature selection models (LASSO, Ridge, Elastic Net).

The overlap among the top 100 SNPs from each model (Figure 1) highlights a consensus set of variants that likely capture true genetic signals rather than algorithm-specific artifacts. The recurrence of these markers across penalization schemes further supports the presence of genomic regions consistently contributing to variation in Eimeria oocyst load. The resulting consensus SNP panel was therefore used as input for the second-stage association modeling, ensuring both biological relevance and computational efficiency.

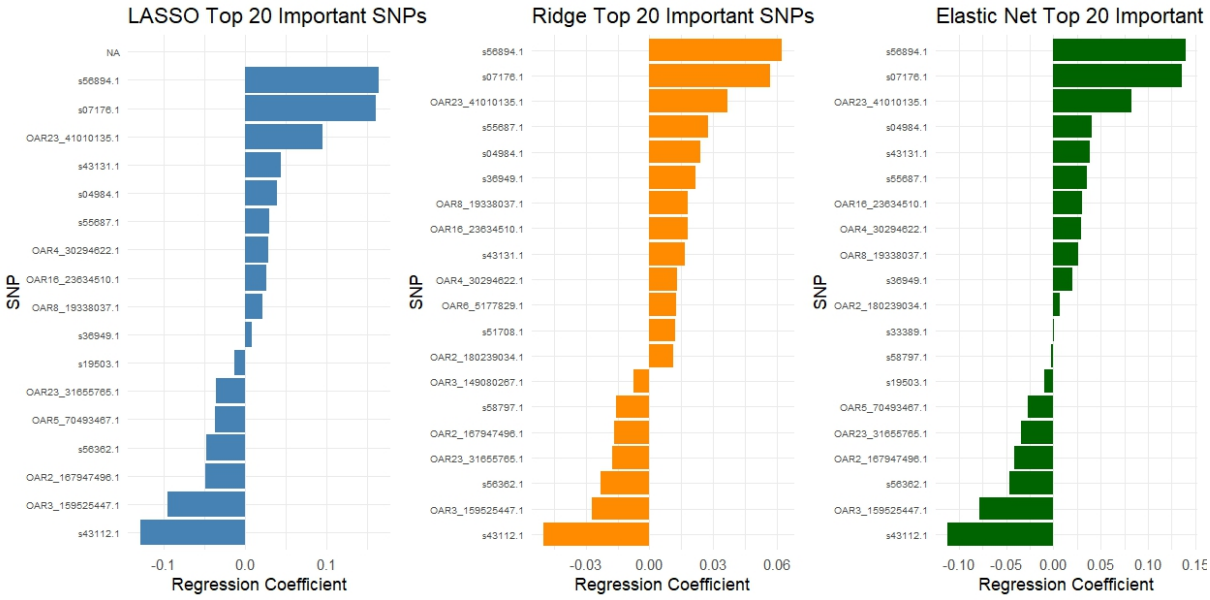


Figure 2. Comparison of regression coefficient of top 20 SNPs among ML algorithms at future selection stage.

In the second stage, three machine learning algorithms—Support Vector Regression (SVR), Random Forest (RF), and XGBoost—were compared for their ability to predict oocyst load using the consensus SNP set. All models demonstrated satisfactory predictive power, although SVR clearly outperformed the others (Table 1). SVR achieved the highest prediction accuracy ($R^2 = 0.440$, RMSE = 0.865), followed by RF ($R^2 = 0.407$, RMSE = 0.890) and XGBoost ($R^2 = 0.319$, RMSE = 0.954).

Table 1. Performance comparison of ML models for prediction of coccidia oocyst load.

Model	R^2	RMSE	Ranking
Support Vector Regression (SVR)	**0.440**	**0.865**	1
Random Forest (RF)	0.407	0.890	2
XGBoost	0.319	0.954	3

Repeated cross-validation confirmed the robustness of the SVR model, with consistently higher correlations between observed and predicted phenotypes. This superior performance reflects the model's ability to capture complex, non-linear genotype–phenotype relationships characteristic of polygenic resistance traits.

Figure 2 illustrates the comparative predictive performance of the models, while Figure 3 presents the relationship between observed and predicted values. The SVR model exhibited the narrowest error distribution, further confirming its reliability and generalization capacity.

3.2. Identification of Informative SNPs

The two-stage approach successfully reduced the SNP space from approximately 48,000 markers to a refined consensus panel of 240 highly informative SNPs. Among these, 20 markers were recurrent across at least two feature selection models (LASSO, Ridge, Elastic Net), indicating strong stability across algorithms (Figure 1).

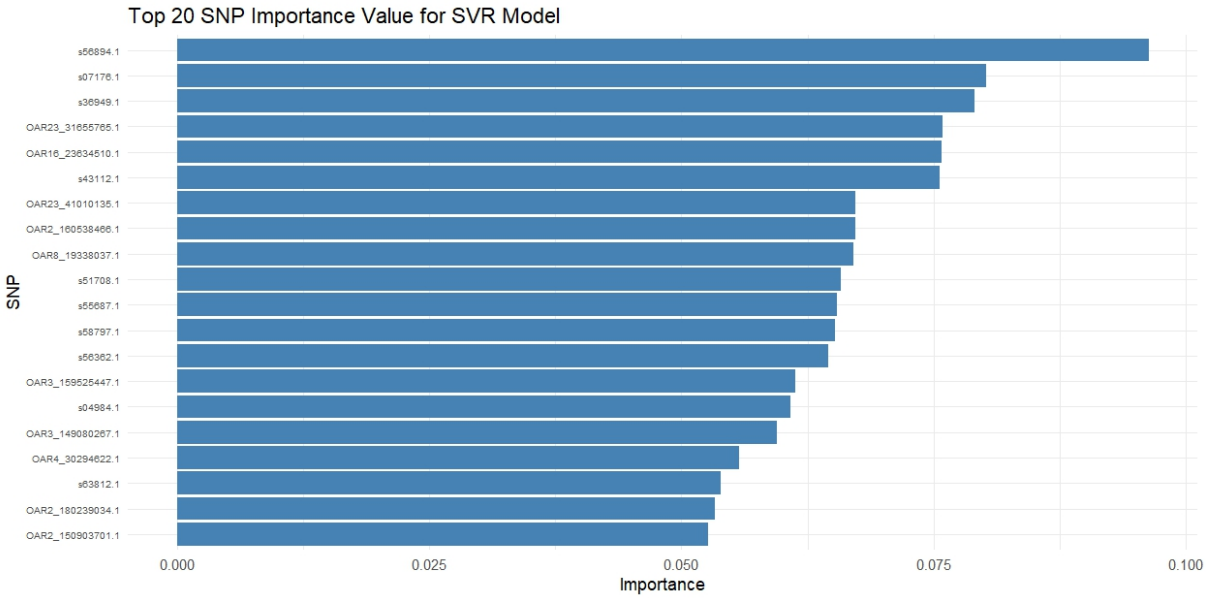


Figure 3. Top 20 SNP importance value from SVR Model.

Top-ranking SNPs were distributed across multiple chromosomes (OAR1, OAR2, OAR3, OAR4, OAR8, OAR12, OAR16, OAR23, OAR25), with particularly dense clusters on OAR2 and OAR3, suggesting the involvement of multiple small-effect loci in the trait's architecture (Table 2).

Table 2. Representative SNPs identified by the ML-based GWAS and their associated candidate genes.

SNP ID	Chr	Position (bp)	Nearest Gene	Functional Category
OAR2_150903701.1	2	141953798	**SCN7A**	Voltage-gated sodium channel; epithelial barrier electrophysiology
OAR2_180239034.1	2	170225946	**AQP4**	Water channel; osmotic balance and mucosal hydration
OAR23_31655765.1	23	30222859	**CHST9**	Sulfotransferase; mucus layer sulfation

SNP ID	Chr	Position (bp)	Nearest Gene	Functional Category
OAR23_41010135.1	23	38700316	**GALNT5**	Glycosyltransferase; mucin-type O-glycosylation
OAR3_149080267.1	3	139117389	**DRD3**	Dopamine receptor; immune–neural regulation
OAR3_159525447.1	3	149407337	**PDE10A**	Phosphodiesterase; cAMP/cGMP pathway modulation
s56362.1	3	170984254	**ATP6V1A**	Vacuolar ATPase; acidification and pathogen clearance
s43112.1	1	244063117	**PCOLCE2**	Extracellular matrix remodeling and tissue repair
s56894.1	8	84419597	**WASHC3**	Actin cytoskeleton and endosomal trafficking
OAR16_23634510.1	16	21605012	**GRAMD1C**	Lipid transport and membrane signaling
s58797.1	25	41360346	**SEL1L**	ER protein quality control during infection
s63812.1	12	37948669	**CNOT2**	Transcriptional regulation and immune signaling

3.3. Functional Annotation and Biological Interpretation

Annotation and pathway enrichment analyses indicated that the significant loci were enriched in biological processes related to **epithelial integrity, ion transport, metabolic regulation, and immune–neural communication.**

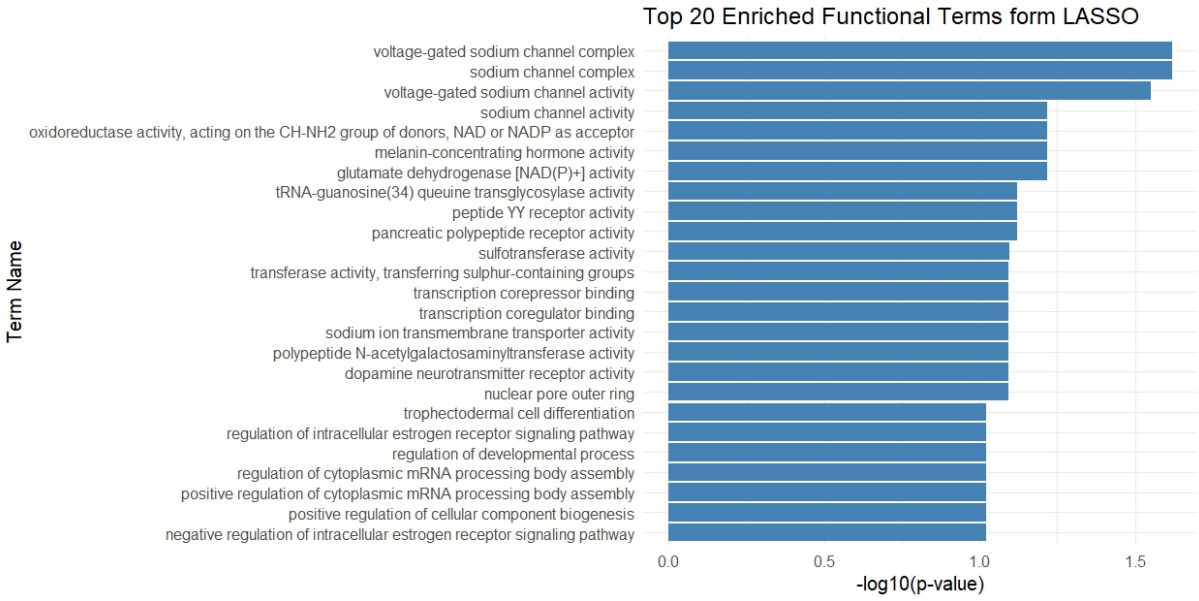


Figure 4. Schematic representation of enriched biological processes and gene networks associated with coccidiosis resistance.

- **Epithelial Defense and Barrier Function:**

The sodium channel genes *SCN7A* and *SCN9A*, along with *AQP4*, are critical for maintaining intestinal epithelial potential and fluid transport. Their modulation under infection stress suggests a host strategy to preserve ion–water balance during *Eimeria*-induced damage.

- **Mucosal Protection:**

CHST9 and *GALNT5* encode enzymes responsible for sulfation and glycosylation of mucins, which enhance the protective mucus layer, limiting oocyst adhesion and invasion.

- **Immune and Neural Regulation:**

PDE10A and *DRD3* influence cAMP/cGMP-mediated signaling and dopaminergic regulation, supporting cross-talk between the enteric nervous system and mucosal immunity.

- **Tissue Repair and Endosomal Function:**

PCOLCE2, *WASHC3*, and *ATP6V1A* participate in extracellular matrix remodeling, actin polymerization, and acidification, respectively, which are essential during epithelial regeneration and pathogen clearance.

- **Metabolic and Transcriptional Control:**

GRAMD1C, *CNOT2*, and *SEL1L* contribute to lipid transport, transcriptional fine-tuning, and ER-associated degradation, all vital for maintaining cellular homeostasis during infection.

A schematic summary of gene interactions and functional categories is presented in *Figure 4*.

DISCUSSION

This study is among the first to apply a comprehensive machine-learning GWAS framework to unravel the genomic architecture of coccidiosis resistance in sheep. The integration of regularization-based feature selection and non-linear regressors effectively captured hidden patterns in SNP data that conventional linear GWAS approaches might overlook (Pérez-Enciso & Zingaretti, 2019; Abdollahi-Arpanahi et al., 2020).

4.1. Model Comparison and Methodological Strengths

The superior performance of SVR highlights the relevance of kernel-based learning for modeling polygenic, non-linear traits such as parasite resistance (Cortes & Vapnik, 1995; González-Recio et al., 2020). Similar approaches have demonstrated strong predictive capacity for growth and wool traits in livestock where complex genotype–phenotype interactions are present (Liaw et al., 2022). Ensemble models such as RF and XGBoost also showed high but slightly lower predictive ability, consistent with their ability to capture primarily additive effects (Breiman, 2001; Chen & Guestrin, 2016).

4.2. Biological Relevance of Identified Genes

The top candidate genes collectively reflect the multifactorial host-defense mechanisms against *Eimeria* infection. Genes regulating epithelial structure and function (e.g., *SCN7A*, *AQP4*, *CHST9*) underscore the importance of maintaining mucosal barrier integrity (Kim et al., 2021). Immune–neural interaction genes (*DRD3*, *PDE10A*) suggest the involvement of neuroimmune signaling in modulating intestinal inflammation and repair (Rose et al., 2012). Similar findings have been reported in studies of nematode and coccidia resistance, where genes involved in epithelial renewal, ion transport, and mucosal defense were identified as critical determinants of resilience (Bishop & Stear, 2003; Sallé et al., 2012). The identification of *ATP6V1A* and *WASHC3* further supports the participation of acidification and cytoskeletal

remodeling processes in intestinal parasite defense—mechanisms previously associated with epithelial activation in mammalian infection models (Yun et al., 2000).

4.3. Implications for Genomic Selection

The candidate loci identified in this study may serve as useful genomic markers for selective breeding programs targeting enhanced resistance to coccidiosis (Bishop & Stear, 2003). Incorporating such loci into genomic prediction pipelines could help reduce disease prevalence without compromising growth performance. The ML-GWAS framework described here can also be adapted to other parasitic or infectious diseases of small ruminants, supporting precision breeding initiatives aligned with the One Health approach (FAO, 2022).

CONCLUSIONS

The two-stage machine-learning GWAS effectively uncovered genomic regions associated with resistance to *Eimeria* spp. in Central Anatolian Merino sheep. The SVR model provided the highest prediction accuracy, validating the use of kernel-based non-linear modeling for complex parasitic traits. Candidate genes implicated in epithelial integrity, mucosal protection, and immune regulation provide strong biological evidence for host resilience mechanisms. These findings can contribute to developing genomic selection indices that incorporate parasite resistance, promoting sustainable sheep production systems in endemic regions.

Conflicts of Interest

The author declares no conflicts of interest.

Figure Legends

- **Figure 1.** Venn diagram showing overlap of selected SNPs across feature selection models (LASSO, Ridge, Elastic Net).
- **Figure 2.** Comparison of regression coefficient of top 20 SNPs among ML algorithms at future selection stage.
- **Figure 3.** Top 20 SNP importance value from SVR Model.
- **Figure 4.** Schematic representation of enriched biological processes and gene networks associated with coccidiosis resistance.

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VARIATIONS IN THE MYOSTATIN (GDF-8) GENE AND THEIR EFFECTS ON MUSCLE DEVELOPMENT

Sedat BEHREM

[1]Aksaray University, Faculty of Veterinary Medicine, Department of Animal Science, Aksaray, Türkiye.
ORCID: 0000-0002-7351-1229
Email: sedatbehrem@aksaray.edu.tr

Yunus ARZIK

[2]Aksaray University, Faculty of Veterinary Medicine, Department of Animal Science, Aksaray, Türkiye.
ORCID: 0000-0002-3068-8155
Email: yunus.arzik@aksaray.edu.tr

ÖZET

Myostatin (MSTN) geni, iskelet kası gelişimini negatif yönde düzenleyen ve çiftlik hayvanlarında et verimini doğrudan etkileyen önemli bir genetik faktördür. Bu derleme çalışmasında, sığır, koyun, domuz, keçi ve tavuk gibi başlıca çiftlik hayvanlarında MSTN genine ait varyasyonların kas gelişimi, karkas özellikleri ve büyüme performansı üzerindeki etkileri değerlendirilmiştir. Ayrıca follistatin, IGF-1 ve aktivin reseptörleri gibi moleküllerle olan etkileşimler ile MSTN'in biyolojik aktivitesi üzerindeki düzenleyici mekanizmalar tartışılmıştır. CRISPR/Cas9 ve RNA interferans gibi modern gen düzenleme teknolojilerinin MSTN ekspresyonunu hedefleyerek kas kütlesini artırmada nasıl kullanılabileceği örnek çalışmalarla sunulmuştur. MSTN varyantları, et verimi yüksek hayvanların ıslahında genetik biyobelirteç olarak değerlendirilebilir. Bununla birlikte, gen düzenlemeye dayalı yaklaşımların etik, yasal ve sürdürülebilirlik boyutları da göz önünde bulundurulmalıdır. Bu kapsamlı değerlendirme, MSTN geninin tarımsal biyoteknoloji ve genetik ıslah uygulamalarında taşıdığı potansiyeli ortaya koymaktadır.

Anahtar Kelimeler Myostatin, GDF-8, kas gelişimi, genetik varyasyon, biyoteknoloji.

ABSTRACT

The Myostatin (MSTN) gene is a critical genetic factor that negatively regulates skeletal muscle development and directly influences meat yield in livestock. This review evaluates the impact of MSTN gene variants on muscle growth, carcass traits, and growth performance in major farm animals, including cattle, sheep, pigs, goats, and chickens. It also discusses molecular regulatory mechanisms involving follistatin, IGF-1, and activin receptors that modulate MSTN activity. The use of modern gene-editing tools such as CRISPR/Cas9 and RNA interference to suppress MSTN expression and enhance muscle mass is highlighted through recent studies. MSTN polymorphisms can serve as valuable genetic biomarkers in the selection of high-yield meat-producing animals. However, ethical, legal, and sustainability concerns regarding gene-editing approaches must also be considered. This comprehensive evaluation underscores the significant potential of the MSTN gene in agricultural biotechnology and genetic improvement strategies.

Keywords: Myostatin, GDF-8, muscle development, genetic variation, biotechnology.

INTRODUCTION

Muscle development is of great importance in animal production, particularly in terms of meat yield. Skeletal muscle constitutes a significant portion of total body weight and is a direct determinant of carcass productivity in livestock. Myostatin (GDF-8) is a protein that negatively regulates skeletal muscle growth and was discovered in 1997 by McPherron and colleagues (McPherron et al., 1997). This protein belongs to the Transforming Growth Factor-beta (TGF-β) superfamily, and mutations occurring in its coding regions can lead to increased muscle mass (Kambadur et al., 1997). Inactivation of the myostatin gene in mouse models has been shown to cause both hyperplasia and hypertrophy, resulting in increased number and size of muscle fibers (McPherron et al., 1997; Grobet et al., 1997). Studies in cattle, sheep, pigs, goats, and poultry have demonstrated that this gene plays a universally conserved regulatory role in muscle development (Clop et al., 2006; Stinckens et al., 2008; Bellinge et al., 2005).

Naturally occurring mutations identified in the MSTN gene of livestock species have led to marked improvements in carcass yield and muscle quality (Grobet et al., 1997; Oldham et al., 2001). For example, the “double-muscling” phenotype observed in Belgian Blue cattle vividly demonstrates the gene’s functional impact. Likewise, variants located in the UTR region of Texel sheep affect muscle development through microRNA-mediated regulation, contributing to superior meat yield (Clop et al., 2006).

In this context, identification of genetic variations and their integration into animal breeding programs enhance economic efficiency and influence crucial traits such as animal welfare and calving ease. Furthermore, recent advances in genome-editing technologies such as CRISPR/Cas9 have made it possible to manipulate these variations in a controlled manner (Crispo et al., 2015). This review discusses the molecular characteristics, genetic variants, species-specific effects, and biotechnological applications of the myostatin gene.

MOLECULAR STRUCTURE AND FUNCTION OF THE MYOSTATIN GENE

The myostatin (MSTN) gene, which negatively regulates muscle development, is located on chromosome 2. In humans, it consists of three exons and two introns, and its coding region is highly conserved across species. Transcription of the gene yields a 376-amino-acid precursor protein, which becomes biologically active after proteolytic cleavage and functions in its homodimeric form by binding to TGF-β receptors (Lee & McPherron, 2001).

Active myostatin can be antagonized by binding proteins such as follistatin, representing a key regulatory mechanism that limits its biological effects (Sharma et al., 1999). Myostatin suppresses muscle cell growth through the Akt/mTOR and Smad signaling pathways, inhibiting both proliferation and differentiation of myocytes. In muscle tissue, its principal role is to restrict muscle cell growth and replication. When MSTN expression is downregulated or its function disrupted, muscle hypertrophy (enlargement of existing fibers) and hyperplasia (increase in fiber number) occur. McPherron et al. (1997) demonstrated that myostatin-deficient mice exhibited nearly double the muscle mass of wild-type animals.

Similar effects have been observed in pigs, sheep, and cattle, making MSTN a major target in selective breeding programs. Mutations in the myostatin gene in Belgian Blue and Piemontese breeds are associated with the double-muscling phenotype (Grobet et al., 1997). Moreover, a SNP in the 3′ UTR region of Texel sheep was found to interact with miR-1 and miR-206, leading to translational repression and increased muscle development (Clop et al., 2006).

Overall, myostatin functions as a key biological regulator limiting muscle growth and serves as a critical target for both basic biological research and applied livestock breeding.

MYOSTATIN VARIANTS AND THEIR EFFECTS IN LIVESTOCK

Cattle

Mutations in the MSTN gene identified in Belgian Blue and Piedmontese cattle cause the well-known "double-muscling" phenotype (Grobet et al., 1997). These mutations often occur within the coding region—particularly in exon 3—as frame-shift deletions that yield nonfunctional proteins, eliminating myostatin's inhibitory effect. Other breeds such as Marchigiana, Limousin, Charolais, Aubrac, and Parthenais also carry MSTN variants influencing muscle mass, carcass yield, and marbling (Dunner et al., 2003).

Missense mutations detected in Charolais and Limousin cattle reduce protein activity, thereby increasing muscle fiber diameter and overall meat proportion. However, these same variants may also lead to adverse production outcomes such as dystocia, low birth weight, reduced fertility, and calf mortality (Kambadur et al., 1997; Bellinge et al., 2005). Most of these changes cause functional losses in regions responsible for dimerization, proteolytic cleavage, or receptor binding, effectively abolishing the gene's regulatory capacity.

In local breeds such as Parthenais and Aubrac, MSTN polymorphisms have been significantly associated with traits like loin eye area, thigh width, and carcass weight, indicating that while selection for these variants can enhance muscularity, it must be balanced with welfare-related and reproductive considerations (Rodgers et al., 2007).

Sheep

In Texel sheep, a SNP located in the 3′ UTR of the myostatin gene affects post-transcriptional regulation, leading to increased muscle growth (Clop et al., 2006). This mutation disrupts microRNA (miR-1 and miR-206) binding sites, reducing translation of the MSTN protein and promoting hypertrophy, particularly in the loin and hindquarter muscles. Consequently, Texel sheep are recognized as a high-meat-yield breed.

The effect of this variant is not limited to Texel sheep. Studies in Suffolk, Awassi, Merino, Barki, and Romney breeds have shown that MSTN genotypes significantly influence growth performance, birth and weaning weights, and carcass characteristics (Zhou et al., 2006; Bellinge et al., 2005). For instance, in Merino sheep, MSTN polymorphisms correlate positively with muscle fiber density and carcass quality, while in Romney sheep, certain variants are linked to increased hind-leg muscle mass.

In sheep, MSTN variants are mainly concentrated in the 3′ UTR, exon 1, and promoter regions. Polymorphisms within the promoter have been shown to directly alter gene expression levels, leading to increased fiber numbers (Sato et al., 2006). Likewise, mutations within microRNA interaction sites regulate translation efficiency and contribute to breed-specific phenotypic variation in musculature.

In summary, although MSTN variant effects differ among breeds, suppression of this gene in high-meat-yield sheep breeds produces substantial phenotypic divergence, highlighting its importance as a target for both genetic selection and biotechnological interventions.

Pigs

In pig breeds such as Large White, Landrace, Duroc, Meishan, and Hampshire, variants have been identified in both the promoter and coding regions of the MSTN gene, influencing muscle fiber composition, fat content, and meat quality (Stinckens et al., 2008). Reduced MSTN expression leads to greater muscle mass and alters the ratio of type I to type II fibers. Some lines with low MSTN levels exhibit faster growth and improved carcass yield.

These variants are primarily located in exons 1–2 and the promoter region. Promoter mutations affect transcription-factor binding sites, directly regulating gene expression and thereby suppressing protein production, which results in myofiber hyperplasia (Li et al., 2011). Comparative analyses between Duroc and Meishan pigs revealed lower MSTN expression in Duroc, correlating with greater muscle mass.

Functional knockdown studies using RNA interference and CRISPR/Cas9 technologies confirmed that suppression of MSTN significantly enhances muscle growth (Cai et al., 2017). Amino acid substitutions caused by natural variants reduce biological activity of the protein, promoting more efficient muscular development.

Tissue-specific expression analyses also show that pigs with lower MSTN expression exhibit higher lean meat percentage and optimal meat quality (Wang et al., 2012). Thus, MSTN variants represent promising markers for selection programs aimed at improving pig growth and carcass traits.

Goats

In goats—particularly Boer, Saanen, Black Bengal, Damascus, Alpine, and Honamlı breeds—MSTN polymorphisms have been identified mainly in introns 1–2 and the promoter region. These variants are significantly associated with carcass weight, loin eye area, body length, muscle thickness, and meat yield. For example, intron 1 variants in Boer goats are positively correlated with loin eye area and meat production (Li et al., 2004). In high-milk-yield breeds such as Saanen and Alpine, MSTN polymorphisms affect growth rate and may be used to optimize dual-purpose breeding strategies for milk and meat (Han et al., 2013). In Damascus goats, MSTN variants influence carcass composition and fat distribution (Zhou et al., 2017).

Studies on Black Bengal goats have demonstrated that certain SNPs in the promoter region of MSTN interact with IGF-1, enhancing muscle protein synthesis and thus meat yield (Sutarno et al., 2005). Positive correlations have also been reported between MSTN expression levels and live weight gain (He et al., 2011). Recent studies in Honamlı goats indicate a strong relationship between the breed's high muscular potential and MSTN gene polymorphisms, emphasizing the need for further population-level investigations (Yıldız et al., 2021).

With the advent of gene-editing technologies in livestock, CRISPR/Cas9-mediated knockout of the MSTN gene in goats has produced significant increases in muscle mass (Zhou et al., 2017). These experimental findings suggest that suppression of MSTN not only enlarges muscle volume but also improves feed efficiency and fattening performance (Jin et al., 2016).

Overall, MSTN variation and its phenotypic effects in goats represent a valuable resource for optimizing within-species genetic potential. These polymorphisms are promising biomarkers for improving meat yield through integration of conventional selection and molecular breeding approaches (Li et al., 2004; Han et al., 2013; Zhou et al., 2017).

Poultry

Studies conducted in poultry, particularly in broiler lines such as Ross 308, Cobb 500, Hubbard, Arbor Acres, and Lohmann, have demonstrated that SNPs in the promoter and coding regions of the MSTN gene are associated with live weight, breast muscle width, feed conversion ratio, and overall growth performance (Sato et al., 2006). Polymorphisms within the promoter region can affect transcription factor binding sites, leading to reduced gene expression. This reduction has been linked to faster muscle growth and higher carcass yield, especially in commercial broilers (Zhou et al., 2006).

Additionally, suppression of MSTN expression can be achieved using molecular techniques such as RNA interference (RNAi) and antisense oligonucleotide technology. Experimental

studies utilizing these approaches have reported increased hypertrophy in breast muscles and accelerated growth rates (Kang et al., 2017). Furthermore, CRISPR/Cas9-mediated gene-editing studies have enabled targeted mutagenesis of the myostatin gene, resulting in significant increases in muscle volume even in newly hatched chicks (Yu et al., 2018).

Interactions between MSTN expression and other growth-related factors such as IGF-1 and follistatin also play key roles in regulating growth parameters. The inverse relationship between IGF-1 and MSTN, particularly during early embryonic development, directly influences the proliferation and differentiation of muscle progenitor cells (Sharma et al., 1999). These molecular interactions are therefore critical when evaluating chicken genotypes for fattening and growth performance.

Identifying genetic variants that serve as potential biomarkers for breeding purposes offers valuable opportunities for developing more efficient poultry lines and reducing economic losses. Genome-wide association studies (GWAS) have identified significant SNPs within the MSTN genomic region, providing essential information for use in genetic selection strategies (Sato et al., 2006; Yu et al., 2018).

MOLECULAR INTERACTIONS IN MYOSTATIN REGULATION

The biological activity of myostatin is tightly regulated through interactions with various regulatory proteins and receptors. Follistatin, in particular, binds myostatin with high affinity, preventing its interaction with target cells and thereby promoting muscle growth (Lee & McPherron, 2001; Amthor et al., 2004). This binding blocks the interaction between myostatin and the activin type IIB receptor (ActRIIB), suppressing the Smad2/3 signaling pathway. Inhibition of this pathway allows activation of genes required for muscle cell proliferation and differentiation (Sharma et al., 1999).

Insulin-like Growth Factor 1 (IGF-1) acts as an anabolic factor that functions in the opposite direction of myostatin. IGF-1 positively regulates myoblast proliferation and differentiation, thus enhancing muscle development (Durieux et al., 2007). The equilibrium between IGF-1 and myostatin plays a crucial role in maintaining muscle mass and functional capacity.

In addition to follistatin, proteins such as FLRG (follistatin-related gene) also inhibit myostatin activity. Although the effects of FLRG on muscle development are not fully elucidated, several studies have reported that overexpression of such inhibitory proteins can induce hypertrophy in skeletal muscles (Zimmers et al., 2002).

Overall, myostatin regulation operates through a complex molecular network. Understanding these interactions is of great significance for developing strategies to treat muscle growth disorders, for designing genetic selection programs, and for applying biotechnological interventions aimed at improving meat yield (Rodgers & Garikipati, 2008).

BIOTECHNOLOGICAL APPLICATIONS AND GENE-EDITING TECHNOLOGIES

Advances in biotechnology have made it possible to manipulate the myostatin gene with high precision. Targeted gene-editing tools such as CRISPR/Cas9 enable the introduction of stable mutations within the MSTN gene, accelerating the genetic selection process in meat production (Crispo et al., 2015). CRISPR-based applications in models such as mice, pigs, sheep, and goats have resulted in substantial increases in muscle mass and improved carcass traits (Li et al., 2018).

Moreover, temporary silencing of MSTN expression can be achieved through RNA interference (RNAi) techniques. Studies using this approach in chickens and mice have reported muscle fiber hypertrophy, demonstrating the potential of RNAi in muscle-enhancement strategies (Sato et al., 2006; Reardon et al., 2001).

Transgenic and MSTN-knockout animal models serve as valuable resources for elucidating the physiological roles of this gene. Myostatin-deficient mice exhibit pronounced hyperplasia (increased fiber number) and hypertrophy (enlarged fiber size) (McPherron et al., 1997; Sharma et al., 1999). Similar outcomes have been reported in pigs and goats following targeted suppression of MSTN expression through genetic engineering (Zhou et al., 2016).

Such biotechnological applications are not only utilized to enhance productivity in breeding programs but also to improve economic efficiency. However, these technologies must be assessed within ethical, legal, and sustainability frameworks. When carefully managed, they hold promise as fundamental tools in future animal genetics research and livestock improvement.

DISCUSSION AND FUTURE PROSPECTS

Due to its central role in muscle development, the myostatin gene has become a pivotal research subject in both basic science and agricultural biotechnology. Experimental inhibition of GDF-8 and analyses of its genetic variants have yielded promising results for developing livestock with higher meat production potential (McPherron et al., 1997; Sharma et al., 1999). For example, in Belgian Blue cattle, inactivating mutations in the MSTN gene cause the double-muscling phenotype, which markedly enhances meat yield (Grobet et al., 1997). Similarly, in Texel sheep, mutations in the 3′UTR of the MSTN gene lead to hypertrophy of muscle fibers and improved growth performance (Clop et al., 2006).

Comparable findings have been reported in goats and chickens, where MSTN polymorphisms are significantly associated with muscle thickness, body size, and live weight (Li et al., 2004; Sato et al., 2006). Modern gene-editing technologies such as CRISPR/Cas9, RNA interference, and transgenic animal models have clearly demonstrated that suppression of myostatin stimulates muscle growth (Crispo et al., 2015; Kang et al., 2017). These tools allow for more precise and rapid selection of high-yield genotypes.

However, the application of these technologies in livestock production must be evaluated within ethical and regulatory contexts, considering food safety and sustainability principles. Factors such as consumer perception, animal welfare, and environmental impact should also be taken into account when designing production models based on myostatin manipulation (Rodgers & Garikipati, 2008).

CONCLUSION

The myostatin (MSTN) gene, a key negative regulator of muscle development, holds strategic importance for improving meat yield in animal production systems. This review has provided a comprehensive evaluation of genetic variations in the MSTN gene across different livestock species and their phenotypic impacts. From the double-muscling phenotype in Belgian Blue and Piedmontese cattle to miRNA-dependent translational regulation in Texel sheep, and from polymorphisms in pigs, goats, and chickens to biotechnological interventions such as gene editing and RNA interference, a wide range of findings highlight the universal yet species-specific regulatory role of myostatin.

While many MSTN variants confer economic advantages such as increased muscle mass and carcass quality, potential risks—including dystocia, reduced fertility, and physiological imbalances—should not be overlooked. Therefore, the development of MSTN-based breeding strategies must involve multifaceted evaluation tailored to species, breed, and production system.

Today, advanced biotechnological tools such as CRISPR/Cas9, RNA interference, and transgenic model systems enable targeted manipulation of MSTN, greatly accelerating genetic

improvement processes. Nevertheless, widespread adoption of these technologies must align with ethical, legal, and sustainability standards and incorporate holistic assessments of public health, animal welfare, and environmental consequences.

In conclusion, the myostatin gene will continue to serve both as a critical target for improving livestock productivity and as a model system that exemplifies the transformative potential of genetic engineering in modern animal science.

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TOHUM NANO-PRİMİNG: SÜRDÜRÜLEBİLİR TARIM İÇİN YENİ BİR YAKLAŞIM

Dr. Öğr. Üyesi Elif ÇATIKKAŞ

Karamanoğlu Mehmetbey Üniversitesi, Teknik Bilimler Meslek Yüksekokulu, Bitkisel ve Hayvansal Üretim Bölümü

Email: eliffcatikkas@gmail.com

ORCID: 0000-0002-0661-0219

Dr. Öğr. Üyesi Said Efe DOST

Karamanoğlu Mehmetbey Üniversitesi, Teknik Bilimler Meslek Yüksekokulu, Bitkisel ve Hayvansal Üretim Bölümü

Email: saidefe.dost@gmail.com

ORCID: 0000-0003-4279-7292

ÖZET

Küresel iklim değişikliği, azalan doğal kaynaklar ve artan gıda talebi, tarımda yeni ve sürdürülebilir yöntemlere olan ihtiyacı artırmaktadır. Bu doğrultuda, nanoteknolojiye dayalı tohum nano-priming uygulamaları gelecek vadeden bir yaklaşım olarak öne çıkmaktadır. Nanoparçacıkların kullanımıyla gerçekleştirilen priming işlemi, tohum metabolizmasını ve sinyal mekanizmalarını düzenleyerek çimlenme hızını ve homojenliğini artırmakta, fide gelişimini desteklemekte ve bitkilerin abiyotik ile biyotik streslere karşı dayanıklılığını güçlendirmektedir. Ayrıca nano-priming, besin elementlerinin alımını kolaylaştırarak gübre kullanımını azaltmakta, pestisit ihtiyacını düşürmekte ve gıda kalitesinin yükselmesine katkı sağlamaktadır. Bu bildiride, tohum nano-primingin temel prensipleri, kullanılan farklı nanoparçacık tipleri ve bitki gelişimi üzerindeki etkileri tartışılacak; tarımsal üretimde sürdürülebilirlik açısından sunduğu fırsatlar ile olası çevresel riskler değerlendirilecektir.

Anahtar Kelimeler: Tohum Nano-Priming, Nanoteknoloji, Sürdürülebilir Tarım, Çimlenme

ABSTRACT

Global climate change, depletion of natural resources, and the increasing demand for food highlight the urgent need for sustainable and innovative strategies in agriculture. In this context, seed nano-priming has recently emerged as a promising approach. This technique, based on the use of nanoparticles, modulates seed metabolism and signaling mechanisms, resulting in faster and more uniform germination, enhanced seedling establishment, and improved tolerance to both abiotic and biotic stresses. Furthermore, nano-priming facilitates nutrient uptake, thereby reducing the need for fertilizers, decreases pesticide application, and contributes to improved food quality. This paper will discuss the basic principles of seed nano-priming, the different types of nanoparticles employed, and their impacts on plant growth and development. In addition, the potential opportunities it provides for sustainable crop production, along with possible environmental risks, will be critically evaluated.

Keywords: Seed Nano-Priming, Nanotechnology, Sustainable Agriculture, Germination

1.GİRİŞ

Günümüzde dünya nüfusunun yaklaşık 8 milyar olduğu tahmin edilmekte ve 2050 yılına kadar 10 milyara ulaşması beklenmektedir (Cardarelli vd., 2022). Birleşmiş Milletler'in öngörülerine göre, 2100 yılı itibarıyla bu rakam 11,2 milyara ulaşacaktır (Omran ve Baek 2022). Nüfusun hızla artması, küresel ölçekte gıda talebini ve beslenme ihtiyaçlarını önemli ölçüde artırmıştır (War vd., 2020). Buna karşın, artan üretim baskısı altında yürütülen yoğun tarım uygulamaları hem çevresel hem de insani boyutlarda ciddi sürdürülebilirlik sorunlarını beraberinde getirmiştir. Kimyasal gübreler ve pestisitlerin aşırı kullanımı sonucu, tarımsal kimyasal kalıntılarının insan vücudunda birikmesi, besin elementlerinin yıkanması, ötrofikasyon, toprak kirliliği ve sera gazı salınımı gibi problemler yaygın hale gelmiştir (Rahman ve Zhang 2018; Kumar vd., 2019a, b).

Bu durum, hem mevcut üretim sistemlerinin ekolojik denge üzerindeki baskısını azaltacak hem de gelecek nesillerin güvenli gıdaya erişimini garanti altına alacak **sürdürülebilir tarımsal yaklaşımların** geliştirilmesini zorunlu kılmaktadır. Çevre ve Kalkınma Komisyonu'nun (WCED) raporunda da vurgulandığı üzere sürdürülebilirlik; mevcut kuşakların ihtiyaçlarını karşılarken, gelecek kuşakların kendi gereksinimlerini karşılama kapasitesini tehlikeye atmadan çevresel etkileri en aza indirme anlayışını ifade etmektedir (Pirzada vd., 2020).

Bu bağlamda, küresel tarım sektörü günümüzde zararlılardan kaynaklanan ürün kayıpları, iklim değişikliğinin olumsuz etkileri ve doğal kaynakların tükenmesi gibi çok yönlü zorluklarla karşı karşıya kalmaktadır (Kokkonen vd., 2021). Geleneksel üretim sistemleri uzun sürmekte pestisit ve gübrelerin yoğun kullanımına dayandığından, çevresel kirlilik ve ekosistem tahribatı giderek artmaktadır (Lowry vd., 2019). Sürdürülebilir tarımın sağlanması ve artan gıda talebine yanıt verebilmek için yenilikçi teknolojilerin tarıma entegre edilmesi gerekmektedir (Kah vd., 2019; Panpatte vd., 2019). Bu noktada **nanoteknoloji**, tarımsal üretimde sürdürülebilirliği destekleyebilecek yenilikçi bir çözüm alanı olarak öne çıkmaktadır (Camara vd., 2019; Shakiba vd., 2020). Toprak ve su arıtımı, nanogübreler ve nanopestisitler gibi nano tabanlı uygulamalar, kullanılan kimyasal miktarlarını azaltırken gıda üretimini ve kalitesini artırmayı hedeflemektedir (Zhao vd., 2020). Ayrıca bu uygulamalar, çevresel yükü hafifleterek ekosistem üzerindeki baskıyı azaltmakta ve çevre dostu bir alternatif sunmaktadır (De La vd., 2020). Özellikle nanopartiküllerin bitki koruma alanındaki kullanımı giderek yaygınlaşmakta; bu durum hem araştırmacıların hem de tarım sektöründeki firmaların dikkatini çekmektedir (Chau vd., 2020).

2. GELİŞME

Nanoteknolojinin tarımsal uygulamalara entegre edilmesi, tohum kaplama tekniklerinde önemli yenilikler sağlamış; bu sayede süreçler daha hassas, verimli ve çevreyle uyumlu hale gelmiştir (Kiran vd., 2021). Tohum kaplama materyallerine nanomalzemelerin eklenmesi, çimlenme başarısının artmasına, besin elementlerinin daha etkin alınmasına, çevresel stres koşullarına karşı koruma sağlanmasına ve tohumla taşınan patojenlerin kontrol altına alınmasına katkıda bulunmaktadır (Shelar vd., 2021). Nanoteknoloji, tohum çimlenmesini büyümeyi teşvik eden maddelerin kontrollü biçimde tohuma iletilmesi yoluyla geliştirebilmektedir. Nanopartiküller, oksin, giberellin ve sitokinin gibi bitki büyüme düzenleyicilerini kapsülleyerek bu hormonların zaman kontrollü salınımını sağlamaktadır (Gowtham vd., 2023; Taheri vd., 2024). Fregonezi vd. (2024), giberellik asidin nanopartiküller içinde yavaş salınımının domates tohumlarında fide gelişimini ve su stresine dayanıklılığı artırdığını bildirmişlerdir. Pathak vd. (2021), düşük dozlarda ZnO nanopartiküllerinin arpa tohumlarının çimlenmesini teşvik ettiğini, yüksek dozlarda ise toksik etki oluşturduğunu göstermiştir. Benzer şekilde, Hao vd. (2016) ile Almutairi vd. (2015) farklı nanomalzemelerin pirinç, mısır, karpuz ve kabak tohumlarında çimlenme ve kök gelişimini nanoparçacık tipi ve derişimine bağlı olarak farklı şekilde

etkilediğini belirtmişlerdir. Çevresel stres faktörleri (kuraklık, sıcaklık, tuzluluk vb.) bitki gelişimini ve verimi sınırlamaktadır. Nanoteknolojiye dayalı tohum kaplamaları, özellikle ZnO, TiO_2, SiO_2 ve karbon esaslı nanopartiküller, tohumların stres koşullarına karşı dayanıklılığını artırmaktadır. Örneğin, Cu nanopartikulleriyle muamele edilen mısır bitkilerinde büyüme, biyokütle ve kuraklık toleransı belirgin şekilde artmıştır. Benzer şekilde, Mosavikia vd. (2022), deve dikeni tohumlarında kitosan nanopartikülleri ve pridoksin ile yapılan nanoprimingin tuzluluk toleransını artırdığını; fotosentetik pigmentler, antioksidan enzim aktiviteleri ve prolin düzeylerini düzenlediğini bildirmiştir. Nanoteknoloji, tohum kaplamaları yoluyla besin maddelerinin bitkiye daha verimli ve hedefe yönelik şekilde iletilmesini sağlamaktadır. Geleneksel gübreler toprağa uygulandığında sızıntı ve yüzey akışı nedeniyle besin kayıpları ve çevre kirliliği meydana gelebilmektedir. Nanogübreler ise tohum kaplamalarına entegre edildiğinde bu kayıpları azaltarak, gerekli besinleri çimlenme ve erken büyüme dönemlerinde doğrudan tohuma ulaştırmaktadır (Yadav vd., 2020). Çinko (Zn), bakır (Cu), demir (Fe) ve magnezyum (Mg) gibi mikro besin elementlerinden yapılan nanopartiküller tohum kaplamalarında kullanılabilmektedir. Bu mikro elementler, klorofil üretimi, enzim aktivasyonu ve solunum gibi bitki metabolizmasının temel süreçlerinde görev almaktadır (Guardiola-Márquez vd., 2023). Buğday tohumlarını 500 mg Zn/L derişiminde ZnO nanoparçacıklarıyla kaplayarak aynı zamanda toprağa da uygulamış ve işlem görmüş tohumlarda çinko içeriğinin yaklaşık 96.9 ± 25.4 mg Zn kg^{-1} düzeyine yükseldiğini belirlemişlerdir. Bu sonuç, ZnO nano parçacıklarıyla yapılan tohum kaplamasının bitkide Zn birikimini artırdığını göstermektedir (Elhaj Baddar vd., 2020). Çin lahanası (Brassica rapa) tohumlarına 20, 40 ve 80 mg L^{-1} derişimlerinde gümüş (Ag) nanoparçacıklarıyla ön işlem uygulamış ve çimlenme ile besin değerini incelemişlerdir. 40 mg L^{-1} derişiminde yapılan uygulamanın verimi %44,3 oranında artırdığı, ayrıca alanin, tirozin, glutamin, histidin ve valin gibi amino asitlerin içeriğini yükselttiği belirlenmiştir. Demir içeriği de %23,8 oranında artmış; bu da Ag nanoparçacıklarının bitkinin besin değerini artırdığını göstermektedir (Zhou vd., 2021). Tohum çimlenmesi ve erken bitki gelişiminde en önemli sorunlardan biri, mantar, bakteri ve virüs gibi tohum kaynaklı patojenlerin varlığıdır. Bu patojenler düşük çimlenme oranı ve fide ölümlerine neden olarak verimi düşürmektedir. Nanoteknoloji, antimikrobiyal nanoparçacıkların tohum kaplamalarına eklenmesiyle bu soruna çözüm sunmaktadır (Shelar vd., 2021). Özellikle gümüş (Ag) nanoparçacıkları geniş spektrumlu antimikrobiyal özellikleriyle bilinmektedir; mikroorganizmaların hücre zarlarını bozarak, ROS üretimini artırarak ve DNA replikasyonunu engelleyerek etkili olmaktadır. Tohum kaplamalarına dahil edildiğinde, zararlı patojenlerin tohum yüzeyinde kolonileşmesini engellemekte ve tohum kaynaklı hastalıkları önemli ölçüde azaltmaktadır. Ag nanoparçacıklarını pirinçte Ustilaginoidea virens mantarına karşı kullanmış ve 2 nm boyutundaki nanoparçacıkların 15 nm olanlardan daha güçlü etki gösterdiğini bildirmiştir. EC_{50} değeri 2.6 mg/mL, EC_{90} değeri 6.72 mg/mL bulunmuştur. Ag nanoparçacıkları mantar gelişimini ve spor oluşumunu doz bağımlı şekilde baskılamış, hücre yapısında hasar ve vakuol birikimi oluşturmuştur (Wen vd., 2023). Bakır oksit (CuO) ve çinko oksit (ZnO) nanoparçacıkları da yaygın olarak kullanılan antimikrobiyal ajanlardır. Bu nanoparçacıklar sadece besin elementi sağlamakla kalmaz, aynı zamanda *Fusarium*, *Rhizoctonia* ve *Pythium* gibi fide hastalıklarına neden olan mantarların gelişimini de engellemektedir. Ayrıca, peroksidaz ve fenilalanin amonyak liyaz gibi savunma enzimlerinin üretimini teşvik ederek bitkinin bağışıklık yanıtını güçlendirmektedir (Daniel vd., 2021).

A. NANOMATERYAL İLE TOHUM KAPLAMA

-Nanopartiküller

Metal oksit nanoparçacıkları, tohum kaplamalarında çimlenme, fide gelişimi ve hastalıklara karşı dayanıklılığı artıran önemli bileşenlerdir (Venkateswaran vd., 2023). ZnO

nanoparçacıkları antimikrobiyal etkileriyle çimlenmeyi %15'ten fazla artırırken kök ve sürgün gelişimini desteklemektedir (Donia vd., 2023). TiO_2 nanoparçacıkları fotosentezi güçlendirmekte ve UV koruması sağlamaktadır. Fe_2O_3 ve Fe_3O_4 nanoparçacıkları demir alımını %20–25 oranında artırarak erken fide gelişimini desteklemektedir (Dola vd., 2021). CuO nanoparçacıkları antifungal özellik göstermekte; düşük dozlarda (~20 ppm) faydalı olsa da yüksek dozlarda toksik etki yaratabilmektedir (Feigl vd., 2023). SiO_2 nanoparçacıkları kaplama dayanıklılığını artırmakta, nem dengesini düzenlemekte ve kurak koşullarda çimlenmeyi %10–15 oranında iyileştirmektedir (Goswami vd., 2023). MgO nanoparçacıkları klorofil sentezi için gerekli magnezyumu sağlayarak fide büyümesini %22 artırmaktadır (Segatto vd., 2023). Ayrıca montmorillonit nanokilleri, tohum çevresinde su ve besin tutulumunu geliştirip kök büyümesini desteklemektedir (Kumari vd., 2024).

-Nanofiberler

Elektrospin yöntemiyle üretilen nanolifler, yüksek yüzey alanı, gözeneklilik ve biyolojik olarak aktif bileşikleri kapsülleme yetenekleri sayesinde tohum kaplamalarında yaygın olarak kullanılmaktadır. Elektrospinning tekniği, büyümeyi teşvik eden maddeler, besinler veya fungisitler gibi bileşenleri taşıyabilen nanoliflerin üretimine olanak sağlamaktadır (Vedakumari vd., 2023). Bu lifler, kapsüllenmiş fungisitlerin kontrollü ve uzun süreli salımını sağlayarak bitkileri hastalıklara karşı korumaktadır. Biyobozunur bir malzeme olan polilaktik asit (PLA) nanolifleri, marul gibi bitkilerin tohum kaplamalarında denenmiştir. Bu lifler, büyümeyi düzenleyici bileşiklerle yüklenerek bunları yavaşça serbest bırakırak, aşırı sızma olmadan fide gelişimini desteklemektedir. Geleneksel film kaplamalarla karşılaştırıldığında, polimerik nanolifli kaplamalar daha yüksek su geçirgenliği, daha iyi fide biyokütlesi ve gelişmiş su alışverişi sağlamaktadır. Farias vd., (2019) soya tohumlarını abamektin veya fluopyram içeren selüloz diasetat nanoliflerle kaplamış ve kaplama kalınlığının süreyle arttığını, ancak kaplamaların homojen kaldığını bildirmişlerdir. 2, 3 ve 4 saatlik kaplamalarda çimlenme oranı %90'ın üzerinde bulunmuş, bu da kaplamanın çimlenmeyi olumsuz etkilemediğini göstermiştir. Zaim vd. (2022) ise çeltik tohumlarının kaplanmasında çinko oksit nanoparçacıkları içeren selüloz asetat biyopolimer nanolifler kullanmış, %17 nanolif oranı ve 100 mg/L ZnO nano parçacığıyla kaplanan tohumlarda yaklaşık %60 çimlenme oranı elde etmişlerdir.

-Nanojeller ve Nanoemilsiyonlar

Nanojeller, suyla şişebilen çapraz bağlı polimer ağlarından oluşan üç boyutlu hidrojel yapılar olup, suda çözünmeden yüksek oranda su tutabilirler (Jessy vd., 2024). Doğal veya sentetik polimerlerden üretilebilen bu yapılar; boyut, yüzey yükü, gözeneklilik, biyobozunurluk gibi özellikleri kimyasal bileşimlerine göre ayarlanabilmektedir (Harini vd., 2024). Tarımsal uygulamalarda nanojeller, gübre veya pestisit gibi agrokimyasalların kontrollü salımı için kullanılmaktadır. Tohum kaplamalarında nanojeller, besin maddelerini veya büyüme düzenleyicilerini kapsülleyerek çevresel faktörlere (pH, nem vb.) bağlı olarak yavaş salım sağlamaktadır. Bu durum, kimyasal kullanımını azaltırken etkinliği artırmaktadır. Lv vd. (2021), alginat esaslı nanojellerle kaplanan tütün tohumlarında aktif maddenin (chloroinconazide) beş gün içinde tamamen salındığını ve bitki büyüme parametrelerinde %20 civarında artış sağlandığını bildirmişlerdir. Nanoemülsiyonlar ise genellikle 20–200 nm çapında damlacıklardan oluşan, yağ-su veya su-yağ tipinde kararlı dispers sistemlerdir (Mushtaq vd., 2023). Küçük damlacık boyutu sayesinde aktif bileşenlerin daha homojen dağılmasını ve etkili bir şekilde kaplanmasını sağlamaktadır. Bu sistemler, besin maddeleri, pestisitler ve büyüme düzenleyicilerin tohuma homojen şekilde taşınmasına olanak tanımaktadır (Preeti vd., 2023). Silva vd. (2019), neem yağı içeren nanoemülsiyonla kaplanan soya tohumlarında *Aspergillus flavus* ve *Penicillium citrinum* gibi fitopatojenlere karşı 25–28 mm'lik inhibisyon zonları elde etmişlerdir. Ayrıca, biyopolimer (kitosan, aljinat, nişasta vb.)

temelli nanoemülsiyonlar çevre dostu olup, bitkilerin bağışıklık sistemini ve büyümesini desteklemektedir (Pallavi vd., 2024; Rehman vd., 2021). Tohum toprağa dikildikten sonra bu nanoemülsiyonlar içerdikleri aktif bileşenleri yavaşça salarak besin ve koruyucu maddelerin sürekli teminini sağlamaktadır (El-Saadony vd., 2021).

B. BİYOPOLİMER NANOMALZEMELER

Doğal, yenilenebilir ve biyobozunur özellikleri nanomalzemelerin gelişmiş fonksiyonlarıyla birleştiren özel bir malzeme grubunda yer almaktadır. Selüloz, kitosan, nişasta, aljinat ve jelatin gibi kaynaklardan elde edilip 1–100 nm boyutuna indirgenerek üretilen bu malzemeler, yüksek yüzey alanı/hacim oranları sayesinde biyolojik sistemlerle etkileşimi artırmakta ve fonksiyonel kaplamalar oluşturabilmektedir (Baranwal vd., 2022). Tarımda tohum kaplamalarında kullanıldıklarında çimlenmeyi artırmakta, patojenlere karşı koruma sağlamakta ve besinlerin kontrollü salımını mümkün kılmaktadır. Bu kontrollü salım özelliği, çevresel faktörlere (örneğin nem) bağlı olarak etkinleşmekte ve gübre/pestisit israfını azaltarak çevresel etkileri düşündürmektedir (Shelar vd., 2023). Biyopolimer nanomalzemeler, gübre veya büyümeyi teşvik edici bileşikleri kapsülleyerek bitkiye bunları kademeli şekilde sağlamakta, böylece çimlenme ve erken fide gelişimini desteklemektedir (Yadav vd., 2023). Ayrıca su tutma kapasitesini artırarak tohum çevresinde nemli bir mikro ortam oluşturmakta ve yararlı mikroorganizmaların gelişimine katkıda bulunmaktadır. Antimikrobiyal ajan içeren biyopolimer kaplamalar, tohumları toprak kaynaklı patojenlere karşı koruyarak kimyasal pestisit ihtiyacını azaltmaktadır (Korbecka-Glinka vd., 2022). Bu kaplamalar, aktif maddelerin (gübre, pestisit veya biyolojik ajanlar) tohum yüzeyine daha iyi yapışmasını ve homojen dağılmasını sağlayarak tarımsal girdilerin etkinliğini artırmaktadır. Yenilenebilir kaynaklardan elde edilen biyopolimerlerin biyo bozunur olması, sentetik plastik kaplamalara göre çevresel açıdan daha sürdürülebilir bir alternatif sunmaktadır (Patta vd., 2023). Ayrıca bu kaplamalar, kuraklık, tuzluluk veya sıcaklık gibi abiyotik streslere karşı koruyucu bir bariyer oluşturarak su alımını düzenler ve stres kaynaklı zararı azaltmaktadır. Böylece biyopolimer nanomalzemeler, hem sürdürülebilir tarım uygulamalarına katkı sağlamakta hem de tohum ve fide gelişimini çok yönlü biçimde desteklemektedir.

-Polisakkarit Tabanlı Nanopartiküller

Bitki kaynaklı biyopolimerler, yenilenebilir olmaları ve çevreyle dost özellikleri nedeniyle dünyada en yaygın bulunan ve birçok uygulaması olan malzemeler arasında yer almaktadır. Bu grupta selüloz, nişasta ve pektin gibi bileşikler bulunmakta; bunlar her biri farklı yapısal roller üstlenmekte ve çeşitli sanayi dallarında kullanılmaktadır (Samir vd., 2022). Proteine dayalı nanomalzemeler ise genellikle doğal proteinlerden elde edilmekte; bu proteinler nanoparçacıklara dönüştürülerek işlevselleştirilmektedir. Bu bağlamda en sık kullanılanlar arasında soya protein nanoparçacıkları, peynir altı suyu proteini nanoparçacıkları, mısır proteini nanoparçacıkları, jelatin nanoparçacıkları, ipek fibroin nanoparçacıkları ve keratin nanoparçacıkları yer almaktadır (De Frates vd., 2018). Selüloz, bitki hücre duvarlarının temel yapısal bileşeni olup, yeryüzündeki en bol biyopolimerdir (Thirumalai vd., 2024). β-1,4 glikozidik bağlarla bağlanmış doğrusal glikoz zincirlerinden oluşan bu polisakkarit, bitkilere yüksek çekme direnci kazandırmaktadır (Arakawa vd., 2017). Nanoyapılı formu olan selüloz nanokristalleri (CNC), asit hidroliziyle elde edilmekte ve yüksek kristallilik, düşük yoğunluk ile biyobozunurluk özellikleri sayesinde çevre dostu malzeme olarak öne çıkmaktadır (Rallini vd., 2017). Tarımda CNC'ler; tohum kaplamalarında dayanıklılığı ve nem tutma kapasitesini artırmak, ayrıca pestisit ve besin taşıyıcı olarak kullanılmak amacıyla değerlendirilmektedir. Örneğin, Avicennia marina yapraklarından elde edilen sülfatlanmış polisakkaritler kullanılarak sentezlenen $Cu_2O/Cu(OH)_2$ nanoparçacıkları, buğday fidelerinde düşük dozlarda büyümeyi teşvik ederken yüksek dozlarda fitotoksik etki göstermiştir (Essa vd., 2020). Ayrıca, TEMPO-

oksitlenmiş selüloz nanoliflerinden üretilen anyonik hidrojellerin mikrogözenekli yapısı, susam fidelerinde çimlenme ve büyümeyi teşvik etmiş, antifungal etki göstermiştir (Zhang vd., 2017). Bu sonuçlar, selüloz bazlı nanomalzemelerin tohum kaplamaları, kontrollü salım sistemleri ve bitki gelişimini destekleyen hidrojel uygulamaları açısından önemli potansiyele sahip olduğunu göstermektedir. Nişasta; patates, mısır ve pirinç gibi birçok bitkide depo karbonhidratı olarak bulunan, amiloz ve amilopektinden oluşan temel bir bitkisel polisakkarittir. Nanoparçacık formuna dönüştürüldüğünde, özgün fizikokimyasal özellikler kazanarak kontrollü salımlı gübreler ve tohum kaplamalarında önemli bir rol oynamaktadır. Pathak vd. (2020), süksinat ile modifiye edilmiş nişasta bazlı biyobozunur bir hidrojelin yüksek su tutma kapasitesi (260 g su g^{-1} hidrojel) sayesinde orta düzeyde su stresi altında mısır tohumlarının çıkış oranını artırdığını bildirmişlerdir. Benzer şekilde, Kumari vd. (2024), montmorillonit ve nişasta kullanarak geliştirdikleri nanokil/nişasta hidrojelinin 20 gün boyunca çinko salınımını sürdürdüğünü ve çinko eksikliği koşullarında pirinç tohumlarının çimlenme ve verimini artırdığını göstermişlerdir. Ayrıca, Sun vd. (2019). saf sıfır değerlikli demir nanoparçacıkları (B-nZVI) ile nişasta ile stabilize edilmiş formlarını (S-nZVI) karşılaştırmış; B-nZVI'nin filiz büyümesini teşvik ederken, S-nZVI'nin yüksek dozlarda köklerde aşırı demir birikimi nedeniyle fitotoksisiteye yol açtığını raporlamıştır. Genel olarak, nişasta bazlı nanomalzemeler biyobozunur yapıları, yüksek nem tutma kapasiteleri ve besin elementlerinin kontrollü salımını sağlamaları nedeniyle sürdürülebilir tarım uygulamaları açısından büyük potansiyele sahiptir (Pathak vd., 2020; Sun vd., 2019). Pektin, kara bitkilerinin özellikle birincil hücre duvarı ve orta lamellasında bulunan, hücreleri birbirine bağlayan heteropolisakkarit bir bileşiktir. Genellikle narenciye ve elmalardan elde edilmekte ve gıda endüstrisinde jel oluşturucu, koyulaştırıcı ve dengeleyici olarak yaygın şekilde kullanılmaktadır. Ayrıca biyouyumluluğu ve sulu ortamlarda jel oluşturabilme yeteneği sayesinde biyomedikal alanda ilaç salım sistemlerinde değerlendirilmektedir (Said vd., 2023). Tarımsal uygulamalarda ise pektin bazlı hidrojeller, biyobozunur tohum kaplama materyalleri olarak; nem tutma, besin salımı ve çevresel streslere karşı koruma sağlama potansiyeli taşımaktadır. Abdukerim vd. (2024), sodyum aljinat/pektin hidrojel ile *Cucumis sativus* tohumlarını kaplayarak *Fusarium* kök çürüklüğünü %53,26 oranında kontrol altına almışlardır. Benzer şekilde, Silva vd. (2019), nem yağı nanoemülsiyonlarını pektin matrisiyle birleştirerek *Glycine max* (soya fasulyesi) tohumları için biyobozunur antifungal nanokompozit filmler geliştirmişlerdir. 59 ± 0,61 nm çapında kararlı nanoemülsiyonlar içeren bu filmler, mekanik dayanımı ve su buharı geçirgenliğini iyileştirmiş, ayrıca *Aspergillus flavus* ve *Penicillium citrinum*'a karşı antifungal etki göstermiştir. Sonuç olarak, pektin bazlı nanomalzemeler, çevre dostu yapıları ve antifungal özellikleriyle sürdürülebilir tarımda tohum koruma ve büyüme destek uygulamaları için umut vadetmektedir (Said vd., 2023; Abdukerim vd., 2024). Chitosan, kitinden deasetilasyon yoluyla elde edilen biyobozunur bir polisakkarittir (Gedda vd., 2016). Tohum kaplamalarında su tutma kapasitesini artırarak çimlenmeyi hızlandırmakta ve tuzluluk gibi abiyotik streslere karşı dayanıklılığı artırmaktadır (Bandara vd., 2020). Ayrıca nitrojen alımını ve antioksidan enzim aktivitelerini (katalaz, süperoksit dismutaz) yükselterek oksidatif stresi azaltmaktadır (Zayed vd., 2017). Antimikrobiyal özellikleri sayesinde tohumları fungal ve bakteriyel enfeksiyonlardan korumakta, böylece kimyasal pestisit ihtiyacını azaltmaktadır (Narayan vd., 2019; El Hadrami vd., 2010). Bitkilerde savunma mekanizmalarını da aktive ederek sürdürülebilir tarıma katkı sağlamaktadır (Gai vd., 2019). Alenazi vd. (2024), 0.05% kitosan ve kitosan nanoparçacıkları uygulamasının *Phaseolus vulgaris* L. bitkisinde farklı tuzluluk düzeylerinde büyüme, verim ve fizyolojik parametreleri belirgin şekilde iyileştirdiğini bildirmişlerdir. Nanoparçacıklar, 50 mM NaCl koşulunda bitki boyunu %38.89, verimi ise %40.8 artırmıştır. Ayrıca H_2O_2 ve MDA düzeylerini düşürürken antioksidan enzim aktivitelerini artırmıştır. Soni vd. (2023), *Oryza sativa* L. tohumlarında kitosan ve kitosan nanoparçacıklarıyla yapılan ön muamelenin tuzluluk stresinde çimlenme ve fide canlılığını

geliştirdiğini göstermiştir. Kitosan nanoparçacıkları, özellikle yüksek tuz konsantrasyonlarında (200 mM NaCl) daha etkili bulunmuştur. Her iki uygulama da klorofil içeriğini ve antioksidan enzim aktivitelerini artırmıştır. Allam vd. (2024), kitosan nanoparçacıklarıyla yapılan ön işlemin *Pancratium maritimum* tohumlarının çimlenmesini, fide gelişimini ve ikincil metabolit üretimini artırdığını bildirmişlerdir. Özellikle 1 mg/mL kitosan çözeltisiyle 8 saatlik uygulama, antioksidan aktiviteyi %186'ya kadar yükseltmiştir.

- Sentetik Polimer Temelli Nanomalzemeler

Biyopolimerlerle birlikte tohum kaplamalarında önemli bir yer edinmiştir. Biyopolimerler toksik olmayan, biyobozunur ve yenilenebilir kaynaklardan elde edilebilen yapıları sayesinde organik tarım için uygundur (Baranwal vd., 2022). Polivinil alkol (PVA), biyouyumluluğu, suda çözünürlüğü ve toksik olmaması nedeniyle öne çıkan sentetik bir polimerdir (Halima vd., 2016). Elektrospin veya çözeltiden üfleme gibi yöntemlerle nanolif ya da nanoparçacık formunda üretilerek gelişmiş fiziksel özellikler kazanmaktadır (Türkoğlu vd., 2024; Vimaladevi vd., 2016). Tıpta doku mühendisliği, yara örtüsü ve ilaç salınım sistemlerinde kullanıldığı gibi, tarımda da kontrollü besin salınımı ve çevresel strese karşı koruma amacıyla tohum kaplamalarında değerlendirilmektedir (Nathan vd., 2023; Lodi vd., 2024). Damasceno vd. (2013), soya fasulyesi tohumlarında PVA nanoliflerle kaplanmış rizobakterilerin canlılığını incelemiş ve bu yöntemin simbiyotik etkinliği artırarak nodül oluşumunu teşvik ettiğini bildirmişlerdir. Benzer şekilde, Raja vd. (2021), yer fıstığı ve karadane tohumlarında bitki büyüme hormonlarını (IAA ve GA_3) PVA nanolifleriyle taşımış ve çimlenme oranlarını sırasıyla %88 ve %86'ya yükseltmiştir. Polihidroksialkanoatlar (PHA) da biyobozunur ve biyouyumlu polimerlerdir. Özellikle polikaprolakton gibi polimerlerle birlikte kullanıldığında etkili tohum kaplamaları oluşturmaktadır. PHA'lar antifungal özellik göstererek *Fusarium* ve *Penicillium* türlerine karşı koruma sağlamaktadır. Usmanova vd. (2024), arpa tohumlarında PHA ve pullulan polimerlerinin *Fusarium oxysporum* enfeksiyonuna karşı koruyucu etkilerini değerlendirmiştir. Bakteri süspansiyonu ve polimer karışımıyla kaplanan tohumlar %95–97 çimlenme oranına ulaşmış, kök ve sürgün gelişimi ile antioksidan enzim aktiviteleri artmıştır. Polivinilpirolidon (PVP) bazlı nanolifler de besin takviyeli tohum kaplamalarında başarı göstermiştir. Krishnamoorthy vd. (2016), cowpea tohumlarını üre ve kobalt nanoparçacıkları içeren PVP nanoliflerle kaplayarak daha düzenli besin salınımı ve daha yüksek çimlenme oranları elde etmiştir. Lif yapısı, film kaplamalara göre daha iyi gaz değişimi ve besin dağılımı sağlamıştır. Chakkalakkal vd. (2022), mısır (*Zea mays*) tohumlarını çinko oksit nanoparçacıkları içeren polikaprolakton nanokompoziti ile kaplamış ve bu yöntemin büyüme ve besin alımını artırdığını göstermiştir. Genel olarak, PVA, PHA, PVP ve polikaprolakton temelli nanopolimerler; tohum kaplamalarında çimlenme, fide gelişimi ve stres toleransını artıran, çevre dostu çözümler olarak öne çıkmaktadır.

3. SONUÇ

Nanoteknoloji tabanlı tohum kaplama ve priming uygulamaları, sürdürülebilir tarımsal üretimde yeni bir dönemi temsil etmektedir. Çalışmalarda görüldüğü üzere; metal oksit nanoparçacıkları (ZnO, TiO_2, SiO_2, CuO vb.) ve biyopolimer temelli nanomalzemeler (kitosan, pektin, aljinat, selüloz, PVA, PHA gibi) tohumların çimlenme oranını, fide gelişimini ve stres toleransını önemli ölçüde artırmaktadır. Bu malzemeler, besin maddelerinin kontrollü salımını sağlayarak bitkinin erken gelişim evresinde besin alımını optimize etmekte, aynı zamanda toprak ve çevre kirliliğini azaltarak ekolojik sürdürülebilirliğe katkı sunmaktadır (Yadav vd., 2023; Shelar vd., 2023).

Ayrıca, biyobozunur nanokompozitler ve nanolif kaplamalar, pestisit kullanımını azaltan, nem dengesini koruyan ve tohum yüzeyinde uzun süreli koruma sağlayan yenilikçi sistemler olarak öne çıkmaktadır (Farias vd., 2019; Zaim vd., 2022). Kitosan ve pektin gibi doğal polimerlerin

antimikrobiyal özellikleri, patojen kaynaklı kayıpları azaltırken; PVA ve PHA gibi polimerlerin taşıyıcı kapasitesi, büyüme düzenleyicilerin ve faydalı mikroorganizmaların etkili biçimde iletilmesini mümkün kılmaktadır (Damasceno vd., 2013; Usmanova vd., 2024). Sonuç olarak, nanoteknolojiye dayalı tohum kaplama sistemleri, yalnızca bitki gelişimini iyileştiren biyoteknolojik bir yenilik değil, aynı zamanda sürdürülebilir tarımın ekolojik, ekonomik ve verimsel boyutlarını güçlendiren bütüncül bir yaklaşımdır. Gelecekte yapılacak araştırmaların, bu nanomalzemelerin doz optimizasyonu, uzun vadeli çevresel etkileri ve tarla koşullarındaki performansına odaklanması, teknolojinin güvenli ve etkin biçimde uygulanabilmesi açısından büyük önem taşımaktadır.

4. KAYNAKÇA

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KÜRESEL PROTEIN AÇIĞINA ÇÖZÜM ARAYIŞI: ALTERNATIF YEM FORMÜLASYONLARI VE MORINGA ÇALIŞMALARINDAN ÖN SONUÇLAR

Dr. Esengül DEMİREL

MORYEM Tarımsal ARGE San. ve Tic. Ltd. Şti.

Email: esendemirel28@gmail.com

ORCID: 0000-0002-6541-0890

ÖZET

Artan dünya nüfusu, iklim değişikliği ve tarımsal üretimdeki kaynak kısıtlılıkları, hayvancılık sektöründe sürdürülebilir yem kaynaklarının geliştirilmesini zorunlu hale getirmektedir. Avrupa Birliği'nin Yeşil Mutabakat hedefleri, yalnızca gıda güvenliği ve iklim dostu üretimi değil, aynı zamanda tarımsal üretimde yenilikçi çözümleri de ön plana çıkarmaktadır. Bu bağlamda yürütülen TÜBİTAK 1507 destekli çalışmamızda amaç, mısır saha artığı, yonca kurusu, sarımsak sap ve kapsül atıkları ile Moringa oleifera yapraklarının farklı dozlarda birleştirilmesiyle elde edilen beş alternatif yem hammaddesinin hayvan beslemede sürdürülebilirlik potansiyelini değerlendirmektir.

Beş farklı yem katkısına ait laboratuvar ön analizleri gerçekleştirilmiş ve in vitro rumen fermantasyonu denemeleri için Erciyes Üniversitesi'ne gönderilmiştir. Ayrıca, Moringa oleifera bitkisi üzerinde kuraklık koşullarında yapılan denemelerden elde edilen fizyolojik veriler, bu türün stres koşullarında dahi üretim potansiyelini koruyabildiğini ortaya koymuştur. Bu ön bulgular, hem AB hem de dünya genelinde hayvan beslemede karşılaşılan iki temel eksikliğe yüksek kaliteli, sürdürülebilir protein kaynağı ihtiyacı ve iklim değişikliğine uyumlu yem formülasyonlarının yetersizliği somut çözümler üretebilecek niteliktedir. Çalışma, alternatif yem kaynaklarının yalnızca hayvansal üretimde verim artışı sağlamakla kalmayıp, aynı zamanda çevresel etkilerin azaltılması ve tarımsal dirençliliğin artırılması açısından da stratejik katkılar sunabileceğini göstermektedir. Nihai sonuçların tamamlanmasıyla birlikte, bu verilerin AB'nin sürdürülebilir tarım politikalarıyla bütünleşebilecek güçlü bilimsel çıktılara dönüştürülmesi hedeflenmektedir.

Anahtar Kelimeler: Sürdürülebilir hayvancılık, Moringa oleifera, İklim değişikliği adaptasyonu, Avrupa Yeşil Mutabakatı

SEEKING SOLUTIONS TO THE GLOBAL PROTEIN DEFICIT: PRELIMINARY FINDINGS FROM ALTERNATIVE FEED FORMULATIONS AND MORINGA STUDIES

ABSTRACT

The growing world population, climate change, and resource limitations in agricultural production make it imperative to develop sustainable feed sources for the livestock sector. The European Union's Green Deal targets not only emphasize food security and climate-friendly production but also highlight the need for innovative solutions in agricultural practices. In this context, the aim of our TÜBİTAK 1507-supported study is **to evaluate the sustainability potential of five alternative feed ingredients, obtained by combining maize field residues, alfalfa hay, garlic stalk and capsule wastes, and Moringa oleifera leaves at different doses, in animal nutrition.**

Preliminary laboratory analyses of these five feed ingredients have been completed and submitted to Erciyes University for in vitro rumen fermentation trials. In addition, physiological data obtained from Moringa oleifera grown under drought conditions revealed that this species is able to maintain its production potential even under stress. These preliminary findings can address two major gaps in animal feeding at both the EU and global levels: the need for high-quality, sustainable protein sources and the lack of climate-resilient feed formulations. The study demonstrates that alternative feed sources may not only improve livestock productivity but also contribute strategically to reducing environmental impacts and enhancing agricultural resilience. Upon completion of the final results, the data are expected to provide robust scientific outputs that can be integrated into the EU's sustainable agriculture policies.

Keywords: Sustainable livestock production, Moringa oleifera, Climate change adaptation, European Green Deal

1. INTRODUCTION

Globally, both small and large ruminants play an increasingly vital role in livestock production and rural livelihoods. Current estimates indicate that the global ruminant population including cattle, sheep, and goats exceeds 4.2 billion head, with cattle representing about 36%, sheep 30%, and goats 27% of the total. This substantial population highlights the importance of alternative feeding strategies, particularly the use of tree and shrub forages, to sustain feed quality and availability during dry or resource-limited periods.

In recent years, growing attention has been directed toward the use of Moringa oleifera forage meal as a high-protein feed component in ruminant nutrition. Owing to its rich nutrient profile, rapid biomass production, and adaptability to semi-arid conditions, Moringa offers a promising alternative protein source for cattle, sheep, and goats. Integrating Moringa and other tree-based forages into ruminant feed systems can therefore help mitigate feed shortages, enhance feed efficiency, and support both economic and ecological sustainability in livestock production.

Globally, the livestock sector is undergoing one of the most critical transformations in its history, driven by the rapidly increasing demand for meat, milk, and eggs. Over the past two decades, the surge in animal-based food consumption has reshaped the sector both economically and environmentally. Between 2000 and 2022, global meat production increased by 55%, reaching 361 million tons (FAO, 2023). One of the most striking developments during this period has been the sharp rise in poultry meat production, which by 2022 surpassed pork to become the most produced meat worldwide.

Asia, home to nearly 60% of the world's population, stands as a central force in global livestock production and consumption, supported by its ongoing demographic and economic growth (Yang et al., 2023). Within the region, China dominates as the largest livestock-producing country, exerting substantial influence over global market dynamics through its domestic production trends.

According to projections, global demand for animal products is expected to rise by 60–70% by 2050, with developing countries accounting for the majority of this growth (Makkar, 2017). Population growth, urbanization, and rising incomes are accelerating structural changes in livestock production systems and consumption patterns. In this evolving landscape, biotechnology and nanotechnology are expected to play key roles in advancing animal health, welfare, and food safety (Yitbarek, 2019).

In Sub-Saharan Africa, for example, poultry meat demand is projected to increase by 214%, and pork demand by 161% by 2050, largely due to urbanization and the growing appetite for animal-sourced foods (Erdaw, 2023). Meanwhile, shifts in China's livestock sector are anticipated to have far-reaching global implications, influencing production trends and trade flows well into the mid-21st century (Bai et al., 2018).

However, this rapid expansion raises major concerns related to food security, resource use, and climate change. The impacts of climate variability on livestock productivity and greenhouse gas emissions underline the urgent need for sustainable production technologies and more resilient food systems (Rojas-Downing et al., 2017). Consequently, the development of innovative, low-cost, and environmentally friendly feed supply strategies will be essential to ensure the sector's long-term viability and contribution to global food security.

Today, the main inputs in animal feed production are conventional crops such as maize and soybean meal, which serve primarily as sources of energy and protein, respectively. Globally, livestock accounts for over 30% of total food consumption, much of which is grain-based; soybean alone represents about 90% of this total (Su and Chen, 2020). However, only a small portion of these grains is directly utilized in industrial livestock farming.

The cultivation of these crops carries significant economic and environmental implications. In particular, soybean production has been identified as one of the main drivers of deforestation in South America, while also contributing substantially to greenhouse gas emissions (Parrini et al., 2023). Consequently, soybean trade affects both the environmental and socio-economic balance of many regions, highlighting the urgent need to develop sustainability-oriented trade policies (Boerema et al., 2016).

Moreover, the dual use of these crops for human consumption and animal feeding has intensified resource competition, further complicating global food security challenges (Khan et al., 2024; Dronne, 2018). The expansion of the so-called "maize–soybean system" has reshaped the interaction and competition between human and animal plant-protein consumption, creating new vulnerabilities in the global food chain, especially in developing economies (Dronne, 2018).

Environmental sustainability represents another pressing global concern. Currently, feed production accounts for a substantial share of the world's agricultural land use, freshwater consumption, and nitrogen pollution. Modern food systems remain heavily dependent on livestock-related greenhouse gas emissions, and addressing this dependency requires globally coordinated efforts that also ensure food security (Uwizeye et al., 2020). The cultivation of soybean and maize, which are predominantly used in livestock rations, has been linked to soil degradation, water scarcity, and broader planetary nutrient imbalances (Wang et al., 2017). These cumulative environmental impacts underscore the urgent need to identify and integrate alternative feed resources that are both sustainable and locally adaptable.

Beyond environmental pressures, economic volatility in feed prices poses a major challenge for farmers. Notably, grain prices began to rise sharply in 2005–2006, exerting significant pressure on feed costs and triggering market instability (Tejeda and Goodwin 2009). Such high and unpredictable feed expenses, coupled with fluctuating output prices, continue to create financial strain for livestock producers, limiting profitability and resilience within the agricultural sector (Minh et al., 2013).

Moringa oleifera (M. oleifera) leaves are a rich source of essential macronutrients that serve as building blocks for animal growth, development, and productivity. Macronutrients such as proteins, lipids, and carbohydrates significantly influence the overall nutritional value of M. oleifera as a feed ingredient. The leaves contain 19.3–28.7% crude protein, providing an abundant supply of essential amino acids necessary for muscle growth and tissue repair (Teixeira et al., 2014). Due to its high protein content, M. oleifera is comparable to traditional feed sources such as maize and exhibits an amino acid profile similar to that of soybean meal.

Analysis of dietary fiber is important for understanding the structural integrity of plant cell walls and their impact on nutrient digestion and absorption (Knudsen, 2001). M. oleifera leaves contain approximately 8.07% crude fiber, contributing to a balanced nutritional profile while maintaining good digestibility (Lesten and Emmanuel, 2018). Generally, low-fiber feed sources are more digestible and thus more efficient in animal diets.

Another remarkable feature of M. oleifera is its high mineral content. Studies have reported ash contents of up to 11.65% in the leaves (Ahmed et al., 2023), which is significantly higher than that of soybean meal, typically ranging between 5.6–7.2% (Kumar et al., 2010). In Botswana's Gaborone region, ash content in M. oleifera leaves varied between 5.6% and 9.1%, with an average value of 7.34% (Masitlha et al., 2024). These variations highlight the influence of soil composition, climatic conditions, and environmental factors on the mineral composition of the plant.

In some experiments, M. oleifera leaf protein concentrate was found to have an ash content of 6.00% (Laura, 2021). The distribution of minerals across plant tissues also varies; for instance, calcium concentrations in the leaves (11,153 mg/kg) and roots (12,834 mg/kg) were similar, while the calcium level in seeds was much lower (565 mg/kg) (Sodamade et al., 2023). This observation reflects the differential partitioning and accumulation of minerals within various plant parts.

M. oleifera leaves also contain substantial lipid content. On a dry matter basis, lipid concentrations range between 1.7% and 10.42%, depending on environmental conditions, analytical methods, and plant maturity (Masitlha et al., 2024). Analyses of leaves from Botswana and Gaborone revealed an average lipid content of 7.8 ± 0.13%, exceeding previously reported values of 2.3%, 5.2%, and 3.0%, suggesting possible regional variations in lipid composition (Waterman et al., 2015).

The lipid fraction of M. oleifera leaves is characterized by the predominance of unsaturated fatty acids, particularly palmitic, oleic, and linoleic acids (Sánchez- Machado et al., 2010). These fatty acids play essential physiological roles, contributing to the plant's energy value and supporting cell membrane integrity, modulation of inflammatory responses, and positive cardiovascular health effects (Masitlha et al., 2024).

Moringa is a drought-tolerant and multi-purpose tree species widely recognized for its medicinal and nutritional properties (Meel et al., 2018). The leaves are highly nutritious, providing an excellent source of protein, β-carotene, vitamins A, B, C, and E, riboflavin, nicotinic acid, folic acid, pyridoxine, essential amino acids, minerals, and various phenolic compounds. For this reason, Moringa leaves are commonly consumed as a vegetable in different culinary preparations across many countries (Khalafalla et al., 2010).

On a dry matter basis, Moringa leaves contain approximately 18.25% crude protein, 3.42% ether extract, 29.03% crude fiber, 9.18% total ash, and 0.83% acid-insoluble ash (Shankpal et al., 2019). This composition indicates that Moringa forage meal (MFM) has a nutrient profile comparable to conventional concentrate mixtures commonly used in livestock diets. However, studies assessing its potential as a partial or complete substitute for commercial concentrate feeds remain limited.

M. oleifera leaves contain a wide range of bioactive compounds, including polyphenols, alkaloids, terpenoids, flavonoids (e.g., quercetin and kaempferol), saponins, and tocopherols. These compounds exert significant immunological effects by regulating the activation of immune cells and cytokine production. Water-soluble polysaccharides, particularly arabinogalactan from Moringa, have been shown to positively shape the gut microbiota, supporting the proliferation of beneficial bacteria such as Lactobacillus and Muribaculaceae, thus enhancing gut-mediated immune responses. The immunomodulatory effects of moringa are associated with increased synthesis of anti-inflammatory cytokines (e.g., IL-10) and suppression of pro-inflammatory enzymes (e.g., COX-2). Furthermore, the antioxidant compounds found in M. oleifera reduce cellular damage caused by oxidative stress by neutralizing reactive oxygen species (ROS) and strengthening endogenous defense systems. All these findings suggest that M. oleifera can be used as a feed additive to support immune system function and enhance disease resistance. Furthermore, these properties give Moringa the potential to become a strategic component in sustainable and environmentally friendly animal production systems.

The increasing global population continues to place significant pressure on agricultural production systems, particularly on the livestock sector, where the demand for sustainable feed resources has become increasingly critical (FAO, 2021). A substantial portion of feed ingredients worldwide still relies on conventional crops such as maize and soybean. However,

these sources remain vulnerable to climate-induced production variability and contribute to the ongoing food–feed competition, raising concerns about long-term sustainability (Alexandratos & Bruinsma, 2012; Van der Linden et al., 2020).

In recent years, the European Green Deal and the Farm to Fork Strategy have established a policy framework that prioritizes climate neutrality, resource efficiency, and circularity in agricultural and food systems (European Commission, 2020). Within this framework, the livestock sector is being reshaped not only to enhance productivity but also to reduce its carbon footprint, improve waste valorization, and strengthen bio-based innovation in feed development (Makkar, 2016).

From a national perspective, Türkiye still exhibits a high dependency on imported feed materials, despite its strong agricultural potential. As of 2023, a considerable proportion of the soybean and maize used in feed production is imported, creating economic and environmental vulnerabilities (TMO, 2023). Therefore, the development of alternative feed formulations derived from local plant biomass and agro-industrial residues represents both an economic opportunity and an ecological necessity (Eren & Duru, 2020).

Among potential bioresources, Moringa oleifera has emerged as a promising multipurpose species due to its high protein, amino acid, and antioxidant content, as well as its ability to grow under semi-arid and drought-prone conditions (Leone et al., 2015; Anwar et al., 2007). Its adaptability to water-limited environments provides a unique advantage for Türkiye, where increasing water scarcity has begun to challenge agricultural sustainability (Khalafalla et al., 2010).

Combining Moringa oleifera leaves with local agricultural by-products such as maize stalk residues, garlic stalk and capsule wastes, and alfalfa hay offers new opportunities for the formulation of circular and sustainable feed systems. Such formulations can enhance microbial fermentation while aligning with the principles of resource efficiency and low-carbon livestock production (Gerber et al., 2013; Schwarm et al., 2021).

Accordingly, this research project, launched on October 1, 2024, with the support of TÜBİTAK 1507, is being systematically carried out within the framework of designated work packages. This article presents how this study is being evaluated in Turkey, based on the preliminary findings and analyses obtained during the project period, as well as technical advances, observations, and evaluations related to five different alternative feed formulations. The study represents an important step in integrating nationally developed biomass resources into sustainable feed strategies; it also contributes to the establishment of scientific and technological foundations that can integrate Turkey's local agricultural potential with the European Union's Green Deal objectives.

2. MATERIALS AND METHODS

The research was conducted in Mersin Province, located in the Mediterranean region of Türkiye, under semi-arid climatic conditions characterized by hot, dry summers and mild winters. The experimental site possesses a well-drained loamy soil profile and an existing greenhouse infrastructure suitable for controlled crop production. These conditions ensured that the cultivation process could be implemented efficiently without major technical limitations.



Figure 1: Preparation of Moringa planting land

The study was designed based on a drip irrigation system, enabling precise water and nutrient delivery to the root zone through a fertigation approach. Irrigation volumes were determined considering open water evaporation and crop coefficients, and the irrigation schedule was arranged on a weekly basis. To monitor soil moisture, samples were taken from 0–120 cm depth before each irrigation and the moisture content was evaluated by gravimetric method. After the plants were established in the soil, the deficit irrigation (100%/control, 75% and 50%) strategy was implemented. Considering the relatively dense planting arrangement (50 × 30 cm), tillage was minimized to prevent soil structure degradation. Water use efficiency (WUE) and irrigation water use efficiency (IWUE) were calculated with equations based on the relationship between plant yield and total water consumption; these indicators were used as basic parameters in the evaluation of resource efficiency and sustainable water management.

The plant material used in this study was Moringa oleifera. Sowing was performed by placing two seeds per hole at a depth of approximately 2 cm. Germination was monitored for two weeks, and non-germinated sites were re-sown. If both seeds germinated, the weaker seedling was thinned once plants reached about 30 cm in height. Fertilization applications planned according to soil analysis results were based on organic farm manure. After the first pruning, a nutrient mixture with balanced NPK content was applied to encourage plant regrowth. Pruning of Moringa plants was planned to limit vertical growth and encourage branching. When the seedlings reached 0.5–1.0 m in height, approximately 10 cm of the terminal shoots were cut. Pruning operations were repeated every 20 cm when new shoots reached 20 cm. Moringa is generally resistant to pests. Weed control is achieved through regular hoeing, and the use of chemical pesticides is avoided.

Harvesting began approximately 75 days after the plants reached the soil. Leaf collection was carried out in the early morning or late afternoon, when water loss was minimal. Harvested leaves were hung in small bundles on strings and dried by natural air circulation, without being compressed. This method was chosen to preserve leaf quality and nutritional value.

In the study, various agronomic parameters were measured to determine the yield and physiological performance of moringa under different irrigation levels. Total leaf, stem, and branch yields were evaluated on both fresh and dry weight basis. For dry weight calculations, samples were oven-dried at 70–75°C until they reached a constant weight, and the results were expressed in terms of dry matter (DM) (Figure 2). Plant height (cm) and stem diameter (cm) were measured at the final harvest. Stem diameter was determined using a calliper 10 cm above the soil surface, and the average of values from three plants was used for each replicate.

Various physiological parameters were monitored to evaluate the effects of irrigation levels on plant physiology. Stomatal resistance measurements were taken before irrigation, every three irrigation periods. One month after the start of programmed irrigation, leaf area of three randomly selected plants was measured at 15-day intervals, and the LAI value was calculated by dividing the results by the planting area. Before irrigation, leaf chlorophyll density was determined every three irrigations.



Figure 2: Moringa development under limited irrigation and processing of moringa dry leaves into moringa flour

Leaf samples from the second harvest, taken 90–95 days after planting, were used for quality parameter analyses (Figure 2). Samples from three replicates at each irrigation level were analyzed at the Kastamonu University Food Engineering Laboratory. Vitamin C (ascorbic acid), lycopene, total carotenoids, and total flavonoids were analyzed.

In this study, five different feed formulations were prepared using locally sourced raw materials. The ingredients used in the formulations were Moringa oleifera leaf meal, garlic harvest residues (stalks and capsules), alfalfa hay, and corn stalk hay. The composition of each mixture was proportioned to correspond to 50 kg of pelleted feed on a dry matter basis. All raw materials were dried to a constant weight and then ground to a particle size suitable for pelletizing.

The pelleting process was carried out at the R&D pilot facility in Mersin, owned by MORYEM Agricultural R&D, a company affiliated with Ankara University Technopark. Pelleted feeds were dried in a moisture-free, ventilated environment until a constant moisture content was reached. Then, samples were taken for analysis in triplicate (n=3). Samples were analyzed in laboratory conditions accredited to TS EN ISO/IEC 17025 (Ankara Food Control Laboratory).

Three independent pellet batches were prepared for each feed type, and analyses were conducted using three subsamples from each batch. For plant-based quality analyses, representative samples were taken from field trials, with each replicate representing three plant samples. Drying, grinding, and homogenization processes were standardized for all samples. Nutritional Content and Chemical Analyses; Dry Matter (DM), Crude Protein and Nitrogen (N), Crude Fat (Ethanol Extraction), Crude Ash, NDF and ADF (Neutral and Acid Detergent Fiber), Crude Fiber, Relative Feed Value (RV). Vitamin and Amino Acid Analyses; Total Amino Acid, Vitamins A, D, E and C. Mineral Matter Analysis (ICP-OES); Ca, Mg, K, Zn and other macro/micro elements were determined using standard calibration solutions (Merck, Germany).



Figure 3: Images of moringa leaves, moringa plantation area and moringa leaf harvest

Moringa leaves and pellet samples were extracted with methanol and stored at -20 °C until analysis. Total Phenolic Compound, Total Flavonoid, DPPH Radical Scavenging Activity, ABTS Radical Scavenging Activity, FRAP (Iron Reducing Power), Lycopene and Carotenoid analyses were performed. Dry Matter, pH and Titratable Acidity, Antioxidant Activity, Total Phenolic and Flavonoid analyses were performed on garlic stem and capsule residues obtained from the Kastamonu-Taşköprü region.

An in vitro ruminal digestion experiment was conducted in the laboratories of the Department of Animal Nutrition and Nutritional Diseases, Faculty of Veterinary Medicine, Erciyes University. Total gas production during rumen fermentation was determined using the in vitro gas production technique developed by Menke et al. (1979). 200 ± 10 mg of dried feed sample, 20 mL of buffer (buffer + macromineral + micromineral + reduction + resazurin mixture), and 10 mL of rumen fluid inoculum were added to 100 mL Fortuna brand glass syringes (Haberle Labortechnik, Germany) and incubated at 39 °C. Eight replicates were made for each mixture, and three blank samples (only buffer and rumen fluid) were used. A total of 48 syringes (8 × 6 mixtures) were incubated. At the end of the 24-hour incubation, the total gas volume (mL) in the syringes was read directly from the syringes. Gas samples were then transferred to an infrared methane analyzer (Sensor Europe GmbH, Erkrath, Germany) via a three-way stopcock, and the methane content (%) was read on the computer screen. Metabolic energy (ME) and degree of organic matter digestion (OMSDgas) were calculated using the equations developed by Menke and Steingass (1988), along with total gas production per hour. After gas measurement after 24 hours of incubation, pH was measured in the remaining fermentation broth using a digital pH meter (Mettler Toledo). Lactic acid and volatile fatty acids (VFA) analyses were performed on samples stored at -20 °C after the addition of 25% metaphosphoric acid (1 mL acid / 4 mL rumen fluid). Lactic acid concentration was determined spectrophotometrically according to the lithium lactate standard (Tekin and Kara, 2020). Volatile fatty acids (acetic, propionic, butyric, isobutyric, valeric, isovaleric, hexanoic, capranoic acid) were analyzed using a GC-FID (Gas Chromatograph – Flame Ionization Detector) device (Ersahince and Kara, 2017). The amount of ammonia nitrogen (NH_3-N) was measured by UV-VIS spectrophotometer using the Megazyme commercial kit (K-AMIAR 02/20, Wicklow, Ireland).

3. RESULTS AND DISCUSSION

The preliminary findings of this study reveal that the designed feed formulations, developed through the integration of four distinct agricultural residues corn field waste, alfalfa hay, garlic

stalks and capsules, and Moringa oleifera leaves present promising potential as sustainable feed ingredients. Each component was selected based on its availability, nutrient profile, and environmental compatibility, aiming to establish a circular model that converts local biomass residues into value-added feed materials.

Overall trends revealed that the five feed formulations exhibited a balanced structure in terms of crude protein, fiber, and mineral composition (Figure 4). The inclusion of *Moringa oleifera* leaves markedly enhanced the crude protein content of the mixtures while improving antioxidant capacity and the presence of bioactive compounds, which positively influenced microbial fermentation. The amino acid profile of Moringa particularly its richness in methionine, leucine, and threonine (Makkar & Becker, 1997; Anwar et al., 2007) supports microbial protein synthesis and enhances nitrogen utilization efficiency in ruminants. Moreover, its high calcium, iron, and potassium content contributes to mineral balance and rumen microbial activity, both of which are essential for maintaining digestive stability.

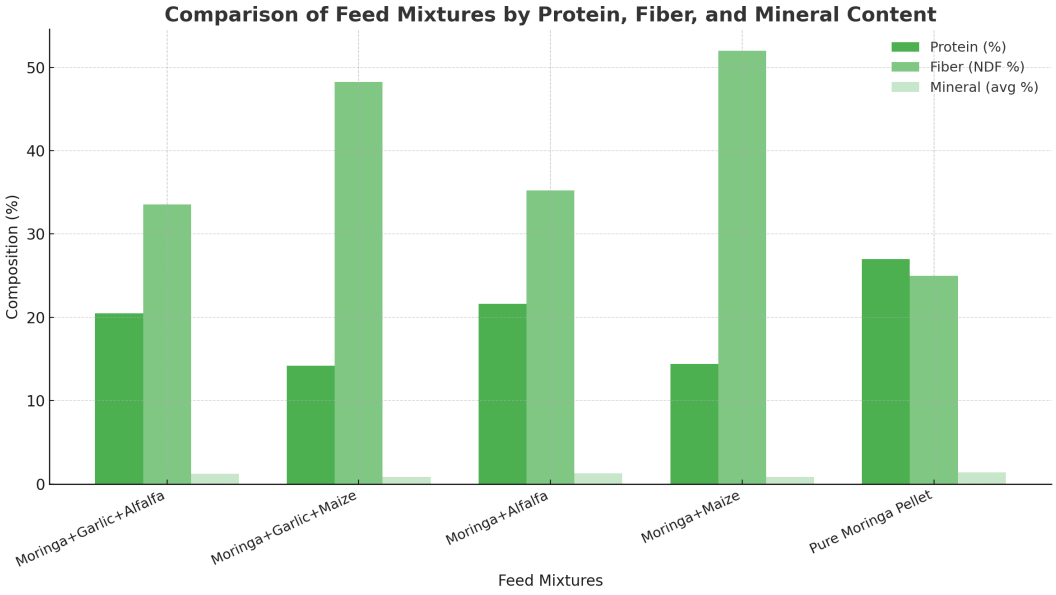


Figure 4: Comparison of Feed Mixtures by Protein, Fiber, and Mineral Content

Conversely, corn field residues and alfalfa hay served as fibrous carbon sources that supported structural integrity and rumen functionality. Their high neutral detergent fiber (NDF) content sustains the activity of cellulolytic bacterial populations within the rumen ecosystem (Van Soest, 1994). This complementary biochemical relationship between Moringa's highly digestible protein fraction and the fibrous constituents of corn and alfalfa resulted in a synergistic effect on the nutritional efficiency of the formulated feeds.

This synergism is consistent with previous findings where *Moringa oleifera* was used as a functional feed component in ruminant nutrition. For example, Nouman et al. (2014) reported that Moringa leaf meal increased gas production and microbial biomass yield, improving rumen fermentation efficiency in vitro (Figure 5). Similarly, Mendieta-Araica et al. (2013) found that substituting alfalfa with Moringa leaves in dairy cow diets enhanced dry matter intake and milk yield, while reducing methane emissions. In line with these results, Sarwatt et al. (2004) demonstrated that supplementing goat diets with Moringa leaves under Tanzanian conditions significantly improved body weight gain and feed conversion efficiency.

From a biochemical perspective, these formulations not only align nutritionally but also show ecological and functional compatibility with the literature. The secondary metabolites present in Moringa such as flavonoids, tannins, and saponins may contribute to maintaining rumen

microbial balance while mitigating excessive protein degradation (Soliva et al., 2005; Patra & Saxena, 2011). Such modulation supports improved nutrient conversion efficiency and reduces nitrogen losses, thus contributing to environmental sustainability.

From a sustainability perspective, the utilization of locally available agricultural residues as feed ingredients in this study provides multifaceted benefits not only by reducing production costs, but also by mitigating agricultural waste accumulation, greenhouse gas emissions, and supporting rural development. The systematic integration of crop residues into feed manufacturing contributes to the practical implementation of a circular bioeconomy model,

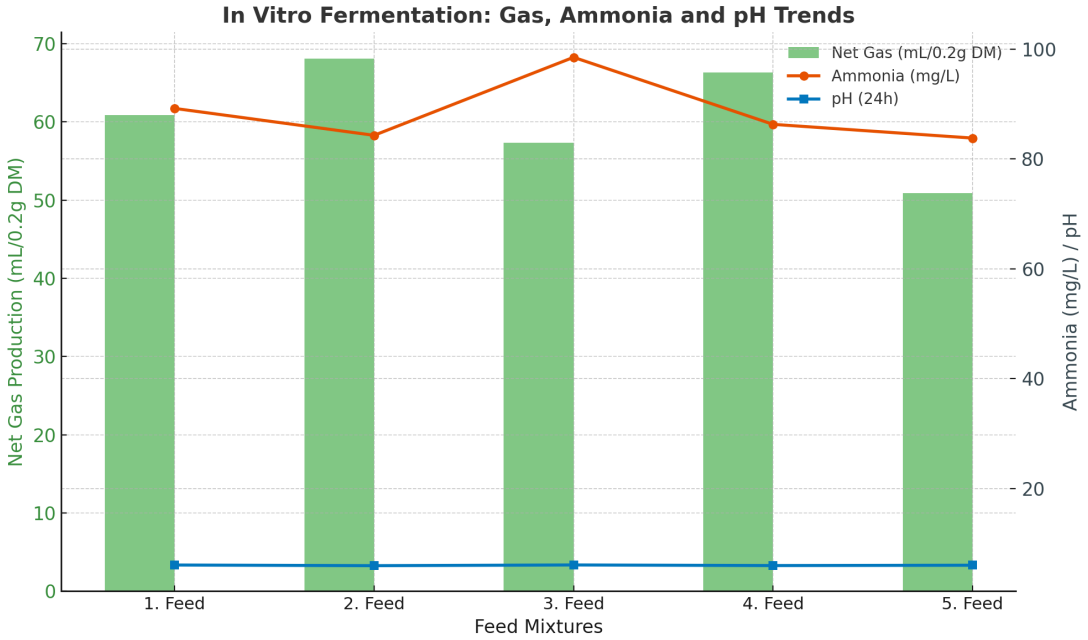


Figure 5: In Vitro Fermentation

which remains an emerging but promising concept in Türkiye. This approach aligns directly with the principles of the European Green Deal, particularly its emphasis on resource-efficient production systems and the Farm to Fork Strategy, which seeks to establish sustainable and climate-resilient livestock production chains.

From an economic standpoint, the development of such alternative feed formulations holds the potential to strengthen domestic feed production capacity, reduce dependency on imported raw materials, and retain economic value within local agricultural ecosystems. The valorization of low-cost residues such as corn stalks, alfalfa hay, and *Moringa oleifera* leaves creates new income opportunities for farmers and enhances the resilience of rural economies. This transformation supports national objectives related to agricultural self-sufficiency, food sovereignty, and rural innovation, ultimately contributing to a more inclusive and locally grounded bioeconomy.

In ecological terms, the controlled reintegration of biomass residues into the production cycle contributes to soil protection, lower carbon emissions, and restoration of natural nutrient cycles. Moreover, the incorporation of *Moringa oleifera* a species highly tolerant to drought and heat stress into feed systems offers a strategic advantage in adapting agricultural production to climate change conditions. This adaptation is consistent with both Türkiye's National Climate Change Strategy and the EU Climate Adaptation Policy Framework, reinforcing the shared goals of low-carbon, resource-efficient food systems.

From an environmental performance perspective, the physiological observations obtained under limited irrigation conditions confirmed the strong adaptive capacity of *Moringa oleifera* to semi-arid climates. Throughout the cultivation period, the plant maintained stable chlorophyll content, leaf water status, and biomass production, indicating its ability to sustain photosynthetic activity and metabolic integrity despite drought stress. These findings are consistent with earlier studies reporting *Moringa oleifera*'s remarkable drought tolerance and water-use efficiency (Nouman et al., 2013; Santos et al., 2019; Aydin et al., 2021). In particular, its ability to maintain stomatal conductance and regulate osmotic balance enables continued growth even under prolonged water limitation (El-Kholy et al., 2020).

Moringa oleifera exhibits high water-use efficiency (WUE) and balanced physiological responses through efficient nitrogen uptake and a well-coordinated root–leaf interaction. Under drought stress, the plant enhances proline accumulation and activates antioxidant defense mechanisms including superoxide dismutase (SOD), catalase (CAT), and peroxidase (POD) which protect cell membrane stability and mitigate oxidative damage (Abd El-Gawad et al., 2021; Rivas et al., 2020). These traits not only limit biomass loss but also help maintain the nutritional quality of the plant under adverse climatic conditions.

In Türkiye, recent field trials have demonstrated that *Moringa oleifera* can be successfully cultivated in Mediterranean, Southeastern Anatolia, and selected Central Anatolian microclimates (Demirbaş et al., 2022; Erdem et al., 2023). Particularly in provinces such as Mersin, Hatay, and Şanlıurfa, the species has shown the ability to regrow from the stem base under mild winter conditions, allowing for three to four harvests per year in semi-arid environments. These findings suggest that Moringa can be established as a perennial, drought-resilient feed source in Türkiye, contributing to the country's broader drought adaptation and water efficiency strategies.

The drought tolerance, physiological plasticity, and regrowth potential of *Moringa oleifera* position it as a strategic species for the development of climate-smart feed systems. Compared to conventional forages, its lower irrigation requirement and high biomass yield significantly enhance irrigation water-use efficiency (IWUE) and reduce pressure on freshwater resources. Therefore, integrating Moringa into national feed production systems directly aligns with Türkiye's National Water Efficiency Policy and the European Green Deal's objectives for climate-neutral and resource-efficient agriculture.

From a technical perspective, the development of these feed formulations also contributes to the national innovation ecosystem supported by the TÜBİTAK 1507 program. The project is a successful example of an applied R&D process that strengthens collaboration between academia, industry, and agriculture. This work, conducted through systematic formulation development and laboratory-scale evaluations, provides a strong foundation for scaling up nutritionally balanced, environmentally friendly, and economically viable feed systems.

Overall, these findings highlight two key contributions of the study: reducing the global protein gap and developing climate-adapted feed formulations. The approach taken here demonstrates that the circular valorization of biomass resources, when combined with climate-resilient species such as Moringa oleifera, can pave the way for more sustainable, self-sufficient, and low-carbon agricultural systems.

4. FUTURE PERSPECTİVES

To fully realize the potential of Moringa oleifera (M. oleifera) as an eco-friendly and nutritionally beneficial livestock feed source, several fundamental research areas must be addressed. Future studies should focus on developing improved processing methods that enhance the bioavailability of M. oleifera's bioactive compounds. Scientific investigation into

enzymatic treatments, optimized drying techniques, and controlled fermentation processes is crucial to making M. oleifera nutrients more accessible after processing. Furthermore, the formulation of balanced feed compositions that effectively integrate M. oleifera into livestock diets should be prioritized. Research must explore optimal combinations that maximize nutrient intake, promote animal growth, and improve overall welfare.

Ongoing studies should also investigate how M. oleifera supplementation affects livestock across different production stages. Long-term trials are needed to evaluate its effects not only on growth and feed conversion efficiency but also on reproductive performance, disease resistance, and animal welfare. Given the variability of bioactive compound concentrations in M. oleifera, further investigation into the influence of cultivation conditions and varietal differences is required. Identifying optimal cultivation practices and extraction methods that maximize beneficial compound concentrations will improve M. oleifera's efficacy as a sustainable feed ingredient.

At the molecular level, research should aim to elucidate the mechanisms underlying M. oleifera's immunomodulatory properties. Studies focusing on the interactions between its bioactive compounds and immune pathways, antioxidant defense systems, and gut microbiota are essential to determine its full potential as a natural immunostimulant in livestock feeding. Understanding these biological mechanisms will enhance its value as a health-supportive additive during stress periods in farm animals.

Additionally, environmental assessment methods and economic modeling tools are required to compare M. oleifera's sustainability advantages over conventional feed crops. Life Cycle Assessment (LCA) studies should evaluate its capacity to reduce greenhouse gas emissions, water use, and land degradation relative to corn and soybean. Economic analyses are also needed to determine cost-benefit ratios and feed price reductions, alongside improvements in animal health and productivity.

As M. oleifera gains recognition as a core feed ingredient, regulatory frameworks ensuring its safe use in livestock systems must be established. Comprehensive safety evaluations and compliance with international feed standards will facilitate its integration into global commercial feed markets. Raising consumer awareness about M. oleifera's advantages will help stimulate market demand for sustainable livestock production. Successful adoption will depend on collaborative partnerships among researchers, agricultural stakeholders, and policymakers to develop science-based implementation strategies for the livestock sector.

Ultimately, M. oleifera represents a valuable, sustainable, and nutrient-rich feed material for agricultural applications. Advancements in processing optimization, feed formulation, molecular research, and environmental-economic evaluation will further strengthen its role in addressing modern global challenges related to food security, animal health, and environmental sustainability.

5. CONCLUSİON

Within the scope of this project, *Moringa oleifera* is evaluated as an alternative feed source in livestock nutrition, providing a strategic solution for sustainable production and environmental efficiency. Owing to its high protein, amino acid, vitamin, and mineral content, Moringa is expected to enhance the performance, digestibility, and immunity of calves when used in combination with agro-industrial residues such as garlic harvest waste, corn stalks, and alfalfa hay in formulated feed mixtures.

The project aims to reduce dependence on high-cost and environmentally intensive feed inputs such as soybean meal and corn, while promoting locally sourced, low-carbon feed formulations that align with sustainable agricultural goals. By leveraging Moringa's underutilized potential

in Türkiye, the project will contribute to the development of climate-resilient feed systems and economically viable production models, particularly in water-stressed agricultural regions.

Moringa-based feed formulations serve not only as a nutrient-rich alternative but also as a natural feed additive that supports animal immunity, mitigates oxidative stress, and improves growth and overall performance. The planned *in vitro* and *in vivo* trials will scientifically validate these effects, providing evidence-based support for reducing Türkiye's dependency on imported protein feed sources.

Expected project-related outcomes include:

1. *Optimum inclusion rate*: Incorporating 10–15% Moringa is expected to improve feed conversion efficiency and weight gain in calves.

2. *Processing technology*: Development of new drying and pelleting methods will enhance flavonoid retention and improve feed quality.

3. *Economic feasibility*: Incorporating locally produced Moringa leaf powder may offer up to a 40% cost reduction compared to soybean meal.

4. *Environmental contribution*: Compared to conventional feed sources, Moringa cultivation offers a threefold lower carbon footprint and reduced water consumption, directly contributing to environmental sustainability objectives.

Future Perspective: This project represents one of the **first systematic scientific evaluations** of Moringa's applicability in Türkiye's livestock sector. The findings will provide a foundation for **farmer training programs, cooperative-based production models**, and **collaborative R&D efforts with the domestic feed industry**. Furthermore, scaling up Moringa cultivation in Türkiye will support **rural development, feed security, and climate adaptation strategies**.

In conclusion, this project positions *Moringa oleifera* as a **transformative feed component** with nutritional, environmental, and economic benefits. By integrating Moringa into livestock feeding systems, the project will strengthen Türkiye's feed self-sufficiency capacity and advance the transition toward a **climate-smart and Green Deal-aligned agricultural model**.

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APPLICATION OF CHROMATOGRAPHIC TECHNIQUES IN THE ANALYSIS OF BIOACTIVE COMPOUNDS IN HORTICULTURAL CROPS

Assoc. Prof. Dr.Müjgan GÜNEY

Yozgat Bozok University, Faculty of Agriculture, Department of Horticulture, Yozgat, Türkiye.

Email: mujgan.guney@yobu.edu.tr

ORCID: 0000-0001-5491-1430

Assoc. Prof. Dr. Hakan KELES

Yozgat Bozok University, Faculty of Agriculture, Department of Horticulture, Yozgat, Türkiye

Email: Hakan.keles@yobu.edu.tr

ORCID: 0000-0002-8225-931X

Assoc. Prof. Dr. Murat GÜNEY

Yozgat Bozok University, Faculty of Agriculture, Department of Horticulture, Yozgat, Türkiye

Email: murat.guney@yobu.edu.tr

ORCID: 0000-0003-2882-8347

ABSTRACT

Extraction, separation, and characterization of bioactive compounds from horticultural crops are essential for linking plant phytochemistry and health promoting functions. This work focuses on recent advances in chromatographic methodologies applied to the analysis of phytochemicals in fruits, vegetables, and other horticultural products. One of the most important steps in this concept is the optimized sample preparation, such as solid phase extraction, liquid–liquid partitioning, and cleanup steps to reduce matrix interferences. High Performance Liquid Chromatography (HPLC), coupled with different detectors such as RID (Refractive Index Detector), DAD (Diode Array Detector), UV (Ultraviolet Detector), and Fluorescent detectors are applied for the determination of a range of phytochemicals which serve as quality parapeters as well as studies on abiotic and biotic stress responses in plants. However, electrospray ionization mass spectrometry (HPLC ESI MS), is shown as the backbone for profiling phenolics, flavonoids, and other nonvolatile metabolites with high sensitivity and selectivity. Gas Chromatography (GC), frequently as GC–MS after derivatization, is effective for volatile compounds as well as FID (Flame Ionization Detector) for determination of fatty acid constituents in horticultural samples. Thin-Layer Chromatography (TLC) and High-Performance TLC (HPTLC) are recognized for rapid screening and fingerprinting of crude extracts, and can be combined with bioassays for activity directed fractionation. Innovative methods, including countercurrent chromatography and two-dimensional liquid chromatography, provide improved capabilities. However, there are still challenges like overlapping compounds (coelution), interference from other substances (matrix suppression), and the absence of standard reference materials. To deal with these issues, methods like using different types of separation, advanced mass spectrometry, and internal standards are used. In summary, chromatography is very important for better understanding the active compounds in fruits and vegetables. It helps us measure them more accurately, understand their structure, and ensure consistent quality in functional foods.

Keywords: Chromatography, Phytochemicals, Quality parameters, Detectors

INTRODUCTION

Horticultural crops including fruits, vegetables, herbs, and ornamental plants—are not only essential components of global diets but are also recognized as rich sources of biologically active compounds, commonly referred to as bioactive compounds. These phytochemicals, such as polyphenols, flavonoids, anthocyanins, alkaloids, carotenoids, glucosinolates, and vitamins, have garnered significant attention in recent decades due to their well-documented health-promoting properties. Numerous epidemiological and clinical studies have demonstrated the antioxidant, anti-inflammatory, antimicrobial, and even anticancer potential of these compounds, linking high fruit and vegetable intake with a reduced risk of chronic diseases such as cardiovascular disease, diabetes, and certain types of cancer (Abedelmaksoud et al., 2025).

The composition and concentration of these bioactive compounds in horticultural products are influenced by a variety of factors, including species, cultivar, ripeness stage, environmental conditions, agricultural practices, and post-harvest handling (Francini et al., 2022) . Consequently, precise profiling of these chemicals is essential for nutritional labeling, functional food development, breeding programs, authenticity verification, and optimization of post-harvest technology.

However, the analysis of bioactive chemicals within complex plant matrices poses significant challanges. Plant tissues exhibit chemical diversity and frequently comprise a blend of structurally analogous chemicals in differing quantities. Moreover, many bioactives exhibit instability, susceptible to degradation under light, oxygen, or heat, or exist in conjugated or bound forms necessitating prior hydrolysis or transformation. In this context, advanced analytical methods are crucial for the precise extraction, separation, identification, and quantification of these substances with high reliability (Altemimi et al., 2017).

Among these techniques, chromatography stands out as a prominent standard for phytochemical analysis. Chromatographic techniques, including high-performance liquid chromatography (HPLC), gas chromatography (GC), and thin-layer chromatography (TLC), facilitate the separation of distinct components from complex plant extracts based on to their physicochemical characteristics. When paired with selective detectors—such as ultraviolet-visible (UV-Vis) spectrophotometry, fluorescence detection, or mass spectrometry (MS)—or utilized alongside other instruments (e.g., GC-MS, LC-MS/MS), these methodologies facilitate both qualitative identification and quantitative analysis at trace levels, even within complex matrices (Custódio-Mendoza et al., 2024).

Chromatographic profiling is also principle step for identifying biomarkers that are important for nutrition or medicine, monitoring changes during crop growth and storage, and ensuring quality control in functional food and nutraceutical production. It also makes it easier to exploration of underutilized or indigenous horticultural species, which may have novel bioactive profiles.

This paper aims to comprehensively review the application of chromatographic techniques in the analysis of bioactive compounds in horticultural crops. It will cover the essential steps of sample preparation and extraction, describe the principles and advances in major chromatographic methodologies, highlight specific examples in fruit and vegetable research, and discuss current challenges and future directions in the field.

Sample Preparation and Extraction for Chromatographic Analysis

Before chromatography, the bioactive compounds must be efficiently extracted from horticultural samples such as leaves, fruits, seeds, peels and etc. The choice of extraction technique, solvent system, and cleanup strongly influences chromatographic outcomes.

Innovations in extraction such as ultrasound-assisted, microwave-assisted, supercritical fluid and deep eutectic solvent extraction have been reported (Nguyen et al., 2024).

Patra et al. (2022) investigated the general extraction of bioactives and the subsequent chromatographic separation. Extraction must mitigate matrix interference (pigments, sugars, lipids) while preserving the integrity of target molecules. Post-extraction, purification procedures (solid phase extraction, liquid-liquid partitioning) may be employed to improve the quality and simplify the extract for chromatography.

Chromatographic Techniques: Principles and Applications

Thin-Layer Chromatography (TLC)

TLC is often employed as a preliminary screening tool. Thin-Layer Chromatography (TLC) is described as an analytical separation technique that operates on a planar stationary phase (a thin layer of sorbent such as silica gel coated on glass, aluminum, or plastic). Compounds in a sample are separated as the mobile phase (solvent) moves across the layer by capillary action, carrying different molecules at different rates according to their physicochemical properties (such as polarity and adsorption affinity) (Poole, 2003).It is cost-effective, provides rapid fingerprinting of phenolics and flavonoids in plant extracts. For instance, Joshi et al. (2024) compared eight solvent systems for TLC profiling of phenolics in plant extracts. Although TLC has some advantages such as simplicity, low cost, and inimal sample preparation, it also has certain limitations, including lower resolution, semi-quantitative results at best, and lower reproducibility compared to column chromatography.

Gas Chromatography (GC) and GC-MS

Gas Chromatography (GC) is primarily employed for the detection and quantification of volatile and semi-volatile organic compounds, such as aroma compounds, essential oils and fatty acids (Joshi et al., 2024). When it is coupled with mass spectrometry (GC-MS), enable accurate structural identification of analytes. In GC, the mobile phase is an inert carrier gas, commonly helium or hydrogen that transports the vaporized sample through a capillary column coated with a stationary phase, where separation occurs based on the compounds' volatilities and interactions with the column (Putri el., 2022). In horticultural research, GC and its coupling with mass spectrometry (GC-MS) are extensively used for the separation, identification, and quantification of volatile organic compounds from plants which are primarily responsible for their aroma and taste. GC typically requires an extraction or sampling method such as headspace sampling, solid phase microextraction (SPME) or dynamic/trap-adsorbent methods; for example, static headspace and dynamic headspace techniques capture plant-emitted VOCs, often via SPME fibres (e.g., DVB/CAR/PDMS) prior to GC-MS analysis (Makhlouf et al., 2024).

Gas chromatography when equipped with a Flame Ionization Detector (FID), is primarily used for the detection and quantification of fatty acids, particularly polyunsaturated fatty acids such as omega-3 and omega-6. The FID provides high sensitivity and a wide linear dynamic range for hydrocarbons, making it ideal for analyzing methyl esters of fatty acids (FAMEs) derived from plant oils and other horticultural products (Toishimanov et al., 2024)

The advantages of GC/GC MS in horticulture encompass elevated sensitivity for volatile analytes, excellent repeatability, comprehensive spectral libraries for identification, and suitability for profiling fragrance compounds, stress-related volatiles, and flavor indicators. However, Gas Chromatography (GC) is best suited for the analysis of volatile, thermally stable, and low molecular weight compounds, but it faces limitations when applied to complex plant matrices, such as co-elution of analytes and insufficient resolution. When coupled with mass spectrometry (GC-MS), additional challenges may arise, including peak overlap, reduced

sensitivity for low-abundance compounds, and limited effectiveness in detecting highly polar, high-boiling, or thermally labile analytes (Gin and Imwinkelried, 2018).

High-Performance Liquid Chromatography (HPLC) and Related Hyphenated Techniques

HPLC (and its faster variant, Ultra-HPLC) is widely employed to separate non-volatile bioactive compounds such as phenolic acids, flavonoids, carotenoids and sugars. HPLC is a liquid phase separation technique wherein a liquid mobile phase, typically a combination of water and organic solvent chemicals, is pushed under high pressure through a column containing a stationary phase, such as reversed phase C18, C8, phenyl, or C30 for pigments, with analytes partitioning between the mobile and stationary phases based on their physicochemical affinities (Ali, 2022).

The fundamental components of an HPLC system consist of a high-pressure pump, solvent delivery system (mobile phase), injection port, chromatographic column (stationary phase), and a detector (or detectors) that transform separated analyte zones into signals. Key considerations in HPLC for horticultural bioactives are column type (for example C18, C8, phenyl), mobile phase composition (aqueous solvents often acidified plus organic modifiers such as methanol or acetonitrile), detector choice (UV/Vis absorbance, diode array detector (DAD), fluorescence detector (FLD), mass spectrometric (MS) detector or Refractive index (RID) detector) and sample preparation to mitigate matrix effects. With UV/Vis or DAD detection one monitors absorbance at one or many wavelengths (e.g., DAD can scan 190–800 nm enabling spectral confirmation) and this is widely used for phenolics and flavonoids (Park et al., 2024). Fluorescence detectors offer higher sensitivity for compounds with native or derivatized fluorescence and are primarily used for the determination of polyamines, hormones, and amino acids (Zheng et al., 2017; Rao et al., 2023). Mass spectrometric detectors (HPLC–MS, UPLC–MS/MS) offer structural insights, exceptional sensitivity, and the capability to correlate phytochemical profiles with biological activity through comprehensive fingerprinting and quantification of trace elements. The review by Jorge Antonio Custódio Mendoza et al. (2024) elucidates the application of both conventional and sophisticated chromatography techniques, including reversed phase HPLC and UHPLC MS, for the detection of phenolic phytochemicals in food products. In the research area of pigments like carotenoids, reversed phase HPLC employing C30 columns and suitable mobile phase gradients (e.g., methanol, methyl tert-butyl ether, water) with DAD or APCI MS detection has effectively separated and quantified lycopene, β-carotene, lutein, and their isomers (Londoño-Giraldo et al.,2021). Modern combined chromatographic techniques (HPLC–MS, UPLC–MS/MS) are currently considered essential for correlating phytochemical profiles with biological activity; however, precise consideration is required for column selection, mobile phase optimization, detector configuration, and matrix cleanup (Sharma and Yadav, 2023).

Application in Horticultural Crops

Although chromatographic research has predominantly concentrated on medicinal plants, the same analytical principles are equally relevant to horticultural crops such as fruits, vegetables, and ornamentals—where bioactive compounds substantially affect nutritional value, sensory quality, shelf life, and overall marketability.

Chromatographic techniques have been extensively utilized to analyze polyphenols and flavonoids in fruit skins and peels, quantify carotenoids in brightly colored vegetables such as carrots and bell peppers, and isolate secondary metabolites like alkaloids and glucosinolates in *Brassica* species.

Furthermore, chromatography is significantly employed in evaluating fruit quality across diverse horticultural practices including different fertilization methods, light or water treatments, and canopy management (Aguilera et al., 2020) as well as in breeding programs where metabolite fingerprints facilitate cultivar differentiation and associate chemical profiles with desirable characteristics (Ürek et al, 2021). Such techniques also supports plant physiology such as alternate bearing (Güney et al., 2023) and stress-biology studies where researchers use chromatographic separation to monitor changes in phytochemical levels in response to abiotic stresses (e.g., drought, salinity, temperature) (Çoban and Aras, 2023) or biotic pressures (e.g., pathogens, pests) Endes (2025), thereby providing markers of resilience and informing crop improvement. Although systematic reviews specifically targeting horticultural crops are less abundant, broader reviews on plant-based foods provide relevant insights. For instance, Abedelmaksoud et al. (2025) highlight the variety of bioactive chemicals in plant-derived products and call for advanced analytical techniques, such as chromatographic methods, for their characterization. Moreover, in the context of agricultural processing, byproducts like peels and pomace have been subjected to extraction and subsequent chromatographic analysis to assess their potential for value-added uses (Nguyen et al., 2024). From a methodological perspective, Cetinkaya (2025) reports that chromatographic techniques are the predominant methods employed for the detection, separation, and quantification of flavonoids in diverse fruit species. These applications collectively underscore the pivotal function of chromatography in evaluating crop quality, monitoring phytochemical diversity among cultivars, environments, and stresses, and measuring the effects of processing and storage on bioactive content.

Challenges and Methodological Considerations

Despite the efficacy of chromatographic technologies in assessing horticulture crops, numerous persistent challenges restrict their routine implementation. A significant challenge is the intricate composition of plant matrices, which frequently contain sugars, fibers, pigments, and lipids that disrupt both separation and detection methods. Standardization presents a significant challenge; variations in sample preparation, chromatographic conditions, and detector calibration can result in inadequate reproducibility and interfere with meaningful comparisons across studies—an issue emphasized by Custódio Mendoza et al. (2024), who advocate for the establishment of harmonized protocols. Sensitivity frequently compromises efficiency; whereas high-resolution methods such as HPLC-MS/MS provide superior detection capabilities, they are laborious, expensive, and necessitate extensive data analysis proficiency. The extensive structural diversity of bioactive chemicals, characterized by variations in polarity, volatility, and stability, necessitates the use of many chromatographic methods. Researchers often require the integration of methodologies, such as employing gas chromatography (GC) for volatile molecules and high-performance liquid chromatography (HPLC) for non-volatiles, as illustrated by Joshi et al. (2024) in their study of glycosides and aglycones. Moreover, simple separation of chemicals is insufficient; precise structural elucidation sometimes necessitates integration with mass spectrometry (MS) or nuclear magnetic resonance (NMR), thereby increasing complexity and cost—a consideration examined by Hurkul et al. (2024) in their study of plant extracts. Ultimately, in horticultural quality control, the substantial expense and technical requirements of advanced chromatographic techniques frequently restrict their practicality, particularly beyond specialized research contexts.

Future Prospects and Recommendations

To enhance the efficacy and significance of chromatographic methods in the analysis of bioactives from horticulture products, many prospective strategies are becoming essential. Initially, the standardization and verification of methodologies, namely in sample preparation,

selection of chromatographic columns, mobile phase compositions, and detection parameters, are crucial for ensuring reproducibility and facilitating significant comparisons across various crops, laboratories, and studies. Standardized protocols would enhance collaboration and facilitate data integration on a global scale. Secondly, the incorporation of high-throughput platforms like ultra-performance liquid chromatography (UPLC) and other rapid screening methodologies can expedite the analysis of various cultivars, environmental conditions, and post-harvest treatments, thereby facilitating extensive phenotyping or breeding initiatives. Third, integrating chromatographic results with bioactivity studies (e.g., antioxidant or antibacterial evaluations) augments the functional significance of chemical profiling. According to Shakeel (2023), this integration connects analytical chemistry and functional assessment, enabling researchers to prioritize molecules with genuine biological significance. Fourth, broadening chromatographic analysis to encompass underutilized by-products and waste streams such as peels, seeds, and pomace constitutes a sustainable valorization strategy. Nguyen et al. (2024) emphasize the bioactive abundance of these fractions and their potential applications in the circular bioeconomy. Fifth, as environmental issues escalate, sustainable chromatographic methods utilizing eco-friendly solvents, reduced sample processing, and energy-efficient instruments are becoming increasingly significant. Hurkul et al. (2024) emphasize advancements in extraction and chromatographic methodologies that conform to green chemistry concepts. Finally, the implementation of sophisticated hyphenated methodologies such as LC-MS/MS, GC×GC-MS, and untargeted metabolomics unveils new possibilities in identifying hitherto uncharacterized chemicals and their dynamic profiles within horticulture matrices. Kiani et al. (2022) investigated this in algae, and the technology is readily applicable to fruit and vegetable systems, facilitating extensive metabolic fingerprinting and functional annotation.

Conclusion

Chromatographic techniques are essential for the precies analysis of bioactive chemicals in horticulture crops. Chromatography facilitates the separation, identification, and quantification of various phytochemicals in complex plant matrices, ranging from detecting using TLC to high-sensitivity quantification using HPLC MS/MS. Despite present limitaions related to standardization, matrix complexity, throughput, and cost, the increasing significance of bioactive chemicals for nutrition, health, and the sustainable use of horticultural by-products guarantees the continued evolution of chromatographic technologies. The future lies on integrated, high-throughput, sustainable methodologies that connect phytochemical profiles to biological functions and crop quality.

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ROLE OF VOLATILE COMPOUNDS IN DETERMINING AROMA AND FLAVOR OF HORTICULTURAL CROPS

Assoc. Prof. Müjgan GÜNEY

Yozgat Bozok University, Faculty of Agriculture, Department of Horticulture, Türkiye.

mujgan.guney@yobu.edu.tr

ORCID: 0000-0001-5491-1430

Lec. Dr. Selcan ÖZYALIN

Yozgat Bozok University, Faculty of Agriculture, Department of Horticulture, Türkiye.

Email: selcan.ozyalin@yobu.edu.tr

ORCID: 0000-0003-4831-8600

Asst. Prof. Dr. Gökçe AYDÖNER ÇOBAN

Yozgat Bozok University, Faculty of Agriculture, Department of Horticulture, Türkiye.

Email: gokce.aydoner@yobu.edu.tr

ORCID: 0000-0002-0851-8803

Assoc. Prof. Dr. Hakan KELES

Yozgat Bozok University, Faculty of Agriculture, Department of Horticulture, Türkiye

Email: Hakan.keles@yobu.edu.tr

ORCID: 0000-0002-8225-931X

ABSTRACT

Volatile organic compounds (VOCs) play a central role in defining the aroma and flavor quality of horticultural crops. This study focuses on the chemical composition, biosynthesis, and analytical characterization of aroma volatiles in fruits and vegetables, and explores their impact on sensory perception and product quality. Main classes of volatiles, including aldehydes, esters, terpenoids, and sulfur-containing compounds, are derived from lipid, amino acid, carotenoid, and phenylpropanoid pathways as well as enzymatic reactions including oxidation, methylation, and glycosylation, which all contribute to their structural diversity. It is important to maintain a dynamic balance between free and bound (glycosidic) forms of aroma compounds, because bound compounds can be released during ripening or processing to enhance aroma intensity. Analytical advances such as headspace SPME, GC–MS, GC×GC, and GC–olfactometry have expanded our ability to detect low-abundance and odor-active volatiles in complex matrices. Several studies in different horticultural plants illustrate how volatile profiles are effected by cultivar, environmental conditions, and postharvest treatment, with key compounds like (E)-2-hexenal, linalool, and esters correlating strongly with perceived aroma. Challenges remain in linking chemical data with sensory characteristics and in managing matrix suppression and low detection thresholds. Nonetheless, understanding VOC composition and regulation offers opportunities for breeding, postharvest handling, and product development aimed at improving flavor quality in horticultural produce.

Keywords: Aroma profile, Gas Chromatography, Fruit quality, Flavor development, Sensory evaluation

1. INTRODUCTION

Horticultural crops such as fruits, vegetables, and ornamentals not only supply nutrients but also contain aroma and flavor compounds, which are the key determinants of consumer choice. Among these quality traits, aroma (the olfactory impression of volatile compounds) and flavor (a composite sensation of taste + aroma + mouth-feel) play especially significant roles. In recent years, advances in analytical chemistry (e.g., GC–MS, GC×GC–TOF MS), genomics, and metabolomics have markedly accelerated our understanding of the volatile constituents of horticultural crops and their regulation (Abbas et al., 2023).

Volatile organic compounds (VOCs) are typically present at trace concentrations (often < 0.01 % of fresh weight in fruits), yet they are major sensory drivers because of their low odor thresholds and the remarkable sensitivity of human olfaction (Forney, 2001). Their contribution to consumer acceptance and apparent freshness, ripeness, and quality is increasingly being documented (Abbas et al., 2023).

In fleshy fruits such as apple, peach, and tomato, the major chemical classes of volatiles include esters, alcohols, aldehydes, ketones, terpenoids, and apocarotenoids (El Hadi et al., 2013). In a detailed review of peach aroma volatiles, Li et al. (2023) highlight how ripening-related changes in esters, lactones, and terpenoids contribute to peach flavour and how newer omics approaches are uncovering regulatory genes. In the case of tomato (a major vegetable/fruit crop), the flavour is increasingly seen as being determined not only by sugars and acids but by a subset of ~25-30 key VOCs among the >400 molecules detected; many derive from amino acids, fatty acids and carotenoids (Kaur et al., 2023).

Vegetables likewise have distinctive volatile profiles. In *Brassica* vegetables (broccoli, cauliflower, kohlrabi, Brussels sprouts), sulphur-compounds (isothiocyanates, nitriles), along with aldehydes and alcohols, dominate the volatile fraction. However, cooking and cultivar dramatically affect profiles. Cooking generally reduced many alcohols but increased some isothiocyanates (Wieczorek and Jeleń, 2019).

These findings highlight how important volatile compounds are for the aroma and flavor of fruits and vegetables. Different crop types and even different varieties have unique volatile profiles, which are shaped by how these compounds are made, controlled, and changed during processing. As new tools like GC×GC TOF MS allow scientists to detect and compare hundreds of volatile compounds (e.g., more than 1,500 found in tomato and pepper by Guan et al., 2025), it's becoming easier to connect these chemicals with how food smells and tastes—and use that knowledge in crop breeding. Scientists are also learning more about the genes and enzymes involved, such as transcription factors and glycosyl transferases, which help manage how aroma compounds are stored and released in fruits. This opens up new possibilities for improving flavor through genetic or metabolic engineering (Qin et al., 2025).

Nevertheless, major knowledge gaps remain: in many crops the full complement of flavour-active volatiles is still unknown, the regulation of fluxes and release (bound vs free forms) is incompletely described, the effect of complex pre- or post-harvest interventions on volatile networks is only partly understood, and the integration of sensory, metabolomic and genomic/epigenomic data remains challenging.

Therefore, this study aimed to summarize current knowledge on volatile compounds in horticultural crops, focusing on their sensory roles, biosynthesis, regulation, and responses to pre- and post-harvest conditions. It also explores strategies for aroma/flavor improvement and highlights key gaps to guide future research and crop quality enhancement.

Major Volatile Compound Classes and Their Contribution to Aroma/Flavor

Volatile compounds in horticultural crops mostly originate from four principal precursor pathways: fatty acid derivatives (e.g., C6 aldehydes/alcohols), terpenoids, phenylpropanoids/benzenoids (derived from amino acids), and breakdown products of carotenoids/apocarotenoids (Mostafa et al., 2022).

Typical aroma compounds categorized into esters (fruity), aldehydes (green/ grassy), alcohols, ketones, terpenes (floral/citrus), lactones, sulfur-containing volatiles, and phenyl/benzenoid (spicy/floral) volatile groups (Abbas et al., 2023).

Esters are among the most potent aroma contributors in many fruits. Their low odor thresholds and fruity/floral characteristics make them key quality markers. For example, esters such as methyl butanoate, ethyl hexanoate, and methyl hexanoate are primary contributors to strawberry flavor. In a comprehensive inheritance study, esters were shown to be highly heritable, and several QTLs (Quantitative Trait Loci) related to ester production were identified across strawberry cultivars (Rey-Serra et al., 2022). However, studies showed that aldehydes and alcohols decrease during ripening while esters increase (Dadwal et al., 2025). Simillary, in pear fruits, esters such as hexyl acetate and amyl acetate increase with maturity and dominate fresh fruit aroma (Shi et al., 2025). A shift in ester/aldehyde ratio can influence perception toward “green” versus “ripe fruit” aroma, e.g., in cherries where higher C6 aldehydes and lower ester levels were associated with off-herbaceous flavour (Villavicencio et al., 2021).

Aldehydes such as hexanal and (E)-2-hexenal are key green leaf volatiles in various horticultural crops, including strawberries, where they enhance fresh, herbaceous, and unripe fragrance profiles. C6 and C9 aldehydes, along with associated alcohols such as (Z)-3-hexenol, are biosynthesized through the lipoxygenase (LOX)–hydroperoxide lyase (HPL) pathway, generally accumulating in unripe, freshly harvested, or mechanically damaged tissues (Villavicencio et al., 2021; Klee and Tieman, 2018). Aldehydes, including benzaldehyde and (E)-2-nonenal, were associated with fruity and nutty sensory characteristics in melon (Majithia et al., 2021). In strawberries, these chemicals are especially prevalent during the initial ripening phases and are more linked to the feeling of freshness than to the flavor of fully ripe fruit. In the case of Korean 'Seolhyang' strawberries, short-term high CO_2 storage effectively sustained hexanal and (E)-2-hexenal concentrations while inhibiting undesirable aldehydes and ketones throughout shelf life, hence keeping favorable freshness characteristics (Kim et al., 2022). Pear investigations indicated that aldehyde accumulation is affected by storage conditions, with hexanal levels increasing at low temperatures (Shi et al., 2025).Nonetheless, although these aldehydes enhance freshness, their excessive accumulation may lead to unwelcome "cut grass" or "green bean" aromas, particularly in the setting of ripe fruit.Common chemical categories encompass esters, aldehydes, alcohols, ketones, terpenes, lactones, sulfur-containing volatiles, and phenyl/benzenoid volatiles. In horticultural fruits and vegetables, the predominant volatiles comprise esters (fruity), terpenes (floral/citrus), C6 aldehydes (green/grassy), and phenylpropanoids (spicy/floral) (Abbas et al., 2023).

Terpenes, comprising monoterpenes (C_{10}), sesquiterpenes (C_{15}), and their oxygenated derivatives, are a highly diversified and prevalent category of plant volatile organic compounds (VOCs). These chemicals are vital in plant-environment interactions and significantly contribute to the scent and flavor profiles of several fruits, flowers, and herbs. Terpenes frequently convey citrus, flowery, pine, woody, spicy, or resinous characteristics based on their structure and concentration (Jin et al., 2025). Monoterpenols, including linalool, geraniol, and nerol, are the predominant aroma-active volatiles in grapes and citrus, particularly in fragrant grape varieties such as Muscat and citrus peel oils (Lin et al., 2019). These substances impart sweet, flowery, and citrus-like

characteristics, particularly concentrated in the skins and glandular tissues of the fruit. In mango (Mangifera indica), monoterpenes including α-pinene, limonene, carene, and myrcene predominantly characterize the peel scent and exhibit considerable variation among cultivars, affecting consumer perceptions of ripeness and freshness (Mesquita et al., 2022).

Linalool and nerolidol are significant contributors to the floral aroma of oolong and green teas derived from tea leaves (Camellia sinensis), with their production being heavily influenced by light, harvest season, and enzymatic glycosidic hydrolysis (Lin et al., 2023). Basil (Ocimum basilicum), a herb recognized for its essential oil composition, contains terpenes such as eucalyptol, linalool, and methyl chavicol, which provide its distinctive spicy and sweet fragrance. Environmental factors, genotype, and developmental stage substantially influence their relative abundance (Güney et al., 2021). Phenylpropanoids and other benzenoids, derived from phenylalanine through the shikimate route, encompass aromatic chemicals such as benzaldehyde, phenethyl alcohol, and eugenol, which impart floral, spicy, or almond-like characteristics. Although their contribution is sometimes less prominent than that of esters in several fruits, they are nonetheless important for the overall scent development in horticulture crops (Abbas et al., 2023).

Many volatile fragrance molecules in fruits and other plant-derived foods are present not only in their free, volatile form but also in a glycosidically bound, non-volatile precursor state. The bonded volatiles are conjugated with sugar moieties, making them odorless until enzymatically or chemically hydrolyzed. Qin et al. (2025) assert that glycosidically bound volatiles provide a significant latent reservoir of aroma-active chemicals that may be liberated during fruit ripening, postharvest storage, thermal processing, or fermentation. The review emphasizes that the emission of these bound volatiles substantially influences the evolution of fragrance profiles, especially during late ripening phases or following tissue damage. Qin et al. underscore the significance of both natural glycosidases and microbial enzymes in facilitating this conversion, therefore affecting the sensory quality of horticultural products.

Biosynthetic Pathways and Regulation of Volatile Compounds

The synthesis of volatile aroma compounds in horticulture crops is controlled by complex biosynthetic pathways and is strictly regulated by genetic, environmental, and physiological variables. Mostafa et al. (2022) reported that the majority of aroma volatiles are produced via four principal metabolic pathways: the fatty acid pathway, yielding aldehydes, alcohols, and esters; the amino acid pathway, resulting in phenylpropanoids and benzenoids; the terpenoid pathway, originating from mevalonate or MEP pathways; and the carotenoid/apocarotenoid degradation pathway. Progress in transcriptomics and genomics has enabled researchers to pinpoint certain genes, enzymes, and regulatory elements implicated in these pathways. Li et al. (2023) discovered genes associated with ester and lactone production in peach and elucidated their transcriptional control during fruit ripening. In addition to heredity, environmental and physiological factors considerably affect volatile profiles. Cultivar, maturity stage, light exposure, temperature, and hormonal signaling, particularly ethylene and auxin, influence the production and emission of volatile chemicals, as outlined by Abbas et al. (2023). Postharvest treatment and storage are critical; for example, Shi et al. (2025) indicated that holding pear fruit at ambient temperature increased ester buildup, while cold storage inhibited fragrance formation and the expression of biosynthetic genes such as PcLOX2 and PcADH1. The sensory impression of scent is not solely determined by particular volatiles. Factors such as odour activity values (OAVs), chemical thresholds, synergistic or suppressive interactions, and the impact of the non-volatile matrix (including sugars, acids, and phenolics) all determine the final flavour profile. An example is the herbaceous off-flavour in cherry, attributed not to a singular volatile ingredient but to a modified volatile mixture interacting with the fruit's matrix

(Villavicencio et al., 2021). Although the majority of research emphasizes culinary crops, volatile chemicals are equally crucial in ornamental and floricultural plants. Zhou et al. (2023), in a review of fragrant flowers, emphasized the influence of chilling stress and epigenetic mechanisms, including DNA methylation, on volatile production and floral scent in roses.

Factors Affecting Volatile Composition and Aroma Quality

The volatile composition and aroma quality of horticultural crops are affacted by a combination of genetic, developmental, hormonal, and environmental factors. Different cultivars exhibit distinct volatile fingerprints, making varietal selection a key determinant of aroma and flavor potential. Abbas et al. (2023) highlight that cultivar identity significantly affects both free and glycosidically bound aroma compounds in fruit. Maturity and ripening stage also play a pivotal role; volatile profiles evolve dynamically during development, with esters generally increasing as fruit matures, while green leaf volatiles like C6 aldehydes tend to decline. In sweet cherry, Villavicencio et al. (2021) found that herbaceous off-flavor was linked to delayed ripening and persistently high levels of hexanal and other aldehydes. Environmental conditions before and after harvest, including light exposure, temperature, water and nutrient availability, orchard microclimate, and harvest timing, further influence volatile biosynthesis and emission. Qin et al. (2025) demonstrated that shading in grape clusters led to a reduction in bound terpenoids, showing how light intensity can affect precursor pools. Postharvest handling, storage conditions, and processing techniques also markedly alter volatile profiles. Cold storage, modified atmospheres, and mechanical processing (such as cutting, peeling, or cooking) can either diminish aromatic quality or shift the balance of key volatiles. In pear, for instance, Shi et al. (2025) observed that room temperature storage accelerated ester accumulation and aroma development compared to low-temperature storage, correlating with enhanced expression of ester biosynthetic genes. In addition to external factors, hormonal regulation plays a vital internal role. Ethylene, auxin, and jasmonates are key signaling molecules that influence the onset of ripening and the activation of volatile biosynthesis pathways. The review by Ke et al. (2025) specifically emphasizes the emerging role of auxin in modulating the expression of genes involved in volatile organic compound (VOC) production, underscoring its broader regulatory role beyond growth and development. Collectively, these factors interact across molecular, physiological, and environmental levels to shape the final aroma profile and sensory perception of horticultural products.

Applications and Future Prospects

Understanding the biosynthesis and regulation of volatile compounds in horticultural crops presents promising opportunities for improving flavor quality, optimizing postharvest management, and expanding industrial applications. Breeding programs increasingly focus on identifying specific volatiles correlated with consumer preference to guide the development of more flavorful cultivars. In tomato, for instance, genetic loci associated with volatile biosynthesis are being actively exploited to enhance aroma and taste attributes (Kaur et al., 2023). In addition to conventional breeding, progress in metabolic engineering and genome editing, especially CRISPR/Cas9 technologies—has facilitated the exact alteration of essential aroma-related genes, such as alcohol acyltransferases (AATs), lipoxygenases (LOX), and terpene synthases. Zhang et al. (2023) studied the increasing potential of these technologies for designing customized aroma profiles in economically significant crops. Volatile compounds function as sensitive biomarkers for assessing postharvest quality. Volatile organic compound profile can signify fruit maturity, flavor potential, early decay, or an outbreak of storage problems. Sun et al. (2025) highlighted significant implications for the advancement of non-invasive, real-time monitoring technology. In addition to their role in fresh produce, volatiles, particularly terpenoids, have commercial value across industries such as food and beverage

flavoring, perfumery, cosmetics, and even biofuel production. Abbas et al. (2023) emphasized the extensive use of horticulturally sourced volatiles, underscoring their importance beyond the consumer sector for fresh produce.

Knowledge Gaps and Challenges

Despite significant progress, many aspects of volatile compound regulation in horticultural crops remain unclear. The conversion of bound to free volatiles, along with transcriptional and epigenetic controls, is still not fully understood, as noted by Qin et al. (2025). Additionally, how volatiles interact with non-volatile compounds like sugars, acids, and phenolics—and how these combinations influence flavor perception—has not been well studied. Linking specific volatile organic compounds (VOCs) to consumer preferences is also challenging, due to the complexity of aroma mixtures and the effects of compound interactions such as suppression or synergy, as shown in cherry studies where no single VOC could explain off-flavors (Villavicencio et al., 2021). Environmental and agronomic factors affecting volatile profiles vary widely by crop and region and are poorly characterized. Post-harvest processes such as peeling, cooking, or packaging can alter the stability and release of aroma compounds, yet these effects remain under-researched in many fresh produce items. Finally, while molecular tools and metabolic engineering offer exciting possibilities for improving flavor, turning these advances into practical breeding strategies or industry-scale applications is still a major hurdle.

Conclusion

Volatile organic compounds are fundamental determinants of aroma and flavor in horticultural crops. The last half-decade (2020-2025) has seen substantial progress in identifying volatile compound classes, biosynthetic pathways, genetic regulation and the influence of pre-/post-harvest factors. Yet, translating this knowledge into improved aroma/flavor remains a frontier. Integrating metabolomics, sensory science, genomics and agronomy offers promise for developing horticultural crops with superior aroma and flavor, while also unlocking wider industrial applications of plant-derived volatiles.

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FARKLI TOHUMLUK ORANLARINDA EKİLEN GELEMEN ÜÇGÜLÜ İLE ARPA KARIŞIMLARININ OT VERİMİ, KALİTE KARAKTERİSTİKLERİ VE YABANCI OT KONTROLÜ ÜZERİNDEKİ ETKİSİ

Yük.Zir.Müh. Muhammet TARHAN

Çukurova Üniversitesi, Fen Bilimleri Enstitüsü, Tarla Bitkileri Anabilim Dalı, Adana, Türkiye

Email: abdulkerimtoygun3@gmail.com

ORCID:0009-0004-1478-9951

Arş.Gör. Asiye Sena ÇAVDAR

Çukurova Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü, Adana, Türkiye

Email: senacavdar00@gmail.com

ORCID:0000-0002-8634-5856

Öğr.Gör.Dr. Adnan GÖKTEN

Çukurova Üniversitesi, Kozan Meslek Yüksekokulu, Adana, Türkiye

Email: agokten@cu.edu.tr

ORCID:0000-0001-8988-9720

Doç.Dr. Recep İrfan NAZLI

Çukurova Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü, Adana, Türkiye

inazli@cu.edu.tr

ORCID: 0000-0002-6416-6603

Dr.Öğr.Üyesi. Hasan Beytullah DÖNMEZ*

Çukurova Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü, Adana, Türkiye

Email: bdonmez@cu.edu.tr (sorumlu yazar)

ORCID:0000-0003-1495-4553

ÖZET

Bu araştırma, Akdeniz iklim koşullarında Gelemen üçgülü (*Trifolium meneghinianum* Clem.) ve arpanın (*Hordeum vulgare* L.) yalın ekimleri ile farklı tohumluk oranlarındaki karışımlarının (%100 Gelemen üçgülü, %100 Arpa, %20 Gelemen üçgülü+%80 Arpa, %40 Gelemen üçgülü + %60 Arpa, %60 Gelemen üçgülü + %40 Arpa, %80 Gelemen üçgülü + %20 Arpa) ot verimi, yem kalitesi ve yabancı ot gelişimi üzerindeki etkilerini belirlemek amacıyla yürütülmüştür. Deneme, 2024-2025 kış yetiştirme mevsiminde Çukurova Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü Araştırma ve Uygulama arazisinde, tesadüf blokları deneme desenine göre üç tekerrürlü olarak kurulmuş ve yürütülmüştür. Araştırma sonuçları, toplam kuru biyomas veriminin 591.0 kg/da ile 906.2 kg/da arasında değiştiğini ve en yüksek verimin saf arpa ekiminden elde edildiğini göstermiştir. Yabancı ot bakımından en yüksek kuru yabancı ot biyoması saf ekim Gelemen üçgülünde (190.6 kg/da) gözlenmiş, arpanın karışıma katılma oranı arttıkça yabancı ot baskısı belirgin şekilde azalmıştır. Karışım uygulamalarında 10 familyaya ait 18 yabancı ot türüne rastlanmış ve Gelemen üçgülünün yalın ekimi ve arpa ile farklı tohumluk oranlarındaki karışımlarında yabani yulaf (*Avena fatua* L.) ve yabani hardalın (*Sinapis arvensis* L.) yabancı ot kompozisyonundaki oranı yüksek olduğu ortaya çıkmıştır. Yem

kalitesi bakımından ise en yüksek ham protein oranı saf Gelemen üçgülünde (%20.0) saptanmıştır. Karışım uygulamalarında ham protein oranı orta düzeyde seyretmiş, nispi yem değeri ise saf ekim Gelemen üçgülünde en yüksek (152.2) değer göstermiştir. Elde edilen bulgular, yalın ekim arpada ve arpa oranının yüksek olduğu karışım uygulamalarında, arpanın hem yüksek kuru ot verimi sağladığını hem de yabancı ot kontrolünde avantaj sunduğunu ortaya koymuştur. Bunun yanında, Gelemen üçgülünün karışımdaki oranının artırılması yem kalitesi açısından önemli bir katkı sunmuştur.

Anahtar Kelimeler: Arpa, Gelemen üçgülü, kalite, verim, yabancı ot

THE EFFECTS OF DIFFERENT SEEDING RATIOS OF GELEMEN CLOVER AND BARLEY MIXTURES ON FORAGE YIELD, QUALITY TRAITS, AND WEED SUPPRESSION

ABSTRACT

This study was conducted to determine the effects of pure sowing of Gelemen clover (*Trifolium meneghinianum* Clem.) and barley (*Hordeum vulgare* L.), as well as their mixtures at different seeding ratios (100% Gelemen clover, 100% barley, 20% Gelemen clover + 80% barley, 40% Gelemen clover + 60% barley, 60% Gelemen clover + 40% barley, 80% Gelemen clover + 20% barley), on biomass yield, forage quality, and weed development under Mediterranean climatic conditions. The field experiment was conducted during the 2024-2025 winter growing season at the Research and Application Area of the Department of Field Crops, Faculty of Agriculture, Çukurova University, Adana, Türkiye. The trial was arranged in a randomized complete block design with three replications. The findings indicated that the total dry biomass yield varied from 591.0 kg/da to 906.2 kg/da, and the highest yield was recorded in the sole barley treatment. The highest dry weed biomass (190.6 kg/da) was observed in the sole Gelemen clover treatment, while weed pressure markedly decreased as the proportion of barley in the mixture increased. In the mixture treatments, 18 weed species belonging to 10 families were identified, and it was revealed that wild oat (*Avena fatua* L.) and wild mustard (*Sinapis arvensis* L.) constituted a high proportion of the weed composition in both sole Gelemen clover and its mixtures with barley at different seeding ratios. In terms of forage quality, the highest crude protein content (20.0%) was determined in sole Gelemen clover. In the mixture treatments, protein content remained at moderate levels, whereas the relative feed value reached its maximum (152.2) in the sole Gelemen clover plots. The findings demonstrated that sole barley cultivation and mixture treatments with higher barley proportions not only provided greater dry forage yield but also offered an advantage in weed control. In addition, increasing the proportion of Gelemen clover in the mixtures contributed significantly to forage quality.

Keywords: Barley, Gelemen clover, yield, quality, weed suppression

GİRİŞ

Yem bitkileri üretimi, verimliliklerini büyük oranda kaybetmiş çayır-mera alanları üzerindeki baskının azalması ve hayvancılığın sürdürülebilirliği açısından stratejik bir öneme sahiptir. Artan nüfus ve hayvansal ürün talebi, yem kaynaklarının çeşitlendirilmesini ve kalite ile verimin aynı anda iyileştirilmesini zorunlu kılmaktadır. Bu bağlamda, farklı bitki türlerinin karışım halinde ekilmesi hem tarımsal ekosistemlerin üretkenliğini artıran hem de hayvan beslenmesinde denge sağlayan önemli bir uygulama olarak öne çıkmaktadır (De Silva vd., 2023). Bunun yanında, baklagil ve tahıl türlerinin birlikte yetiştirildiği karışık ekim sistemleri, dünya genelinde düşük maliyetle yüksek verimlilik ve yem kalitesi sağlamasının yanında yabancı ot kontrolü açısından da öne çıkan alternatifler arasında değerlendirilmektedir (Sleugh vd., 2000; Lithourgidis vd., 2011; Bedoussac vd., 2015).

Karışık ekim sistemlerinde baklagiller, simbiyotik azot fiksasyonu yoluyla toprağın besin döngüsüne önemli katkılar sağlamakta ve yetiştirildikleri alanlarda azot gübrelemesi ihtiyacını azaltmaktadır. Bunun yanında, tahıllar topraktaki azot alımı için baklagillere göre rekabet üstünlüğü sağlamasından dolayı baklagillerin büyüme ve gelişmeleri için daha fazla atmosferik azot fikse etmesini teşvik etmektedir (Giambalvo vd., 2011; Raza vd., 2023). Bu durum, özellikle azotlu gübre girdisinin azaltılmasında ekolojik ve ekonomik bir avantaj sağlamaktadır (Annicchiarico ve Tomasoni, 2010). Ayrıca, baklagillerin ham protein içeriğinin yüksek olması (Solomon vd., 2011), yemlerin besleyici değerini artırmakta ve ruminantların protein ihtiyacını karşılamada önemli bir rol oynamaktadır. Tahılların ise hızlı büyüme, yoğun kardeşlenme ve güçlü kök yapıları sayesinde yüksek kuru madde verimi sağlamaktadır (Peltonen-Sainio vd., 2009). Bu nedenle, baklagil-tahıl karışımları, her iki tür grubunun avantajlarını bir araya getiren tamamlayıcı sistemler olarak dikkat çekmektedir.

Yabancı ot rekabeti bakımından da karışık ekim sistemlerinin avantajı açıktır. Saf olarak kültüre alınan biçok baklagil yembitkisi yabancı otlarla rekabet edememekte ve buna bağlı olarak yabancı ot yoğunluğu yüksek seviyelere ulaşabilmektedir (Petraki vd., 2025). Buna karşılık tahıl ağırlıklı karışımlar, hızlı büyüme ve güçlü toprak örtüsü oluşturma özellikleri sayesinde yabancı ot gelişimini baskılamaktadır (Banik vd., 2006). Dönmez ve Hatipoğlu (2023), suni mera tesisinde koruyucu bitki olarak karışıma dahil edilen arpanın yabancı ot yoğunluğunu azalttığını bildirmişlerdir.

Son yıllarda yapılan çalışmalar, tahıl-baklagil karışımlarının başarısında ekolojik koşulların yanı sıra, tür uyumu ve türlerin karışımdaki tohumluk oranlarının kritik faktörler olduğunu göstermiştir (Ross vd., 2003; Salama ve Badry, 2015; Dönmez vd., 2024). Nitekim Lithourgidis vd. (2006), fiğ ile yulaf ve tritikalenin farklı tohumluk oranlarındaki karışımlarının ot verimi ve ot kalitesini inceledikleri araştırmada başarı için tür seçiminin önemini vurgulamış ve baklagil-tahıl türlerinin tohumluk karışımının 65:35 oranında tutulmasının hem verimi hem de kaliteyi optimize ettiğini bildirmişlerdir. Osman ve Nersoyan (1986), yüksek ot verimi ve ot kalitesi için tahıl-baklagil karışımlarında türlerin tohumluk oranlarının 66:33 olması gerektiğini bildirmişlerdir.

Bu araştırmada, Gelemen üçgülü (*Trifolium meneghinianum* Clem.) ve arpanın (*Hordeum vulgare* L.) yalın ekimleri ile farklı tohumluk oranlarındaki karışımlarının ot verimi, ot kalitesi ve yabancı ot gelişimi üzerindeki etkisinin tespit edilmesi amaçlanmıştır.

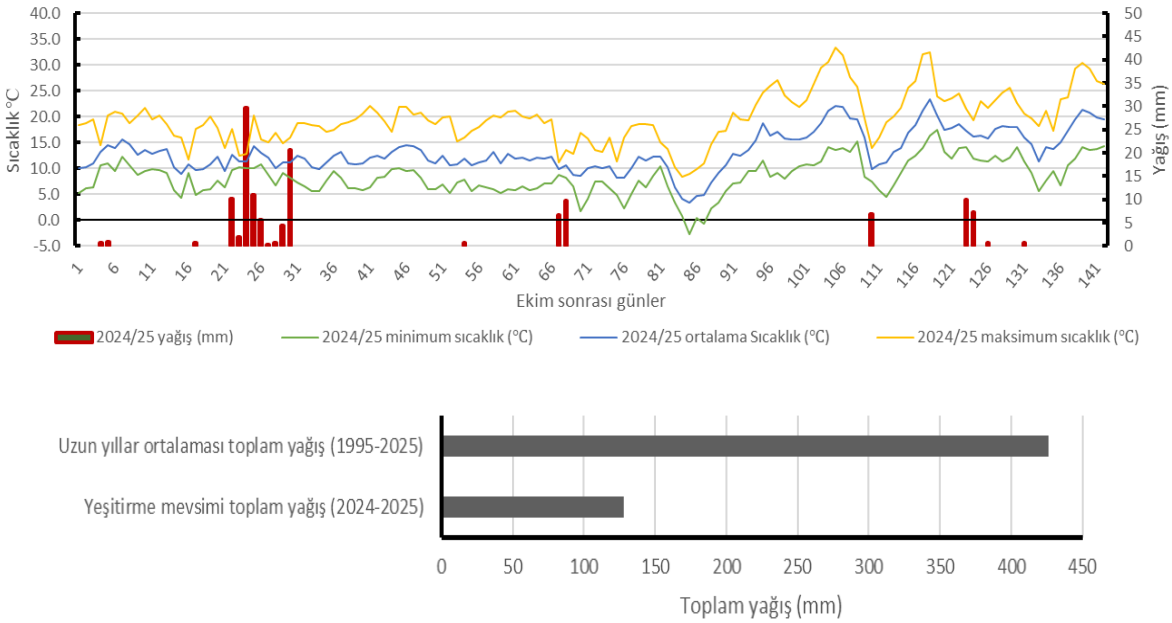
MATERYAL VE METOT

Deneme alanı, iklim ve toprak özellikleri

Deneme, Çukurova Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü Araştırma ve Uygulama arazisinde 2024-2025 kış yetiştirme mevsiminde yürütülmüştür. Araştırmanın yürütüldüğü deneme alanının deniz seviyesinden yüksekliği 33 m'dir. Deneme alanından alınan

toprak örnekleri Çukurova Üniversitesi Ziraat Fakültesi Toprak Bilimi ve Bitki Besleme Bölümü laboratuvarında analiz edilmiştir. Analiz sonuçlarına göre; toprak pH'nın 7.24, organik madde içeriğinin %1.42, kireç içeriğinin %32.7 ve toprak tekstürünün killi yapıda olduğu anlaşılmıştır.

Denemenin yürütüldüğü Adana iline ait 2024-2025 yetiştirme mevsimi ve uzun yıllar ortalaması iklim değerleri Şekil 1'de verilmiştir (Anonim, 2025).



Şekil 1. Denemenin yürütüldüğü Adana iline ait 2024-2025 yetiştirme mevsimi ve uzun yıllar ortalaması iklim diyagramı

Akdeniz ikliminin hüküm sürdüğü Adana ilinde, uzun yıllar ortalaması toplam yağış 426.1 mm olurken, 2024-2025 yetiştirme mevsiminde toplam yağış 128.2 mm olarak gerçekleşmiştir (Şekil 1). Bunun yanında, araştırmanın yürütüldüğü Ocak-Nisan ayları (ekimden sonra 32-141 günler arası) arasında 42 mm yağış gerçekleşmiş ve söz konusu aylarda ciddi kuraklık gözlenmiştir. Diğer taraftan ekimden sonra 83-89 günler arası sıcaklıklar 0 °C'nin altına düşmüş (Şekil 1) ve don zararı ortaya çıkmıştır.

Deneme deseni ve uygulamalar

Deneme tesadüf blokları deneme desenine göre 3 tekerrürlü olarak kurulmuş ve yürütülmüştür. Her parsel 5 m uzunluğunda 6 sıradan oluşmuş ve sıra arası mesafe 20 cm olarak ayarlanmıştır. Araştırmada materyal olarak, Karadeniz Tarımsal Araştırma Enstitüsü Müdürlüğünden temin edilen Gelemen üçgülünün Yörem55 çeşidi ve Doğu Akdeniz Tarımsal Araştırma Enstitüsü Müdürlüğünden temin edilen Arpanın Ay çeşidi (yazlık) kullanılmıştır. Araştırmada Gelemen üçgülü ve arpanın yalın ekimleri ile farklı tohumluk oranlarındaki karışımları (%100 Gelemen üçgülü, %100 Arpa, %20 Gelemen üçgülü+%80 Arpa, %40 Gelemen üçgülü+%60 Arpa, %60 Gelemen üçgülü+%40 Arpa, %80 Gelemen üçgülü+%20 Arpa) test edilmiştir.

Ekim, bakım ve hasat işlemleri

Araştırmada yaz dönemi boş bırakılan deneme alanı, erken sonbaharda toprak işleme ve tesviye işlemlerinin ardından ekime hazır hale getirilmiştir. Ekim öncesi türlerin tohumları çimlenme testine tâbi tutulmuş ve saf ekimlerinde Gelemen üçgülünün 2 kg/da, arpanın 16 kg/da tohumluk miktarları dikkate alınarak, test edilen karışım uygulamalarının tohumluk miktarları Gençkan (1985)'a göre hesaplanmıştır. Ekim işlemi 01.12.2024 tarihinde, markörle açılan sıralara

türlerin tohumları karıştırılarak aynı sıraya elle yapılmıştır. Deneme alanına ekimle birlikte dekara saf 5 kg N ve saf 5 kg P_2O_5 olacak şekilde 20:20:0 taban gübresi uygulanmıştır. Karışımda yer alan türlerin homojen çıkışını sağlayabilmek amacıyla ekimden sonra bir defa olmak üzere, araştırma süresince toplamda dört defa sulama yapılmıştır. Denemenin yürütüldüğü sürede yabancı ot mücadelesi yapılmamıştır. Deneme alanında yaprak bitleri gözlenmiş ve "*Acetamiprid*" etken maddeli insektisit ile mücadele edilmiştir. Hasat işlemi Gelemen üçgülünün %40-50 çiçeklenme döneminde olduğu 21.04.2025 tarihinde, 5-7 cm yükseklikten el orağı ile gerçekleştirilmiştir.

İncelenen özellikler

Hasatta 50 x 50 cm boyutlarındaki çerçeve, her bir parselde 3 adet olacak şekilde tesadüfi olarak yerleştirilmiş ve çerçeve içinde kalan ot biçilmiştir (Dönmez vd., 2024). Her parselde 3 örnekleme alanından biçilen ot laboratuvara götürülüp karışımda yer alan türler ve yabancı ot türleri elle ayrıştırılmıştır. Ayrıştırılan bu türler kese kağıtlarına yerleştirilerek 70°C'de 48 saat etüvde kurutulmuş ve sabit ağırlığa gelen her bir türün ayrı ayrı kuru ağırlıkları belirlenmiştir. Üç örnekleme alanında her tür için belirlenen kuru ağırlıkların ortalaması alınarak her bir türün parseldeki kuru ağırlığı tespit edilmiş ve gerekli dönüşümler yapılarak karışımda yer alan türler ve yabancı ot türlerinin dekara verimi hesaplanmıştır. Araştırmada yer alan karışım türleri ile yabancı ot türlerinin kuru ot verimi değerleri toplanmış ve toplam kuru biyomas verimi hesaplanmıştır.

Araştırmada karışım uygulamalarında bulunan yabancı ot türleri Davis (1965), Anonim (2008) ve Gökten ve Tansı (2015)'ya göre belirlenmiştir. Ayrıca, her karışım uygulamasında tespit edilen yabancı ot türlerinin ağırlığa göre yabancı ot kompozisyonundaki oranları aşağıdaki eşitlik yardımıyla saptanmıştır (Dönmez ve Hatipoğlu, 2023).

Türün yabancı ot kompozisyonundaki oranı

$$(\%)=\frac{\text{Parselde tespit edilen yabancı ot türünün kuru ağırlığı}}{\text{Parseldeki toplam kuru yabancı ot ağırlığı}} \times 100$$

Etüvde kurutulan Gelemen üçgülü ve arpaya ait kuru örnekler öğütülerek 1 mm'lik elekten geçirilmiştir. Öğütülen örneklerin ham protein oranı Kjeldahl yöntemi ile belirlenmiştir (N konsantrasyonu x 6.25). Karışım türlerinin NDF ve ADF oranları Van Soest vd. (1991) tarafından açıklandığı gibi yarı otomatik ANKOM220 lif analiz cihazı (ANKOM Technology, Macedon, NY, ABD) kullanılarak belirlenmiştir. Nispi yem değeri Sheaffer vd. (1995) tarafından açıklanan aşağıdaki eşitlikler yardımıyla hesaplanmıştır.

Sindirilebilir Kuru Madde Oranı (SKMO) = $88.9 - (0.779 \times \%\text{ADF})$

Kuru Madde Tüketimi (KMT) = $\frac{120}{\%\text{NDF}}$

Nispi Yem Değeri (NYD) = $\text{SKMO} \times \text{KMT} \times 0.775$

Verilerin değerlendirilmesi

Araştırmadan elde edilen veriler tesadüf blokları deneme desenine göre MSTAT-C (Michigan State University V. 2.10) istatistik paket programında varyans analizine tâbi tutulmuştur. Önemli çıkan özellik ortalamaları Duncan çoklu karşılaştırma testi ile $P<0.05$ önem düzeyinde karşılaştırılmıştır (Yurtsever, 2011).

BULGULAR VE TARTIŞMA

Toplam kuru biyomas verimi

Araştırmada Gelemen üçgülü ve arpanın yalın ekimleri ile farklı tohumluk oranlarındaki karışımlarından saptanan toplam kuru biyomas verimi ortalamaları Çizelge 1'de verilmiştir.

Çizelge 1'de izlendiği gibi, farklı karışım uygulamalarında saptanan toplam kuru biyomas verimi 591.0 kg/da (%100 Gelemen üçgülü) ile 906.2 kg/da (%100 Arpa) arasında değişmiş ve bu değişimin istatistiki olarak önemli olduğu ortaya çıkmıştır. Araştırmada toplam kuru biyomas verimi bakımından yalın ekim arpa, %20 Gelemen üçgülü+%80 Arpa (851.7 kg/da), %60 Gelemen üçgülü+%40 Arpa (887.6 kg/da) ve %40 Gelemen üçgülü+%60 Arpa karışımları hariç, test edilen diğer karışım uygulamalarına göre önemli derecede daha yüksek değer göstermiştir. Karışım uygulamalarının ortalaması olarak toplam kuru biyomas verimi ortalaması ise 789.4 kg/da olarak tespit edilmiştir. Bu sonuçlar, yalın ekim arpa ve bunun yanında Gelemen üçgülü ile arpanın %40 ve daha yüksek tohumluk oranlarındaki karışımlarının daha yüksek kuru biyomas verimi verdiğini ortaya koymaktadır. Yalın arpa ekiminde ve arpanın karışımdaki tohumluk oranlarının %40 ve daha fazla olduğu karışım uygulamalarında toplam kuru biyomas veriminin yüksek seviyelere ulaşması, arpanın yüksek kardeşlenme eğiliminde olması ve hızlı büyüme yeteneğine bağlı olarak rekabet üstünlüğü sağlaması (Ross vd., 2004) ile açıklanabilir. Benzer şekilde Dönmez vd. (2024), baklagil-buğdaygil karışımlarında buğdaygil oranı arttıkça kuru ot veriminin arttığını ve özellikle buğdaygil ağırlıklı karışımların verim açısından üstün olduğunu bildirmişlerdir. Ayrıca Chen vd. (2004), karışık ekimdeki türlerin su, besin ve ışık yönünden rekabet ettiklerini ve bu rekabetin karışım otu veriminde önemli farklılıklara neden olduğunu bildirmişlerdir. Salama (2020), baklagil-tahıl karışımında türlerin sırasıyla %75-%25 oranında karıştırılmasının yalın ekimlere göre daha yüksek verim verdiğini rapor etmişlerdir.

Çizelge 1. Gelemen üçgülü ve arpanın yalın ekimleri ile farklı tohumluk oranlarındaki karışımlarından saptanan toplam kuru biyomas verimi, Gelemen üçgülü kuru ot verimi, arpa kuru ot verimi ve kuru yabancı ot verimi ortalamaları

Karışım Uygulamaları	Toplam kuru biyomas verimi (kg/da)**	Gelemen üçgülü kuru ot verimi (kg/da)**	Arpa kuru ot verimi (kg/da)**	Kuru yabancı ot verimi (kg/da)**
Gelemen üçgülü (%100)	591.0 c^{+}	400.3 a	- -	190.6 a
Arpa (%100)	906.2 a	- -	893.5 a	12.6 d
%20 Gelemen üçgülü + %80 Arpa	851.7 a	201.9 b	636.3 b	13.5 d
%40 Gelemen üçgülü + %60 Arpa	795.4 ab	206.0 b	562.4 bc	27.0 cd
%60 Gelemen üçgülü + %40 Arpa	887.6 a	226.3 b	623.5 b	37.8 bc
%80 Gelemen üçgülü + %20 Arpa	704.8 bc	216.8 b	441.8 c	46.2 b
Ortalama	**789.4**	**250.3**	**631.5**	**54.6**

$^{+}$) Aynı sütunda benzer küçük harflerle gösterilen ortalamalar arasında Duncan testine göre $P<0.05$ önem düzeyinde istatistiki olarak fark yoktur.

**) $P\leq0.01$ düzeyinde önemli.

Gelemen üçgülü kuru ot verimi

Yalın ekim Gelemen üçgülü ile Gelemen üçgülü ve arpanın farklı tohumluk oranlarındaki karışımlarından saptanan Gelemen üçgülü kuru ot verimi ortalamaları Çizelge 1'de verilmiştir.

Çizelge 1'de görüldüğü üzere, Gelemen üçgülü kuru ot verimi ortalaması 201.9 kg/da (%20 Gelemen üçgülü+%80 Arpa) ile 400.3 kg/da (Gelemen üçgülü %100) arasında değişmiş ve bu değişimin istatistiki olarak önemli olduğu ortaya çıkmıştır. Araştırmada Gelemen üçgülü kuru ot verimi bakımından yalın ekim Gelemen üçgülü, test edilen diğer karışım uygulamalarına göre önemli derecede daha yüksek değer göstermiştir. Bunun yanında, en düşük Gelemen üçgülü kuru ot verimi ortalaması %20 Gelemen üçgülü + %80 karışımında tespit edilirken, Gelemen üçgülünün arpa ile yer aldığı karışım uygulamaları söz konusu karışımla benzer istatistiki grupta yer almıştır. Karışım uygulamalarının ortalaması olarak Gelemen üçgülü kuru ot verimi ortalaması ise 250.3 kg/da olarak saptanmıştır. Yalın ekim Gelemen üçgülünün yabancı otlara, Gelemen üçgülü ile arpanın farklı tohumluk oranlarındaki karışım uygulamalarında ise Gelemen üçgülünün yabancı otlar ve arpaya karşı rekabet üstünlüğü gösteremediği söylenebilir. Nitekim Caballero vd. (1995), farklı tohumluk oranlarındaki baklagil tahıl karışımlarında, baklagil türünün tahıllarla rekabet edemediğini ve buna bağlı olarak verim kayıplarının ortaya çıktığını rapor etmişlerdir.

Arpa kuru ot verimi

Araştırmada yalın ekim arpa ve arpanın Gelemen üçgülü ile farklı tohumluk oranlarındaki karışımlarından saptanan arpa kuru ot verimi ortalamaları Çizelge 1'de verilmiştir.

Çizelge 1'de izlendiği üzere, arpa kuru ot verimi 441.8 kg/da (%80 Gelemen üçgülü+%20 Arpa) ile 893.5 kg/da (Arpa %100) arasında değişmiş ve bu değişimin istatistiki olarak önemli olduğu ortaya çıkmıştır. Araştırmada arpa kuru ot verimi ortalaması yalın ekim arpada, test edilen diğer karışım uygulamalarına göre önemli derecede daha yüksek değer göstermiştir. Bunun yanında arpa kuru ot verimi ortalaması %80 Gelemen üçgülü+%20 Arpa karışımında, %40 Gelemen üçgülü+%60 Arpa karışımı hariç test edilen diğer karışım uygulamalarına göre önemli derecede daha düşük değer göstermiştir. Karışım uygulamalarının ortalaması olarak ortalama arpa kuru ot verimi ise 631.5 kg/da olarak tespit edilmiştir. Bu sonuçlar, yüksek kardeşlenme eğiliminde olan arpanın yabancı otlara ve Gelemen üçgülü ile karışımlarında rekabet üstünlüğü olduğunu ortaya koymaktadır (Salama, 2020).

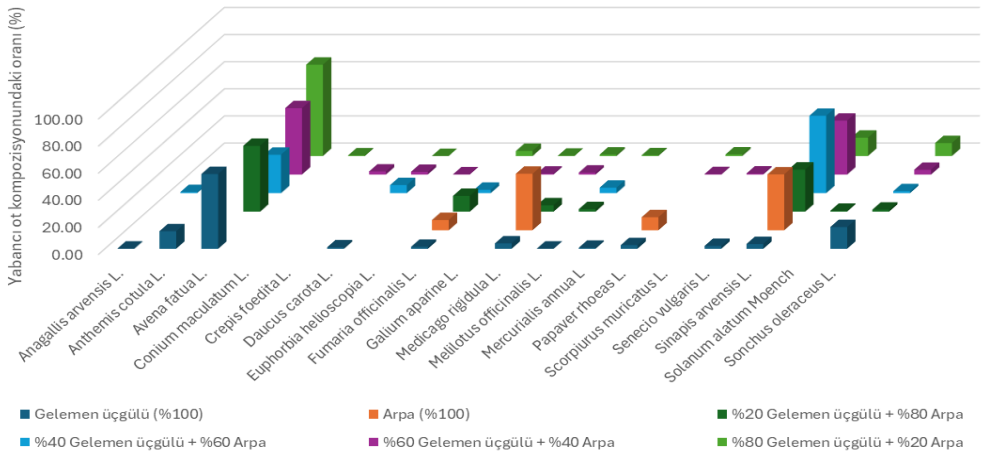
Kuru yabancı ot verimi

Araştırmada Gelemen üçgülü ve arpanın yalın ekimleri ile farklı karışım uygulamalarında saptanan kuru yabancı ot verimi ortalamaları Çizelge 1'de verilmiştir.

Çizelge 1'de de görüldüğü üzere, farklı karışım uygulamalarında kuru yabancı ot verimi ortalaması 12.6 kg/da (Arpa %100) ile 190.6 kg/da (Gelemen üçgülü %100) arasında değişmiş ve bu değişimin istatistiki olarak önemli olduğu ortaya çıkmıştır. Araştırmada kuru yabancı ot verimi ortalaması yalın ekim Gelemen üçgülünde, diğer karışım uygulamalarındakine göre önemli derecede daha yüksek değer verirken, kuru yabancı ot verimi ortalaması yalın ekim arpa ve benzer istatistiki grupta yer alan %20 Gelemen Üçgülü+%80 Arpa karışımında, diğer karışım uygulamalarındakine göre önemli derecede daha düşük değer göstermiştir. Bu sonuçlar, arpanın karışımda yer alan Gelemen üçgülünün yanında (Çizelge 1) yabancı otlara karşı rekabet avantajının olduğunu, Gelemen üçgülünün ise yabancı otlara karşı rekabet edemediğini ortaya koymaktadır. Coruh ve Tan (2016) çokyıllık baklagil tesisinde arkadaş bitki olarak kullanılan tahıl türlerinin yabancı ot kontrolünde başarı sağladığını bildirmişlerdir. Nitekim bizim çalışmamızda da arpanın karışıma katılma oranının artmasıyla kuru yabancı ot verimi linear olarak azalmıştır.

Yabancı ot türlerinin kompozisyondaki oranı

Araştırmada Gelemen üçgülü ve arpanın yalın ekimleri ile farklı tohumluk oranlarındaki karışımlarından saptanan yabancı ot türlerinin yabancı ot kompozisyondaki oranları Şekil 2'de verilmiştir.



Şekil 2. Gelemen üçgülü ve arpanın yalın ekimleri ile farklı tohumluk oranlarındaki karışımlarından saptanan yabancı ot türlerinin yabancı ot kompozisyonundaki oranları

Şekil 2'de görüldüğü üzere, Gelemen üçgülü ile arpanın farklı karışım uygulamalarında *Apiaceae* familyasından 2 tür, *Asteraceae* familyasından 4 tür, *Brassicaceae* familyasından 1 tür, *Euphorbiaceae* familyasından 2 tür, *Fabaceae* familyasından 3 tür, *Papaveraceae* familyasından 2 tür, *Poaceae* familyasından 1 tür, *Primulaceae* familyasından 1 tür, *Rubiaceae* familyasından 1 tür ve *Solanaceae* familyasından 1 tür olmak üzere toplam 18 tür tespit edilmiştir. Araştırmada Gelemen üçgülünün yalın ekiminde ve Gelemen üçgülünün arpa ile farklı tohumluk oranlarındaki karışımlarında yabani yulaf (*Avena fatua* L.) ve yabani hardalın (*Sinapis arvensis* L.) yabancı ot kompozisyonundaki oranı yüksek olurken (Acar vd., 2011), yalın ekim arpada yabani yulaf gözlenmemiş ve yabancı ot kompozisyonundaki yabani hardal oranı %41.2 olmuştur. Bunun yanında yalın ekim arpada yabancı ot kompozisyonundaki sert yonca (*Medicago rigidula* L.) oranı ise %41.7 olarak saptanmıştır.

Ham protein oranı

Araştırmada Gelemen üçgülü ve arpanın yalın ekimleri ile farklı karışım uygulamalarından saptanan ham protein oranı ortalamaları Çizelge 2'de verilmiştir.

Çizelge 2'de de görüldüğü üzere, farklı karışım uygulamalarında ham protein oranı ortalaması %13.4 (Arpa %100) ile %20 (Gelemen üçgülü %100) arasında değişmiş ve bu değişimin istatistiki olarak önemli olduğu ortaya çıkmıştır. Yalın ekim Gelemen üçgülünde ham protein oranı ortalaması, benzer istatistiki grupta yer alan yalın ekim arpa ve Gelemen üçgülünün arpa ile farklı tohumluk oranlarındaki karışım uygulamalarındakine göre istatistiki olarak önemli derecede daha yüksek değer vermiştir. Diğer taraftan, Gelemen üçgülü ve arpanın yalın ekimleri ile farklı karışım uygulamalarının ortalaması olarak ortalama ham protein oranı ise %15.1 olmuştur. Bir baklagil olan Gelemen üçgülünün buğdaygillere göre daha yüksek protein oranına sahip olması ve karışım uygulamalarında arpanın Gelemen üçgülüne göre kompozisyondaki oranının fazla olması, yalın Gelemen üçgülünün diğer karışım uygulamalarına göre daha yüksek ham protein oranına sahip olmasının nedeni olarak gösterilebilir (Salama ve Badry, 2015; Yucel vd., 2018). Nitekim De Santis vd. (2004), baklagil bitkilerinin yapraklarının yumuşak dokulu olduğunu ve buğdaygillere göre daha yüksek protein oranına sahip olduğunu rapor etmiştir.

NDF oranı

Araştırmada Gelemen üçgülü ve arpanın yalın ekimleri ile farklı tohumluk oranlarındaki karışım uygulamalarından saptanan NDF oranı ortalamaları Çizelge 2'de verilmiştir.

Çizelge 2'de görüldüğü gibi, farklı karışım uygulamalarında NDF oranı ortalaması %38.3 ile %62.5 arasında değişmiş ve bu değişimin istatistiki olarak önemli olduğu ortaya çıkmıştır. Araştırmada NDF oranı ortalaması yalın ekim Gelemen üçgülünde, benzer istatistiki grupta yer alan yalın ekim arpa ile arpa ve Gelemen üçgülünün farklı tohumluk oranlarındaki karışımlarındakine göre önemli derecede daha yüksek değer göstermiştir. Bunun yanında, farklı karışım uygulamalarının ortalaması olarak ortalama NDF oranı ise %55.3 olarak tespit edilmiştir. NDF bitkinin olgunluk düzeyini belirleyen ve çiftlik hayvanlarının yem alımını doğrudan etkileyen orandır (Yavuz vd., 2009). NDF oranı düştükçe sindirilebilirlik artmakta ve çiftlik hayvanlarının yem alımı da artmaktadır (Pedraza vd., 2017). Araştırmamızda yalın ekim Gelemen üçgülü, arpanın yalın ekimi ve Gelemen üçgülü ile farklı tohumluk oranlarındaki karışımlarına göre daha yüksek NDF oranı değeri vermiştir (Salama, 2015).

Çizelge 2. Gelemen üçgülü ve arpanın yalın ekimleri ile farklı tohumluk oranlarındaki karışımlarından saptanan ham protein, NDF, ADF oranı ve nispi yem değeri ortalamaları

Karışım Uygulamaları	Ham protein oranı (%) **	NDF oranı (%) **	ADF Oranı (%) ö.d.	Nispi yem değeri **
Gelemen üçgülü (%100)	20.0 a	38.3 b	33.9	152.2 a
Arpa (%100)	13.4 b	62.5 a	37.5	89.0 b
%20 Gelemen üçgülü + %80 Arpa	13.9 b	59.5 a	38.9	91.7 b
%40 Gelemen üçgülü + %60 Arpa	14.4 b	56.9 a	37.4	98.3 b
%60 Gelemen üçgülü + %40 Arpa	13.7 b	58.4 a	38.3	94.7 b
%80 Gelemen üçgülü + %20 Arpa	15.3 b	56.4 a	36.2	100.2 b
Ortalama	**15.1**	**55.3**	**37.0**	**104.3**

+) Aynı sütunda benzer küçük harflerle gösterilen ortalamalar arasında Duncan testine göre P<0.05 önem düzeyinde istatistiki olarak fark yoktur.

**) P≤0.01 düzeyinde önemli, ö.d.: önemli değil (P>0.05)

ADF oranı

Araştırmada Gelemen üçgülü ve arpanın yalın ekimleri ile farklı tohumluk oranlarındaki karışım uygulamalarından saptanan ADF oranı ortalamaları Çizelge 2'de verilmiştir.

Çizelge 2'de izlendiği gibi, araştırmada yer alan türlerin yalın ekimleri ile farklı karışım uygulamalarında saptanan ADF oranı ortalaması %33.9 ile %38.9 arasında değişmiş ve bu değişimin istatistiki olarak önemli olmadığı bulunmuştur. Araştırmada en düşük ADF oranı ortalaması yalın ekim Gelemen üçgülünde tespit edilirken, ADF oranı ortalaması bakımından söz konusu karışım uygulamasını %36.2 ile %80 Gelemen üçgülü+ %20 Arpa karışımı ve %37.4 ile %40 Gelemen üçgülü + %60 Arpa karışımı izlemiştir. Bunların yanında, farklı karışım uygulamalarının ortalaması olarak ortalama ADF oranı ise %37.0 olmuştur.

Nispi yem değeri

Gelemen üçgülü ve arpanın yalın ekimleri ile farklı tohumluk oranlarındaki karışımlarından saptanan nispi yem değeri ortalamaları Çizelge 2'de verilmiştir.

Çizelge 2'de görüldüğü gibi, Gelemen üçgülü ve arpanın yalın ekimleri ile farklı tohumluk oranlarındaki karışımlarında nispi yem değeri ortalaması 89.0 ile 152.2 arasında değişmiş ve bu değişimin istatistiki olarak önemli olduğu ortaya çıkmıştır. Nispi yem değeri ortalaması yalın ekim Gelemen üçgülünde, benzer istatistiki grupta yer alan diğer karışım uygulamalarındakine göre önemli derecede daha yüksek değer göstermiştir. Bunun yanında, farklı karışım uygulamalarının ortalaması olarak ortalama nispi yem değeri 104.3 olmuştur. Nispi yem değeri, NDF ve ADF değerleri ile negatif ilişkide bulunan ve yemin kalitesini rakamsal olarak ifade eden bir indekstir (Yavuz vd., 2009; Cinar vd., 2019). Nispi yem değerine göre, Ball vd. (2001) tarafından (151'den yüksek; en yüksek kalite, 151-125; yüksek kalite, 124-103; iyi, 102-87; orta, 86-75; kötü ve 75'den daha düşük; çok kötü) yemin kalitesi kategorize edilmiştir. Bu değerlere göre yalın Gelemen üçgülü en yüksek kalitede yer alırken, yalın arpa ve Gelemen üçgülünün arpa ile karışımları orta sınıfta yer almıştır.

SONUÇ

Araştırma bulguları, yüksek kardeşlenme eğiliminde olan arpanın yalın ekiminde ve özellikle arpa oranı yüksek karışım uygulamalarında, hem yüksek kuru ot verimi verdiğini hem de yabancı ot kontrolünde avantaj sağlandığını ortaya koymuştur. Diğer taraftan, yalın ekilen Gelemen üçgülünde ve Gelemen üçgülünün karışımdaki oranının artırılması ile yem kalitesinin arttığı anlaşılmıştır. Bu araştırma, karışık ekim sistemleri ile kaba yem üretimi yapacak üreticilere ön bilgi verecek olup, yapılacak araştırmalar için kaynak oluşturacaktır.

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MEYVE TÜRLERİNDE DOKU KÜLTÜRÜ UYGULAMALARI: BAŞARILAR, SORUNLAR VE ÇÖZÜM YAKLAŞIMLARI

Doç. Dr. Murat GÜNEY
Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü
Email: murat.guney@yobu.edu.tr
ORCID: 0000-0003-2882-8347
Öğr. Gör. Dr. Selcan ÖZYALIN
Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü
Email: selcan.ozyalin@yobu.edu.tr
ORCID: 0000-0003-4831-8600
Doç. Dr. Hakan KELES
Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü
Email: hakan.keles@yobu.edu.tr
ORCID: 0000-0002-8225-931X
Doç. Dr. Servet ARAS
Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü
Email: servet.aras@yobu.edu.tr
ORCID: 0000-0002-0347-6552

ÖZET

Doku kültürü, bitki biyoteknolojisinde güçlü bir araç olmasının yanı sıra meyve yetiştiriciliğinde sürdürülebilir, verimli ve kaliteli üretim sistemlerinin geliştirilmesine önemli katkılar sağlamaktadır. Meyve yetiştiriciliğinde doku kültürü uygulamaları, bitkilerin klonal çoğaltımı yoluyla genetik olarak homojen materyal elde edilmesini ve genetik modifikasyonlar aracılığıyla hastalıklara karşı daha dirençli hale getirilmesini mümkün kılmaktadır. Bu teknikler, meyve türlerinin üretiminde hastalıksız ve yüksek kaliteli bitkiler elde edilmesini sağlarken, aynı zamanda belirli fonksiyonel bölgelerin ve metabolik bileşiklerin gelişimi üzerinde olumlu etkiler yaratmaktadır. Son yıllarda yapılan araştırmalar birçok meyve türünde doku kültürü ve mikroçoğaltım tekniklerinin yüksek başarı oranlarına ulaştığını ortaya koymuştur. Meristem kültürü, hızlı çoğaltımın yanı sıra genetik olarak daha stabil ve ticari değeri yüksek bitki materyallerinin elde edilmesine olanak tanımaktadır. Ancak, doku kültürü uygulamaları genetik stabilite kaybı, kalus kalitesinin düşmesi, fenolik madde salınımı, kontaminasyon ve adaptasyon sürecindeki zorluklar gibi bazı sınırlayıcı faktörlerle karşı karşıyadır. Bu sorunların aşılabilmesi için uygun eksplant seçimi, kültür ortamı bileşiminin optimize edilmesi, uygun büyüme düzenleyicilerinin kombinasyonu ve ışık koşullarının kontrolü büyük önem taşımaktadır. Doku kültürü tekniklerindeki ilerlemeler, yalnızca üretim verimliliğini değil, aynı zamanda çevresel sürdürülebilirliği de artırmaktadır. Geleneksel yöntemlere göre daha az alan ve su kullanımı gerektiren bu teknikler, özellikle su kaynakları sınırlı bölgelerde avantaj sağlamaktadır. Ayrıca, doku kültürüyle üretilen bitkilerin hastalıklara karşı daha dirençli ve genetik olarak kararlı olması, uzun vadede meyve yetiştiriciliğinde

ekonomik kazanç, çevresel denge ve biyolojik çeşitliliğin korunması açısından önemli bir potansiyel sunmaktadır.

Sonuç olarak, meyvecilikte doku kültürü uygulamaları; başarı oranları, karşılaşılan zorluklar ve çözüm stratejileri açısından değerlendirildiğinde, modern tarımda sürdürülebilir üretimi destekleyen ve gelecekte daha geniş uygulama alanı bulması beklenen yenilikçi bir teknolojik yaklaşım olarak öne çıkmaktadır.

Anahtar Kelimeler: Doku kültürü, *in vitro* teknikler, meyve türleri, mikroçoğaltım

ADVANCES, CHALLENGES, AND SOLUTION STRATEGIES IN TISSUE CULTURE APPLICATIONS OF FRUIT SPECIES

ABSTRACT

Tissue culture is a powerful and versatile tool in plant biotechnology, contributing significantly to the development of sustainable, efficient, and high-quality fruit production systems. In fruit cultivation, tissue culture enables the production of genetically homogeneous material through clonal propagation and the enhancement of disease resistance through genetic modification. These techniques not only ensure the production of disease-free and high-quality plants but also promote the development of specific functional tissues and metabolic compounds. Recent research has demonstrated the high effectiveness of tissue culture and micropropagation methods in numerous fruit species. Meristem culture facilitates rapid plant multiplication and allows the production of genetically stable and commercially valuable plant materials. However, tissue culture applications face several challenges, including genetic instability, reduced callus quality, phenolic exudation, contamination, and difficulties during the acclimatization stage. Overcoming these limitations requires careful explant selection, optimization of culture medium composition, appropriate combinations of growth regulators, and control of environmental conditions such as light and temperature. Advancements in tissue culture methodologies not only improve production efficiency but also contribute to environmental sustainability. Compared to conventional propagation techniques, tissue culture requires less space and water, offering particular advantages in regions with limited natural resources. Furthermore, tissue-cultured plants—with their enhanced genetic stability and disease resistance—provide long-term economic benefits, environmental resilience, and support for biodiversity conservation in fruit cultivation.

In conclusion, when evaluated in terms of success rates, challenges, and solution strategies, tissue culture applications in fruit growing represent an innovative technological approach that supports sustainable and environmentally friendly practices in modern agriculture and holds great potential for broader use in the future.

Keywords: Tissue culture, *in vitro* techniques, fruit species, micropropagation

1. GIRIŞ

Doku kültürü, bitki biyoteknolojisinin en kapsamlı ve etkili yöntemlerinden biri olarak, meyve türlerinin üretiminde önemli bir rol oynamaktadır. Bu teknik, genetik olarak homojen ve sağlıklı bitki materyalleri elde edilmesine olanak tanırken, aynı zamanda bitkilerin klonal çoğaltılması ve genetik modifikasyon süreçlerinde temel bir yapı taşı oluşturur (Silva ve ark., 2019; Espinosa-Leal ve ark., 2018). Meyve yetiştiriciliği, dünya genelinde artan gıda talebi ve sınırlı tarım alanları nedeniyle sürdürülebilir ve verimli üretim sistemleri geliştirme ihtiyacı taşımaktadır. Doku kültürü uygulamaları bu bağlamda, hastalıklara karşı dirençli ve yüksek verimli bitki türlerinin yetiştirilmesinde dikkate değer başarılara ulaşmıştır (Wada ve ark., 2020; Abebaw ve ark., 2021).

Meyve türlerinin doku kültürü ile üretimi, bitkilerin genetik potansiyelini en optimize şekilde kullanabilmekte ve üreticilere yüksek kalite ve hastalıksız ürünler sunabilmektedir. Özellikle meristem kültürü, bu süreçte yüksek hız ve genetik istikrar sağlamakla birlikte, tarım ekonomisinde ve gıda güvenliğinde ciddi katkılar sağlamaktadır (Wada ve ark., 2020; Chavan ve ark., 2024). Doku kültürü yöntemleri, bitkilerin gelişimsel süreçlerinin kontrol edilmesi ve özelleştirilmesi için de kullanılmakta, bu da meyve türlerinin istenen fiziksel ve kimyasal özelliklere sahip olması açısından büyük önem taşımaktadır (Espinosa-Leal ve ark., 2018; Galatalı ve ark., 2021).

Bununla birlikte, meyve doku kültürü uygulamaları bazı zorluklarla da karşı karşıya kalmaktadır. Genetik stabilite kaybı, kalus kalitesinin düşmesi, kontaminasyon ve adaptasyon problemleri gibi konular, bu yöntemlerin etkinliğini kısıtlamaktadır (Silva ve ark., 2019; Galatalı ve ark., 2021; Godana ve ark., 2023). Bu sorunların üstesinden gelebilmek için eksplant seçimi, kültür ortamı bileşimi, büyüme düzenleyicileri ve ışık koşulları gibi parametrelerin optimize edilmesi büyük öneme sahiptir (Espinosa-Leal ve ark., 2018; Costa ve ark., 2019). Ayrıca, doku kültürü tekniklerinin çevresel sürdürülebilirliğe sağladığı katkılar da göz ardı edilmemelidir; bu uygulamalar geleneksel yöntemlere kıyasla daha az alan ve su tüketmektedir, bu da özellikle su kaynaklarının kısıtlı olduğu bölgelerde büyük avantaj sağlamaktadır (Wada ve ark., 2020; Bhakta ve ark., 2020).

Sonuç olarak, doku kültürü uygulamaları, meyve yetiştiriciliğinde yenilikçi bir teknolojik yaklaşım olarak dikkat çekmekte ve sürdürülebilir üretim sistemlerinin geliştirilmesinde önemli bir rol oynamaktadır. Bu uygulamaların başarısı, karşılaşılan zorluklarla başa çıkma stratejileri ile daha da pekiştirilebilir. Gelecekte, doku kültürü tekniklerinin daha geniş uygulama alanları bulması ve modern tarımın temel unsurlarından biri olarak ön plana çıkması beklenmektedir (Shishodia ve ark., 2025; Hasan ve ark., 2020).

Meyve bitkileri, kaliteli tohum üretiminin güç olması, çelikle çoğaltmanın sınırlı verim göstermesi veya hastalık taşıma riskinin yüksek olması gibi nedenlerle, doku kültürü teknikleri için son derece uygun materyaller sunmaktadır. Doku kültürü, aseptik koşullarda hücrelerin, dokuların ya da organların çoğaltılması ve rejenerasyonu yolu ile klonal çoğaltma, temiz materyal elde etme, genetik ıslah ve koruma gibi birçok avantaj sağlar. Örneğin, bu teknikler hastalıksız anaç üretiminden, nadir veya zorlu çoğaltılan meyvecilerin çoğaltılmasına kadar geniş bir uygulama alanına sahiptir. Bu bağlamda, meyve türlerinde doku kültürü uygulamalarının faydaları büyük olsa da, özgül meyve türlerine uyarlanması sırasında birtakım teknik ve pratik zorluklar ortaya çıkmaktadır.

Bu çalışmada, meyve türlerinde doku kültürü bağlamında üç ana başlık altında konular ele alınacaktır: (1) gelişmeler/yenilikler, (2) karşılaşılan zorluklar ve (3) çözüm stratejileri. Son bölümde, bulguların özeti ile birlikte ileriye dönük öneriler sunulacaktır.

2. Doku kültürü uygulamalarında gelişmeler

2.1 Mikrokültür ve klonal çoğaltma

Meyve türlerinde klonal çoğaltma amacıyla doku kültürü tekniklerinin artan şekilde kullanıldığına dair çok sayıda çalışma vardır. Örneğin, yüksek verimli ve hastalıksız anaç üretimi için mikroçoğaltma sistemleri başarıyla uygulanmaktadır (Correia ve ark., 2024). Ayrıca, meyve türlerine özel besi ortamlarının ve düzenleyicilerin optimize edilmesiyle çoğaltma oranlarında iyileşme kaydedilmiştir (Güney, 2019; Georgieva ve ark., 2021).

Mikrokültür, bitki biyoteknolojisinde önemli bir konum kazanmış bir tekniktir ve meyve türlerinin klonal çoğaltma süreçlerinde hayati bir rol oynamaktadır. Bu yöntem, genetik olarak homojen ve patojenlerden arınmış bitkilerin hızla üretilmesini sağlarken, tarımsal verimliliği artırmak için de kritik bir mekanizmadır (Hailu ve ark., 2022; Sharma ve ark., 2023). Klonal çoğaltmada, belirli bir bitkiden alınan eksplantların (örneğin meristematik dokular) laboratuvar ortamında çoğaltılması ve gelişim sürecinin yönlendirilmesi hedeflenir. Böylece, istenen karakteristiklere sahip bitkilerin yüksek miktarda ve kısa sürede üretilmesi mümkün hale gelir (Hailu ve ark., 2022).

Mikrokültür tekniği, özellikle tarım endüstrisinde çeşitli avantajlar sunmaktadır. Bu yöntemle üretilen bitkiler, saha koşullarında en az direnç gösterecek şekilde hastalıklara karşı daha dayanıklı hale getirilmektedir (Sharma ve ark., 2023). Bitkilerin farklı gelişim aşamalarında, kültür ortamında kullanılan büyütme düzenleyicileri, organogenez sürecini etkileyerek bitkilerin kök ve sürgün gelişimini optimize eder (Elyazid ve ark., 2021). Bunun yanı sıra, mikrokültür uygulamaları, bitki türlerinin genetik çeşitliliğini artırarak yeni genotiplerin oluşturulmasına yardımcı olur; bu durum, meyve türlerinin genetik kaynaklarının korunması ve iyileştirilmesi açısından önem taşır (Hailu ve ark., 2022; Cappelletti ve ark., 2016; Güney, 2023).

Ancak mikrokültür ve klonal çoğaltma uygulamaları bazı güçlükler içermektedir. Özellikle transplantasyon sonrası aklimatizasyon süreci büyük zorluklar içermektedir. Laboratuvar ortamında sağlanan yüksek nem düzeyleri, bitkilerin dış ortam koşullarında kurumasına neden olabilmekte ve bu da toprağa aktarılan bitkilerin sağlığını etkilemektedir (Moreno-García ve ark., 2025). Ayrıca, genetik stabilite kaybı ve mikroorganizma kontaminasyonları gibi sorunlar, klonal çoğaltmanın verimliliğini tehdit eder (Nguyen & Ho, 2019; Jiang ve ark., 2015). Bu sıkıntıların aşılması için, eksplant seçimi ve kültür ortamlarının optimize edilmesi hayati öneme sahiptir. Özellikle, ideal büyüme faktörlerinin belirlenmesi ve uygulanması başarılı bir mikrokültür süreci için kritik öneme sahiptir (Wijerathna-Yapa ve ark., 2022).

Gelişmiş mikrokültür teknikleri, su kullanımını önemli ölçüde azaltarak çevresel sürdürülebilirliğe de katkıda bulunmaktadır. Düşük alan ihtiyacı, yerel ekosistemler üzerindeki baskıyı azaltmakta ve uzun vadede tarımsal üretkenliğin artırılmasına yardımcı olmaktadır (Hailu ve ark., 2022; Yasemin ve Beruto, 2024). Gelecekte, mikrokültür ve klonal çoğaltma uygulamalarının daha fazla yaygınlaşması ve çeşitli meyve türleri için optimize edilmiş tekniklerin geliştirilmesi beklenmektedir, bu da meyve yetiştiriciliğinde sürdürülebilir bir yaklaşımın temelini oluşturacaktır (Domingues ve ark., 2024).

2.2 Somatik embriyogenez, organogenez

Somatik embriyogenez (SE) ve organogenez, bitki doku kültürü uygulamalarında önemli rol oynayan iki temel rejeneratif süreçtir. Bu süreçler, meyve türlerinin klonal çoğaltımının gerçekleştirilmesinde ve genetik çeşitliliğin artırılmasında kritik öneme sahiptir (Wang ve ark., 2023; Guan ve ark., 2016). Somatik embriyogenez, bitki hücrelerinin, embriyo benzeri yapılar oluşturmak için dedifferentiyasyon ve yeniden farklılaşma sürecine girmesi olarak tanımlanabilir. Bu yöntem, genetik çeşitliliğin korunmasında ve araştırmalarda potansiyel

taşımaktadır, çünkü homojen ve hastalıksız bitki materyalleri üretebilme yeteneğine sahiptir (Mohammadi ve ark., 2023; Silva ve ark., 2009).

Somatik embriyogenez sürecinde uygun bir eksplant seçimi ve büyüme düzenleyicilerinin (auxin ve sitokinin gibi) kullanımı büyük önem taşır (Silva ve ark., 2009). Örneğin, Passiflora türlerinde yapılan araştırmalar, zygotik embriyoların kullanımı ile somatik embriyogenez sürecinin etkinliğinin artırılabileceğini göstermektedir (Fernando ve ark., 2007). Somatik embriyogenez, bitkilerin nadir hastalıklara ve çevresel stres faktörlerine karşı dayanıklılığını artırmak için de kullanılmaktadır (Mohammadi ve ark., 2023). Dolayısıyla, bu teknik, genetik mühendislik ve elde edilen embriyoların genetik stabilitesini göz önünde bulundurarak, gelecekte çeşitli meyve türlerinin geliştirilmesinde önemli bir araç olarak dikkate alınmalıdır (Aroonluk ve ark., 2019).

Diğer bir önemli süreç ise organogenezdir. Organogenez, doku kültürü ortamında bitkisel organların (kök, dal, yaprak) oluşumunu ifade eder. Bu süreç, normal şartlarda bitkinin gelişimi sırasında meydana gelen doğal olayları taklit ederek, belirli bir organ oluşturma kapasitesine sahip hücrelerin belirlenmesini sağlar (Huh ve ark., 2017; Rodge ve Patil, 2020). Organogenez, özellikle büyük hacimlerde ve kısa sürelerde bitki üretiminin sağlanmasında önemli bir rol oynamaktadır (Debnath ve Arigundam, 2020). Bunun yanı sıra, organogenez ile elde edilen bitkiler genellikle daha az genetik varyasyon gösterirler, bu da ekonomik olarak avantaj sağlayan homojen bir üretim sağlar (Karakoyun ve ark., 2023).

Organogenez sürecinde, bitki büyüme düzenleyicilerine (özellikle BAP ve NAA gibi hormonlar) uygun kombinasyonların kullanılması, değişik organların oluşumunu sağlar (Huh ve ark., 2017). Bu uygulamalar, bitki gelişiminde farklı aşamalarda kritik olduklarından, genç yapraklar ve kollar genellikle bu süreçte en ideal eksplantlar olarak tercih edilir (Debnath, 2007). Bu bağlamda, organogenez ve somatik embriyogenez süreçlerinin birlikte kullanımı, bitki kültüründeki tekrar eden sorunları minimize etmekte ve daha sağlıklı bir çoğaltım süreci sağlamaktadır (Ali-Dinar ve ark., 2021).

Ayrıca, hem somatik embriyogenez hem de organogenez süreçlerinde elde edilen callus, genellikle genetik modifikasyonlar için bir başlangıç materyali olarak kullanılmaktadır. Callus hücre grupları, embriyo ve organ oluşumunun yanı sıra, genetik materyalin transferi için de yararlı bir platform sunmaktadır (Zhang ve ark., 2022; Elsheikh ve ark., 2013). Bu nedenle, somatik embriyogenez ve organogenez, yalnızca bitki biyoteknolojisi için değil, aynı zamanda tarımsal verimlilik açısından da büyük bir potansiyele sahiptir.

2.3 Hastalıklardan ari materyallerin çoğaltımı

Meyve türlerinde hastalıksız anaç elde edilmesi büyük önem taşır. Doku kültürü yöntemi, anaç materyallerinin virus veya viroidlerden arındırılmasında yaygın olarak kullanılmaktadır. Bu yolla sağlıklı ve homojen anaç üretimi mümkün kılınmış, pazara sunulan materyal kalitesi artmıştır (Penna ve Jain, 2023).

Hastalıklar, bitki üretiminde en büyük tehditlerden biridir ve meyve türlerinde verim kayıplarına neden olan önemli faktörler arasında yer alır. Hastalıklardan ari materyallerin çoğaltımı, bitki biyoteknolojisinde ve tarım pratiğinde kritik bir öneme sahiptir. Bu yöntem, bitkilerin sağlıklı ve genetik olarak homojen materyallerden elde edilmesini sağlar, böylece hem verimlilik artar hem de ürün kalitesi yükselir (Huh ve ark., 2017).

In vitro bitki kültürü, hastalıklardan ari materyallerin üretiminde tercih edilen yöntemlerden biridir. Bu süreçte, hastalık taşıyan bitkilerin maksimum derecede dezenfekte edilmesi ve yapılan kültür işlemlerinin mikroorganizmalar açısından temiz bir ortamda gerçekleştirilmesi gereklidir (Huh ve ark., 2017). Eksplantların temizliği ve hastalıksız olması, başarılı bir doku kültürü sürecinin temelini oluşturur. Literatürde, sağlıklı eksplantların kullanımı ile yapılan in

vitro çoğaltım yöntemlerinin, bitki kökenli hastalıkların kontrolünde etkili olduğu kanıtlanmıştır (Şener ve Kurt, 2022).

Özellikle meyve türleri, hastalıklara karşı hassasiyetleri nedeniyle in vitro kültür ortamında korunma ve çoğaltım işlemlerinin titizlikle yapılması gerekmektedir. Örneğin, *Passiflora edulis* gibi türlerin hastalıklardan ari bitki materyalleri ile çoğaltılması, bu bitkilerin hem üretiminde hem de sürdürülebilirliğinde olumlu sonuçlar vermektedir (Huh ve ark., 2017). Ayrıca, bu türlerin mikrokültür teknikleri ile hastalıklardan ari bir şekilde çoğaltılması, hem üretim sürecinin hızlanmasına hem de sağlık açısından daha kaliteli ürünlerin elde edilmesine yardımcı olmaktadır (Ngomuo ve ark., 2014; Güney, 2023).

Hastalıksız bitki materyallerinin elde edilmesi sırasında kullanılan büyüme düzenleyicileri (auxinler, sitokininler), bitki gelişimini etkileyerek sağlıklı ve dayanıklı materyallerin üretilmesine katkı sağlar. Bunun yanı sıra, in vitro çoğaltma süreçleri, bitkilerin genetik çeşitliliğini korurken, aynı zamanda sağlıklı bireylerin üretimini mümkün kılar. Bu süreçler, sağlıklı çeşitli bitkilerin elde ediliminde önemli bir yöntem sunar (Gaínza-Cortés ve ark., 2015).

Hastalıksız materyallerin çoğaltılması, tarımda yalnızca verim kaybını önlemekle kalmaz; aynı zamanda bitkilerin yüksek kaliteli ürünler vermesini de destekler. Alınan hastalıksız eksplantlar ile elde edilen bitkiler, genellikle daha dayanıklı ve verimlidir (Şener ve Kurt, 2022). Bu durum, hastalıklara karşı direnci artıran özelliklerin kazandırılmasına ve bu sayede daha sürdürülebilir tarım uygulamalarının oluşmasına olanak tanır (Gaínza-Cortés ve ark., 2015).

2.4 Optimizasyon ve biyoteknolojik entegrasyon

Doku kültürü sistemlerinde besi ortamlarının, hormon kombinasyonlarının ve rejenerasyon protokollerinin optimize edilmesiyle verim artışı sağlanmıştır. Ayrıca, moleküler markırlar, genetik transformasyon ve omik teknolojiler doku kültürü ile entegre edilmeye başlanmıştır (Pithiya ve ark., 2022).

Meyve türlerinde doku kültürü uygulamaları, mikrokültür, somatik embriyogenez, temiz materyal üretimi ve biyoteknolojik entegrasyon gibi alanlarda önemli ilerlemeler göstermiştir. Bu gelişmeler, meyve bahçeciliği ve anaç üretiminde kalite ve sürdürülebilirliği artırma potansiyeli taşımaktadır (Güney, 2019).

Kültür koşullarının optimize edilmesi, bitki dokusunun büyümesi ve gelişimi için gerekli olan ideal ortamın sağlanmasını içerir. Bu, genellikle besin ortamlarının bileşimi, pH düzeyi, ışık yoğunluğu ve sıcaklık gibi faktörlerin dikkatlice ayarlanmasını gerektirir. Örneğin, bitki büyüme düzenleyicileri olan auxin ve sitokininlerin kombinasyonları, somatik embriyogenez ve organogenez süreçlerinde kritik rol oynar; bu nedenle bu hormonların dozajlarının optimize edilmesi, başarılı doku kültürü uygulamalarında başarıya ulaşmada kilit faktördür (Qiang ve ark., 2020; Hesami ve ark., 2020).

Son yıllarda, biyoteknolojinin sunduğu yenilikler, bu optimizasyon süreçlerinin daha da geliştirilmesini mümkün kılmaktadır. Gelişmiş teknikler, mikro akışkan sistemler ve biosensörler gibi biyoteknolojik aletlerin kullanımı, doğru ve hızlı değerlendirme yaparak bitki kültürü koşullarının optimize edilmesini sağlamaktadır (Shishodia ve ark., 2025; Jamshidi ve ark., 2019). Bu tür entegre sistemler, özellikle metabolit sentezini artırmak ve bitkilerin besin verimliliğini sağlamak için kullanılmaktadır.

Bunlara ek olarak, bitki kültür teknikleri ve genetik mühendisliği uygulamalarının bir araya getirilmesi, etkinliğin artırılmasında önemli bir rol oynamaktadır. Yenilikçi yöntemlerle, belirli bitki türlerinin genetik özellikleri üzerinde değişiklikler yapılarak, daha yüksek kaliteli ve hastalıklara dayanıklı bitki çeşitleri elde edilebilir. Örneğin, Amerikan ginsenginin *(Panax quinquefolius*) doku kültürü uygulamalarının optimizasyonu, ginsenosid üretimini artırmaya

yönelik önemli katkılar sağlamıştır (Qiang ve ark., 2020; Nawrot-Chorabik & Pietrzykowski, 2018).

Hastalıksız bitki materyalleri elde etmek için in vitro koşulların optimize edilmesi, biyoteknolojik yöntemlerle birleştiğinde, bitki üretiminde sürdürülebilir bir yaklaşım sunar (Karim, 2022; Hesami ve ark., 2020). İleri biyoteknolojik yöntemler, bitki doku kültüründe olası kontaminasyonların önlenmesi ile ilgili çözümler geliştirmekte, bu da daha sağlıklı bitki materyallerinin elde edilmesine yardımcı olmaktadır (Rawal & Keharia, 2019; Mahna, 2013).

Bu bağlamda, özellikle yüksek değerli metabolitlerin üretimi için, hücre kültürlerinin optimum koşullarda yürütülmesi önem taşımaktadır. Bitki hücre kültürü ile elde edilen biyoaktif bileşenler, hem gıda hem de ilaç sektöründe kullanılabilen önemli doğal ürünlerdir. Örneğin, bitki hücre kültürü teknikleri, cilt bakımında kullanılan doğal antioksidanların üretiminde önemli bir rol oynamaktadır (Bouzroud ve ark., 2023; Georgiev ve ark., 2018). Metabolitlerin bu tür süreçler aracılığıyla üretilmesi, ticari pazarda büyük bir fırsat sunmakta, aynı zamanda doğanın korunmasına yarar sağlamaktadır.

3. Karşılaşılan Zorluklar

3.1 Kontaminasyon, aseptik koşul, maliyet

Doku kültürü sistemlerinde kontaminasyon (bakteri, fungus, vb.) hâlâ en yaygın teknik sorundur. Birçok meyve türü için anaç materyali güçlü sterilizasyon gerektirirken, bu aşamada rejenerasyon yeteneği azalabilmektedir. (Pithiya ve ark., 2022). Ayrıca, aseptik ortam, enerji tüketimi ve iş gücü maliyetleri doku kültürünün genişletilmesini sınırlamaktadır (Pandey ve ark., 2024).

Bitki doku kültürü uygulamalarında en yaygın sorunlardan biri kontaminasyondur. Kontaminasyon, genellikle bakteriyel ve fungal patojenlerin doku kültürü ortamında üremesi ile meydana gelir ve bu durum, bitki gelişimini olumsuz yönde etkileyebilir (Akdemir ve ark., 2016). Aseptik koşulların sağlanmaması, örneğin sterilizasyon işlemlerinin yetersiz yapılması, kontaminasyon riskini artırır. Kontaminasyonla başa çıkılması gerektiğinden, mikroorganizmalara karşı etkili önlemler alınması büyük önem taşır; bu genellikle steril ortam koşullarında ve uygun malzemelerle sağlanmalıdır (Tekdal, 2020).

Aseptik koşulların sağlanması, doku kültürü başarı oranını doğrudan etkileyen bir faktördür. Uygun aydınlatma, sıcaklık, nem ve aseptik şartların oluşturulması, bitki hücrelerinin veya dokularının sağlıklı bir şekilde gelişebilmesi için gereklidir. Aksi takdirde, ortamda bulunan patojenlerin kontrol altına alınamaması, doku kültürlerinin çökmesine ve beklenen sonuçların elde edilememesine yol açar. Örneğin, ortam kültürlerinde kullanılan besin çözeltilerinin mineral ve vitamin içeriğinin titizlikle optimize edilmesi gerekir, zira bu koşullar, bitki hücrelerinin gelişimini etkileyebilir (Okudur ve Ercan, 2016).

Doku kültürü süreçlerinin maliyetleri, genellikle küçük ölçekli işletmeler için engelleyici bir faktör olarak ortaya çıkmaktadır. Doku kültürü laboratuvar ekipmanları, steril malzemeler ve besin çözeltileri gibi giderler, başlangıç maliyetlerini artırmaktadır. Bunun yanı sıra, enerji tüketimi ve iş gücü maliyetleri de etkin bir doku kültürü sürecinin gerektirdiği önemli masraf kalemleridir. Yüksek maliyetler, küçük çiftçiler veya yeni girişimler için doku kültürlerinin uygulanabilirliğini zorlaştırabilir (Can ve Gürel, 2023).

3.2 Genotip bağımlılığı

Meyve türlerinde veya çeşitlerinde doku kültürü protokollerinin geliştirilmesi büyük ölçüde genotipe bağlıdır; yani bir çeşitte işe yarayan protokol başka bir çeşitte başarısız olabilir. Örneğin, muz (*Musa spp.*) için yapılan bir derlemede somatik embriyogenez etkinliğinin genotipe göre büyük farklılık gösterdiği belirtilmiştir.

Genotip bağımlılığı, belirli bir bitki genotipinin, doku kültürü koşullarında ne derece farklı bir performans sergilediğini gösterir. Farklı genotipler, benzer çevresel koşullara maruz kaldıklarında bile, farklı gelişim yolları izleyebilirler. Örneğin, bazı genotiplerin daha yüksek çoğaltım oranlarına sahip olduğu, bazılarının ise belirli hastalıklara karşı daha dirençli olduğu gözlemlenmiştir. Genotip bağımlılığı, bitki doku kültürü süreçlerinde düzgün bir şekilde göz önüne alınmalıdır, çünkü bu durum, istenen özelliklere sahip bitkilerin seçiminde ve elde edilmesinde kritik öneme sahiptir.

Özellikle, bitkisel ürünlerin kalitesinin artırılmasında ve genetik çeşitliliğin korunmasında genotip bağımlılığı belirleyici bir faktördür. Farklı genotiplerin doku kültürü ve genetik modifikasyon teknikleri ile bir araya getirilmesi, daha iyi verimliliğe ve hastalıklara karşı dirençli bitkilerin yetiştirilmesine olanak tanır.

3.3 Akklimatizasyon

İn vitro üretilmiş bitkilerin sera/mezopotamya aşamasından dış ortama adaptasyonu (akklimatizasyon) sıkıntılıdır. Bu aşamada yaşayabilirlik, kök gelişimi, stres toleransı gibi faktörler başarısız olma nedenlerindendir.

Akklimatizasyon, mikro ortamdan makro ortama geçişi ifade eder ve genellikle bitkilerin dış ortamdaki sıcaklık, nem, ışık ve besin koşullarına adapte olmasını kolaylaştıran aşamaları içerir. Bu süreç, laboratuvar ortamında üretilen bitkilerin, bitki örtüsünün nem seviyeleri, sıcaklık değişimleri ve güneşli veya karanlık gibi çevresel faktörlere karşı dayanıklılık kazanmasına yardımcı olur (Güney, 2023; Akyüz ve ark., 2024). Akklimatizasyon, kriterler ve protokoller belirlenmiş bir süreçtir. Genellikle, bitkilerin laboratuvar ortamındaki mikro iklim koşulları ile dış ortamın iklim koşulları arasındaki farkların yavaşça azaltılması hedeflenir. İlk aşama, bitkilerin dış ortamda maruz kalacağı stres faktörlerine programlanmasıdır.

Dış koşullara adaptasyon, bitkinin fiziksel ve metabolik süreçlerinin çevrelerine etkili bir şekilde yanıt vermesini sağlamaktadır. Bu adaptasyon, bitkilerin stres toleransını artırarak kuraklık, aşırı sıcaklık veya soğuk hava gibi zorlu koşullara karşı daha dirençli hale gelmelerine yardımcı olur. Mikoriza aşılamasının bu süreçte etkili olduğu belirlenmiştir; doku kültürü ile üretilen bitkilerin dış koşullara alıştırılmasında önemli bir rol oynar.

Meyve türleri, dış ortamın iklimsel koşullarına uyum sağlama sürecinde çeşitli zorluklarla karşı karşıya kalabilir. Özellikle, su eksikliği ve aşırı sıcaklık gibi stres koşulları, bitkilerin gelişimini olumsuz etkileyebilir. Bu gibi koşullarda, akklimatizasyon sürecinin başarılı bir şekilde yürütülmesi, bitkilerin adaptasyon yeteneğini artırarak dış ortam entegrasyonunu sağlar (Güney, 2019).

3.4 Genetik stabilite ve somaklonal varyasyon

Bitki doku kültürü, klonal çoğaltmanın sağlanmasında ve bitkilerin ıslahında geniş uygulamalara sahip bir tekniktir. Ancak, bu süreç aynı zamanda genetik stabilite ve somaklonal varyasyon gibi önemli zorlukları da beraberinde getirir. Somaklonal varyasyon, in vitro çoğaltım esnasında ortaya çıkan genetik veya epigenetik değişikliklerdir ve bu değişiklikler, bitkilerin belirli özelliklerini etkileyebilir (Guan ve ark., 2016; Vítámvás ve ark., 2019; Beaudoin ve ark., 2021).

Genetik stabilite, bir bitki türünün genetik yapısının, doku kültürü uygulamaları sırasında değişmeden kalma yeteneğidir. Bu stabilitenin korunması, özellikle tarımsal uygulamaların sürdürülebilirliği açısından kritik öneme sahiptir. Genetik stabilitenin sağlanması, bitkilerin tutarlı özellikler göstermesini ve bu sayede yüksek verimlilikle elde edilmesini garanti eder. Doku kültürü süreçlerinde meydana gelen genetik değişiklikler, özellikle çoğaltım aşamasında istenmeyen varyasyonların oluşmasına sebep olabilir (Das ve ark., 2016; Mallaya ve

Ravishankar, 2012; Wang ve ark., 2013). Örneğin, bir bitkinin belirli hastalıklara karşı direncini artırmak amacıyla yapılan doku kültürü çalışmaları, bazen istenmeyen somaklonal varyasyonlara yol açarak genetik istikrarı tehlikeye atabilir (Li ve ark., 2010).

Somaklonal varyasyon, doku kültürü ortamında hücrelerin stres altında kalmalarından kaynaklanan genetik değişikliklerdir. Bu varyasyonlar, kromozomal yeniden düzenlenmeler, DNA metilasyon değişiklikleri ve nokta mutasyonları gibi süreçler sonucu meydana gelir (Beaudoin ve ark., 2021; Regalado ve ark., 2015). Somaklonal varyasyonlar, genellikle olumlu ya da olumsuz etkiler doğurabilir; bazı durumlarda, istenen özelliklere sahip yeni bitki çeşitlerinin elde edilmesine fırsatlar doğururken, diğer durumlarda ise istenen genetik profilin kaybedilmesine yol açabilir (Akomeah ve ark., 2018; Velasco & Fernandez, 2022).

Bu bağlamda, somaklonal varyasyonların kontrolü ve yönetimi, bitki doku kültürü süreçlerinde büyük bir zorluk teşkil etmektedir. Genetik çeşitliliği artırmanın yanı sıra, tüketicilerin beklentilerine uygun, hastalıklara dayanıklı ve yüksek verim sağlayan bitki türlerinin geliştirilmesinde somaklonal varyasyonların olumlu yönleri ortaya çıkabilmektedir (Wang ve ark., 2013; Wang ve ark., 2022). Somaklonal varyasyonlar, ayrıca tarımsal ıslah süreçlerinde alternatif bir yöntem olarak kullanılarak, yeni çeşitlerin oluşturulmasına ve bunların adaptasyon kabiliyetinin artırılmasına katkıda bulunabilir (Shiddalingeswara ve ark., 2014).

4. Çözüm Stratejileri

4.1 Protokol optimizasyonu ve standardizasyon

Her meyve türü ve çeşidi için özel protokoller geliştirilmesi önerilmektedir. Bu bağlamda farklı hormon kombinasyonları, besi ortamları, sterilizasyon yöntemleri sistematik olarak teste tabi tutulmalıdır (Güney, 2019; Güney, 2023). Örneğin, yüksek çilek (*Fragaria* × *ananassa*) veya yaban mersini (*Vaccinium spp.*) gibi türlerde başarılı protokoller yayımlanmıştır (Correia ve ark., 2024).

Doku kültürü tekniklerinin etkinliğini artırmak için kesin protokollerin geliştirilmesi ve standartlaştırılması kritik öneme sahiptir (Üstünsoy ve ark., 2018). Üretim süreçlerindeki tutarlılığı sağlamak amacıyla her tür bitki için özel ve optimize edilmiş büyüme ortamları gereklidir. Besin ortamları, büyüme düzenleyicileri ve diğer kültürel faktörlerin sistematik bir değerlendirmesi, farklı türlerin ihtiyaçlarını karşılayacak şekilde yapılmalıdır. Protokollerin optimize edilmesi, hem ekonomik verimliliği artırır hem de bitki sağlığını iyileştirir (Uzer ve Özaslan, 2023).

4.2 Bioreaktör ve otomasyon teknolojilerinin entegrasyonu

Makroskala klonal çoğaltma için bioreaktör sistemleri, otomasyon ve robotik katmanlar geliştirilebilir. Böylece iş gücü ve maliyet düşürülebilir, üretim verimliliği artabilir. (Pithiya ve ark., 2022).

Bioreaktörler, bitki doku kültürü uygulamalarında yüksek verimlilik sağlamak için önemli araçlardır. Otomasyon teknolojilerinin entegrasyonu ile birlikte, doku kültürü süreçlerinin kontrolü daha kolay hale getirilir; bu, hem süreç sürekliliğini sağlar hem de hataları en aza indirir (Uslu ve ark., 2020). Bu tür gelişmeler, üretim kapasitesinin artırılmasına ve laboratuvar verimliliğinin optimizasyonuna katkıda bulunarak, sürdürülebilir tarımsal üretim için gerekli olan kritik bir akım yaratmaktadır.

4.3 Genotip seçimi ve anaç materyali kullanımı

Doku kültürü süreçlerinde başlangıç materyali olarak uygun, sağlıklı ve yüksek çoğaltılabilirlik gösteren genotiplerin seçilmesi önemlidir. Anaç materyallerin kullanımı, çoğaltma verimliliğini artırabilir.

Doku kültürü süreçlerinde genotip seçimi, bitkilerin elde edileceği anaç materyali ile doğrudan ilişkilidir. Farklı genotiplerin, doku kültürü süreçlerinde gösterdikleri farklı performanslar, istenilen özellikleri taşıyan bireylerin seçilmesini zorunlu kılmaktadır (Bayılmış ve Özçelik, 2017). Genetik olarak stabil ve hastalıklara dayanıklı anaç materyallerinin kullanımı, doku kültürü uygulamalarında başarılı sonuçlar elde edilmesini sağlamaktadır.

4.4 Akklimatizasyonun iyileştirilmesi

İn vitro aşamadan sera ve saha koşullarına geçişi daha etkin kılmak için akklimatizasyon protokolleri geliştirilmelidir (ışık, CO_2, nem, sıcaklık yönetimi). Bu aşamada mikroskobik ve moleküler göstergeler izlenebilir.

Laboratuvar ortamında üretilen bitkilerin dış ortama adaptasyonu, akklimatizasyon sürecinin iyileştirilmesi ile sağlanabilir. Bu süreçte, bitkilerin dış ortam koşullarına yavaş yavaş maruz bırakılması, genellikle başarılı akklimatizasyon için bir strateji olarak benimsenmektedir. Bitkilerin su, ışık ve nem koşullarına yavaşça alıştırılması, sağlıklı bir adaptasyon sürecinin geliştirilmesinde kritik bir yere sahiptir. Akklimatizasyon süreçlerinin optimize edilmesi, doku kültürü ile üretilen bitkilerin sağlığı ve büyüme performansını önemli ölçüde artırabilir (Güney, 2019; Güney, 2023).

4.5 Moleküler izleme ve genetik stabilitenin korunması

Somaklonal varyasyonu kontrol altına almak için rutin genetik izleme (örneğin, moleküler markerlarla) yapılmalı, alt kültür sayıları sınırlandırılmalı, uygun hormon rejimleri kullanılmalıdır (Guan ve ark., 2016).

Bitki doku kültürü süreçlerinin başarıyla yürütülmesi için genetik stabilitenin korunması büyük önem taşır. Genetik değişikliklerin izlenmesi, somaklonal varyasyonların kontrolü açısından önemli bir adımdır. Moleküler izleme teknikleri, genetik çeşitliliğin ve değişimlerin değerlendirilmesine olanak tanır; böylece, hastalık ve çevresel stres faktörlerine dayanıklı bitki materyallerinin geliştirilmesi kolaylaşır. Genetik stabiliteyi korumak amacıyla gen etkileşimlerinini biçimlendirilmesi ve izlenmesi, başarıyla görev yapan bitkisel fonksiyonlar için zemin hazırlamaktadır.

5. Sonuç ve İleriye Dönük Perspektifler

Bitki doku kültürü, modern tarım ve bitki biyoteknolojisi uygulamalarında önemli bir yer tutmakta; özellikle meyve türlerinde hızlı çoğaltma, hastalıklardan arındırılmış anaç üretimi, genetik ıslah ve genetik kaynakların korunması gibi hedeflere ulaşmada büyük potansiyel sunmaktadır. Bu teknikler sayesinde meyve üretiminde kalite, verimlilik ve çevresel sürdürülebilirlik önemli ölçüde artırılabilir.

Bununla birlikte, meyve türlerinde doku kültürü uygulamalarının geniş ölçekli ve ticari düzeye taşınması hâlâ birtakım zorluklarla sınırlıdır. En yaygın teknik engeller arasında kontaminasyon riski, genotipe özgü protokol gerekliliği, akklimatizasyon aşamasında düşük başarı oranı, genetik stabilitenin korunması ve maliyet/iş gücü gereksinimleri yer almaktadır.

Bu zorlukların üstesinden gelebilmek amacıyla geliştirilen çeşitli çözüm stratejileri, doku kültürü sistemlerinin daha verimli ve sürdürülebilir biçimde uygulanmasını mümkün kılmaktadır. Üzerinde durulan başlıca stratejiler aşağıda özetlenmiştir:

Protokol optimizasyonu ve standardizasyonu: Her bitki türü ve genotipi için en uygun büyüme düzenleyicileri ve besin ortamlarının belirlenmesi, rejenerasyon başarı oranlarını doğrudan etkilemektedir.

Bioreaktör ve otomasyon teknolojilerinin entegrasyonu: Özellikle ticari üretimde verimliliği artırmak ve insan kaynaklı hataları en aza indirmek için otomasyon sistemleri kritik bir rol

oynamaktadır. Bioreaktör sistemleri, büyük hacimli çoğaltım süreçlerinde üretim maliyetlerini düşürebilir.

Genotip seçimi ve elit anaç materyali kullanımı: Doku kültürüne yüksek yanıt veren genotiplerin seçimi, hem rejenerasyon oranlarını artırmakta hem de genetik kararlılığı korumaya yardımcı olmaktadır.

Akklimatizasyon ve dış ortam adaptasyonunun iyileştirilmesi: İn vitro koşullarda üretilen bitkilerin sera ve tarla koşullarına başarılı şekilde geçiş yapabilmesi için ışık, nem, sıcaklık ve substrat gibi çevresel faktörlerin optimize edilmesi gerekmektedir.

Moleküler izleme ve genetik stabilitenin korunması: Somaklonal varyasyonları izlemek ve genetik homojenliği sağlamak amacıyla moleküler marker teknolojileri ve genetik analiz yöntemleri giderek daha yaygın kullanılmaktadır.

Ekonomik analiz ve ticari ölçek planlaması: Üretim sürecinin toplam maliyetinin değerlendirilmesi ve ölçeklenebilirliğin ekonomik boyutta analiz edilmesi, teknolojinin tarımsal üretime entegrasyonunu kolaylaştırmaktadır.

Bu stratejilerin bütüncül olarak ele alınması, sadece meyve türlerinde değil, tüm bitki doku kültürü uygulamalarında başarıyı artıracaktır. Ayrıca, biyoteknolojik araçların (örneğin gen düzenleme, marker destekli seleksiyon) doku kültürü ile entegre edilmesi, hem bitki ıslah süreçlerini hızlandırmakta hem de tarımsal sürdürülebilirliğe katkı sağlamaktadır.

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MEYVE GENOTİPLERİNDE HASTALIK DİRENCİNİN MOLEKÜLER MARKÖRLERLE BELİRLENMESİNE YÖNELİK GÜNCEL YAKLAŞIMLAR

Doç. Dr. Murat GÜNEY
Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü
Email: murat.guney@yobu.edu.tr
ORCID: 0000-0003-2882-8347
Doç. Dr. Hakan KELES
Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü
Email: hakan.keles@yobu.edu.tr
ORCID: 0000-0002-8225-931X
Öğr. Gör. Dr. Selcan ÖZYALIN
Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü
Email: selcan.ozyalin@yobu.edu.tr
ORCID: 0000-0003-4831-8600
Dr. Öğr. Üyesi Gökçe AYDÖNER ÇOBAN
Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü
Email: murat.guney@yobu.edu.tr
ORCID: 0000-0002-0851-8803

ÖZET

Artan dünya nüfusu ve buna paralel olarak yükselen gıda talebi, meyve yetiştiriciliğinde hastalıklara dayanıklı genotiplerin geliştirilmesini zorunlu hale getirmiştir. Bitkisel üretimde karşılaşılan patojen kaynaklı hastalıklar, verim ve kalite kayıplarının yanı sıra ekonomik zararların da başlıca nedenlerinden biridir. Bu durum, üreticileri kimyasal pestisitlere bağımlı hale getirmekte, ancak yoğun kimyasal kullanımı hem çevresel sürdürülebilirlik hem de insan sağlığı açısından önemli riskler taşımaktadır. Bu nedenle, hastalıklara dayanıklı genotiplerin ıslah edilmesi, kimyasal kullanımını azaltarak çevreye duyarlı üretim sistemlerinin oluşturulmasında stratejik bir rol oynamaktadır. Moleküler markır teknolojileri, meyve türlerinde genetik dayanıklılığın belirlenmesi ve ıslah programlarının yönlendirilmesinde son derece etkili araçlardır. Bu yöntemler, mevcut kültür çeşitleri ve yeni genotipler arasındaki genetik varyasyonun ortaya çıkarılmasında yüksek doğruluk ve tekrarlanabilirlik sağlar. SNP (tek nükleotid polimorfizmleri) ve SSR (Basit dizi tekrarları) gibi moleküler markırlar, hastalık dayanıklılığı ile ilişkili gen bölgelerinin tespit edilmesine ve QTL (nicel özellik lokusları) analizleriyle direnç genlerinin haritalanmasına olanak tanımaktadır. Bu yaklaşımlar, işaretleyici destekli seleksiyon (MAS) uygulamalarının etkinliğini artırarak, klasik ıslah sürecini hızlandırmakta ve genetik çeşitliliğin korunmasına katkı sağlamaktadır. Son yıllarda yapılan çalışmalar, elma, şeftali, badem, ceviz, antepfıstığı, armut ve ayva gibi meyve türlerinde dayanıklılıkla ilişkili genlerin tanımlandığını ve bu genlerin biyoinformatik araçlar aracılığıyla karakterize edildiğini ortaya koymaktadır. Bu kapsamda, gen ekspresyon analizleri, fonksiyonel genomik ve proteomik çalışmalar, dayanıklılıkla ilişkili genetik mekanizmaların aydınlatılmasında yeni bir perspektif kazandırmıştır. Ayrıca, farklı genotiplerin çevresel stres

koşullarına tepkilerinin değerlendirilmesi, dayanıklılığın fizyolojik ve biyokimyasal yönlerinin anlaşılmasına katkı sağlamaktadır.

Sonuç olarak, moleküler markır temelli hastalık dayanıklılığı araştırmaları, sürdürülebilir meyve yetiştiriciliği ve çevre dostu üretim sistemlerinin geliştirilmesinde güçlü bir biyoteknolojik araç olarak öne çıkmaktadır. Bu yaklaşımlar, yalnızca hastalıklarla mücadelede değil, aynı zamanda gıda güvenliğinin sağlanması, biyolojik çeşitliliğin korunması ve tarımsal üretimde sürdürülebilirliğin artırılması açısından da geleceğe yönelik büyük bir potansiyel sunmaktadır.

Anahtar Kelimeler: Moleküler markırlar, meyve türleri, hastalık etmenleri, marköre dayalı seleksiyon (MAS)

ABSTRACT

The increasing global population and the corresponding rise in food demand have made the development of disease-resistant genotypes in fruit cultivation a necessity. Pathogen-induced diseases encountered in plant production are among the main causes of yield and quality losses, as well as significant economic damage. This situation forces producers to rely heavily on chemical pesticides; however, excessive chemical use poses serious risks to both environmental sustainability and human health. Therefore, breeding disease-resistant genotypes plays a strategic role in reducing chemical dependency and establishing environmentally friendly production systems. Molecular marker technologies are highly effective tools for determining genetic resistance in fruit species and guiding breeding programs. These methods provide high accuracy and reproducibility in revealing genetic variation between existing cultivars and newly developed genotypes. Molecular markers such as SNPs (Single Nucleotide Polymorphisms) and SSRs (Simple Sequence Repeats) enable the identification of genomic regions associated with disease resistance and the mapping of resistance genes through QTL (Quantitative Trait Loci) analyses. Such approaches enhance the efficiency of Marker-Assisted Selection (MAS), accelerate traditional breeding processes, and contribute to the conservation of genetic diversity. Recent studies have reported the identification and bioinformatic characterization of resistance-related genes in several fruit species, including apple, peach, almond, walnut, pistachio, pear, and quince. Furthermore, gene expression analyses, functional genomics, and proteomics have provided new insights into the molecular mechanisms underlying disease resistance. Evaluating the responses of different genotypes to environmental stress factors also contributes to understanding the physiological and biochemical aspects of resistance.

In conclusion, molecular marker-based studies of disease resistance represent a powerful biotechnological approach for developing sustainable and eco-friendly fruit production systems. These strategies not only support effective disease management but also contribute to food security, biodiversity conservation, and the long-term sustainability of agricultural production.

Keywords: Molecular markers, fruit species, disease agents, marker-based selection (MAS)

1. GIRIŞ

Meyve üretiminde verim, kalite ve sürdürülebilirliği tehdit eden hastalık etmenlerinin artan etkisi, modern ıslah programlarında biyoteknolojik yenilikler ve DNA tabanlı moleküler markör teknolojilerinin entegrasyonuyla hastalıklara genetik düzeyde dirençli, yüksek verimli ve çevresel streslere uyumlu meyve genotiplerinin geliştirilmesine yönelik çalışmlar yaygınlaşmaya başlamıştır (Goswami ve ark., 2022).

Moleküler markörler, hastalıklara karşı genetik direncin belirlenmesinde güçlü bir araç olarak kullanılmakta; genotipler arasındaki varyasyonları tanımlayarak ıslahçılara yüksek düzeyde hassasiyet sağlamaktadır. Bu yöntemler sayesinde genetik olarak dirençli bireylerin tespiti mümkün olmakta ve ıslah sürecinde en uygun genotiplerin seçilmesi kolaylaşmaktadır. Ayrıca, markör destekli analizler, patojenlerin genetik yapısının incelenmesine ve konak–patojen etkileşimlerinin daha iyi anlaşılmasına katkı sağlamaktadır. Son yıllarda elma, çilek ve badem gibi farklı meyve türlerinde yürütülen araştırmalar, moleküler markörlerin kullanımıyla hastalık direncini artırmaya yönelik stratejilerin başarıyla uygulanabileceğini göstermektedir. Örneğin, çilek genotiplerinde Phytophthora ve antraknoz etmenlerine karşı dayanıklılık, markör analizleriyle belirlenmiş ve bu sayede dirençli varyetelerin geliştirilmesi sağlanmıştır. Benzer şekilde, elma ve bademde de genetik temelli direnç analizleri, hastalıklara dayanıklı genotiplerin erken dönemde seçilmesine olanak tanımaktadır.

Moleküler markörlerin meyve genotiplerinde hastalık direncinin belirlenmesinde kullanımı, modern bitki ıslahında stratejik bir araç hâline gelmiştir. Bu yöntemler, yalnızca hastalıkların önlenmesine katkı sağlamakla kalmayıp, genetik çeşitliliğin korunması ve sürdürülebilir tarımsal üretimin desteklenmesi açısından da büyük önem taşımaktadır. Bununla birlikte, mevcut literatürün özellikle bazı meyve türleri için sınırlı veri sunduğu dikkate alındığında, daha kapsamlı ve güncel araştırmalara ihtiyaç duyulmaktadır. Bu çalışma, meyve genotiplerinde genetik direncin değerlendirilmesinde moleküler markörlerin uygulama potansiyelini inceleyerek, biyoteknolojik ilerlemelerin hastalık direncinin artırılmasındaki rolünü ortaya koymayı amaçlamaktadır.

2. Moleküler Markörler ve Hastalık Direncindeki Önemi

Moleküler markörler (SSR, AFLP, RAPD, SNP gibi) bitki genomundaki genetik varyasyonları tanımlamada kritik öneme sahiptir. Bu markörler, özellikle hastalık direncinin genetik temelini daha iyi anlamamıza yardımcı olur ve ıslah sürecini hızlandırır. Domateste yapılan kapsamlı çalışmalar, marker-assisted selection (MAS) uygulamaları sayesinde Tomato yellow leaf curl virus, Fusarium oxysporum, Phytophthora infestans ve Cladosporium fulvum gibi patojenlere karşı dirençli hatların geliştirildiğini göstermiştir (Lee ve ark., 2015). Benzer şekilde, elma ve çilek gibi türlerde genom tabanlı markörlerin geliştirilmesi, hem kalite özelliklerinin hem de hastalık direncinin bir arada seçilmesini sağlamıştır. Böylece genetik ıslah süreçlerinde klasik yöntemlerin çok ötesinde bir doğruluk ve hız elde edilmiştir (Han ve ark., 2020; Labadie ve ark., 2020).

Moleküler markörler, tarım ve bitki ıslahı alanında, özellikle hastalıklara dayanıklılık özelliklerinin belirlenmesinde büyük bir öneme sahiptir. Bu markörler, genetik çeşitliliğin belirlenmesi, hastalıklara karşı dirençli çeşitlerin seçimi ve ıslah çalışmalarının desteklenmesi gibi birçok alanda kullanılmaktadır. Özellikle ceviz, badem, elma, antepfıstığı ve çilek gibi bahçe bitkileri üzerinde yapılan araştırmalar, moleküler markörlerin tarımsal üretimi nasıl etkilediğini açıkça göstermektedir. Ceviz hastalıkları, özellikle antraknoz gibi fungal hastalıklar, bu tür bitkilerin üretiminde ciddi sorunlar yaratmakta olup, moleküler markörler bu hastalıklarla mücadelede önemli bir araç olarak kullanılmaktadır. Örneğin, Bitlis ilinde ceviz antraknozu üzerindeki çalışmalarda, Ophiognomonia leptostyla'nın moleküler karakterizasyonu detaylandırılmış ve bu markörler aracılığıyla hastalığa karşı dayanıklılığın

artırılması hedeflenmiştir (Koç ve ark., 2020). Elmada yapılan çalışmalar da moleküler markörlerin önemini vurgulamaktadır. Van Gölü havzasında yetiştirilen elma ağaçlarında, Erwinia amylovora'nın neden olduğu ateş yanıklığı hastalığının saptanması ve yaygınlık oranının belirlenmesi amacıyla moleküler teknikler kullanılmıştır (Kıpçak ve Akköprü, 2017). Bu bağlamda, moleküler markörler, hastalığa karşı direnç göstermeyen çeşitlerin belirlenmesinde de etkin bir yöntem olarak kullanılmaktadır. Çilek bitkileri de moleküler markörlerin etkili olduğu bir diğer alandır. Çilek alanlarında yapılan araştırmalarda, *Botrytis cinerea* gibi fungal hastalıkların moleküler analizleri ile hastalık kontrolü ve dayanıklılık kaynaklarının belirlenmesi üzerine çalışmalar yapılmaktadır (Uysal ve Erkılıç, 2022). Çilek bitkisinde, antraknoz (*Colletotrichum spp.*) ve fitofthora (*Phytophthora spp.*) gibi fungal patojenler, ciddi hastalıklara yol açmakta ve verim kaybına neden olmaktadır. Antraknoz, özellikle çilek meyvelerinde çürümeye yol açarak ürün kalitesini düşürmekte, buna ek olarak fitofthora hastalığı kök çürümesine neden olarak bitkinin gelişimini olumsuz etkilemektedir (Ertek ve ark., 2022). Bu patojenler, uygun çevresel koşullarda hızla yayılmakta ve çilek yetiştiriciliği için ekonomik kayıplara yol açmaktadır (Koc & Karabulut, 2019). Özellikle sıcaklık ve nem oranındaki değişimler, bu hastalıkların meydana gelmesinde kritik rol oynamaktadır (Ağçam, 2022). Bu tür patojenlerin moleküler teknikler ile tespiti, hastalıklara karşı alınacak tedbirlerin zamanında uygulanmasına olanak sağlamaktadır. Badem bitkileri üzerindeki araştırmalar da benzer süreçleri göstermektedir. Moleküler markörler, hastalık direncinin belirlenmesinde kullanılmaktadır. Ceviz ve badem gibi bitkilerin çeşitli türlerinin hastalıklara karşı genetik dayanıklılık seviyeleri, moleküler markörlerle belirlenebilmektedir. Bu bağlamda, genotipler arasında hastalıklara dayanıklılık düzeyi belirgin bir şekilde farklılık göstermekte ve bu farklılıklar moleküler markörlerle net bir şekilde tespit edilebilmektedir. Moleküler markörlerin bahçe bitkileri üzerindeki etkisi, hastalıklara karşı direnç geliştirme ve verimliliği artırma konusunda kritik bir rol oynamaktadır. Özellikle ceviz, badem, elma, antepfıstığı ve çilek gibi bitkilerde hastalık direncinin artırılması için bu markörlerin kullanılması, tarımda verimlilik ve kaliteyi artırma potansiyeli taşımaktadır (Palacıoğlu ve ark., 2020).

3. Genetik Çeşitlilik, Fenotipik Özellikler ve Direnç Mekanizmaları

Meyve genotiplerinde genetik çeşitlilik, fenotipik özellikler ve direnç mekanizmaları üzerine yapılan araştırmalar, tarım biyoteknolojisi ve bitki ıslahı alanında kritik öneme sahiptir. Genetik çeşitlilik, bitkilerin hastalıklara, zararlılara ve çevresel stres faktörlerine karşı dayanıklılığını belirleyen temel unsurlardan biridir. Farklı genotiplerin patojenlere verdiği tepkiler, direnç mekanizmalarının çeşitliliğini ve bu mekanizmaların ıslah programlarındaki önemini ortaya koymaktadır. Örneğin, çarkıfelek meyvesinde (*Passiflora edulis*) yürütülen çalışmalar, genotipler arasında hastalıklara duyarlılıkta belirgin farklılıklar bulunduğunu ve bu çeşitliliğin dirençli bireylerin seçimi açısından kritik olduğunu göstermiştir (Castro ve ark., 2018). Benzer şekilde, elma (*Malus × domestica*) genomunun yeniden dizilenmesiyle elde edilen veriler, yabani türlerle gerçekleşen doğal melezleşmelerin dayanıklılık gen havuzunu zenginleştirdiğini ve modern çeşitlerde "seçici süpürme bölgeleri" oluşturduğunu ortaya koymuştur (Duan ve ark., 2017). Bu durum, yabani akrabalardan genetik materyal aktarımının hastalık direncinin geliştirilmesinde stratejik bir araç olduğunu göstermektedir. Ayrıca, ceviz, badem, antepfıstığı ve çilek gibi bahçe bitkilerinde yürütülen genetik çalışmalar da benzer biçimde direnç genlerinin belirlenmesi ve çeşit geliştirme çalışmalarına önemli katkılar sağlamaktadır (Pal ve ark., 2024).

Genetik çeşitliliğin artırılması, yalnızca dayanıklı genotiplerin geliştirilmesi açısından değil, aynı zamanda meyve kalitesi ve fizyolojik performansın iyileştirilmesi bakımından da büyük önem taşımaktadır. Bu bağlamda moleküler markör teknolojileri, dayanıklılığın belirlenmesi, genetik varyasyonun haritalanması ve ıslah programlarında doğru genotiplerin seçimi için etkin

biçimde kullanılmaktadır. Elmada yapılan genom-genişlik ilişkilendirme analizleri (GWAS), meyve asitliği, renk ve sertlik gibi kalite parametreleriyle ilişkili SNP bölgelerinin aynı zamanda hastalık toleransını düzenleyen metabolik yollarla bağlantılı olduğunu göstermiştir (Han ve ark., 2020). Çilekte gerçekleştirilen flavonoid temelli metabolit QTL (mQTL) analizlerinde ise antosiyanin ve fenolik bileşik birikiminin savunma tepkileriyle doğrudan ilişkili olduğu belirlenmiştir (Labadie ve ark., 2020).

Fenotipik özellikler, genetik temellerle birlikte değerlendirildiğinde bitkilerin çevresel streslere ve patojen saldırılarına karşı uyum kapasitesini belirlemektedir. Çilek gibi mikrobiyal patojenlere maruz kalan bitkilerde fenotipik özelliklerin izlenmesi, dayanıklı çeşitlerin seçimi açısından önemli ipuçları sunmaktadır (Abas ve ark., 2024). Ayrıca, melatonin gibi biyokimyasal bileşiklerin bitkilerde savunma tepkilerini aktive ederek hastalıklara karşı dayanıklılığı güçlendirdiği ve stres toleransını artırdığı gösterilmiştir (Hao ve ark., 2025). Genetik çeşitlilik, fenotipik özellikler ve direnç mekanizmalarının birlikte değerlendirilmesi, hastalıklara dayanıklı, yüksek verimli ve çevresel streslere uyumlu meyve çeşitlerinin geliştirilmesinde büyük bir potansiyel taşımaktadır. Bu alanlardaki bilimsel ilerlemeler, sürdürülebilir tarım uygulamalarına katkı sağlamakta ve gelecekte daha dirençli meyve genotiplerinin geliştirilmesi için güçlü bir temel oluşturmaktadır (Xu ve ark., 2022; Kumari ve ark., 2023).

4. Moleküler ve Genetik Yaklaşımlarla Direnç Geliştirme

Moleküler ve genetik yaklaşımlar, bahçe bitkileri gibi tarımsal ürünlerde hastalık direncinin geliştirilmesinde merkezi bir rol oynamaktadır. Modern tarım uygulamalarında, bitkilerin patojenlere, zararlılara ve iklim değişikliğinin neden olduğu stres koşullarına karşı dayanıklılığını artırmak amacıyla genetik ve biyoteknolojik teknikler yaygın biçimde kullanılmaktadır. Bu kapsamda, moleküler markör teknolojileri, genetik mühendislik ve genom düzenleme sistemleri, hastalıklara karşı dirençli bitki çeşitlerinin geliştirilmesinde etkili araçlar olarak öne çıkmaktadır (Kıymacı ve ark., 2023; Güneş, 2024).

Moleküler ıslah, klasik seleksiyon yöntemlerinin ötesine geçerek genetik temelli ve hedefe yönelik bir yaklaşıma olanak tanır. Marker-destekli seleksiyon (MAS), marker-destekli geriye melezleme (MABC) ve marker-destekli gen piramitleme (MARS) yöntemleri, birden fazla direnç geninin aynı bitkide birleştirilmesini ve bu genetik kombinasyonun kalıcı hâle getirilmesini sağlar (Jiang, 2013). Bu teknikler, kahverengi çürüklük, antraknoz ve kök ur nematodu gibi kompleks patojenlere karşı dayanıklılık kazandırmada önemli başarılar sunmuştur (Lee ve ark., 2015). Benzer şekilde, genomik seleksiyon (GS) ve kantitatif özellik lokusu (QTL) haritalama yöntemlerinin entegre biçimde uygulanması, hem verim hem de hastalık direnci özelliklerinin eş zamanlı iyileştirilmesine olanak tanımaktadır. Papaya (*Carica papaya* L.) üzerine yapılan genom yeniden dizileme çalışmalarında, dar genetik tabanın markör çeşitliliğini sınırladığı; ancak yüksek polimorfizm gösteren SSR markörlerinin geliştirilmesiyle ıslah etkinliğinin artırılabileceği belirlenmiştir (Nantawan ve ark., 2022). Bu durum, genetik varyasyonun genişletilmesi ve transkriptomik ile metabolomik gibi çoklu omik yaklaşımların ıslah programlarına entegre edilmesinin önemini vurgulamaktadır.

Genetik markörler, türler arasında genetik çeşitliliği değerlendirmek, dayanıklılık genlerinin lokalizasyonunu belirlemek ve istenilen özelliklerin seleksiyonunu desteklemek amacıyla kullanılmaktadır. Domates gibi birçok kültür bitkisinde yürütülen çalışmalarda, belirli patojenlere karşı direnç seviyeleri genetik analizlerle saptanmış ve marker destekli seleksiyon (MAS) yöntemleriyle yüksek verim ve dayanıklılık gösteren genotipler geliştirilmiştir (Kıymacı ve ark., 2023). Bununla birlikte, genetik mühendisliği ve CRISPR/Cas9 gibi ileri genom düzenleme teknolojileri, belirli gen bölgelerinin hedeflenmesiyle bitkilerde hastalık direncinin artırılmasına olanak tanımaktadır. Örneğin, eukaryotik başlatma faktörü (eIF4)

geninin düzenlenmesi yoluyla bitkilerde viral hastalıklara karşı genetik güvenliğin güçlendirilebileceği gösterilmiştir (Güneş, 2024). Bu tür hedefe yönelik yaklaşımlar, genetik çeşitliliğin korunmasını desteklerken, bitkilerin çevresel streslere karşı daha dirençli hâle gelmesini de sağlamaktadır. Ayrıca, genetik transformasyon teknikleri de direnç geliştirmede önemli bir yer tutmaktadır. Çarkıfelek meyvesinde yapılan transgenik çalışmalar, viral enfeksiyonlara karşı dayanıklılığın artırılabileceğini ortaya koymuştur (Correa ve ark., 2015). Turna yemişinde (*Vaccinium macrocarpon*) yüksek epikutiküler wax içeriğini belirleyen QTL'nin tanımlanması, hem su kaybını azaltarak fizyolojik direnci artırmakta hem de patojen girişine karşı doğal bir bariyer görevi görmektedir (Erndwein ve ark., 2023).

Bitki beslenmesi ve çevresel faktörler de moleküler düzeyde hastalık direncini etkileyen önemli bileşenlerdir. Örneğin, bor bileşiklerinin bitkilerde savunma mekanizmalarını güçlendirdiği ve belirli elementlerin dengeli uygulanmasıyla patojenlere karşı dayanıklılığın artırılabileceği bildirilmiştir (Gedük ve ark., 2020). Moleküler biyokimya temelli araştırmalar, bitkilerin spesifik besin gereksinimlerinin karşılanmasıyla dayanıklılık tepkilerinin optimize edilebileceğini göstermektedir (Küçükyumuk ve Bayındır, 2023). Moleküler ve genetik yaklaşımlar, bahçe bitkilerinde hastalık direncinin artırılmasında inovatif, etkili ve sürdürülebilir çözümler sunmaktadır. Markör destekli seleksiyon, genom düzenleme ve genetik mühendisliği gibi ileri tekniklerin yanı sıra, bitki beslenmesi stratejilerinin optimize edilmesi de ıslah programlarının başarısını artırmaktadır. Bu yaklaşımlar, gelecekte farklı bitki türlerinde uygulanarak, hastalıklara daha dayanıklı ve verimli bahçe bitkilerinin geliştirilmesine öncülük etmektedir (Karakurt ve ark., 2020).

5. Geleceğe Yönelik Genomik ve Biyoteknolojik Stratejiler

Geleceğe yönelik genomik ve biyoteknolojik stratejiler, tarımsal üretimde sürdürülebilirlik, verimlilik ve hastalık direncinin artırılması açısından büyük önem taşımaktadır. Genetik biyoteknoloji, bahçe bitkileri gibi tarımsal ürünlerin hastalıklara karşı dayanıklılığını güçlendirmek, ürün kalitesini iyileştirmek ve çevresel streslerin etkisini azaltmak için giderek daha fazla kullanılmaktadır. Bu bağlamda, son yıllarda hızla gelişen yeni nesil dizileme (NGS), tüm genom dizileme (WGS), RNA-seq ve CRISPR/Cas9 gibi hedefe yönelik gen düzenleme teknolojileri, bitkilerde direnç genlerinin hızlı ve doğru biçimde tanımlanmasını ve düzenlenmesini mümkün kılmaktadır (Jiang, 2013; Li ve ark., 2022). Bu gelişmeler, genetik ağların karmaşık yapısını çözümlemeye, gen ekspresyon kalıplarını incelemeye ve direnç mekanizmalarının moleküler temellerini anlamaya olanak sağlamaktadır. Örneğin, CRISPR/Cas9 teknolojisi ile belirli gen bölgelerinin düzenlenmesi sayesinde bitkilerde viral ve fungal patojenlere karşı genetik dayanıklılık kazandırılabilmektedir (Kolchenko ve ark., 2023). Bu sayede, hastalık kaynaklı verim kayıplarının önüne geçilmekte ve çevresel stres faktörlerine daha toleranslı genotiplerin geliştirilmesi mümkün olmaktadır.

Moleküler markörlerin (SSR, SNP) kullanımı, direnç genlerinin belirlenmesi ve dayanıklı genotiplerin ıslah programlarına entegre edilmesi açısından hâlen temel bir strateji konumundadır. Özellikle elma (*Malus* × *domestica*) gibi türlerde yapılan genom analizleri, modern çeşitlerde belirli allel sıklıklarının artış gösterdiğini ve bunların selektif ıslah süreçlerinde bilinçli olarak seçildiğini göstermektedir (Shamshin ve ark., 2018; Zhen ve ark., 2018). Bu durum, markör destekli seleksiyonun, modern ıslah programlarının başarısında vazgeçilmez bir araç hâline geldiğini göstermektedir. Buna ek olarak, QTL haritalama ve genetik eşleştirme analizleri, verim, meyve kalitesi, asitlik ve şeker içeriği gibi özelliklerle ilişkili gen bölgelerinin tanımlanmasını sağlamaktadır. Örneğin, elma genotiplerinde yapılan çalışmalar, kaliteyle ilişkili genlerin aynı zamanda hastalık toleransını etkileyen metabolik yollarda yer aldığını göstermektedir (Guan ve ark., 2015). Böylece, hem dayanıklı hem de üstün kalite özelliklerine sahip yeni çeşitlerin geliştirilmesi mümkün olmaktadır. Geleceğe yönelik

bir diğer önemli yaklaşım, yabani akrabaların ve egzotik gen kaynaklarının ıslah programlarına entegre edilmesidir. Bu genetik kaynaklar, hem biyotik hem de abiyotik streslere karşı direnç genlerinin çeşitliliğini artırarak, entegre dayanıklılık stratejilerinin temelini oluşturmaktadır (Costa ve ark., 2018). Ayrıca, yerel çeşitlerin genetik karakterizasyonu ve korunması da, biyolojik çeşitliliğin sürdürülmesi ve yerel adaptasyon kapasitesinin geliştirilmesi açısından stratejik bir öneme sahiptir (Saucedo ve ark., 2018; Zun-Chun ve ark., 2016).

Genomik ve biyoteknolojik stratejilerin entegrasyonu, modern tarımın en güçlü araçlarından birini temsil etmektedir. Yeni nesil dizileme teknolojileri, moleküler markör sistemleri ve gen düzenleme yaklaşımları sayesinde, genetik çeşitlilikten en üst düzeyde yararlanılarak çevresel değişimlere karşı daha dirençli, yüksek verimli ve kaliteli meyve çeşitlerinin geliştirilmesi mümkün olacaktır. Bu yenilikçi yaklaşımlar, sürdürülebilir tarım uygulamalarına ve küresel gıda güvenliğine önemli katkılar sunmaktadır (Kolchenko ve ark., 2023; Gostinčar ve ark., 2025).

6. Sonuç

Meyve genotiplerinde hastalıklara karşı genetik direncin moleküler markörlerle belirlenmesi, modern bitki ıslahında devrim niteliğinde bir ilerleme olarak değerlendirilmektedir. Moleküler markör teknolojileri, genetik çeşitliliğin tanımlanması, dayanıklılık genlerinin belirlenmesi ve uygun genotiplerin seçilmesiyle ıslah sürecini önemli ölçüde hızlandırmaktadır. Bu yaklaşımlar, çevresel faktörlerden etkilenmeyen, tekrarlanabilir ve yüksek doğrulukta sonuçlar sağlayarak klasik seleksiyon yöntemlerinin ötesine geçmiştir. Yapılan araştırmalar, moleküler markörlerin kullanımıyla hastalık direncine ilişkin genetik mekanizmaların net bir biçimde ortaya konabildiğini ve bu sayede dirençli genotiplerin etkin biçimde tespit edilip ıslah çalışmalarında kullanılabildiğini göstermektedir. Bu yöntem, yalnızca hastalıklara karşı direnç kazandırmakla kalmayıp; aynı zamanda yüksek verim, kalite ve adaptasyon kapasitesine sahip meyve çeşitlerinin geliştirilmesine olanak tanımaktadır.

Moleküler biyoteknoloji uygulamaları, hastalıklara dayanıklı çeşitlerin geliştirilmesinin yanı sıra, doğal genetik kaynakların korunması ve yerel çeşitlerin ıslah programlarına dâhil edilmesi açısından da stratejik önem taşımaktadır. Bu durum, özellikle iklim değişikliğine bağlı biyotik ve abiyotik stres faktörlerine karşı tarımsal sistemlerin dayanıklılığını güçlendirmekte ve genetik çeşitliliğin sürdürülebilir yönetimini desteklemektedir. Sonuç olarak, moleküler markörlerin ve genomik araçların meyve ıslahına entegrasyonu, sürdürülebilir tarım ve gıda güvenliği açısından temel bir bilimsel stratejidir. Bu yaklaşımlar, gelecekte hastalıklara karşı daha dayanıklı, yüksek kaliteli ve çevresel değişimlere uyumlu meyve çeşitlerinin geliştirilmesine olanak tanırken, tarımsal üretim sistemlerinin uzun vadeli verimliliğini ve istikrarını da güvence altına alacaktır.

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YOZGAT İLİNDE YETİŞTİRİLEN SIYAH ALACA (HOLSTEIN) SIĞIRLARIN SÜT VERİMİ VE ÜREME PARAMETRELERİNİN İNCELENMESİ

Hilmi YETER

Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Zootekni Bölümü

Email: hilmi.yeter@tarimorman.gov.tr

ORCID: 0009-0000-9102-8479

***Doç. Dr. Orhan ERMETİN**

Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Zootekni Bölümü

Email: orhan.ermetin@yobu.edu.tr

ORCID: 0000-0002-3404-0452

*Sorumlu yazar

ÖZET

Bu çalışma, Yozgat İli Damızlık Sığır Yetiştiricileri Birliği'ne üye 112 işletmede yetiştirilen Siyah Alaca (Holstein) sığırlarının süt verim özelliklerini ortaya koymak amacıyla yürütülmüştür. Çalışmada, 2003–2022 yılları arasında düzenli olarak kaydedilen toplam 1840 baş ineğe ait süt verim kayıtları değerlendirilmiştir. Araştırmada incelenen işletmelerde, 305 günlük süt verimi ortalama 7375 litre, laktasyon süresi 358 gün, kuru dönem süresi 59 gün olarak belirlenmiştir. Ayrıca, döl verim özellikleri kapsamında servis periyodu ortalama 139 gün, buzağılama aralığı ise 419 gün olarak hesaplanmıştır. Elde edilen veriler, 305 günlük süt verimi (305 GSV), laktasyon süresi (LS) ve kuru dönem (KD) üzerine; buzağılama yılı, parite, buzağılama mevsimi, buzağılama yaşı ve işletme koşullarının etkilerini incelemek amacıyla değerlendirilmiştir.

Sonuçlar, çevresel faktörlerin ve işletme koşullarının süt verimi ve döl verimi özellikleri üzerinde önemli düzeyde etkili olduğunu ortaya koymaktadır. Özellikle buzağılama mevsimi ve parite faktörleri, süt verim düzeylerinin değişkenliğinde belirleyici rol oynamıştır. Elde edilen bulgular, Yozgat ilinde yetiştirilen Siyah Alaca sığırlarının mevcut verim düzeylerini ortaya koymakla birlikte, bölgesel hayvan ıslahı programlarının gelecekteki hedeflerinin belirlenmesine katkı sağlayacak niteliktedir. Bu kapsamda, genetik parametrelerin doğru şekilde belirlenmesi ve uygun seleksiyon stratejilerinin uygulanması, bölgesel süt sığırcılığı verimliliğinin artırılması açısından büyük önem taşımaktadır. Ayrıca, elde edilen sonuçların Türkiye genelindeki Siyah Alaca yetiştiriciliği verileriyle karşılaştırılması, bölgesel farklılıkların ortaya konulmasına olanak sağlamaktadır.

Bu bulguların, sürdürülebilir süt sığırcılığına yönelik ıslah çalışmalarına rehberlik edeceği ve gelecek nesillerde daha yüksek verim ve döl performansına sahip Siyah Alaca sürülerinin yetiştirilmesine katkı sağlayacağı düşünülmektedir.

Anahtar Kelimeler: Siyah Alaca Süt Sığırı, Süt Verim Özellikleri, Genetik Parametreler, Hayvan Islahı, Yozgat

Teşekkür: Bu çalışma, Hilmi Yeter'in yüksek lisans tezinin bir bölümünden üretilmiştir.

INVESTIGATION OF MILK YIELD AND REPRODUCTIVE PARAMETERS OF HOLSTEIN CATTLE RAISED IN YOZGAT PROVINCE

ABSTRACT

This study was conducted to investigate the milk yield characteristics of Holstein cattle raised in 112 farms that are members of the Yozgat Cattle Breeders' Association. A total of 1,840 milk yield records belonging to Holstein cows, recorded regularly between 2003 and 2022, were evaluated. The average 305-day milk yield was found to be 7,375 liters, while the mean lactation length and dry period were determined as 358 days and 59 days, respectively. In terms of reproductive traits, the average service period was calculated as 139 days and the calving interval as 419 days. The study further examined the effects of factors such as calving year, parity, calving season, age at calving, and herd conditions on milk production traits including 305-day milk yield (305-DMY), lactation length (LL), and dry period (DP). The findings indicated that environmental factors and herd management practices had significant effects on both milk yield and reproductive performance. In particular, parity and calving season were found to play a decisive role in the variability of milk yield levels.

These results not only provide an overview of the current production levels of Holstein cattle raised in Yozgat province but also contribute valuable insights into the future targets of regional breeding programs. Accurate determination of genetic parameters and the implementation of appropriate selection strategies are of crucial importance for improving dairy cattle productivity in the region. Moreover, the results allow for comparisons with Holstein production data across Turkey, thus highlighting regional differences and production dynamics.

It is anticipated that the findings will serve as a guiding tool for sustainable dairy cattle breeding programs, contributing to the development of Holstein herds with higher milk yield and improved reproductive performance in future generations.

Keywords: Holstein Dairy Cattle, Milk Yield Traits, Genetic Parameters, Animal Breeding, Yozgat

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1.GİRİŞ

Dünyada 2020 yılında inek, manda, keçi, koyun ve diğer çiftlik hayvan türlerinden üretilen toplam süt miktarı 910.419 milyon ton olup bu üretim içinde en yüksek payı (%81) inek sütü oluşturmaktadır (FAO, 2022).

Türkiye'de sığır popülasyonun genetik yapısı değişmiş ve toplam popülasyon içerisindeki sütçü kültür ve melez sığır genotiplerinin sayısı hızlı bir şekilde artarken yerli sığır ırklarının toplam sayısı azalmıştır. Tablo 1'de sunulan verilere göre 1990 yılında Türkiye toplam sığır popülasyonu içinde kültür ve kültür melezlerinin toplam sığır varlığı içindeki oranı yaklaşık %44 iken, 2024 yılında 16.824.208 başa ulaşan toplam sığır popülasyonu içinde kültür ve kültür melezlerinin oranı %94 olarak değişmiştir (TÜİK, 2025).

Tablo 1. Türkiye tür ve ırklarına göre büyükbaş hayvan sayılarının yıllar içinde değişimi

Türkiye tür ve ırklarına göre büyükbaş hayvan sayıları				
Yıl	**Sığır - Kültür**	**Sığır - Kültür melezi**	**Sığır - Yerli**	**Manda**
1990	1 253 865	4 033 375	6 685 683	366 150
1995	1 702 000	4 776 000	5 311 000	255 000
2000	1 806 000	4 738 000	4 217 000	146 000
2005	2 354 957	4 537 998	3 633 485	104 965
2010	4 197 890	4 707 188	2 464 722	84 726
2015	6 385 343	5 733 803	1 874 925	133 766
2020	8 838 498	7 594 127	1 532 857	192 489
2024	8 213 136	7 669 922	941 150	162 051

Türkiye'ye ithal edilen ilk kültür sığır ırkı her ne kadar Siyah Alaca (Holstein) olmasa da, ülkemizde yürütülen erken dönem melezleme ve ıslah çalışmalarında çeşitli nedenlerle bu ırk uzun süre ön plana alınmamıştır. Bu dönemde yerli ırkların ıslahı, kombine verimli tiplerin kullanımı, bölgesel iklim uyumu ve kamu işletmelerinin o günkü yetiştiricilik hedefleri daha baskın olmuş; bu nedenle Siyah Alaca bazı projelerde ikincil planda tutulmuştur. Ancak 1980'lerden sonra çiğ süt talebinin artması, yem teknolojisinin gelişmesi, örgütlü süt pazarlamasının yaygınlaşması ve yüksek verimli genotiplere ulaşımın kolaylaşmasıyla birlikte Siyah Alaca'nın üstün süt verim potansiyeli saha koşullarında çok daha belirgin biçimde ortaya çıkmıştır. Bugün gelinen noktada Siyah Alaca, hem saf yetiştiricilikte hem de melezleme programlarında Türkiye'de en yaygın kullanılan ve yetiştirici tarafından en çok kabul gören kültür ırkı durumundadır. Bununla birlikte, ülkemizde yetiştirilen yerli Siyah Alaca popülasyonunun süt ve döl verimi özelliklerini tanımlamak, çevre faktörlerinin etkisini ortaya koymak, uygun damızlıkların seçimini kolaylaştırmak ve genetik ilerlemeyi hızlandırmak amacıyla çok sayıda araştırma, saha projesi ve birlik kayıt sistemi devreye sokulmuştur. Böylece hem ithal edilen genetik materyalin ülke koşullarındaki performansı izlenebilmekte hem de Türkiye'ye özgü Siyah Alaca sürülerinin ıslah hedefleri daha gerçekçi biçimde belirlenebilmektedir (Karakoyunlu, 2024).

Yozgat ili hayvancılık bakımından önemli bir potansiyele sahip olup tarımsal işletmelerin büyük kısmında hayvancılık, bitkisel üretimle birlikte yürütülmektedir. Geçmişte daha çok yerli ırklara dayanan hayvan varlığı, son yıllarda kültür ve kültür melezi ırkların yaygınlaşmasıyla birlikte önemli ölçüde değişmiştir. Yozgat İl Tarım ve Orman Müdürlüğü (2024) verilerine göre ilde süt sığırcılığında Simmental ve melezleri ilk sırayı alırken, Merkez, Akdağmadeni,

Çekerek, Kadışehri, Sarıkaya ve Sorgun ilçelerinde süt sığırcılığının yanı sıra besicilik de yaygın olarak yapılmaktadır. Buna karşılık dağlık köylerde hâlâ yerli ırk hayvancılık sürdürülürken, diğer ilçelerde kültür ve kültür melezi hayvanlar hâkimdir. Kültür ırkına yönelişle birlikte ilde süt verimi her geçen gün artmakta, kurulan ve 1.080 üyesi bulunan Damızlık Sığır Yetiştiricileri Birliği aracılığıyla da yetiştiricilerin örgütlenmesi ve ekonomik açıdan güçlendirilmesi hedeflenmektedir. Tablo 2'de Yozgat ili büyükbaş hayvan varlığı verilmiştir.

Tablo 2. Yozgat ili büyükbaş hayvan varlığı

Yozgat Büyükbaş Hayvan Varlığı						
Yıl	**Sığır Kültür**	**Sığır Melez**	**Sığır Yerli**	**Sığır Toplam**	**Manda**	**Büyükbaş Toplam**
2021	136.199	91.150	11.484	238.833	3.820	242.653
2022	130.136	82.889	6.214	219.239	3.321	222.560
2023	138.260	77.615	7.655	223.530	3.033	226.563

Siyah Alaca sığırların süt tipi ırklarında vücut önden arkaya doğru yavaş yavaş genişler ve derinlik artar. Bedenleri ince ve narin yapılıdır, kemik çıkıntıları belirgindir. Baş yapısı asil ve zarif, deri ince ve yumuşak olup boyunda dikey kıvrımlar oluşturur. Vücut tüyleri kısa ve parlaktır; süt damarları uzun ve belirgindir; memeler dolgun ve büyüktür (İnal ve ark., 2016). Siyah Alaca sığırlarda ergin canlı ağırlık dişilerde 500–700 kg, erkeklerde ise 800–1000 kg; cidago yüksekliği ise yaklaşık 147 cm'dir. Düvelerde en uygun ilkine tohumlama yaşı 15 ay olup bu yaşta ortalama canlı ağırlık 360 kg'dır. Siyah Alaca ırkında gebelik süresi ortalama 9 aydır ve ilk buzağı genellikle 24–27 aylık yaşta alınmaktadır. Siyah Alaca buzağılar ortalama 40 kg doğum ağırlığıyla dünyaya gelir. Ancak Siyah Alaca sığırlar meme ve ayak rahatsızlıklarına karşı nispeten hassas olduklarından mera koşullarına tam olarak uygun değildir (Alpan ve Arpacık, 2002; İnal ve ark., 2016; Özdemir, 2024).

2. MATERYAL VE METOD

Araştırma materyalini, Yozgat Damızlık Sığır Yetiştiricileri Birliği'ne üye işletmelerden alınan, Siyah Alaca Sığırlara ait soy kütüğü kayıtları (hayvanların kulak numaraları, ana ve babalarının kulak numaraları, doğum tarihi, buzağılama tarihi, 305 gün süt verimi, laktasyon süresi, servis peryodu, buzağılama aralığı ve kuruda kalma süresi) oluşturmuştur. Çalışmada, 2003–2022 yılları arasında düzenli olarak kaydedilen toplam 1840 baş ineğe ait süt ve döl verim kayıtları değerlendirilmiştir.

Veriler analize hazırlanırken; yıl ve laktasyon sırası gruplarında hayvan sayısı 100'ün altında olanlar, ölü doğum, yavru atma, hastalık veya sakatlık gibi nedenlerle sürüden çıkarılanlar ile kayıtları düzensiz olan ya da aşırı (uç) değer gösteren hayvanlar değerlendirmeye alınmamıştır.

Verim özelliklerinden 305 günlük süt verimi (305 GSV), laktasyon süresi (LS) ve kuruda kalma süresine (KKS) etkili olduğu düşünülen buzağılama yaşı, buzağılama mevsimi, buzağılama yılı, işletme (sürü) koşulları ve laktasyon sırası gibi faktörlerin belirlenmesinde Minitab 17 istatistik paket programından yararlanılmıştır. İlk aşamada tüm faktörler modele dâhil edilmiş, daha sonra "step-down" yaklaşımı uygulanarak istatistiksel bakımdan önemsiz olan etkiler modelden sırasıyla çıkarılmış ve $P \leq 0,01$ düzeyinde anlamlılık gösteren faktörler modelde tutulmuştur (Ulutaş, 1998). Anlamlı bulunan grupların ortalamaları arasındaki farklar ise Tukey çoklu karşılaştırma testi ile değerlendirilmiştir (Sheskin, 2004; Karaağaç, 2019).

Çalışmanın ikinci aşamasında, 305 GSV, LS ve KKS üzerine etkili olduğu ilk analizlerde belirlenen sabit faktörlere ek olarak hayvanın doğrudan genetik etkisini de içeren bireysel hayvan modeli (animal model) kurulmuş ve söz konusu özelliklere ait genetik (additif) ve fenotipik varyans–kovaryans bileşenleri MTDFREML paket programı kullanılarak tahmin edilmiştir (Boldman ve ark., 1995). Üçüncü aşamada ise bu varyans bileşenleri temel alınarak hayvanların damızlık değerleri En İyi Doğrusal Yansız Tahmin (BLUP- Best Linear Unbiased Prediction) yöntemi ile hesaplanmıştır. Çevresel faktörlerin etkisini test etmek için kullanılan doğrusal modeller aşağıda verilmiştir.

İBY, SP, BA, GBTS, LSV, 305-GSV, LS, özelliklerine etki eden makro çevre faktörlerinin etkilerinin analizi için Varyans Analizi Tekniği (General Linear Model) kullanılmıştır. İstatistik olarak etkisi önemli bulunan faktörlerin ortalamaları Tukey Çoklu Karşılaştırma Testine göre karşılaştırılmıştır (Sheskin, 2004). Çevresel aktörlerin etkilerinin incelenmesinde Karaağaç, (2019)'ın belirttiği aşağıda verilen model kullanılmıştır:

$$Y_{ijklm}=\mu+ a_i+ b_j+ c_k+ d_l +b_{yx}(X_{ijklm})+ b_{yz}(Z_{ijklm})+ (İl*Mevsim)_{ij} + (İl*Yıl)_{ik} + (Mevsim*Yıl)_{jk} + e_{ijklm}$$

Bu modelde;

Y_{ijklm} : i. İldeki, j. Buzağılama mevsimindeki, k. Buzağılama yılında, l. Laktasyon sırasındaki m. ineğin üzerinde durulan döl (SP, GBTS, BA) ve süt (LSV, 305GSV, LS) verim özelliğe ilişkin gözlem değeri

μ : popülasyon ortalamasını,

a_i : i. buzağılama ilinin etki miktarını (i: 1-9),

b_j : j. buzağılama mevsiminin etki miktarını (j: 1-4; Kış-İlkbahar-Yaz-Sonbahar), c_k : k. Buzağılama yılının etki miktarını (k:1-12; 2012-2022),

d_l : l. laktasyon sırasının etki miktarını (l: 1-3; 1-3),

b_{yx} : Y'nin X'e göre regresyon katsayısını (doğrusal etki) (İBY'nın 1 ay değişimine karşı üzerinde durulan özellikteki değişim miktarı)

b_{yz} : Y'nin Z'ye göre regresyon katsayısını (doğrusal etki) (Buzağılama yaşının 1 yıl değişimine karşı üzerinde durulan özellikteki değişim miktarı)

$(İl* Yıl)_{ij}$; $(il*Mevsim)_{ik}$= İl* Yıl ve il*Mevsim interaksiyon terimi $(Mevsim*Yıl)_{jk}$= Mevsim*Yıl özellik arasındaki interaksiyon terimi e_{ijklm} : Hatayı (rasgele etki miktarını) ifade etmektedir.

3. BULGULAR VE TARTIŞMA

3.1. 305 Gün Süt Verimi (305 GSV)

İneklerde laktasyon süresi 305 gün olarak kabul edilir. Bundan dolayı normal koşullarda 305 günden kısa süren laktasyonlar tamamlanmış olarak kabul edilir ve düzeltme yapılmaz. Örneğin 290 gün süren bir laktasyon verimi, 305 günlük verim olarak değerlendirilir. Damızlık veya kasaplık olarak satılmak, ölüm, yavru atma vb. genotipe bağlı olmayan nedenlerle tamamlanamayan laktasyonlar, tamamlanmamış laktasyonlar olarak isimlendirilmektedir. Bu laktasyonlar da; laktasyon, 180 günden kısa ise değerlendirilmemekte, 180 günden uzun ise de 305 güne göre geliştirilmiş düzeltme katsayıları kullanılarak 305 güne tamamlanmaktadır (Boztepe ve ark. 2015). Araştırmada elde edilen 305 gün süt verimi üzerine etkili çevre faktörleri Tablo 3'de sunulmuştur.

Tablo 3. Siyah Alaca ineklerde 305 gün süt verimi üzerine etkili çevre faktörleri

		N	$\bar{X} \pm S_{\bar{x}}$	P
İşletme Büyüklüğü	1-5 baş	125	7506.81 ± 158.61^{A}	<0.001
	6-10 baş	159	7531.28 ± 134.27^{A}	
	11-50 baş	667	7127.81 ± 68.80^{B}	
	51-200 baş	61	7222.10 ± 278.29^{B}	
	>200 baş	828	7493.98 ± 62.75^{A}	
Laktasyon Sırası	1	911	6934.73 ± 53.08^{C}	<0.001
	2	526	7837.29 ± 80.98^{AB}	
	3	245	7439.13 ± 127.27^{B}	
	4	105	8044.94 ± 177.34^{A}	
	5	53	8082.51 ± 243.25^{A}	
Buzağılama Mevsimi	Kış	510	7552.83 ± 76.85^{A}	<0.001
	İlkbahar	465	7542.35 ± 76.06^{A}	
	Yaz	434	7335.50 ± 84.74^{A}	
	Sonbahar	431	6944.07 ± 97.02^{B}	

^{AB}: Aynı sütunda farklı harfleri taşıyan grup ortalamaları arası farklar önemlidir (P<0.05)

Tablo 3'de görüldüğü üzere, Siyah Alaca ineklerde 305 günlük süt verimi işletme büyüklüğü, laktasyon sırası ve buzağılama mevsiminden önemli derecede etkilenmiştir (P<0,001). Çok küçük (1–10 baş) ve çok büyük (>200 baş) işletmelerdeki ineklerin süt verimleri daha yüksek bulunurken, orta büyüklükteki işletmeler daha düşük bir grupta yer almıştır. Laktasyon sırasının ilerlemesiyle süt verimi artmış ve en yüksek değerler 4. ve 5. laktasyonda belirlenmiştir. Kış ve ilkbaharda buzağılayan inekler daha yüksek süt verimi gösterirken, sonbaharda buzağılayan ineklerin süt verimi anlamlı olarak daha düşük olmuştur. Farklı harf taşıyan ortalamalar arasındaki farklar istatistiksel olarak önemlidir (P<0,05).

Siyah Alaca ineklerde 305-GSV özelliğinin tanımlayıcı fenotipik değerlerini belirlemeye yönelik yapılan araştırmalar Tablo 4'de verilmiştir.

Tablo. 4. 305 GSV ile ilgili yapılan bazı araştırma sonuçları

Irk	**Araştırıcı**	**Araştırma Yapıldığı Yer**	**305GSV (kg)**
Siyah alaca	Parlak ve Kandır (2015)	Afyonkarahisar	6884.1
	Alkoyak ve Çetin (2018)	Kırşehir	8986
	Keser (2016)	Tekirdağ	5630.1
	Soyudal (2017)	Bursa	8450
	Sarar ve Tapkı (2017)	Koçaş Tarım İşletmesi	6588.4
	Kheirabadi ve Alijani (2014)	İran	9059

Bu çalışmada Yozgat ilinde Siyah Alaca ineklerde 305 günlük süt verimi 7375 kg olarak belirlenmiştir. Bu değer, Afyonkarahisar'daki (6884 kg; Parlak ve Kandır, 2015) ve Koçaş

Tarım İşletmesi'ndeki (6588 kg; Sarar ve Tapkı, 2017) bildirişlerden yüksek, Bursa (8450 kg; Soyudal, 2017) ve Kırşehir (8986 kg; Alkoyak, 2016) sonuçlarından ise daha düşüktür. İran'da bildirilen 9459 kg'lık ortalama ise yoğun seçilim ve üstün besleme koşullarını yansıttığından bölge koşullarımızdan beklenen değerin üzerindedir. Buna göre Yozgat'taki sürülerin süt verim düzeyi, ülkemizdeki pek çok bölgesel çalışmayla karşılaştırılabilir hatta bir kısmından yüksektir; ancak bakım-besleme ve sürü yönetimindeki farklılıkların azaltılmasıyla bu ortalamanın daha üst düzeylere çıkarılabileceği anlaşılmaktadır.

3.2. Laktasyon Süresi (LS)

Çalışmada elde edilen laklasyon verisi ile ilgili veriler Tablo 5'de sunulmuştur.

Tablo 5. Siyah Alaca ineklerde laktasyon süresi üzerine etkili çevre faktörleri

		N	$\bar{X} \pm S_{\bar{x}}$	P
İşletme Büyüklüğü	1-5 baş	101	371.11 ± 6.41^{A}	0.044
	6-10 baş	114	359.41 ± 6.17^{ABC}	
	11-50 baş	531	351.04 ± 2.87^{BC}	
	51-200 baş	42	344.00 ± 10.40^{C}	
	>200 baş	629	366.77 ± 2.80^{AB}	
Laktasyon Sırası	1	725	360.18 ± 2.46^{AB}	0.040
	2	393	368.62 ± 3.60^{A}	
	3	186	345.12 ± 4.97^{BC}	
	4	78	359.53 ± 7.28^{AB}	
	5	35	336.31 ± 11.71^{C}	
Buzağılama Mevsimi	Kış	397	364.21 ± 3.49^{AB}	0.023
	İlkbahar	365	366.62 ± 3.44^{A}	
	Yaz	308	355.03 ± 3.96^{BC}	
	Sonbahar	347	352.29 ± 3.62^{C}	

ABC: Aynı sütunda farklı harfleri taşıyan grup ortalamaları arası farklar önemlidir (P<0.05)

Tablo 5'e göre Siyah Alaca ineklerde laktasyon süresi; işletme büyüklüğü, laktasyon sırası ve buzağılama mevsiminden anlamlı şekilde etkilenmiştir (P<0,05). En uzun laktasyonlar küçük işletmelerde (1–5 baş) ve çok büyük işletmelerde (>200 baş) görülürken, 51–200 başlık işletmelerde laktasyon süresi en düşük düzeyde belirlenmiştir. Laktasyon sırası ilerledikçe laktasyon süresinde kısalma eğilimi ortaya çıkmış, özellikle 2. laktasyondaki inekler en uzun laktasyonu göstermiş, 5. laktasyondakiler ise en kısa grupta yer almıştır. Mevsim bakımından ise ilkbahar ve kışın buzağılayan ineklerin laktasyonları daha uzun sürmüş, sonbaharda buzağılayanların laktasyonları daha kısa gerçekleşmiştir. Bu bulgular, laktasyonun yalnızca hayvanın potansiyeline değil, işletme yönetimi ve mevsimsel koşullara da duyarlı olduğunu göstermektedir.

Türkiye'nin farklı bölgelerinde Siyah Alaca ineklerle yapılan çalışmalarda laktasyon süresi (LS) değerleri geniş bir aralıkta rapor edilmiştir. Türkiye geneli için 319–364 gün (Kumlu ve Akman, 1999; Özkök, 2006; Şahin, 2009; Genç, 2014), İç Anadolu'da ise çoğunlukla 295–325 gün, bazı çalışmalarda ise 326–398 gün arasında değerler bildirilmiştir (Özçelik, 1994; Duru ve Tuncel, 2002; Erdem ve ark., 2007; Bakır ve ark., 2009; Şahin ve Ulutaş, 2010; Keser, 2016;

Sarar ve Tapkı, 2017; Alkoyak ve Çetin, 2018; Karaağaç, 2019). Bu araştırmada hesaplanan ortalama LS değerlerinin söz konusu çalışmaların önemli bir kısmıyla benzer veya daha uzun olması, bu dönemde sürülerde süt verimini artırmaya yönelik seleksiyonun ve buna eşlik eden daha iyi besleme-yönetim uygulamalarının, memede süt sentez süresini uzatmasıyla açıklanabilir.

3.3. Kuruda Kalma Süresi (KKS)

Çalışmada elde edilen kuruda kalma süresi ile ilgili veriler Tablo 6'da sunulmuştur.

Tablo 6. Siyah Alaca ineklerde kuruda kalma süresi üzerine etkili çevre faktörleri

		N	$\bar{X} \pm S_{\bar{x}}$	P
İşletme Büyüklüğü	1-5 baş	101	56.97 ± 1.06^{B}	0.003
	6-10 baş	114	58.18 ± 1.10^{B}	
	11-50 baş	531	57.72 ± 0.55^{B}	
	51-200 baş	42	62.17 ± 1.67^{A}	
	>200 baş	629	59.57 ± 0.43^{AB}	
Laktasyon Sırası	1	725	58.03 ± 0.44^{B}	0.043
	2	393	59.13 ± 0.59^{B}	
	3	186	59.11 ± 0.78^{B}	
	4	78	59.26 ± 1.34^{B}	
	5	35	62.60 ± 1.75^{A}	
Buzağılama Mevsimi	Kış	397	58.59 ± 0.61	0.651
	İlkbahar	365	58.25 ± 0.64	
	Yaz	308	58.97 ± 0.59	
	Sonbahar	347	58.88 ± 0.61	

AB: Aynı sütunda farklı harfleri taşıyan grup ortalamaları arası farklar önemlidir ($P<0.05$)

Sonuç olarak, araştırmada Siyah Alaca ineklerin kuruda kalma sürelerinin genel olarak **57–60 gün bandında** seyrettiği, ancak işletme ve yaşa bağlı olarak bu sürenin **56,97 günden (1–5 baş işletmeler)** başlayıp **62,17 güne (51–200 baş işletmeler)** kadar çıkabildiği belirlenmiştir. Benzer şekilde laktasyon sırası ilerledikçe kuru sürenin hafifçe uzadığı ve **1. laktasyonda 58,03 gün olan** sürenin **5. laktasyonda 62,60 güne** yükseldiği görülmüştür. Bu bulgular, özellikle daha büyük ve yaşlı hayvanların bulunduğu sürülerde doğum sonrası döneme hazırlığı güçlendirmek, meme dokusunun yenilenmesini sağlamak ve bir sonraki laktasyonda yüksek süt verimini sürdürebilmek amacıyla kuru dönemin sahada bilinçli olarak üst sınıra yakın uygulandığını göstermektedir.

Bu çalışmada kuruda kalma süresi (KKS) **59 gün** olarak hesaplanmıştır ve bu değer süt sığırcılığında "önerilen 45–60 gün" aralığına oldukça yakındır. Ancak literatürdeki bazı çalışmaların bundan belirgin şekilde **daha uzun** kuru dönemler bildirdiği görülmektedir. Örneğin çeşitli çalışmalarda KKS'nin 65 gün (Duru ve Tuncel, 2002), 67 gün (Topaloğlu ve Güneş, 2004), 68 gün (Özçakır ve Bakır, 2003), 79 gün (Bakır ve ark., 2009), 82 gün (Erdem ve ark., 2007), 82 gün (Şahin ve Ulutaş, 2010), 86 gün (Koçak ve ark., 2007) ve Sarar ve Tapkı (2017)'de 67 gün olarak saptamışlardır.

Çalışmada tespit edilen **59 günlük** değer, bu çalışmaların önemli bir bölümünden **daha kısadır.** Ayrıca, 59 günlük KKS ne çok kısa (buzağı gelişimini ve meme dokusunun yenilenmesini riske sokacak kadar) ne de çok uzun (döl verimini geciktirecek kadar) bir süredir. Bu da çalışmada değerlendirilen işletmelerde kuru dönemlerin düzenli izlendiğini ve doğuma hazırlığın çoğunlukla zamanında yapıldığını göstermektedir.

3.4. Servis Periyodu (SP)

Çalışmada elde edilen servis peryodu ile ilgili veriler Tablo 7'de sunulmuştur.

Tablo 7. Siyah Alaca ineklerde servis periyodu üzerine etkili çevre faktörleri

		N	$\bar{X} \pm S_{\bar{x}}$	P
İşletme Büyüklüğü	1-5 baş	125	148.16 ± 5.76^{A}	0.046
	6-10 baş	159	142.26 ± 5.35^{A}	
	11-50 baş	667	133.73 ± 2.58^{AB}	
	51-200 baş	61	122.77 ± 8.16^{B}	
	>200 baş	828	146.70 ± 2.38^{A}	
Laktasyon Sırası	1	911	139.64 ± 2.21^{AB}	0.040
	2	526	148.39 ± 3.03^{A}	
	3	245	132.62 ± 4.35^{AB}	
	4	105	141.07 ± 6.27^{AB}	
	5	53	127.09 ± 9.02^{B}	
Buzağılama Mevsimi	Kış	510	146.54 ± 3.12^{A}	0.010
	İlkbahar	465	145.06 ± 2.96^{A}	
	Yaz	434	136.22 ± 3.30^{B}	
	Sonbahar	431	134.56 ± 3.20^{B}	

^{AB}: Aynı sütunda farklı harfleri taşıyan grup ortalamaları arası farklar önemlidir ($P<0.05$)

Araştırmada Siyah Alaca ineklerde servis periyodu ortalamalarının 122,77 ile 148,39 gün arasında değiştiği ve çevresel faktörlere duyarlı olduğu belirlenmiştir. Bu değerler saha koşullarında döl veriminin kısmen geciktiğini göstermektedir. Servis periyodu işletme büyüklüğüne göre önemli düzeyde farklılık göstermiştir (P=0,046). En kısa servis periyodu 51–200 başlık işletmelerde 122,77 gün olarak saptanırken (B), 1–5 baş, 6–10 baş ve >200 başlık işletmelerde SP'nin 142–148 gün arasında ve daha uzun olduğu görülmüştür (A). Bu durum orta büyüklükteki işletmelerin tohumlama ve döl verimi yönetimini daha etkin yaptığını, çok küçük ve çok büyük ölçekli işletmelerde ise ilk tohumlama zamanının gecikebildiğini düşündürmektedir.

Laktasyon sırası da servis periyodu üzerine etkili olmuştur (P=0,040). İkinci laktasyondaki inekler en uzun servis periyoduna (148,39 gün) sahip olurken, 5. laktasyondakiler 127,09 gün ile en kısa grupta yer almıştır (B). Bu bulgu, orta yaşlı ineklerde doğum sonrası dönemde döl tutmanın biraz daha gecikebildiğini, yaşlı ineklerde ise sürüden çıkarılma baskısına bağlı olarak daha kısa SP uygulandığını göstermektedir. Buzağılama mevsimi bakımından kış ve ilkbaharda buzağılayan ineklerin servis periyotları daha uzun (146,5 ve 145,1 gün) bulunmuş, yaz ve sonbaharda buzağılayanlarda ise SP 134–136 güne düşmüştür (P=0,010). Bu durum kış ve

erken ilkbahar dönemlerinde negatif enerji dengesi, barınak koşulları ve döl tutmanın gecikmesi gibi etmenlerin etkili olabileceğini göstermektedir.

Sonuç olarak, bu çalışmada elde edilen servis periyodu değerleri, incelenen sürülerde döl veriminin çevresel ve işletme kaynaklı faktörlerden etkilendiğini; özellikle küçük ve çok büyük ölçekli işletmeler ile kış-ilkbahar döneminde buzağılayan ineklerde östrus tespiti, ilk tohumlama zamanı ve döl tutma başarısının iyileştirilmesiyle bu sürenin kısaltılabileceğini ortaya koymaktadır.

Bizim çalışmamızda Siyah Alaca ineklerde servis periyodu (SP) ortalaması **139 gün** olarak belirlenmiştir. Bu değer, süt sığırı işletmelerinde "ideale yakın" kabul edilen **60–90 gün** aralığının (Akman ve ark., 2001) ve yetiştiricilerin pratikte hedeflediği **100–110 gün** düzeyinin (Boztepe ve ark., 2015) üzerindedir. Türkiye'de bazı işletmelerde bildirilen SP değerleriyle karşılaştırıldığında da bizim bulgumuzun görece uzun olduğu görülmektedir.

Türkiye'de araştırma yapan Özçelik, (1994) 95–133 gün; Özçelik ve Arpacık, (2000) 114 gün; Koçak ve ark., (2007) 87–100 gün; Duru ve Tuncel, (2002); 93 gün; Sehar ve Özbeyaz, (2005) 109 gün; Bilgiç ve Alıç, (2005) 95 gün; Erat ve ark., (2013) 77–137 gün olarak tespit etmişlerdir.Buna göre 139 günlük SP'nin, özellikle kurumsal işletmelerde bildirilen çoğu değerden **daha uzun** olduğu söylenebilir. Bu fark; işletmelerde kızgınlık tespitinin yeterince hassas yapılamaması, ilk tohumlama zamanının gecikmesi, doğum sonrası dönemdeki metabolik/sosyal stresler veya süt verimi yüksek ineklerde döl tutmanın fizyolojik olarak biraz daha geç gerçekleşmesiyle ilişkili olabilir. Dolayısıyla bu işletmelerde SP'nin 110–120 gün bandına çekilmesi, hem yılda bir buzağı hedefini destekleyecek hem de laktasyonlar arası aralığın kısaltılmasıyla sürü verimliliğini artıracaktır.

3.5. Buzağılama Aralığı (BA)

Çalışmada elde edilen buzağılama aralığı ile ilgili veriler Tablo 8'de sunulmuştur.

Tablo 8. Siyah Alaca ineklerde buzağılama aralığı üzerine etkili çevre faktörleri

		N	$\bar{X} \pm S_{\bar{x}}$	P
İşletme Büyüklüğü	1-5 baş	125	428.16 ± 5.76^{A}	0.049
	6-10 baş	159	422.26 ± 5.35^{A}	
	11-50 baş	667	413.73 ± 2.58^{AB}	
	51-200 baş	61	402.77 ± 8.16^{B}	
	>200 baş	828	426.70 ± 2.38^{A}	
Laktasyon Sırası	1	911	419.64 ± 2.21^{AB}	0.300
	2	526	428.39 ± 3.03^{A}	
	3	245	412.62 ± 4.35^{AB}	
	4	105	421.07 ± 6.27^{AB}	
	5	53	407.09 ± 9.02^{B}	
Buzağılama Mevsimi	Kış	510	426.54 ± 3.12^{A}	0.018
	İlkbahar	465	425.06 ± 2.96^{A}	
	Yaz	434	416.22 ± 3.30^{B}	
	Sonbahar	431	414.56 ± 3.20^{B}	

[AB]: Aynı sütunda farklı harfleri taşıyan grup ortalamaları arası farklar önemlidir (P<0.05)

Araştırmada Siyah Alaca ineklerde buzağılama aralığı ortalamalarının yaklaşık **402–428 gün** arasında değiştiği belirlenmiştir. Bu değerler, ideal kabul edilen 365 günün üzerinde olup sürülerde döl veriminin çevresel ve yönetimsel faktörlerden etkilendiğini göstermektedir. Buzağılama aralığı işletme büyüklüğüne göre önemli düzeyde farklılık göstermiştir (P=0,049). En kısa BA 51–200 başlık işletmelerde **402,77 gün** olarak saptanırken, 1–5 baş, 6–10 baş ve >200 başlık işletmelerde bu süre **422–428 gün** aralığında ve daha uzun bulunmuştur. Bu sonuç, orta büyüklükteki işletmelerde döl verimi yönetiminin daha başarılı olduğunu, çok küçük ve çok büyük ölçekli işletmelerde ise tohumlama zamanının veya döl tutmanın gecikebildiğini düşündürmektedir.

Laktasyon sırası ile buzağılama aralığı arasındaki farklar istatistiksel olarak önemli bulunmamıştır (P=0,300). Bununla birlikte 2. laktasyondaki ineklerin BA'sı **428,39 gün** ile nispeten daha uzun, 5. laktasyondakilerin ise **407,09 gün** ile daha kısa gerçekleşmiştir. Bu durum yaşlı ineklerde sürüden çıkarılma baskısına bağlı olarak daha sık buzağılama hedeflendiğini düşündürmektedir. Buzağılama mevsimi BA üzerinde etkili olmuştur (P=0,018). Kış ve ilkbaharda buzağılayan inekler **425–427 gün** ile daha uzun aralıklarda buzağılamış, buna karşılık yaz ve sonbaharda buzağılayanlarda bu süre **414–416 güne** düşmüştür. Kış-ilkbahar dönemlerinde enerji dengesi ve çevre koşullarına bağlı döl tutma gecikmelerinin bu farkı oluşturduğu değerlendirilmektedir."

Sonuç olarak, bu çalışmada belirlenen buzağılama aralıkları saha koşullarında döl veriminin hedeflenen 365 günün üzerinde seyrettiğini, özellikle küçük ve çok büyük ölçekli işletmeler ile kış-ilkbahar döneminde buzağılayan ineklerde östrus tespiti, zamanlı tohumlama ve doğum sonrası bakımın iyileştirilmesiyle bu sürenin kısaltılabileceğini ortaya koymaktadır.

Süt verim yönlü ineklerde BA'nın, 340-370 gün arasında olmak üzere, ortalama 365 gün (1yıl) olması istenmektedir. Bu değerlerden sapmalar süt veriminin azalmasına yol açmaktadır (Akman, 1997). Yine Boztepe ve ark. (2015) tarafından BA'nın 365-390 gün (12-13 ay) arasında tutulması önerilmektedir.

Bu çalışmada buzağılama aralığı (BA) **yaklaşık 406 gün** olarak hesaplanmıştır. Bu değer, süt sığırı işletmeciliğinde "ideal" kabul edilen **365 gün/yılda bir buzağı** hedefine göre uzun olmakla birlikte, Türkiye'de Siyah Alaca sürüler üzerinde yapılmış birçok çalışmanın bildirdiği değerlerden **daha kısa** ya da **onlara oldukça yakındır.**

Türkiye'de farklı iller ve işletmelerde yapılan çalışmalarda BA'nın genellikle **390–430 gün** aralığında değiştiği görülmektedir. Bazı çalışmalarda 420 günün üzerinde değerler rapor edilmiştir (Özçelik, 1994; Bilgiç ve Alıç, 2005; Koçak ve ark., 2007; Bakır ve ark., 2009; Şahin ve Ulutaş, 2010; Sarar ve Tapkı, 2017).

Bu farkın temel nedeni, aynı çalışmada belirlenen **servis periyodunun 139 gün** gibi nispeten uzun bir düzeyde seyretmesi ve buna 59 günlük kuruda kalma süresinin eklenmesiyle gebelik aralığının bir miktar uzamasıdır. Nitekim literatürde BA'nın uzamasının çoğu kez **SP'nin uzamasını** takip ettiği, yani sorun kaynağının çoğunlukla tohumlamaya geç başlama veya geç döl tutma olduğu bildirilmektedir (Özçelik ve Arpacık, 2000; Duru ve Tuncel, 2002; Sehar ve Özbeyaz, 2005; Erdem ve ark., 2007). Dolayısıyla 406 günlük değer, hem ülkemizdeki bazı işletmelerinde bildirilen 417–430 günlük değerlerden **daha kısa** olması bakımından olumlu, hem de 365 günlük hedefe hâlâ **iyileştirme payı** olduğunu göstermesi bakımından dikkat çekicidir.

Bu sonuçlar, incelenen illerde döl verimi yönetiminin tamamen yetersiz olmadığını; kızgınlık tespiti, ilk tohumlama yaşı/doğum sonrası ilk tohumlama zamanı ve besleme-nedenli doğum

sonrası gecikmelerin azaltılmasıyla BA'nın 390–395 gün bandına çekilebileceğini göstermektedir.

4. SONUÇ

Bu çalışmada Yozgat ilinde yetiştirilen Siyah Alaca sığırların 2003–2022 yılları arasında tutulan 1.840 başlık kayıtları değerlendirilmiş ve bölgedeki sürülerin hem süt verimi hem de döl verimi bakımından Türkiye ortalamalarıyla karşılaştırılabilir düzeyde olduğu görülmüştür. Laktasyon süresinin 358 gün ve kuru dönem süresinin 59 gün düzeyinde gerçekleşmesi, işletmelerde sağım ve kurutma yönetiminin genel olarak doğru yapıldığını, sürenin hem çok kısalmadığını hem de gereksiz yere uzatılmadığını ortaya koymuştur. İşletme büyüklüğü, laktasyon sırası ve buzağılama mevsimi gibi çevresel faktörlerin 305-GSV, laktasyon süresi ve kuru dönem üzerine anlamlı etkilerinin bulunması, bölgedeki verim farklılıklarının yalnızca genetik değil, büyük ölçüde yönetim kaynaklı olduğunu da göstermektedir.

Döl verimi bakımından hesaplanan **139 günlük servis periyodu** ve **yaklaşık 406 günlük buzağılama aralığı** ise sürülerde hedeflenen 365 gün/yılda bir buzağı düzeyine tam olarak ulaşılamadığını, ancak Türkiye'de farklı illerde Siyah Alacalar için bildirilen 390–430 günlük değerlere göre daha iyi bir seviyenin yakalandığını ortaya koymaktadır Bu durum, çalışma materyalinin saha koşullarını iyi yansıttığını, ancak kızgınlık tespiti, ilk tohumlama zamanının belirlenmesi, doğum sonrası negatif enerji dengesinin azaltılması ve kış–ilkbahar buzağılamalarında barınak-besleme yönetiminin güçlendirilmesiyle döl verimi göstergelerinin 390 gün bandına çekilebileceğini düşündürmektedir. Nitekim 51–200 başlık işletmelerde BA'nın 402,8 gün, SP'nin ise 122,8 gün olması; orta ölçekli iyi yönetilen işletmelerde üreme performansının belirgin biçimde daha iyi olduğuna işaret etmektedir.

Elde edilen bulgular bütün olarak değerlendirildiğinde, Yozgat ilindeki Siyah Alaca sürülerinin verim düzeyinin artırılmasında yalnızca genetik ilerlemenin değil, **işletme büyüklüğüne uygun sürü yönetimi modellerinin, mevsime duyarlı besleme programlarının ve döl verimi odaklı kayıt-izleme sistemlerinin** birlikte kullanılması gerektiği anlaşılmaktadır. Bu veriler, bölgeye özgü seleksiyon hedeflerinin daha gerçekçi olarak tanımlanmasına imkân vermekte ve DSYB kayıtlarının düzenli tutulmasının bölgesel ıslah programları için ne kadar kritik olduğunu göstermektedir.

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DOĞUM ÖNCESI KONDİSYON YÖNETİMİNİN SÜT SIĞIRLARINDA ÜREME PERFORMANSINA ETKİLERİ

Doç. Dr. Orhan ERMETİN

Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Zootekni Bölümü

Email: orhan.ermetin@yobu.edu.tr

ORCID: 0000-0002-3404-0452

ÖZET

Süt sığırcılığında üretkenlik yalnızca süt verimi ile sınırlı olmayıp, üreme performansı, metabolik sağlık ve genel sürü refahı ile doğrudan ilişkilidir. Doğum öncesi dönem, bu bağlamda kritik bir geçiş sürecini temsil etmekte olup, ineklerin metabolik adaptasyonları, enerji dengesi ve hormonal düzenlemeleri üzerinde belirleyici rol oynamaktadır. Bu dönemde uygulanan kondisyon yönetimi, doğum sonrası dönemde ortaya çıkabilecek negatif enerji dengesi, metabolik bozukluklar ve düşük fertilite gibi sorunların önlenmesinde stratejik bir faktördür. Vücut kondisyon skoru (VKS), ineklerin enerji rezervlerini ve yağ dokusu durumunu değerlendirmede en yaygın kullanılan araçtır. Araştırmalar, optimal VKS düzeyinde (genellikle 3,0–3,5) doğuma giren ineklerin daha yüksek döl tutma oranlarına, daha kısa servis periyoduna ve daha sağlıklı bir laktasyon başlangıcına sahip olduklarını ortaya koymaktadır. Buna karşın, düşük kondisyonlu ineklerde doğum sonrası kızgınlıkların geciktiği, fertilitenin zayıfladığı ve süt veriminin olumsuz etkilendiği bildirilmektedir. Yüksek BCS değerleri ise metabolik stres, doğum güçlüğü ve yem alımında azalma riskini beraberinde getirmektedir.

Beslenme stratejileri, özellikle kuru dönem ve geçiş dönemi boyunca, enerji dengesi ve metabolik sağlık açısından kritik öneme sahiptir. Negatif enerji dengesi (NED), yüksek düzeyde yağ mobilizasyonu ve ketozis gibi sorunlara yol açarak üreme performansını olumsuz etkilemektedir. Ayrıca, insülin, leptin, IGF-I ve progesteron gibi hormonların enerji dengesiyle ilişkili olarak üreme fonksiyonları üzerinde belirleyici olduğu vurgulanmaktadır. Bu nedenle, doğum öncesi dönemde uygun beslenme programlarının uygulanması, kondisyon kayıplarının sınırlanması ve metabolik hastalıkların önlenmesi, sürülerin üretkenliği ve sürdürülebilirliği açısından vazgeçilmezdir. Sonuç olarak, doğum öncesi kondisyon yönetimi yalnızca bireysel hayvan sağlığına değil, aynı zamanda işletme ekonomisine ve uzun vadeli ıslah programlarına da katkı sağlayan temel bir yönetim aracıdır.

Anahtar Kelimeler: Vücut Kondisyon Skoru, Negatif Enerji Dengesi, Üreme Performansı, Süt Sığırı, Kondisyon Yönetimi

IMPACT OF PREPARTUM BODY CONDITION MANAGEMENT ON REPRODUCTIVE PERFORMANCE OF DAIRY COWS

ABSTRACT

Productivity on a dairy farm isn't confined to milk yield; it's tightly woven with performance, metabolic health, and the overall welfare of the herd. The pre-parturient period marks a transition when cows undergo metabolic adjustments, shift their energy balance, and experience sweeping hormonal changes. Managing body condition during this window is a move to forestall postpartum issues such as negative energy balance (NEB), metabolic disorders, and a dip in fertility. The body condition score (BCS) stands as the adopted yardstick for gauging energy reserves and adiposity in dairy cattle. Evidence from the literature points out that cows entering the calving window with a BCS in the corridor—somewhere between 3.0 and 3.5—tend to boast higher conception rates, experience briefer service intervals, and enjoy a more robust lactation curve. On the side, animals saddled with a low BCS frequently display postponed estrus, diminished fertility, and a slump in milk yield; while those perched at the opposite extreme with an excessively high BCS are prone to metabolic disturbances, dystocia, and a noticeable dip in feed intake.

Well-designed nutrition programs during the pre-calving period and the subsequent transition phase are essential for keeping a cow’s energy balance on an even keel and its metabolism stable. A negative energy balance (NEB) triggers mobilization, opens the door to ketosis, and dampens reproductive performance. Meanwhile, hormones such as insulin, leptin, IGF-I, and progesterone, tightly interwoven with energy metabolism, exert an influence on function. Consequently, implementing pre-partum feeding strategies, preventing steep body-condition declines, and sidestepping metabolic disorders are key to boosting herd productivity and ensuring long-term sustainability. All told, managing pre-partum condition isn't just a driver of each animal’s health; it also feeds into farm economics and the success of long-range breeding improvement programs. For that reason, it should be seen as a bedrock management tool in dairy operations.

Keywords: Body Condition Score, Negative Energy Balance, Reproductive Performance, Dairy Cows, Condition Management

1.GİRİŞ

Süt sığırcılığı hayvansal üretimin başlıca alanlarından biridir ve ekonomi ile toplum açısından stratejik değer taşır. Sürdürülebilir süt üretimi büyük ölçüde besleme düzeyi, rasyon bileşimi ve besin dengesine dayanır. Dengeli bir besleme programı yalnızca yüksek süt verimini değil, döl verimini, bağışıklık yeterliliğini ve genel hayvan sağlığını da korur (McDonald ve ark., 2011; NRC, 2021).

Yetersiz ya da dengesiz besleme metabolik bozukluklara, döl tutmama sorunlarına ve süt verimindeki dalgalanmalara zemin hazırlar. Enerji ile protein dengesi korunamadığında negatif enerji dengesi gelişir ve bu durum doğum sonrasında ketozis ile yağlı karaciğer riskini yükseltir (Butler, 2014).

Modern süt sığırcılığında besleme yönetimi yalnızca rasyon yazmaktan ibaret değildir. Yem kalitesinin düzenli analizi, hayvanın içinde bulunduğu fizyolojik evreye göre besin planlaması ve uygulamanın sürekli izlenmesi bu kapsamın parçasıdır (NASEM, 2021; Tricarico ve ark., 2020; von Keyserlingk ve ark., 2013). Bu nedenle besleme yönetimi verimlilik, hayvan refahı ve çevresel sürdürülebilirlik için sektörün temel direklerinden sayılır (Walsh ve ark., 2011; Butler, 2003; Cardoso ve ark., 2020). Besin maddelerinin yetersiz ya da dengesiz verilmesi belirgin verim kaybına hatta hayvan ölümlerine yol açabilir. Bunun doğal sonucu olarak dönemsel tarımsal gelir ve kârlılık düşer, uzun vadede işletme değeri zayıflar ve varlıkların sürdürülebilirliği riske girer (Kalantari ve ark., 2016; VandeHaar ve ark., 1998; Brady ve ark., 2021; Liebe ve ark., 2020).

Yüksek verimli sürülerde dölleme ve süt üretimiyle kaybolan besin öğeleri ancak yeterli ve dengeli içerikli konsantre yemlerle telafi edilebilir. İnek ve gebelik döneminde yavrunun sağlıklı gelişimi için protein, vitamin ve mineral gereksinimlerinin eksiksiz karşılanması yaşama gücünü ve doğum sonrası süt verimini destekler (NASEM, 2021; Cardoso ve ark., 2020). Üreticinin pik laktasyonda protein gereksiniminin başlangıç ve son evrelere göre daha yüksek olduğunu bilip rasyonu buna göre ayarlaması teknik yetiştiricilik açısından kritiktir. Sonuç olarak süt sığırı beslemesinde gereksinimlerin dengeli karşılanması, canlı ağırlık kaybı ile sindirim bozukluklarının en aza indirilmesi ve hayvan sağlığının korunması sürdürülebilir ve kârlı üretimin önkoşuludur (VandeHaar ve St-Pierre, 1998; NASEM, 2021).

Alınan besin öğeleri önce yaşamsal gereksinimleri karşılamak için kullanılır. İhtiyaçlar karşılandıktan sonra artan enerji sırt, bel, kaburga hattı ile kuyruk sokumu, döş ve genital bölge çevresinde yağ olarak depolanır. Enerji alımı düştüğünde önce bu periferik yağ depoları mobilize edilerek gereksinimler karşılanır. Enerji açığı sürerse mobilizasyon artar. Vücut kondisyonu canlı hayvanda yağ kütlesinin yağ dışı dokuya, yani kas ve iskelete oranını ifade eder (Wright ve Russel, 1984).

2. VÜCUT KONDİSYON SKORU (VKS) VE ÖNEMİ

Vücut kondisyon skoru (VKS), laktasyonda ya da kuru dönemdeki ineklerin canlı ağırlık ve vücut ölçülerinden bağımsız biçimde, vücut yağlarının gözle değerlendirilmesine dayanır (Hady ve ark., 1994; Gallo ve ark., 1996). Sığırlar başta olmak üzere birçok türde enerji rezervlerini yani yağ dokusunu belirlemede en pratik yöntemlerden biri kabul edilir (Tapkı ve ark., 2005). Uygulama çoğu zaman besleme amaçlı düşünülse de VKS'nin süt verimi, sürü sağlığı, üreme performansı ve hayvan refahı üzerinde belirleyici etkileri vardır ve bu etkiler doğrudan işletmenin kârlılığına yansır (Bewley ve Schutz, 2008; Yolcu, 2024).

Sahada VKS, hayvanın belirli odak bölgelerindeki deri altı yağ kalınlığına bakılarak verilen bir puandır; canlı ağırlık ya da ölçülerden bağımsız çalışır (Serin, 2004). Günlük uygulamada amaç, zayıf ile yağlı hayvanı ortak bir dilde sınıflandırmaktır. Son yıllarda sürü yönetiminde

besleme, refah, bakım ve sağlık uygulamalarının yanında ek bir göstergeye dönüştü ve verimi artırmaya yönelik kararları destekler hale geldi (Koçyiğit, 2017). Sübjektif olsa da hızlı, pratik ve düşük maliyetlidir; bu sayede her inek için uygun bakım-besleme planı çıkarılabilir, sürüde kondisyon birliği sağlanabilir (Domecq ve ark., 1997; Roche ve ark., 2009; Singh ve ark., 2018). Ayrıca yalnızca kondisyonu değil, üreme başarısı ve verimlilik hakkında da fikir verir; sütçü ineklerde doğum öncesi ve sonrası üreme sonuçlarıyla bağlantısı gösterildiği için sahada hedeflenen fertiliteye ulaşmada işe yarar bir rehberdir (Serin, 2004).

Süt verimine odaklı seleksiyon zaman içinde üreme performansını aşağı çekebilir ve bazı sağlık risklerini büyütebilir. Bu nedenle VKS'yi düzenli aralıklarla izlemek, enerji rezervlerini takip etmek ve bu bilgiye dayalı sürü yönetimi uygulamak önemlidir. Vücut yağını dolaylı ama güvenilir biçimde tahmin etmek, laktasyon boyunca uygun kondisyona tutunmayı sağlar; bunun sonucu olarak süt verimi daha istikrarlı seyreder, üreme ve metabolik hastalık olasılığı azalır, işletme kârlılığı desteklenir (Suriyasathaporn ve ark., 1998).

VKS değerlendirilirken yaş, ırk ve vücut büyüklüğü gibi hayvansal faktörler dikkate alınmalıdır. Yaşlı ineklerin gençlere göre daha düşük puanlara eğilimli olduğu bildirilmiştir. Irklar arasında vücut yağ dağılımı ile enerji depolama kapasitesi farklılık gösterir; örneğin Jersey ve Siyah Alaca gibi sütçü ırklar çoğu zaman Simental gibi kombine verimli ırklara kıyasla daha yüksek VKS sergiler ve etçi ırklar sütçü ırklardan daha fazla vücut yağı taşır. Ayrıca küçük ve orta cüsseli ırkların büyük ırklara göre daha yüksek kondisyon puanlarına sahip olabildiği belirtilmiştir (Choy, 2002; Kara, 2015).

Ferguson ve ark. (1994) skorlamanın pratik, yalın ve yetiştiricinin kolayca uygulayabileceği bir çerçevede olması gerektiğini vurgular. Ward (2003) ise yöntemin göründüğü kadar kolay olmadığını, sağlıklı bir puanlama için deneyim gerektiğini ve çiftlik sistemlerine entegrasyonun her zaman sorunsuz ilerlemediğini belirtir. Bu gözlemler, sığırlarda vücut enerji rezervlerini belirlemeye yönelik alternatif yaklaşımların araştırılmasını hızlandırmıştır. Yöntem değişse de amaç aynıdır: hayvanın vücut yağ düzeyini, dolayısıyla enerji durumunu değerlendirmek. Nitekim süt sığırlarında yağ durumu süt verimi, erken laktasyon gereksinimleri ve üreme performansı gibi birçok süreci etkiler (Erdem ve Atasever, 2004; Kara, 2015).

3.VÜCUT KONDİSYON SKORU VE ÖLÇÜM YÖNTEMLERİ

Vücut kondisyon skoru bazı çalışmalarda bağımsız bir ölçüm olarak kullanılır, son yıllarda ise kimi sınıflandırma şemalarının parçası olarak ele alınır. Uygulamada temel dayanak kuyruk sokumu, bel ve sağrı bölgelerindeki yağ dokusunun görsel ya da palpasyonla incelenmesidir (Uğur, 2014). Süt sığırlarında yağlılık düzeyini hızlı ve pratik biçimde belirlemek için uygundur. Birkaç farklı skala vardır; üçlü, dörtlü, yedili, dokuzlu sistemler bildirilmiştir. En sık kullanılan ise 1-5 arası beşli skala. Bu sistemde 1 aşırı zayıf, 5 aşırı yağlı hayvanı ifade eder. Ayrıca 0,25 ya da 0,5'lik ara puanlar ölçümü daha hassas hale getirir (Serin, 2004; Diler, 2011; Diler ve Aydın, 2015; Varışlı ve Tekin, 2011).

Daha nesnel sonuçlar için VKS ölçümlerinde ultrason kullanımı yaygınlaşmıştır. Yöntem belirli frekanstaki ses dalgaları ile özellikle sırt bölgesindeki deri altı yağ kalınlığını ölçer. Gözleme dayalı skorlara kıyasla daha tutarlı çıktılar sağlayabilir ve tekrar ölçümlerde operatör etkisini azaltır (Ayres ve ark., 2009; Koçyiğit, 2017). Üretici açısından VKS'nin anlaşılır, pratik ve kolay uygulanabilir olması kritik bir gerekliliktir. Ferguson ve ark. (1994) yalın bir skorlama çerçevesinin sahada benimsenmesini kolaylaştırdığını vurgular. Ward (2003) ise doğru puanlamanın eğitim ve deneyim istediğini, bu nedenle bazı işletmelerde sisteme tam uyum sağlanamadığını belirtir. Bu gözlemler vücut enerji rezervlerini belirlemeye yönelik alternatif yaklaşımların geliştirilmesini teşvik etmiştir. Özellikle süt sığırlarında vücut yağ oranı süt verimi, laktasyon sürecindeki metabolik denge ve üreme performansı üzerinde doğrudan etkilidir (Erdem ve Atasever, 2004).

Vücut kondisyon skoru sistemi önce Jefferies (1961) tarafından koyunlar için 0-5 arası bir ölçekle tanımlandı. Daha sonra besi sığırlarına, ardından süt sığırlarına uyarlandı. Lowman ve ark. (1976) süt sığırlarında 1-5 arası skala ile standardizasyon sağladı. Pryce ve ark. (2001) 1-5 arası puanlamanın sektör genelinde standartlaşması gerektiğini bildirdi (Jefferies, 1961; Lowman ve ark., 1976; Pryce ve ark., 2001).

Tek ve evrensel bir VKS sistemi yoktur. Ülkeler kendi iklimine, yetiştirme hedeflerine ve ırklarına uygun ölçekler geliştirmiştir. Örneğin Avustralya'da Earle (1976) 1-8 arası bir sistem önermiştir. İngiltere'de Mulvany (1977) 0-5 arası altı düzeyli bir yaklaşım sunmuştur. Amerika'da Wildman ve ark. (1982) ile Edmonson ve ark. (1989) 1-5'lik beşli skalayı yaygınlaştırmıştır. Yeni Zelanda'da Garinger ve McGowan (1982) 1-10 arası onlu bir sistem kullanmıştır. Danimarka'da Landsverk (1992) 1-9 arası puanlamayı uygulamıştır. Tablo 1'de bu farklı sistemlerde normal kondisyon aralıkları özetlenmiştir (Bewley ve Schutz, 2008; Earle, 1976; Mulvany, 1977; Wildman ve ark., 1982; Edmonson ve ark., 1989; Garinger ve McGowan, 1982; Landsverk, 1992; Kara, 2015; Canatan, 2013).

Tablo 1. VKS belirlemede farklı puanlama sistemlerinde normal kondisyon aralıkları

Puanlama sistemleri	**1-8**	**1-5**	**1-9**	**1-10**
Normal kondisyon aralığı	4,5-5,5	3,0-3,75	5,0-7,0	5,5-7,0

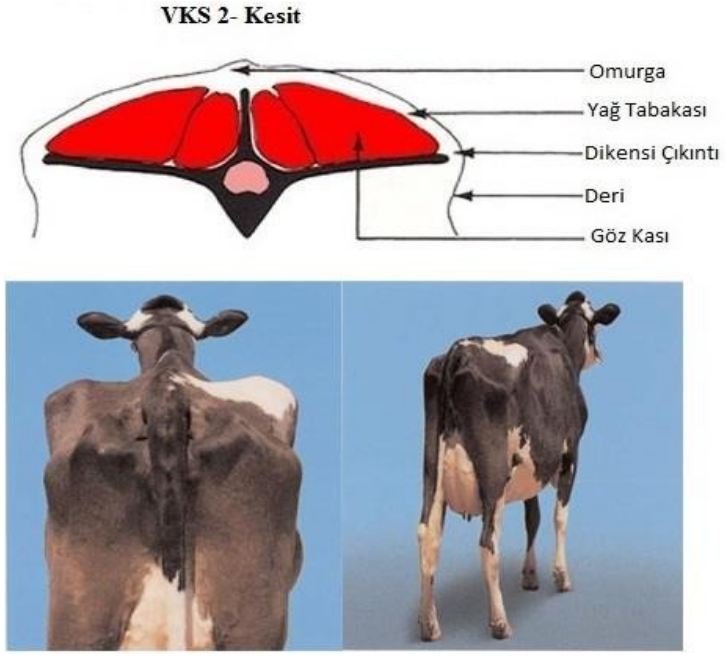
Günümüzde süt sığırlarında vücut kondisyon skorunun belirlenmesinde en yaygın kullanılan yöntem, **Edmonson ve ark. (1989)** tarafından geliştirilen beşli skala sistemidir. Bu sistem, İngiltere, Avustralya, Yeni Zelanda ve Amerika'da kullanılan farklı kondisyon değerlendirme yöntemlerinin karşılaştırılması ve uyarlanması sonucunda oluşturulmuştur. Pratik uygulanabilirliği, görsel kolaylığı ve üretici tarafından hızlı şekilde öğrenilebilir olması nedeniyle günümüzde araştırmacılar ve yetiştiriciler tarafından tercih edilen standart yöntem haline gelmiştir.

Vücut kondisyon skoru 1 olan inekler oldukça zayıf, hatta kaşektik görünümde olup belirgin kemik çıkıntılarına sahiptir. Pelvis kemikleri ve bel omurları ince deri altında kolayca fark edilir. Açlık çukuru derindir ve kısa kaburgalar ayrı kemik parçaları gibi seçilebilir. Kuyruk sokumu çevresinde derin çukurluklar bulunur ve deri bu bölgede katlanmış bir görünüm sergiler (Kara, 2015; Canatan, 2013). Bu durum, hayvanda aşırı zayıflığın en belirgin göstergelerindendir.(Şekil 1).



Şekil 1. Vücut kondisyon skoru 1.0 olan bir ineğin görünüşü (Kara, 2015)

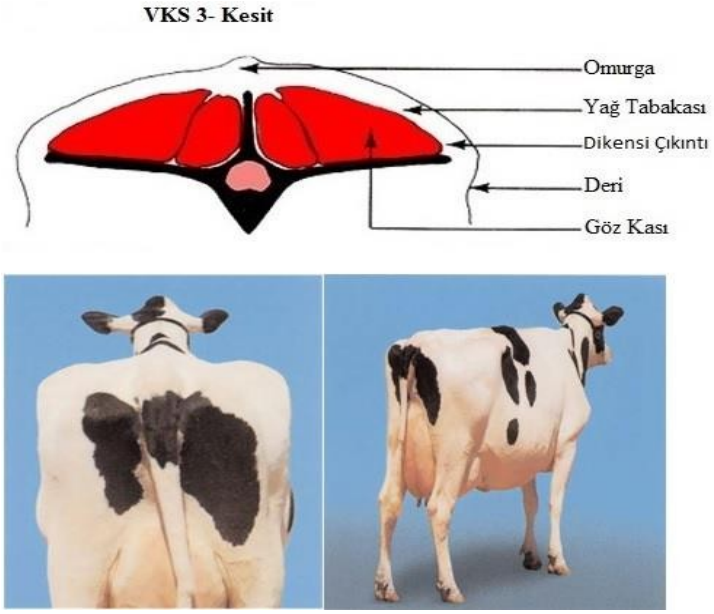
Vücut kondisyon skoru 2 olan inekler genellikle erken laktasyon döneminde ciddi negatif enerji dengesi (NEB) yaşayan hayvanlardır. Bu inekler oldukça zayıf görünmekle birlikte sağlık durumu genellikle stabildir; ancak düşük kondisyon süt ve döl verimini olumsuz etkiler. Sırt hattı belirgin, fakat omurlar tek tek seçilemez. Kısa kaburgalar belirgin olsa da daha bütünleşik bir yapıdadır. Kalça kemiği ile oturak yumrusu arasındaki açı belirgindir ve ligament çizgileri keskin şekilde fark edilir. Sağrı kasları hafif dolgunluk gösterirken kemik çıkıntıları hâlâ belirgindir. Kuyruk sokumu bölgesi çukur görünümlü olup, kemiklerin üzerinde az miktarda yağ dokusu bulunur. (Şekil 2).



Şekil 2. Vücut kondisyon skoru 2.0 olan bir ineğin görünüşü (Kara, 2015)

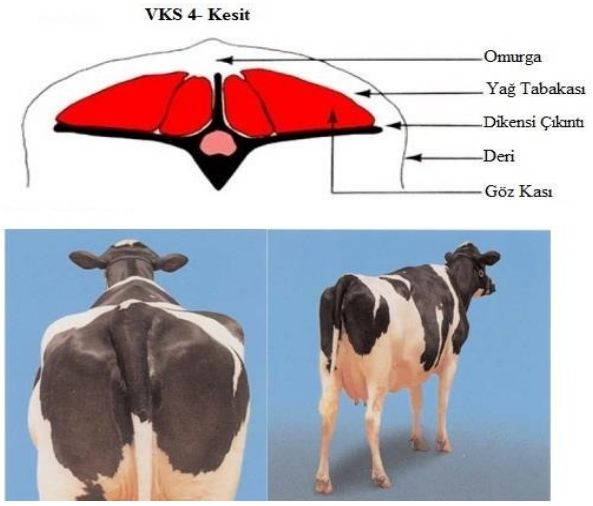
Vücut kondisyon skoru 3 olan inekler, genellikle laktasyonun büyük bölümü için ideal durumdadır (Şekil 3). Sırt hattı hâlâ seçilebilir olsa da omurlar yuvarlak bir görünüm kazanmıştır. Kısa kaburgalar yaklaşık 1–1,5 cm kalınlığında doku ile kaplı olup, daha düşük

skorlu ineklerdeki kadar keskin değildir. Kalça ve oturak yumruları belirginliğini korur ancak aralarındaki açı giderek U biçimine dönüşmüştür. Bu kemikler arasındaki açı hâlâ fark edilebilir düzeydedir. Kuyruk sokumu çevresi hafif çukur görünümlü olup, önceki skorlardaki gibi deri kıvrımı bulunmaz (Kara, 2015; Canatan, 2013).



Şekil 3. Vücut kondisyon skoru 3.0 olan bir ineğin görünüşü (Kara, 2015)

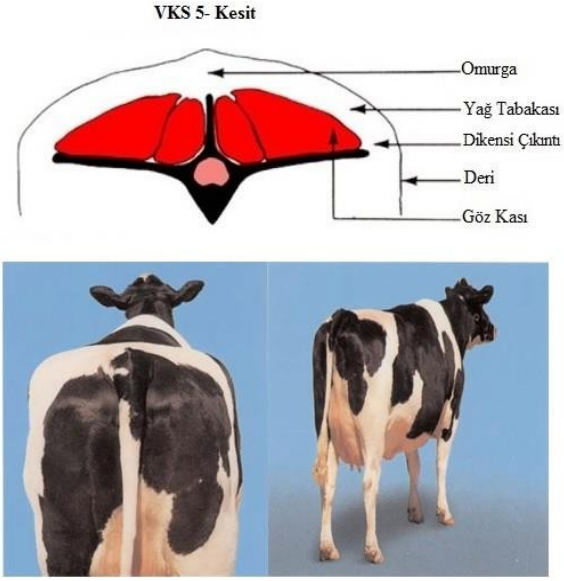
Vücut kondisyon skoru 4 olan inekler, fazla kondisyonlu ve etli bir görünüme sahiptir. Arkadan bakıldığında kemik çıkıntıları neredeyse düzleşmiştir. Sırt çizgisi belirgin değildir ve kısa kaburgalar sadece elle kontrol edildiğinde fark edilir. Kalça kemiği ile oturak yumrusu yuvarlaklaşmış, bu bölgelerdeki yağ birikimi açıkça görülür. Kuyruk sokumu çevresi dolgun olup, deri kıvrımı bulunmaz. Kalça ve oturak yumruları arasındaki yapı U şeklini almış, açlık çukuru ise dışbükey bir form kazanmıştır (Kara, 2015; Canatan, 2013). Sağrı bölgesinde yağlanma belirgindir. (Şekil 4).



Şekil 4. Vücut kondisyon skoru 4.0 olan bir ineğin görünüşü (Kara, 2015)

Vücut kondisyon skoru 5 olan inekler aşırı yağlıdır ve bu durum metabolik hastalıklar, topallık ve üreme problemleri açısından ciddi risk taşır. Hayvanın vücut yapısı tamamen yuvarlak görünür; omurga ve omurlar fark edilmez, sırt düzleşmiştir. Kısa kaburgalar gözle seçilemez, yalnızca elle hissedilebilir. Bel, kalça ve kuyruk bölgelerinde kemik çıkıntıları kaybolmuştur. Kalça kemiği ile oturak yumrusu arasındaki bölge tamamen yağla doludur ve aradaki açı düz

bir çizgi hâline gelmiştir. Kuyruk sokumu çevresi dolgun, açlık çukuru ise dışbükey görünümde olur. Şekil 5'de örnek resim verilmiştir (Kara, 2015; Canatan, 2013).



Şekil 5. Vücut kondisyon skoru 2.0 olan bir ineğin görünüşü (Kara, 2015)

Vücut kondisyon skoru, süt inekleri için kuru dönemin başlangıcı, buzağılama, doğum sonrası ilk ay, orta ve geç laktasyon olmak üzere beş dönemde ölçülmesi önemli ve kritiktir. Özellikle ilk buzağılamadaki kondisyon, doğum sonrası performans ve sonraki laktasyonları belirgin biçimde etkiler. 1–5 ölçeğinde ideal VKS döneme göre değişir. Ölçüm sıklığı işletmenin büyüklüğü, personel ve hedeflere göre planlanmalı; pratikte doğumda, ilk tohumlamada, laktasyon ortasında, kuruya ayrılmadan ~90–100 gün önce ve kuru dönem sonunda değerlendirme önerilir. İlgili dönemler ve hedef VKS'ler Tablo 2'de özetlenmiştir (Kellogg, 2010; Kara, 2015).

Tablo 2. Çeşitli dönemlerde ideal VKS aralıkları

Laktasyon Evresi	**VKS**
Kuru başlangıcı	3,5-4,0
Buzağılama (İnek)	3,5-4,0
Doğumdan bir ay sonra	2,5-3,0
Orta laktasyon	3
Geç laktasyon	3,25-3,75
Buzağılama (Düve)	3,5

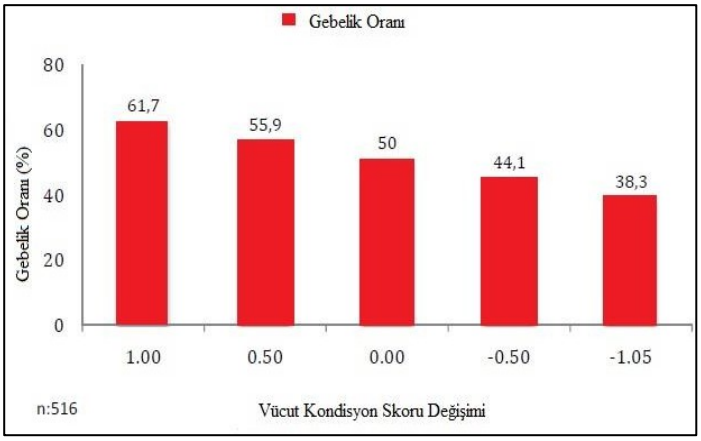
Arslan ve Tufan (2010), süt sığırlarında vücut kondisyon skorunun verim özelliklerine bağlı olarak laktasyon süresince değişkenlik gösterdiğini ve bu nedenle belirli aralıklarla değerlendirilerek ardışık ölçümlerin karşılaştırılmasının önemli olduğunu vurgulamışlardır.

4.VÜCUT KONDİSYONUNUN FERTİLİTE ÜZERİNDEKİ BELİRLEYİCİ ETKİLERİ

Süt sığırlarında vücut kondisyon skorunun (VKS) laktasyon dönemlerine göre değiştiği uzun süredir bilinmektedir. Wildman ve ark. (1982) farklı evrelerde VKS'nin anlamlı biçimde farklılaştığını, ileri dönemde değişimin daha durağan seyrettiğini bildirmiştir. Aynı çalışmada persistensi yüksek ineklerin ortalama VKS'sinin daha yüksek olduğu, kondisyon düzeyi arttıkça servis periyodunun uzama eğilimi gösterdiği belirtilmiştir. Buna karşılık Butler (2003)

doğumda kondisyonu yüksek ineklerde servis periyodunun daha kısa olabildiğini saptamıştır (Wildman ve ark., 1982; Butler, 2003).

Edmonson ve ark. (1989) VKS'nin süt ve döl verimiyle yakından ilişkili olduğunu ve bu nedenle sürü yönetiminde düzenli kondisyon takibinin yararlı bir araç sayılması gerektiğini vurgulamıştır. Butler (2003) dönemsel VKS değişimlerinin enerji metabolizmasıyla bağlantılı olduğunu, doğum sonrası dönemde artan kondisyon kaybının hastalık ve fertilite sorunlarını sıklaştırabildiğini belirtmiştir (Edmonson ve ark., 1989; Butler, 2003).



Şekil 6. Doğumdan sonra VKS ve fertilite arasındaki ilişki (Ferguson ve Galligan, 1993; Kara, 2013)

Gearhart ve ark. (1990) ile Ruegg (1991) ideal kondisyon düzeyinin ineğin fizyolojik durumuna ve laktasyon evresine göre değiştiğini ifade etmiştir. Linn (1991) doğumdan sonra kondisyondaki kayıp arttıkça gebelik oranının azaldığını, bir puandan az kayıpta yaklaşık %50, iki puanı aşan kayıpta ise %21 gebelik oranı görüldüğünü bildirmiştir (Gearhart ve ark., 1990; Ruegg, 1991; Linn, 1991).

Ruegg ve ark. (1992) ile Van Horn ve Wilcox (1992) doğum dönemi için ideal VKS aralığını 3,0 ile 3,75, laktasyonun tepe noktasında 2,25 ile 2,75, kuru dönemde 3,0 ile 3,75 olarak önermiştir. Waltner ve ark. (1993) izlem verilerine dayanarak doğum sayısı arttıkça kondisyon kaybının da arttığını göstermiştir. Ferguson ve Galligan (1993) bir puanın altındaki orta düzey kondisyon kaybının üreme performansını belirgin olumsuz etkilemediğini, ancak çok zayıf (<2,5) ya da aşırı yağlı (>3,5) ineklerde riskin yükseldiğini bildirmiştir (Ruegg ve ark., 1992; Van Horn ve Wilcox, 1992; Waltner ve ark., 1993; Ferguson ve Galligan, 1993).

Ruegg ve Milton (1995) doğumda düşük kondisyonda buzağılayan ineklerde gebelik başına tohumlama sayısının arttığını ve servis süresinin uzama eğilimi gösterdiğini rapor etmiştir. Ancak doğumdaki VKS'nin ilk östrus, ilk tohumlama aralığı ve servis periyodu üzerindeki etkileri istatistiksel olarak anlamlı bulunmamıştır. Ferguson ve ark. (1994) kuruya ayrılmadan önce, laktasyonun yaklaşık 200. günü ile kuruya çıkarma arasında VKS'nin 2,75 ile 3,50 aralığında tutulmasını ve kuruya ayrılan ineklerde 3,25 ile 3,50 puan hedeflenmesini, böylece doğum sonrası risklerin azaltılmasını önermiştir. Gallo ve ark. (1996) düşük verimli ineklerde en düşük VKS'nin laktasyonun üçüncü ayında, yüksek verimli ineklerde ise dördüncü ayında görüldüğünü; bu azalmanın orta ve geç dönemde telafi edildiğini bildirmiştir (Ruegg ve Milton, 1995; Ferguson ve ark., 1994; Gallo ve ark., 1996).

Domecq ve ark. (1997) kuru dönem, erken laktasyon ve doğum sonrası VKS değişimlerinin gebelik oranıyla ilişkisini incelemiş; modele ekledikleri laktasyon sayısı, ilk 120 gün süt verimi ve doğum ile laktasyonun dördüncü haftasındaki VKS değişkenleri arasında, 120 günlük süt verimindeki artışın gebelik oranını yükselttiğini, laktasyonun 30. günündeki VKS düşüşünün

ise gebelik oranını azalttığını göstermiştir. Laktasyonun ilk ayında bir puandan az kondisyon kaybeden ineklerin ilk tohumlamada gebe kalma olasılıklarının, bir puandan fazla kaybedenlere göre yaklaşık %50 daha yüksek olduğu bildirilmiştir. Çalışma, gözlenen sağlık sorunlarının gebelik sonucundan çok VKS ve süt verimiyle ilişkili olduğunu ve özellikle kuru dönem ile doğumdan sonraki ilk 30 günde kondisyon izlemenin ilk tohumlamada başarısızlık riskini öngörmede değerli olduğunu vurgulamıştır (Domecq ve ark., 1997).

Markusfeld ve ark. (1997) aşırı kondisyon kaybının üreme performansını olumsuz etkilediğini bildirmiştir. Domecq ve ark. (1997) daha az kondisyon kaybeden ineklerde enerji dengesinin daha hızlı kurulduğunu ve bunun daha iyi döl verimiyle sonuçlanmasının beklendiğini desteklemiştir. Drame ve ark. (1999) hem VKS düzeyinin hem de kaybının ilk tohumlama aralığı ve servis periyodunu öngörmede yararlı göstergeler olabileceğini rapor etmiştir. Diğer çalışmalar da kuru dönem, doğum ve doğum sonrası evrelerde VKS düzeyi ile değişim eğrisinin, ovaryum fonksiyonlarının yeniden başlaması dahil, üreme performansında belirleyici rol oynadığını göstermiştir (Markusfeld ve ark., 1997; Domecq ve ark., 1997; Drame ve ark., 1999; Ruegg, 1991; Loeffler ve ark., 1999; Prandi ve ark., 1999).

Pryce ve Løvendahl (1999) laktasyonun belirli evrelerinde vücut yağ oranındaki ya da VKS'deki düşüklüğün östrus siklusunun sürekliliğini ve üreme başarısını etkileyebildiğini göstermiştir. Buna paralel olarak Drame ve ark. (1999) doğum sonrası düzenli VKS izlemesiyle saptanacak kondisyon kayıplarının ilk tohumlama aralığı ve servis periyodunu tahminde yararlı olacağını belirtmiştir (Pryce ve Løvendahl, 1999; Drame ve ark., 1999).

Yaylak ve Kaya (2000) yüksek süt verimine yönelik seleksiyon ve üretim uygulamalarının üreme ve sağlık sorunlarına yakalanma riskini artırabileceğini bildirmiştir. VKS'nin düzenli takibi, enerji rezervlerinin izlenmesine ve bu sayede sürü yönetiminin iyileştirilmesine imkân verir. Kondisyon büyük ölçüde depo yağlara bağlı olduğundan doğru ve düzenli değerlendirme ile laktasyon boyunca ideal kondisyona yakın seyir sağlanabilir; bu da süt verimini optimize eder, üreme ve sağlık problemlerini azaltır. Pratikte VKS genellikle erken laktasyonda hızla düşer, pik süt veriminden sonra kademeli olarak yükselir ve bu artış kuru dönemde de sürebilir (Yaylak ve Kaya, 2000).

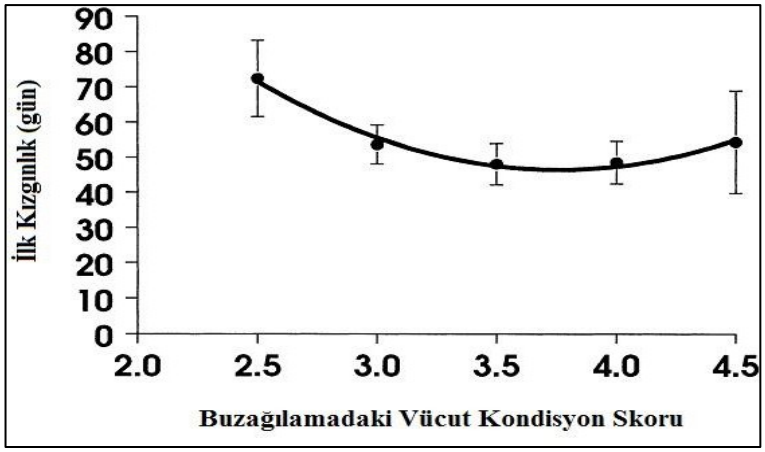
Düşük fertilite ve yavru verimi süt sığırçılığında önemli sorunlardır. Genotip, hastalıklar, iklim, bakım ve besleme ile süt verimi düzeyi gibi etmenler belirleyicidir. Bu etmenlerin etkisiyle ortaya çıkan düşük ya da yüksek VKS de fertiliteyi olumsuz etkileyebilir. Nitekim bazı çalışmalarda uygunsuz kondisyonun döl veriminde düşüşe yol açtığı bildirilmiştir (Richards ve ark., 1986; Loeffler ve ark., 1999; Moreira ve ark., 2000).

Gillund ve ark. (2001) vücut yağ mobilizasyonuna bağlı VKS değişimlerinin fertilitedeki düşüşlerle ilişkili olduğunu; doğum sonrası 0,5 puanı aşan VKS kaybının döl veriminde azalmaya ve gebelik başına tohumlama sayısında artışa yol açtığını bildirmiştir. Pryce ve ark. (2001) VKS'nin laktasyon boyunca kilit bir değişken olduğunu, erken laktasyon kadar diğer kritik evrelerdeki VKS değişimlerinin de östrusun yeniden başlaması ve üreme başarısı üzerinde etkili olabileceğini vurgulamıştır. Bu nedenle dönemsel VKS düzeyleri ve dönemler arası VKS kayıpları yakından izlenmelidir (Gillund ve ark., 2001; Pryce ve ark., 2001).

Doğum sonrası VKS'de 0,5 puandan fazla düşüş genellikle döl verimini azaltır. Doğum ile ilk tohumlama arasındaki dönemde yaklaşık bir puanlık kayıp ilk tohumlama aralığını uzatır ve ilk tohumlamada gebelik olasılığını düşürür. Bir puanı aşan kayıplar gebelik başına tohumlama sayısını belirgin biçimde artırır (Ferguson ve Galligan, 1993; Walsh ve ark., 2011; Roche ve ark., 2013; Carvalho ve ark., 2014; Akbar ve ark., 2015; Pinedo ve ark., 2022).

Friggens (2003) doğumda zayıf kondisyonda olan ineklerin rezervlerini doğumdan sonra hızla yerine koyabilseler bile bunun üreme açısından dezavantaja dönüşebildiğini; hedefin altında

kondisyonda buzağılayan ineklerde ilk kızgınlığın daha geç görüldüğünü göstermiştir (Şekil 7) (Friggens, 2003).



Şekil 7. Buzağılamadaki VKS ile ilk kızgınlık zamanı arasındaki ilişki (Ferguson ve Galligan, 1993; Kara, 2013)

Moreira ve ark. (2000) doğumda VKS'si düşük ineklerde anöstrus süresinin uzadığını, ilk tohumlamada gebelik oranının düştüğünü bildirdi. Üreme başarısı kaliteli ovum üretimi ve embriyonun gebeliği sürdürmeye dönük sinyal üretimi gibi ardışık basamaklara bağlıdır ve bu basamaklar hayvanın önceki ile mevcut enerji dengesiyle yakından ilişkilidir (Moreira ve ark., 2000; Stockdale, 2001).VKS doğum öncesinde ve sonrasında doğal olarak değişir. Doğumda çok düşük ya da çok yüksek VKS ile erken laktasyonda hızlı VKS kaybı genelde olumsuz enerji dengesi ve düşük döl verimiyle birliktedir. Bu yüzden doğum için yaklaşık 3,0–3,25 aralığı ve erken dönemde sınırlı VKS kaybı önerilir. Bu yaklaşım hem sağlık göstergelerini hem de üreme sonuçlarını iyileştirir (Roche ve ark., 2009; Walsh ve ark., 2011; Carvalho ve ark., 2014; Roche ve ark., 2013; Akbar ve ark., 2015; Pinedo ve ark., 2022).

Friggens (2003) doğumda zayıf kondisyondaki ineklerde ilk kızgınlığın daha geç görülebildiğini gösterdi. Kim ve Suh (2003) laktasyonu beş dönemde inceleyerek VKS'nin özellikle doğum ve erken laktasyonda belirgin dalgalandığını rapor etti (Friggens, 2003; Kim ve Suh, 2003). Erdoğan ve Alaçam (2003) tohumlama dönemindeki VKS'nin ilk ve üçüncü tohumlamada gebelik oranı, gebelik başına tohumlama sayısı, doğum ile ilk tohumlama aralığı ve yeniden gebe kalma süresi gibi temel göstergelerle yakından ilişkili olduğunu bildirdi. Ayrıca kondisyonu yüksek ineklerin doğum sonrası daha fazla kondisyon kaybettiğini, daha az kuru madde tükettiğini ve postpartum sağlık sorunlarını daha sık yaşadığını not etti (Erdoğan ve Alaçam, 2003).

Yaylak (2003) doğumdaki VKS ile kondisyon kaybının üreme parametreleri üzerinde istatistiksel olarak anlamlı bir etkisi bulunmadığını, ancak VKS'nin 3,50 ve üzeri olduğunda döl veriminin daha yüksek gerçekleşebildiğini ifade etti. Ryan ve ark. (2003) buzağılama döneminde VKS'nin yaklaşık 3 civarında tutulmasının üreme performansını desteklediğini ve bu hedefin kuru dönemde dengeli besleme ile sağlanabildiğini vurguladı (Yaylak, 2003; Ryan ve ark., 2003).

Roche ve ark. (2007) laktasyon boyunca, özellikle tohumlama dönemi ile doğum–tohumlama aralığında VKS kaybının döl verimi açısından kritik olduğunu vurguladı. Postpartum ilk östrus ve ilk tohumlamanın gecikmesi doğum aralığını uzatır, yıllık buzağı hedefinden sapmalara ve toplam süt üretiminde azalmaya yol açar. Düşük gebelik oranları tohumlama sayısını artırır ve ekonomik kaybı büyütür (Roche ve ark., 2007). Bewley ve ark. (2008) buzağılama ile erken laktasyondaki VKS değişimlerinin sağlık ve üremeyi olumsuz etkileyebildiğini bildirdi. Erken laktasyonda sınırlı kayıp fizyolojik olarak kabul edilebilir, yine de yetiştiricilerin bu kaybı en

aza indirmeyi hedeflemesi önerilir. Roche ve ark. (2009) buzağılama VKS'si ile süt ve döl verimi ile sağlık sorunları arasındaki ilişkinin doğrusal olmadığını gösterdi. Buna göre doğumdaki ideal aralık 3,0–3,25'tir. 3,0'ın altında süt ve döl verimi düşme eğilimindedir, 3,5 ve üzerindeki değerlerde kuru madde tüketimi azalır ve metabolik hastalık riski yükselir (Bewley ve ark., 2008; Roche ve ark., 2009).

VKS takibi oranları yaklaşık olarak ABD'de %5, Avrupa'da %1,7, Türkiye'de %0,08 düzeyindedir. Çimen (2010) VKS'nin gelişmiş ülkelerde kârlılık açısından önemli bir yönetim aracı olduğunu belirtir. Kuru dönemde aşırı yağlılık doğum güçlüğü, sonun atılamaması ve yem tüketiminde azalma ile birlikte ketozis, yağlı karaciğer ve süt humması riskini artırır. Kızgınlık, ovulasyon ve implantasyon olumsuz etkilenir ve döl verimi geriler (Çimen, 2010).

Varışlı ve Tekin (2011) yağ mobilizasyonuna bağlı VKS değişimlerinin fertiliteyi düşürebildiğini bildirdi. VKS ölçümü uygun kondisyonda kalmayı destekleyen pratik bir araçtır. Tohumlama döneminde düşük VKS'nin döl verimini olumsuz etkileyebileceği rapor edilmiştir, ancak bu etkinin bazı çalışmalarda istatistiksel olarak anlamlı bulunmadığı da belirtilmiştir (Varışlı ve Tekin, 2011).

Roche ve ark. (2013) VKS'nin kuru dönem, buzağılama, erken laktasyon ve tohumlama dönemlerinde düzenli olarak değerlendirilmesini önerdi ve dönemlere ait önerilen aralıkları Tablo 3'te topladı (Roche ve ark., 2013; Kara, 2015).

Tablo 3. Belirli dönemler ve hedef kondisyon skorları

Süt Sığırları	İnekler	Düveler
Kuru dönem (Buzağılamadan 7-8 hafta once)	2,5-3	-
Buzağılamadan 3 hafta önce	2,5-3	2,5-3
Tohumlama öncesi	2-3	2-2,5

5. SONUÇ

Kârlı süt sığırcılığı yılda bir buzağıya ve yüksek süt verimine dayanır. Bunu fizyolojiye uygun bakım ve besleme sağlar. Enerji durumunu izlemek için en pratik araç vücut kondisyon skorudur (VKS). VKS, kondisyona bağlı üreme, süt ve sağlık risklerini erken fark ettirir. Sürü yönetimini ve rasyon planını somut veriye bağlar. Birçok ülkede bu işlem rutindir. Bizde yaygınlaşması için saha örgütlenmesi, eğitim ve uzman personel gerekir. Sürü düzenli izlenirse verimlilik kalıcı biçimde artar.

Kuru dönemde orta kondisyonu korumak esastır. Bu durum sonraki laktasyonda süt miktarını, süt bileşimini ve döl verimini belirler. Aşırı yağ döl verimini düşürür. Metabolik sorunları artırır. İlk kızgınlık, ilk tohumlama ve gebe kalma olasılığını olumsuz etkiler. Bu yüzden kuru dönemde VKS düzenli izlenir. Gereksiz yağlanma ve hızlı kayıplar engellenir. Hayvanlar skora göre gruplandırılır. Rasyon her gruba göre düzenlenir. Yılda bir buzağı hedefi için doğumdan sonra yaklaşık 80 gün içinde yeniden gebelik planlanır. Bu hedef doğum sonrası yönetimle kazanılır ve işletmenin sonucunu doğrudan etkiler.

VKS'nin düzenli kullanımı yüksek verime selekte sürülerde artan üreme ve sağlık risklerini kontrol etmeye yardım eder. Ölçüm sıklığı işletmenin ölçeğine ve iş akışına uygun seçilir. İş gücünü aksatmayacak bir program izlenir. Kararlar tek bir ölçüme değil dönemler arası değişime dayanır. Çünkü doğum öncesi ile doğum sonrası skor farkı tohumlama sayısını, ilk tohumlamada gebelik oranını ve açık günleri tek değerlerden daha iyi açıklar.

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TÜRKİYE'DE MERA KANUNU UYGULAMALARINDA ORTAYA ÇIKAN SORUNLAR VE ÇÖZÜM YOLLARI

Selahattin ÇINAR

Kırşehir Ahi Evran Üniversitesi, Ziraat Fakültesi

Email: s.cinar@ahievran.edu.tr

ORCID: 0000-0002-9049-0044

ÖZET

Türkiye'de çayır meralar, 1998 yılına kadar çeşitli düzenlemeler ile yönetilmeye çalışılmıştır. Çayır meralar ile ilgili müstakil bir kanun ilk kez 1998 yılında 4342 sayılı Mera Kanunu olarak çıkarılmıştır. 1998'de kabul edilen 4342 sayılı Mera Kanunu kapsamındaki, kanun uygulamaları Tarım ve Orman Bakanlığı Bakanlık İl Müdürlükleri marifeti ile yürütülmektedir. Mera Kanunu ile 13.1 mil. ha mera alanda mera tespiti, 12.7 mil.ha alanda mera tahditi, 8.1 mil.ha alanda ise mera tahsisi yapılmıştır. Ülke genelinde 37 ilde 442.859 ha alanda kiralama yapılmış, 2959 adet mera ıslahı ve amenajmanı projesi ile 2.2 mil.ha mera alanı, mera ıslahı ve amenajmanı projesi kapsamına alınmış ve ıslahı yapılmıştır. Mera vasıf değişikliğini içeren Mera Kanunun 14. maddesi ile 406,6 bin ha mera alanı, mera vasfı dışına çıkarılmıştır.

4342 sayılı Mera Kanununun kabul edilişinden itibaren geçen süre içerisinde kanun uygulamaları ile kanunun zayıf ve eksik kaldığı bir çok yönü ön plana çıkmıştır. Mera kanunu ile mera alanlarında işgal ve tecavüzlerin yeterince önlenemediği, ilgili birimlerce tutulan tutanakların gereğinin yapılmadığı, mera kiralamalarının sınırlı düzeyde kaldığı, kiralanan meraların bir kısmında yem bitkisi, tahıl yetiştirildiği, 14. Madde ile mera kayıplarının sürekli arttığı, özellikle son yıllarda organize sanayi bölgeleri için mera vasfı dışına çıkarılan mera alanlarında artış olduğu, uygulanan ıslah projelerinde uygulamalarda süreklilik sağlanamadığı, kendisine tahsisi yapılan merada hayvan sahiplerinin amenajman ilkelerine uymadıkları, otlatma bedelleri ödemedikleri, il otlatma planlarına uymadıkları söylenebilir. Belirtilen bu durumlara karşı uygulanacak cezai müeyyidelerin bir kısmının olmadığı bir kısmının ise uygulanmadığı belirlenmiştir. Mera alanlarının korunması, tekniğine uygun kullanılması, verimliliklerinin artması ve sürdürülebilirliklerinin sağlanması için yetersiz kalan Mera Kanununda bazı değişikliklerin yapılması zaruri hale gelmiştir denilebilir.

Anahtar Kelimeler: Mera Kanunu, uygulama, sürdürülebilirlik, tesbit, tahdit, tahsis

PROBLEMS AND SOLUTIONS EMERGING IN THE APPLICATIONS OF RANGE LAW IN TÜRKİYE

ABSTRACT

In Turkey, range were tried to be managed with various regulations until 1998. An independent law regarding range was first enacted in 1998 as the Range Law Numbered. 4342. The law implementations within the scope of the Range Law Numbered. 4342, which was accepted in 1998, are carried out by the Provincial Directorates of the Ministry of Agriculture and Forestry. With the range Law, range determination was made in 13.1 mil. hectares of range land, range restriction was made in 12.7 mil. hectares of range land, and range allocation was made in 8.1 mil. hectares of range land. Leases were made in 442,859 hectares of land in 37 provinces throughout the country, 2959 range improvement and management projects and 2.2 mil. hectares of range land were included in the scope of range improvement and management projects and their improvement was carried out. With clause 14. of the Range Law, which includes the change in range qualification, 406.6 thousand hectares of range land have been excluded from range qualification.

In the period since the enactment of the Range Law Numbered. 4342, many aspects of the law that are weak and incomplete have come to the forefront with the implementation of the law. It can be said that occupation and encroachment in range areas could Numberedt be prevented sufficiently with the range law, the necessary procedures for the minutes kept by the relevant units were Numberedt carried out, range rentals remained limited, fodder plants and grains were grown in some of the leased range, range losses have been constantly increasing with clause 14, especially in recent years, there has been an increase in range areas excluded from range qualification for organized industrial zones, continuity in the implementation of the implemented improvement projects could Numberedt be ensured, animal owners in the range allocated to them did Numberedt comply with the management principles, did Numberedt pay grazing fees, and did Numberedt comply with the provincial grazing plans. It was determined that some of the penal sanctions to be applied against these specified situations were Numberedt implemented and some were Numberedt implemented. It can be said that it has become necessary to make some changes in the Range Law, which is insufficient, in order to protect range areas, use them according to their technique, increase their productivity and ensure their sustainability.

In this study, the missing and unimplemented aspects of the Range Law are discussed.

Keywords: Range Law, application, determination, limitation, allocation

1. GIRIŞ VE MERA YÖNETIMI TARIHÇESI

Türkiye'de mera, yaylak ve kışlakların yönetimi, tarihsel süreç boyunca tek bir yasal mevzuat altında toplanamamış, bu durum da yönetimde ciddi dağınıklıklara ve sorunlara yol açmıştır. 1998 yılına kadar mera uygulamaları, farklı kurumların sorumluluğunda ve çok sayıda farklı kanun hükümleri çerçevesinde yürütülmekteydi. Bu parçalı yapının hukuki dayanakları arasında Osmanlı döneminde 1858 tarihli Kanunname-i Arazi, 1924 tarihli Köy Kanunu, 1930 tarihli Belediyeler Kanunu, 1945 ve 1950 tarihli Çiftçiyi Topraklandırma Kanunu, 1956 tarihli Orman Kanunu, 1973 tarihli Toprak ve Tarım Reformu Kanunu ve 1985 tarihli İmar Kanunu gibi mevzuatlar yer almaktaydı. Bu durum, meraların bütüncül bir yaklaşımla korunmasını ve yönetilmesini oldukça zorlaştırmaktaydı. Meralar, bu karmaşık hukuki yapıdan, **28 Şubat 1998** tarihinde yürürlüğe giren ve bu alanlara özgü ilk yasal düzenleme olan **4342 Sayılı Mera Kanunu** ile kurtulmuştur.

2. 4342 Sayılı Mera Kanunu ile Gelen Yenilikler

Kanun, mera, yaylak ve kışlakların korunması, tespit edilmesi, sınırlandırılması (tahdit), tahsis edilmesi (kullanım amacı belirleme) ve ıslahının sağlanmasını temel amaç olarak belirlemiştir. Bu düzenleme ile birlikte, mera alanlarının teknik olarak otlatma ilkelerine uygun olarak kullanılması zorunluluğu getirilmiş, alanların sürdürülebilir verimliliği hedeflenmiştir.

Mera Kanununu ile gelen bazı yenilikler şunlardır;

- **Tespit, Tahdit ve Tahsis:** Mera alanlarının tespit, tahdit ve tahsis işlemleri yapılmış, ihtiyaca göre yeni alanlar mera olarak tescil edilmiştir.
- **Sürdürülebilirlik:** Meraların verimliliklerinin sürdürülebilir hale getirilmesi için otlatma ilkelerine uyulma zorunluluğu getirilmiştir.
- **Kiralama Yetkisi:** İhtiyaç fazlası ve ıslaha muhtaç alanların, uygun projelerle özel sektöre kiraya verilmesine imkân tanınmıştır.
- **Otlatma Hakkı ve Ücreti:** Mera alanını kullanan köy ve belde halkına otlatma hakkı verilmiş, bu hak karşılığında otlatma ücreti ödeme yükümlülüğü getirilmiştir.
- **Islah Çalışmaları:** Verim ve kalite artışı için mera alanlarının devlet eliyle ıslah edilmesine başlanılmıştır.
- **Vasıf Değişikliği:** İl Mera Komisyonlarınca uygun görülen meraların vasfının değiştirilebileceği belirtilmiştir.

2. Mera Yönetiminin Kurumsal Yapılanması ve Uygulamalar

Mera Kanunu'nun yürürlüğe girmesiyle birlikte, mera yönetimi **Tarım ve Orman Bakanlığı** çatısı altında bir kurumsal hiyerarşi ile örgütlenmiştir. Bu yapının merkezinde Bakanlığa bağlı Bitkisel Üretim Genel Müdürlüğü bünyesindeki Çayır Mera ve Yem Bitkileri Daire Başkanlığı yer almaktadır. Yerelde ise valilikler, İl Tarım ve Orman Müdürlükleri ve bu müdürlüklere bağlı Çayır Mera Yem Bitkileri Şubeleri sorumludur. Karar organı olarak İl Mera Komisyonları görev yaparken, uygulamada Teknik Ekipler ve Mera Yönetim Birlikleri bulunmaktadır.

Kanun uygulamaları kapsamında 2023 yılı sonu itibarıyla toplam **13.147.701 hektar** alan tespit edilmiş, bu alanın **12.740.779 hektarı** tahdit edilmiş ve bunun **8.302.548 hektarı** tahsis edilmiştir (BUGEM, 2024).

2.1. Mera Kiralamaları ve Islah Çalışmaları:

Mera alanlarının kullanımında önemli bir yer tutan kiralama faaliyetleri 2006 yılında başlamıştır. 2006 ile 2023 yılları arasında yapılan kiralamalar Çizelge 1'de görülmektedir.

Çizelge 1.Mera Kanununa göre yapılan kiralamalar

Yıllar	Kiralanan İl Sayısı	Kiralanan Toplam Alan (ha)	Uzun Süreli (ha)	Mevsimlik (ha)	Kiralama Bedeli (TL)
2006	23	175.411,00	613,00	174.798,00	1.289.523,00
2007	30	205.936,00	696,00	205.240,00	323.656,00
2008	30	199.951,13	845,07	199.106,06	1.480.699,42
2009	31	200.809,36	737,26	200.072,10	1.326.394,79
2010	36	161.161,00	1.635,68	159.525,32	1.563.332,00
2011	35	137.338,54	3.651,94	133.686,60	2.897.131,56
2012	29	121.957,94	1.259,33	120.698,61	2.459.548,02
2013	24	392.092,14	665,04	391.427,10	3.937.363,90
2014	33	365.525,08	1.726,50	363.798,58	6.395.298,40
2015	30	208.551,00	4.494,00	204.057,00	5.792.997,00
2016	27	230.621,34	1.241,49	229.379,85	4.165.866,70
2017	32	251.565,43	3.983,78	247.581,65	5.196.513,50
2018	34	265.752,72	2.681,42	261.019,30	8.552.037,98
2019	33	257.974,38	25.779,02	232.195,37	9.474.320,78
2020	33	288.951,86	10.219,36	278.732,20	14.279.053,92
2021	35	351.172,09	6.696,87	344.475,22	17.762.941,45
2022	35	378.918,55	7.860,28	371.058,27	19.915.876,68
2023	37	451.684,20	8.824,40	442.859,80	27.910.064,19
Toplam			**83.610,44**		**134.722.619,29**

Anonim, 2024

Çizelge 1'de görüldüğü üzere 2023 yılına kadar toplam 37 farklı ilde mera kiralaması yapılmış ve uzun süreli kiralanan alan 2023 yılında 8.824 ha'a mevsimlik kiralama ise 442.859 ha'a ulaşmıştır. Bu kiralamalardan elde edilen toplam bedel ise **134.722.619,29 TL olarak gerçekleşmiştir.** Kiralamaların büyük çoğunluğu, yaklaşık **yüzde 99,5'i**, göçer hayvancılık yapan üreticilere ve işletme sahiplerine yönelik olup, uzun süreli ıslah amaçlı kiralamalar (83.610,44 ha) toplam kiralamaların küçük bir kısmını oluşturmuştur.

Tarım İl Müdürlüklerinin Üniversiteler ve Tarımsal Araştırma Enstitüleri ile birlikte yürütmüş olduğu Mera Islahı ve Amenajmanı projelerinin sayıları ve toplan alanları Çizelge 2'de görülmektedir

Bölgeler	Proje Sayısı (adet)	Alanı (ha)
Ege	**273**	**55.04**
Marmara	**381**	**79.62**
Akdeniz	**350**	**172.30**
İç Anadolu	**471**	**486.45**
Karadeniz	**593**	**363.39**
Doğu Anadolu	**632**	**915.09**
Güney Doğu Anadolu	**259**	**129.45**
Toplam	**2.959**	**2.201.34**

Anonim, 2024

Çizelge 2'de görüldüğü üzere 2023 yılı sonuna kadar 2959 adet Mera Islahı ve Amenajmanı projelesi yürütülmüş ve 2.2 mil.ha alan ıslah edilmiştir. En çok ıslah projesi Doğu Anadolu, İç Anadolu ve Karadeniz Bölgesinde yürütülmüştür Islah projelerinin sürdürülebilirliği anlamında ciddi sorunlar vardır. Bu projelerin süresi bittikten sonra ıslah edilen merada hayvanını otlatan üreticilerden toplanan otlatma ücretleri ile proje uygulamalarının daha öncesinde devlet tarafından yürütülen uygulamalara devam edilmesi gerekir. Ancak uygulamada bu pek mümkün olmamıştır. Proje süreleri bittiğinde uygulamalar devam ettirilmemiş otlatma planlarına uyulmamıştır, uyulmamaktadır (Hatipoğlu ve ark., 2021; Cevher ve ark., 2015). Bundan dolayı ıslah projelerinde sürdürülebilirliğin olduğu söylenemez. Bu projelerde en büyük sorun merayı kullananların otlatmanın temel ilkelerine uymamaları, otlatma ücreti toplanılmaması mera ıslahını ancak proje süresi ile sınırlı tutmaktadır. Islah projesi uygulanan meralar proje bitiş süresi sonrasında proje uygulanma sürecinin başındaki duruma tekrar dönmektedir diyebiliriz.

2.2. Mera Kayıpları: Tahsis Amacı Değişiklikleri

Mera Kanununun 14. Maddesi ile İl Mera Komisyonunca uygun görülen bazı meralarda tahsis amacı değişikliği yapılarak mera vasfı dışına çıkarılmıştır. Yıllar itibariyle mera vasfı dışına çıkarılan mera alanları Çizelge 3'de görülmektedir.

Çizelge 3. Mera kanunu 14.maddesine göre tahsis amacı değişiklikleri

Yıl	Madden	Turizm	Kamu Yatırımı	İmar Planı	Köy Kanunu	Ülke Güvenliği	Doğal Afet	EPDK	Jeotermal	Kentsel Dönüşüm	OSB	Elektronik Haberleşme	Geçici 3.Madde	Toplam
1998	35	0	1971	689	0	0	0	0	0	0	0	0	0	2696
1999	31	0	7781	694	42	0	0	0	0	0	0	0	0	8547
2000	0	0	4697	523	0	21	0	0	0	0	0	0	33	5273
2001	1682	0	4629	855	11	4	0	0	0	0	0	0	246	7427
2002	152	12	2024	779	0	10	0	0	0	0	0	0	35	3012

2003	208	2	2325	314	6	4729	0	0	0	0	0	0	183	7767
2004	100	5	3547	13897	21	1702	26	0	0	0	0	0	500	19798
2005	226	0	2217	21180	60	116	73	0	0	0	0	0	925	24798
2006	514	65	3667	19108	35	4641	9	0	0	0	0	0	1357	29396
2007	436	2237	1791	16419	56	936	136	2	0	0	0	0	540	22553
2008	1066	0	5384	14021	17	18996	71	387	16	0	0	0	194	40151
2009	736	0	2238	8062	16	109	44	83	1	0	0	0	149	11438
2010	5799	33	1468	16587	29	2149	56	978	87	0	0	0	274	27459
2011	803	1356	3407	6199	25	79	130	1131	129	0	0	0	98	13356
2012	1800	670	4729	17264	173	2032	1357	268	25	0	0	0	35	28352
2013	768	0	3414	9931	11	354	366	2393	0	0	0	0	21	17257
2014	879	644	2229	1614	23	8205	5	246	7	0	0	0	12	13864
2015	1187	14	3901	2763	9	8100	12	445	313	349	0	0	23	17116
2016	1752	0	1801	5364	14	2208	11	517	26	322	0	0	16	12030
2017	2266	8	1822	3134	4	5693	55	387	36	0	45	0	72	13522
2018	3415	0	269	1000	3	0	0	0	48	147	631	0	90	5603
2019	1792	221	2690	11899	35	297	77	0	0	239	1124	149	132	18655
2020	2447	13	5575	7305	20	120	0	271	129	23	3125	2	29	19059
2021	905	16	1448	1469	12	1692	24	438	40	2687	0	0	0	8731
2022	2202	10	9609	1703	10	554	2	1030	13	16	2463	1	2	17615
2023	1980	32	1421	2665	36		0	2069	29		2887	2	1	11122
Toplam	**33180**	**5338**	**86054**	**185438**	**668**	**62746**	**2455**	**10645**	**899**	**3783**	**10276**	**155**	**4964**	**406601**

Anonim, 2024

Çizelge 3'de görüldüğü üzere Mera alanlarının korunmasında en büyük sorunlardan biri olan tahsis amacı değişiklikleri, Kanunun 14. maddesi kapsamında yürütülmektedir. 1998 ve 2023 yılları arasında, çeşitli kamu yararı gerekçeleriyle toplam 406.601,47 hektarlık mera alanının vasfı değiştirilmiştir. Bu kaybın en büyük payını sırasıyla İmar Planları (185.438,13 ha), Kamu Yatırımları (86.054,27 ha) ve Ülke Güvenliği (62.745,75 ha) konuları oluşturmaktadır. Buna

göre istatistiklerde 14.6 mil.ha olan, tesbit alanı olarak 13.1 mil. ha olan mera alanlarının 406.601 ha ı mera vasfından çıkarılmıştır.

3. Mera Kanunu Uygulamalarında Ortaya Çıkan Bazı Sorunlar

4342 Sayılı Mera Kanunu'nun 27 yıllık uygulamasında hem yasal hem de idari-teknik düzeyde çözülmesi gereken önemli sorunlar birikmiştir.

3.1. Yasal ve Kurumsal Nitelikli Sorunlar:

1.Meraların hukuki sorumluluğunun Hazineyi temsilen Tarım ve Orman Bakanlığı'nda olmaması, Bakanlığın hukuki süreçlerde taraf olma yetkisini kısıtlamakta ve koruma çabalarını zayıflatmaktadır.

2. Mera alanlarının işgal ve tahrip edilmesine yönelik mevcut yaptırımların caydırıcılığı oldukça düşüktür; bu durum, meraların sürekli işgaline zemin hazırlamaktadır.

3. Kanunun 14. maddesi kapsamında yapılan vasıf değişiklikleri nedeniyle yaşanan sürekli mera kaybı, en büyük sorunlardan birini oluşturmaktadır. Bakanlığın ıslah ettiği, meralar bile mera vasfından çıkarılabilmektedir.

4. Büyükşehir Belediyesi Kanunu'nun yürürlüğe girmesiyle köy tüzel kişiliklerinin mahalleye dönüşmesi, mera kullanım hakkı sahipliği ve yönetimi konularında yeni hukuki ve idari sorunları beraberinde getirmiştir.

5. Mera Yönetim Birlikleri, mera idaresinde beklenen etkinliği gösterememiş ve çoğunlukla pasif kalmıştır.

6. Mera işgallerine karşı 3091 Sayılı Kanun'un (Taşınmaz Mal Zilyetliğine Yapılan Tecavüzlerin Önlenmesi Hakkında Kanun) uygulaması yetersiz kalmakta ve işgallere kalıcı bir çözüm getirememektedir.

3.2. İdari ve Teknik Nitelikli Sorunlar:

1. Mera alanlarının korunması ve denetlenmesi için görevli idari personel bulunmamaktadır. Bu durum, otlatma rejimlerinin sağlıklı bir şekilde uygulanmasını ve denetlenmesini engellemektedir.

2. Orman içi meralarda otlatmanın düzenlenmesi konusundaki eksiklikler, orman ve mera arasındaki hassas dengenin korunmasını zorlaştırmaktadır.

3. İl Mera Komisyonlarının yapısında, mera konusunda uzmanlaşmış teknik uzmanların yeterli çoğunlukta olmaması, kararların bilimsel ve hukuki açıdan sağlam temellere oturtulmasını engellemektedir.

4. Vasıf değişikliklerinde, özellikle Organize Sanayi Bölgeleri gibi bazı kamu yatırımları için ot bedelinin alınmaması, mera alanı kayıplarını artırmaktadır.

5.Bazı kamu kurumlarının 14. madde izin süreci tamamlanmadan mera alanlarında faaliyetlere başlaması, yasal süreçlerin ihlal edildiğini göstermektedir.

4. Önerilen Kanunu Değişiklikleri

Mevcut sorunların üstesinden gelmek ve meraların korunmasını sağlamak amacıyla, kanun değişikliği yapılmalıdır. Bu öneriler, yasal, kurumsal, idari ve mali alanlarda köklü değişiklikleri öngörmektedir.

4.1. Kurumsal ve Hukuki Çözümler:

1. **Hukuki Sorumluluğun Transferi ve Taraf Olma Yetkisi:** Meraların hukuki sorumluluğu, Hazineyi temsilen **Tarım ve Orman Bakanlığı'na** verilerek, Bakanlığın davalarda taraf olma yetkisi sağlanmalıdır.

2. **Mera Muhafaza Memuru Kadrosu:** Mera alanlarını işgal ve tahrip olaylarından korumak için, Kanuna özel yetkilerle donatılmış **"Mera Muhafaza Memuru"** kadrosunun ihdası zorunludur.

3. **Mera Yönetiminin Yeniden Düzenlenmesi:** Etkinliği düşük olan Mera Yönetim Birlikleri kaldırılmalı, mera idaresindeki sorumluluk muhtar ve yeni ihdas edilecek mera muhafaza memuruna devredilmelidir.

4. **Cezai İşlemde Güçlendirme:** Mera işgali ve tahrip eylemlerine karşı 3091 Sayılı Kanun uygulamasının yetersizliği göz önüne alınarak, daha caydırıcı yaptırımlar için **Ceza Muhakemesi Kanunu'na (CMK)** atıf yapılmalıdır.

5. **Tanım ve Kapsam Genişletilmesi:** Büyükşehir yasasıyla köy tüzel kişiliği sona eren yerleşimler için **"kırsal mahalle"** tanımı yapılarak, Mera Kanunu uygulamalarının bu yerlerde devamı sağlanmalıdır.

4.2. Koruma ve Kullanım Esaslarına Yönelik Çözümler:

1. **Vasıf Değişikliğinde Ot Bedeli Zorunluluğu:** Mera vasfı değişikliklerinde (Devlet Denetleme Kurulu'nun önerisine uygun olarak) meranın ekonomik değeri olan **ot bedelinin** kesinlikle alınma zorunluluğu, kanuna eklenmelidir.

2. **İzinsiz Faaliyet Yasağı:** Tahsis amacı değişikliği talebi sonuçlanıp resmi izinler alınmadan mera alanlarında herhangi bir faaliyete (inşaat, hafriyat vb.) başlanması kesinlikle yasaklanmalı ve bu yasağı ihlal edenlere ağır para cezaları getirilmelidir.

3. **Yasaklar ve Yaptırımlar:** Kanuna, meranın işgali, üzerindeki ağaçların kesilmesi, tıbbi bitki sökümü, hafriyat veya inşaat molozu dökülmesi, doğal çimin kesilmesi, kum, çakıl, taş, toprak gibi malzeme alınması ve her tür inşaat (ev, yapı) yapılması gibi eylemleri kesin olarak yasaklayan ve bunlara karşılık yüksek para cezaları öngören hükümler eklenmelidir.

4. **Islah Edilmiş Meraların Vasıf Değişikliklerinin Önlenmesi:** Islah programına alınmış mera alanlarının vasıf değişikliği yapılmaması engellenerek, korunması sağlanmalıdır.

5. **Gelirlerin Mera Islahına Tahsisi:** Mera gelirleri ve tahsil edilen para cezaları, köylerde Muhtarlık, diğer yerlerde ise İl Müdürlüğü Döner Sermaye bünyesinde açılacak **Mera Özel Hesabına** yatırılmalı ve bu tutarların **sadece mera ıslahı ve yönetimi için kullanılması** kanuni bir zorunluluk haline getirilmelidir.

6. **Otlatma Hakkı ve Otlatmanın Teknik Kuralları:** Otlatma hakkı olmayanların otlatma yapması, otlatma periyoduna uyulmaması ve otlatma kapasitesinin üzerinde hayvan sokulması gibi kural ihlallerine verilecek cezalar kanuna eklenmelidir.

Bu detaylı düzenlemeler, meraların hem çevresel hem de ekonomik varlık olarak korunmasını ve sürdürülebilir bir şekilde yönetilmesini hedeflemektedir.

Sonuç

Mera Kanunu meralara mahsus özel bir kanun olması dolayısıyla kabul edildiği yıl itibariyle Türkiyede çok önemli bir açığı kapatmış bir kanundur ancak Kanun çıktıktan sonra uygulamaları ile birlikte bazı eksik yönleri ortaya çıkmıştır. Kanun mera alanlarının tespit, tahdit, tahsisi, kiralanması, ıslahı yönünde bir dizi yenilikleri beraberinde getirmiş olmakla birlikte mera işgallerini, amenajman ilkelerini engelleyememiş, uygulamalarda

sürdürülebilirlik sağlanamamıştır. Diğer taraftan tahsis değişikliğini içeren 14.madde ile mera alanlarının kayıpları son yıllarda hızla artmıştır. İl Mera Komisyonlarında yeterli mera uzmanının olmaması da bu alanların yeterince korunamamasına yol açıştır. Hayvancılığın en ucuz beslenme alanı olan doğal mera alanlarının korunması, verim ve kalitelerinde süreklilik sağlanması için kanunun bazı maddelerinde değişiklik yapılması gerekmektedir.

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ORTA ANADOLU BÖLGESİ MERALARINDA YAPILAN VEJETASYON ARAŞTIRMALARI

Zir.Müh. Melek KURT

Kırşehir Ahi Evran Üniversitesi Fen Bilimleri Enstitüsü Tarla Bitkileri Anabilim Dalı

Email: melekkakurt@gmail.com

ORCID: 0009-0003-2890-735X

Prof.Dr. Rüştü HATİPOĞLU

Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü

Email: rustu.hatipoglu@ahievran.edu.tr

ORCID: 0000-0002-7977-0782

Arş. Gör. Ömer Afşin ÇİL

Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü

Email: omer.cil@ahievran.edu.tr

ORCID: 0009-0009-7669-9181

ÖZET

Orta Anadolu Bölgesi meraları, Türkiye'nin doğal çayır ve mera ekosistemleri içinde önemli bir yere sahiptir. Bu doğal kaynaklar; kaba yem kaynağı, biyolojik çeşitlilik ve erozyon kontrolü gibi birçok kritik öneme sahiptir. Ancak uzun yıllardır devam eden yanlış kullanım ve aşırı otlatma, bitki örtüsünün kaybına ve mera verimliliğinin azalmasına yol açmıştır. Türkiye'deki çayır mera alanı 14.6 milyon ha olup, Orta Anadolu Bölgesi meraları toplam mera alanının yaklaşık %33,3'ünü oluşturmaktadır. Bölge, karasal iklim özellikleri, yarı kurak toprak yapısı ve değişken topoğrafyası nedeniyle doğal bitki örtüsü açısından hassas alanlar içermektedir.

Çeşitli illerde yapılan vejetasyon etütleri, Orta Anadolu meralarının botanik kompozisyon açısından zengin ancak verim ve sürdürülebilirlik açısından zayıf durumda olduğunu, mera alanlarının büyük kısmının orta ve zayıf sınıfta yer aldığını ortaya koymuştur. Meralarda Poaceae (buğdaygiller) ve Fabaceae (baklagiller) familyalarından değerli yembitkilerinin oranı çok düşmüş olup, istilacı türlerin yaygınlığı %60'ın üzerinde ve çıplak alan oranı %30-45 civarındadır. Bitki örtüsündeki azalma, yem verimini düşürmekte ve hayvansal üretimi olumsuz yönde etkilemektedir. Kuru ot verimleri düşük seviyelerde olup, bu nedenle de mevcut otlatma kapasiteleri potansiyelin çok altındadır.

Bu bildiride Orta Anadolu bölgesi meralarında sürdürülen vejetasyon araştırmaları irdelenmiş ve Orta Anadolu Bölgesi meralarının sürdürülebilir kullanımı için; sürdürülebilir mera yönetimi kapsamında otlatma planlarının hazırlanması ve uygulanması, mera yönetim birliklerinin etkinleştirilmesi, çiftçilerin bilinçlendirilmesi gerektiği sonucuna varılmıştır.

Anahtar Kelimler: Orta Anadolu, mera, vejetasyon, sürdürülebilir mera yönetimi, biyoçeşitlilik

VEGETATION STUDIES CONDUCTED IN THE RANGELANDS OF THE CENTRAL ANATOLIA REGION

ABSTRACT

The pastures of the Central Anatolia Region hold a significant place within Turkey's natural meadow and rangeland ecosystems. These natural resources are critical for many purposes, including forage resources, biodiversity, and erosion control. However, long-standing misuse and overgrazing have led to vegetation loss and reduced rangeland productivity. Turkey's meadow and rangeland area is 14.6 million hectares, and meadow and rangeland area in the Central Anatolia Region constitute approximately 33.3% of the total meadow and rangeland area. The region contains vulnerable areas in terms of natural vegetation due to its continental climate, semiarid soil structure, and variable topography.

Vegetation studies conducted in various provinces have revealed that Central Anatolian rangelands are rich in botanical composition but poor in terms of productivity and sustainability. The proportion of valuable forage crops from the Poaceae and Fabaceae families has decreased significantly, the prevalence of invasive species exceeds 60%, and the proportion of bare graound is around 30-45%. The majority of rangelands are in the medium to poor range. The decline in vegetation reduces forage yields and negatively impacts animal production. Hay yields are low, and therefore current grazing capacity is far below potential.

In this presentation, vegetation researches conducted in the Central Anatolian rangelands were reviewed. From the review, it was concluded that sustainable use of Central Anatolian rangelands requires the preparation and implementation of grazing plans within the framework of sustainable rangeland management, the activation of rangeland management associations, and the raising of farmer awareness.

Keywords: Middle Anatolia, rangeland, vegetation, sustainable rangeland management, biodiversity

1.GİRİŞ

Ülkemizde doğal çayır meralar, insan beslenmesinde kullanılan hayvansal ürünlerin üretiminde girdi olarak kullanılan kaba yemin en önemli ve en ucuz kaynağını oluşturur. Aynı zamanda bu alanlar biyoçeşitlilik, erozyon kontrolü ve canlılar için doğal yaşam alanı olması açısından oldukça öneme sahiptirler. Ancak, ülkemizdeki çayır mera alanları yüzyıllardan beri tekniğine uygun olmayan kulanım sonucu bitki örtülerini önemli ölçüde kaybetmiş ve verimleri azalmıştır.

Türkiye'de bulunan çayır mera alanı 14.6 milyon ha olup, toplam yüzölçümün %18.94'lük bölümünü kaplamaktadır (TÜİK, 2025). Orta Anadolu meraları ise ülkemizdeki toplam mera alanının yaklaşık %33.3'ünü oluşturmaktadır (Ünal ve ark., 2012 a). Ülkemiz meralarında olduğu gibi Orta Anadolu meraları da buğdaygil, baklagil ve diğer familyaları içeren bitkilerle kaplı iken zamanla ağır ve erken otlatılmayla beraber bitki örtüsünün önemli bir kısmını kaybetmiş verimliliği azalmıştır.

Gün geçtikçe azalan mera alanlarında mevcut bitki örtüsünün iyileştirilmesi ve bu alanlardan en yüksek verimin sağlanması yönünde çalışmalar yapılması gerekmektedir. Meralarda yapılacak olan bu amenajman ve ıslah çalışmalarında ise planlanmanın doğru bir şekilde yapılması, yürütülmesi ve tamamlanması için mera vejetasyonu hakkında kantitatif verilerin bulunması gerekir (İspirli ve ark., 2016). Vejetasyon hakkındaki kantitatif bilgiler ise vejetasyon etüdü çalışmalarıyla sağlanır.

Bu bildiride Orta Anadolu bölgesi meralarında yapılan vejetasyon araştırmaları literatür ışığında irdelenmiştir.

2. ORTA ANADOLU BÖLGESİNİN GENEL ÖZELLİKLERİ

2.1 Coğrafi Konum

Orta Anadolu Bölgesi, Türkiye'nin yedi coğrafi bölgesinden biri olan İç Anadolu Bölgesi'nin merkezinde yer alır. Yüzölçümü yaklaşık 151.000 km² olan İç Anadolu Bölgesi, Türkiye topraklarının %21'ini kaplayarak Doğu Anadolu'dan sonra en büyük ikinci bölgedir (Anonim, 2025). Aksaray, Ankara, Çankırı, Eskişehir, Karaman, Kayseri, Kırıkkale, Kırşehir, Konya, Nevşehir, Niğde, Sivas ve Yozgat illerini içinde bulundurur.

Bölge, kuzeyde Karadeniz Bölgesi'nin iç sıradağlarının güney eteklerinden, güneyde ise Akdeniz Bölgesi ile Toros Dağları'nın kuzey eteklerinden sınırlanır. Doğuda Doğu Anadolu Bölgesi, batıda ise Ege ve Marmara Bölgeleri ile komşudur.

Orta Anadolu, geniş platolar, ovalar ve kapalı havzalarla kaplıdır. Yükselti genel olarak 900-1500 metre arasında değişir. Bölgenin ortasında yer alan Konya Ovası, Türkiye'nin en büyük ovası olup, tarımsal üretim açısından büyük öneme sahiptir. Ayrıca, Tuz Gölü gibi önemli doğal oluşumlar da bu bölgede bulunmaktadır (Anonim, 2025).

İç Anadolu Bölgesi'nin bu coğrafi özellikleri, hem doğal kaynakların dağılımını hem de insan yerleşimlerini ve ekonomik faaliyetleri şekillendirmiştir.

2.2 İklim Özellikleri

Orta Anadolu bölgesi, karasal iklim özelliklerinin etkisi altındadır. Yazlar sıcak ve kurak, kışlar ise soğuk ve yağışlı geçer. Orta Anadolu bölgesi ortalama olarak 300-400 mm civarında yağış alır. İlkbahar ayları bölgenin en yağışlı geçtiği zamanlardır. Yazlar oldukça kurak geçer ve mera alanları için olumsuz etiler yaratır.

Bölgede yaz ile kış arasındaki sıcaklık farkı fazladır. Yaz aylarında sıcaklıklar yüksek değerlerde seyrederken, kış aylarında sıcaklıklar sıfırın altına düşebilir.

Yağışların düşük olması ve yüksek buharlaşma oranı, toprak neminin yok olmasına neden olur. Ayrıca, kuru ve kurutucu rüzgarlar bitki örtüsünü tahrip ederek rüzgar erozyonuna neden olmaktadır. Bununla beraber bitki gelişimi yavaşlar ve çayır ve mera verimliliği azalır. Bu bölgede de görülen iklim değişikliğine bağlı kuraklık eğilimi, son yıllarda bölgedeki doğal bitki örtüsü kompozisyonunda da değişikliklere yol açmaktadır.

2.3 Toprak Özellikleri

Orta Anadolu bölgesi, yarı kurak iklim özelliklerine sahip geniş bozkır alanlarıyla kaplıdır. Bölge genel olarak kireçli, az organik maddeli ve su tutma kapasitesi yüksek topraklara sahiptir. Toprak yapısı çoğunlukla killi-tınlıdır. Yer yer tuzluluk probleminin yüksek olduğu bölgede alkali topraklar yaygındır. Orta Anadolu bölgesi meraları ağır ve yanlış otlatma sonucu erozyon riskiyle karşı karşıya gelmiş ve mera verimleri doğrudan etkilenmiştir.

Örneğin, Karaman ili Ayrancı ilçesi Divle köyünde yürütülen bir model mera projesinde toprakların ağır killi balçık yapıda olduğu, azot ve organik madde yönünden fakir ancak tuzluluk problemi içermediği saptanmıştır (Acar ve ark., 2023).

Ayrıca Eskişehir ili Karaören köyünde yapılan çalışmalarda, toprağın kumlu balçık yapıda olduğu ve orta derecede verimli bir mera örtüsüne sahip olduğu belirlenmiştir (Babalık ve Ercan, 2018). Bu durum, bölgedeki toprak yapısının yerel mikroklima ve topoğrafik unsurlara bağlı olarak çeşitlilik gösterdiğini ortaya koymaktadır.

3. ORTA ANADOLU MERALARININ DURUMU VE VEJETASYON ÖZELLİKLERİ

Orta Anadolu meraları, biyolojik çeşitlilik açısından zengin ve tarım ve hayvancılık bakımından kritik öneme sahip mera alanlarıdır. Fakat ülke genelinde olduğu gibi Orta Anadolu meralarında da ekosistem bozulmaları yaşanmış ve verim kayıpları ortaya çıkmıştır.

Karmaşık bitki sistemine sahip olan Orta Anadolu meraları, özellikle *Poaceae* (buğdaygiller) ve *Fabaceae* (baklagiller) familyalarına ait birçok bitki türü içermektedir. Orta Anadolu bölgesinde bulunan ve verim açısından öneme sahip bitki türleri; *Festuca ovina, Andropogon gryllus, Hedysarum varium, Thymus squarrosus, Artemisia fragrans, Medicago sativa* olarak saptanmıştır (Ünal ve ark, 2012 a)

Nevşehir'in Paşalı köyünde yapılan bir çalışmada 733 ha alanda otsu bitkiler, çalılar ve çimenler olmak üzere 78 bitki türü tespit edilmiştir. Türlerin 60 tanesi otsu bitki, 11 tanesi buğdaygil ve 7 tanesi çalı türü olarak belirlenmiştir (Fırıncıoğlu ve ark., 2008).

Sivas ili Çelebiler köyünde yapılan araştırmada 21 örneklem alanından 179 bitki türü kaydedilmiş ve bu alanlar biyoçeşitlilik açısından zengin olarak kabul edilmiştir (Ünal ve ark., 2016).

Orta Anadolu meralarının aşırı otlatma baskısı altında olduğu ve bu nedenle otsu bitkilerin azaldığı bazı çalı türlerinin (örneğin *Thymus spp*.) baskın hale geldiği belirlenmiştir(Bahar ve ark., 2024).

4. ORTA ANADOLU BÖLGESİ MERALARINDA YAPILAN ARAŞTIRMALAR

4.1 Yapılan Çalışmalardan Bazı Örnekler

'Ulusal Mera Kullanım ve Yönetimi Projesi' kapsamında Orta Anadolu Bölgesi meralarında toplam 16 ilde 1212 etüt noktasında çalışmalar yapılmıştır (Anonim, 2012). Yapılan çalışmalar sonucu elde edilen bulgulara göre;

Aksaray ilinde, 77 durakta vejetasyon etütü yapılmış 263 farklı tür tespit edilmiştir. Tespit edilen türlerin 35 adedinin (%13,4) buğdaygil, 36 adedinin (%13,7) baklagil ve 191 adedinin

(%72,9) diğer familyalara ait olduğu ortaya çıkmıştır. Çalışılan durakların 5'inin iyi (%3,54), 39'unun orta (%35,4) ve 33'ünün zayıf (%53,33) mera durumuna sahip olduğu tespit edilmiştir.

Ankara ilinde, 60 durakta vejetasyon etütü yapılmış 287 farklı tür tespit edilmiştir. Tespit edilen türlerin 34 adedinin (%11,9) buğdaygil, 47 adedinin (%16,4) baklagil ve 205 adedinin (%71,7) diğer familyalara ait olduğu ortaya çıkmıştır. Çalışılan durakların 2'si iyi (%3,33), 26'sı orta (%43,33) ve 32'si de zayıf (%53,33) mera durumuna sahip olmuştur.

Çankırı ilinde, 41 durakta vejetasyon etüdü yapılmış 329 farklı tür tespit edilmiştir. Tespit edilen türlerin 37 (%11,3) adedinin buğdaygil, 54 (%16,5) adedinin baklagil ve 237 (%72,3) adedinin diğer familyalara ait olduğu ortaya çıkmıştır. Çalışılan duraklarından, 1 durak çok iyi (%2,44), 3 durak iyi (%7,32), 24 durak (%58,54) orta ve 13 (%31,71) durak zayıf olarak tespit edilmiştir.

Eskişehir ilinde, 142 durakta vejetasyon etüdü yapılmış 275 farklı tür tespit edilmiştir. Tespit edilen türlerin 33 (%12,0) adedinin buğdaygil, 39 (%14,2) adedinin baklagil ve 202 (%73,7) adedinin diğer familyalara ait olduğu ortaya çıkmıştır. Çok iyi mera tespit edilememiş olup, 2 durak (%1,41) iyi, 88 durak orta (%61,97) ve 52 durak (%36,62) zayıf olarak tespit edilmiştir.

Karaman ilinde, 56 durakta vejetasyon etüdü yapılmış 142 farklı tür tespit edilmiştir. Tespit edilen türlerin 30 (%21,2) adedinin buğdaygil, 24 (%16,9) adedinin baklagil ve 87 (%61,2) adedinin diğer familyalara ait olduğu ortaya çıkmıştır. Çok iyi mera tespit edilememiş olup, 2 durak (%3,57) iyi, 39 durak orta (%69,64) ve 15 durak (%26,79) zayıf olarak tespit edilmiştir.

Kayseri ilinde, 60 durakta vejetasyon etüdü yapılmış 253 farklı tür tespit edilmiştir. Tespit edilen türlerin 27 (%10,7) adedinin buğdaygil, 42 (%16,7) adedinin baklagil ve 183 (%72,6) adedinin diğer familyalara ait olduğu ortaya çıkmıştır. Çok iyi mera tespit edilememiş olup, 2 durak (%3,57) iyi, 39 durak orta (%69,64) ve 15 durak (%26,79) zayıf olarak tespit edilmiştir.

Kırıkkale ilinde, 64 durakta vejetasyon etüdü yapılmış ve 184 farklı tür tespit edilmiştir. Tespit edilen türlerin 27 adedinin (%14,8) buğdaygil, 25 adedinin baklagil (%13,7) ve 131 adedinin (%71,6) diğer familyalara ait türler olduğu ortaya çıkmıştır. Yapılan değerlendirmeler sonucunda 1 durağın çok iyi (%1,56), 6 durağın iyi (%9,38), 41 durağın orta (%64,06) ve 16 durağın ise zayıf (%25,0) mera durumuna sahip olduğu belirlenmiştir.

Kırşehir ilinde, 36 durakta vejetasyon etüdü yapılmış ve 206 farklı tür tespit edilmiştir. Tespit edilen türlerin 26 (%12,7) adedinin buğdaygil, 31 (%15,1) adedinin baklagil ve 148 (%72,2) adedinin diğer familyalara ait türler olduğu tespit edilmiştir. Çalışılan duraklardan 1'i (%2,78) iyi, 29'u (%80,56) orta ve 6'sı (%16,67) da zayıf mera durumuna sahip olmuştur.

Konya ilinde, 278 durakta vejetasyon etüdü yapılmış ve 334 farklı tür tespit edilmiştir. Tespit edilen türlerin 47 (%14,1) adedinin buğdaygil, 38 (%11,4) adedinin baklagil ve 248 (%74,5) adedinin diğer familyalara ait olduğu ortaya çıkmıştır. Değerlendirmeler sonucunda 4 (%1,44) durak çok iyi, 25 (%8,99) durak iyi, 112 (%49,28) durak orta ve 137 (%40,29) durak zayıf olarak sınıflandırılmıştır.

Nevşehir ilinde, 31 durakta vejetasyon etüdü yapılmış ve 184 farklı tür tespit edilmiştir. Tespit edilen türlerin 15 (%8,2) adedinin buğdaygil, 15 (%8,2) adedinin baklagil ve 153 (%83,6) adedinin diğer familyalara ait olduğu ortaya çıkmıştır. Değerlendirmeler sonucunda çok iyi ve iyi mera durumları tespit edilemezken 19 (%61,29) durak orta ve 12 (%38,71) durak zayıf olarak sınıflandırılmıştır.

Niğde ilinde, 53 durakta vejetasyon etüdü yapılmış ve 137 farklı tür tespit edilmiştir. Tespit edilen türlerin 20 (%14,6) adedinin buğdaygil, 18 (%13,2) adedinin baklagil ve 98 (72,2) adedinin diğer familyalara ait olduğu ortaya çıkmıştır. Değerlendirmeler sonucunda 1 (%1,89) durak çok iyi, 2 (%3,77) durak iyi, 18 (%33,96) durak orta ve 32 (%60,38) durak zayıf olarak sınıflandırılmıştır.

Sivas ilinde, 103 durakta vejetasyon etüdü yapılmış ve 423 farklı tür tespit edilmiştir. Tespit edilen türlerin 45 (%10,7) adedinin buğdaygil, 70 (%16.6) adedinin baklagil ve 307 (%72,7) adedinin diğer familyalara ait olduğu ortaya çıkmıştır. Değerlendirmeler sonucunda çok iyi meraya rastlanmazken, 6 (%5,83) durak iyi, 62 (%60,19) durak orta ve 35 (%33,98) durak zayıf olarak sınıflandırılmıştır.

Yozgat ilinde, 44 durakta vejetasyon etüdü yapılmış ve 220 farklı tür tespit edilmiştir. Tespit edilen türlerin 31 (%14,1) adedinin buğdaygil, 30 (%13,7) adedinin baklagil ve 158 (%72,1) adedinin diğer familyalara ait olduğu ortaya çıkmıştır. Yapılan değerlendirme sonucunda çok iyi ve iyi mera durum sınıfına sahip mera tespit edilemezken 28 (%63,64) durağın orta ve 16 (%36,36) durağın ise zayıf mera durumuna sahip olduğu belirlenmiştir.

Ünal ve ark., (2012 b) Çankırı ili genelindeki mera alanlarında 2008 yılında meraların mevcut durumunu ve sağlığını belirlemek; uygun mera yönetim ve ıslah metotlarının geliştirilmesine zemin hazırlamak amacıyla 41 farklı durakta tekerlek nokta yöntemi ile vejetasyon etüdü yapmışlardır. Ayrıca toprak örnekleri alınarak fiziksel ve kimyasal analizler yapılmıştır. Bitki ile kaplı alan ortalama %65.19, çıplak alan %34.81 olarak bulunmuştur. Azalıcı bitki türleri oranı %14.72, çoğalıcı türler %24.80, istilacı türler %60.48 olarak belirlenmiştir. Meraların %90.2'si orta ve zayıf sınıfa girmiştir. 24 mera durağı riskli veya *sorunlu sağlık* durumunda olduğu değerlendirilmiştir. Çalışma sonunda, meralarda bozulma sürecinin hızlı şekilde devam ettiği, yönetim ve ıslah uygulamalarının acilen hayata geçirilmesi gerektiği sonucuna varılmıştır.

Babalık, (2019) Konya ili, Taşkent ilçesi, Ilıcapınar Yaylası merasında 2017-2018 yılları arasında meranın bitki ile kaplı alanını, botanik kompozisyonunu, otlatma kapasitesini, topraküstü ve toprakaltı biyokütlesini ve mera durumunu belirlemek amacıyla vejetasyon ölçümleri için transekt ve kuadrat yöntemlerini kullanmış, toprak analizleri yapmış ve verileri SPSS 20 ile istatistiksel olarak değerlendirmiştir. Bitki ile kaplı alan ortalaması %33.5 olarak tespit edilmiştir. Botanik kompozisyonda buğdaygiller %56.2, baklagiller %12.0, diğer familyalar %31.8 oranında yer almıştır. Topraküstü biyokütle 474.8 kg/da, toprakaltı biyokütle 820.5 kg/da olarak bulunmuştur. Otlatma kapasitesi 36.9 BBHB; mera durumu ise "orta" olarak belirlenmiştir. Sürdürülebilir mera yönetimi için doğal bitki örtüsünün korunması, otlatma kapasitesine uyulması ve mera alanlarında koruma uygulamalarının hayata geçirilmesi önerilmiştir.

Altıntaş ve ark., (2018) Tokat, Amasya ve Sivas illerinde ıslah edilmiş meraların sürdürülebilirliğini etkileyen faktörleri, üretici görüşleri doğrultusunda belirlemek ve mera ıslah çalışmalarının etkilerini değerlendirmek amacıyla 2018 yılında 188 üreticiyle anket ve probit regresyon modeli kullanılarak analiz yapmışlardır. Sosyo-ekonomik veriler, mera kullanımı, yem tüketimi, otlatma planı bilgisi gibi değişkenler değerlendirilmiştir. Ankete katılanların %68,62'si mera ıslahı ile kaba yem veriminde artış olduğu, % 61.17'si et ve süt veriminde artış olduğu, % 57.45'i hayvanlara evde besleme ile yedirilen yemde azalma olduğunu bildirmiştir. Üreticilerin çoğunun mera kanunu ve yönetmelikleri hakkında yeterli bilgiye sahip olmadıkları, mera Yönetim Birliklerinin yeterince etkin çalışmadıkları belirlenmiştir. Otlatma planına uyulmamasının sürdürülebilirliği tehdit ettiği saptanmıştır. Probit analizine göre üretici yaşı arttıkça sürdürülebilirliğe olan inancın azaldığı belirlenmiştir. Sonuç olarak mera ıslah çalışmalarının kısa vadede olumlu etkiler sağladığı belirlenmiştir. Ancak sürdürülebilirliğin sağlanması için üreticilerin bilgilendirilmesi, otlatma planlarına uyulması ve mera yönetiminin etkinliğinin büyük önem taşıdığı sonucuna varılmıştır.

Şahin ve ark., (2016) Nevşehir ili genelindeki meraların floristik yapısını belirlemek, bitki türlerinin çeşitliliğini ve otlatmaya karşı tepkilerini inceleyerek mera yönetimi ve sürdürülebilirliği açısından değerlendirmek amacıyla 2008 yılında 31 merada tekerlek-nokta

yöntemi ile toplam 12.400 noktada bitki örtüsü okuması yapmışlardır. Bitkiler "Flora of Turkey"'e göre teşhis edilmiştir. Türlerin otlatmaya tepkileri (azalıcı, çoğalıcı, istilacı) sınıflandırılmıştır.. İncelenen noktalarda toplam 183 bitki türü tespit edilmiştir, bunların 25'inin endemik olduğu, ortalama tür sayısının 27.3 olduğu saptanmıştır. Bitki türlerinin %90'ından fazlasının (164 tür) istilacı türlerden oluştuğu belirlenmiştir. En yaygın 4 familya; Poaceae (buğdaygiller), Asteraceae (papatyagiller), Lamiaceae (ballıbabagiller), Fabaceae (baklagiller) olarak belirlenmiştir. Bitki örtüsünün %44'ünün çıplak alanlardan oluştuğu, en baskın türlerin; *Festuca valesiaca*, *Poa bulbosa*, *Bromus tomentellus*, *Thymus sipyleus* olduğu saptanmıştır. Özellikle buğdaygil türlerinin il meralarında hâkim olduğu, meraların büyük kısmının orta ve zayıf verim sınıfında yer aldığı belirlenmiştir. Çalışma sonucunda Nevşehir meralarının floristik açıdan zengin, ancak istilacı türlerin çokluğu oluşturduğu, çıplak alan oranının yüksekliği ve meraların genel zayıf durumunun sürdürülebilir mera yönetiminin önemini ortaya koyduğunu açıklanmıştır. Bu zenginliğin korunması için uygun mera kullanımı ve ıslah tekniklerinin uygulanması önerilmiştir.

Kendir (1999), Ankara ili Ayaş ilçesinde doğal bir meranın bitki örtüsünü, yem verimini ve mera durumunu belirlemek ve ayrıca bitki türlerinin botanik kompozisyonunu ve otlatma kapasitesini ortaya koymak amacıyla 1997 ve 1998 yıllarında vejetasyon araştırmaları yapmıştır. Transekt yöntemi ile 100'er ölçüm yapılmıştır. Bitki türleri tespit edilip, botanik kompozisyonları ve dip kaplama oranları hesaplanmıştır. Toprak örnekleri alınarak analiz edilmiştir. Kuru ot verimleri familyalara göre hesaplanmış ve mera durumu değerlendirilmiştir. Araştırma bulguları, meranın yalnızca %14.46'sı bitki örtüsü ile kaplı, geri kalan kısmın çıplak alan olduğunu ortaya koymuştur. Bitki örtüsünün botanik kompozisyonunun; %49.65 buğdaygiller, %38.39 diğer familyalar ve %11.96 baklagillerden oluştuğu saptanmıştır. En yaygın türlerin, *Festuca ovina* (koyun yumağı) %49, *Thymus sipyleus* (kekik) %28, *Koeleria cristata* (sorguçlu gümüş otu) %15 olduğu belirlenmiştir. Yem veriminin, ortalama 102.12 kg/da olduğu ve verime en fazla katkı sağlayan bitki gurubunun buğdaygiller olduğu belirlenmiştir. Mera durumunun 3.71 ile "zayıf" mera olarak saptandığı açıklanmıştır. 1 büyükbaş hayvan için gerekli mera alanı 42.30 da olarak hesaplanmıştır. Ayaş merasının, erozyon ve aşırı otlatma nedeniyle ciddi bozulma gösterdiği, vejetasyonun zayıf olmasının, mera kalitesini düşürdüğü ve otlatma kapasitesini sınırladığı sonucuna varılmıştır.

SONUÇ

Bu literatür çalışması Orta Anadolu bölgesi meralarının vejetatif özelliklerini ve durumunu belirlemek amacıyla yapılan araştırmaları bir araya getirmek ve irdelemek amacıyla yapılmıştır. Derlenen literatür sonucunda Orta Anadolu meralarının Türkiye meralarının önemli bir kısmını oluşturduğu sonucuna varılmıştır. Yapılan çalışmalar, meraların, uzun süredir devam eden bilinçsiz kullanım, aşırı otlatma ve yetersiz mera yönetimi vs. nedenlerle ciddi bir biyolojik ve ekolojik bozulma süreci içerisinde olduğunu göstermiştir.

Çeşitli araştırmalarda Orta Anadolu bölgesi meralarının botanik kompozisyon açısından zengin, ancak verimsiz olduğu sonucuna varılmıştır. Poaceae (buğdaygiller) familyası hâkim olsa da, özellikle istilacı türlerin yaygınlığı (%60'ın üzerinde) ve yüksek oranda çıplak alanların (%30-45) varlığı, meraların verimlilik ve sürdürülebilirlik açısından zayıf durumda olduğunu göstermiştir.

Bitki örtüsündeki azalma yalnızca ekolojik bozulmayı değil, aynı zamanda yem verimi ve hayvansal üretim üzerinde de olumsuz etkiler yaratmaktadır. Çalışmalarda kuru ot verimlerinin oldukça düşük seviyelerde (örneğin 102.12 kg/da) olduğu ve 1 büyükbaş hayvan için ihtiyaç duyulan mera alanının 40 da'nın üzerine çıktığı görülmüştür. Bu durum, mevcut otlatma kapasitesinin aşılması halinde daha da büyük tahribatların yaşanabileceğini ortaya koymaktadır.

Yapılan çalışmaların ortak önerisi, sürdürülebilir mera yönetimi için:

- Otlatma planlarının hazırlanması ve uygulanması,
- Mera Yönetim Birlikleri'nin etkinleştirilmesi,
- Çiftçilerin eğitilerek mera yasaları konusunda bilinçlendirilmesi,
- Koruma altına alınmış deneme alanları oluşturularak doğal yenilenmenin teşvik edilmesi,
- Vejetasyon izleme çalışmalarının düzenli olarak yürütülmesi,

gibi tedbirlerin bir bütün olarak ele alınması gerektiğidir (Altıntaş ve ark., 2018; Ünal ve ark., 2012 a ve b).

Sonuç olarak, Orta Anadolu meralarının korunması, yalnızca bölgesel tarım ve hayvancılık bakımından değil, ülkenin genel biyoçeşitlilik ve toprak koruma stratejileri açısından da yaşamsal öneme sahiptir. Bu nedenle yapılacak tüm vejetasyon araştırmaları, sadece botanik kompozisyonu saptamakla kalmayıp, uzun vadeli mera yönetimi ve ıslah projelerine yön verecek veriler üretmelidir.

KAYNAKÇA

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FARKLI IBA DOZLARININ VE BAKTERİ UYGULAMASININ KARADUT (*Morus nigra l.*) ODUN ÇELİKLERİNİN KÖKLENMESİ ÜZERİNE ETKİSİ

Prof. Dr. Aysen KOÇ

Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü, Yozgat

Yozgat Bozok University, Faculty of Agriculture, Department of Horticulture, Yozgat

Email: aysen.koc@yobu.edu.tr

ORCID: 0000-0002-9766-721X

Ziraat Mühendisi Haydar YILMAZ

Toprak, Gübre ve Su Kaynakları Merkez Araştırma Enstitüsü Müdürlüğü, Ankara

Soil, Fertilizer and Water Resources Central Research Institute, Ankara

ORCID: 0000-0001-6381-187X

ÖZET

Dut'un anavatanı ve doğal yayılış alanı olan ülkemizde meyve yetiştiriciliği yapılan her bölgede dut yetiştirilmektedir. Dutun çoğaltılmasında vejetatif çoğaltma yöntemleri içerisinde çelikle çoğaltma yöntemi en fazla kullanılan yöntemdir. Bu konu ile ilgili yapılan çalışmalarda genellikle IBA'nin 4000–8000 ppm'lik konsantrasyonları kullanılmıştır. Kök gelişimini artırdığı ve bitki gelişimini düzenlediği bilinen köklenme üzerine pozitif etkileri olan bazı bakteri türleri bilinmektedir. Çalışmamızda Yozgat'tan selekte edilen bölgeye has karadutlarının IBA ve bakteri uygulamalarıyla çoğaltılması çalışması ilk kez denenmiştir. Yozgat ilinden seleksiyon ile belirlenmiş olan karaduta ait odun çelikleri mart ayında alınmış ve içeriğinde IBA (2000, 4000, 6000 ve 8000 ppm) ve içeriğinde *Pseudomonas fluorescens*, *Paenibacillus polymyx*, *Bacillus megaterium* ile *Pantoea agglomerans* bakteri türleri olan ticari biyopreparatın hem tekli hem de ikili kombinasyonları ile muamele edildikten sonra perlit+torf (1:1) ortamına dikilmiştir. Çelikler alttan ısıtmalı köklenme ortamında üç ay süre ile tutulduktan sonra sökülmüştür. Kontrol ve IBA'nın 2000 ppm dozunda köklenme olmamıştır. Uygulamalar içerisinde köklenme oranı en yüksek Bakteri + 6000 ppm IBA uygulamasında %50 olarak tespit edilmiştir. Çelik başına kök sayısı ortalama olarak 1,83 ile 2,97 adet, kök uzunluğu ise 2,5 ile 3,8 cm arasında değişmiştir. Uygulamaların köklerin toplam kuru madde oranına etkisi %50 ile 54,09 arasında olduğu ölçülmüştür. Köklenen çelikler saksılara alındıktan üç ay sonra canlılık oranlarına bakıldığında en yüksek oran %20 ile Bakteri + 6000 ppm IBA uygulamasından elde edilmiştir. Karadut fidan üretiminde Bakteri ve 6000 ppm IBA'nın birlikte uygulanması köklenmeyi artırmıştır. Bu konuda yapılan çalışmalarda kullanılan materyalin çeşit olmamasından kaynaklı genetik farklılıklar, çelik alma zamanı, köklendirme ortamının koşuları ve çelik alınan ağacın fizyolojik durumu gibi faktörlerin bir sonucu olarak farklı sonuçlar elde edilmiştir.

Anahtar Kelimeler: Karadut, odun çeliği, IBA, Bakteri.

EFFECT OF DIFFERENT IBA DOSES AND BACTERIAL APPLICATIONS ON ROOTING OF BLACK MULBERRY (*morus nigra l.)* WOOD CUTTINGS

ABSTRACT

Türkiye, which is the native and natural distribution area of mulberry, mulberry is grown in every region where fruit is cultivated. In the propagation of mulberry, the method of propagation by cuttings is the most widely used method among vegetative propagation methods. In the studies on this subject, 4000-8000 ppm concentrations of IBA were generally used. Some bacterial species known to increase root growth and regulate plant growth are known to have positive effects on rooting. In our study, the propagation of black mulberries selected from Yozgat province with IBA and bacteria treatments was tried for the first time. Blackberry cuttings were taken in March and treated with commercial biopreparation containing IBA (2000, 4000, 6000 and 8000 ppm) and Pseudomonas fluorescens, Paenibacillus polymyx, Bacillus megaterium and Pantoea agglomerans bacterial species in single and double combinations and then planted in perlite + peat (1:1) medium. Cuttings were kept in a bottom-heated rooting medium for three months and then removed. There was no rooting in control and 2000 ppm dose of IBA. The highest rooting rate among the treatments was 50% in the Bacteria + 6000 ppm IBA treatment. The average number of roots per cuttings ranged between 1.83 and 2.97 pcs and root length between 2.5 and 3.8 cm. The effect of the treatments on the total dry matter content of the roots was measured between 50 and 54.09%. Three months after the rooted cuttings were taken into pots, the highest rate of vitality was obtained from Bacteria + 6000 ppm IBA treatment with 20%. Co-application of bacteria and 6000 ppm IBA increased rooting in black mulberry seedling production. The reason for the different results obtained in studies on this subject may be due to genetic differences caused by the lack of variety in the material used, the time of cutting, the conditions of the rooting medium, and the physiological condition of the tree from which the cuttings were taken.

Keywords: Mulberry, cutting, IBA, Bacteria.

1. INTRODUCTION

Mulberry (Morus spp.) belongs to the Urticales order, Moraceae family, and Morus genus. Approximately 10-12 species are commonly cultivated. These species include: Black mulberry (*Morus nigra*), White mulberry (*Morus alba*), Chinese mulberry (*Morus australis*), African mulberry (*Morus mesozygia*), Mongolian mulberry (*Morus mongolica*), Texas mulberry (*Morus microphylla*), Red mulberry (*Morus rubra*), Linden-leaved mulberry (*Morus tiliaefolia*), Himalayan mulberry (*Morus serrata*), *Morus trilobata*, *Morus notabilis, Morus cathayana*, and *Morus liboensis*. Among these species, the mulberry species most commonly cultivated worldwide and in our country are *Morus alba* (white mulberry), *Morus nigra* (black mulberry), and *Morus rubra* (red mulberry) (Yaltırık, 1972; Vijayan et al., 2011). Turkey is one of the native habitats and natural distribution areas of the mulberry.

Mulberry cultivation can be easily carried out in every region of Turkey where fruit trees are grown. Mulberries thrive in warm, temperate and sunny regions. The optimum temperature range is 24–28 °C. As with many other plants, they continue to grow regularly in air temperatures ranging from 5 to 36 °C (Özgen, 2010). In mulberry production, vegetative methods such as grafting, layering, tissue culture and propagation by cuttings are employed. However, the high labour requirements and lack of trained personnel to perform grafting limit its success. Tissue culture propagation has not yet been widely adopted due to the need for specialised techniques and equipment. Propagation by cuttings is the most widely used method as it yields better results than other vegetative propagation methods (Güneş, 2013).

The success of propagation by cuttings depends on the type and variety of the cutting, the ecological conditions in which the parent plant is grown and the type of cutting. Therefore, these factors should be considered when researching the propagation of a species by cuttings. In cutting propagation methods, perlite is commonly used in rooting media and indole-3-butyric acid (IBA) is used to promote rooting (Ryu, 1977). Researchers studying the propagation of mulberry plants by cuttings have found that rooting-inducing hormones increase root formation (Şenel, 2002).

In propagation studies of mulberry plants using cuttings, commercially available IBA is generally used at a concentration of 4000–8000 ppm. Freshly cut cuttings are dipped into the prepared solution for 5–10 seconds and then planted in the rooting medium. Heating the root zone to 21–27 °C during the day and 16–21 °C at night will promote cell division and facilitate rooting, especially in the rooting of woody cuttings (Güneş, 2013). The purpose of applying plant growth regulators to cuttings is to promote root formation, accelerate rooting, and increase the number of roots per cutting (Özbek, 1991). In steel propagation applications, different doses of IBA hormone have mostly been used. In their study, Ünal et al. (1992) noted that IBA doses did not achieve maximum rooting rates. The success rate in the study conducted by Karadeniz and Şişman (2003) was 23.4% with a 2000 ppm IBA application. Koyuncu et al. (2003) achieved a rooting rate of 33.3% with a 5000 ppm IBA application. Erdoğan and Aygün (2006) reported a rooting rate of 60% with a 6000 ppm IBA application. Yıldız et al. (2009) reported a rooting rate of 24% with a 6000 ppm IBA application. Sezgin (2009) reported that the rooting success rate of cuttings treated with a 7000 ppm IBA application varied between 20% and 60%, depending on the parent plant. Ekizoğlu (20010) A rooting rate of 96.11% was achieved with a 2000 ppm IBA application to cuttings taken in November. Gökçek (2014) found that the best rooting of wood cuttings of the Horum Karadut variety was achieved with an 8000 ppm IBA dose. Terzioğlu (2015) obtained the highest rooting rate and root number with an 8000 ppm IBA application and the highest root length with a 4000 ppm IBA application. Yağlıoğlu (2015) achieved the highest rooting rate (48.3%) with a 6000 ppm IBA + 100 ppm SA (cinnamic acid) application to cuttings taken in November and January. Edizer et al. (2016) found the best

rooting rate to be 66.70%.The average root number was 3, the average root length was 43.40 mm, and the usable cutting rate for seedling production was 43.33%. At an IBA application of 8000 ppm, Altuncu (2019) achieved a rooting rate of 73.33% at a pH of 7.0 with a vertical cutting application. Macit (2019) found that the average rooting rate was 69.4% for cuttings dipped in a 6,000 ppm IBA solution and rooted for 60 days. 8% and 120 days in the rooting medium was 65.6%. Öz et al. (2021) reported that the highest rooting rate was obtained from cuttings dipped in a 6,000 ppm solution (66.7%) or a powdered IBA preparation (51.2%).

Some bacterial species belonging to the genera Agrobacterium, Bacillus, Streptomyces, Pseudomonas and Alcaligenes are known to promote root development and regulate plant growth. While these species have positive effects on rooting, using bacterial species and strains that promote and enhance rooting is crucial for ensuring ecosystem sustainability and minimising potential damage. Recent studies have demonstrated the impact of plant growth-promoting bacteria on plant health and productivity. Using biofertilizers composed of beneficial microorganisms compatible with nature, instead of synthetic chemicals, increases plant growth, maintains soil fertility, and significantly reduces environmental damage (O'connell, 1992). It has been determined in many studies that the application of non-pathogenic bacteria such as *Agrobacterium, Bacillus, Streptomyces, Pseudomonas,* and *Alcaligenes* to cuttings promotes root formation by synthesizing auxin (Patena et al., 1987; Srinivasan et al., 1996; Tripp and Stomp, 1997; Goto, 2012). Although the exact mechanism of root formation is not known, it is accepted that it involves the synthesis of certain phytohormones, such as auxin, the inhibition of ethylene synthesis and the mineralisation of nutrients (Steenhoudt & Vanderleyden, 2000; Goto, 2012). Ercişli et al. (2000) investigated the effects of 2000, 4000, 6000 ppm IBA and 3 different races of Agrobacterium rubi (A1, A16, A18) on the rooting of woody cuttings in Kütahya sour cherry. While no rooting was obtained in the control treatment, the highest rooting rate (70.0%) was obtained from the 2000 ppm IBA+A16 treatment. Çekiç et al. (2013) applied 6,000 ppm indole-3-butyric acid (IBA) and 2,000 ppm paclobutrazol to black mulberry wood cuttings. While there was no rooting in the control group, the application of 6,000 ppm IBA provided 11.6% rooting, the application of 2,000 ppm paclobutrazol provided 1.4% rooting and the combined application of 6,000 ppm IBA and 2,000 ppm paclobutrazol provided 60.5% rooting. A study examining the effects of IBA (500 and 1000 ppm) and bacterial (Bacillus T33, T7 and Microbacterium R23) applications on the rooting of blueberry (Myrtus communis L.) cuttings determined that applications increased rooting compared to the control. The highest rooting occurred in the Bacillus T33 (50%) and 500 ppm + T7 (68.89%) applications (Arıkan et al., 2015). Kınık and Çelikel (2017) investigated the effects of ten rhizobacterium strains and 1000 ppm auxin applications on the rooting of rosehip cuttings, finding that Bacillus megaterium and Pseudomonas fluorescens applications produced the highest rooting rate. In a subsequent study by Çınar (2019), the rooting rates of wood cuttings from bitter orange, trifoliate orange, Carrizo citrange and Troyer citrange rootstocks were investigated using 1000, 2000 and 4000 ppm of indole-3-butyric acid (IBA) in combination with the bacterial strains Agrobacterium rubi A-18 and Bacillus OSU-142. The highest rooting rates were observed in bitter orange rootstock with the 4000 ppm IBA + OSU-142 application (20.00%), and in trifoliate orange rootstock with the 1000 ppm IBA + OSU-142, 2000 ppm IBA + OSU-142, 4000 ppm IBA + OSU-142 and 1000 ppm IBA + A-18 applications. Applications of 4000 ppm IBA + A-18 (% 20.00) and ppm IBA + A-18 in Carrizo citrange were detected in the rootstock, as were applications of 1000 ppm IBA, 2000 ppm IBA and OSU-142 (% 13.33) in Troyer citrange.

2. MATERIAL METHOD

The study used wood cuttings of black mulberry selected from Çekerek in Yozgat as plant material (Figure 1). The study was conducted in the cutting propagation unit of the Faculty of Agriculture's greenhouses at Bozok University's Erdoğan Akdağ East Campus (Figure 2).



Figure 1. General appearance and fruit photographs of black mulberry trees



Figure 2. Taking wood cuttings and planting them in the rooting set

Rooting Materials

Auxin (IBA): Indole-3-butyric acid (IBA, Merck KGaA, Germany) was used at 2000, 4000, 6000, and 8000 ppm as an auxin-group growth regulator in the study.

Microorganism-Containing Fertilizer: A biopreparation containing the bacterial strains *Pseudomonas fluorescens, Bacillus megaterium, Paenibacillus polymyx,* and *Pantoea agglomerans* was used. Depending on the amount of chemical pesticide and fertiliser residue in the soil, moisture content, organic matter content, and temperature, these bacterial isolates can survive for at least 18 months after colonising the plant root zone in the soil.

Perlite: Commercial perlite was used as the rooting medium. Sterile and organic perlite weighs 70-90 $kg.m^{-3}$. Perlite, which doesn't decompose, is non-toxic, odorless, and white in color. It holds water for 50-60% of its volume.

Peat: This type of organic soil is formed by the cyclical accumulation of plant roots and stems over thousands of years, with plant activity increasing as water levels in lake beds drop. Plant death occurs as water levels rise in winter. This natural process is repeated over time.

Method

In the study, single and dual combinations of control, IBA (2000, 4000, 6000, and 8000 ppm), and bacteria treatments were used to enhance root development and formation in black mulberry wood cuttings (Table 1). The study was conducted with 3 replicates, with 10 cuttings per replicate. A total of 10 treatments x 3 replicates x 10 cuttings = 300 wood cuttings were used. The cuttings were kept in the rooting medium for 3 months (12 weeks). A 1:1 peat:perlite mixture was used as the rooting medium. The treated cuttings were planted in a fogging unit containing perlite:peat, heated under the ground at 20-25°C, with 90-95% relative humidity.

Table 1. Single and dual treatments of IBA and bacteria applied to cuttings

1. Control
2. Bacteria
3. IBA (2000 ppm)
4. IBA (4000 ppm)
5. IBA (6000 ppm)
6. IBA (8000 ppm)
7. Bacteria + IBA (2000 ppm)
8. Bacteria + IBA (4000ppm)
9. Bacriteria+ IBA (6000 ppm)
10. Bacteria + IBA (8000 ppm)

Preparation and planting of wood cuttings: Wood cuttings were prepared from the base and middle parts of the shoots, 12-15 cm long. They were stored in polyethylene bags in the cold storage of the Faculty of Agriculture at 0ºC and 80% humidity until the trial was established. After the treatments were prepared and applied, two-thirds of the cuttings were planted in perlite/peat, a rooting medium. In the control treatment, two-thirds of the cuttings were immersed in distilled water before planting in the rooting medium.

Preparation and application of auxin (IBA): Cuttings were dipped for 5 seconds in an IBA solution prepared at 2000, 4000, 6000, and 8000 ppm before planting.

Preparation and application of microorganism-containing fertilizer: 500 ml of a solution containing four different bacterial strains was mixed homogeneously with 5 liters of sterile water and 250 g of granulated sugar as an adhesive. Cuttings were kept in the prepared bacterial solution for 6 hours (Figure 3). Cuttings to be treated with bacteria + IBA were kept in the bacterial solution for 6 hours, then immersed in the prepared IBA solution at different doses for 5 seconds before being planted (Figure 3).



Figure 3. IBA doses and bacterial preparation

Measurements Performed in the Study

The observations and analyses were conducted after the cuttings planted in the rooting medium were kept in a perlite+peat medium for 3 months (12 weeks) that callus formation rate (%), rooting rate (%), root length (cm), root number (number/cutting), fresh root weight (g), dry root weight (g), dry root ratio (%) and viability ratio of living cuttings after seedling formation (%) were measured.

Statistical Analysis

The study employed a randomized plot design. Data collected were analyzed using a normality test, an ANOVA test, and arithmetic mean and percentage (%) values. Statistical analyses were performed using the SPSS 20.0 software package. The resulting percentage values were analyzed after angle transformation.

3. RESULTS AND DISCUSSION

The effects of single and dual applications of plant growth-promoting bacteria and IBA on the rooting parameters of blackberry wood cuttings were found to be statistically significant (Table 2 and Table 3).

The callus formation rate (%) was highest in the single and dual applications of IBA (6000 ppm), Bacteria + IBA (6000 ppm), and Bacteria + IBA (8000 ppm). When examining the rooting rate (%), the highest was determined to be 50.03% from the Bacteria + IBA (6000 ppm) application. In terms of the number of roots per cutting, the highest result among the applications was achieved with the Bacteria + IBA (6000 ppm) application. In terms of root length, the highest measurements were obtained at the Bacteria, IBA (6000 ppm), IBA (8000 ppm), Bacteria + IBA (4000 ppm), Bacteria + IBA (6000 ppm), and Bacteria + IBA (8000 ppm) doses (Table 2).

Table 2. Effect of different treatments on callus formation, rooting rate, root number, and root length in blackberry cuttings

Applications	Callus formation rate (%)	Rooting rate (%)	Number of roots (per cutting)	Root length (cm)
Control	6.67 f	0.00 g	0.00 d	0.00 c
Bacteria	13.30 e	3.33 f	1.83 c	**3.75 a**

IBA (2000 ppm)	6.67 f	0.00 g	0.00 d	0.00 c
IBA (4000 ppm)	26.67 d	16.67 e	2.13 bc	2.94 ab
IBA (6000 ppm)	**53.34 a**	33.35 b	2.18 b	**3.83 a**
IBA (8000 ppm)	40.00 b	30.07 c	2.17 b	**3.75 a**
Bacteria + IBA (2000 ppm)	13.33 e	3.33 f	1.83 c	2.53 b
Bacteria + IBA (4000ppm)	33.33 c	26.67 d	2.17 b	**3.51 ab**
Bacriteria+ IBA (6000 ppm)	**53.33 a**	**50.03 a**	**2.97 a**	**3.49 ab**
Bacteria + IBA (8000 ppm)	**53.33 a**	33.33 b	2.17 b	**3.43 ab**

Edizer et al. (2016) obtained the highest callus formation at 100% with 8000 ppm IBA application, followed by 3000 ppm IBA + 150 ppm NAA at 86.67% and 6000 ppm IBA at 80.003%. They determined that the lowest callus formation was 60.00% in cuttings treated with 4000 ppm IBA. Yıldız and Koyuncu (2000) stated that the callus formation rate decreased with the use of low BD doses. Macit (2019) determined the highest callus formation rates of 8.90% and 5.93% in his propagation study conducted at different planting and harvesting times on November 4 and December 17.

In woody plants, Ünal et al. (1992) reported that IBA doses did not achieve maximum rooting rates. The success rate in the study by Karadeniz and Şişman (2003) was 23.4% with a 2000 ppm IBA application, Koyuncu et al. (2003) reported a rooting rate of 33.3% with a 5000 ppm IBA application, Erdoğan and Aygün (2006) reported a rooting rate of 60% with a 6000 ppm IBA application, Yıldız et al. (2009) reported a rooting rate of 24% with a 6000 ppm IBA application, and Sezgin (2009) found that rooting success in cuttings treated with 7000 ppm IBA varied between 20% and 60% depending on the parent plant, Ekizoğlu (2010) achieved a rooting rate of 96.11% with a 2000 ppm IBA application in cuttings taken in November, Koç (2011) humidity content caused significant changes in rooting percentage. The highest rooting ratio (% 63,11) was observed in cutting planted in medium with 40% humidity. Gökçek (2014) found that an 8000 ppm IBA dose provided the best rooting in the rooting of wood cuttings of the Horum Karadut variety, Terzioğlu (2015) obtained the highest rooting rate and root number with 8000 ppm IBA, and the highest root length with 4000 ppm IBA application, Yağlıoğlu (2015) obtained the highest rooting rate (48.3%) with 6000 ppm IBA + 100 ppm SA (Cinnamic Acid) application in cuttings taken in November and January, Edizer et al. (2016) determined the best rooting rate (66.70%), average root number (3), average root length (43.40 mm), and usable cutting rate for seedling production (43.33%) At 8000 ppm IBA application, Altuncu (2019) obtained the highest rooting rate of 73.33% at pH 7.0 and vertical cutting application. Macit (2019) found that the average rooting rate for cuttings dipped in a 6000 ppm IBA solution and left in a rooting medium for 60 days was 69.4%, the average rooting rate for cuttings kept in the rooting medium for 90 days was 72.8%, and the average rooting rate for cuttings kept in the rooting medium for 120 days was 65.6%. Öz et al. (2021) reported that the highest rooting rate was obtained from cuttings dipped in a 6000 ppm solution (66.7%) or powdered IBA preparation (51.2%). Çekiç et al. (2013) applied 6000 ppm indole butyric acid (IBA) and 2000 ppm Pacroburazol to blackberry wood cuttings. While there was no rooting in the control group, the 6000 ppm IBA application resulted in 11.6%, the 2000 ppm Paclobutrazol application resulted in 1.4%, and the combined application of 6000 ppm indole butyric acid (IBA) and 2000

ppm Paclobutrazol resulted in 60.5% rooting. In a study examining the effects of IBA (500 and 1000 ppm) and bacterial (Bacillus T33, T7, Microbacterium R23) on the rooting of myrtle (Myrtus communis L.) cuttings, it was determined that the applications increased rooting compared to the control, with the highest rooting occurring in the Bacillus T33 (50%) and 500 ppm + T7 (68.89%) applications (Arıkan et al., 2015). Kınık and Çelikel (2017) investigated the effects of 10 rhizobacterial strains and 1000 ppm auxin application on the rooting of rosehip cuttings and found the highest rooting rates with Bacillus megaterium and Pseudomonas flourescens applications. Çınar (2019) investigated the effects of 1000, 2000, and 4000 ppm IBA alone and in combination with Agrobacterium rubi A-18 and Bacillus OSU -142 bacterial strains on citrus, trifoliate, Carrizo citrus, and Troyer citrus rootstock wood cuttings. The highest rooting rate was observed in the Citrus rootstock with 4000 ppm IBA + OSU-142 (20.00%) application, For the three-leaf rootstock, the highest rooting rates were achieved with 1000 ppm IBA + OSU-142, 2000 ppm IBA + OSU-142, 4000 ppm IBA + OSU-142, 1000 ppm IBA + A-18, 2000 ppm IBA + A-18, and 4000 ppm IBA + A-18 (20.00%) applications, In the Carrizo rootstock, 4000 ppm IBA + OSU -142 (20.00%) applications, and in the Troyer rootstock, 1000 ppm IBA, 2000 ppm IBA, and OSU-142 (13.33%) applications.

In our study, when examined in terms of age and dry root weight, the Bacteria+IBA (6000 ppm) application yielded the highest values. The dry root ratio ranged between 50.40% and 54.16%. The percentage of surviving seedlings among rooted seedlings was highest with the Bacteria+IBA (6000 ppm) treatment (Table 3). The effects of different treatments on fresh and dry root weights, dry root ratio, and the percentage of surviving seedlings in black mulberry cuttings were found to be significant. In our study, when fresh and dry root weights were examined, the Bacteria+ IBA (6000 ppm) treatment yielded the highest values. The dry root ratio, calculated by dividing dry root weights by fresh root weights, ranged from 50.40% to 54.16%. The highest percentage of surviving seedlings among rooted seedlings was obtained from the Bacteria+ IBA (6000 ppm) treatment. Özkan and Arslan (1996), at hardwood cuttings, the highest rooting ratio (56.67%) and average number of roots (2.53 pieces) were abtained by 4000 ppm, practical cutting ratio at plant production (33.33%) was determined by 2000 ppm and in other characteristics were found by 1000 ppm IBA concentrations.

Table 3. Effect of different treatments on fresh and dry root weight, dry root ratio, and percentage of surviving seedlings in blackberry cuttings

Applications	Fresh root weight (g)	Dry root weight (g)	Dry root ratio (%)	Survival rate of seedlings (%)
Control	0.00 c	0.00 c	0.00 b	0.00 d
Bacteria	2.45 b	1.33 b	54.02 a	0.00 d
IBA (2000 ppm)	0.00 c	0.00 c	0.00 b	0.00 d
IBA (4000 ppm)	2.59 b	1.34 b	52.08 a	0.00 d
IBA (6000 ppm)	2.76 b	1.47 b	52.06 a	20.17 c
IBA (8000 ppm)	2.82 b	1.43 b	51.77 a	22.20 b
Bacteria + IBA (2000 ppm)	2.30 b	1.18 b	50.40 a	0.00 d
Bacteria + IBA (4000ppm)	2.83 b	1.42 b	50.40 a	0.00 d
Bacriteria+ IBA (6000 ppm)	**4.16 a**	**2.27 a**	54.16 a	**33.33 a**
Bacteria + IBA (8000 ppm)	2.75 b	1.47 b	53.37 a	20.00 c

In conclusion, the study investigated the effects of single and double treatments of 0, 2000, 4000, 6000, and 8000 ppm IBA and bacteria on rooting of black mulberry wood cuttings. According to the results, the best rooting rate was 50.03%, and the best average root count of 2.97 per root was observed in cuttings treated with bacteria and 6000 ppm IBA. No rooting was observed in the control cuttings, which received no hormone treatment, or in cuttings treated with 2000 ppm.

Based on the findings, it can be concluded that applying Bacteria + 6000 ppm IBA to root black mulberry wood cuttings is the optimal growth regulator dose for rooting, root number, root length, and the number of usable cuttings for seedling production. The differing results in the literature on this subject may be due to factors such as genetic differences due to the lack of diversity in the material used, the ecological conditions in the rooting environment, the timing of cuttings, or the physiological condition of the tree from which the cuttings were taken.

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TÜRKİYE'DE YAPILMIŞ MERA VEJETASYON ETÜDÜ ÇALIŞMALARI

Mustafa Alper SAVAŞ
Kırşehir Ahi Evran Üniversitesi, Ziraat Fakültesi, Türkiye
Email: mustafaalper.savas@tarimorman.gov.tr
ORCID: 0009-0002-8156-8775
Umut Edis ULUCAN
Kırşehir Ahi Evran Üniversitesi, Ziraat Fakültesi
Email: umutedisulucan@gmail.com
ORCID: 0009-0002-8700-7506
Prof. Dr. Selahattin ÇINAR
Kırşehir Ahi Evran Üniversitesi, Ziraat Fakültesi, Türkiye
Email: s.cinar@ahievran.edu.tr
ORCID: 0000-0002-9049-0044

ÖZET

Bu çalışma, Türkiye'nin farklı ekolojik bölgelerinde yürütülmüş mera vejetasyon etütlerini inceleyerek, ülke meralarının mevcut durumu ve vejetatif özelliklerini karşılaştırmalı olarak ortaya koymayı amaçlamaktadır. Literatür taramasına dayalı olarak gerçekleştirilen çalışmada Akdeniz, Ege, Marmara, İç Anadolu, Doğu Anadolu, Güneydoğu Anadolu ve Karadeniz bölgelerinde farklı vejetasyon etüd yöntemleri kullanılarak yapılan vejetasyon etüd çalışmaları sonucu elde edilen bulgular değerlendirilmiştir. İncelenen çalışmalarda; bitki ile kaplı alan oranı %15–95, buğdaygil oranı genellikle %30–45, baklagil oranı %10–25 ve diğer familya türleri oranı %35–50 arasında değişmektedir. Bölgesel farklılıklar bulunmakla birlikte, tüm bölgelerde azalıcı türlerin oranı düşerken istilacı türlerin oranı belirgin şekilde yüksek seyretmektedir. Meraların büyük çoğunluğu "zayıf" mera durumu sınıfında yer almakta; bu durum, uzun süreli erken ve ağır otlatma baskısı ile kuraklık gibi ekolojik streslerin yaygın etkisini yansıtmaktadır. Bulgular, ülke meralarının sürdürülebilirliğinin sağlanabilmesi için bölgeye özgü ıslah yöntemlerinin belirlenmesi, otlatma yönetiminin bilimsel esaslara göre düzenlenmesi ve mera kullanım politikalarının güçlendirilmesi gerektiğini göstermektedir.

Anahtar Kelimeler: Mera vejetasyonu, botanik kompozisyon, istilacı türler, mera durumu, Türkiye

RANGELAND VEGETATION SURVEY STUDIES CONDUCTED IN TURKEY

ABSTRACT

This study aims to comparatively reveal the current status and vegetative characteristics of Turkey's rangelands by examining rangeland vegetation surveys conducted across different ecological regions of the country. Based on a comprehensive literature review, the findings of studies carried out in the Mediterranean, Aegean, Marmara, Central Anatolia, Eastern Anatolia, Southeastern Anatolia, and Black Sea regions were evaluated. These studies employed transect, quadrat, point-frame, and loop methods to collect vegetation data. Across the studies examined, vegetation cover varied between 15% and 95%, while the proportion of grasses generally ranged from 30% to 45%, legumes from 10% to 25%, and other plant families from 35% to 50%. Although regional variations were observed, all regions exhibited a decline in the proportion of decreaser species, while the proportion of invasive species remained consistently high. The majority of the rangelands were classified as being in "poor" condition, reflecting the widespread impact of prolonged early and heavy grazing pressure combined with drought-related ecological stresses. The findings emphasize the need to identify region-specific improvement methods, establish scientifically based grazing management strategies, and strengthen rangeland use policies to ensure the sustainability of Turkey's rangelands.

Keywords: Rangeland vegetation, botanical composition, invasive species, rangeland condition, Türkiye

GİRİŞ

Dünya genelinde artan nüfus, iklim değişikliği ve doğal kaynakların sınırlılığı gibi faktörler, sürdürülebilir doğal kaynak kullanımını küresel ölçekte zorunlu hale getirmiştir. Bu kaynakların başında, sahip oldukları zengin biyoçeşitlilik ve hayvansal üretime yönelik kaliteli kaba yem sağlama potansiyelleriyle çayır ve mera alanları gelmektedir.

Meralar sadece yem üretimiyle sınırlı kalmayıp, toprak erozyonunu önleme, su rejimini düzenleme ve habitat çeşitliliği sağlama gibi birçok ekolojik hizmet sunmaktadır. Yağmur sularını sünger gibi emerek toprağa sızmalarını sağlayan bu alanlar, hem yer altı su kaynaklarını beslemekte hem de suyun yüzeysel akışını dengelemektedir.

Bununla birlikte, Türkiye'deki mera alanlarında uzun yıllardır süren aşırı ve zamansız otlatma uygulamaları, bu değerli alanların bozulmasına yol açmıştır. Ayrıca tarımsal mekanizasyonun gelişmesiyle birlikte meralar, tarla arazilerine dönüştürülerek azalmaya başlamıştır.

Ülkemizde 1940'larda yaklaşık 44 milyon hektar olan mera alanı, günümüzde 14,6 milyon hektara kadar düşmüş ve bu azalma sadece miktar olarak değil, niteliksel bozulmayı da beraberinde getirmiştir. Bugün birçok mera, besleme değeri düşük, istenmeyen türlerin hâkim olduğu bitki topluluklarıyla kaplı hale gelmiştir.

Meralar canlı bir ekosistem olup; iklim, topoğrafya, toprak yapısı ve biyotik faktörler tarafından şekillendirilen dinamik bir yapıya sahiptir. Bu nedenle, her bir meranın bitki örtüsü kendine özgü olup zaman içinde değişim gösterir. Bu değişimler ya daha verimli bir yöne ya da bozulmaya doğru olabilir. Bu çalışmalarla birlikte mera durumu, otlatma kapasitesi, bitki örtüsünün toprak koruma fonksiyonu gibi birçok parametre belirlenebilir.

Vejetasyon etüdünün başlıca amacı, meraların botanik kompozisyonunu ve yem verim potansiyelini ortaya koymak, ıslah gereksinimlerini belirlemek ve sürdürülebilir mera yönetimi için veri sağlamaktır. Böylece yalnızca hayvansal üretim değil, toprak ve su kaynaklarının korunması, biyoçeşitliliğin devamlılığı ve iklim direncinin artırılması da sağlanmış olur.

Sonuç olarak, Türkiye gibi yarı kurak iklim kuşağında yer alan bir ülkede, meraların korunması ve ıslah edilmesi büyük önem taşımaktadır. Bu amaçla yapılacak her türlü müdahale ve yönetim uygulamasının ilk adımı, bilimsel temelli bir vejetasyon analizi ile başlamalıdır.

GENEL TANIMLAR

1.1. Vejetasyon ve Vejetasyon Etüdü

Vejetasyon, belirli bir coğrafi alanın bir bölümünde, benzer yaşam koşullarına uyum sağlamış bitki türlerinin oluşturduğu toplulukların bütünüdür. Bu bitki toplulukları, bitki örtüsü olarak adlandırılır. Bitki örtüsü doğada rastlantısal olarak oluşmaz; aksine, belirli ekolojik faktörlerin etkisiyle şekillenmiş, floristik yapısı büyük ölçüde belirlenmiş, iklimsel koşullarla uyumlu, zamanla istikrar kazanmış ve bir ya da birkaç baskın tür tarafından tanımlanan birimler olarak değerlendirilir(Akman ve Ketenoğlu, 1987). Bitki örtüsü ekosistem hizmetlerinde temel rol oynar; örneğin, bitki örtüsü yağışları sünger gibi tutarak toprak erozyonunu önler ve akarsu kıyılarını stabilize eder. Bitkiler fotosentez yoluyla atmosferden karbondioksiti çekerek karbon havuzları oluşturur ve su kalitesini iyileştirir. Ayrıca vejetasyon, çok sayıda tür için yaşam ortamı sağlayarak biyoçeşitliliği destekler. Tüm bu işlevler, bitki topluluklarının ekosistem bütünlüğü ve sürdürülebilirliği açısından kritik önemde olduğunu göstermektedir(Mullins, 2020).

Vejetasyon etüdü, bir alandaki bitki topluluklarının tür kompozisyonu, örtü derecesi ve yapısal özelliklerinin sistematik olarak saptanmasıdır. Etüdler mevcut vejetasyon tiplerinin tanımlanmasına ve bunlar arasındaki farklılıkların anlaşılmasına olanak tanır(Babalık, 2004).

Türkiye'deki mera çalışmalarında vejetasyon etütleri, dominant yem bitkisi türlerinin belirlenmesi, mera sağlık durumunun değerlendirilmesi ve otlatma kapasitesinin saptanması gibi amaçlarla yaygın olarak kullanılmaktadır.

1.2. Bazı Vejetasyon Etüdü Yöntemleri

Mera ekosistemlerinde vejetasyon etüdü için çeşitli kantitatif yöntemler kullanılmaktadır. En yaygın teknikler arasında transekt, kuadrat, nokta çerçeve ve lup teknikleri yer alır. Transekt yönteminde saha boyunca uzanan bir hat üzerinde bitki ile kaplı alan, frekans ve botanik kompozisyon gibi parametreler ölçülürken, kuadrat yönteminde sabit büyüklükteki (örneğin 1×1 m²) kare alanlarda bitki yoğunluğu veya biyokütle belirlemesi yapılır. Nokta çerçeve metodunda transekt hattı üzerindeki belirli aralıklarda küçük bir çerçeve veya pim altından bitki örtüsü gözlenerek örtü oranı saptanır. Lup yöntemi ise benzer prensiple bir metal halkalı kare veya daire içinde bitkileri saymayı esas alır; örneğin 20 m'lik bir lup hattında 20 cm aralıklarla toplam 100 nokta ölçümü yapılarak örtü ve kompozisyon hesaplanabilir. Bu yöntemlerin her biri, çayır-meralarda bitki ile kaplı alan, botanik kompozisyon ve kuru ot verimi gibi temel örtü parametrelerini nicel olarak ortaya koymak için yaygın şekilde kullanılmaktadır(Babalık, 2004).

Farklı ekolojik temalara yönelik mera çalışmalarında da bu yöntemlerden faydalanılmaktadır. Örneğin Çaçan ve Başbağ (2016) çalışmasında Bingöl Yelesen–Dikme meralarında kuzey, güney, doğu ve batı olmak üzere dört bakı yönü ile 1700–1992 m yükseltilerinde toplam 12 ayrı mera kesiminde nokta çerçeve yöntemi uygulanmıştır. Her bir 50 m'lik hat boyunca 5 m aralıklarla noktalar alınmış, her noktada 10'ar bitki gözlemi yapılarak toplamda 4800 gözlem üzerinden örtü ve kompozisyon değerleri belirlenmiştir. Benzer şekilde Baykal vd. (2024) Erzurum-İspir'de bir lup hattı boyunca her 20 cm'de bir olmak üzere 100 nokta üzerinden bitki örtüsünü saptamış, *Poaceae, Fabaceae* ve diğer bitki gruplarının örtü oranlarını hesaplamıştır.

1.3. Vejetasyon Etüdünün Amaçları

Vejetasyon etüdü, ekosistemlerin bitkisel bileşiminin ortaya konması, tür çeşitliliğinin saptanması ve habitat özelliklerinin tanımlanması gibi genel ekolojik amaçlarla yapılan temel çalışmalardan biridir. Bu tür çalışmalar, bitki topluluklarını inceleyerek ekosistem yapısını ortaya koyar ve tür kompozisyonundaki farklılıkları belirler; bu sayede biyoçeşitliliğin izlenmesi ve ekosistem yönetimi için önemli veriler sağlar(Babalık, 2004). Özetle, vejetasyon etüdü çalışmaları ekosistemlerin tanımlanması, sınıflandırılması ve izlenmesine yönelik araştırmalar için vazgeçilmez bir araçtır.

Türkiye'de mera vejetasyon etütleri özellikle otlatma kapasitesi belirleme, mera durumu ve sağlığı değerlendirme, botanik kompozisyon analizi ve ıslah planlama gibi uygulamalı amaçlarla yürütülmektedir. Örneğin, Yavuz ve Karagül (2014) Düzce Esenli merasında uygulanan çeşitli ıslah yöntemlerinin mera otlatma kapasitesi ve bitki kompozisyonu üzerindeki etkilerini incelemiş; elde ettikleri verilerle mera yönetiminde kullanılacak ıslah stratejilerini değerlendirmişlerdir. İspirli vd. (2016) çalışmalarında ise doğal meralarda tespit edilen bitki türleri ve örtü oranları kullanılarak azalıcı, çoğalıcı ve istilacı türlerin yüzdelerini belirlemiş; bu verilerle meraların "iyi, orta, zayıf" durum sınıflaması yapılmış ve meraların yarıdan fazlasının ıslah programlarına öncelik verilmesi gerektiği ortaya konulmuştur.

Sonuç olarak, vejetasyon etütleri hem doğal habitatların izlenmesi ve biyoçeşitliliğin değerlendirilmesi hem de mera yönetimi uygulamalarında kritik bir araçtır. Elde edilen veriler, ekosistemlerin korunması ve izlenmesinde olduğu kadar meraların otlatma kapasitesi ve bitki kompozisyonu esas alınarak yapılan mera durumu değerlendirmesi ve ıslah planlaması kararlarında da temel bilgi kaynağı olarak kullanılmaktadır.

1.4. Vejetasyonu Etkileyen Faktörler

Bitki örtüsünün oluşumu ve dağılışı üzerinde temel olarak iklim, toprak özellikleri ve topografik koşullar etkilidir. İklim elemanları (sıcaklık, yağış, nem ve benzeri) bitkilerin büyüme döngülerini ve fenolojisini doğrudan belirler; uzun dönemde iklim değişimleri vejetasyon kompozisyonunu etkiler. Topografya ise yerel ölçekte mikroklimayı, toprak su rejimini ve besin maddelerini düzenleyerek bitki topluluklarının çeşitliliğini ve yapısını şekillendirir. Bunun yanı sıra, bitkiler arası rekabet ve hayvan otlatması gibi biyotik etkileşimler de bitki topluluklarının bileşimini etkilemektedir.

Örneğin kuzeye kıyasla güneye bakan yamaçlar daha fazla güneş ışınımı aldığı için bitki örtüsü daha sıcak ve kurak koşullara uyum gösterir. Öte yandan, yoğun otlatma baskısı altında kalan meralarda dayanıklı otsu türler çoğalırken niteliği yüksek vejetasyon azalır.

Bununla birlikte yapılan birçok çalışmada mera ıslahı ve amenajman uygulamalarının bitki örtüsünü iyileştiği bildirilmiş olup; üstten tohumlama, yabancı ot kontrolü, gübreleme ve otlatmanın düzenlenmesi gibi yöntemlerin meradaki bitki kaplılık oranını arttırdığı ve istenilen iyi türlerin oransal artışını sağladığı tespit edilmiştir. Benzer şekilde, koruma statüsü altındaki mera alanlarında otlatma kısıtlamaları ve bakım önlemleri sayesinde doğal vejetasyon yapılarının daha iyi muhafaza edildiği değerlendirilmiştir.

TÜRKİYE'DE VEJETASYON ETÜDÜ ÇALIŞMALARI

1.5. Akdeniz Bölgesi

Akdeniz Bölgesi'nde yapılmış birçok mera vejetasyon araştırmasına göre Akdeniz Bölgesi'nin meralarının büyük kısmında bitki örtüsü kompozisyonu bozulmuş durumda olduğu, buğdaygiller ve baklagillerin oranının ideal düzeylerin altına düştüğü buna karşın istilacı yabancı otlar ve düşük kaliteli türlerin baskın hale geldiği bildirilmiştir. Örneğin birçok merada baklagiller %10–20'yi geçmezken, istilacı türler bitki örtüsünün yarıdan fazlasını oluşturabilmektedir. Bitki ile kaplı alan oranı bazı alanlarda %30'un altına kadar düştüğünden, toprak yüzeyi büyük ölçüde açıkta kalarak erozyona maruz kalmaktadır. Bazı taban meralarda ise kaplılık %90'ı aşsa bile, bu örtü hayvanların yararlanamadığı dikenli ve acı otlardan oluşmaktadır. İncelenen meralardaki tür çeşitliliği genel olarak yüksek olsa da (20-30 familya, onlarca bitki türü), aşırı otlatma sonucunda kıymetli türlerin yerini istilacı türler aldığı için mera kalite sınıfı zayıf çıkmaktadır. Nitekim çoğu çalışmada mera durumunun "zayıf" ya da "çok zayıf" kategorisinde olduğu belirtilmiştir. Sadece birkaç merada (yüksek rakımlı ve daha az bozulmuş alanlarda) mera durumu "orta" bulunmuştur.

Bu bulguların temel nedenlerinin iklim ve yanlış mera yönetimi olduğu birçok çalışmada bildirilmiştir. Akdeniz ikliminin uzun yaz kuraklığı, mera bitkilerinin büyüme sezonunu kısaltarak tek yıllık ve düşük verimli türleri hâkim kılmaktadır. Çok daha önemlisi, uzun yıllar kontrolsüz ve yoğun otlatma meraların doğal dengesini bozmuştur. Kaliteli, otlatmaya duyarlı çok yıllıklar azalırken, otlatmaya dayanıklı çalılar ve yabancı otlar çoğalmıştır. Toprak yapısı ve eğim de lokal farklılıklara yol açmıştır; örneğin killi ve sığ topraklı, engebeli arazilerde bitki örtüsü daha zayıf kalmıştır.

Sonuç olarak, Akdeniz Bölgesi meralarının birçoğunda vejetasyon kompozisyonu yem kalitesi açısından arzu edilen düzeyde değildir. İstilacı ve değersiz türlerin baskın olduğu, verimin düşük ve mera durumunun zayıf olduğu tespit edilmiştir. Bu durum, iklimden ziyade mera yönetim hatalarına bağlı bozulmayı göstermektedir. Meraların yeniden sağlıklı ve verimli hale gelebilmesi için uygun ıslah çalışmaları (üstten tohumlama, gübreleme, dinlendirme ve benzeri) ile birlikte planlı otlatma (otlatma zamanı ve kapasitesine riayet) uygulanması önerilmektedir. Aksi halde, mevcut bozulma ilerleyerek meraların sürdürülebilir hayvancılık için sunduğu faydalar tamamen kaybolabilir.

Akdeniz Bölgesinde Yapılmış Bazı Çalışmalar:

Çınar vd. (2019) tarafından Adana İli Tufanbeyli İlçesine bağlı 5 köy merasında 2010 yılında yürütülen çalışmada her merada ki 12 hat üzerinde toplam 1200 noktada etüd çalışması yapılmış ve merada ki bitki türleri, kaplılık oranları ve mera kalite değerleri saptanmıştır. İncelenen meralarda bitki ile kaplılık oranı %90'ın üzerinde bulunmuş olup bitki örtüsünün ortalama botanik kompozisyonunun %36,9 buğdaygil, %22,0 baklagil, %41,1 diğer familyalara ait türlerden oluştuğu bildirilmiştir. Çalışmaya göre azalıcı türler ortalama %20,9, çoğalıcılar %11,9 oranında kalırken istilacılar %67,2'ye ulaşmıştır. Mera kalite puanları 2.40–3.92 aralığında hesaplanmış ve buna göre mera durumu zayıf sınıfına girmiştir. Sonuç olarak Tufanbeyli meralarında uzun yıllar erken ve aşırı otlatma yapılması, kaliteli bitkilerin yerini düşük kaliteli istilacı bitkilere bırakmasına yol açmıştır. Mera ıslahı ve otlatmanın kontrol altına alınması gerektiği vurgulanmıştır.

Öten vd. (2016) tarafından Antalya ilinin farklı ekolojik koşullara sahip 6 ilçesinde ki (Elmalı, Korkuteli, İbradı, Döşemealtı, Aksu, Manavgat) doğal mera alanlarında 2013 yılında yürütülen çalışmada 21 farklı mera noktasında modifiye tekerlekli nokta metodu ile bitki türleri ve kaplama durumları belirlenmiştir. Toplamda 176 farklı bitki türü saptanmış olup bunların 34'ü buğdaygil, 39'u baklagil ve 103'ü diğer familyalara ait türlerdir. İncelenen meralarda bitki ile kaplılık oranı %71,9 ile %95,1 arasında değiştiği ve botanik kompozisyonun genel ortalama olarak %19,3 buğdaygil, %22,1 baklagil ve %58,5 diğer familyalara ait türlerden oluştuğu bildirilmiştir. Mera durum sınıfları bazı alanlarda zayıf, bazı alanlarda ise orta bulunmuş; ancak mera sağlığı genelde "sağlıklı" (erozyon ve toprak açısından henüz kritik seviyede değil) olarak değerlendirilmiştir. Sonuç olarak yapılan çalışmada Antalya genelindeki doğal meraların tür çeşitliliğinin zengin olduğu ancak özellikle baklagil oranlarının düşük ve diğer familyaların baskınlığının dikkat çekici olduğu bildirilmiş olup meralardaki bitki örtüsü çoğunlukla zayıf durumda olduğundan, yöre meralarının ıslah edilmesi ve uygun otlatma planlarının yapılması tavsiye edilmiştir.

Babalık ve Sönmez (2010) tarafından yürütülen, Isparta ili merkez ilçeye bağlı Bozanönü köyü Kırtepe merasında ki 2005-2006 yıllarında iki vejetasyon dönemini kapsayan araştırmada transekt yöntemi kullanılmış olup bitki ile kaplı alan, botanik kompozisyon ve kuru ot verimi ölçülmüştür. Araştırma alanında 32 familyaya ait 129 bitki türü tespit edilmiş olup bitki ile kaplı alan değeri ortalama %18,3 olarak bulunmuş ve bu düşük kaplılığın, erozyon riskini yükselttiği bildirilmiştir. Botanik kompozisyonun %52,5'inin buğdaygillerden, %9,2'sinin baklagillerden ve %38,4'ünün diğer familyalara ait bitki türlerinden oluştuğu ve buğdaygillerin oranının nispeten yüksek olmasına rağmen bunların önemli bir kısmının tek yıllık kalitesiz otlardan oluştuğu, baklagillerin ise vejetasyonda yok denecek kadar az kaldığı vurgulanmıştır. Mera kuru ot verimi 80,3 kg/da olarak hesaplanmış ve bu verime göre bir büyükbaş hayvan biriminin 6 aylık otlatılması için yaklaşık 68 dekar mera gerektiği hesaplanmıştır. Sonuç olarak Bozanönü merasının, uzun yıllar aşırı otlatma sonucu çok zayıf duruma geldiği ve bitki örtüsünün büyük kısmının kaybolduğu, meranın verimsiz ve erozyona açık hale geldiği bildirilmiş olup meranın acilen dinlendirilmesi ve ıslah çalışmalarına tabi tutulması önerilmiştir.

Bilgen ve Özyiğit (2005) tarafında Antalya'nın Korkuteli ve Elmalı ilçelerine bağlı altı doğal mera alanının da 2003 yılında yürütülen araştırma da her bir merada arazi büyüklüğü ve yapısına göre belirlenen örnek alanlarda transekt yöntemi kullanılarak dip kaplama oranı (bitki ile kaplı alan) ve botanik kompozisyon ölçümleri yapılmıştır. Elmalı ilçesindeki Yalnızdam merasında bitki ile kaplı alan değeri %75,5 gibi nispeten yüksek bulunurken, diğer 5 merada bu oran %43'ün altında kalmıştır. En düşük kaplılık değeri Korkuteli Büyük Söğle merasında %29,8 olarak tespit edilmiştir. Meralardaki tür çeşitliliği genel olarak düşük bulunduğu, Yalnızdam'da 12 tür, Büyük Söğle'de 30 tür saptandığı ve bu sonuçlara göre inceleme

alanlarının flora açısından fakirleştiğini bildirilmiştir. Ayrıca tüm meralarda baklagil familyasından türlerin oranının çok düşük olduğu belirtilmiş olup botanik kompozisyonda buğdaygiller ve özellikle diğer familyalardan gelen otsu bitki türleri ağırlık kazanmıştır. Sonuç olarak Korkuteli ve Elmalı'daki doğal meraların durumu genel olarak zayıf olarak değerlendirilmiştir. Araştırma da bölgedeki meraların verimliliğini artırmak için uygun mera yönetimi ve ıslah çalışmalarının gerekliliğini vurgulamıştır.

1.6. Doğu Anadolu Bölgesi

Doğu Anadolu meralarında yapılan çok sayıda çalışmada genellikle mera bitki kompozisyonu %10–%60 arasında değişen oranlarda buğdaygillerden, %4–%33 oranlarında baklagillerden ve geri kalan oranlarda diğer familyalardan oluştuğu görülmüştür. Mera örtüsü çalışmalarda çoğu zaman %70–%90 civarında bulunurken, bazı yüksek kesimlerde %30–%40 düzeyinde bulunmuştur.

Araştırmalar, bu meraların verim ve kalite yönünden zayıf sınıfa girdiğini göstermektedir. Örneğin Bulgurcuk Köyü'nde bitkilerin %84,7'si istilacı türlerden oluşmuş ve mera "zayıf" olarak belirlenmiştir. Benzer şekilde Bingöl Çiçekyayla'da mera kalite derecesi 2,59 (zayıf) bulunmuş, kuru ot verimi düşük çıkmıştır. Çoğu çalışmada mera taşıma kapasitesi de düşük çıkmış ve sürdürülebilir otlatma için yetersiz olarak rapor edilmiştir.

Bu olumsuz durumların temel nedenleri, Doğu Anadolu'nun soğuk ve kurak iklimi ile birlikte aşırı otlatma baskısıdır. Kışlar uzun ve kar yağışlı, yazlar kısa olduğu için bitkiler yeterince gelişememekte; buna ek olarak kontrolsüz otlatma toprağı çıplak bırakmakta, erozyon ve verim kaybına yol açmaktadır. Toprak özellikleri ve eğimli araziler de mera kalitesini düşüren diğer faktörlerdir. Bu nedenle bölge meralarının iyileştirilmesi için otlatma yönetiminin düzenlenmesi, mera ıslah çalışmaları ve toprak verimliliğinin artırılması gereklidir.

Genel olarak, Doğu Anadolu meraları düşük verimli, istilacı tür baskısının yüksek olduğu alanlar olarak tanımlanabilir; bu durum bölgenin iklim ve arazi yapısından kaynaklanmakta ve sürdürülebilir kullanım için acil tedbirler alınmasını zorunlu kılmaktadır.

Doğu Anadolu Bölgesinde Yapılmış Bazı Çalışmalar:

Baykal vd. (2024) tarafından Erzurum İli, İspir İlçesi, Çayırözü Mahallesi merasında lup metodu kullanılarak yapılan çalışma 2020 yılında yürütülmüş ve toplam 59 takson tespit edilmiştir. Botanik kompozisyonda, buğdaygiller %21,33, baklagiller %19,46 ve diğer familya türleri %59,21 oranında bulunmuştur. Bitki kaplılık oranı %67,66 olarak hesaplanmış olup mera kalite derecesi 2,98 olarak belirlenmiş ve mera durumunun "zayıf" sınıfına girdiği ve Çayırözü yaylasının verim ve kalitesinin düşük olduğu bildirilmiştir.

Çaçan ve Balkan (2021) tarafından Elâzığ İli, Karakoçan İlçesi, Bulgurcuk Köyü merasında meranın bitki kompozisyonu, verimi ve mera durumu incelenmiş ve toplam 15 familyaya ait 39 bitki türü belirlenmiştir. Bitki kaplılık oranı %91,7 bulunmuş, kompozisyonda buğdaygiller %61,6, baklagiller %15,6, diğer familyalar %22,8 olarak tespit edilmiştir. Baskın tür *Aegilops triuncialis* (%35,8) olarak saptanmış, diğer baskın türler ise *Trifolium campestre, Hordeum bulbosum* türleri olduğu bildirilmiştir. Mera durumu "zayıf" olarak belirlenmiş; meradaki bitkilerin %84,7'sinin istilacı, %5,8'inin azalıcı, %9,5'inin çoğalıcı olduğu rapor edilmiştir.

Barlak (2012) tarafından Van İli, Çaldıran İlçesi, Başeğmez Köyü merasının bitki ile kaplı alanı, botanik kompozisyonu ve verimi incelenmiştir. Bitki kaplılık oranı %77 olarak bulunmuş, kompozisyonda buğdaygiller %11, baklagiller %7,6, diğer familyalar %81,4 oranında tespit edilmiştir. Kuru ot verimi 61,8 kg/da hesaplanmış, mera taşıma kapasitesi ve kalite düzeyi düşük bulunmuştur. Elde edilen bulgular üzerinden Başeğmez meralarının da düşük üretim potansiyeline sahip olduğunu bildirilmiştir.

1.7. Ege Bölgesi

Ege Bölgesinde yapılan çalışmalarda vurgulanan ortak bulgu, uzun yıllar kontrolsüz ve aşırı otlatmanın mera vejetasyonunu olumsuz etkilediği yönündedir. Aşırı otlatma sonucunda, yüksek yem değerine sahip narin türler azalmakta, onların yerine hayvanların tercih etmediği dikenli-yabancı otlar baskın hale gelmektedir. Ayrıca, yaz kuraklığı ve uygun olmayan toprak koşulları gibi çevresel etkenler de baklagiller başta olmak üzere faydalı bitkilerin gelişimini kısıtlayarak mera kalitesini düşürmektedir.

Sonuç olarak, Ege Bölgesi mera ekosistemlerinin sürdürülebilirliği için acilen tedbir alınması gerekmektedir. Çalışmalar, mevcut meraların bitki örtüsünü iyileştirmek ve verimliliğini arttırmak amacıyla otlatma baskısının azaltılmasını, meraların uygun tekniklerle ıslah edilmesini ve planlı mera yönetimi uygulanmasını önermektedir. Bu sayede meraların yeniden kaliteli bitki türleriyle kaplanması, erozyonun önlenmesi ve bölgenin hayvancılık faaliyetlerine sağladığı katkının sürdürülebilmesi mümkün olabilecektir.

Ege Bölgesinde Yapılmış Bazı Çalışmalar:

Babalık ve Kirazlı (2024) tarafından Aydın ili Karacasu ilçesi 1550 m rakımlı Taşoluk doğal merasında 2022 yılı vejetasyon döneminde gerçekleştirilen çalışmada lup ve kuadrat metotları kullanılarak botanik kompozisyon ve mera verimi incelenmiştir. Araştırma sonucunda merada 37 familyaya ait 147 bitki taksonu belirlenmiştir. En fazla türe sahip familyaların papatyagiller (17 tür), ballıbabagiller (13 tür) ve buğdaygiller (9 tür) olduğu bildirilmiştir. Bitki örtüsüyle kaplı alan oranı %44 olup botanik kompozisyonun %44,8'ini buğdaygiller, %31,2'sini baklagiller, %24,0'ünü diğer familyalar oluşturmaktadır. Mera alanında ölçülen kuru ot verimi 302,0 kg/da, otlatma kapasitesi 59.9 BBHB olarak hesaplanmıştır. Mera durumu "orta" sınıfta tespit edilen alanda, yoğun otlatma nedeniyle vejetasyonun tahrip olduğu gözlenmiştir. Çalışma, meranın iyileştirilmesi için otlatma baskısının azaltılmasını ve uygun ıslah yöntemlerinin uygulanmasını önermektedir.

Öten vd. (2022) tarafından Denizli ilinin 7 ilçesinden seçilen 12 doğal mera alanında yürütülen bu çalışma, modifiye tekerlekli lup yöntemi ile mera vejetasyon özelliklerini belirlemeyi amaçlamıştır. 2015 yılında yapılan vejetasyon etüdü sonucunda incelenen meralarda toplam 234 bitki türü tespit edilmiştir. Türlerin dağılımı incelendiğinde 51'inin buğdaygil, 56'sının baklagil ve 127'sinin diğer familyalara ait olduğu belirlenmiştir. Bitki ile kaplılık oranı meradan meraya değişmekle birlikte %41 ile %50 arasında bulunmuştur. Mera florasında en sık rastlanan türler, baklagillerden *Vicia sativa* (yabani fiğ), buğdaygillerden *Cynodon dactylon* (yayılıcı ayrık) ve diğer familyalardan *Carduus pycnocephalus* (bir devedikeni türü) olarak rapor edilmiştir. Botanik kompozisyon açısından, meralardaki türlerin %13'ü azalıcı, %22'si çoğalıcı ve %65'i istilacı grupta yer almaktadır. Bu sonuç mera bitki örtüsünün büyük ölçüde kalite kaybına uğrayıp yabancı otların hâkim hale geldiğini göstermektedir. Nitekim mera durum sınıflaması sonucunda 1 mera "riskli", 11 mera "zayıf" durumda bulunmuş; mera sağlığı değerlendirmesinde ise bazı alanlar "iyi", çoğunluğu "orta" olarak sınıflandırılmıştır. Çalışma, Denizli meralarında aşırı otlatma baskısının bitki kompozisyonunu olumsuz etkilediğini vurgulamakta ve meraların ıslahı için üstten tohumlama, tekrar ekim, yabancı ot mücadelesi gibi yöntemlerle birlikte otlatma planının düzenlenmesini önermektedir.

Aksu (2006) tarafından İzmir'in Aliağa ilçesinde bulunan yaklaşık 60 ha büyüklüğündeki bir doğal merada gerçekleştirilen bu araştırma, mera vejetasyonunun floristik bileşimini ve verim potansiyelini belirlemeyi amaçlayan bir yüksek lisans tez çalışmasıdır. 2002–2005 yılları arasında mera alanına 18 adet otlatmadan koruma kafesi yerleştirilmiş; vejetasyon ölçümleri korunan alanlarda quadrat (1,44 m²) yöntemi ile yapılmıştır. Elde edilen sonuçlara göre meranın kuru ot verimi ortalama 293,6 kg/da düzeyinde bulunmuş ve 180 günlük otlatma süresi için otlatma kapasitesi 48.66 BBHB olarak hesaplanmıştır. Bitki boyu ortalama 27 cm olup mera

yüzeyinin %66'sı bitki örtüsüyle kaplı bulunmuştur. Botanik kompozisyon (biyokütle ağırlığına göre) incelendiğinde, %65,6'sının buğdaygil, %6,1'inin baklagil ve %28,2'sinin diğer familya bitkilerinden oluştuğu tespit edilmiştir. Bu düşük baklagil oranı, meranın uzun yıllar yoğun ve plansız otlatılması nedeniyle arzu edilen baklagil türlerinin azalmasıyla ilişkilendirilmiştir. Araştırmada, meranın mevcut durumunun sürdürülebilir olmadığı belirtilmiş ve ivedilikle ıslah ile amenajman çalışmalarına başlanarak öncelikle meradaki bozulmanın durdurulması, ardından verim potansiyelini artırıcı önlemlerin alınması tavsiye edilmiştir.

1.8. Güneydoğu Anadolu Bölgesi

İncelenen çalışmalar bölge meralarının bitki örtüsü ve verim özelliklerinin genel olarak zayıfladığını göstermektedir. Yapılan çalışmalarda buğdaygiller ve baklagillerin botanik kompozisyondaki oranları oldukça düşük kalırken, diğer familyalardan yabancı otlar baskın konuma geçmiştir. Birçok mera alanında istilacı türler bitki çeşitliliğinin %90'ından fazlasını oluşturmakta, yem değeri yüksek azalıcı türlerin ise yok denecek kadar azaldığı bildirilmektedir. Bitkiyle kaplı alan oranlarının mera sağlığı açısından çoğunlukla yeterli düzeyde (%50–80 civarında) olduğu ancak kıraç ve aşırı otlatılan kesimlerde %30'un altına kadar düştüğü rapor edilmiştir. Tür zenginliği familya çeşitliliği bakımından yüksek olmakla birlikte, en fazla tür içeren grupların papatyagiller ve baklagiller gibi familyalardan çoğu otlatmaya dayanıklı tek yıllık türler olduğu belirtilmiştir. Özellikle kıraç alanlardaki meraların kuru ot üretiminin son derece düşük olduğu (örneğin Ergani'de 15–25 kg/ da) bununla birlikte taban meralarda nispeten yüksek ot verimi alınabildiği (örneğin Övündüler Köyü 425 kg/da kuru ot verimi) tespit edilmiştir. Tüm meralar floristik kompozisyon ve verim yönünden "zayıf" sınıfta yer alırken, bitki kaplılık oranı açısından çoğunlukla "sağlıklı" kabul edilmiştir.

Bölgedeki meraların bu durumda olmasının temel nedenleri yarı kurak iklim koşulları ve uzun yıllar kontrolsüz şekilde süren aşırı otlatmadır. Düşük ve düzensiz yağış, kaliteli ve çok yıllık mera bitkilerinin gelişimini sınırlandırırken, yıl boyu yoğun otlatma ise bitki örtüsünün hızla bozulmasına yol açmıştır. Sonuç olarak meralar istilacı, değersiz otların egemen olduğu, verimi ve yem kalitesi düşmüş alanlara dönüşmüştür. Bu gidişatı tersine çevirebilmek için mera alanlarının ıslah programlarına alınması, otlatma planlarının uygulanması, uygun gübreleme ve yabani ot mücadelesi gibi önlemlerin hayata geçirilmesi gerekmektedir. Aksi takdirde mera ekosistemlerindeki bozulma ilerleyecek ve bölge hayvancılığının kaba yem açığı büyümeye devam edecektir.

Sonuç olarak Güneydoğu Anadolu meraları yoğun otlatma ve iklimsel kısıtlar nedeniyle ciddi verim kaybına uğramış, kompozisyonları bozulmuştur. Acil ıslah ve sürdürülebilir mera yönetimi uygulanmadığı takdirde, meraların sağladığı ekolojik ve ekonomik faydaların daha da azalacağı bir çok araştırmada rapor edilmektedir.

Güneydoğu Anadolu Bölgesinde Yapılmış Bazı Çalışmalar:

Demirhan (2019) tarafından Siirt ili Kurtalan ilçesi Gözpınar Köyü taban merasında 2017 yılında yapılmış olan yüksek lisans çalışmasında, mera vejetasyonunun yapısı ve toprak özellikleri incelenmiştir. Modifiye edilmiş lup yöntemiyle gerçekleştirilen vejetasyon etütlerinde 9 familyaya ait toplam 23 bitki türü belirlenmiştir. Botanik kompozisyonda buğdaygiller %35,3, baklagiller %28,6 ve diğer familyalar %36,1 oranında yer almıştır. Kalite sınıflandırmasına göre türlerin sadece 2'si azalıcı, 2'si çoğalıcı çıkmış; geri kalan 19 tür istilacı olarak kaydedilmiştir. Mera bitkiyle kaplı alan oranı %76,9 olarak ölçülmüş, toprakların orta bünyeli, hafif alkalin ve tuzsuz olduğu tespit edilmiştir. Çalışma sonucunda, istilacı türlerin baskın olması nedeniyle meranın durumunun zayıf olduğu, ancak toprak verilerine dayanarak uygun ıslah önlemleriyle iyileştirilebileceği belirtilmiştir.

Seydoşoğlu ve Kökten (2018) tarafından Batman ili Beşiri ilçesine bağlı 14 köy merasında 2018 vejetasyon döneminde yürütülen çalışmada, mera durumu, mera sağlığı ve botonik kompozisyonu değerlendirilmiştir. Tekerlekli lup yöntemi ile her merada 400 nokta gözlemi yapılmıştır. Araştırma alanlarında 117 farklı bitki türü tespit edilmiş; bunların 17'si buğdaygil (%30,9), 32'si baklagil (%34,7) ve 68'i diğer familyalara (%34,4) ait türler olarak bildirilmiştir. Türlerin kalite derecelerine göre dağılımında ise 7 tür azalıcı (%2,6), 8 tür çoğalıcı (%6,8) ve 102 tür istilacı (%90,6) olarak belirlenmiştir. Mera florasının büyük ölçüde istenmeyen istilacı türlerden oluşması nedeniyle çalışma alanlarının "zayıf mera" durumda, ancak bitki örtüsü devamlılığı açısından "sağlıklı mera" sınıfında olduğu rapor edilmiştir. Araştırmacılar, bölgede aşırı, erken ve düzensiz otlatmanın mera tahribatındaki rolünü vurgulayarak, sürdürülebilirlik için otlatma planı uygulanması, gübreleme ve yabancı ot kontrolü gibi ıslah tedbirlerinin alınması gerektiğini önermektedir.

Seydoşoğlu vd. (2015) tarafından Diyarbakır ili Silvan ilçesinin taban kesimindeki 6 köy merasında nokta çerçeve metodu ile yapılan vejetasyon etütlerinde 11 familyadan 43 bitki türü belirlenmiştir. Mera alanlarına göre bitki ile kaplılık oranları %46,2 ile %72,0 arasında tespit edilmiştir. Botanik kompozisyon analizinde, meralardaki buğdaygil oranlarının %30,8–72,9, baklagil oranlarının %16,9–48,3, diğer familyalara ait bitkilerin oranlarının ise %10,2–39,7 arasında değişim gösterdiği rapor edilmiştir. Çalışma bulguları, hemen tüm meralarda istilacı türlerin baskın olduğunu, özellikle değerli buğdaygil ve baklagil yem bitkilerinin düşük oranlarda kaldığını göstermiştir. Sonuç olarak Silvan ilçesindeki taban meraların yoğun otlatma baskısı altında kompozisyon bakımından bozulduğu, mera iyileştirmeleri (gübreleme, dinlendirme, yabani ot kontrolü ve benzeri) ile verimin artırılmasının gerekli olduğu belirtilmiştir.

Aydın vd. (2014) tarafında Mardin ili Derik ilçesindeki mera alanında 2012-2013 yıllarında yürütülen çalışmada sekiz hat üzerinde nokta yöntemi ile meranın botanik kompozisyonu iki yıl boyunca izlenmiştir. 16 farklı familyadan 53 bitki türü tespit edilmiştir. Araştırma sonuçlarına göre mera alanının ortalama %53,3'ü bitki ile kaplı bulunmuştur. Kaplama alanına göre botanik kompozisyonda buğdaygiller %4,0, baklagiller %23,2 ve diğer familyalar %72,8 pay almıştır. Merada en yaygın türlerin *trifolium* (*Trifolium campestre*, %16,95), güneşgülü (*Helianthemum sp.*, %13,75), *brom* (*Bromus spp.,* %9,83) ve peygamber çiçeği (*Achillea sp.,* %8,48) olduğu rapor edilmiştir. Ortalama bitki boyu 7,6 cm olarak ölçülmüş, vejetasyonun büyük kısmının cüce formlu yıllık otlardan ibaret olduğu gözlenmiştir. İki yıllık veriler karşılaştırıldığında yağışlı yılın sonunda bitki örtüsünde belirgin artış görülmüş, ilk yıl %39 olan kaplılık ikinci yıl %67'ye yükselmiştir. Kalite bakımından, belirlenen 53 türün 2'si azalıcı, 1'i çoğalıcı, geri kalan 50'si istilacı kategorisinde yer almıştır. Sonuç olarak, meradaki bitki örtüsünün çoğunlukla hayvanların yemediği yabancı otlardan oluştuğu, mera durumunun zayıf olduğu belirtilerek bu meranın ıslahı için ek tedbirler alınması önerilmiştir.

1.9. İç Anadolu Bölgesi

İç Anadolu Bölgesi'nde farklı meralarda yapılan vejetasyon çalışmalarına göre meraların bitki örtüsü kompozisyonu büyük ölçüde bozulmuştur. Kaliteli yem bitkileri olan buğdaygil ve baklagillerin oranı azalırken, yoğun otlatmaya dayanıklı değersiz otların (diğer familyalar) payı birçok yerde yarıdan fazladır. Bitki ile kaplı alan oranı düşüktür; bazı meralarda toprağın ancak %15'i bitkiyle kaplıyken geniş alanlar çıplak kalmıştır. Bu durum mera verimini olumsuz etkilemiş, yıllık kuru ot üretimi dekar başına 100 Kg'ın altına düşmüştür. İyi durumdaki bazı meralarda bile bitki örtüsü ancak arazinin yarısını kaplamaktadır. İncelenen meraların çoğu "orta" veya "zayıf" durumda olup sadece çok azı iyi durumda bulunmuştur. Yoğun ve kontrolsüz otlatma sonucunda mera kalitesi düşmüş, taşıma kapasitesi çok azalmıştır.

Bölgedeki meraların zayıf durumu, yarı kurak iklim koşulları ile yıllardır süren aşırı otlatmanın bir sonucudur. Düşük yağış ve kuraklık, bitki büyümesini sınırlandırırken, erken ve yoğun otlatma bitkilerin yenilenmesine fırsat vermemiştir. Bunun sonucunda, verimli türler yerini yabancı otlara bırakmış, toprak örtüsü incelmiş ve erozyon artmıştır. Eğimli ve sığ topraklı arazilerde bu bozulma daha da şiddetlidir. Sonuç olarak, İç Anadolu meralarının büyük kısmı verim ve kalite açısından optimumun altındadır. Bu meraların sürdürülebilir yönetim ilkeleriyle yeniden düzenlenmesi, aşırı otlatmanın kontrol altına alınması ve gerekli ıslah çalışmalarının yapılması bölge meralarının sağlığını ve verimini artırmak için zorunludur.

İç Anadolu Bölgesinde Yapılmış Bazı Çalışmalar:

S Ünal vd. (2012) tarafından Ankara ilindeki meraların durumunu değerlendirmek amacıyla 2009-2010 yıllarında 60 farklı mera noktasında vejetasyon etütleri gerçekleştirmiştir. Tekerlekli nokta yöntemi ile yürütülen bu çalışmada, ortalama bitki ile kaplı alan %60.5, çıplak alan %39.5 olarak ölçülmüştür. Mera bitki örtüsünü oluşturan türlerin %10,2'si otlatmaya hassas azalıcı türler, %25,7'si çoğalıcı türler olup geriye kalan büyük kısım istilacı otsu bitkilerdir. Mera durum sınıflandırmasına göre incelenen 60 meradan 2'si "iyi", 26'sı "orta" ve 32'si "zayıf" durumda bulunmuştur. Mera sağlığı açısından yapılan değerlendirmede noktaların çoğunun riskli ya da problemli kategoride olduğu belirlenmiştir. Sonuç olarak Ankara meralarının genelinde yapısal bir bozulma ve verim düşüşü tespit edilmiş; sürdürülebilir mera yönetimi ve ıslah tedbirlerinin acilen uygulanması gerektiği önerilmiştir.

Sabahaddin Ünal vd. (2012) tarafından 2008 yılında Çankırı ilinde yürütülen çalışma, ilin tümünü temsil edecek şekilde seçilen 41 mera noktasında bitki örtüsü ve mera sağlığı değerlendirmesi yapmıştır. Tekerlekli nokta yöntemi ile yapılan ve toprak özelliklerinden erozyon şiddetine kadar çeşitli parametrelerin kaydedildiği bu araştırmada, meralarda ortalama bitki ile kaplı alan %65,2, çıplak alan %34,8 olarak tespit edilmiştir. Azalıcı türler toplam vejetasyonun %14,7'sini, çoğalıcılar %24,8'ini oluşturmuş; geri kalan bitki örtüsünü istilacı karakterde türler meydana getirmiştir. Mera durumu değerlendirmesinde 41 meradan 1'i "çok iyi", 3'ü "iyi", 23'ü "orta" ve 14'ü "zayıf" kategoride yer almıştır. Mera sağlığı bakımından da 24 durak "riskli" veya "problemli" olarak sınıflandırılmıştır. Bu bulgular, Çankırı yöresi meralarının yapısal olarak bozulmuş olduğunu ve bozulma sürecinin hızlı şekilde sürdüğünü ortaya koymaktadır. Çalışma, tahrip olmuş meralarda uygun mera yönetimi ve ıslah uygulamalarının bir an önce devreye alınması gerektiğini vurgulamaktadır.

Babalık ve Ercan (2018) tarafından Eskişehir ili Seyitgazi ilçesindeki Karaören köyü merasında, 2016 yılı vejetasyon döneminde mera özelliklerini araştırmıştır. Transekt ve kuadrat yöntemleri kullanılarak yapılan çalışmada mera florası ayrıntılı olarak incelenmiş ve bölgedeki biyoçeşitlilik ortaya konmuştur. Araştırma alanında 49 familyaya ait toplam 89 bitki taksonu tespit edilmiştir. En zengin üç familya, 10 tür ile buğdaygiller (*Poaceae*), 8 tür ile baklagiller (*Fabaceae*) ve 7 tür ile papatyagiller (Asteraceae) olup yem açısından önemli familyaların çeşitliliği yüksektir. Meranın bitki ile kaplı alanı %51,2 olarak ölçülmüş, vejetasyonun botanik kompozisyonunda buğdaygiller %44 ile en büyük paya sahipken baklagiller %23, diğer familyalar %33 oranında yer almıştır. Karaören merasının ot verimi topraküstü biyomas olarak 351,6 kg/da toprak altı biyomas olarak 560,7 kg/ da seviyesinde saptanmıştır. Mera durumu değerlendirmesinde bu mera "iyi durumda" olarak sınıflandırılmıştır. Sonuçlar, Karaören merasının İç Anadolu koşullarına rağmen nispeten iyi korunmuş ve çeşitli bitki örtüsüne sahip olduğunu, uygun yönetimle meraların verimli halde tutulabileceğini göstermektedir.

1.10. Karadeniz Bölgesi

Karadeniz Bölgesi'ndeki farklı mera araştırmaları, bölge meralarının bitki örtüsü yoğun fakat kalite açısından sorunlu olduğunu göstermektedir. İncelenen meralarda buğdaygiller ve baklagillerin toplamı genellikle vejetasyonun yarısından azını oluştururken, diğer

familyalardan bitkiler baskın hale gelmiştir. Örneğin bazı meralarda baklagil oranı %5–10 gibi çok düşük değerlere inerken, istilacı türlerin oranı %50–70'e ulaşmaktadır. Yüksek yağış sayesinde meraların toprakları %60–90 oranında bitkiyle kaplı olsa da bu örtünün büyük kısmı hayvanların tercih etmediği düşük kaliteli otlardan oluşmaktadır. Birçok mera alanında yıllarca süren aşırı otlatma nedeniyle lezzetli ve besleyici bitkiler yerlerini dikenli, acı veya çalı formundaki bitkilere bırakmıştır. Nitekim mera durum dereceleri çoğunlukla "zayıf" sınıfta yer almakta, bu da verim ve otlatma kapasitesinin düşüklüğüne işaret etmektedir.

Bölgedeki meraların bu duruma gelmesinde iklim, arazi yapısı ve özellikle otlatma baskısı başlıca rol oynamıştır. Yağışlı iklim ve derin toprak potansiyeli aslında kaliteli mera bitkilerini destekleyebilmesine rağmen, eğimli arazilerde kontrolsüz otlatma ve bakım eksikliği vejetasyonu olumsuz etkilemiştir. Birçok çalışma, mera ıslahı ve planlı otlatma yapılmadıkça mevcut bitki örtüsünün giderek fakirleşeceğini vurgulamıştır. Öte yandan, bazı kuzey yayla kesimlerinde baklagillerin yeniden yükselebildiği, güneyin kurak noktalarında ise iyice azaldığı görülmüştür. Bu da uygun yönetim ve ekosistem koşulları sağlandığında meraların kendini toparlayabileceğine işaret etmektedir.

Sonuç olarak, Karadeniz Bölgesi meralarının çoğu şu anda orta veya zayıf durumda olup acil tedbir gerektirmektedir. Otlatma rejiminin düzenlenmesi, meraların dinlendirilmesi ve gerekli alanlarda üstten tohumlama ile kaliteli türlerin artırılması tavsiye edilmektedir.

Karadeniz Bölgesinde Yapılmış Bazı Çalışmalar:

Yavuz vd. (2012) tarafından Amasya ilindeki meraların vejetasyon özelliklerini belirlemek amacıyla 2012 yılında 106 noktada mera etüdü gerçekleştirmiş olup toplam 186 bitki türü tespit edilmiş ve bunların 42'si baklagil, 40'ı buğdaygil, 104'ü diğer familyalara ait bitki türleri olarak rapor edilmiştir. Ortalama bitki ile kaplı alan oranı %77,8 olarak ölçülmüştür. Botanik kompozisyonda baklagillerin payı %22,84, buğdaygillerin %41,81, diğer familyaların %35,35 olarak hesaplanmıştır. Kalite gruplarına göre ise kompozisyonun %18,07'sini azalıcı değerli türler oluştururken, %53,52'si istilacı türlerden meydana gelmiştir. Sonuçlar Amasya meralarında yabancı otların hâkim, kaliteli otların ise düşük oranda kaldığını göstermiştir. Çalışma, meraların bu durumunun uzun süreli aşırı otlatmaya bağlı olduğunu belirterek mera yönetimi ve ıslahı konularında öneriler sunmuştur.

Uzun vd. (2016) tarafından 2016 yılında Bartın ili Merkez ilçeye bağlı 15 köy merasında vejetasyon çalışmalarını modifiye tekerlekli lup metodu ile yürütülmüştür. İncelenen meralarda toplam 128 bitki türü saptanmış olup türlerin kalite derecelerine göre dağılımı, 18 türün azalıcı, 10 türün çoğalıcı ve 100 türün (89 otsu + 11 çalı/ağaç formunda) istilacı grupta olduğunu göstermiştir. Meraların bitkiyle kaplı alan oranı ortalama %93,57 gibi oldukça yüksek bulunmuştur. Ancak botanik kompozisyonda azalıcı türlerin oranı %15,52, çoğalıcıların %15,59 iken istilacı türler %68,89 gibi baskın bir değere ulaşmıştır. Mera durum değerlendirmesi sonucunda 15 meradan 1'i "Çok iyi", 1'i "İyi", 6'sı "Orta" ve 7'si "Zayıf" sınıfa girmiştir. Mera sağlığı açısından ise 14 mera "Sağlıklı", 1 mera "Sorunlu" olarak belirlenmiştir. Aşırı otlatılan alanlarda toprak sıkışması artmış, kaliteli bitki oranı azalmıştır. Sonuç olarak meraların yaklaşık yarısının acilen ıslaha ihtiyaç duyduğu, diğer yarısının ise dikkatli kullanılmazsa hızla bozulacağı vurgulanmıştır.

Erkovan (2000) tarafından 2000 yılında Bayburt ili Aydıntepe ilçesi Çiğdemlik köyü meralarının vejetasyon yapısını ve mevcut durumu yüksek lisans tezi çalışması kapsamında incelenmiştir. Araştırmada mera üç kesime (I, II, III) ayrılarak her birinin bitki türleri, botanik kompozisyonu ve mera durumu değerlendirilmiştir. İncelenen kesimlerde toplam 63 bitki türü tespit edilmiştir. I. kesim dışında diğer iki kesimde koyun yumağı (*Festuca ovina*) en baskın bitki olurken, I. kesimde mavi ayrık (*Elymus hispidus*) dominant tür olarak belirlenmiştir. Ayrıca buğdaygillerden yumrulu salkımotu (*Poa bulbosa*) ve baklagillerden çok başlı geven

(*Astragalus multiceps*) yaygın türler arasında saptanmıştır. Botanik kompozisyon, ortalama olarak %39,67 buğdaygil, %23,05 baklagil ve %37,28 diğer familyalardan türlerden oluşmuştur. Bitki örtüsünün toprağı kaplama oranı, I. kesimde %60,5, II. kesimde %65,3 ve III. kesimde %70,2 olarak ölçülmüştür. Bu veriler ışığında, Çiğdemlik merasının orta derecede bir kapalılığa sahip ancak bitki bileşiminin kalite bakımından tam dengeli olmadığı görülmüştür. Mera durumunun iyileştirilmesi için otlatma baskısının kontrolü ve uygun ıslah önlemlerinin gerekliliği vurgulanmıştır.

Çatal vd. (2019) tarafından 2019 yılında Rize ili İkizdere ilçesindeki Ovit Yaylası'nda botanik kompozisyon ve mera durumunu belirlemek amacıyla yürütülen çalışmada Lup metodunun kullanılmış ve toplam 45 bitki taksonu belirlenmiştir: Bunların 6'sının buğdaygillere (*Poaceae*), 4'ünün baklagillere (*Fabaceae*), 35'inin ise diğer familyalara ait olduğu tespit edilmiştir. Araştırma alanının bitki ile kaplı alan oranı %63,40 gibi nispeten düşük bir değerde bulunmuştur. Botanik kompozisyonda buğdaygiller %39,35, baklagiller %6,61, diğer familyalar %54,04 oranlarına sahiptir. Merada en yaygın bulunan ilk üç tür; *Festuca woronowii* (17,66%), *Nardus stricta* (13,90%) ve *Sibbaldia parviflora* (12,80%) olarak kaydedilmiştir. Bu türler, yüksek rakımlı ve aşırı otlatılmış alanların karakteristik dayanıklı bitkileridir. Mera durumu, 1,976'lık mera derecesi ile "çok zayıf" olarak belirlenmiştir. Sonuç olarak, Ovit yaylası merasının gerek bitki örtüsü yoğunluğu gerekse kompozisyon kalitesi bakımından ciddi anlamda bozulmuş olduğunu göstermektedir. Çalışma, özellikle kontrollü otlatma rejimi uygulanmasını ve üstten tohumlama başta olmak üzere diğer ıslah yöntemlerinin devreye sokulmasını önermiş; aksi takdirde yayladaki mera ekosisteminin kendini yenileyemeyeceğini vurgulamıştır.

1.11. Marmara Bölgesi

Marmara Bölgesi'nde incelenen dört mera çalışması, bölgedeki doğal meraların bitki kompozisyonu ve verim durumuna ışık tutmaktadır. Genel olarak meraların botanik kompozisyonunda buğdaygiller ve baklagiller önemli yer tutmakla birlikte, aşırı otlatma ve çevresel koşullar nedeniyle birçok alanda istilacı yabancı otlar baskın hale gelmiştir.

Çalışmalarda ölçülen kuru ot verimleri de meraların yetersiz durumda olduğuna işaret etmektedir. Sonuç olarak, Marmara Bölgesi meralarında verim ve kalite sorunları tespit edilmiştir. İklimsel faktörler (yağış rejimi) verimi yıllara göre etkilese de asıl belirleyici etmen, mera yönetimindeki yetersizliklerdir. Aşırı otlatma ve ihmal, meraların bitki çeşitliliğini olumsuz yönde değiştirmiş; kaliteli yem bitkileri yerini büyük ölçüde yabancı otlara bırakmıştır. Bu çalışmalar, bölgedeki meraların ıslaha ve sürdürülebilir otlatma programlarına ihtiyaç duyduğunu vurgulamaktadır. Uygun tedbirlerle (dinlendirme, aşırı yükün azaltılması, baklagil ekimi ve benzeri) meraların üretkenliğinin ve ekolojik dengesinin yeniden tesis edilebileceği raporlanmıştır. Marmara meralarının mevcut durumu zayıf-orta düzeyde olup iyileştirme uygulamaları yapılmadıkça bölgesel hayvancılığı destekleme kapasitesi sınırlı kalacağı bildirilmiştir.

Marmara Bölgesinde Yapılmış Bazı Çalışmalar:

Gür ve Altın (2015) tarafından Tekirdağ ilinin farklı yörelerinde seçilen doğal mera alanlarında yürütülmüş olan çalışma meraların vejetasyon yapısı ve bazı ekolojik özellikleri incelemiştir. Araştırmada çeşitli mera parçalarında bitki türleri saptanmış; botanik kompozisyon, bitkiyle kaplılık, kuru ot verimi ve toprak özellikleri (pH, organik madde ve benzeri) analiz edilmiştir. Tekirdağ meralarında toplam 67 bitki taksonu belirlenmiştir. Ortalama botanik kompozisyon oranları %48,7 buğdaygil (Poaceae), %21,4 baklagil (Fabaceae) ve %29,9 diğer familyalar şeklindedir. Bitki örtüsü kaplılık oranı %60 ile %78 arasında değişmiş, kuru ot verimi 210–340 kg/da aralığında ölçülmüştür. Toprak analizleri meraların genelde orta derecede verimli ve pH'nın nötr civarında olduğunu göstermiştir. Tekirdağ yöresi meralarının mevcut florasında

buğdaygil türlerinin ağırlıkta olduğu, baklagillerin nispeten düşük kaldığı görülmüştür. Mera verimi bölgedeki yağış ve toprak koşullarına göre düşük-orta düzeydedir. Genel olarak, yoğun otlatmanın etkileri Tekirdağ meralarında da gözlenmekte; korunmuş alanlar daha iyi durumda iken, tahrip olmuş alanlarda istilacı tür oranlarının çok yüksek olduğu vurgulanmaktadır.

Şahbaz (2010) tarafından İstanbul ili Silivri ilçesine bağlı Fener köyü doğal merasında 2008-2009 yılları arasında yürütülen yüksek lisans araştırması, meranın verimi, botanik kompozisyonu ve bitki boyları üzerine odaklanmıştır. Toplam 1908 dekarlık köy merası 9 parçaya ayrılarak incelenmiş; 6 tekerrürlü deneme deseniyle farklı biçim zamanlarında yeşil ve kuru ot verimleri ölçülmüş, bitki boyu gelişimi izlenmiştir. Botanik kompozisyon, biçilen örneklerde ağırlık oranları esas alınarak baklagil, buğdaygil ve diğer familyalar olarak hesaplanmıştır. Meranın ortalama kuru ot verimi 2008'de 219 kg/da 2009'da 237 kg/da olarak belirlenmiştir. Kompozisyonda baklagiller her iki yılda da başat konumda bulunmuş(2008'de %53,5, 2009'da %53,45 baklagil); buğdaygiller %34– 35 civarı, diğer familyalar ise %12–13 olarak tespit edilmiştir. Ağırlıkça baklagil hâkimiyetinin, mera florasında *Trifolium spp., Medicago spp.* gibi türlerin bulunmasından kaynaklandığı belirtilmiştir. Mera durumu, hesaplanan kalite derecesine göre zayıf bulunmuş olup aşırı otlatma belirtileri raporlanmıştır. Nitekim meranın taşıma kapasitesi 96.7 BBHB (Büyükbaş Hayvan Birimi) olarak hesaplanmışken, fiilen meradan yararlanan hayvan varlığının 482.5 BBHB'ye karşılık geldiği bildirilmiştir. Bu durum, meranın kapasitesinin yaklaşık 5 katı hayvan otlatıldığı anlamına gelmekte ve yoğun aşırı otlatma sorununu ortaya koymaktadır. Fener köyü merası verim ve kalite bakımından zayıflamış, bitki örtüsü büyük ölçüde düşük boylu ve yıllık otlardan oluşur hale gelmiştir. Mevcut otlatma baskısının azaltılması ve mera ıslahı yapılması önerilmektedir.

Kurt (2016) tarafından Kırklareli Lüleburgaz İlçesi Doğal Merasında 2014-2015 yıllarında koruma altındaki bir askeri mera alanında gerçekleştirilen yüksek lisans tezinde, meranın botanik kompozisyonu ve verim potansiyelleri araştırılmıştır. 6000 m²'lik korunmuş mera sahasında, tesadüf bloklu deneme deseniyle 4 tekerrür halinde çalışılmıştır. 2014 ve 2015 yıllarında Mart-Eylül döneminde belirli aralıklarla biçim yapılarak yeşil ot ve kuru ot verimleri ölçülmüş; ayrıca farklı familyalara ait baskın türlerin gelişim durumları ve bitki boyları izlenmiştir. Botanik kompozisyon, hasat edilen örneklerin yeşil ve kuru ağırlıklarına göre *Poaceae, Fabaceae* ve diğerleri olarak hesaplanmıştır. 2014 yılında ortalama yeşil ot verimi 1245 kg/da 2015 yılında 1172 kg/da olarak belirlenmiştir. Aynı yılların ortalama kuru ot verimleri ise sırasıyla 391 kg/da ve 318 kg/da'dır. 2015 yılındaki düşüş, yağışın daha az olmasından kaynaklanmıştır. 2014'te bitki örtüsü kompozisyonu yeşil ağırlık temelinde %66,0 buğdaygil, %14,2 baklagil, %19,8 diğer iken; 2015'te %59,1 buğdaygil, %14,0 baklagil, %26,9 diğer şeklinde bulunmuştur. Kuru ot ağırlığına göre kompozisyonda da buğdaygiller her iki yılda en yüksek payı almıştır (2014: %70,9; 2015: %61,4), baklagillerin oranı düşük kalmıştır (yaklaşık %12-14). Florada tespit edilen önemli türler arasında *Lolium perenne* (çok yıllık çim), *Bromus spp.* (Brom otları) gibi buğdaygiller ile *Trifolium campestre, Trifolium pratense* (üçgüller) gibi baklagiller ve çeşitli diğer yabani otlar bulunmaktadır. Lüleburgaz'ın korunan mera sahasında bile buğdaygillerin baskın, baklagillerin zayıf olduğu bir vejetasyon yapısı rapor edilmiştir.

SONUÇ

Yapılan literatür taraması, Türkiye'deki çayır-mera alanlarının genel olarak bozulma eğiliminde olduğunu göstermektedir. Ülke mera alanları, 1940'larda yaklaşık 44 milyon hektar iken günümüzde yaklaşık 14,6 milyon hektara gerilemiş; bu azalma sadece alan kaybı değil aynı zamanda mera bitki örtüsünün niteliğinde de ciddi bozulmaya yol açmıştır. Çeşitli çalışmalar, Türkiye meralarında yem değeri yüksek buğdaygil ve baklagil türlerinin oranlarının azalmasına karşın, az değerli ve istilacı türlerin hızla yayıldığını raporlamıştır.

Genel olarak bitki örtüsü çeşitliliği fiziksel olarak yüksek olsa da kaliteli türlerin baskınlığı azaldığından mera kondisyon sınıfı düşmüş durumdadır. Birçok bölgede toprak yüzeyi büyük ölçüde çıplak kalmakta, örtü oranları ideal düzeyin altına düşmekte ve bu da erozyon ile verim kaybını beraberinde getirmektedir. Elde edilen veriler, arazideki degradasyonun temel sebeplerini "azalan yağış miktarı ve uzun kurak mevsimler ile kontrolsüz, yoğun otlatma" olarak işaret etmektedir. Bu bağlamda, meralarda sürdürülebilirliği sağlamak için meraların dinlendirilmesi, ıslah edilmesi (baklagil ekimi, gübreleme ve benzeri) ve otlatma kapasitelerinin planlı şekilde düzenlenmesi gibi önlemler önerilmektedir. Aksi halde mevcut bozulma sürdürülerek mera ekosistemlerinin ot üretme potansiyeli ve toprağı koruma fonksiyonu yitirilme tehlikesiyle karşılaşmaktadır.

Türkiye'nin farklı coğrafi bölgelerinde yapılan etütler, ortak bozulma eğilimine rağmen çeşitli farklılıklar ortaya koymaktadır. Akdeniz ve Ege Bölgeleri gibi yaz kuraklığının belirgin olduğu alanlarda, kuru mevsime dayanıklı çok yıllık buğdaygil türleri halen görece yüksek oranda bulunabilse de aşırı otlatma sonucu istilacı yabancı otlar egemen hale gelmiştir. Örneğin bazı Akdeniz meralarında baklagil oranı %10–20'nin altına inerken, yabancı otlar bitki örtüsünün yarıdan fazlasını kaplamaktadır. Bu durum, meraların yem kalitesini düşürmüş ve genel olarak "zayıf" mera sınıfına sokmuştur. Marmara ve Karadeniz Bölgeleri ise yağışlı iklim sayesinde örtü oranı yüksek (%60–90) karakterlidir; ancak burada da verimli yem bitkilerinin azlığı sorun olarak öne çıkmaktadır. Karadeniz'de çok yıllık otsuların varlığına rağmen eğimli arazilerde kontrolsüz otlatma, bitki örtüsünü bozulmaya itmiştir. Çeşitli çalışmalarda, bu bölgelerde baklagil payının genelde düşük olduğu, istilacı türlerin hakimiyeti nedeniyle mera durum derecelerinin "orta" ya da "zayıf" seviyede olduğu bildirilmiştir. Yüksek rakımlı Marmara meralarında bile verim genellikle 200–700 kg/da aralığında kalmakta (bu da çoğu mera için yetersiz sayılmaktadır) ve mezofil otsuların oranı düşük olduğundan kalite problemleri yaşanmaktadır. Özetle, kuzeybatı bölgeler bol yağış nedeniyle gerek fazlaca bitki örtüsü sunsa da bu örtü büyük oranda hayvanların tercih etmediği türlerden oluştuğu için mera sağlığı sorunu devam etmektedir.

İç Anadolu Bölgesi'ndeki meraların bitki örtüsü kompozisyonu büyük ölçüde bozulmuştur. Yarı kurak iklime uyumlu buğdaygil ve baklagil türleri yıldan yıla azalarak yerini dikenli, otsu yabancı türlere bırakmıştır. Birçok çalışma, İç Anadolu meralarında bitkiyle kaplı alan oranının düşük (%15–60 arası değişim) ve kuru ot veriminin dekar başına 100 kg'ın altında olduğunu göstermiştir. Bu meraların büyük kısmı "orta" veya "zayıf" sınıflandırılmış, taşıma kapasiteleri hızla azalmış durumdadır. Bölge ikliminin kuraklığı ile aşırı otlatmanın birleşik etkisi, verimli otsuların gelişimini engellemiş; sonuçta toprak örtüsü incelmiş, erozyon artmıştır.

Doğu ve Güneydoğu Anadolu Bölgeleri ise ülkenin en düşük mera verimliliğine sahip alanları olarak öne çıkmaktadır. Yüksek dağlık kesimler (Doğu Anadolu) hem soğuk iklim koşulları hem yoğun otlatma nedeniyle bitkisel üretimi sınırlı kalan meralar sunmaktadır. Bu meralarda çalışmalar, buğdaygil oranının genellikle %10–60, baklagillerin ise %4–33 arasında değiştiğini göstermiş, kuru ot verimi çok düşük bulunmuş ve mera durumu çoğu alanda "zayıf" kategoride raporlanmıştır. Güneydoğu'da ise mevsimsel iklim stresi ile sürekli otlatma bir araya gelerek meraların kompozisyonunu büyük ölçüde bozmuştur. Birçok Güneydoğu merasında istilacı türler bitki çeşitliliğinin %90'ından fazlasını oluştururken, yem değeri yüksek türlerin hemen hemen yok seviyesinde kaldığı bulunmuştur. Bu durum, bölge hayvancılığında kaba yem açığını derinleştirmektedir. Her iki bölgede de, yağış yetersizliğinin ve yıllık otlatma baskısının azaltılması için acil önlemler alınması gerekliliği vurgulanmaktadır.

İncelenen çalışmaların hemen hepsi standart vejetasyon ölçüm yöntemlerini kullanmıştır. Bitki örtüsü kompozisyonu ve kaplılık oranı belirlemek için transekt, kuadrat, nokta çerçeve veya lup yöntemleri yaygın şekilde tercih edilmiştir. Bu yöntemler farklılık gösterse de, hepsi bitki

topluluğu yapısını nicel olarak ortaya koymaktadır. Yöntem tercihlerinden kaynaklanan farklar, örneğin örtü oranının hesaplanma biçimi (bitki boyu ya da bireysel nokta sayımı gibi) sonuçlarda küçük değişikliklere yol açabilmektedir. Ancak mevcut araştırmalarda ki sonuçlar, kullanılan metotlara bakılmaksızın, Türkiye meralarının genel bozulma trendleri konusunda tutarlılık göstermektedir. Sonuç olarak, çayır-mera yönetiminde uyulması gereken sürdürülebilir uygulamalar (dinlendirerek otlatma, tarım dışı kullanımın sınırlandırılması, ıslah çalışmaları vb.) üzerinde de önemli bir temel oluşturacaktır.

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HIZLI BİTKİ ISLAHI: BİR GÜNCEL DURUM DEĞERLENDİRMESİ

Deniz SEVİLMİŞ

Dr., Doğu Akdeniz Tarımsal Araştırma Enstitüsü, Adana, Türkiye

Email: deniz.sevilmis@tarimorman.gov.tr, (sorumlu yazar)

ORCID: 0000-0003-3030-3160

Ayşe Nuran ÇİL

Dr., Doğu Akdeniz Tarımsal Araştırma Enstitüsü, Adana, Türkiye

Email: aysenuran.cil@tarimorman.gov.tr

ORCID: 0000-0001-8520-6013

Y. Ahu AĞAN

Dr., Doğu Akdeniz Tarımsal Araştırma Enstitüsü, Adana, Türkiye

Email: yasarahu.olmez@tarimorman.gov.tr

ORCID: 0000-00031922-1228

ÖZET

Bitki ıslahında ıslah hatlarının verimini ve ürün kalitesini artırırken değişen biyotik ve abiyotik stres faktörlerine dayanıklı bitki çeşitleri ve melezleri geliştirmeye yönelik sürekli ihtiyaç göz önüne alındığında, dünya çapında bitki ıslahçıları uzun zamandır saf hatlar elde etmek için gereken süreyi kısaltmanın yöntemlerini aramaktadır. Saf hatların hızlı üretimi için en son geliştirilen yaklaşım hızlı ıslahtır. Bu teknolojinin basit, uygun maliyetli ve oldukça uyarlanabilir olduğu kanıtlanmıştır. Hızlı ıslah, dünya çapında çeşitli yetiştirme ve araştırma programlarına aktif olarak entegre edilmiş ve farklı yetiştirme bölgelerinde evrensel uygulanabilirliğini göstermiştir.

Hızlı ıslah şunları teşvik eden koşullar oluşturarak her neslin vejetatif dönemini en aza indirir: 1) hızlandırılmış çiçeklenme, 2) hızlı tohum olgunlaşması ve 3) ardışık ıslah döngülerini sağlamak için hasat sonrası dormansinin üstesinden gelinmesi. Bu yaklaşımın uzun gün mahsullerinde büyümeyi hızlandırmadaki uygulanabilirliği ilk olarak 2018'de gösterilmiştir. Yazlık buğday, arpa, nohut ve bezelye için yılda altı nesil, kolza tohumu için ise yılda dört nesil elde etmek başarılmıştır. Uzun gün mahsullerindeki başarısının ardından soya fasulyesi, kinoa, kenevir ve diğerleri dahil olmak üzere kısa gün türleri için optimize edilmiş protokoller geliştirilmiştir. Hızlı ıslah protokolleri çok çeşitli bitki türleri için oluşturulmuştur.

Bu derlemenin amacı, yöntemin bitki vejetasyon periyodunun kısalmasını etkileyen faktörlerin bir araya getirilmesini sağlamak, yayınlanmış hızlandırılmış ıslah protokollerini özetlemek ve hızlı ıslah uygulamasını tanımlamaktır.

Anahtar kelimeler: Hızlı ıslah, bitki ıslahı, ıslah döngüleri

SPEED BREEDING: A CURRENT STATUS REVIEW

ABSTRACT

Plant breeders throughout the world have been searching for ways to shorten the time needed to obtain pure lines, given the continuous need for breeding plant varieties and hybrids that are resistant to shifting biotic and abiotic stress factors while enhancing yield and product quality.Speed breeding is the most modern method for producing pure lines rapidly. This technology has shown itself to be easy to use, reasonably priced, and very flexible. Speed breeding has proven to be universally applicable in a variety of growing environments and has been actively incorporated into numerous breeding and research projects across the globe.

In order to assure further breeding cycles, speed breeding reduces the vegetative period of each generation by fostering 1) early flowering, 2) rapid seed development, and 3) overcoming post-harvest dormancy. In 2018, the viability of this strategy for enhancing long-day crop growth was initially shown. For spring wheat, barley, chickpeas, and peas, six generations annually have been attained, whereas for rapeseed, four generations annually. Optimized procedures have been constructed for short-day species, including as hemp, quinoa, soybeans, and others, in response to the success of long-day crops. Speed breeding methods have been developed for many different types of plants.

This review's objectives are to give a summary of published speed breeding protocols, explain how speed breeding is applied, and give an overview of the elements influencing the method's capacity to shorten the plant vegetation period.

Keywords: Speed breeding, plant breeding, breeding cycles

GİRİŞ

Islah ve genetik araştırmalardaki sınırlayıcı faktörlerden biri, saf hatlar geliştirmek için gereken zamandır. Bu, bir yandan tek bir neslin uzun vejetatif döneminden, diğer yandan da genellikle bitki materyalinde ardışık 4-6 nesil kendi kendine tozlaşma gerektiren kendileme özelliklerinden kaynaklanmaktadır. Birçok araştırmacı homozigot bitki hatlarının hızlı gelişimini sağlayan yaklaşımlar aramıştır. Bu araştırmaların sonucunda, sonbahar-kış döneminde sera yetiştiriciliği, tek tohumlu iniş, mekik ıslahı (shuttle breeding), embriyo kültürü ve çift haploid teknolojisi gibi yöntemler uygulamaya konulmuştur. Tüm bu yöntemlerin hem avantajları hem de sınırlamaları vardır. Bitkilerin vejetatif döneminde önemli bir kısalma sağlayan en son yaklaşımlardan biri hızlı ıslahtır. Bu yöntem, ekimden çiçeklenmeye kadar geçen süreyi kısaltan faktörlerin uygulanmasına ve ayrıca, gelişmenin generatif evresini hızlandıran ve hasat sonrası dormansiyi gideren tekniklere dayanmaktadır (Blinkov ve ark., 2025).

Işık ve sıcaklık manipülasyonuna ve fiziksel sınırlamaya dayanan hızlı ıslah, ıslah döngüsünü hızlandırarak bitki ıslahının farklı aşamalarını etkilemektedir. Hızlı ıslah, kullanıma sunulmasından bu yana ekonomik açıdan önemli birçok türün ıslah programlarını hızlandırmıştır. Hızlı ıslah, homozigotluğa hızlı bir ilerleme ve halihazırda gelişmiş veya dönüştürülmüş hatların, yani gen düzenlemeli mahsullerin ve transgenik mahsullerin değerlendirilmesini sağlar. Hızlı ıslah teknikleri ayrıca kaynak açısından verimli genotipleme ve fenotiplemeyi de kolaylaştırır; ancak hızlı ıslah koşullarının bitki büyümesi ve gelişimi üzerindeki olumsuz etkilerini değerlendirmek ve azaltmak için daha fazla araştırmaya ihtiyaç vardır. Hızlı ıslah protokolleri artık küçük veya geniş ölçekli benimseme ve yerel ihtiyaçlara/yeniliklere dayalı daha fazla değişiklik için mevcuttur. Bu nedenle hızlı ıslah protokolleri, ürün dayanıklılığı ve adaptasyonu için kritik olan genlerin tanımlanması ve aktarılması potansiyellerini gerçekleştirmek için aşamalı olarak iyileştirilebilir ve modern ıslah teknikleriyle birleştirilebilir (Varshney ve ark., 2021).

Islahta döngü devir hızını artırma teknikleri yaygın olarak hızlı ıslah terimi altında gruplandırılmaktadır (Ghosh ve ark., 2018). Bunlar,

1) Hızlandırılmış tek tohumlu nesil eldesi için homozigot hatların hızlı gelişimi,
2) DNA işaretleyici teknolojisi kullanılarak bir yılda daha fazla ıslah döngüsü,
3) Stresli koşullar ve olgunlaşmamış embriyoların in vitro kültürü kullanılarak bir yılda daha fazla nesil,
4) Olgunlaşmamış tohum hasadı ve fotoperiyot tepkisi kullanılarak gen atlatma uygulamalarını içermektedir (Samantara ve ark., 2022).

Hızlı döngü teknikleri, bitki büyüme ortamının (örneğin bitki yoğunluğu, fotoperiyot ve sıcaklık) optimize edilmesi, çiçeklenme metabolik yolağını hedefleyen genetik mühendisliği, genç bitkilerin olgun anaçlara aşılanması, bitki büyüme düzenleyicilerinin uygulanması ve olgunlaşmamış tohumların hasat edilmesi gibi herhangi bir kombinasyonu içerebilir (Chiurugwi ve ark., 2019).

1. HIZLI ISLAHIN KULLANIM ALANLARI

Hızlı ıslahın uygulamaları arasında çift ebeveynli ve daha karmaşık haritalama popülasyonlarının geliştirilmesi, özellik piramiti oluşturma, geri melezlemelerin hızlandırılması, yetişkin bitki özelliklerinin fenotiplenmesi, mutant çalışmaları ve genetik dönüşüm deneyleri yer almaktadır (Watson ve ark., 2018). Son araştırmalar, gen düzenleme, yüksek verimli fenotipleme ve genotipleme, genomik seçilim ve MAS gibi yeni ortaya çıkan tekniklerin hızlı ıslah ile birleştirilerek mahsül iyileştirmenin hızlandırılmasındaki gücünü göstermiştir (Gosal ve ark., 2020). Ayrıca, çok sayıda akraba hattı üretmenin maliyeti ve alan

gereksinimleri, bu hatların yüksek bitki yoğunluklarında ekilmesiyle en aza indirilebilir (Yao ve ark., 2017). Hızlı ıslah, düşük çimlenme oranı, zayıf canlılık ve bazen çarpık büyüme gibi çift haploid teknolojisiyle ilişkili zorlukların üstesinden gelinmesine de yardımcı olmaktadır (Ferrie, 2007). Genetik haritalama amaçları açısından, birden fazla nesil kendi kendine döllenmeden sonra geliştirilen rekombinant saf hatlar (RIL'ler), tekrarlanan döllenme sırasında meydana gelen çoklu mayoz olayları ve bunun sonucunda ortaya çıkan daha yüksek rekombinasyon sıklığı nedeniyle çift haploide göre avantajlı olabilir. Benzer şekilde, ayrılan nesillerin ilerlemesi ve değerlendirilmesi, hızlı ıslah koşulları altında kısa sürede tek tohum nesli ile yapılabilir; bu da geleneksel soyağacı yetiştirme yöntemine kıyasla zaman tasarrufu ve maliyet açısından verimlidir (Jahne ve ark., 2020). Bu teknik, ıslah süresini kısaltmada etkili olmuş ve klasik ıslaha kıyasla üç kat daha yüksek generasyon atlatma sağlamıştır (Samantara ve ark., 2022).

Hızlı ıslah, haritalama popülasyonlarının oluşturulmasında oyunun kurallarını değiştiren bir unsur olarak ortaya çıkmıştır. Geleneksel olarak, genetik haritalama için çeşitli ayrışan popülasyonlar oluşturmak zaman alıcı bir süreçti. Ancak, hızlı ıslahın nesiller arasında hızla geçiş yapabilme yeteneği bu alanı dönüştürmüştür. Araştırmacılar artık büyük ve genetik olarak çeşitli haritalama popülasyonlarını verimli bir şekilde üretebilmekte ve bu da onlara temel özelliklerle ilişkili genleri saptamak için gerekli kaynakları sağlamaktadır (Gaba ve ark., 2021). Bu atılım, nicel özellik lokusu (QTL) analizi ve MAS alanını önemli ölçüde hızlandırmıştır (Chiurugwi ve ark., 2019). Çalışmalar, pirinçte tuzluluk stres toleransını artırmak için bir biotron hızlı ıslah sistemi aracılığıyla geliştirilen bir haritalama popülasyonunun kullanımını göstermiştir (Sharma ve ark., 2023).

Tek bir ürün çeşidine birden fazla istenen özelliğin dahil edilmesi uygulaması olan özellik istifleme (Trait stacking), modern tarımda önem kazanmıştır (Voss-Fels ve ark., 2019). Hızlı ıslah, bu sürecin hızlandırılmasında önemli bir rol oynamaktadır. Birden fazla bitki neslini hızla üretme ve değerlendirme yeteneği sayesinde, ıslahçılar çok özellikli kombinasyonları verimli bir şekilde oluşturabilir ve değerlendirebilirler (Bermejove ark., 2016). Bu verimlilik yalnızca zamandan tasarruf sağlamakla kalmaz, aynı zamanda kaynakları da korumaktadır. Sonuç olarak, ürün ıslahçıları son derece uyumlu ve dayanıklı çeşitleri daha etkili bir şekilde geliştirebilirler. Bu çok özellikli ürünler, değişen iklim koşullarından gelişen zararlı baskılarına kadar çeşitli zorluklara dayanabilir. Hızlı ıslah tarafından mümkün kılınan hızlandırılmış özellik istifleme, dinamik olarak değişen bir dünyanın taleplerini karşılayabilen ürün çeşitlerinin geliştirilmesine katkıda bulunur. Bu, kuraklık ve tuzluluk gibi abiyotik streslere karşı toleransı artırmak için hücresel detoksifikasyon, ozmolit birikimi, antioksidan mekanizmalar ve sinyal yollarıyla ilişkili genlerin istiflenmesine odaklanan pirinç çalışmalarını içeriyordu (Shailani ve ark., 2021). Avrupa iki sıralı arpa çeşidi Scarlett örneğinde, hastalık direncini artırmak için hızlı özellik introgresyonu ve hızlı ıslah gibi yenilikçi tekniklerin kullanımı gerçekleştirilmiştir. Bu, dört donör hattan birden fazla hastalık direnci geninin değiştirilmiş bir geri melezleme yaklaşımıyla entegre edilmesiyle sağlanmış ve bu da iki yıl gibi oldukça kısa bir sürede 87 introgresyon hattının oluşturulmasına yol açmıştır (Hickey ve ark., 2017). Buğday ıslahında çoklu özellikler için istenen alelik kombinasyonlarına sahip popülasyonu geliştirmek için erken nesil seleksiyon kullanıldı. Bu yenilikçi çok özellikli fenotipleme yöntemi, uygun alelik kombinasyonlarının hızlı bir şekilde seçilmesi için kök sistemi mimarisi, yaprak pası direnci ve bitki boyunu bir araya getirmektedir. Bu yaklaşım, hızlı ıslahla kusursuz bir şekilde uyum sağlayarak her yıl dört ardışık tarama yapılmasına olanak tanımakta ve ıslah verimliliğini önemli ölçüde artırmaktadır (Alahmad ve ark., 2018).

2. HIZLI ISLAHA YARDIMCI UYGULAMALAR

Araştırmacılar, çiçeklenme başlangıcına kadar geçen süreyi kısaltmak ve embriyo gelişimi ile tohum olgunluğunu hızlandırmak için gece/gündüz sıcaklığını, mevcut ışık spektrumunu ve yoğunluğunu ve fotoperiyot süresini değiştirirler (Hickey ve ark., 2017). Bitkilerin ışık süresi ve kalitesindeki değişikliklere çiçeklenme sürelerini kısaltarak yanıt vermesiyle, ışığa özellikle önem verilir. Bitki büyümesini ve gelişimini hızlandırmak için yapay elektrik lambalarının kullanımı uzun zamandır yaygın olarak kullanılmaktadır (Wheeler, 2008). Fotoperiyot uzatma, o zamandan beri uzun gün türlerinde çiçeklenme süresini değiştirmek için yaygın olarak kullanılmaktadır. Gelişmiş LED aydınlatma sistemlerinin ortaya çıkışı, yaşam döngüsünü hızlandırma çabalarını tamamlayarak, gölgeden kaçınma gibi ışık tepkilerini tetiklemek ve çiçeklenmeye hızlı ilerlemeyi teşvik etmek için dalga boyu bileşiminin değiştirilmesini mümkün kılmıştır (Christopher ve ark., 2015).

2.1. GÜN UZUNLUĞU

Gün uzunluğu, bitkiler için mevsimsel değişiklikleri gösteren önemli bir çevresel sinyal görevi görmektedir. Bitkiler, üreme organlarının oluşumunun başlaması, yumru oluşumu, uykuda kalmaya geçiş ve diğer fizyolojik tepkiler dahil olmak üzere çeşitli gelişimsel süreçlerle fenotipik olarak ortaya çıkan, gün/gece süresindeki değişikliklere genetik olarak programlanmış tepkilere sahiptir. Fotoperiyodik tepkilerine göre bitkiler üç gruba ayrılabilir: i) kısa gün bitkileri, gün uzunluğu kritik bir eşiğin altına düştüğünde çiçeklenmeye başlar (genotipe bağlı olarak tipik olarak 8-15 saat ışık); ii) uzun gün bitkileri, çiçek açmak için kritik bir eşiği aşan gün uzunluklarına ihtiyaç duyar (genotipe bağlı olarak tipik olarak 9-18 saatten fazla ışık); iii) nötr-gün bitkileri, fotoperiyodik değişikliklere hiçbir çiçeklenme tepkisi göstermez. Kritik gün uzunluğu, aşıldığında (uzun gün bitkileri için) veya altında kalındığında (kısa gün bitkileri için) çiçeklenmeyi tetikleyen belirli fotoperiyot eşiğini temsil eder. Bu eşik, türler arasında ve hatta aynı tür içindeki çeşitler arasında önemli ölçüde değişiklik göstermektedir (Jackson, 2009). Hızlı ıslahta, hızlı çiçeklenmeyi teşvik etmek için optimum gün uzunlukları, mahsulün fotoperiyodik hassasiyetine göre dikkatlice seçilmektedir (Kigoni ve ark., 2023).

Uzun gün ve nötr gün bitkileri için 22 saat ışık/2 saat karanlık fotoperiyodu önerilir. Çok sayıda çalışma, bu uzatılmış gün uzunluğunun *Triticeae* tahıllarında (Ficht ve ark., 2023), bezelyede (Cazzola ve ark., 2020), kolzada ve daha kısa fotoperiyotlara kıyasla birçok başka türde çiçeklenme başlangıcını önemli ölçüde hızlandırdığını göstermiştir (Song ve ark., 2021). Sürekli aydınlatma uzun gün mahsulleri için kullanılabilirken, karanlık bir dönemin dahil edilmesi gece-gündüz döngüsünde gen ifadesinin korunmasına yardımcı olur ve büyüyen bitkilerin fizyolojik durumunu iyileştirir (Mitache ve ark., 2023). Yapay aydınlatmanın 22 saatlik sürenin tamamı boyunca kullanılması gerekmez; sera koşullarında en ekonomik yaklaşım, karanlık dönemlerde yapay aydınlatma ile desteklenen 10 saat doğal gün ışığından yararlanmayı içerir. Doğal ve yapay aydınlatmanın bu kombinasyonu, uzun süreli yapay aydınlatma rejimlerine kıyasla bitki başına eşdeğer gelişim oranları ve tohum üretimiyle sonuçlanır (Cha ve ark., 2023).

Kısa gün bitkileri, evrensel bir optimum fotoperiyottan yoksundur ve bu da çiçeklenmenin hızlandırılmasını destekleyen gün uzunluğu koşullarının önceden değerlendirilmesini gerektirir. Aşırı kısa fotoperiyotlar, bu türlerde çiçeklenmeyi geciktiren stres tepkilerine neden olabilir (Schilling ve ark., 2023). Türlere özgü gereksinimler belirlenmiştir: Pirinç, soya ve börülce 10/14 saat gece/gündüz uygulamasında maksimum çiçeklenme hızlanmasına ulaşır (Jahne ve ark., 2020). Başarılı çiçeklenme ve tohum tutumunun ardından, fotoperiyodun uzatılması tohum olgunlaşmasını daha da hızlandırabilir (Schilling ve ark., 2023).

2.2. IŞIK KAYNAKLARI VE SPEKTRAL KOMPOZİSYON

Kontrollü büyüme koşulları altında, yapay aydınlatma güneş radyasyonunun yerine geçerek fotosentezi kolaylaştırırken fotomorfogenez, fotoperiyodizm ve fototropizmi etkiler. Bitki aydınlatma sistemleri akkor lambaları, floresan tüpleri, yüksek basınçlı cıva lambalarını, yüksek basınçlı sodyum lambalarını, metal halojenür lambalarını ve ışık yayan diyotları (LED'ler) kapsar. Bu ışık kaynakları spektral özellikleri, ışık verimliliği, güç tüketimi, çalışma ömrü, ısı emisyonu, güvenilirlik ve bertaraf gereksinimleri açısından önemli ölçüde farklılık gösterir (Dutta Gupta ve Agarwal, 2017). Hızlı ıslah uygulamaları için, 400-700 nm spektrum aralığında fotosentetik olarak aktif radyasyon (PAR) sağlayabilen tüm aydınlatma sistemleri uygundur (Ghosh ve ark., 2018). Hızlandırılmış bitki büyümesi için en sık kullanılan aydınlatma teknolojileri arasında metal halojenür (Kigoni ve ark., 2023), yüksek basınçlı sodyum (Marenkova ve ark., 2024), floresan (Cazzola ve ark., 2020) ve LED aydınlatma sistemleri yer almaktadır (Cha ve ark., 2023). Farklı lamba tiplerini birleştiren hibrit aydınlatma sistemleri, optimum spektral kompozisyonu elde etmek için uygulanabilir (Ghosh ve ark., 2018).

Uzun gün bitkileri için LED armatürler, sürekli aydınlatma sırasında enerji verimliliği sağlaması nedeniyle belirli avantajlar sunar (Watson ve ark., 2018) ve hassas spektral ayarlama yetenekleri gibi ek avantajlar da sağlar (Choi ve ark., 2023). Bitkiler, ışık spektral kompozisyonu konusunda farklı tercihler sergiler ve bu da çeşitli bitkiler için farklı ışık kaynaklarının kullanılmasını gerektirir (Ghosh ve ark., 2018). Örneğin, hızlı ıslahta börülce üzerinde yapılan çalışmalar, metal halojenür lambalara kıyasla LED aydınlatma altında önemli ölçüde daha başarılı tozlaşma olduğunu göstermiştir (Edet ve Ishii, 2022).

Işık spektral kompozisyonunun manipüle edilmesi, temel bitki büyüme ve gelişim parametrelerinin değiştirilmesini sağlar (Ouzounis ve ark., 2015). Uzak kırmızı ışık, vejetatif büyüme hızını etkileyen en güçlü morfogenetik faktörlerden birini temsil eder. Bitki fizyolojik tepkileri yalnızca uzak-kırmızı ışığın varlığıyla değil, aynı zamanda kırmızı ışığa oranıyla da belirlenir (Demotes-Mainard ve ark., 2016). Hızlı ıslahta uzak-kırmızı ışığın kolza tohumunda (Song ve ark., 2021), tritikalede (Blinkov ve ark., 2025), pirinçte generatif evreye geçişi önemli ölçüde hızlandırmada oldukça etkili olduğu kanıtlanmıştır (Jahne ve ark., 2020). Mahsul türüne bağlı olarak, uzak-kırmızı ışık çiçeklenme süresini 3-20 gün azaltabilir (Blinkov ve ark., 2025). Ancak, çeşitli kırmızı-uzak-kırmızı oranları da dahil olmak üzere, tüm bitkiler hızlı ıslahta uzak-kırmızı ışık altında hızlandırılmış çiçeklenme göstermez. Bezelye (Mobini ve Warkentin, 2016) ve soya gibi ürünler bu spektruma hiçbir tepki göstermez (Jahne ve ark., 2020). Ayrıca, uzak-kırmızı ışık, boğum arası uzama, bitki yatması ve başak başına tane sayısında azalma gibi istenmeyen etkilere yol açabilir (Choi ve ark., 2023). Kırmızı ve mavi ışık spektrumları ayrıca hızlı ıslah koşulları altında hızlandırılmış bitki büyümesinde önemli roller oynar (Ghosh ve ark., 2018). Daha erken çiçeklenmeyi ve olgunlaşmayı teşvik etmenin ötesinde, bu spektrumlar bitki boyunun kısalmasına ve daha kompakt büyüme alışkanlıklarına katkıda bulunur; bunlar özellikle büyüme odası yetiştiriciliği için avantajlıdır (Blinkov ve ark., 2025). Tüm dalga boyları bitki örtüsü süresinin kısalmasını desteklemez; UV-A ve yakın kızılötesi radyasyonun ışık spektrumuna eklenmesinin, aspir bitkisinde vejetatif büyümeyi yavaşlattığı gözlemlenmiştir (Gaoua ve ark., 2025).

2.3. IŞIK YOĞUNLUĞU

Işık yoğunluğu, spektral kompozisyonla birlikte en kritik ışık kalitesi parametrelerinden birini temsil eder. Işık yoğunluğundaki değişiklikler fotosentez verimliliğini etkileyebilir ve bitki morfolojik, anatomik, fizyolojik ve biyokimyasal özelliklerinde değişikliklere neden olabilir (Shafiq ve ark., 2021). Çok sayıda çalışma, ışık yoğunluğunun hızlı ıslah koşulları altında fenolojik faz ilerleme hızını da etkilediğini göstermiştir (Kabade ve ark., 2024). Optimum ışık

yoğunluğu yalnızca generatif faza hızlı geçişi kolaylaştırmakla kalmaz, aynı zamanda bitkilerin iyi bir fizyolojik durumda kalmasına da yardımcı olur (Mitache ve ark., 2024). Bitki türleri değişken ışık yoğunluğu gereksinimleri gösterse de, hızlı ıslahta evrensel olarak en çok uygulanabilir yoğunluk, yetişkin bitki taç yüksekliğinde 450-500 mmol/m²/s arasında değişmektedir (Ghosh ve ark., 2018). Buğday üzerinde yapılan çalışmalar, 400 mmol/m²/s'nin altındaki ışık yoğunluklarının daha yavaş bitki gelişim hızlarına yol açtığını göstermektedir (Ficht ve ark., 2023). Işık yoğunluğunun 800-1000 mmol/m²/s'ye çıkarılması, soya (Jahne ve ark., 2020) ve pirinç gibi bazı ürünlerde çiçeklenmeyi ve olgunlaşmayı hızlandırabilir (Kabade ve ark., 2024). Daha yüksek ışık yoğunlukları, kontrollü büyüme ortamlarında önemli avantajlar sağlayan daha kompakt bitki mimarisini de destekleyebilir (Jahne ve ark., 2020). Bununla birlikte, aşırı yüksek ışık yoğunlukları fotosentetik fotoinhibisyona, oksidatif hasara ve hücresel bileşenlerin bozulmasına neden olabilir ve sonuçta gelişimsel gecikmelere yol açabilir (Shafiq ve ark., 2021). Yüksek ışık yoğunluklarının olumsuz etkileri nohut ve mercimek için hızlı ıslahta deneysel olarak gösterilmiş olup, düşük büyüme oranları, yaprak kavrulması, bitki solması ve zayıf tohum üretimi olarak ortaya çıkmıştır (Mitache ve ark., 2024).

2.4. SICAKLIK

Sıcaklık, bitki gelişimini etkileyen temel bir faktörü temsil eder ve tohum çimlenme hızı, vejetatif ve generatif evrelerdeki ilerleme, uygun mayoz bölünme, gamet canlılığı, tozlaşma başarısı ve nihayetinde nihai verim dahil olmak üzere kritik süreçleri yönetir (Fu ve ark., 2022). Hızlı ıslah protokolleri, gelişim oranlarını en üst düzeye çıkarmak için her bir bitkiye göre uyarlanmış dikkatli bir sıcaklık rejimi seçimi gerektirir (Ghosh ve ark., 2018). Hızlı ıslah koşullarında bitki yetiştirmek için en yaygın gündüz sıcaklıkları 22-25°C'dir. Bu gündüz sıcaklık aralığı çoğu uzun gün tahıl (Watson ve ark., 2018), *Brassica* üyeleri (Ghosh ve ark., 2018) ve diğerleri için uygundur (Mitache ve ark., 2024). Pirinç (Kabade ve ark., 2024), pamuk, soya ve diğer sıcak mevsim mahsulleri için gündüz sıcaklıkları 28-32°C'ye çıkarılabilir (Blinkov ve ark., 2025). Hızlı ıslahta hassas sıcaklık kontrolünün sağlanması kritik bir gerekliliktir, çünkü önemli sıcaklık dalgalanmaları stres tepkilerini tetikleyebilir ve vejetatif büyüme oranlarını azaltabilir (Watson ve ark., 2018). Bazı soğuk stresi uygulamaları hızlı ıslahta faydalı olabilir. Örneğin, kotiledon aşamasında soğuk sertleştirme domateste çiçeklenmeyi hızlandırır (Gimeno-Páez ve ark., 2025), baklada çiçeklenme başlangıcından sonra kısa süreli sıcaklık düşüşü ise ilk alt çiçeklerde tohum oluşumunu iyileştirir (Mobini ve ark., 2020).

3. ÖRNEKLER

Öncü çalışmalar, mahsul yetiştirme döngülerinin hızlandırılması için zemin hazırlamıştır. Bu çalışmalar, 22 saat ışık ve 22/17 °C sıcaklıkların bir kombinasyonunu ve olgunlaşmamış tohum hasat tekniklerini kullanarak buğday, arpa ve kanolaya odaklanmıştır. Bu müdahaleler, nesil sürelerini buğday için 65 güne, arpa için 68 güne ve kanola için 98 güne düşürerek yılda yaklaşık 4 ila 6 nesil elde edilmesini sağlamıştır (Watson ve ark., 2018). Tarla bitkilerinde hızlı ıslah alanında yapılmış birçok çalışmanın bazıları şunlardır:

Çil, (2023) tarafından yürütülmüş çalışmada, çiçeklenmeden 13 gün sonra olgunlaşan ayçiçeği (*Helianthus annuus*) embriyoları izole edilmiş ve 22/2 saat gündüz/gece fotoperiyodu, 24/18°C gündüz/gece, LED aydınlatmada, %70 hava neminde yetiştirilen petri kaplarında nesil değişimi için kültüre alınmıştır. Bitkiler 52-67 günde çiçeklenmiş, embriyo izolasyonu 65-80 günde tekrar edilebilmiş ve yılda 4-5 nesil elde edilmiştir.

Gaoua ve ark., (2025), dört LED uygulaması (beyaz, tam spektrum, kırmızı + mavi + beyaz ve kontrol) ile aspir (*Carthamus tinctorius*) bitkisinin etkili hızlı ıslahını araştırmışlar ve hasat süresini kırmızı + mavi + beyaz LED kombinasyonu altında en kısa elde etmişlerdir. Bitki boyu,

bitki başına tohum sayısı ve başak başına tohum sayısı, sırasıyla tam spektrum LED, kontrol ve kırmızı + mavi + beyaz LED kombinasyonları altında en yüksek olmuştur. Tozlaşmadan 10 gün sonra kurtarılan olgunlaşmamış embriyolar %57 çimlenme oranı göstermiş ve tozlaşmadan sonraki gün sayısı arttıkça çimlenmede artış eğilimi görülmüştür. Çimlenme oranları, çeşitler veya hormon uygulamaları arasında önemli ölçüde farklılık göstermemiştir.

Watson et al., (2018) yetiştirmeyi 1 saat gün doğumu/gün batımı simülasyonu ile 22 saat gündüz/2 saat gece fotoperiyodu koşullarında; yetişkin bitki seviyesinde ışık yoğunluğunu 440-650 µmol/m²/s, 22/17°C gündüz/gece, gün doğumu/gün batımı sırasında kademeli sıcaklık değişimleri ve %70 neme ayarlayarak gerçekleştirmişlerdir. Baklalar ekimden 6 hafta sonra toplanmış ve 35°C'de 5 gün kurutulmuş, tohumlar oda sıcaklığında nemli filtre kağıdına ve agar plakalarına yerleştirilmiş, 4 gün boyunca 4°C'de tutulmuş ve ardından 5 gün oda sıcaklığında bekletilmiştir. Çiçeklenme 44-49 gün sonra gerçekleşmiştir. Her biri 75-80 gün süren, yılda 4 jenerasyon elde etmişlerdir.

Samineni ve ark., (2020) nohutta (*Cicer arietinum*), yarı kontrollü sera koşullarında, fotoperiyodu uzatmak için ek gece aydınlatması altında, çiçeklenmeyi 23-56 gün arasında sürede, 1 generasyonu 43-79 gün arası sürede elde etmişler, toplamda yılda 6-7 jenerasyon üretebilmişlerdir.

Ghosh ve ark., (2018), Mürdümük'te (*Lathyrus sativus*) büyümeyi 1 saatlik gündoğumu/günbatımı simülasyonuyla 22/2 saatlik gündüz/gece fotoperiyodunda, yetişkin bitki seviyesinde ışık yoğunluğunu 440-650 µmol/m²/s uygulayarak, gündoğumu/günbatımı sırasında kademeli değişikliklerle 22/17°C gündüz/gece sıcaklıklarında, nemi %70 olacak şekilde 31 günde çiçeklendirmiş, bir yılda her biri 80 gün süren 4.5 jenerasyon sağlayabilmişlerdir.

Mitache et al., (2024), mercimekte (*Lens culinaris*), yetiştirme sürecinde ekim yoğunluğunu >300 tohum/m² ayarlamış, 18/6 saat gündüz/gece fotoperiyodu, LED aydınlatma, 410-730 nm spektrum, 74-93 µmol/m²/s (4000-5000 lüks) ışık yoğunluğu ve 23-25/14-16°C gündüz/gece sıcaklığı ayarlamışlar ve çiçeklenmeyi 27 günde sağlamışlardır. Her biri 62-76 gün olan 6 jenerasyon elde etmişlerdir.

4. ZORLUKLAR VE SINIRLAMALAR

Hızlı ıslah farklı bitki türlerinde genetik kazanım oranını artırmak için güçlü bir araçtır; ancak sınırlamaları vardır. Hızlı ıslah kurulduktan sonra, türler yoğun büyüme koşullarına yanıt olarak genotiple farklılıklar gösterebilir (Tanaka ve ark., 2016). Yoğun büyüme koşulları genellikle sınırlı tohum verimiyle sonuçlanır ve bu da sonraki saha değerlendirmelerini kısıtlayabilir (Gonzalez-Barrios ve ark., 2021). Yeni nesil seyrek fenotiplemeli saha deneme tasarımlarının kullanımı, düşük tohum sayılarının üstesinden gelinmesine yardımcı olabilir (Watson ve ark., 2018).

Agronomik özellikler için fenotipleme, hızlı ıslah ile birlikte gerçekleştirilebilir; ancak fenotipik ifade kontrollü ortam koşulları altında önyargılı olabileceğinden dikkatli olunması gerekir. Sonuç olarak, hızlı ıslah koşullarındaki tarla bitkilerinin fenotiplemesi, özellik ifadesinin tarla ortamıyla ilişkili olduğunu doğrulamak için tarlada doğrulanmalıdır. Örneğin, bor toleransı, hızlı ıslah koşullarıyla bütünleşmek üzere hidroponik olarak yetiştirilen bezelyede güvenilirlik açısından ayırt edilmiş ve buğdayda hızlı ıslah teknikleri, hastalık direnci gibi fenotip taramalarıyla birleştirilmiştir (Bennett ve ark., 2017). Çiçeklenme süresi ve bitki boyu gibi çeşitli agronomik karakterler, hızlı ıslah koşullarında kaydedildiğinde, tarla bazlı belirleme ve üretimle ilişkilidir ve bu nedenle dolaylı seçilimi kolaylaştırabilir (Watson ve ark., 2018). Bununla birlikte, yulafta bitki boyu ve çiçeklenme zamanında gözlemlendiği gibi, genotipler ve büyüme sistemleri arasındaki çapraz etkileşim nedeniyle bazı karakterler tutarlı bir şekilde

fenotiplenmeyebilir (Gonzalez-Barrios ve ark., 2021). Hızlı ıslah koşullarında bitki yetiştirirken karşılaşılan diğer büyük zorluklar arasında, bu kadar yoğun koşullar altında zararlı ve hastalık yönetimi ve gen keşfi amacıyla haritalama popülasyonları geliştirilirken bireylerin izlenmesi gerekliliği yer almaktadır (Samantara ve ark., 2022).

Hız için çabalarken bitkiler fizyolojik kapasitelerinin sınırında yetiştirilir ve hızlı döngü değişimine elverişli koşullar genellikle bitkinin kendini savunma yeteneğine zarar verir ve dikkatli bir yönetim olmadan değerli üreme materyalinin felaket düzeyinde kaybına yol açabilir. Azaltma, her tür için ve bazı durumlarda tür içindeki genotipler için fotoperiyot doygunluğunu ve sıcaklık sınırlarını belirlemek üzere koşulların uyarlanmasından kaynaklanır. Her nesilde her bireyden yedek tohum tutulması, kontrollü ortam veya benzeri durumlarda bir neslin hastalık, zararlı veya güç kaybından etkilenmesi durumunda genetik kayba karşı da sigorta sağlamaktadır (Samantara ve ark., 2022).

Temel sınırlamalardan biri, hedef türlerin hızlı döngüsüne uygun kontrollü ortam koşullarına erişimdir. Gelişmiş kontrollü ortam tesisleri kolayca bulunamıyorsa hızlı ıslah ortamları pahalı hale gelir ve hızlı ıslahı embriyo kurtarma ve MAS gibi diğer tekniklerle birleştirmek ek kaynaklar ve uzmanlık gerektirir. Diğer zorluklar arasında, örneğin kış aylarında sürekli elektrik temini ve sıcaklık koruması yer alır (O'connor ve ark., 2013). Gelişmiş ülkelerde bu kadar sorunlu olmasa da, sınırlı altyapı, yetersiz uzmanlık ve uluslararası kuruluşlarla sınırlı iş birlikleri nedeniyle kaynak bakımından fakir ülkelerde araştırma ve ıslah için hızlı ıslahın rutin kullanımı bir zorluk olmaya devam etmektedir (Wanga ve ark., 2021).

Saf hat, tekrarlayan seleksiyon, toplu seleksiyon, kitle seleksiyon ve soyağacı seçimi de dahil olmak üzere geleneksel seçilim tekniklerinde bulunan uzun ve genişletilmiş seçilim ve kendileme döngüleri nedeniyle hızlı ıslahta uygulamaya uygun görülmemektedir. Bu geleneksel yöntemler, modern tarımsal bağlamlarda hızlı ıslahın gerektirdiği ıslah talepleri ve hassasiyetle uyuşmamaktadır (Jagadish ve ark., 2016). Buna karşılık, tek bitki seçimi (SPS, single plant selection) ve tek tohum nesli (SSD, single seed descent) gibi belirli ıslah yöntemlerinin hızlı ıslah ilkeleriyle olağanüstü derecede uyumlu olduğunu belirtmekte fayda vardır (Jahne ve ark., 2020).

Çalışmalar, ışık kalitesinin, özellikle kırmızı ve uzak kırmızı oranının, bezelye, nohut, bakla, mercimek ve acı bakla gibi serin mevsim baklagillerinin çiçeklenme süresini önemli ölçüde etkilediğini ortaya koymuştur. Bu bulgular, baklagil yetiştiriciliğinde tek tohum neslini hızlandırmak için çok önemlidir ve baklagil mahsullerini geliştirmeye yönelik biyoteknolojik araçlarda pratik uygulamalar sunmaktadır (Croser ve ark., 2016).

İlk çaprazlamalardan sonra homozigot hatları hızla oluşturmak için hızlı ıslah yaklaşımları, fotoperiyot, sıcaklık, toprak nemi, popülasyon yoğunluğu ve karbondioksit seviyeleri gibi büyüme değişkenlerinin değiştirilmesini gerektirir (Potts ve ark., 2023). Bu ayarlamalar, her yıl birden fazla üreme döngüsünün oluşturulmasını kolaylaştırarak, çeşitli ortamlardaki üreme süreçlerini hızlandırmak ve çeşitli seçim teknikleri kullanarak popülasyonları değerlendirmek için uygun hale getirir. Sonuç olarak, bu adaptasyonlar gelişmiş genetik kazanıma katkıda bulunur (Shamshiri ve ark., 2018). Birçok ürün türü ve genotipinde büyümeyi, gelişmeyi, çiçeklenmeyi ve tohum oluşumunu artırmak, fotoperiyot rejiminin manipüle edilmesini gerektirir. Raporlara göre, belirli fotoperiyot rejimleri buğday, arpa, nohut ve yer fıstığı gibi ürünlerde erken çiçeklenmeye neden olabilir. Elektrik kaynaklarının istikrarsız olduğu ülkelerde iç mekan hızlı ıslah için, fotoperiyodu ayarlamak amacıyla düşük enerjili LED'ler ve güneş enerjisi sistemleri kullanılabilir (Potts ve ark., 2023).

Toprak neminin modülasyonu, bitki biyometrik gelişimi üzerindeki doğrudan ve dolaylı etkisi nedeniyle mahsul gelişiminde hayati önem taşır. Çiçeklenmeden sonra, toprak nem içeriğinin azaltılmasının buğday, arpa, kanola ve nohutta hızlı tane dolumunu ve olgunlaşmasını

kolaylaştırdığı gösterilmiştir (Gilland, 2002). Etkili toprak nem yönetimi stratejileri çok yönlüdür ve açık alanlar veya kontrollü iç mekan ortamları olsun, çeşitli ortamlarda kullanıma uyarlanabilir. Hem su kıtlığının hem de aşırı suyun buğday, inci darısı, bezelye ve arpada erken çiçeklenmeyi ve olgunlaşmayı tetiklediği gözlemlenmiştir (Gudi ve ark., 2022). Bu yaklaşımlar, daha akıcı ve verimli bir nesil devir sürecine yol açarak optimizasyon için muazzam bir potansiyel taşır. Dahası, iç mekan yetiştiriciliği, toprak nem kontrolü açısından benzersiz bir avantaj sunar. İç mekan tesislerinin kontrollü parametreleri dahilinde, yetiştiriciler, mahsullerin özel ihtiyaçlarını karşılamak için nem seviyelerini yönetmede daha fazla hassasiyete ve esnekliğe sahiptir (Sinha ve ark., 2021).

5. SONUÇ

Yapay aydınlatma ile ilgili ilk deneylerden LED ışıklar ve güneş enerjisi gibi son teknolojilerin kullanımına kadar uzanan hızlı ıslahın yolculuğu, bitki ıslahında devrim yapma potansiyelini ortaya koymaktadır. Fotoperiyot, sıcaklık, toprak nemi ve popülasyon yoğunluğu gibi çevresel değişkenleri hassas bir şekilde ayarlayarak, hızlı ıslah, geleneksel ıslah döngülerini önemli ölçüde kısaltarak hızlı ürün üretimini mümkün kılar ve faydaları oldukça çoktur.

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KENEVİR BİYOKÜTLESİNİN ANAEROBİK FERMANTASYONLA ENERJİYE DÖNÜŞTÜRÜLMESİ: BİYOGAZ VE BİYOMETAN PERSPEKTİFİ

Doç. Dr. Gülizar Kurtoğlu Akkaya

Necmettin Erbakan Üniversitesi, Mühendislik Fakültesi, Konya

Email: gakkaya@erbakan.edu.tr ka.gulizar@gmail.com

ORCID: 0000-0003-4779-0428

Dr. Öğr. Üyesi N. Berk Bıtrak

Süleyman Demirel Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, Isparta

Email: berkbitrak@sdu.edu.tr, berkbitrak@gmail.com

ORCID: 0000-0002-6822-3564

Prof. Dr. Kâmil Ekinci

Isparta Uygulamalı Bilimler Üniversitesi, Ziraat Fakültesi, Isparta

Email: kamilekinci@isparta.edu.tr

ORCID: 0000-0002-7083-5199

ÖZET

Artan enerji talebi, fosil yakıtların sınırlı rezervleri ve çevresel etkileri sürdürülebilir enerji kaynaklarının geliştirilmesini zorunlu hale getirmiştir. Bu bağlamda, organik atıkların oksijensiz koşullarda mikroorganizmalar tarafından parçalanarak biyogaz ve biyometana dönüştürülmesini sağlayan anaerobik fermantasyon, teknik ve ekonomik açıdan uygulanabilirliği kanıtlanmış bir yöntem olarak öne çıkmaktadır. Biyogaz üretimi sonrasında anaerobik fermantasyon hem enerji üretimi hem de atık yönetiminde çevresel etkilerin azaltılmasına katkı sunmaktadır. Hidroliz, asidojenez, asetojenez ve metanojenez aşamalarından oluşan bu biyokimyasal süreç, yenilenebilir enerji teknolojileri arasında önemli avantajlara sahiptir. Bu çerçevede, düşük Δ-9-tetrahidrokanabinol (THC) içeriği, yüksek biyokütle verimi ve farklı iklim koşullarına uyum sağlayabilmesi ile dikkat çeken endüstriyel kenevir, enerji üretiminde potansiyel bir hammadde olarak öne çıkmaktadır. Literatürde, yüksek lignin içeriğine rağmen kenevir biyokütlesinin umut verici biyometan potansiyeli sunduğu ve uygulanan mekanik ya da kimyasal ön işlemlerle metan veriminin belirgin şekilde artırılabildiği raporlanmıştır. Ayrıca, kenevir atıklarının hayvansal gübre gibi diğer organik substratlarla ko-fermantasyonu sinerjik etkiler yaratarak biyogaz üretiminde performans artışı sağlayabilmektedir. Bu çalışmada, endüstriyel kenevir işleme atıklarının anaerobik fermantasyon yoluyla biyogaz ve biyometan üretim potansiyeli değerlendirilecek, mevcut literatürdeki çalışmalarda kenevirin biyogaz üretimindeki rolüne ilişkin araştırmalara yer verilecek ve bu hammaddenin yenilenebilir enerji üretimindeki stratejik önemi ortaya konacaktır. Böylece elde edilecek bulgular sürdürülebilir enerji üretimi, çevre dostu atık yönetimi ve iklim değişikliğiyle mücadele politikalarına katkı sağlaması öngörülmektedir.

Anahtar Kelimeler: Kenevir, Biyogaz, Biyometan potansiyeli (BMP), anaerobik fermantasyon, yenilenebilir enerji

ENERGY CONVERSION OF HEMP BIOMASS THROUGH ANAEROBIC FERMENTATION: PERSPECTIVES ON BIOGAS AND BIOMETHANE

ABSTRACT

The growing global demand for energy, limited fossil fuel reserves and the adverse environmental impact of fossil fuels have made the development of sustainable energy sources imperative. In this context, anaerobic fermentation — the decomposition of organic waste by microorganisms in an oxygen-free environment, resulting in the production of biogas and biomethane — has emerged as a technically and economically viable method. This process contributes to energy generation and mitigating the environmental impact of waste management. Consisting of four biochemical stages — hydrolysis, acidogenesis, acetogenesis and methanogenesis — anaerobic fermentation offers several advantages over other renewable energy technologies. Within this framework, industrial hemp, characterized by its low THC content, high biomass yield and adaptability to diverse climatic conditions, stands out as a promising energy production feedstock. Despite its relatively high lignin content, the literature reports that hemp biomass exhibits notable biomethane potential and that mechanical or chemical pretreatments can significantly enhance methane yields. Furthermore, co-fermenting hemp residues with other organic substrates, such as animal manure, has been shown to produce synergistic effects and improve biogas production efficiency. This study will evaluate the potential of industrial hemp processing residues for biogas and biomethane production through anaerobic fermentation. Findings from existing literature will be discussed to elucidate hemp's role in biogas generation and highlight its strategic importance as a renewable energy resource. The results obtained are expected to contribute to sustainable energy production, eco-friendly waste management and climate change mitigation policies.

Keywords: Hemp, Biogas, Biomethane Potential (BMP), Renewable Energy.

GİRİŞ

İnsan yaşamını sürdürebilmek ve üretim faaliyetlerini devam ettirebilmek için enerjiye ihtiyaç duyar. Ancak mevcut küresel enerji yapısı hâlâ büyük ölçüde yenilenemeyen fosil yakıtlara dayanmaktadır. Bu durum, hem enerji arz güvenliği hem de çevresel sürdürülebilirlik açısından ciddi bir tehdit oluşturmaktadır (Abraham vd., 2020). Fosil yakıt rezervlerinin sınırlı olması, enerji fiyatlarında yaşanan dalgalanmalar ve bu kaynakların yanması sonucu ortaya çıkan yüksek miktardaki sera gazı (GHG) emisyonları, günümüzde enerji krizinin ve iklim değişikliğinin temel nedenleri arasında yer almaktadır (Millati vd., 2020; Paudel vd., 2017).

Artan enerji talebi, nüfus artışı ve ekonomik büyüme gibi faktörler, yenilenebilir enerji kaynaklarını ekonomik olarak cazip ve çevresel açıdan sürdürülebilir bir alternatif haline getirmiştir (Paudel vd., 2017). Yenilenebilir enerji; güneş, rüzgâr, jeotermal, hidroelektrik ve biyokütle gibi doğal kaynaklardan elde edilmekte, böylece fosil yakıtlara olan bağımlılığı azaltarak enerji arz güvenliğini güçlendirmektedir.

Bu kaynaklar içinde biyokütle enerjisi, hem çevre dostu olması hem de doğrudan bitkisel ve organik atıklardan enerji üretimine olanak tanıması nedeniyle özel bir öneme sahiptir. Biyokütle, fotosentez yoluyla atmosferden aldığı karbondioksiti enerji üretimi sırasında yeniden atmosfere saldığı için karbon nötr bir döngü oluşturur (Millati vd., 2020). Bu özelliği, onu iklim değişikliğiyle mücadelede stratejik bir yenilenebilir enerji kaynağı haline getirmektedir.

Biyokütle kaynakları arasında lignoselülozik biyokütle, dünyadaki en verimli karbon depolarından biri olarak öne çıkmaktadır. Yıllık küresel üretimi yaklaşık 12×10^{10} ton düzeyindedir ve karasal bitkiler tarafından yakalanan biyoenerji, insanlığın toplam enerji talebinin yaklaşık 3–4 katı kadardır (Guo vd., 2015). Bu, lignoselülozik biyokütlenin gelecekteki enerji güvenliğini sağlamada önemli bir potansiyele sahip olduğunu göstermektedir. Bununla birlikte, bu potansiyelin verimli şekilde kullanılmaması hâlinde çevresel riskler ortaya çıkabilmektedir. Örneğin, bitki samanının yakılması gibi geleneksel uygulamalar; arazi israfına, hava kirliliğine ve karbon salımına neden olmaktadır (Cheng & Zhong, 2014; Zhang vd., 2018). Dolayısıyla biyokütlenin sürdürülebilir şekilde değerlendirilmesi, çevresel faydanın en üst düzeye çıkarılması açısından kritik öneme sahiptir.

Enerji talebinin karşılanmasında fosil kaynakların uzun vadede güvenilir bir çözüm sunamayacağı açıktır. Bu nedenle araştırmalar, biyokütle tabanlı biyoyakıtlar üzerine yoğunlaşmıştır. Günümüzde mısır, buğday, pirinç, soya fasulyesi ve şeker kamışı gibi çeşitli tarımsal ürünler biyoyakıt üretiminde kullanılmaktadır (Abraham vd., 2020; Prade vd., 2011). Ancak bu hammaddeler genellikle gıda kaynaklarıyla rekabet ettiği için, yeni nesil biyoyakıt çalışmaları gıda dışı lignoselülozik materyallere yönelmiştir. Bu tür biyokütleler, yüksek karbon içeriği ve düşük maliyetleriyle sürdürülebilir enerji üretimi açısından büyük avantaj sağlamaktadır.

Bu kapsamda anaerobik fermantasyon, lignoselülozik biyokütlenin enerjiye dönüştürülmesinde en etkili teknolojilerden biridir. Bu biyokimyasal süreçte organik maddeler, oksijensiz ortamda mikroorganizmalar tarafından parçalanarak biyogaz üretir (Angelidaki vd., 2018; Appels vd., 2011). Elde edilen biyogazın temel bileşeni metan (CH_4) olup, hem elektrik ve ısı üretiminde hem de biyometan saflaştırması yoluyla doğalgaz yerine kullanılabilmektedir. Böylece, hem enerji üretiminde fosil kaynaklara bağımlılık azalmakta hem de karbon salımı minimize edilmektedir (Kumar vd., 2017).

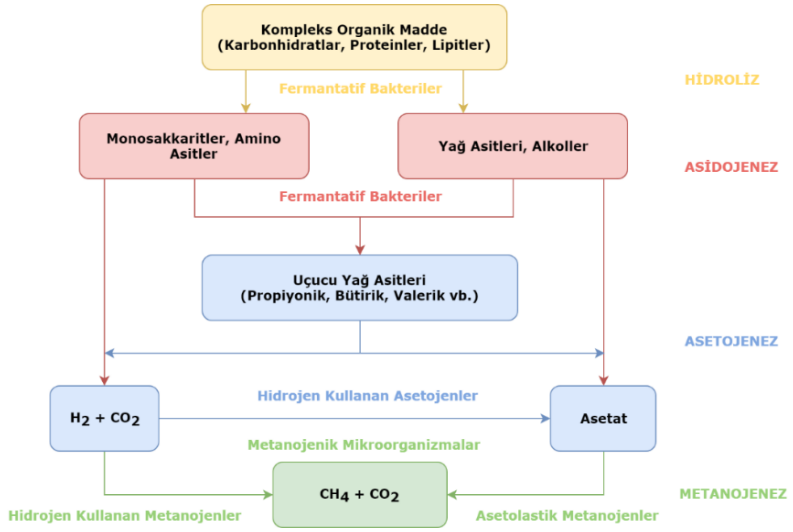
Sonuç olarak, fosil yakıtların çevresel zararları ve sınırlı rezervleri göz önüne alındığında, biyokütle tabanlı biyogaz üretimi, enerji arz güvenliği ve iklim değişikliğiyle mücadele açısından geleceğin en sürdürülebilir çözümlerinden biri olarak değerlendirilmektedir.

1. ANAEROBİK FERMANTASYON

Anaerobik koşullarda organik atıkların ayrıştırılması, tarihsel olarak atık yönetimi ve enerji geri kazanımı alanlarında kullanılan en eski biyoteknolojik süreçlerden biridir. Günümüzde ise anaerobik fermantasyon sürdürülebilir enerji üretimi ve çevresel etkilerin azaltılması açısından en yaygın tercih edilen biyolojik dönüşüm yöntemlerinden biri hâline gelmiştir. Biyogaz teknolojisi, dünya genelinde gelişmiş/gelişmekte olan ülkelerde ekonomik uygulanabilirliği, enerji geri kazanım verimliliği ve çevresel sürdürülebilirliği ile etkinliğini kanıtlamıştır (Angelidaki vd., 2018).

Anaerobik fermantasyon, oksijensiz koşullar altında organik maddelerin mikroorganizmalar tarafından biyokimyasal reaksiyonlarla stabilize edilmesi ve biyogaza dönüştürülmesi sürecidir (Chen vd., 1980; Safley Jr & Westerman, 1990). Bu biyogaz genellikle %50–70 CH_4 ve %30–50 karbondioksit (CO_2) içerirken, az miktarda hidrojen sülfür (H_2S), amonyak (NH_3) ve hidrojen (H_2) gibi bileşenler de bulunabilir. Böylece anaerobik fermantasyon hem enerji üretimi sağlar hem de atığın çevresel etkilerini azaltarak sürdürülebilir bir döngü oluşturur.

Bu süreç, biyokimyasal olarak dört temel aşamada gerçekleşir: hidroliz, asidojenez, asetojenez ve metanojenez (Dichtl, 1997). Her aşamada farklı mikrobiyal topluluklar aktif rol oynar ve sistemin genel verimliliği bu topluluklar arasındaki simbiyotik dengeye bağlıdır (Şekil 1; (Chernicharo, 2007).



Şekil 1. Anaerobik ayrışmanın metabolik aşamaları (Chernicharo, 2007).

Anaerobik fermantasyonun birinci aşaması olan "hidroliz" esnasında hammaddenin kompleks yapıları (örneğin karbonhidratlar, yağlar gibi) daha basit organik yapılara (örneğin aminoasitler, şeker, yağ asitleri) dönüştürülür. Bu aşamada kompleks maddeler fermentatif bakteriler tarafından üretilen enzimlerin yardımı ile ayrışır ve çözünmüş hale geçer, böylece fermantatif bakterilerin hücre duvarlarından geçebilecek bir yapıya dönüşürler (Henze vd., 2008). Hidroliz sırasında katı partiküller suda çözünür bir hale geçtikleri için bu aşamaya sıvılaştırma (likifikasyon) da denilmektedir (Avcıoğlu Onurbaş, 2011).

Mikroorganizmalarca gerçekleştirilen ikinci temel adım asidojenezdir. Asidojenez fazında fermantatif bakteriler enerji ihtiyaçlarını karşılamak için çözünmüş bileşikleri hücre içerine alırlar. Daha sonra mikroorganizmalarca ayrışan bu bileşikler daha basit bileşenlere dönüştürülür ve hücre dışına atılır (Henze vd., 2008). Fermantasyon işleminde, substratlar hem elektron verici hem de alıcı olarak hizmet eder (Eddy vd., 2014). Bu aşamada üretilen en bilinen bileşikler uçucu yağ asitleri (valerik, propiyonik ve bütirik asitler), alkoller (etanol), laktik asit, CO_2, H_2, NH_3 ve H_2S'dür (Henze vd., 2008). Bu aşamada çözünmüş karbonhidratlar; etanol,

hidrojen ve karbondioksite, aminoasitler; süksinik asit ve hidrojene ve yağ asitleri ise asetat ve hidrojene dönüşür. Asetat, sadece çözünebilir organik bileşiklerin fermantasyonu yoluyla değil, aynı zamanda asetojenez yoluyla da üretilebilir (Gerardi, 2003). Asidojenez fazı anaerobik arıtmada gerçekleşen en hızlı fazdır ve metan üretimi asit üretimine göre daha yavaş gerçekleştiğinden dolayı çözünmüş organik madde konsantrasyonunda oluşan ani artışlar asit üretimini tetikleyerek sistemde aşırı yüklemeye sebep olabilir. Bu durumda metan üretimi yavaşlar ve üretilen asit sonucu sistemde ani pH düşmesine yol açarak prosesi inhibe eder (Henze vd., 2008).

Asetojenez fazında asetojenik mikroorganizmalarca fermantasyon devam eder ve asidojenez aşamasında oluşan uçucu yağ asitleri metan üretiminin öncüsü olan asetat, hidrojen ve karbondioksite dönüşür (Eddy vd., 2014). Burada asetat üretimi asidojenezden farklı olarak, asetojenik mikroorganizmaların aktivitesi ile gerçekleştirilir (Gerardi, 2003). Bu aşamada en önemli besin maddeleri anaerobik fermantasyonda kilit rol oynayan propiyonik ve bütirik asitlerdir (Henze vd., 2008). Hidrojene dönüşümü yeterli hızda gerçekleşmeyen uçucu yağ asitleri asidojenez aşamasında olduğu gibi sistemde birikerek pH'nın ani şekilde değişmesine yol açabilir. Bunun yanı sıra hidrojen üreten asetojenik mikroorganizmalar ile hidrojen tüketen metanojenik mikroorganizmalar arasında hassas bir denge de mevcuttur (Christensen, 2011; Eddy vd., 2014). Bu hassas dengeye rağmen hidrojenin kısmi basıncı çok düşük bir seviyede seyreder. Bunun sebebi üretilen hidrojenin metanojenler ve sülfat indirgeyen mikroorganizmalar tarafından hızlı şekilde tüketilmesiyle alakalıdır (Henze vd., 2008).

Anaerobik fermantasyonun dördüncü ve son aşaması olan metanojenez, metanojenik mikroorganizmalarca önceki aşamalarda üretilen asetat, hidrojen ve karbondioksitin metana çevrildiği aşamadır. Metan üretimi için iki grup metanojenik mikroorganizma görev alır; asetolastik metanojenler, asetatı metan ve karbondioksite dönüştürürler, hidrojen kullanan metanojenler ise elektron vericisi olarak hidrojen ve elektron alıcısı olarak karbondioksiti kullanarak metan üretirler (Eddy vd., 2014; Henze vd., 2008). Metanojenik mikroorganizmalar, asetat, karbondioksit, hidrojen, formate, metanol, etanol ve bazı durumlarda methylamine gibi organik molekülleri de metabolize etmektedirler (Balch vd., 1979; Weimer, 1998; Zinder vd., 1984). Kompleks organik bileşiklerin metana dönüşmesi, hammaddenin metanojenik mikroorganizmalar tarafından kullanılabilen substratlara dönüştürülmesiyle sağlanabilir. Bu aşamaya kadar en kritik nokta asetat üretimidir çünkü anaerobik fermantasyonda üretilen metanın yaklaşık %70'si asetattan sağlanmaktadır. Bu durumda asetat üretimi biyogaz veya metan üretimi açısından bir "darboğaz" olarak adlandırılabilir (Avcıoğlu Onurbaş, 2011; Eddy vd., 2014; Gerardi, 2003). Asetolastik metanojenlerin büyüme oranı oldukça düşüktür. Bu durum anaerobik reaktörlerin uzun adaptasyon süresine olan ihtiyacı açıklamaktadır. Hidrojen kullanan metanojenler, 4 ila 12 saatlik iki katına çıkma zamanları ile asetolastik metanojenlerden çok daha yüksek büyüme oranına sahiptir (Henze vd., 2008). Asidojenik, asetojenik ve metanojenik mikroorganizmaların çalışma hızı kabaca aynı olduğu sürece, metanojenez aşamasının metabolik aktivitesi korunur (Gerardi, 2003).

Bu dört aşamanın dengeli ilerlemesi hem metan üretiminde maksimum verim hem de proses stabilitesi için zorunludur. Ancak bu denge yalnızca mikrobiyal etkileşimlerle değil, aynı zamanda çevresel ve mühendislik parametrelerinin dikkatle optimize edilmesiyle sürdürülebilir (Angelidaki vd., 2018; Appels vd., 2011).

Anaerobik sistemlerin performansını belirleyen çevresel faktörler arasında **pH, sıcaklık, karbon/azot oranı (C/N), organik yükleme hızı (OLR)** ve **karıştırma** koşulları öne çıkar. Metanojenlerin optimum pH aralığı 6.8–7.4'tür; bu aralığın dışına çıkılması mikrobiyal aktiviteyi baskılar ve gaz üretimini düşürür (Gerardi, 2003). Sıcaklık açısından mezofilik (35-37 °C) sistemler kararlı mikrobiyal yapılar sağlarken, termofilik (50-55 °C) koşullar daha hızlı

reaksiyonlar sunar fakat stabilite riskini artırır (Eddy vd., 2014). Uygun C/N oranı (20-30), mikroorganizmaların beslenme dengesini korur; düşük oranlar amonyak toksisitesine, yüksek oranlar ise besin eksikliğine neden olur (Henze vd., 2008). OLR'nin kontrolü, pH dengesini koruyarak uçucu yağ asidi birikimini engeller; karıştırma ise sıcaklık homojenliği ve substrat-mikroorganizma teması açısından sürecin verimliliğini artırır (Christensen, 2011).

Anaerobik fermantasyonun başarısı, yalnızca süreç parametrelerinin kontrolüne değil, aynı zamanda kullanılan **biyokütlenin kimyasal bileşimine** de bağlıdır. Günümüzde tarımsal artıklar, hayvansal gübreler, gıda endüstrisi atıkları ve lignoselülozik materyaller, biyogaz üretiminde yaygın olarak değerlendirilmektedir (Mao vd., 2015; Weiland, 2010). Lignoselülozik biyokütleler, yüksek selüloz ve hemiselüloz içerikleri sayesinde iyi bir karbon kaynağıdır; ancak lignin varlığı, mikrobiyal parçalanmaya karşı direnç göstererek biyogaz üretimini sınırlar (Kumar vd., 2017). Bu nedenle, selüloz ve hemiselülozun erişilebilirliğini artırmak için fiziksel, kimyasal veya biyolojik **ön işlem teknikleri** uygulanması gereklidir.

Farklı organik atıkların birlikte sindirildiği **anaerobik ko-fermantasyon** yaklaşımı, substratlar arasındaki besin dengesini iyileştirerek sinerjik etkiler yaratabilir. Ancak bazı durumlarda kimyasal uyumsuzluklar antagonistik etkilere yol açabilir (Bıtrak, 2021). Bu nedenle, farklı substratların birlikte kullanım potansiyelinin değerlendirilmesinde **biyokimyasal metan potansiyeli (BMP)** testleri büyük önem taşır. BMP, belirli bir substrattan elde edilebilecek maksimum metan miktarını belirleyen temel göstergedir ve sistem tasarımı, kütle dengesi hesapları ve enerji verimliliği analizlerinde kritik rol oynar (Angelidaki vd., 2009; Labatut vd., 2011; Weinrich vd., 2018). Ancak laboratuvar koşullarında belirlenen bu potansiyelin tam ölçekli sistemlerde sürdürülebilir şekilde gerçekleşebilmesi, substrat bileşimi kadar çevresel koşulların ve işletme stratejilerinin de optimize edilmesine bağlıdır.

Son yıllarda yapılan araştırmalar, sürdürülebilir enerji üretimi ve çevresel rehabilitasyon hedefleri doğrultusunda, yeni nesil lignoselülozik biyokütle türlerine yönelmiştir. Bu bağlamda **endüstriyel kenevir (*Cannabis sativa L.)***, yüksek biyokütle verimi, düşük pestisit gereksinimi, kısa büyüme süresi ve farklı iklim koşullarına adaptasyon yeteneği ile ön plana çıkmaktadır (Barta vd., 2013; Ingrao vd., 2018). Lignoselülozik yapısı nedeniyle belirli teknik zorluklar barındırsa da, uygun ön işlem uygulamalarıyla kenevir biyokütlesinin yüksek metan verimi sağladığı bildirilmektedir (Nges vd., 2012; Schroyen vd., 2018).

2. ENDÜSTRIYEL KENEVİR

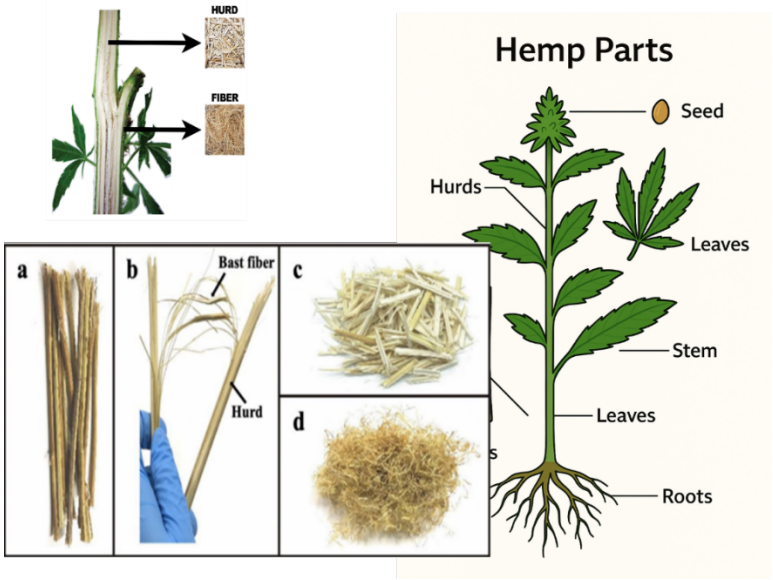
Endüstriyel kenevir (*Cannabis sativa L.*), son yıllarda yalnızca geleneksel lif ve tohum üretiminde değil, aynı zamanda sürdürülebilir biyokütle kaynaklarının geliştirilmesi bağlamında da dikkat çeken stratejik bir bitki türü olarak öne çıkmaktadır. Bu bitkinin çok yönlü kullanım potansiyeli, çevresel, ekonomik ve endüstriyel açıdan geniş bir etki alanı yaratmaktadır. Endüstriyel kenevirin bu denli istisnai bir konuma sahip olmasının temel nedenlerinden biri, psikoaktif türlerden genetik olarak ayrışmış olmasıdır. Endüstriyel kenevir türleri, Δ-9-tetrahidrokanabinol (THC) oranı bakımından %0,3'ün altında değerlere sahiptir ve bu yönüyle narkotik amaçlı türlerden net biçimde ayrılmaktadır (Desanlis vd., 2013). Bu fark, yalnızca yasal açıdan güvenli bir hammadde değil, aynı zamanda sürdürülebilir endüstriler için etik ve ekonomik bir alternatif haline getirmiştir.

Agronomik açıdan değerlendirildiğinde, kenevirin biyolojik yapısı yüksek verimliliğiyle dikkat çeker. C_3 fotosentetik yapıya sahip bu yıllık bitki, lignoselülozik biyokütle üretiminde son derece etkilidir. Literatürde, kenevirin ayda yaklaşık 50 cm büyüyebildiği, 4 m'ye kadar ulaşabildiği ve kuru madde veriminin 7,6–15 Mg ha^{-1} $yıl^{-1}$ arasında değiştiği raporlanmaktadır (Burczyk vd., 2008; Jankauskiene vd., 2015; Strzelczyk vd., 2022). Bu yüksek biyokütle üretimi, enerji yoğunluğu açısından da son derece avantajlıdır; enerji değeri 124–223 GJ ha^{-1} $yıl^{-1}$ aralığında bildirilmektedir. Düşük pestisit gereksinimi, geniş iklim aralığında yetişebilme

kapasitesi ve kuraklığa karşı dayanıklılığı, keneviri çevresel olarak sürdürülebilir tarım sistemleri için ideal bir tür haline getirmektedir (Finnan & Styles, 2013). Böylece kenevir üretimi yalnızca ekonomik kazanç değil, aynı zamanda toprak verimliliği, biyoçeşitlilik ve karbon döngüsünün desteklenmesi bakımından da önemli ekosistem hizmetleri sağlar.

Endüstriyel kenevirin çevresel katkıları, üretim potansiyeli kadar önemlidir. Derin ve yaygın kök sistemi, toprakta biriken ağır metallerin ve kirleticilerin uzaklaştırılmasını sağlayarak fitoremedasyon uygulamalarında etkili bir araç haline getirmektedir (Akkaya vd., 2025; Visković vd., 2024). Bu özelliği sayesinde kenevir, kirlenmiş toprakların rehabilitasyonunda "çift işlevli" bir bitki olarak değerlendirilmektedir; bir yandan çevresel iyileştirme sağlarken, diğer yandan ekonomik değeri yüksek biyokütle üretimi gerçekleştirmektedir. Ayrıca, yüksek karbon tutma kapasitesiyle iklim değişikliğinin etkilerinin azaltılmasına da katkıda bulunur. Yapılan çalışmalar, bir hektarlık kenevir tarlasında yılda önemli miktarda CO_2'nin sabitlenebildiğini ortaya koymuştur (Kaur & Kander, 2023; Visković vd., 2024). Bu yönüyle kenevir hem karbon yutağı işlevi gören hem de karbon-nötr üretim sistemlerine entegre edilebilen nadir tarımsal türlerden biridir.

Endüstriyel kenevirin endüstriyel değerlendirme potansiyeli oldukça geniştir. Bitkinin sap kısmı, lif ve hurd (odunsu iç kısım) olmak üzere iki temel fraksiyona ayrılır (Şekil 2). Lif, sapın yaklaşık %25'ini, hurd ise %75'ini oluşturur (Schluttenhofer & Yuan, 2017). Kenevirin lignoselülozik yapısı, selüloz (%40–48), hemiselüloz (%20–25) ve lignin (%15–20) oranlarıyla tipik enerji bitkilerinden biri olan miscanthus ile benzerlik göstermektedir (Jankauskiene vd., 2015). Lif fraksiyonu yüksek selüloz içeriği (%70–75) sayesinde tekstil ipliği, kâğıt hamuru, biyokompozit ve ısı yalıtım malzemeleri gibi katma değeri yüksek sektörlerde kullanılmaktadır. Buna karşın hurd fraksiyonu, daha yüksek lignin ve mineral içeriğiyle özellikle yapı sektöründe "hempcrete" (kenevir betonu) üretiminde, ayrıca hayvan yataklığı, sunta ve biyokütle yakıtı üretiminde değerlendirilmektedir (Jami vd., 2019; Stevulova vd., 2018).



Şekil 2. Endüstriyel kenevir ve kısımları (Tyagi vd., 2022)

Kenevirin bu kimyasal yapısı, biyoyakıt üretimi açısından da önemli fırsatlar sunar. Lignoselülozik fraksiyon, biyogaz, biyoetanol ve biyodizel üretimi için uygun bir substrat niteliği taşımaktadır. Yapılan araştırmalar, özellikle hurd ve lif fraksiyonlarının, ön işlem uygulanmadan dahi yüksek BMP'ye sahip olduğunu göstermiştir (Heiermann vd., 2009; Jankauskiene vd., 2015). Bu durum, kenevirin hem enerji üretiminde hem de karbon nötrlüğü hedefleriyle uyumlu döngüsel ekonomi uygulamalarında güçlü bir alternatif olduğunu

kanıtlamaktadır. Ayrıca, kenevir tohum yağı biyoetanol ve biyodizel üretiminde önemli bir hammadde niteliği taşırken, yağ çıkarımı sonrasında elde edilen küspe de %50'ye varan protein içeriğiyle yem olarak değerlendirilmektedir (Capcanari vd., 2023; Süzerer vd., 2023).

Bu kapsamda, endüstriyel kenevir yalnızca lif ve tohum üretimiyle sınırlı bir tarım ürünü değil, aynı zamanda çevresel rehabilitasyon, yenilenebilir enerji üretimi ve sürdürülebilir endüstriyel dönüşüm açısından stratejik bir biyoresürstür. Lif, hurd, tohum ve yağ fraksiyonları üzerinden farklı değer zincirlerine entegre olabilen bu bitki, hem toprak kalitesinin artırılması hem de karbon sekestrasyonu, enerji üretimi ve atık geri kazanımı hedefleriyle uyumlu bir biyodöngü modelinin temel bileşenini oluşturmaktadır.

3. ENDÜSTRİYEL KENEVİRİN ANAEROBİK FERMANTASYON POTANSİYELİ

Endüstriyel kenevir, lignoselülozik yapısı, yüksek büyüme hızı ve farklı bitki fraksiyonlarının (yaprak, sap, lif, hurd, tohum) kimyasal çeşitliliği sayesinde anaerobik fermantasyon süreçlerinde yenilenebilir enerji üretimi için önemli bir biyokütle kaynağıdır. Lifli dokuların yüksek lignin içeriği hidroliz hızını azaltırken, fenolik bileşiklerin belirli bir eşiğin üzerinde bulunması metan üretimini geçici olarak baskılayabilmektedir. Schroyen vd. (2017, 2015), fenolik konsantrasyonun 100 mg L^{-1}'den 2000 mg L^{-1}'ye yükselmesinin metan oluşumunda belirgin bir inhibisyona yol açtığını, ancak mikrobiyal toplulukların zamanla bu koşullara adapte olarak inhibitör etkinin kısmen ortadan kalktığını bildirmiştir. Lignin miktarı, BMP'nin en belirleyici bileşenlerinden biridir ve bu nedenle lignin bariyerinin enzimatik veya termo-kimyasal ön işlemlerle zayıflatılması metan üretim verimini önemli ölçüde artırmaktadır (Schroyen vd., 2018).

Kenevirin farklı fraksiyonlarındaki selüloz, hemiselüloz ve lignin oranları biyobozunabilirlik üzerinde doğrudan etkilidir. Özellikle selüloz/hemiselüloz oranı yüksek, lignin oranı düşük olan yaprak fraksiyonları, birim kuru madde başına daha yüksek metan verimi sağlar (Adamovi vd., 2014). Bununla birlikte kenevirin çeşidi, yetiştirme koşulları, hasat zamanı ve partikül boyutu gibi faktörler biyogaz verimini büyük ölçüde etkiler. Mikroorganizmaların optimum aktivitesi için C/N oranının 16–20 arasında tutulması önerilmekte; azot, fosfor ve kükürt eksiklikleri ise metanojenik faaliyetleri sınırlandırmaktadır (Álvarez vd., 2010; Hinken vd., 2008; Mshandete vd., 2004; Nges vd., 2012). Dolayısıyla uygun besin dengesi, özellikle karışık substratlı sistemlerde sürecin kararlılığını ve metan verimini artıran temel bir faktör olarak öne çıkmaktadır.

Tarla denemeleri, ön işlem uygulanmamış kenevir biyokütlesinin enerji üretiminde pek çok klasik enerji bitkisiyle rekabet edebildiğini göstermiştir. Prade vd. (2011), İsveç'in güneyinde yürüttükleri çalışmada biyogaz üretimi için en uygun hasat döneminin Eylül–Kasım, katı biyoyakıt üretimi için ise Şubat–Nisan olduğunu bildirmiştir. Biyogaz için hektar başına enerji getirisi 296 GJ ha^{-1}, katı yakıt için ise 201 GJ ha^{-1} olarak hesaplanmıştır. Takip eden çalışmalar, sonbaharda hasat edilen taze biyokütlenin biyogaz üretimi açısından, ilkbaharda hasat edilen kuru biyokütlenin ise ısı ve kojenerasyon sistemleri için daha avantajlı olduğunu göstermiştir (Kreuger, Prade, vd., 2011; Prade vd., 2012). Kenevirin farklı fenolojik evrelerinde yürütülen deneysel çalışmalarda, en yüksek metan verimi erken gelişim aşamasında (309–316 L CH_4 kg^{-1} ODM) gözlenmiş; olgunlaşmayla birlikte bu değer 289–302 L CH_4 kg^{-1} ODM'ye düşse de artan biyokütle üretimi hektar başına metan verimini 142–175 m^3 ha^{-1}'den 2780–3230 m^3 ha^{-1}'e yükseltmiştir. Ortalama metan oranı %60 civarında saptanmış, farklı gübreleme stratejileri arasında anlamlı fark bulunmamıştır. Bu sonuçlar, biyogaz tesislerinden elde edilen sindirim ürünlerinin (katı ve sıvı faz) kenevir yetiştiriciliğinde etkili bir geri besin kaynağı olarak değerlendirilebileceğini göstermektedir (Michal vd., 2023; Velechovský vd., 2021).

Balodis vd. (2011), Letonya koşullarında kenevirin 12.6 t DM ha^{-1} verimle mısır ve kolzayla rekabet edebildiğini ve 116 GJ ha^{-1} düzeyinde metan enerji verimi sağladığını bildirmiştir. Adamovičs vd. (2014), Futura 75 ve Uso 31 çeşitlerinde ince öğütülmüş fraksiyonların 208 GJ ha^{-1}, kaba fraksiyonların ise 148 GJ ha^{-1} enerji verimi ürettiğini raporlamıştır. Benzer şekilde, Pakarinen vd. (2011), Finlandiya koşullarında kenevirin 14 t DM ha^{-1} biyokütle ve 108 GJ ha^{-1} metan enerji verimiyle mısırla eşdeğer performans sergilediğini ortaya koymuştur. Bu bulgular Gissén vd. (2014) tarafından yapılan yaşam döngüsü analizleriyle desteklenmiş ve kenevirin arazi kullanımı ve çevresel etki açısından sürdürülebilir enerji bitkileri arasında güçlü bir alternatif olduğu gösterilmiştir. Bu sonuçlar birlikte değerlendirildiğinde, ön işlemsiz kenevir biyokütlesinin, doğru hasat zamanlaması ve parçacık boyutu kontrolüyle, pek çok geleneksel enerji bitkisine benzer metan verimi sağlayabildiği görülmektedir.

Bununla birlikte, kenevirin lignin içeriği ve fenolik bileşiklerinin mikrobiyal bozunmayı sınırlaması nedeniyle, son yıllarda araştırmalar biyobozunabilirliğin artırılmasına yönelik ön işlem stratejilerine yönelmiştir. Kreuger vd. (2011b), buhar ön işleminin yalnızca mekanik öğütmeye kıyasla metan verimini belirgin biçimde artırdığını ve aynı biyokütlenin etanol–metan eş üretiminde kullanılmasının enerji çıktısını iki katına kadar yükselttiğini bildirmiştir. Schroyen vd. (2017, 2015), veratril alkol ve lakaz enzimleriyle yapılan biyokimyasal ön işlemlerin fenolik bileşiklerin yaklaşık %80'ini uzaklaştırarak inhibitör etkileri azalttığını, ancak toplam biyogaz üretimindeki farkın sınırlı kaldığını göstermiştir. Schroyen vd. (2018) ise lignin içeriği ile BMP arasındaki ilişkiyi modelleyerek kenevirin BMP değerini 238 L CH_4 kg^{-1} VS olarak belirlemiş; bu değerin buğday samanına yakın, ancak miscanthus'tan daha yüksek olduğunu rapor etmiştir.

Son dönemde yapılan çalışmalar, enerji dönüşüm zincirinin optimizasyonu amacıyla biyokimyasal ve termokimyasal süreçlerin entegrasyonuna odaklanmıştır (Daglioglu vd., 2024). Özellikle hidrotermal karbonizasyon ve buhar gazlaştırma süreçleri, lignoselülozik kenevir biyokütlesinin çok aşamalı enerji dönüşümüne olanak tanımaktadır. NaOH ön işleminin kenevir hurdasından biyometan üretimini %164 oranında artırdığı, 200 °C'de elde edilen hidrokömürün 1278 mL g^{-1} H_2 verimiyle en yüksek biyohidrojen performansını sağladığı bildirilmiştir. Bununla birlikte, sindirim ürünlerinden elde edilen hidrokömürlerin yüksek kül içeriği nedeniyle gazlaştırma aktivitesi düşük bulunmuştur. Ancak aynı koşullarda (200 °C) elde edilen sıvı faz, 213 mL CH_4 g^{-1} KOİ değerine ulaşarak en yüksek BMP'yi vermiştir. Bu bulgular, kenevir biyokütlesinin biyogaz, biyohidrojen ve hidrokömür üretim rotalarının ardışık biçimde değerlendirilmesinin enerji dönüşüm verimini önemli ölçüde artırabileceğini göstermektedir.

Kenevirin diğer biyokütlelerle birlikte sindirimi, yani ko-fermantasyon yaklaşımı, sürecin hem kararlılığını hem de besin dengesini iyileştirmektedir. Nges vd. (2012), domuz ve kümes hayvanı gübresi ile gıda ve mezbaha atıklarının temel substratına kenevir, mısır ve tritikale ilavesinin metan verimini %30 oranında artırdığını bildirmiştir. Böske vd. (2014) ise at gübresiyle birlikte kenevir, keten, buğday samanı ve ladin talaşı kullanılan yukarı akışlı katı durum reaktörlerinde kenevirin 168 L CH_4 kg^{-1} VS değeriyle keten ve odun yongalarına kıyasla daha yüksek performans sergilediğini ve termofilik koşullarda metan oranının %59,8'e ulaştığını rapor etmiştir (Tablo 1). Bu çalışmalar, kenevirin karışık substratlı sistemlerde C/N oranını dengeleyerek inhibitör etkileri azalttığını ve biyogaz üretiminde sinerjik bir katkı sunduğunu göstermektedir.

Tablo 1. Endüstriyel kenevir ve farklı biyokütlelerin BMP değerlerinin karşılaştırılması

Bitki / Hammadde	BMP (L_{CH_4}/kgVS)	Açıklama	Kaynak
Kenevir (genel, sap-ağırlıklı fraksiyonlar)	≈ 230–250	Ortalama metan verimi, hasat zamanına göre sınırlı değişim gösterir	(Adamovi vd., 2014)
Kenevir (yaprak fraksiyonu)	≈ 330–370	Yapraklar düşük lignin içeriği nedeniyle en yüksek CH4 verimi sağlar.	(Adamovi vd., 2014)
Mısır silajı	≈ 280–360	En yaygın referans enerji bitkisi: yüksek hektar verimi sayesinde toplam üretim yüksektir.	(Weiland, 2010)
Şeker pancarı (posası/silajı)	≈ 320–450	Kolay parçalanabilir karbonhidrat içeriği sayesinde yüksek biyogaz verimi	(Szwarc & Szwarc, 2020)
Çim / Grass silaj	≈ 290–320	Orta- yüksek metan verimi; ancak protein oranı değişkendir.	(Weiland, 2010)
Buğday sapı	≈ 230 (ön işlemsiz) → ≈ 280–300 (ön işlemli)	Yüksek lignin oranı nedeniyle ön işlem gerektirir.	(Weiland, 2010)

Öte yandan yaşam döngüsü değerlendirmeleri, kenevirin yalnızca enerji üretiminde değil, aynı zamanda çevresel rehabilitasyonda da ikili bir işlev üstlendiğini ortaya koymuştur (Todde vd., 2022). Ağır metallerle kirlenmiş topraklarda yetiştirilen kenevirin değerlendirilmesine yönelik dört farklı tedarik zinciri senaryosunda, kirlenmiş biyokütlenin anaerobik sindirim veya yakma yoluyla işlenmesi en yüksek enerji tasarrufu (25.3–36.8 GJ ha^{-1}) ve emisyon azaltımı (579–641 kg CO_2e ha^{-1}) sağlamıştır. Monte Carlo simülasyonlarıyla doğrulanan bu bulgular, kirlenmiş arazilerin kenevir temelli biyoenerji üretimiyle yeniden işlevsel hale getirilebileceğini göstermektedir (Todde vd., 2022). Ekonomik açıdan değerlendirildiğinde, Barta vd. (2013), buhar ön işlem, etanol fermantasyonu, anaerobik fermantasyon ve kojenerasyonun entegre biçimde uygulanmasının yüksek enerji çıktısı sağladığını, ancak biyokütle tedarik maliyetleri ve biyogaz fiyatları nedeniyle ekonomik sürdürülebilirliğin sınırlı kaldığını belirtmiştir. Bununla birlikte kenevirin düşük pestisit gereksinimi, hastalıklara dayanıklılığı ve organik tarımla uyumu, onu gıda, yem ve enerji üretimi arasında dönüşümlü kullanılabilecek sürdürülebilir bir enerji bitkisi haline getirmektedir (Gissén vd., 2014; Kreuger, Sipos, vd., 2011; Prade vd., 2012).

Sonuç olarak, kenevirin anaerobik fermantasyon süreçlerindeki potansiyeli, hem ön işlemsiz uygulamalarda rekabetçi BMP değerleri hem de lignin yapısının çözülmesiyle elde edilen yüksek verimli ön işlemli sistemlerle güçlenmiştir. Termo-kimyasal süreçlerin entegrasyonu ve ko-fermantasyon stratejileri ise enerji dönüşüm verimini daha da artırarak, kenevirin biyogaz tabanlı biyorafineri sistemlerinde merkezi bir hammadde olarak değerlendirilebileceğini göstermektedir.

Tablo 2. Literatürde endüstriyel kenevir biyokütlesinin biyogaz üretimine ilişkin seçilmiş çalışmalar

Kaynak	Araştırma	Yer	Biyokütle	Diğer Biyokütlelerle Karşılaştırma	Kuru Madde (Dm) Verimi (T/Ha)	Enerji İçeriği (Gj/Ha) veya Metan Verimi	Başlıca Bulgular
(Schroyen vd., 2015)	Fenolik bileşiklerin metan üretimi üzerindeki inhibitör etkisinin değerlendirilmesi	Belçika	Kenevir	X	n.a.	100–2000 mg/L fenolik derişiminde CH_4 üretiminde azalma	Fenolik bileşiklerin yüksek konsantrasyonlarda metan oluşumunu baskıladığı, mikrobiyal adaptasyonla etkilerin zamanla azaldığı gösterildi.
(Schroyen vd., 2017)	Lignin bozunumu ve detoksifikasyon enzimlerinin etkisi	Belçika	Kenevir	X	n.a.	%80 fenolik uzaklaştırma, toplam CH_4 üretiminde sınırlı artış	Veratril alkol ve lakaz enzimiyle fenoliklerin azaltılması, süreç başlangıcındaki toksisiteyi azalttı.
(Schroyen vd., 2018)	BMP tahmininde lignin içeriğinin belirleyici rolü	Belçika	Kenevir, Buğday, Miscanthus, Keten	✓	n.a.	BMP: 238 L CH_4/kg VS	Lignin miktarının BMP'nin en güçlü belirleyicisi olduğu, kenevirin orta düzeyde potansiyel sunduğu gösterildi.
(Michal vd., 2023)	Farklı büyüme evresi ve gübreleme rejimlerinin biyogaz ve metan üretimi üzerine etkisi	Çekya	Kenevir	X	12 tDM/ha, %32 KM	309–316 L CH_4/kg ODM; MHY: 2780–3230 m^3/ha	Erken evrede en yüksek metan verimi; BGP sindirim ürünlerinin etkili bir gübre alternatifi olduğu gösterildi.
(Daglioglu vd., 2024)	NaOH ön işlemi, HTC ve buhar gazlaştırma entegrasyonu ile	Türkiye	Kenevir hurdası	X	n.a.	1278 mL H_2/g, 213 mL CH_4/g KOİ	NaOH ön işlemi biyometanı %164 artırdı; 200 °C'deki

	biyometan ve biyohidrojen üretimi					hidrokömür en yüksek H_2 verimini sağladı.
(Todde vd., 2022)	Kirlenmiş topraklarda yetiştirilen kenevirin fitoremediasyon ve enerji geri kazanımı	İtalya	Kenevir (kirlenmiş toprak)	X	n.a.	25.3–36.8 GJ ha^{-1} enerji tasarrufu	Kirlenmiş biyokütlenin anaerobik fermantasyonu ve yakma ile işlenmesi, 579–641 kg CO_2e/ha azaltımı sağladı; fitoremediasyonla enerji geri kazanımı önerildi.

4. SONUÇ VE ÖNERİLER

Endüstriyel kenevir (*Cannabis sativa L.*), yüksek biyokütle üretim kapasitesi, kısa büyüme süresi, düşük pestisit gereksinimi ve çok yönlü kullanım alanlarıyla döngüsel ekonomi vizyonunun merkezinde konumlanabilecek stratejik bir tarım ürünüdür. Bitkinin tüm fraksiyonlar-lif, hurd, tohum ve yaprak-enerji, malzeme ve çevre yönetimi açısından farklı değer zincirlerine entegre edilebilmekte, böylece "atık üretmeyen üretim" ilkesine dayalı bütüncül bir biyorafineri modeli oluşturulabilmektedir. Anaerobik fermantasyon süreci, bu sistemin enerji yönelimli dönüşümünde temel bir teknoloji olup hem biyogaz üretimi hem de sindirim artıklarının tarımsal döngüye geri kazandırılması sayesinde çevresel sürdürülebilirliğin sağlanmasında kilit rol üstlenmektedir.

Biyorafineri yaklaşımının yaygınlaştırılması, kenevirin yalnızca biyogaz üretiminde değil, aynı zamanda biyohidrojen, biyokömür, biyoplastik ve biyogübre üretim hatlarında eş zamanlı olarak değerlendirilmesine olanak tanımaktadır. Bu entegre dönüşüm yaklaşımı, kaynak verimliliğini en üst düzeye çıkarırken atık yönetimi ve enerji tüketim maliyetlerini azaltmakta; dolayısıyla "döngüsel değer zinciri" konseptinin tarımsal uygulamalarda somutlaşmasını sağlamaktadır. Son yıllarda yapılan çalışmalar, NaOH veya buhar ön işlemiyle desteklenen fermantasyon hatlarının biyogaz verimini %150'nin üzerinde artırabildiğini ve lignin bariyerinin parçalanmasıyla biyobozunabilirliğin anlamlı biçimde iyileştirildiğini göstermektedir. Ayrıca, bu tür sistemlerin hidrotermal karbonizasyon ve kojenerasyon süreçleriyle entegrasyonu, enerji dönüşüm zincirinde sıfır atık hedefini teknik olarak erişilebilir kılmaktadır. Böylelikle kenevir temelli biyorafineri sistemleri, enerji üretimi, karbon döngüsü ve atık yönetimini bütünleştiren bir sürdürülebilirlik modeli haline gelmiştir.

Gelecekteki araştırmaların, kenevirin enerji dönüşümündeki potansiyelini daha etkin kullanabilmek adına üç temel eksende yoğunlaşması gerekmektedir. İlk olarak, ön işlem optimizasyonu, farklı kenevir fraksiyonlarının (lif, hurd, yaprak) kimyasal ve enzimatik ön işlem kombinasyonlarıyla biyokimyasal metan potansiyelinin artırılmasını ve sürecin enerji girdisi–çıktısı dengesiyle birlikte modellenmesini içermelidir. İkinci olarak, hibrit enerji sistemleri üzerine çalışmalar derinleştirilmelidir. Anaerobik fermantasyonun fotobiyolojik, elektrokimyasal veya termokimyasal süreçlerle entegrasyonu, aynı biyokütleden çoklu enerji ürünlerinin (CH_4, H_2, biyokömür) eş zamanlı olarak elde edilmesini mümkün kılacak ve bu sayede enerji verimliliği yeni bir boyut kazanacaktır. Üçüncü olarak ise, karbon nötrlüğü ve yaşam döngüsü değerlendirmesi odaklı modelleme çalışmaları ön plana çıkmalıdır. Kenevir tabanlı biyogaz üretiminin karbon ayak izi, toprak karbon sekestrasyonu ve karbondioksit emisyon dengelemesi parametreleriyle birlikte değerlendirilmesi, sistemin iklim politikalarıyla entegrasyonunu güçlendirecektir.

Sonuç olarak, kenevir temelli biyorafineri sistemleri yalnızca yenilenebilir enerji üretimini değil, aynı zamanda toprak sağlığını, atık yönetimini ve karbon dengesini birlikte hedefleyen yeni nesil döngüsel ekonomi uygulamaları için güçlü bir fırsat sunmaktadır. Bu vizyonun hayata geçirilebilmesi, kenevirin ulusal enerji ve çevre politikalarında "karbonsuz büyüme" hedeflerine entegre edilmesiyle mümkün olacaktır. Böyle bir yaklaşım, yalnızca biyokütle temelli enerji güvenliğini güçlendirmekle kalmayacak, aynı zamanda tarımsal kalkınmayı ve iklim değişikliğiyle mücadeleyi destekleyen yenilikçi bir yeşil dönüşüm stratejisine öncülük edecektir.

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FARKLI KOYUN IRKLARININ SÜTTEN KESİLMİŞ KUZULARININ YAPAY MERADAKİ BÜYÜME PERFORMANSLARININ BELİRLENMESİ

Ziraat Yük.Müh.Şaban IŞIK,

Bahri Dağdaş Uluslararası Tarımsal Araştırma Enstitüsü Müdürlüğü Tarla Bitkileri Bölümü Konya

Email: sabanisik@gmail.com

ORCID:0009-0000-9085-6934

Dr. Şükrü DOĞAN

Bahri Dağdaş Uluslararası Tarımsal Araştırma Enstitüsü Müdürlüğü Hayvancılık Araştırma Bölümü Konya

Email: dogansukru@hotmail.com

ORCID: 0000-0001-8673-2904

Zir.Yük.Müh. Seydi AYDOĞAN

Bahri Dağdaş Uluslararası Tarımsal Araştırma Enstitüsü Müdürlüğü Kalite ve Teknoloji Bölümü Konya

Email: seydiaydogan@tarimorman.gov.tr

ORCID: 0000-0003-04721211

Zir.Yük.Müh. Murat Küçükçongar

Bahri Dağdaş Uluslararası Tarımsal araştırma Enstitüsü Müdürlüğü Tarım Ekonomisi Bölümü Konya

Email: kucukcongar@gmail.com

ORCID: 0000-0003-0366-7276

ÖZET

Bu araştırma, Konya Bahri Dağdaş Uluslararası Tarımsal Araştırma Enstitüsü Müdürlüğünde tesis edilen mera arazisinde yürütülmüştür. Araştırmada enstitümüzde bulunan 4 farklı koyun ırkının (AKK, OAM, Hasmer ve Hasak) sütten kesilmiş kuzularının (2,5 – 3 aylık) meradaki büyüme performansları ve otlatmanın meranın verim ve botanik kompozisyonlarına olan etkileri incelenmiştir. Bu amaçla mera parselleri Nisan - Temmuz ayları arasında 84 gün süre ile kuzularla otlatılıp büyüme performansları belirlenmiş ve daha sonra mera parselleri 24 Eylül'e kadar otlatılmaya devam edilmiştir. Tesadüf blokları deneme deseninde 3 tekerrürlü olarak yürütülen denemede sütten kesilmiş kuzular meraların kapasitesine göre rastgele olarak deneme alanlarına alınmıştır. Otlatma denemesi boyunca hayvanların canlı ağırlık değişimi, meranın ot verimi, meranın besin madde içeriği ve botanik kompozisyonu gibi veriler ölçülmüştür.

Anahtar Kelimeler: Kuzu, yapay mera, otlatma, ot verimi, botanik kompozisyon

ABSTRACT

This project was conducted on the pastural land which established in Bahri Dagdas International Agricultural Research Institute. In the research, the performance of weaned lambs(two and a half- three mounths) of 4 different sheep breeds (AKK, OAM, Hasmer and Hasak) was monitored and the effect of grazing on pasture production and botanical composition was measured. Pasture was grazed with lambs for eighty four day between April and July and growth performance of lambs was monitored and than Pastures was continued to graze until 24 September. The grazing trial in which weaned lambs is allocated to paddocks randomly depending on the pasture capacity was conducted on a completely randomized block design with three replicates. The measurements of animal liveweight gain changes, herbage production, nutritive value and botanical composition was taken during the grazing trial.

Key Words : Lamb, artificial pasture, grazing, herbage yield, botanical composition

1.GİRİŞ

İhtiyaç duyulan kaliteli ve ucuz kaba yemlerin üretilememesi hayvancılık sektörünün gelişmesini sınırlandıran en önemli engellerden biri olduğu bilinmektedir. Kaliteli kaba yemler esas olarak çayır ve meralar ile yem bitkileri yetiştiriciliğinden sağlanmaktadır. Tarla bitkilerinin artıkları kullanılarak bir miktar kaba yem üretilse de bunun miktarı oldukça sınırlıdır. Doğal çayır ve meralarımızın aşırı ölçüde tahrip edilmelerinden dolayı verim güçlerini yitirmişlerdir. Bunun sonucu olarak, ihtiyaç duyulan kaliteli kaba yem yeterli miktarda üretilememektedir.

Modern hayvancılık işletmelerin de yemin önemli bir girdi olduğu bilinmektedir. Yemin en ucuz elde edildiği kaynak mera alanları olup yapay meralar bu tip işletmeler için büyük önem taşımaktadır. Son yıllarda da uygulanan tarım politikaları ile hayvancılığa ve yem bitkileri ekimine verilen desteklerden dolayı bölgede modern hayvancılık işletmelerinin sayısının artması, ekstansif şartlarda beslenen hayvanların yapay mera ihtiyacını artırmaktadır.

Hayvancılık işletmelerinin sayısının artmasına rağmen, doğal meralardan faydalanma her geçen gün azalmaktadır. Meraların kullanımı konusunda yaşanan genel sorunlar içerisinde yer alan aşırı ve zamansız otlatma, meraların kapasitesinin çok üzerinde hayvan otlatılması gibi faktörler buralarda da kendisini yoğun bir şekilde hissettirmektedir. Ayrıca yetersiz yağış ve yağışların yıl içerisindeki dağılımındaki düzensizlikler buna eklenince yapılan çalışmalar başarısızlıkla sonuçlanmaktadır.

Doğal meraların verim potansiyellerinin azalması, Gıda, Tarım ve Hayvancılık Bakanlığının çiftçi desteklemeleri kapsamında yapay mera alanlarını desteklemesi ve artan et fiyatları neticesinde koyun üretimi yapan çiftçilerin yapay meralar oluşturması gerekliliğini ortaya çıkarmaktadır.

Bu şekilde doğal meralara olan baskılar azaltılabilecek ve kaliteli kaba yem ihtiyacı karşılanabilecektir. Bu aynı zamanda doğal meraların sürdürülebilir nitelik kazanmalarına yardımcı olacaktır.

Temelde bu çalışmada yağlı kuyruklu olan AKK ile ince kuyruklu olan OAM ve et verimi yönünde melezleme çalışmaları ile enstitümüzde elde edilmiş Hasmer ve Hasak koyun ırklarının sütten kesilmiş kuzularının meradaki büyüme performansına bakılmış ve bu kuzuların meranın ot verimi ve botanik kompozisyonuna olan etkileri ölçülmüştür. Mevcut şartlarda bölgemizde çiftçilerin elinde bu meralardan faydalanabilecek farklı morfoloji (kuyruk yapısı vb.) ve verim yönünde (et, yün vb.) koyun ırkları (Dağlıç gibi) bulunmaktadır. Bu koyun ırklarının entansif şartlardaki verimleri ortaya konmuş olmasına rağmen mera üzerindeki verimleri bilinmemekte olup meradaki performansları ve meranın verimine olan etkileri farklı olması muhtemeldir.

2.LİTERATÜR ÖZETİ

Yapay mera tesisine yönelik buğdaygil yem bitkileri ile baklagil yem bitkilerinin karışımlarının ekimi ile ilgili bazı araştırmalara ait sonuçlar aşağıda özetlenmiştir.

Ateş ve ark.(2008b), tarafından Yeni Zelanda kurak meralarında farklı otlatma yoğunluklarında yaklaşık 3 ay süre ile yapılan kuzu besisinde ortalama kuzu başı günlük canlı ağırlık artışı 300 g olarak kaydedilmiş olup besi sonu kuzulardaki ortalama canlı ağırlık değişimi 29-41 kg arasında olmuştur.

İşliel ve ark. (1962), 1957 ve 1961 yılları arasında Orta Anadolu şartlarında bölgeye uygun karışımların tespiti çalışmalarını yapmışlardır. Kılçıksız brom+domuz ayrığı+çayır üçgülü karışımından ortalama 3904 kg/da, kılçıksız brom+domuz ayrığı+çayır üçgülü+ yonca

karışımından ortalama 3350 kg/da, kılçıksız brom+domuz ayrığı+çayır üçgülü+adi otlak ayrığı+yonca karışımından ise ortalama 4222 kg/da ot aldıklarını belirtmişlerdir.

Tekeli (1977), Kurak bölge şartlarında yapay mera kurmak için en uygun ekim yönteminin tespiti çalışmalarında yonca, kılçıksız brom ve mavi ayrık kullanmış, tohumların karışık veya ayrı ayrı olarak sıraya ekimlerinin elverişli ekim yöntemi olduğunu belirtmiştir.

Tosun ve ark. (1977), yapay meralardan elde edilen kuru ot miktarının doğal meralara göre yaklaşık 3 katı daha fazla olduğunu belirtmişlerdir. Erzurum kıraç şartlarında en uygun mera ıslah metodunun mevcut bitki örtüsünün tamamen öldürmek sureti ile hazırlanan iyi bir tohum yatağı olduğunu ve buraya bölgeye adapte olmuş yem bitkileri tohumu karışımlarının ekilmesi gerektiğini belirtmişlerdir.

Sheaffer ve ark. (1984) ile Kleczek (1990), karışımlardan sözü edilen faydaların sağlanabilmesi için uygun türlerin seçimine bağlı olduğunu belirtmişlerdir. Otlatma amacıyla seçilen yatık ve yarı yatık türler tesisteki diğer türden zarar görebileceğini vurgulamışlardır. Bu yüzden karışımlardan uzun yıllar faydalanabilmek amacıyla uyumlu ve rekabet gücü birbirlerine yakın türleri bir araya getirmek gerektiğini söylemişlerdir. Bu konuda yaptıkları çalışmada taban arazilerdeki yapay mera tesisleri için ak üçgül ve gazal boynuzu ile birlikte çok yıllık çim, kelp kuyruğu, çayır yumağı, çayır salkım otu ve kılçıksız brom gibi buğdaygilleri sıkça kullanmışlardır.

Haris(1987), sulu ve kurak meralarda ki botanik kompozisyondaki farklılığın nedeni olarak türler arasında su için yapılan rekabetin olduğunu bildirmiştir. Örnek olarak yağışlı geçen yıllarda özellikle yağışlı yaz aylarında ve sulanan meralarda ak üçgül artış göstermektedir

Tosun ve ark. (1989), Erzurum'da kıraç şartlarda karışımda %25 oranında baklagil kullanarak, yonca+buğdaygil ve korunga+buğdaygil ile tesis ettikleri iki ayrı suni merada yürütmüşlerdir. Araştırıcılar hafif, orta ve ağır olmak üzere 3 otlatma yoğunluğunu esas alarak karışımların çeşitli yönlerden performansını değerlendirmişlerdir. Karışımda buğdaygil olarak; otlak ayrığı, kılçıksız brom ve koyun yumağı olmak üzere 3 tür kullanılmıştır. Tabii merada dekarda 3, 4 ve 5 koyun otlatılırken, suni meralarda, 6, 10 ve 14 koyun otlatılmıştır. Suni meralarda doğal meradan iki kat fazla kuru ot verimi sağlanmıştır. Yine dekara canlı ağırlık artışı en fazla yonca+buğdaygil merasında 38,7 kg ile gerçekleşirken, doğal merada bu değer 2.12 kg'da kalmıştır. Meralarda yenen ot miktarı, kuru ot verimi ve botanik kompozisyon, otlatma yoğunluğuna bağlı olarak önemli ölçüde değişmemiştir. Araştırıcılar, klimaks durumdan tamamen uzaklaşmış kıraç meraların otlatma sistemlerine uyulması ile ıslahının mümkün olabileceğini, ancak bunun için çok uzun bir zamana ihtiyaç duyulduğunu, böyle alanlarda sürüm yapıldıktan sonra yapay mera kurulması işleminin en başarılı ve ekonomik sonuçları verdiğini belirtmişlerdir.

Vallentine (1989), tabii meraların çok sayıda türden meydana gelmesine karşın genellikle yapay meralarda buğdaygil ve baklagillerden oluşan birkaç türe yer verildiğini vurgulamış, karışımlardan oluşan bitkilerin mevcut şartları iyi değerlendirip daha yüksek verim sağladığını, baklagilin fikse ettiği azottan buğdaygillerin istifade ettiğini, karışımdaki buğdaygiller baklagillerden kaynaklanan şişme gibi problemleri hafiflettiğini, farklı türlerin karışımlarından temin edilen yemin hayvanlar için daha dengeli ve besleyici olduğunu vurgulamıştır.

Serin ve ark. (1997), yaptıkları araştırmada taban arazilerde yapay mera tesisi için kullanılabilecek yem bitkileri ile bunların karışımlarını belirlemişlerdir. Sulu şartlarda yetişen ve otlatmaya dayanıklı olan baklagillerden ak üçgül ve gazal boynuzu ile buğdaygillerden kelp kuyruğu, kırmızı yumak, çok yıllık çim, çayır yumağı, çayır salkım otu ve kılçıksız bromu yalnız veya karışım halinde yetiştirmişlerdir. Üç yıllık ortalama sonuçlarına göre, karışımlar kuru ot (1096.0 kg/da) ve ham protein verimi (155.1 kg/da) yönünden yalnız ekimlerden (730.7

ve 87.0 kg/da) üstün olmuştur. Ak üçgül ile kırmızı yumak (Nova Rubra) çayır yumağı ve kılçıksız brom; gazal boynuzu ile kırmızı yumak (Nova Rubra ve Victor) çok yıllık çim (diploid), çayır yumağı ve kılçıksız brom karışımları yüksek kuru ot verimi sağlamışlardır. Bunlar arasında ak üçgül+kırmızı yumak (Nova Rubra), gazal boynuzu+kırmızı yumak (Nova Rubra ve Victor), gazal boynuzu+çok yıllık çim (diploid) ve gazal boynuzu+çayır yumağı karışımlarının ham protein verimlerini de yüksek bulmuşlardır. En yüksek ham protein oranı (%8.93) yalnız ekilen ak üçgülde belirlenirken, gazal boynuzu+çok yıllık çim (diploid)'de baklagil oranı (%60.9), gazal boynuzu+kırmızı yumak (Nova Rubra) karışımında ise karışım etkinliği (1.68) en yüksek olduğunu tespit etmişlerdir.

Bakoğlu ve ark. (1999) Erzurum meralarında yaygın bitki türlerinin ham protein, ham selüloz oranları ile mineral madde içeriklerini inceledikleri çalışmalarında, 92 bitki türünde ortalama %16,2 oranında ham protein bulmuşlardır. Baklagiller en yüksek (%21,1), buğdaygiller en düşük (%11,8), diğer familyalara ait türler (%15,7) ise bu iki değer arasında yer almıştır. Bitkilerin ortalama ham selüloz oranı %29,8 olarak bulunmuştur. Buğdaygiller ortalamanın üzerinde (%33,3), baklagiller (%28,0) ve diğer familyalar (%28,0) ise ortalamanın altında ve birbirine yakın değerlerde ham selüloz oranına sahip olmuşlardır.

Brand (2000), farklı koyun ırklarının meralarda ot seçiminin farklı olduğunu, Dorper koyun ırkının merinoslara göre daha az seçici olduğundan dolayı daha fazla mera bitkisinden yararlandığını bildirmiştir.

Yerli koyun ırklarımızın entansif şartlarda yoğun kuzu besisi performansına ait değerlerin 270-320 g/baş/g arasında değiştiği bildirilmiştir (Aktaş ve ark 2001) Ancak bu koyun ırklarımızın merada besi performanslarına ait veriler bulunmamaktadır.

Steinheim ve ark (2008), farklı koyun ırklarının meradaki ot seçme davranışlarının farklı olduğu bildirmektedirler. Soder ve ark (2009), ruminantların kompleks karışımlardan oluşan meralardaki ot tercihleri farklılıklar olduğunu, bu farklılıkların hayvanin tüketeceği ot miktarını, meranın kompozisyonunu ve besin madde muhtevasını da etkilediğini bildirmiştir.

3.MATERYAL VE METOT

3.1.MATERYAL

3.1.1.Araştırma Alanının Yeri, İklim ve Toprak Özellikleri

Araştırma, Bahri Dağdaş Uluslararası Tarımsal Araştırma Enstitü Müdürlüğü'ne ait sulanabilen arazide yapılmıştır.

Araştırmanın yapıldığı ve uzun yıllara ait bazı iklim değerleri mukayese bakımından Çizelge 1'de verilmiştir. Otlatma yılına rastlayan aylarda 2013 yılı sıcaklık ortalaması 14 C° ve toplam yağış miktarı 158.6 mm, 2014 yılı sıcaklık ortalaması 15.9 C° ve toplam yağış miktarı 212.2 mm olarak gerçekleşmiştir. Uzun yıllar ortalamasına göre sıcaklık 14.2 C° ve toplam yağış miktarı 188.8 mm olarak gerçekleşmiştir.

Çizelge 1. Araştırma yerinin otlatma dönemindeki 2013-2014 ve uzun yıllara ait sıcaklık ve yağış değerleri.

Aylar	Sıcaklık(C°)			Yağış(mm)		
	2013	2014	UYO	2013	2014	UYO
Ocak	1.5	3.8	3.0	26.6	58.8	44.2
Şubat	4.4	4.8	-8.5	33.6	17.4	28.1
Mart	7.0	8.1	8.6	8.6	20.4	12.6

Nisan	11.3	12.3	11.1	33.0	19.2	41.4
Mayıs	17.8	16.6	17.5	32.6	26.0	18.8
Haziran	21.1	21.2	20.9	17.0	31.4	39.8
Temmuz	22.8	27.4	26.2	2.2	3.0	2.4
Ağustos	22.7	27.1	27.6	0.6	4.6	0.7
Eylül	17.5	21.8	21.8	4.4	31.4	0.8
Ortalama	**14.0**	**15.9**	**14.2**			
Toplam				**158.6**	**212.2**	**188.8**

UYO(uzun yıllar ortalaması)

Araştırmanın yürütüldüğü deneme parsellerinin bazı fiziksel ve kimyasal özelliklerini tespit etmek amacıyla ekimden önce 0-30 cm'lik katmanından toprak örnekleri alınmıştır. Alınan örnekler Toprak ve Su Kaynakları Araştırma Enstitüsü Müdürlüğü laboratuvarında analiz edilmiştir. Analiz sonuçlarına göre Çizelge 2'de görüldüğü gibi deneme yerine ait topraklar %2.38 organik madde, %18.60 kireç içermektedir. Tuzsuz, killi ve hafif alkali (pH7.91) yapıdadır.

Çizelge 2. Araştırma yeri topraklarının bazı fiziksel ve kimyasal özellikleri.

Toprak derinliği (cm)	Toplam Tuz (%)	Organik Madde (%)	Kireç(%)	Fosfor P_2O_5 (kg/da)	Potasyum K_2O (kg/da)	Bünye	pH
0-30	0.046	2.38	18.60	7.97	107.05	Killi	7.91

3.1.2.Bitki Materyali

Bitki Materyali olarak Konya ekolojik koşullarında önceki yıllarda denemeye alınan çok sayıda karışımdan en iyi sonucu veren, hayvanlar için lezzetli olan, verimi yüksek, otlatmaya dayanıklı yapay mera karışımında kullanılan türler ve oranları Çizelge 3'te belirtilmiştir.

Çizelge 3. Karışımda kullanılan bitkilerin oranları ve miktarları

Bitki Adı	%	gr/da	Karışım miktarı(gr)
1.*Lotus corniculatus* (Gazal boynuzu)	10	2500	250
2.*Trifolium repens* L. (Ak üçgül)	20	2500	450
3.*Lolium perenne* L. (İngiliz çimi)	20	3750	750
4.*Dactylis glomerata* L. (Domuz ayrığı)	30	1000	300
5.*Festuca arundinacea* (Kamışsı Yumak)	20	3750	750
Toplam ekilecek tohum miktarı			2500



Şekil 1. Denemede kullanılan buğdaygil ve baklagil karışımlarından genel görünüm.

3.1.3.Hayvan Materyali

Denemede; hayvan materyali olarak Bahri Dağdaş Uluslararası Tarımsal araştırma Enstitüsünde bulunan koyunculuk ünitesinde yetiştirilen her yıl, aynı yaş ve canlı ağırlıkta Akkaraman, Orta Anadolu Merinosu, Hasmer ve Hasak ırkları koyunların 2,5-3 aylık yaşta sütten kesilmiş kuzuları kullanılmıştır.

Şekil 2. Otlatılacak kuzuların tartım ve seçimi



3.2. METOT

Araştırmada ele alınan konular bazında, birinci yıl yapay mera tesis edilmiş, ikinci ve üçüncü yıllarda ise otlatma ile birlikte 21 gün aralıklarla ölçüm ve gözlemler yapılmıştır.

Deneme Deseni ve Süresi: Araştırma, tesadüf blokları deneme deseninde 3 tekerrürlü olarak 33 ay süreli olarak yürütülmüştür.

Çizelge 4. Denemenin kurulması (otlatma planı ve tekerrür (blok) dağılımı)

1.Tekerrür	2.Tekerrür	3.Tekerrür
a	c	b
b	b	d
c	d	a
d	a	c

a-Akkaraman, b-Orta Anadolu Merinosu, c-Hasmer, d-Hasak

Meranın Parsel Alanı, Toprak Hazırlığı, Ekim Şekli ve Zamanı: Tesis edilen mera parsellerinin her biri 25 m x 40 m = 1000 m^2 boyutlarında olup toplam 12000 m^2'dir. Çalışmada kullanılan tohumların küçük olması, çimlenme ve çıkış zorluğu nedeniyle tohum yatağı hazırlığı özenle yapılmıştır. Arazi nadas-buğday ekim nöbetinden sonra Eylül 2011 tarihinde kulaklı pullukla sürülmüştür. 2012 yılı İlkbaharın kazayağı-tırmık ile ikilenerek uygun tesviye ile tohum yatağı hazır hale getirilmiştir. Deneme parsellerine, dekara 2500 gr tohum karışımı gelecek şekilde ekim mibzeriyle 15 cm sıra aralığında, 4-5 cm derinliğe 10 Nisan 2012 tarihinde ekilmiştir.



Şekil 3. Ekimi yapılan parsellerin tohum ve toprak hazırlığı çalışmalarından genel görüntü.

Mera Alanının Çitle Çevrilmesi

Deneme alanının etrafı beton tel çitle çevrilmiştir.



Şekil 4. Yapay mera çit çalışmalarından görüntüler.

Bakım: Tesis yılında karışımdaki bitkilerin yıl boyunca çıkıştan otlatma periyoduna ve kışa giriş, kıştan çıkışa kadar geçen sürede bitkilerin gelişme durumları izlenerek gerekli bakımlar yapılmıştır. Deneme dönemi içerisinde arzu edilmeyen yabancı otlarla makine ve elle mekanik mücadele yapılmıştır.

Barınak ve Gölgeliklerin Yapımı: Meranın ikinci yılı olan 2012 yılında mera parsellerinin köşelerine 12'şer m^2'lik barınak ve gölgelikler yapılmıştır.

Sulukların Yapımı: Mevcut Enstitü deki koyunculuk ünitesinde bulunan çeşmeden yere gömülerek borularla getirilen su borusu ile her bir barınakların içerisine otomatik şamandıralı suluk tasları monte edilmiştir. Kuzuların su ihtiyaçlarını otomatik su taslarından giderilmiştir.



Şekil 5. Hayvan barınak ve suluk yapımından görüntüler.

Gübreleme: Toprak analizlerine bağlı olarak, tohum yatağı hazırlanırken dekara saf madde hesabı ile 10 kg azot ve 10 kg fosfor verilmiştir. Denemenin ileriki aşamalarında ise toprak analizleri sonuçlarına göre 2013 yılı Ekim ayında dekara 5 kg fosfor (P_2O_5) hesabıyla diamonyum fosfat, 2013-2014 Nisan aylarında ise 5 kg saf N hesabıyla amonyum nitrat(%33 N) gübresi uygulanmıştır.

Yapay Meranın Sulanması: Sulama suyu sondaj kuyusundan temin edilmiştir. Kuyudan çıkan su, deneme tarlasına borularla getirilerek yağmurlama ile sulama yapılmıştır.

Birinci yıl hava sıcaklığındaki değişmeler ve topraktaki nem miktarı dikkate alınarak sulama yapılmıştır. İkinci yıl ve sonrası için her 21 günde bir toprak nemini ölçmek suretiyle eksik nemi tarla kapasitesine tamamlayarak sulama yapılmıştır. 2013 yılında toplam 768 mm, 2014 yılında ise 600 mm su uygulanmıştır. İki yıllık ortalama 684 mm su uygulanmıştır.



Şekil 6. Sulama ve gübrelemeden genel görüntüler.

Kuzuların Tartılması ve Meraya Yerleştirilmesi: Kuzular meraya alınacakları gün aç karna tartılmış ve başlangıç ağırlıkları tespit edilmiştir. Kuzuların ortalama canlı ağırlıkları, yaşı ve cinsiyeti eşit olacak şekilde gruplandırılmıştır. Kuzu grupları deneme parsellerine ilk yıl 17 Nisan 2013 tarihinde, ikinci yıl ise 24 Nisan 2014 tarihinde tesadüfi olarak dağıtılmıştır. Meraya yerleştirilen kuzular otlatma periyodu boyunca 21 gün aralıkla aç karna tartılarak canlı ağırlık artışları belirlenmiştir. Bu uygulama her iki yılda da Eylül ayının son haftasına kadar devam etmiştir.



Şekil 7. 2013 yılı otlatmadan görüntüler.



Şekil 8. 2014 yılı otlatmadan görüntüler.

Meradan Örnek Alınması: Otlatma başlangıcında ve 21 gün aralıklarla devam eden örnek alma işlemlerinde otlatılmayan alanlardaki tel kafeslerin içerisinden ve otlatılan alanlardan el ile örnekler alınmıştır. Bu örneklerden verim ve botanik kompozisyon değerleri tespit edilmiştir. Örnek alma işlemi her iki yılda da Nisan ayında başlayıp Eylül ayının son haftasına kadar devam etmiştir.



Şekil 9. Botanik kompozisyondan görüntüler.

Otlatma Planı ve Zamanı: Otlatma 12 dekarlık bir alanda yürütülmüştür. Bitkilerin gelişme ve verimlerine göre birinci yıl tesis yılı ikinci yıl ve üçüncü yılda ise otlatma yılı olarak değerlendirilmiştir. Kuzular meraya sokulmadan önce deneme dışı diğer meralarda 15 gün süre ile alıştırma yapılmıştır. Söz konusu denme parselleri tel çit ile çevrilerek parsellerin her biri 1dekar olacak şekilde dizayn edilmiştir. Otlatma işlemi sürekli otlatma sistemine göre parsellerde yapılan incelemeler ve gözlemler sonucunda bir plan dahilinde 4 grup hayvan ırkları ile karışımların otlatma olgunluğuna geldiği Nisan - Temmuz ayları arasında 84 gün otlatma kapasitelerine uygun şekilde otlatma yapılarak besi performansları belirlenmiştir. Daha sonra mera parselleri bir ay süre zarfında dinlendirilerek tekrar 24 Eylül'e kadar otlatılmaya devam edilmiştir. Otlatma denemesi boyunca yirmi bir gün aralıklarla hayvanların canlı ağırlık değişimi, meranın ot verimi, meranın besin madde içeriği ve botanik kompozisyonu gibi veriler ölçülmüştür.

Çalışmada Yapılan Gözlem ve Ölçümler: Bitkilerin çimlenme ve çıkış zamanları büyüme ritimleri, botanik kompozisyonları değişimi (kışa girişte, kıştan çıkışta, otlatma öncesi ve otlatma sonrası), kışa giriş, kıştan çıkış ve otlatma sonrası gelişme durumları verim ve kalite özellikleri gibi bazı gözlemler yapılmıştır. Bu amaçla; Otlatma parsellerinde her otlatma periyodu başında ve otlatma sonuna kadar 21 gün aralıklarla ot verimi ölçülmüştür. Ayrıca otlatma esnasındaki bitki gelişmesini ve parsellerin toplam ot üretimini değerlendirmek için otlatma başlangıcında parsellere 3'er adet 1.10'ar metrekarelik tel kafes yerleştirilmiştir. Otlatma periyodu başından itibaren otlatma sonuna kadar 21 gün aralıklarla yeşil ve kuru ot verimini ölçmek için her parsele yerleştirilen bu kafeslerden 2- 3 cm yükseklikten biçim yapılmıştır. Otlatma başlangıcında parsellere konulan kafesler vasıtasıyla otlatma periyodu boyunca hayvanların tüketimine sunulan toplam ot miktarı tespit edilmiştir. Ayrıca otlatma periyodu ve yoğunluğuna bağlı olarak bitki kompozisyonunda meydana gelecek değişimleri izlemek üzere her 21 günde bir parsellerdeki kafes ve otlatılan alanlardan alınan örneklerden bitki kompozisyonu ağırlıkça tespit edilmiştir. Her iki yılda da kafeslerden Nisan ayından Eylül ayının son haftasına kadar 8 biçim alınmıştır.

1.Yeşil Ot Verimi(kg/da): Her parsele meranın bütününü temsil edecek şekilde tesadüfi olarak 1.2 m^2(1.1x1.1m) büyüklükte 3 adet kafes yerleştirilmiştir. Otlatma başlangıcında ve otlatma periyodu içerisinde her 21 günde 1 m^2'lik alan içerisindeki otlar toprak seviyesinden 2-3 cm yükseklikten biçilmiştir. Kafesler daha sonra rastgele seçilip toprak seviyesinden 2-3 cm yükseklikten biçimi yapılmış olan yeni alanlara konulmuştur. Her parseldeki kafeslerden elde edilen yeşil otlar tartılarak parsel verimi gram olarak tespit edilmiş ve parselin yeşil ot verimi dekara kg olarak çevrilmiştir.

2.Kuru Ot Verimi(kg/da): Tespit edilen yeşil ot ağırlıkları 70 Cº' de sabit ağırlığa gelene kadar kurutulmuş ve oranlanmak suretiyle kuru ot verimleri tespit edilmiştir.

3.Kuru Madde, Oranları (%) ve Verimleri(kg/da): Kuru madde oranları her bölmeden biçilerek (otlanan alanlardan) 21 günde bir alınan karışım örneklerinden rastgele örnekleme metoduna göre alınan örneklerden 70 ^{0}C 'de 24 saat kurutulduktan sonra tartılıp taze ağırlığa oranlanmıştır. Kuru madde verimleri ise kuru ot verimi ile kuru madde oranının çarpılması ile kg/da olarak hesap edilmiştir (Buğdaycıgil ve ark. 1996).

4. Botanik Kompozisyon(%): Otlatmanın etkilerini belirlemek amacıyla 21 günde bir kuru ağırlığa göre botanik kompozisyon tespiti yapılmıştır. Bunun için alınan ot örnekleri türlere göre ayrılarak kurutulup tartılmış, her türün ağırlığı toplam ağırlığa oranlanmak suretiyle botanik kompozisyon hesaplanmıştır.

5.Ham Protein Oranları (%) ve Verimleri (Kg/Da): Ham protein, oranları otlatılan kısımlardan tesadüf olarak elle biçilen bitki örnekleri 70 Cº' de sabit ağırlığa gelene kadar kurutulmuş ve değirmende homojen şekilde öğütüldükten sonra toplam N miktarı, 6.25 katsayısı ile çarpılarak (azot oranı * 6.25) azot tayin cihazı LECO FP 528 ile belirlenmiştir. Ham protein verimleri ise ham protein oranları ile dekara kuru ot verimleri çarpılarak karışımların dekara protein verimleri bulunmuştur (Anonymous, 2009).

6. Asit Deterjanda Çözünmeyen Lif (Adf) İçeriği (%): Örneklerin ADF içerikleri Van Soest vd. (1991) metoduna göre Gerhard–Fibretern marka cihazla tespit edilerek elde edilen tartım değerlerinin oranlanması suretiyle ADF değerleri tespit edilmiştir.

7. Nötr Deterjanda Çözünmeyen Lif (Ndf) İçeriği (%): Örneklerin NDF içerikleri Van Soest vd. (1991) metoduna göre Gerhard–Fibretern marka cihazla tespit edilerek elde edilen tartım değerlerinin oranlanması suretiyle NDF değerleri tespit edilmiştir.

8. Ham Kül İçeriği (%): Örnekler kül fırınında 550 C^0'de rengi beyaz ya da açık gri renk olana kadar yakılarak kül oranı tespit edilmiştir (Karabulut ve Canbolat 2005).

9. Ham Selüloz(%): Van Soest vd. (1991) metoduna göre Gerhard–Fibretern marka cihazla tespit edilmiştir. Elde edilen tartım değerlerinin oranlanması suretiyle selüloz değerleri tespit edilmiştir.



Şekil 10. Laboratuvar analizinden görüntüler

10. Hayvan Performansı: Otlatma süresi boyunca hayvanlara ek yem verilmemiştir. Mera örneklemesine paralel olarak 21 günde bir hayvanlar tartılmış ve canlı ağırlıklar belirlenmiştir. Hayvan performanslarına ait veriler, kuzuların günlük canlı ağırlık artışları (gr/gün) ve kuzuların hektar alanda et verimleri(kg/gün/ha) üzerinden değerlendirilmiştir.

3.3. VERİLERİN DEĞERLENDİRİLMESİ

Denemeden elde edilen 2013, 2014 yılları ve iki yıllık ortalamalara ait veriler Tesadüf bloklarında İki Faktörlü (Yıl, Irk) Deneme desenine göre varyans analizi uygulanmıştır. İncelenen özelliklere ait ortalamalar ise "Tukey" önem testine göre gruplandırılmıştır. Buna göre aynı gruba giren ortalamalar aynı harflerle, birbirinden farklı ortalamalar ise farklı harflerle gösterilmiştir. İstatistik analizlerde Jump 15 istatistik paket programından yararlanılmıştır.

4. BULGULAR

4.1.Yeşil Ot Verimi (kg/da)

Denemenin iki yıllık bulguları sonucunda; Konya şartlarında oluşturulmuş sulanan meradan elde edilen toplam iki yıllık ortalama yeşil ot verimleri; hayvan ırklarının bulunduğu parseller arasında istatistikî olarak (P>0.05) önemsiz bulunmuştur (Çizelge 5). Çalışmada, AKK, OAM, Hasmer ve Hasak ırklarının bulunduğu parsellerin yeşil ot verimleri sırası ile; 2013 yılında 3615,3659,3675ve 3616 kg/da, 2014 yılında ise 3206, 3248, 3232 ve 3256 kg/da yıllar ortalaması ise 3410, 3454, 3456, 3434 kg/da elde edilmiştir.

Çizelge 5. 2013-2014 yılları ortalama yeşil ot verimleri (kg/da)

Kuzu ırkları	Yıllar(kg/da)		Ortalama
	2013	2014	
AKK	3615	3206	3410
OAM	3659	3248	3454
Hasmer	3675	3232	3456
Hasak	3616	3256	3434
F değeri	ÖD	ÖD	ÖD

Çizelge 6. 2013-2014 yılları her biçim toplam ortalama yeşil ot verimleri (kg/da)

B. S	**2013**				**2014**			
	AKK	**OAM**	**Hasmer**	**Hasak**	**AKK**	**OAM**	**Hasmer**	**Hasak**
1	1096a	1048ab	1062ab	1041ab	934bc	946bc	907c	941bc
2	478d-f	435e-g	483d-f	498d-f	402f-j	412e-j	411e-j	436e-g
3	408e-j	426e-h	423e-h	416e-ı	296h-n	314 g-k	308g-m	308g-m
4	408e-j	481d-f	439e-g	418e-h	188k-n	190k-n	196k-n	199k-n
5	298h-n	283jn	190 k-n	311g-ı	183k-n	189k-n	286 ı-n	202k-n
6	539de	593d	590d	508d-f	539d-e	515d-f	531d-f	531d-f
7	218k-n	213k-n	221k-n	220k-n	463d-f	421e-h	454e-f	458ef
8	169n	180n	172n	179 mn	202k-n	263k-n	240k-n	212k-n
T	3615ab	3659a	3675ab	3616ab	3206c	3248c	3232c	3256c

Kuzuların tartımına paralel olarak 21 günde bir biçim yapılarak yılda 8 biçim yapılmıştır (Çizelge 6). En yüksek biçimi otlatma başlangıcında; 2013 yılında otlatma başlangıcı 1.biçimde 1096-1062 kg/da arasında alınırken en düşük biçimi otlatma sonunda; 2013 yılında 8.biçimde 179 -169 kg/da alınmıştır. 2014 yılında ise yine en yüksek biçimi otlatma başlangıcında1.biçimde 946-907 kg/da arasında alınırken en düşük biçimi 5.biçimde 202-189 kg/da alınmıştır. Denemenin genelinde iklim ve otlatma yoğunluğuna bağlı olarak otlatma başından otlatma sonuna kadar yeşil ot veriminde azalma görülmüştür.

4.2. Kuru Ot Verimi (kg/da)

Denemenin iki yıllık bulguları sonucunda; Konya şartlarında oluşturulmuş sulanan meradan elde edilen iki yıllık toplam ortalama yaş ot verimleri; hayvan ırklarının bulunduğu parseller arasında istatistikî olarak (P>0.05) önemsiz bulunmuştur (Çizelge 7). Çalışmada; AKK, OAM, Hasmer ve Hasak ırklarının bulunduğu parsellerin kuru ot verimleri sırası ile 2013 yılında 900, 907, 880 ve 908 kg/da, 2014 yılında, kg/da 765, 766, 766 ve 786 kg/da, yıllar ortalaması ise 833, 836, 823 ve 847 kg/da elde edilmiştir.

Çizelge 7. 2013-2014 yılları ortalama kuru ot verimleri (kg/da)

Kuzu ırkları	Yıllar(kg/da)		Ortalama
	2013	2014	
AKK	900	765	833
OAM	907	766	836
Hasmer	880	766	823
Hasak	908	786	847
F değeri	ÖD	ÖD	ÖD

Kuzuların tartımına paralel olarak 21 günde bir biçim yapılarak yılda 8 biçim yapılmıştır. Her biçimden elde edilen örnekler etüvde kurutulduktan sonra gerekli tartım ve oranlama yapılarak; en yüksek kuru ot verimini otlatma başlangıcında; 2013 yılında 1.biçimde 268-258 kg/da arasında alınırken en düşük kuru ot verimini otlatma sonunda; 2013 yılında 8.biçimde 37-42 kg/da alınmıştır. 2014 yılında ise yine en yüksek kuru ot verimini otlatma başlangıcında 250-232 kg/da arasında alırken en düşük kuru ot verimini 5.biçimde 42-47 kg/da alınmıştır. Denemenin genelinde iklim ve otlatma yoğunluğuna bağlı olarak otlatma başından otlatma sonuna kadar kuru ot verimlerinde azalma görülmüştür(Çizelge 8).

Çizelge 8. 2013-2014 yılları her biçim için toplam ortalama kuru ot verimleri(kg/da)

B. S	**2013**				**2014**			
	Ak karaman	**K mernosu**	**Hasmer**	**Hasak**	**Ak karaman**	**K mernosu**	**Hasmer**	**Hasak**
1	268a	267a	239ab	258ab	232b	248ab	246ab	250ab
2	120c-k	104d-n	109c-k	136cd	95jq	87k-t	92j-r	100h-o
3	99 h-o	102e-n	101f-n	90k-s	58y	64q-y	60r-y	68 o-y
4	122c-j	139c	132c-g	117c-ı	57t-y	56t-y	61r-y	57 t-y

5	78n-v	75nw	72n-x	82 m-u	42xy	42k-y	42x-y	47v-y
6	133c-f	131c-h	134c-e	137c	127c-ı	114c-m	114c-m	112c-m
7	44w-y	48qvy	45wy	47k-y	98ı-p	86 l-t	95 lq	101g-n
8	37o-y	42xy	37y	42w-y	56t-y	66 p-y	57 t-y	51 u-y
T	900a	907a	880ab	909a	765b	766b	767b	786b

4.3.Kuru Madde Oranları (%) ve Verimleri (kg/da):

2013-2014 yıllara ve ortalamalarına ait kuru madde oranları (%) ve verimleri(kg/da) çizelge 9'da görüldüğü gibi farklı kuzu ırklarında uygulanan parsellerdeki karışımlar arasında yıllar ortalaması olarak gruplar arasında önemli bir fark bulunmamıştır.

Çizelge 9. 2013-2014 yılları ortalama kuru madde oranları (%) ve kuru madde verimleri (kg/da)

Kuzu ırkları	**KMO (%)**		**KMV (kg/da)**		**Yıllar Ortalama**	
	2013	**2014**	**2013**	**2014**	**KMO (%)**	**KMV (kg/da)**
AKK	93.7	92.3	842	702	93.1	772
OAM	93.8	92.2	850	703	93.0	777
Hasmer	93.4	92.1	819	704	93.0	762
Hasak	93.9	92.3	850	722	93.8	786
F değeri	ÖD	ÖD	ÖD	ÖD	ÖD	ÖD

Çalışmada, AKK, OAM, Hasmer ve Hasak ırklarının bulunduğu parsellerin kuru madde oranları ve kuru madde verimleri sırası ile 2013 yılında % 93.7, 93.8, 93.4, 93.9 ; 842, 850, 819, 850, 2014 yılında ise % 92.3, 92.2, 92.1, 92.3; 702, 703, 704, 722 kg/da yıllar ortalaması ise % 93.1, 93.0, 93.0, 93.8 ;772, 777, 762, 786 kg/da elde edilmiştir.

4.4. Karışımların Ağırlıkça Botanik Kompozisyonu (%)

Karışımı oluşturan bitki türlerini ağırlıkça botanik kompozisyonu bulmak için, her parseldeki otlanılan alanlardan tesadüfi elle örnek alınarak bitkiler türlerine göre ayrılmıştır. Bu türler ayrı ayrı tartılarak toplam ağırlığa oranlanıp her bitki türlerin botanik kompozisyonundaki ağırlıkça yüzdesi bulunmuştur. Otlatma yoğunluğu ve yaz sıcaklığına bağlı olarak İngiliz çiminin birinci ve ikinci yılda karışımdaki oranı yaz aylarında düşmüştür. Yıllar ortalaması olarak denemede kullanılan karışımdaki bitki türlerine göre % oranları İngiliz çimi 9.1-8.9, domuz ayrığı 22.0-21.2, kamışsı yumak 19.9-18.7, gazal boynuzu 33.1-32.4, ak üçgül 6.3-5.4 yabancı ot ve diğerleri11.0- 10.5 arasında değişmektedir. Karışımda en yüksek değerler gazal boynuzu, domuz ayrığı ve kamışsı yumak bitki türlerinden alınmış, İngiliz çimi ile yabancı ot birbirine yakın değerler alırken en düşük oran ak üçgülden elde edilmiştir (Çizelge 10).

Çizelge 10. 2013-2014 yılları botanik kompozisyon (% ağırlık)

Yıllar ortalaması	Kuzu ırkları	İÇ	DA	KY	G.B	A.Ü	Y.O ve D
2013	Hasak	10.6a	23.2a	20.3ab	33.4ab	3.3b	8.9c
	AKK	10.9a	22.9a	19.2bcd	33.9a	3.8b	9.0c

	Hasmer	11.3a	22.7a	20.2abc	33.3ab	4.2b	8.0c
	OAM	11.2a	22.5a	21.2a	33.0abc	3.8b	8.5c
2014	Hasak	7.2b	20.9b	18.8cd	32.9abc	7.5a	12.6ab
	AKK	7.6b	21.1b	18.2d	32.0bc	8.8a	12.0b
	Hasmer	7.2b	19.8b	19.0bcd	31.5c	8.1a	14.0a
	OAM	7.1b	20.5b	18.7d	32.5abc	7.9a	12.5ab
2013-2014	Hasak	8.9a	22.0a	19.6ab	33.1a	6.3a	10.8a
	AKK	9.3a	22.0a	18.7b	32.9a	5.4b	10.5a
	Hasmer	9.3a	21.2a	19.6ab	32.4a	6.2ab	11.0a
	OAM	9.1a	21.5a	19.9a	32.7a	5.4b	10.5a
	F değeri	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

İÇ(İngiliz Çimi), DA(Domuz ayrığı), KY(Kamışsı yumak), GB(Gazal Boynuzu), AÜ(Aküçgül),YO(Yabancı ot)

4.5.Ham Protein Oranı(%) ve Verimi (kg/da)

2013-2014 yıllarında kuzu ırklarına bağlı olarak karışımların ham protein oranı ve ham protein verimlerine ait değerler Çizelge 11'de verilmiştir. Araştırmada ham protein oranı ve protein verimi bakımından karışımlar arasında fark istatistikî olarak (P>0.05) önemsiz bulunmuştur. Çalışmada, AKK, OAM, Hasmer ve Hasak ırklarının bulunduğu parsellerin protein oranı ve protein verimleri sırası ile 2013 yılında % 18.6, 18.4, 18.6, 18.7; 147.2, 156.0, 149.6, 160.8 kg/da 2014 yılında ise % 18.1, 18.3, 18.0, 18.1; 145.6, 147.2, 146.4, 148.8 kg/da yıllar ortalaması ise % 18.3, 18.4, 18.3, 18.4; 146.4, 151.2, 147.2, 154.4 kg/da elde edilmiştir.

Çizelge 11. Ortalama ham protein oranı (HPO) (%) ve kuru otta ham protein verimi (HPV) (kg/da)

Kuzu ırkları	**HPO (%)**		**HPV (kg/da)**		**Yıllar Ortalama**	
	2013	**2014**	**2013**	**2014**	**HPO (%)**	**HPV (kg/da)**
AKK	18.6	18.1	147.2	145.6	18.3	146.4
OAM	18.4	18.3	156.0	147.2	18.4	151.2
Hasmer	18.6	18.0	149.6	146.4	18.3	147.2
Hasak	18.7	18.1	160.8	148.8a	18.4	154.4
F değeri	ÖD	ÖD	ÖD	ÖD	ÖD	ÖD

4.6.ADF ve NDF Oranları (%)

2013-2014 yıllarında kuzu ırklarına bağlı olarak karışımların ADF oranı ve NDF oranlarına ait değerler Çizelge 12'de verilmiştir. Araştırmada ADF oranı ve NDF oranı bakımından karışımlar arasındaki ortalamada fark istatistikî olarak (P>0.05) önemsiz bulunmuştur. Çalışmada, AKK, OAM, Hasmer ve Hasak ırklarının bulunduğu parsellerin ADF oranı ve NDF oranları sırası ile 2013 yılında % 31.3, 31.3, 31.4,31.5; % 47.4, 47.4, 47.6,47.5 2014 yılında ise % 33.4, 33.3, 33.3, 33,3; % 51.2, 51.5, 51.4, 51.5 yıllar ortalaması ise % 32.2, 32.3, 32.3, 32.4; 49.3, 49.6, 49.5, 49.5 elde edilmiştir.

Çizelge 12. Ortalama ADF(%) ve NDF(%) oranları

Kuzu ırkları	ADF (%)		NDF (%)		Yıllar Ortalama	
	2013	2014	2013	2014	ADF (%)	NDF (%)
AKK	31.3	33.4	47.4	51.2	32.2	49.3
OAM	31.3	33.3	47.4	51.5	32.3	49.6
Hasmer	31.4	33.3	47.6	51.4	32.3	49.5
Hasak	31.5	33.3	47.5	51.5	32.4	49.5
F değeri	ÖD	ÖD	ÖD	ÖD	ÖD	ÖD

4.7. Ham Kül ve Selüloz Oranları(%)

2013-2014 yıllarında kuzu ırklarına bağlı olarak karışımların ham kül ve selüloz oranlarına ait değerler Çizelge 13'de verilmiştir. Araştırmada ham kül oranı ve selüloz oranı bakımından karışımlar arasındaki ortalamada fark istatistikî olarak (P>0.05) önemsiz bulunmuştur. Çalışmada, AKK, OAM, Hasmer ve Hasak ırklarının bulunduğu parsellerin ham kül oranı ve selüloz oranları sırası ile 2013 yılında % 12.4, 12.3, 12.5, 12.3; % 25.3, 25.1, 25.6, 25.6 2014 yılında ise % 11.7, 11.6, 11.7, 11.7; % 29.3, 29.2, 29.4, 29.3 yıllar ortalaması ise % 12.0, 12.0, 12.1, 12.0 ;% 27.3, 27.2, 27.4, 27.5 elde edilmiştir.

Çizelge 13.Yıllar ortalama ham kül(%) ve selüloz(%) oranları

Kuzu ırkları	Ham kül(%)		Selüloz (%)		Yıllar Ortalaması	
	2013	2014	2013	2014	Ham kül(%)	Selüloz(kg/da)
AKK	12.4	11.7	25.3	29.3	12.0	27.3
OAM	12.3	11.6	25.1	29.2	12.0	27.2
Hasmer	12.5	11.7	25.6	29.4	12.1	27.4
Hasak	12.3	11.7	25.6	29.3	12.0	27.5
F değeri	ÖD	ÖD	ÖD	ÖD	ÖD	ÖD

4.8. Hayvan Performansı

Kuzuların Günlük Canlı Ağırlık Artışları (gr/gün)

Toplam otlatma periyodu boyunca kuzuların iki yıllık günlük canlı ağırlık artışları Çizelge 14'de verilmiştir. 2013 yılında kuzuların günlük ortalama canlı ağırlık artışları 71.0 - 99.6 gr/gün arasında değişmiştir. 2014 yılında ise kuzuların günlük ortalama canlı ağırlık artışları 84.2 - 106.8 gr/gün arasında değişmiştir. 2013 ve 2014 yılları ortalaması ise 80.3 - 93.8 gr/gün arasında değişmiştir.

Günlük canlı ağırlık artışlarını ırklar arasında karşılaştırdığımızda her iki yılda da en yüksek AKK ırkından (2013 yılı 99.6 gr/gün, 2014 yılı 106.8 gr/gün iki yıl ortalaması ise 103.2 gr/gün) elde edilmiştir. Denemedeki diğer Hasak, Hasmer ve OAM ırklarının sırasıyla ortalama günlük canlı ağırlık artışları 2013 yılında 70.7, 79.8 ve 71.0 gr/gün; 2014 yılında 84.2, 97.8 ve 86.5 gr/gün, iki yıl ortalaması ise 77.4, 88.8 ve 78.7 gr/gün olarak tespit edilmiştir. Otlatma periyodu boyunca günlük canlı ağırlık artışı bakımından ırkların ortalamaları arası fark istatistik olarak önemli bulunmuştur (P<0.001).

Kuzuların Et Verimi (kg/ha/gün)

Toplam otlatma periyodu boyunca kuzuların iki yıllık et verimleri Çizelge 15'de verilmiştir. 2013 yılında kuzuların Hektar alanda ortalama et verimi günlük 4.2 - 7.1 kg, 2014 yılında ise 5.1 - 6.4 kg arasında değişmiştir. 2013 ve 2014 yılları ortalaması sırasıyla 5.1 ve 5.6 kg olarak tespit edilmiş ve yıllar arası farklılık istatistik olarak önemli bulunmuştur ($P<0.001$).

Hektar alanda günlük et verimi (kg/gün/ha) artışlarını ırklar arasında karşılaştırdığımızda ortalama her iki yılda da en yüksek AKK ırkından (2013 yılı 7.1 kg, 2014 yılı 6.4 kg iki yıl ortalaması ise 6.7 kg) elde edilmiştir. Diğer ırklar olan Hasak, Hasmer ve OAM ırklarında sırasıyla 2013 yılında 4.2, 4.8 ve 4.3 kg; 2014 yılında 5.1, 5.9 ve 5.2 kg; iki yıl ortalaması olarak ise 4.6 kg, 5.3 kg ve 4.7 kg olarak tespit edilmiştir. Otlatma periyodu boyunca hektar alanda et verimi bakımından ırkların ortalamaları arasındaki fark istatistik olarak önemli bulunmuştur ($P<0.001$).

Çizelge 14. 2013 ve 2014 yılları otlatma periyodu boyunca kuzuların dönemlere ait günlük canlı ağırlık değişimleri (g/gün)

FAKTÖR	1. Dönem		2. Dönem		3. Dönem		4. Dönem		5. Dönem		6. Dönem		7. Dönem		Toplam	
	N	GLM±SEM	N	GLM±SEM	N	GLM±SEM	N	GLM±SEM	N	GLM±SEM	N	GLM±SEM	N	GLM±SEM	N	GLM±SEM
YIL																
2013	120	135.4±4.34	120	126.5±5.91	96	36.0±5.08	96	-71.2±5.08	72	91.8±4.26	72	174.3±7.04	72	31.8±9.83	72	80.3±2.73
2014	72	135.8±5.79	72	196.9±5.33	72	123.7±6.71	72	-12.0±6.23	72	52.7±4.49	72	169.9±7.38	72	14.0±8.71	72	93.8±2.71
P		0.959		0.001		0.001		0.001		0.001		0.662		0.164		0.001
IRK																
AKK	48	138.7±7.17	48	187.3±8.37^{a}	42	120.6±10.10^{a}	42	-18.3±7.77^{a}	36	76.2±6.56	36	189.9±11.70^{a}	36	22.4±14.10^{b}	36	103.2±4.29^{a}
HASAK	48	140.1±7.27	48	147.0±8.59^{b}	42	76.7±10.10^{b}	42	-52.6±8.60^{b}	36	67.7±7.55	36	175.5±8.70^{ab}	36	-8.5±14.50^{b}	36	77.4±3.46^{b}
HASMER	48	137.6±7.09	48	156.7±11.40^{ab}	42	56.7±9.65^{b}	42	-35.5±8.81^{ab}	36	75.1±8.08	36	178.3±10.50^{ab}	36	32.2±11.00^{b}	36	88.8±3.47^{b}
OAM	48	125.8±7.42	48	155.9±9.52^{b}	42	65.3±9.90^{b}	42	-60.0±7.74^{b}	36	70.0±5.65	36	144.6±8.23^{b}	36	45.7±11.50^{a}	36	78.7±3.25^{b}
P		0.498		0.005		0.001		0.001		0.727		0.012		0.023		0.001
YIL*IRK																
2013 AKK	30	145.6±8.17	30	151.3±8.91	24	79.0±10.20^{c}	24	-30.0±12.40^{b}	18	96.5±7.98	18	191.5±13.20	18	22.8±24.60	18	99.6±5.79
2013 HASAK	30	142.2±8.57	30	107.9±9.45	24	20.0±7.02^{d}	24	-87.5±9.88^{c}	18	79.4±10.10	18	186.5±10.80	18	19.1±21.70	18	70.7±5.15
2013 HASMER	30	130.3±8.87	30	132.4±16.20	24	17.1±8.64^{d}	24	-66.3±10.60^{bc}	18	105.9±7.84	18	181.5±15.00	18	21.4±14.50	18	79.8±4.18
2013 OAM	30	123.5±8.57	30	114.4±10.10	24	27.8±9.33^{d}	24	-101.2±10.30^{c}	18	85.2±7.16	18	137.6±14.30	18	64.0±15.80	18	71.0±3.75

2014 AKK	18	131.9±11.39	18	223.3±9.98	18	162.2±12.20[a]	18	-6.6±12.20[a]	18	56.0±8.09	18	188.4±19.70	18	22.0±14.70	18	106.8±6.40
2014 HASAK	18	138.0±11.73	18	186.0±8.10	18	133.3±7.66[ab]	18	-17.7±8.73[ab]	18	56.0±10.80	18	164.6±13.40	18	-36.1±17.60	18	84.2±4.19
2014 HASMER	18	145.0±11.06	18	181.0±10.90	18	96.3±13.40[bc]	18	-4.8±14.38[a]	18	44.3±9.79	18	175.1±15.20	18	42.9±16.50	18	97.8±4.77
2014 OAM	18	128.2±12.12	18	197.4±11.20	18	102.9±14.30[bc]	18	-18.8±8.14[ab]	18	54.8±7.28	18	151.6±8.33	18	27.3±16.00	18	86.5±4.73
P		0.540		0.489		0.245		0.049		0.147		0.65		0.141		0.724
GENEL	**192**	**135.6±3.62**	**192**	**161.7±4.22**	**168**	**79.8±3.67**	**168**	**-41.6±4.02**	**144**	**72.2±3.08**	**144**	**172.1±4.98**	**144**	**22.9±6.36**	**144**	**87.0±1.75**

[a,b,c,d] : Aynı sütunda faktör seviyelerinde farklı harfleri taşıyan ortalamalar birbirinden farklıdır (P<0.05).

Çizelge 15. 2013 ve 2014 yılları otlatma periyodu boyunca kuzuların dönemlere ait günlük et üretimi (kg/gün/ha)

FAKTÖR	1. Dönem		2. Dönem		3. Dönem		4. Dönem		5. Dönem		6. Dönem		7. Dönem		Toplam	
	N	GLM±SEM	N	GLM±SEM	N	GLM±SEM	N	GLM±SEM	N	GLM±SEM	N	GLM±SEM	N	GLM±SEM	N	GLM±SEM
YIL																
2013	120	13.6±0.38	120	12.7±0.59	96	2.9±0.41	96	-5.7±0.38	72	5.8±0.29	72	10.9±0.47	72	2.2±0.64	72	5.1±0.23
2014	72	8.2±0.51	72	11.8±0.32	72	7.4±0.40	72	-0.7±0.46	72	3.2±0.27	72	10.2±0.44	72	0.8±0.52	72	5.6±0.16
P		0.001		0.287		0.001		0.001		0.001		0.244		0.098		0.027
IRK																
AKKARAMAN	48	11.2±0.62	48	14.3±0.61^{a}	42	8.0±0.62^{a}	42	-1.4±0.58^{a}	36	5.1±0.51	36	12.3±0.77^{a}	36	1.9±0.99^{ab}	36	6.7±0.35^{a}
HASAK	48	11.3±0.63	48	11.0±0.61^{b}	42	4.8±0.62^{b}	42	-4.0±0.58^{b}	36	4.1±0.45	36	10.5±0.52^{ab}	36	-0.5±0.87^{b}	36	4.6±0.21^{b}
HASMER	48	10.9±0.62	48	12.1±1.05^{ab}	42	3.6±0.62^{b}	42	-2.8±0.65^{ab}	36	4.5±0.49	36	10.7±0.63^{ab}	36	1.9±0.66^{ab}	36	5.3±0.21^{b}
MERİNOS	48	10.1±0.66	48	11.6±0.67^{ab}	42	4.2±0.64^{b}	42	-4.6±0.57^{b}	36	4.2±0.34	36	8.7±0.49^{b}	36	2.7±0.69^{a}	36	4.7±0.20^{b}
P		0.488		0.022		0.001		0.001		0.222		0.001		0.031		0.001
YIL*IRK																
2013 AKKARAMAN	30	14.6±0.76	30	15.1±0.89	24	6.3±0.82	24	-2.4±0.99^{b}	18	6.9±0.68	18	13.3±0.96	18	2.5±1.80	18	7.1±0.57^{a}
2013 HASAK	30	14.2±0.74	30	10.8±0.95	24	1.6±0.56	24	-7.0±0.79^{c}	18	4.8±0.61	18	11.2±0.65	18	1.1±1.30	18	4.2±0.31^{d}
2013 HASMER	30	13.0±0.78	30	13.2±1.62	24	1.4±0.69	24	-5.3±0.85^{bc}	18	6.4±0.47	18	10.9±0.90	18	1.3±0.87	18	4.8±0.25^{cd}
2013 MERİNOS	30	12.4±0.75	30	11.4±1.01	24	2.2±0.75	24	-8.1±0.83^{c}	18	5.1±0.43	18	8.3±0.86	18	3.8±0.95	18	4.3±0.23^{d}
2014 AKKARAMAN	18	7.9±0.98	18	13.4±0.60	18	9.7±0.73	18	-0.4±0.73^{a}	18	3.4±0.49	18	11.3±1.18	18	1.3±0.88	18	6.4±0.38^{ab}

2014 HASAK	18	8.3±1.02	18	11.2±0.49	18	8.0±0.46	18	-1.1±0.52^{ab}	18	3.4±0.65	18	9.9±0.81	18	-2.2±1.06	18	5.1±0.25^{bcd}
2014 HASMER	18	8.7±0.96	18	10.9±0.66	18	5.8±0.80	18	-0.3±0.88^{a}	18	2.7±0.59	18	10.5±0.91	18	2.6±0.99	18	5.9±0.29^{abc}
2014 MERİNOS	18	7.7±1.05	18	11.8±0.67	18	6.2±0.86	18	-1.1±0.49^{ab}	18	3.3±0.44	18	9.1±0.50	18	1.6±0.96	18	5.2±0.28^{bcd}
P		0.521		0.477		0.197		0.018		0.084		0.387		0.22		0.035
GENEL	**192**	**10.9±0.32**	**192**	**12.2±0.39**	**168**	**5.1±0.26**	**168**	**-3.2±0.29**	**144**	**4.5±0.19**	**144**	**10.6±0.31**	**144**	**1.5±0.40**	**144**	**5.4±0.12**

^{a,b,c,d} : Aynı sütunda faktör seviyelerinde farklı harfleri taşıyan ortalamalar birbirinden farklıdır (P<0.05).

GLM : General Linear Model

SEM : Standard Error Mean

4.9. Ekonomik Analiz

Bu çalışmada, 2013 ve 2014 yılı ortalaması olarak kuzu ırklarına göre hayvan başına AKK ırkında 15,48 kg, OAM 10,65 kg, Hasmer ırkında 12 kg, Hasak ırkında 11,61 kg canlı ağırlık artışları gerçekleşmiştir. Irklara göre bu canlı ağırlık artışının brüt üretim değeri en yüksek 170,28 TL ile AKK olurken bunu 132 TL ile Hasmer, 127,71 TL ile Hasak ve 117,15 TL ile OAM takip etmektedir.(Çizelge 16.)

Çizelge 16. Kuzu gruplarına göre hayvanların ortalama canlı ağırlık artışlarının ekonomik analizi

Kuzu ırkları	HB Toplam Canlı Ağırlık Artış Miktarı (kg)	Birim fiyatı (TL/kg)	HB Toplam CA Artışının Brüt Üretim Değeri (TL)	Kısmi Bütçe Analizi	
				Hayvan Başına (TL)	Hektara (TL)
AKK	15,48	11	170,28	53,13	3.187,80
OAM	10,65	11	117,15	0,00	0,00
Hasmer	12,00	11	132,00	14,85	891,00
Hasak	11,61	11	127,71	10,56	633,60

5.TARTIŞMA VE SONUÇ:

Araştırmada, elde edilen kuru ot verimi değerleri ortalama 783.0-827.5 kg/da arasında yeşil ot verimleri ise 3299.5-3421.5 kg/da arasında değişim göstermiştir. Bu değerler, İşliel ve ark. (1962)'nın bildirdiği gibi, yeşil ot verimi(3350-4222 kg/da), Serin ve ark. (1997)'nın bildirdiği gibi, kuru ot verimi (1096-731 kg/da), tespit etmişlerdir. Işık ve ark.(2011) bildirdiği araştırmada elde edilen yeşil ot verimi (3894-1856 kg/da) ve kuru ot verimi (973-459 kg/da) elde etmişlerdir. Bu değerlerle araştırmamızda elde edilen değerler kıyaslandığında kimi yukarıdaki değerlerden yüksek, kimi değerlerden paralel ve kimi değerlerden düşük çıkmıştır.

Araştırmada elde edilen ham protein oranı ve ham protein verimleri ortalama sırası ile %18.3-%18.4 ve 146.4-154.4 arasında değişim göstermiştir. Bu değerler; Çukurova ve Konya taban koşullarında buğdaygil yem bitkisi türleri ile bazı çok yıllık baklagil yem bitkisi türlerinin karışımlarında; Çukurova koşullarında (Çınar S.,2012) protein oranlarının % 9.9 - % 20.6, protein verimlerinin ise 80.9-232.4 kg/da arasında değişen ve Konya koşullarında ise (Işık ve Ark.2012) protein oranlarının % 16.8 - % 17.5, protein verimlerinin ise 78.5-164.6 kg/da elde etmişlerdir. Bu değerlerle araştırmamızda elde edilen değerler kıyaslandığında kimi yukarıdaki değerlerden yüksek, kimi değerlerden paralel ve kimi değerlerden düşük çıkmıştır.

Araştırmada elde edilen ADF ve NDF oranları ortalamaları sırası ile % 32.2-32.4; % 49.3-49.6 arasında değişim göstermiştir. Çukurova ve Konya taban koşullarında buğdaygil yem bitkisi türleri ile bazı çok yıllık baklagil yem bitkisi türlerinin karışımlarında ADF ve NDF oranlarının Çukurova koşullarında (Çınar S.,2012) ADF oranlarının % 26.7 - % 40.2, NDF oranlarını ise % 38.5-%70.9 arasında değişen ve Konya koşullarında (Işık ve Ark.2012) ADF oranlarının % 37.9 - % 41.0, NDF oranlarını ise % 56.2- %59.4 arasında değişen değerlerde elde ettiği verilerle paralellik ve uyum göstermektedir.

Araştırmada elde edilen ham kül (%) ve selüloz (%) oranları ortalamaları sırası ile %12.0-%12.1; % 27.2- % 27.5 arasında değişim göstermiştir. Bu değerler; Çukurova ve Konya taban koşullarında buğdaygil yem bitkisi türleri ile bazı çok yıllık baklagil yem bitkisi türlerinin

karışımlarında ham kül (%) ve selüloz (%) oranlarının Çukurova koşullarında (Çınar S.,2012) Ak üçgülde ham selüloz oranı biçim zamanına bağlı olarak % 23.7 - % 27.4, Çayır kelp kuyruğunda ise % 24.7 - % 29.4 olarak tespit etmiştir. Yoncada ham kül oranı ve ham selüloz oranı biçim zamanına bağlı olarak sırası ile % 12.80 - % 15.56 ; % 26.44 - % 35.13 arasında değiştiğini tespit etmiştir. Konya koşullarında (Işık ve Ark.2012) ham kül (%) ve selüloz (%) oranlarının sırası ile % 10.6 - % 10.9; 22.7 kg - 24.6 kg arasında değişen değerler elde etmişlerdir. Bu değerlerle araştırmamızda elde edilen değerler kıyaslandığında kimi yukarıdaki değerlerden yüksek, kimi değerlerden paralel ve kimi değerlerden düşük çıkmıştır.

Sonuç olarak yapay mera karışımında otlatma periyoduna bağlı olarak, meranın ot verimi ve kalitesindeki değişim ile bu değişimin merada otlayan kuzuların performansı üzerine etkilerinin incelenmesi amacıyla yürütülen bu projeden iki yıllık elde edilen verilerden yola çıkarak;

Merada elde edilen botanik kompozisyon değerlerine göre otlatılan kısımlarda ilk baharda buğdaygil oranları artarken yaz mevsimine doğru gittikçe doğrusal bir azalma olmaktadır. Özellikle İngiliz çiminin oranları ilkbaharda hızla artmasına karşın yaz mevsimine doğru ilerledikçe hızla düşüş yaşanmıştır. Yaz sıcaklarında domuz ayrığı daha iyi gelişme göstermiştir. Karışımda baklagil oranları ilkbahardan itibaren yaza doğru iyi gelişme gösterdiği yaz aylarında oranlarının daha çok arttığı görülmüştür. Genel olarak değerlendirildiğinde hayvanlar tarafından en az tercih edilen tür kamışsı yumak olmuştur. Nedeni ise sert yapılı olmasından kaynaklanmaktadır.

Günlük canlı ağırlık artışlarını ırklar arasında karşılaştırdığımızda her iki yılda da en yüksek AKK ırkından (2013 yılı 99.6 gr/gün, 2014 yılı 106.8 gr/gün iki yıl ortalaması ise 103.2gr/gün) elde edilmiştir. Denemedeki diğer ırklardan Hasak, Hasmer ve OAM ırklarında günlük canlı ağırlık artışı sırasıyla 2013 yılında 70.7, 79.8 ve 71.0 gr/gün, 2014 yılında 84.2, 97.8 ve 86.5 gr/gün, iki yıl ortalaması ise 77.4, 88.8 ve 78.7 gr/gün olarak tespit edilmiştir. Otlatma periyodu boyunca ırkların günlük canlı ağırlık değişimleri ortalamaları arası fark istatistik olarak önemli bulunmuştur ($P<0.001$). GCAA'nın en yüksek olduğu dönemin 2014 deneme yılının 2. Döneminde olduğu tespit edilmiştir. 1. Dönem GCAA'ları bakımından yıl ve ırk faktörlerinin etkisi önemsiz bulunmuştur. 2. Dönemden itibaren yıl ve ırk faktörleri arasındaki farklılık önemli seviyede bulunmuştur. 2 yıllık deneme boyunca otlatma periyodunun her döneminde AKK ırkı kuzular diğer ırklara göre daha yüksek performans göstermişlerdir. Mera şartlarında Hasmer ve Hasak ırkı kuzuların pnömoniye yakalanma ihtimalinin daha yüksek olduğu bu sebeple mera şartlarındaki dinlenme barınaklarının kuzey yönünün mutlak suretle kapatılması gerektiği tespit edilmiştir. Bu amaçla 2013 yılının Mayıs ayından itibaren denemedeki bütün dinleme barınaklarının kuzey yönü branda ile kapatılmıştır. Ayrıca mera şartlarında beslenme programının Hasak, Hasmer ve OAM kuzularının gluteal bölgesinin (anüs ile meme arası) sürekli ıslak kalmasına ve özellikle yaz aylarında sinek zararlısına bağlı olarak kurtlanmalara sebebiyet verdiği gözlenmiştir. Bu amaçla 2013 yılında meradaki bütün kuzulara dış parazit mücadelesi yapılmıştır. 2014 yılında ise dış parazit mücadelesi ile beraber kuyruk bölgesinde yıkama işlemi gerçekleştirilmiştir. Bu amaçla dış parazit ilacı olarak ivermectin gurubu (Mektizan), yıkama ilacı olarak ta Biyotoks F kullanılmıştır. Uygulama uygun dozda her 21 günde bir tekrarlanmıştır. 2 yıllık deneme boyunca AKK rkının pnömoni ve kurt zararlısına karşı daha dayanıklı olduğu gözlenmiştir.

Hektar alanda günlük et verimi (kg/gün/ha) artışlarını ırklar arasında karşılaştırdığımızda her iki yılda da en yüksek AKK (2013 yılı 6.0 kg, 2014 yılı 6.4 kg iki yıl ortalaması ise 6.7 kg) elde edilmiştir. Denemedeki diğer ırklardan Hasak, Hasmer ve OAM ırklarında hektar alanda günlük et verimi sırasıyla 2013 yılında 4.2, 4.8 ve 4.3 kg; 2014 yılında 5.1, 5.9 ve 5.2 kg, iki yıl ortalaması ise 4.6 kg, 5.3 kg ve 4.7 kg olarak tespit edilmiştir. Otlatma periyodu boyunca denemedeki ırkların hektar alanda günlük et verimi ortalamaları arası fark istatistik olarak

önemli bulunmuştur (P<0.001). Et verimi üzerine yıl faktörünün etkisi önemli olup 2014 yılında daha yüksek et verimi elde edilmiştir (5.6 kg/gün/ha). 2013 ve 2014 yıllarında 1. otlatma dönemine ait ortalama GCAA arasında fark bulunmaz iken, aynı döneme ait hektar alanda günlük et verimi bakımından önemli olarak bulunan farklılık birim alandaki hayvan sayısından (2013 yılında 10 baş/da; 2014 yılında 6 baş/da) kaynaklanmaktadır.

Denemenin iki yıllık sonucunda sıcaklık, sürekli otlatma sisteminin etkisine bağlı olarak merada ot veriminin azaldığı dönemlerde AKK kuzuları OAM, Hasmer, Hasak kuzulara göre daha iyi gelişme göstermiştir.

OAM, Hasmer ve Hasak kuzularının ise mera şartlarında büyüme performanslarının benzerlik gösterdiği tespit edilmiştir.

OAM ırkına göre hayvan başına ve hektara canlı ağırlık artışı değerinin kısmi bütçe analizi sonucuna göre AKK, Hasmer ve Hasak ırklarında daha fazla gelir elde edilmektedir (Çizelge 16).

Aynı dönemde mera parselleri arasındaki kuru ot verimi, ham protein, ham kül, selüloz, NDF, ADF oranları üzerine ırkın etkisi önemsiz bulunmuştur. Ancak bahse konu verim özellikleri üzerine otlatma döneminin etkisi önemli bulunmuştur.

Bitki örtüsü zayıf ve botanik kompozisyonunda yeterli oranda iyi cins yem bitkileri bulundurmayan vejetasyonlarda, diğer ıslah yöntemleriyle başarıya ulaşmanın mümkün olmadığı yerlerde yapay mera tesisi yoluna gidilmelidir. Yapay mera tesis edilirken, karışıma giren türlerin birbirleri ile uyum sağlamaları hatta birbirlerinin olumsuz yönlerini gidermeleri gerekir (Altın, 1987).

Yüksek üretim ve otlatma için sürülerek tarla arazisine dönüştürülen alanlarda yapay mera kurulması akılcı bir çözümdür. Ancak otlatmanın mutlaka mera yönetim ilkelerine uygun yapılması gerekmektedir. Yapay meralarda otlatma amenajman ilkesine uyulması, Konya bölgesinde özellikle otlatma sistemlerinden sürekli otlatmadan kaçınıp münavebeli otlatma yoluna gidilmesinin uygun olacağı sonucuna varılmıştır. Aksi halde bu araştırmada da görüldüğü gibi, hayvanların otladığı kısımlarda bitkilerin kendini toparlamalarına fırsat verilmemekte ve meranın yoğun otlatılması, ekilen türlerde ve verimde kayıplara yol açarak merada daha az hayvan otlatılmasına, daha az üretimin gerçekleşmesine yol açmaktadır. Sıcaklığın en yüksek, ot verimin en düşük olduğu yaz aylarında, sürekli otlatma sistemine göre düzenlenen mera alanının muhafazası için dinlendirilmesinin uygun olacağı, dinlendirme şansı olmayan işletmelerde bu dönemde hayvanlara kaliteli kuru ot gibi ek yem verilmesinin gerektiği düşünülmektedir.

6.KAYNAKÇA

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ÇUKUROVA BÖLGESİNDE PAMUK (*gossypium spp.*) GENOTİPLERİNİN TARIMSAL VE LİF ÖZELLİKLERİNİN ISLAH POTANSİYELİ AÇISINDAN DEĞERLENDİRİLMESİ

Arş. Gör. Korhan ÖZCEYLAN

Çukurova Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü, Adana

Email: kozceylan@cu.edu.tr

ORCID: 0000-0003-0226-6198

Prof. Dr. Özgül GÖRMÜŞ

Çukurova Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü, Adana

Email: ogurmus@cu.edu.tr

ORCID: 0000-0003-2214-6708

ÖZET

Bu araştırma, ABD pamuk germplazm koleksiyonundan temin edilen iki farklı türe (*G. hirsutum ve G. barbadense*) ait bazı genotiplerin Çukurova koşullarında tarımsal performans ve lif kalite özelliklerinin belirlenmesi ve yürütülecek ıslah programlarına aktarılabilirliğinin araştırılması amacıyla yürütülmüştür. Araştırmada materyal olarak farklı tarımsal özelliklere sahip 10 genotip (SA 74, SA 263, SA 333, SA 345, SA 405, SA 408, SA 907, SA 1479, SA 1484 ve SA 1535) ile bölgede yaygın olarak yetiştirilen 2 ticari çeşit (Lazer ve May 455) kullanılmıştır. Deneme, 2024 yılında Çukurova Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü Araştırma ve Uygulama Alanı'nda tesadüf blokları deneme desenine göre 3 tekrarlamalı olarak kurulmuştur. Çalışmada, genotiplerin tarımsal özellikleri (bitki boyu, bitkideki boğum sayısı, odun dalı sayısı, meyve dalı sayısı, koza sayısı, tek kozada kütlü ağırlığı, çırçır randımanı ve kütlü pamuk verimi) ile lif kalite özellikleri (lif inceliği, lif uzunluğu, lif mukavemeti, kopma anında lif uzaması, iplik olabilirlik indeksi, yansıma ve sarılık dereceleri) incelenmiştir. Sonuçlar, test edilen pamuk genotiplerinin incelenen tarımsal ve lif kalite özellikleri bakımından önemli derecede farklılık gösterdiğini ortaya koymuştur. Kütlü pamuk verimi 2699–4995 kg/ha arasında değişmiş, en yüksek değer SA 1484 genotipinden elde edilmiştir. Lif uzunluğu, lif mukavemeti, kopma anında lif uzaması ve iplik olabilirlik indeksi bakımından ise SA 1479 genotipi ön plana çıkmıştır. Ancak *G. barbadense* L. türüne ait olan bu genotip, en düşük kütlü pamuk verimine (2699 kg/ha) sahip olmuştur. Tekstil lifinin iplik yapılabilirliğini ve pamuğun fiyatını önemli ölçüde belirleyici özellik olan lif inceliği 4.4-5.4 arasında değişim göstermiş, en ince liflere SA 333 genotipinde ulaşılmıştır. Genotipler arasında SA 405, 32.2 mm lif uzunluğu ile *G. barbadense* genotipine SA 1479 (32.5 mm) benzer uzunlukta lifleri oluşturmuştur. Saptanan lif mukavemeti değerleri 28.0-38.2 (g/tex) arasında değişkenlik göstermiştir. Sonuç olarak, genotiplerin tarımsal ve lif kalite özellikleri birlikte değerlendirildiğinde, bunların bölgesel pamuk ıslah programlarında ebeveyn olarak kullanılmasıyla hem yüksek verimli hem de üstün lif kalitesine sahip pamuk çeşitlerinin geliştirilmesine katkı sağlayabileceği belirlenmiştir.

Anahtar kelimeler: Pamuk, Tarımsal özellikler, Lif kalitesi, Genetik kaynak, Kütlü pamuk verimi

EVALUATION OF AGRONOMIC AND FIBER TRAITS OF COTTON (*gossypium spp.*) GENOTYPES FOR BREEDING POTENTIAL IN THE CUKUROVA REGION

ABSRACT

This study was conducted to determine the agronomic performance and fiber quality characteristics of some genotypes belonging to two different species (*G. hirsutum* L. and *G. Barbadense* L.) obtained from the U.S. cotton germplasm collection under Çukurova conditions, and to investigate their potential transferability to breeding programs. As research material, 10 genotypes with different agronomic traits (SA 74, SA 263, SA 333, SA 345, SA 405, SA 408, SA 907, SA 1479, SA 1484, and SA 1535) and 2 commercial cultivars commonly grown in the region (Lazer and May 455) were used. The experiment was established in 2024 at the Research and Experimental Area of Çukurova University, Faculty of Agriculture, Department of Field Crops, according to a randomized complete block design with 3 replications. In the study, agronomic traits of the genotypes (plant height, number of nodes, number of monopodial branches, number of sympodial branches, number of bolls, seed cotton weight, ginning turnout, and seed cotton yield) as well as fiber technological properties (fiber fineness, fiber length, fiber strength, fiber elongation, spinning consistency index, reflectance, and yellowness) were examined. The results revealed that the tested cotton genotypes showed significant differences in the studied traits. Seed cotton yield ranged between 2699–4995 kg/ha, with the highest value obtained from genotype SA 1484. In terms of fiber length, fiber strength, fiber elongation, and spinning consistency index, genotype SA 1479 stood out. However, this genotype, belonging to the species *G. barbadense* L., had the lowest seed cotton yield (2699 kg/ha). Fiber fineness, which is a highly decisive trait for spinnability and the price of cotton, ranged between 4.4 and 5.4, with the finest fibers obtained in genotype SA 333. Among the genotypes, SA 405 produced fibers with a length of 32.2 mm, similar to the *G. Barbadense* L. genotype SA 1479 (32.5 mm). The determined fiber strength values ranged between 28.0 and 38.2 (g/tex). As a result, when the agronomic and fiber quality traits of the genotypes were evaluated together, it was determined that their use as parents in regional cotton breeding programs could contribute to the development of cotton cultivars with both high yield and superior fiber quality.

Keywords: Cotton, Agronomic traits, Fiber quality, Germplazm, Seed cotton yield

1. GİRİŞ

Pamuk (Gossypium spp.), yalnızca ekonomik değeri yüksek bir lif bitkisi değil; aynı zamanda yağ, yem ve biyoenerji hammaddesi potansiyeli ile stratejik öneme sahip bir endüstri bitkisidir (Saleem ve ark., 2024). Pamuğun ve yan ürünlerinin ekonomik değerinin korunması amacıyla son 100 yıldır pamuk genetik kaynaklarının toplanması ve korunmasına yönelik uluslararası çabalar artmıştır (Campbell ve ark., 2010; Hinze ve ark., 2025). Kökenini 20. yüzyılın başlarında yürütülen toplama girişimlerinden alan modern ABD pamuk germplazm koleksiyonunda, günümüzde yetiştirilen kültür çeşitleri ile yabani pamuk türlerine ait sekiz yerel ırk belirlenmiştir (Percy ve ark., 2014). Bitki genetik kaynakları ve germplazm koleksiyonları, tarımsal üretimi biyotik ve abiyotik stres faktörlerinin zararlı etkilerinden koruyarak, hem günümüz hem de gelecek kuşakların gıda ve lif ihtiyacını güvence altına alan stratejik rezervlerdir. Bu rezervler özellikle kültür çeşitleri, yerel genotipler ve yabani akrabaların korunması ile sürdürülebilir tarımın ve ıslah çalışmalarının vazgeçilmez bir altyapısını oluşturur (Hinze ve ark., 2025). Ayrıca germplazm koleksiyonları tarımsal üretim haricinde ilaç, biyoteknoloji ve ekosistem hizmetleri açısından da stratejik bir öneme sahiptir. Tüm önemli tarla bitkilerinde modern çeşitlerden sürekli artan verim beklentisi, gen bankalarında bulunan genetik varyasyonun gelecekteki ıslah faaliyetleri için çok daha kritik bir rol oynayacağını göstermektedir. Koleksiyonlardan elde edilen genetik materyaller, özellikle kalite özelliklerinin iyileştirilmesi ve biyotik-abiotik streslere dayanıklı çeşitlerin geliştirilmesinde önemli rol oynar. Örneğin, son yıllarda yeni DNA dizileme teknolojileri, moleküler belirteçler ve genomik seçim teknikleri ile birlikte koleksiyonların taranması, spesifik genlerin hızlı şekilde ıslah programlarına aktarılmasına olanak sunmakta (McCouch ve ark., 2016; Cortés ve Barnaby, 2023), bu da pamuk verimi ve lif kalitesinin daha da geliştirilmesine katkı sağlamaktadır.

Tekstil endüstrisinde üretim verimliliği ve pamuklu dokuma kumaşların kalitesi, büyük ölçüde liflerinin sahip olduğu kalite özelliklerine bağlıdır. Lif uzunluğu, lif mukavemeti, lif inceliği (mikroner değeri), parlaklık ve renk derecesi gibi parametreler; iplik üretiminde eğirme verimliliğini, dokuma/örme performansını ve kumaşın kullanım özelliklerini etkilemektedir. Örneğin uzun ve ince lifler, daha dayanıklı ve düzgün yüzeyli ipliklerin üretilmesini sağlarken, düşük mukavemet veya yüksek varyasyon gösteren lifler üretim sırasında iplik kopuşlarını artırarak maliyetleri yükseltebilmektedir (Bradow ve Davidonis, 2000). Ayrıca pamuk lif kalitesi, tekstil ürünlerinin konfor, estetik ve dayanıklılık özellikleri açısından da stratejik öneme sahiptir. Tüketicilerin talep ettiği yüksek kaliteli kumaşlar, özellikle düşük mikroner değerine sahip, parlak ve homojen renkte liflerden elde edilmektedir. Bu nedenle iplik ve tekstil işletmeleri, farklı pamuk çeşitleri arasında kalite parametrelerine dayalı seçim yaparak üretim stratejilerini belirlemektedir. Son yıllarda özellikle genetik iyileştirme ve hassas tarım uygulamaları ile lif kalitesinin artırılmasına yönelik araştırmalar yoğunlaşmıştır (Özgüven ve Türker, 2010; Yang ve ark., 2023; Prince Charles ve Pandiyarajan, 2025).

Küresel ölçekte iklim değişikliğinin pamuk üretim alanlarında yarattığı belirsizlikler, lif kalite özelliklerinin korunmasını daha da kritik hale getirmiştir (Khan et al., 2025). Hasat dönemindeki yağışlar, sıcaklık dalgalanmaları ve kuraklık gibi faktörler, lif inceliği ve mukavemeti üzerinde olumsuz etkilere neden olabilmektedir (Saini ve ark., 2023). Bu bağlamda hem üreticiler hem de tekstil sanayi, kalite kayıplarını azaltacak yeni çeşitlerin geliştirilmesine ve hasat sonrası kalite koruma yöntemlerine yönelmektedir .

Bu çalışma, ABD Pamuk Germplazm Koleksiyonundan temin edilen bazı genotiplerin Çukurova koşullarında tarımsal performans ve lif kalite özelliklerinin değerlendirilmesini amaçlamaktadır. Elde edilecek sonuçlar, bölgesel ıslah programlarında ebeveyn olarak

kullanılabilecek genotiplerin seçilmesine katkı sağlayarak, hem yüksek verimli hem de üstün lif kalitesine sahip pamuk çeşitlerinin geliştirilmesine zemin oluşturacaktır.

2. MATERYAL ve YÖNTEM

Bu çalışma, Çukurova Üniversitesi Tarla Bitkileri Araştırma ve Uygulama alanında 2024 yılında yürütülmüştür. Çalışmanın yürütüldüğü Adana ilinin uzun yıllar ve 2024 yılına ait sıcaklık, yağış ve nem değerleri Çizelge 1'de verilmiştir.

Çizelge 1. Adana ili uzun yıllar ve 2024 yılına ait meteorolojik veriler.

Aylar	Ort. Sıcaklık (°C)		Ort nem (%)		Toplam Yağış (mm)	
	Uzun Yıllar	2024	Uzun yıllar	2024	Uzun Yıllar	2024
Ocak	9.6	12.3	66.4	71.9	112.1	74.1
Şubat	10.7	13.7	66.3	71.1	88.1	27.3
Mart	13.5	15.6	65.7	64.4	65.9	80.2
Nisan	17.6	21.8	67.4	66.1	51.6	29.3
Mayıs	21.9	22.5	66.6	70.4	48.6	91.8
Haziran	25.7	30.2	66.6	62.4	22.1	0.0
Temmuz	28.3	30.8	69.0	67.9	10.1	8.6
Ağustos	28.8	30.6	68.5	66.9	9.2	1.4
Eylül	26.2	27.4	63.6	65.9	19.5	52.0
Ekim	21.8	22.8	60.6	51.5	43.0	0.0
Kasım	16.0	16.1	63.0	60.7	72.2	123.3
Aralık	11.3	11.9	67.3	67.8	125.1	86.2
Toplam/Ortalama	**19.3**	**21.3**	**65.9**	**65.6**	**667.5**	**574.2**

Kaynak: Adana Meteoroloji Bölge Müdürlüğü

Çizelge 1 incelendiğinde, denemenin yürütüldüğü 2024 yılında uzun yıllar ortalamasına göre 93.3 mm daha az yağış gerçekleştiği, ortalama sıcaklık ve ortalama nem değerlerinin ise uzun yıllara göre birbirlerine yakın olduğu görülmektedir.

Denemenin yürütüldüğü tarlaya ait toprak analizleri Çukurova Üniversitesi Toprak ve Bitki Besleme Bölümü Analiz Laboratuvarında gerçekleştirilmiş olup, değerler Çizelge 2'de verilmiştir. Çizelge 2'de görüldüğü gibi denemenin kurulduğu toprağın pH'sı 8.2 olup hafif alkali bir özellik göstermektedir. Organik madde içeriği (%1.34) bakımından fakir bir toprak olup, yararlanılabilir fosfor ve potasyum düzeyleri sırasıyla 10.9 ppm ve 323 ppm'dir. Toprağın kireç oranı %31.63, tuz içeriği ise 0.2 Mmhos/cm olarak belirlenmiştir.

Çizelge 2. Deneme yeri toprağının bazı fiziksel ve kimyasal özellikleri

Derinlik (cm)	Tekstür	pH	Tuz (Mmhos/cm)	Kireç (%)	Org. Madde (%)	Yarayışlı P (ppm)	Yarayışlı K (ppm)
0-20	Killi-Tınlı	8.2	0.2	31.63	1.34	10.9	323

Kaynak: ÇÜ Toprak ve Bitki Besleme Bölümü

Denemede, ABD pamuk germplazm koleksiyonundan sağlanan 10 adet genotip (SA 74, SA 263, SA 333, SA 345, SA 405, SA 408, SA 907, SA 1479, SA 1484 ve SA1535) ile bölgede yaygın olarak yetiştiriciliği yapılan Lazer ve May 455 çeşitleri kullanılmıştır (Çizelge 3). Deneme, Tesadüf blokları deneme desenine göre 3 tekrarlamalı olarak kurulmuştur. Araştırmada kullanılacak materyaller 2023 yılında tohum çoğaltma çalışmalarına alınarak, çok farklı morfolojik özellikteki bitki tiplerine sahip genotipler, büyümenin her aşamasında izlenmiş ve bu çalışma amacına uygun olanlar seçilmiştir. Deneme ekim işlemleri, hava koşulları ve toprak sıcaklıklarının uygun olduğu 19 Nisan 2024 tarihinde sıra arası 70 cm, sıra üzeri ise 10 cm olacak şekilde gerçekleştirilmiştir. Denemeye ait parsellerin hasat işlemleri 10 Ekim 2024 tarihinde gerçekleştirilmiştir.

Çizelge 3. Çalışmada kullanılan materyallere ait bazı bilgiler.

Genotip İsim	Taksonomi	Köken	ÇR (%)	UHML (mm)	Str (g/tex)	Mik.	Elg
SA 74	*G. hirsutum* L.	Teksas, ABD	33.3	26.92	31.3	4.03	8.6
SA 263	*G. hirsutum* L.	Teksas, ABD	27.8	35.81	37.9	3.88	7.9
SA 333	*G. hirsutum* L.	Teksas, ABD	26.0	*	*	3.8	8.5
SA 345	*G. hirsutum* L.	Teksas, ABD	29.5	31.75	41.6	4.25	5.7
SA 405	*G. hirsutum* L.	Teksas, ABD	28.1	35.31	39.5	3.53	7.2
SA 408	*G. hirsutum* L.	Teksas, ABD	29.0	35.81	39.4	3.45	7.9
SA 907	*G. hirsutum* L.	Teksas, ABD	27.4	35.31	39.5	3.15	7.7
SA 1479	*G. barbadense* L.	Teksas, ABD	33.6	*	*	3.5	9.1
SA 1484	*G. hirsutum* L.	Teksas, ABD	34.9	*	*	4.0	9.5
SA 1535	*G. hirsutum* L.	Kuzey Karolina,ABD	34.0	*	*	4.2	6.5
Lazer	*G. hirsutum* L.	Türkiye	46.0	31.0	35.0	4.7	7.0
May 455	*G. hirsutum* L.	Türkiye	44.0	30.0	32.0	4.6	7.7

*USDA kayıtlarında bu veriler eksiktir.

ÇR: Çırçır Randımanı, UHML: Lif Uzunluğu, Str: Lif mukavemeti,
Mik:Mikroner, Elg: Kopma anında lif uzaması

Kaynak: USDA, 2025

2.1. Kütlü pamuk verimi (kg/da), morfolojik ve lif kalite özelliklerin ölçümü

Çalışmada, bitki boyu, boğum sayısı, koza sayısı, odun dalı ve meyve dalı sayıları her parselden kenar tesiri çıkarıldıktan sonra ortadaki iki sıradan rastgele seçilen 10 bitkiden ortalamaları alınarak belirlenmiştir. Bitki boyu toprak yüzeyinden bitkinin tepe noktasına kadar olan mesafenin ölçülmesiyle, boğum, odun dalı, meyve dalı ve koza sayıları ise ana gövde üzerinde oluşan yapıların sayılmasıyla saptanmıştır. Hektara kütlü pamuk verimi ise 10 m^2'lik her parselde 2. ve 3. sırada bulunan tüm bitkilerin hasat sonrası tartılarak elde edilen değerlerin

hektara çevrilmesiyle saptanmıştır. Her parselden toplanan 30 adet koza örneğinden ise tek koza kütlü ağırlığı ve çırçır randımanı değerleri hesaplanmıştır. Tek kozadan çıkan kütlü ağırlığı hassas terazide tartılarak belirlenmiştir. Çırçır randımanı ise laboratuvar tipi rollergin çırçır makinesi kullanılarak, aşağıdaki eşitlik yardımıyla belirlenmiştir.

Çırçır Randımanı (%) =[LA / KPA] x100

Burada; LA= Lif ağırlığını (g), KPA= Kütlü pamuk ağırlığını (g) ifade etmektedir.

30 adet koza örneğinden elde edilen lifler ise kalite özelliklerinin analiz edilmesi amacıyla Pamuk Araştırma Enstitüsü (Aydın/Nazilli) Lif Kalite Laboratuvarına gönderilmiştir. Burada HVI 1000 cihazı kullanılarak, lif inceliği, lif uzunluğu, lif mukavemeti, kopma anında lif uzaması, iplik olabilirlik indeksi, yansıma ve sarılık derecesi ölçümleri yapılmıştır.

Araştırmadan elde edilen veriler R programında "agricoale" paketi kullanılarak varyans analizi, "ggplot2" paketi ile biplot analizleri gerçekleştirilmiştir. İstatistiksel olarak önemli çıkan özellik ortalamaları en küçük güvenilir fark (EGF) testi ile %5 önem düzeyinde karşılaştırılmıştır. CV katsayıları yüksek olan odun dalı ve meyve dalı sayısı verilerine karekök transformasyonu gerçekleştirilmiştir. Transformasyon sonrası verilere normallik testi yapılmıştır.

3. BULGULAR ve TARTIŞMA

Araştırma sonuçları, pamuk genotiplerinde incelenen özelliklerin, bitki boyu, koza sayısı, tek koza kütlü ağırlığı, çırçır randımanı ve kütlü pamuk verimi yönünden istatistiki olarak önemli derecede fark yarattığını (P<0.01) ortaya koymuştur (Çizelge 4).

Çizelge 4. Genotiplerin tarımsal özellikler açısından varyans analiz sonuçları.

		Gözlemlerin Kareler Ortalaması							
VK	**SD**	**Bitki boyu (cm)**	**Boğum sayısı (adet)**	**Odun Dalı Sayısı (adet)**	**Meyve Dalı Sayısı (adet)**	**Koza Sayısı (adet)**	**Tek Koza Kütlü Ağırlığı (g)**	**Çırçır randımanı (%)**	**Kütlü pamuk verimi (kg/ha)**
Genotip	11	343.30**	3.336	0.312	7.067	25.828**	1.743**	0.004**	13252.7**
Blok	2	294.74	16.403	0.26	5.214	3.633	0.432	0.0002	420.92
Hata	22	61.77	3.964	0.264	6.402	5.880	0.144	0.0001	1.071
Genel	35	-------	--------	-------	-------	--------	--------	--------	--------
CV (%)		8.3	9.7	18.8[i]	9.4[i]	11.7	7.1	2.9	8.4

*p≤ 0.05, ** p≤ 0.01 hata sınırları içerisinde istatistiksel olarak önemli

[i]: Karekök transformasyonu yapılmıştır.(Veriler normal dağılım göstermektedir.)

VK: Varyasyon kaynağı, SD: Serbestlik derecesi, CV: Varyasyon katsayısı

Lif kalite özelliklerinde ise lif uzunluğu, lif mukavemeti, kopma anında lif uzaması, iplik olabilirlik indeksi ve sarılık derecesi değerlerinin P < 0.01önem düzeyinde istatistiksel olarak anlamlı bir fark oluşturduğu görülmektedir (Çizelge 5).

Çizelge 5. Genotiplerin lif kalitesi açısından varyans analiz sonuçları.

VK	Gözlemlerin Kareler Ortalaması							
	SD	**Lif İnceliği**	**Lif Uzunluğu (mm)**	**Lif Kopma Mukavemeti (g/tex)**	**Kopma Anında Lif Uzaması**	**İplik Olabilirlik İndeksi**	**Yansıma Derecesi**	**Sarılık derecesi**
Genotip	11	0.264	9.022**	28.097**	0.312**	992.34**	11.046	1.151**
Blok	2	0.083	1.552	11.848	0.002	50.977	11.245	0.502
Hata	22	0.151	2.712	8.500	0.024	305	8.635	0.304
Genel	35	------	------	------	------	------	------	------
CV (%)		7.8	5.6	9.1	2.1	12.1	3.8	6.1

*p≤ 0.05, ** p≤ 0.01 hata sınırları içerisinde istatistiksel olarak önemli

VK: Varyasyon kaynağı, SD: Serbestlik derecesi, CV: Varyasyon katsayısı

3.1. Bitki Boyu (cm)

Çalışmada ortalama bitki boyu değerleri 78.1-116.8 cm aralığında değişim göstermiş olup en düşük değer SA 408 genotipinde görülürken, en yüksek değer SA 1479 genotipinde belirlenmiştir (Çizelge 6). ABD germplazm kaynaklarında SA 1479 genotipine ilişkin bitki boyunun 152-183 cm, diğer genotiplerin ise 91-122 cm aralığında değerlere sahip olduğu bildirilirken, bizim çalışmamızda da benzer şekilde SA 1479 genotipi diğer genotiplere göre daha uzun boylu olmuştur (USDA, 2025). Bitki boyu, pamukta bitki mimarisi kavramını etkileyen önemli bir özelliktir (Shang ve ark., 2015). Bitki boyu ana gövde üzerinde bulunan boğumların uzamasının bir fonksiyonu olup, pamuk bitkisinin biyolojik veriminin oluşumunda önemli bir rol oynar. Ayrıca, bitkilerin yatmaya karşı direnci de esas olarak bitki boyundan etkilenir. Bu nedenle, pamuk bitkisinde besin dağılımının optimum düzeyde olması, başka bir deyişle vejetatif-generatif dengenin sağlanması ve yüksek verim elde edilebilmesi için uygun bir bitki boyu geliştirme süreci gereklidir (Liu ve ark., 2013).

Çizelge 6. Pamuk genotiplerinin tarımsal özelliklerinin ortalama değerleri

Genotip	Bitki boyu (cm)	Boğum sayısı (adet)	ODS (adet)	MDS (adet)	Koza Sayısı (adet)	Tek Koza Kütlü Ağırlığı (g)	ÇR (%)	Kütlü Pamuk Verimi (kg/ha)
SA 263	92.7 b-e[1]	19.6	0.7	10.9	15.7 f	5.6 bcd	34 cd	3098 ef
SA 345	96.7 bcd	21.1	1.1	9.5	17.3 ef	5.4 b-e	33 d	3138 ef
SA408	78.1 f	19.6	1.4	11.9	19.7 b-f	4.9 e	36 b	3615 de
SA 1479	116.8 a	21.7	1.6	14.2	21.6 a-d	3.4 f	35 bc	2699 f
SA 74	103.1 bc	22.4	1.3	11.3	18.3 def	6.5 a	34 cd	4342 bc
SA 333	91.6 cde	21.8	0.9	12.1	19.3 c-f	5.7 bc	34 cd	3642 de
SA1535	82.3 ef	19.8	1.3	11.3	19.7 b-f	5.9 ab	34 cd	4289 bc

SA 405	90.6 c-f	19.7	1.0	12.7	20.6 b-e	5.1 cde	31 e	3793 cd
SA 907	99.6 bcd	20.4	0.6	13.4	24.9 a	5.1 de	33 d	4101 bcd
SA1484	106 ab	20.7	1.5	12.7	23.4 ab	6.0 ab	35 bc	4995 a
May455	89.0 def	20.4	1.5	10.5	24.8 a	5.0 de	43 a	4307 bc
Lazer	87.3 def	19.0	1.2	9.0	23.0 abc	5.4 b-e	43 a	4441 b
EGF	**13.31**	**---**	**---**	**---**	**4.11**	**0.64**	**0.02**	**55.41**

[1] Benzer küçük harflerle gösterilen Genotip ortalamaları arasında EGF testine göre %5 önem seviyesinde istatistiksel olarak anlamlı fark yoktur.

ODS: Odun dalı sayısı, MDS: Meyve dalı sayısı, ÇR: Çırçır randımanı

EGF: En küçük güvenilir fark.

3.2. Boğum Sayısı (adet)

Çalışmada ortalama boğum sayısı değerleri genotipler arasında istatistiksel olarak önemli fark oluşturmamakla birlikte 19-22.4 adet arasında değişim göstermiş olup, en düşük değer Lazer çeşidinde gerçekleşirken, en yüksek değer SA 74 genotipinde bulunmuştur (Çizelge 6). Pamuk bitkisinde boğum sayısı; verim potansiyeli, bitki yapısı, olgunlaşma süresi ve lif kalitesi üzerinde doğrudan etkilidir. Fazla veya az boğum, hem verimi hem de lif kalitesini olumsuz etkileyebilir, bu nedenle optimum boğum sayısı pamuk ıslahında kritik bir parametredir (Bourland ve ark., 1992). Bitki büyümesinin kontrolünde dört dönemin önemli olduğu bilinmektedir. Bu dönemler; taraklanma öncesi, taraklanma, çiçeklenme ve çiçeklenme doruğu dönemleridir. Tüm bu dönemlerde ana gövdede oluşan boğum sayılarının bilinmesi, erkencilik ve bitki büyüme düzenleyicilerinin kullanım zamanının belirlenmesi gibi konularda kritik öneme sahiptir (Bölek ve ark., 2007). Önceki çalışmalar incelendiğinde, boğum sayısı değerlerinin yetişme koşulları ve çeşide bağlı olarak 16-24 adet arasında gerçekleştiği görülmektedir (Ören ve Basal, 2006; Tarhan ve Karademir, 2019; Sağır ve ark., 2021).

3.3. Odun Dalı ve Meyve Dalı Sayısı (adet)

Çalışmada, genotipler arasında ortalama odun dalı sayısı değerleri açısından istatistiksel olarak önemli farklılık oluşmadığı, değerlerin 0.6-1.6 adet arasında gerçekleştiği, en düşük değerin SA 907 genotipinde, en yüksek değerin ise SA 1479 genotipinde oluştuğu görülmektedir (Çizelge 6). Önceki çalışmalar incelendiğinde, odun dalı sayısı değerlerinin bizim çalışmamıza benzer aralıkta olduğu görülmektedir (Sadık ve Kaynak, 2017; Haliloğlu ve Çoklu, 2024; Kaya ve Karayağlı, 2024). Çalışmada ortalama meyve dalı sayısı değerleri de istatistiksel olarak önemli fark oluşturmadığı, genotipler arasında 9.0-14.2 adet arasında değişim gösterdiği, en düşük değerin Lazer çeşidinde, en yüksek değerin ise SA 1479 genotipinde gerçekleştiği bulunmuştur (Çizelge 6). Pamuk bitkisinde verim değerini doğrudan etkileyen bir parametre olduğundan meyve dalı sayısının yüksek olması istenilen bir durumdur.

3.4. Koza sayısı (adet)

Çalışmada ortalama koza sayısı değerlerinin 15.7-24.9 adet arasında değişim gösterdiği, en düşük değerin SA 263, en yüksek değerin ise SA 907 genotipinde gerçekleştiği görülmektedir (Çizelge 6). Bu genotiplere ait ABD germplazm kaynaklarında belirtilen veriler incelendiğinde, bizim bulgularımızla paralellik gösterdiği anlaşılmaktadır (USDA, 2025). Koza sayısı, pamuk bitkisinde verim bileşenlerini oluşturan önemli bir bulgudur. Bitkinin verimliliğini oluşturan esas konulardan biri olan koza sayısının fazla olmasının yanında hasat edilebilir olması da önem arz etmektedir. Elde edilen sonuçlar göstermektedir ki tüm genotipler kabul edilebilir seviyede koza sayısına sahip olmuştur. Koza sayısını etkileyen faktörler içinde bakım işlemleri ve ekim normu optimum değerler içerisinde olmalıdır. Bu çalışmada bitkinin üretmiş olduğu toplam koza sayıları (açmış+açmamış kozalar) dikkate alınmıştır.

3.5. Tek Koza Kütlü Ağırlığı (g)

Çalışmada, tek kozadan elde edilen ortalama kütlü ağırlıkları 3.4-6.5 g arasında değişim göstermiş olup, en düşük değer SA 1479 genotipinde, en yüksek değer ise SA 74 genotipinde bulunmuştur. ABD germplazm kaynaklarında da belirtildiği gibi *G. barbadense* L. türüne ait olan SA 1479 genotipi daha fazla koza sayısına sahip ancak daha küçük yapıda kozalar oluşturmuştur (USDA, 2025). Pamuk bitkisi indeterminent büyüme özelliği gösterdiğinden koza sayısının tahmin edilmesinde sadece çiçek sayısına ya da yeni açmış kozalara bakmak doğru değildir. Pamuk, generatif döneminde dahi uygun şartları buldukça vejetatif büyüme eğilimi gösterecektir. Hasat edilebilir kozalar dikkate alınarak tek koza kütlü ağırlıkları belirlenmiştir.

3.6. Çırçır Randımanı (%)

Çalışmada, çırçır randımanı değerleri %31-43 değerleri arasında değişim göstermiş olup, en düşük değer SA 405 genotipinde görülürken, en yüksek değer May 455 ve Lazer çeşitlerinde saptanmıştır. ABD germplazm kaynaklarında genotiplere ait veriler incelendiğinde, bu çalışmada tüm genotipler bir miktar daha yüksek çırçır randımanı değerlerine sahip olmuştur (USDA, 2025). Lif ağırlığının kütlü pamuk ağırlığına oranlanması ile elde edilen çırçır randımanı, özellikle pamuk fiyatının belirlenmesinde önemli bir parametre olup, ıslah edilen çeşitlerde yüksek değerlerde olması istenir. Bu çalışmada genotipler arasındaki çırçır randımanı değerleri incelendiğinde özellikle *G. hirsutum* L. türüne ait olan SA 408 ile *G. barbadense* L. türüne ait SA 1479 genotipleri yüksek lif oranı değerleri ile ön plana çıkmaktadır.

3.7. Kütlü Pamuk Verimi

Çalışmada, ortalama kütlü pamuk verim değerleri 2699-4995 kg/ha değerleri arasında değişim göstermiş olup, en düşük değer *G barbadense* L. türüne ait olan SA 1479 genotipinde oluşurken, en yüksek değer *G. hirsutum* L. türüne ait SA 1484 genotipinde belirlenmiştir. SA 1479 genotipi düşük kütlü pamuk verimi gerçekleştirmesine rağmen yüksek kaliteli lifler oluşturmuştur. Kütlü pamuk verimi, birim alandaki bitki sayısı, bir bitkide ortalama koza sayısı ve tek koza kütlü ağırlığı olmak üzere üç verim bileşeninin çarpılmasıyla hesaplanır. Daha önceki çalışmalar, özellikle koza ağırlığının daha fazla iyileşmesiyle pamuk veriminde artışla sonuçlandığını göstermektedir (Tang ve ark., 1993; Iqbal ve ark., 2013; Shakeel ve ark., 2015). Bu nedenle, verim bileşenlerinin kütlü pamuk verimini nasıl değiştirdiğinin bilinmesi, pamuk ıslahında yeni çeşitlerin seçimi için oldukça önemlidir. Pamuk veriminin iyileştirilmesi, özellikle ilk konum kozaları ve fizyolojik olarak sağlıklı bitkide gelişecek olan diğer konum kozaların daha fazla oluşumuyla gerçekleştirilebilir (Dong ve ark., 2014). Genel olarak en fazla koza ağırlığı ve en iyi lif kalitesi için bitkinin orta bölümünde (5-9. boğum arası oluşan kozalar) yer alan birinci ve ikinci konum kozalarıdır(Tan, 1992). Bu kozalar pamuk veriminin sırasıyla %60 ve %30'nu oluşturmaktadır (Oosterhuis, 2001). Bu çalışmada, özellikle SA 1484 genotipi, yüksek koza sayısı ve tek koza kütlü ağırlığı değerleri ile yüksek verim özelliği göstermesinden dolayı ıslah çalışmalarında ebeveyn olarak kullanılmasında önem kazanmıştır.

3.8. Lif İnceliği

Çalışmada, genotipler arasında ortalama lif inceliği değerleri açısından istatistiksel olarak önemli farklılık oluşmadığı, değerlerin 4.4-5.4 arasında gerçekleştiği, en düşük değerin SA 333 genotipinde, en yüksek değerin ise SA 408 genotipinde oluştuğu görülmektedir (Çizelge 7). Lif inceliği büyük oranda çeşidin genetik yapısı tarafından belirlenen bir özellik olmakla birlikte, kozanın bitki üzerindeki konumu, ekim zamanı, yetiştirme sezonundaki çevresel faktörler ve kültürel uygulamalar tarafından da önemli derecede etkilenmektedir. Çok yüksek lif inceliği değerleri (>4.5) lifin kaba olduğu anlamına gelip, tekstil endüstrisi için istenilen bir durum değildir. Çok düşük lif inceliği değerleri (<3.8) ise liflerin olgun olmadığı ve iplik yapımında

kopmaların yüksek olacağı anlamına gelir (Bange ve Constable, 2009). Islah açısından bakıldığında mikroner genellikle lif uzunluğu ve mukavemeti gibi diğer kalite parametreleriyle negatif korelasyon gösterdiğinden, kabul edilebilir bir mikroner değerine ulaşmak ıslahçılar için önemli bir zorluktur (Song ve ark., 2021). Genellikle 3.8–4.5 aralığındaki mikroner değerleri iplik üretiminin verimliliği yönünden ideal kabul edilmektedir (Bange ve ark., 2010). Ülkemizde ve dünya genelinde, tekstil sektöründe ciddi bir sorun olan ve lif fiyat düşüşlerine yol açan kaba lif (yüksek mikroner) sorununa yönelik genetik kaynaklardan yararlanılarak çözüm stratejileri geliştirilebilir. Çalışmamızda bu bağlamda SA 333 genotipi ülkemiz pamuk ıslahçılarına önemli bir materyal olarak sunulabilir.

3.9. Lif Uzunluğu (mm)

Çalışmada, ortalama lif uzunluğu değerleri 27.4-32.5 mm arasında değişim gösterdiği, en düşük değerin SA 263 genotipinde, en yüksek değerin ise *G. barbadense* L. türüne ait olan SA 1479 genotipinde bulunmuştur. ABD germplazm kayıtlarında belirtilen lif uzunluğu değerlerine göre bizim bulgularımız daha düşük olmuştur (Çizelge 3). Bu durumun genel olarak çevre koşulları, nem ve sıcaklık stresleri gibi faktörlerden etkilenmesiyle gerçekleştiği düşünülmektedir. Lif uzunluğu en önemli kalite özelliği olarak kabul edilmekte olup, tekstil endüstrisi ve iplik teknolojisi için büyük önem taşımaktadır. Ticari üretim için daha uzun lifli pamuk çeşitleri tercih edilmektedir. Lif uzunluğu değerleri "25.15-27.94 mm arası orta; 27.94-32.00 mm arası uzun" olarak sınıflandırılmaktadır (Dağdelen ve ark., 2009). Çalışmada genotiplere göre saptanan lif uzunluğu değerleri incelendiğinde, SA 345, SA 405, SA 907, SA1479, SA 1484, May 455 ve Lazer genotipleri 28.85-32.65 mm ile "uzun" kategorisinde yer almış ve pamuk ıslah programlarında ebeveyn seçiminde önemli görülmüşlerdir.

3.10. Lif Mukavemeti (g/tex)

Çalışmada ortalama lif mukavemeti değerleri 28.0-38.2 g/tex arasında değişim gösterdiği, en düşük değerin SA 263, en yüksek değerin ise *G. barbadense* L. türüne ait olan SA 1479 genotipinde oluştuğu görülmektedir (Çizelge 7). Lif mukavemeti kavramı, belirli bir hacimdeki lif demetinin kopması için gereken güç olarak ifade edilmektedir. Çoğunlukla genetik yapıdan belirlenen bu lif özelliği, çevre koşullarından çok etkilenmemekle beraber özellikle hasat zamanı oluşacak olumsuz koşullarda önemli azalmalar ile sonuçlanabilmektedir (Cevheri, 2022). Ülkemizde yetiştirilen pamukların lif mukavemeti değerleri 25-38 g/tex arasında değiştiği, ortalama olarak 30.9 g/tex olduğu rapor edilmiştir (Özbek, 2009). Lif mukavemeti değerleri "<21 çok zayıf, 22-24 zayıf, 25-27 orta, 28-30 kuvvetli ve >31 çok kuvvetli" olmak üzere sınıflandırılmaktadır (Uster, 2008). Bu çalışmamızda da genotiplerin USTER HVI 1000 skalasına göre saptanan lif mukavemeti değerleri incelendiğinde SA 263, SA 408, SA 74 ve SA 1535 genotipleri "kuvvetli" sınıfında yer alırken, SA 345, SA 1479, SA 333, SA 405, SA 907 ve SA 1484 genotipleri ise "çok kuvvetli" sınıfında yer almıştır. Bu durum ıslah amacıyla seçilecek genotiplerin lif mukavemeti yönünden önemini artırmıştır.

3.11. Kopma Anında Lif Uzaması (%)

Çalışmada, ortalama kopma anındaki lif uzaması değerlerinin %7.0-7.9 arasında değişim gösterdiği, en düşük değerin SA 1535 genotipinde, en yüksek değerin ise May 455 çeşidinde oluştuğu görülmektedir (Çizelge 7). Elde edilen sonuçlar incelendiğinde, SA 345 genotipi, USDA kayıtlarında belirtilen değerden 1.5 birim daha esnek oluşuyla dikkat çekmektedir. Kopma anında lif uzaması değerleri "<5 çok düşük, 5.1-5.8 düşük, 5.9-6.7 orta, 6.8-7.6 yüksek ve >7.7 çok yüksek" olarak sınıflandırılmaktadır (Uster, 2008). Bu çalışmada genotiplerin USTER HVI 1000 skalasına göre belirlenen kopma anındaki lif uzaması değerleri incelendiğinde, SA 263, SA 345, SA 408, SA 333, SA 1535, SA 405, SA 907 ve SA 1484 genotipleri "yüksek" sınıfında yer alırken, SA 74 ve SA 1479 genotipleri çok yüksek sınıfında

yer almıştır. Bu durum pamuk ıslahında ebeveyn seçiminde kopma anında lif uzaması değeri bakımından SA 74 ve SA 1479 genotiplerinin önemini arttırmıştır.

Çizelge 7. Pamuk genotiplerinin lif kalitesi özelliklerinin ortalama değerleri.

Genotip	Lif İnceliği	Lif Uzunluğu (mm)	Lif Mukavemeti (g/tex)	Kopma Anında Lif Uzaması (%)	İplik Olabilirlik İndeksi (%)	Yansıma derecesi (%)	Sarılık derecesi
SA 263	4.7	27.4 d[1]	28.0 e	7.4 bc	123.3 cd	75.2	8.8 cde
SA 345	4.7	30.8 abc	30.7 cde	7.2 cde	151.8 abc	78.4	8.4 de
SA408	5.4	28.6 cd	29.7 cde	7.4 bc	121.6 d	75.3	8.7 de
SA 1479	5.1	32.5 a	38.2 a	7.8 a	180.3 a	73.7	9.9 a
SA 74	4.9	27.3 d	29.4 de	7.8 a	129.1 cd	75.8	9.7 ab
SA 333	4.4	28.1 cd	31.4 b-e	7.3 bcd	144.7 bcd	79.3	8.6 de
SA1535	5.2	28.3 cd	29.1 de	7.0 e	128.6 cd	77.5	9.3 a-d
SA 405	5.0	32.2 ab	34.6 abc	7.2 cde	159.3 ab	77.8	8.2 e
SA 907	5.2	28.8 cd	32.3 b-e	7.0 e	129 cd	73.3	8.9 b-e
SA1484	4.8	30.2 abc	36.3 ab	7.1 de	163.1 ab	78.0	8.9 b-e
May455	5.3	29.1 cd	32.6 b-e	7.9 a	145.1 bcd	75.9	10.0 a
Lazer	5.3	29.5 bcd	33.2 bcd	7.5 b	150.8 a-d	77.9	9.6 abc
EGF	**0.7**	**2.8**	**4.9**	**0.3**	**29.6**	**---**	**0.9**

[1] Benzer küçük harflerle gösterilen Genotip ortalamaları arasında LSD testine göre %5 önem seviyesinde istatistiksel olarak anlamlı fark yoktur.

EGF: En küçük güvenilir fark.

3.12. İplik Olabilirlik İndeksi (%)

Çalışmada, ortalama iplik olabilirlik indeksi değerleri %121.6-180.3 arasında değişim göstermiş, en düşük değerin SA 408 genotipinde, en yüksek değerin ise *G. barbadense* L türüne ait SA 1479 genotipinde oluştuğu görülmektedir (Çizelge 7). İplik olabilirlik indeksi, liflerin eğrilebilirliğini tahmin etmek için kullanılan bir hesaplamadır. Bu indeksin belirlenmesinde lif mukavemeti, lif inceliği, lif uzunluğu, lif üniformite indeksi, yansıma ve sarılık dereceleri birlikte değerlendirilir. Genel olarak iplik olabilirlik indeksi ne kadar yüksekse, iplik mukavemeti o kadar yüksektir (Uster, 2008). Tekstil endüstrisinde %120 ve üzerindeki değerler yüksek kabul edilir. Elde edilen sonuçlar incelendiğinde, genotiplerin tümünde %120'den daha yüksek iplik olabilirlik indeksi değerlerine ulaşılmıştır.

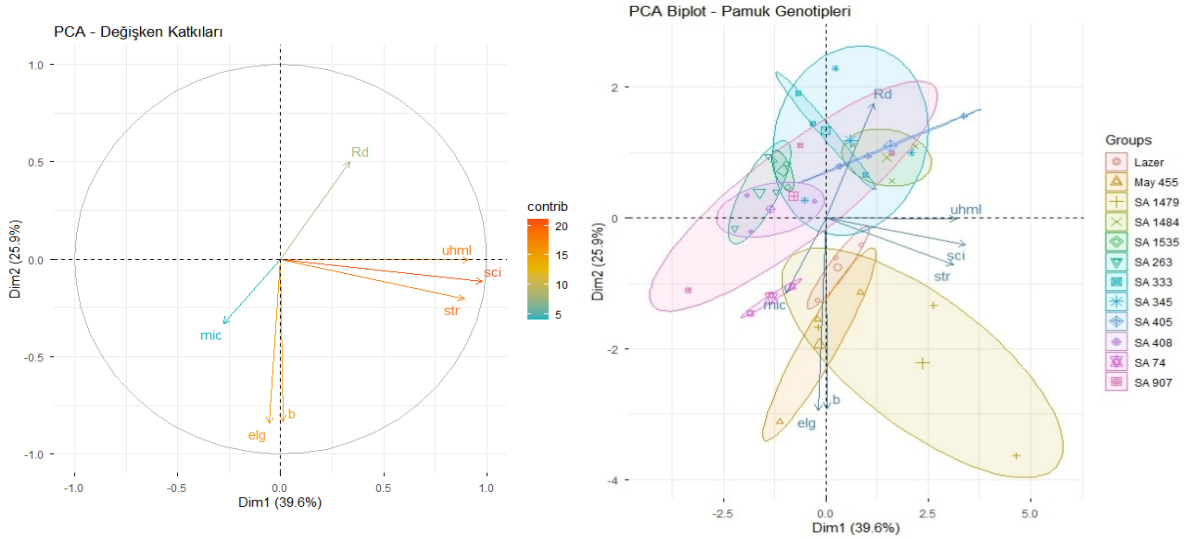
3.13. Yansıma ve Sarılık Dereceleri (%)

Çalışmada, pamuk genotiplerinin ortalama yansıma değerleri %73.3-79.3 aralığında değişmiş olup, en düşük değer SA 907 genotipinde, en yüksek değer ise SA 333 genotipinde gerçekleşmiştir. Ülkemiz pamuklarının lif yansıma değerlerinin %56-82 arasında değiştiği, ortalama değerin ise %70 olduğu bilinmektedir (Özbek, 2009). Bu çalışmadan elde edilen

sonuçlar incelendiğinde, genotipler arasında gerçekleşen lif yansıma değerlerinin ülkemiz ortalama değerlerinden daha yüksek olduğu anlaşılmaktadır.

Çalışmada, lif sarılık değerleri ise 8.2-10.0 değerleri arasında değişim göstermiş olup, en düşük değer SA 405 genotipinde, en yüksek değer ise May 455 çeşidinde gerçekleşmiştir. Çalışmada sarılık (+b) değerinin 4-8 arasında olduğu durumlarda lif sarılık yüzdesinin standart değere yakın olduğu kabul edilmiştir (Uster, 2008). Bu çalışmadan elde edilen sarılık derecesi değerlerine bakıldığında, tüm genotiplerin "iyi" sınıfında yer aldıkları görülmektedir (Uster, 2008).

3.14. Çalışmada Kullanılan Genotiplerin PCA-Biplot ve Değişken Katkıları Analizleri



Şekil 1. Çalışmada kullanılan pamuk genotiplerinde lif kalite özelliklerine ait değişken katkıları ve biplot grafiği.

Şekil 1'de pamuk genotiplerinin lif kalite özellikleri bakımından dağılımını gösteren temel bileşen analizi (Principal Component Analysis, PCA) sonuçları verilmiştir. Analiz sonucunda birinci (Dim1) ve ikinci (Dim2) temel bileşenler toplam varyansın yaklaşık %65.1'ini (%39.6 + %25.5) açıklamıştır. Bu yüksek varyans oranı, grafikteki genotipler arasındaki farklılıkların güvenilir biçimde temsil edildiğini göstermektedir. Biplot'ta genotipler farklı sembollerle gösterilmiş, her grubun etrafındaki elipsler %95 güven aralığını yansıtmıştır. Elipslerin konumu ve örtüşme düzeyi, gruplar arası benzerlik veya ayrışma derecesini ortaya koymaktadır. Örneğin, Lazer ve May 455 çeşitlerinin (sarı renkle gösterilen grup) PCA düzleminde lif kalite değerleri açısından diğerlerinden belirgin biçimde ayrıştığı görülmektedir. Bu durum, söz konusu genotiplerin özellikle lif inceliği ve kopma anında lif uzaması bakımından farklı değerlere sahip olduğunu göstermektedir. Buna karşın SA 408, SA 74 ve SA 907 genotiplerinin kümelerinin kısmen örtüşmesi, bu grupların benzer lif kalite profillerine sahip olduklarına işaret etmektedir. Değişkenleri temsil eden vektörlerin yönü ve uzunluğu, her bir özelliğin varyansa katkı düzeyini yansıtmaktadır. Grafikte lif uzunluğu ve lif mukavemeti vektörlerinin aynı doğrultuda uzanması, bu iki özelliğin pozitif korelasyon gösterdiğini ortaya koymaktadır. Buna karşılık, lif inceliği vektörünün zıt yönde yer alması, lif inceliği yüksek genotiplerde genellikle daha kısa boylu veya düşük mukavemetli liflerin bulunduğunu göstermektedir. Bu bulgu, literatürde sıklıkla vurgulanan incelik–mukavemet arasındaki ters ilişkiyi doğrulamaktadır (Song ve ark., 2021; Prasad ve ark., 2022). Genel olarak PCA biplot analizi, pamuk genotiplerinin lif kalite parametreleri bakımından hem grup içi benzerliği hem de gruplar arası farklılıkları açık biçimde ortaya koymuştur. Özellikle SA 1484, SA 1535, SA 263, SA 333 ve SA 345 genotipleri, lif uzunluğu ve mukavemet parametreleriyle yüksek korelasyon göstermiş ve üstün kalite potansiyeli taşımıştır. Bu genotipler, yüksek kaliteli ve dayanıklı lif üretimi

hedefleyen ıslah programlarında değerli ebeveyn adayları olarak öne çıkmaktadır. Buna karşılık, Lazer ve May 455 genotipleri kopma anında lif uzama oranı değerleri bakımından avantajlı olsa da, lif inceliği yönünden sınırlı kalmıştır. Bu nedenle, söz konusu genotiplerin yüksek dayanıklılık potansiyeli taşıyan SA 333 veya SA 1535 gibi genotiplerle melezlenmesi, lif kalitesi bakımından dengeli kombinasyonlar oluşturabilir. Sonuç olarak, SA 1484 × Lazer, May 455 × SA 345 ve SA 1535 × SA 408 kombinasyonları, lif uzunluğu, dayanıklılık ve esneklik özelliklerini bir araya getirebilecek potansiyel melezler olarak önerilmektedir.

4. SONUÇ

ABD pamuk germplazm koleksiyonundan elde edilen on genotip ile iki ticari çeşidin Çukurova koşullarında tarımsal performans ve lif kalite özelliklerinin belirlenmesi amacıyla yürütülen çalışmada, genotipler arasında hem verim hem de lif kalite özellikleri bakımından istatistiksel olarak anlamlı farklılıklar oluşmuştur. Kütlü pamuk verimi 2699–4995 kg/ha arasında değişmiş, en yüksek değer SA 1484 (*G. hirsutum* L.), en düşük değer ise SA 1479 (*G. barbadense* L.) genotipinde belirlenmiştir. Lif uzunluğu (32.5 mm), mukavemeti (38.2 g/tex) ve iplik olabilirlik indeksi (%180.3) bakımından SA 1479 genotipi ön plana çıkarken, en ince lifler SA 333 genotipinde saptanmıştır. Lif kalite özellikleri incelendiğinde, lif uzunluğu ile lif mukavemeti arasında pozitif, lif inceliğinde ise negatif korelasyon gerçekleştiği görülmüştür. Ayrıca, SA 1484, SA 405, SA 333 ve SA 1535 genotipleri lif kalite parametreleri açısından yüksek korelasyon sergileyerek üstün kalite potansiyeli taşımıştır. Sonuç olarak, SA 1484 ve SA 405 genotipleri yüksek verim özellikleriyle; SA 1479 ve SA 333 genotipleri ise üstün lif kalitesiyle öne çıkmıştır. Bu genotiplerin bölgesel pamuk ıslah programlarında ebeveyn olarak kullanılması, Çukurova koşullarına uyumlu, hem yüksek verimli hem de yüksek lif kalitesine sahip yeni pamuk çeşitlerinin geliştirilmesine önemli katkı sağlayacaktır.

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İKLİM DEĞİŞİKLİĞİNİN KOYUN YETİŞTİRİCİLİĞİNE ETKİSİ: ISI STRESİ, PERFORMANS, ADAPTASYON STRATEJİLERİ

Doktorant Beyza YILMAZ*

Niğde Ömer Halisdemir Üniversitesi Fen Bilimleri Enstitüsü, Hayvansal Üretim ve Teknolojileri Anabilim Dalı, NİĞDE

Email: byzylmz.95@gmail.com

ORCID: 0000-0001-6696-5006

Prof. Dr. Ayhan CEYHAN

Niğde Ömer Halisdemir Üniversitesi Tarım Bilimleri ve Teknolojileri Fakültesi, Hayvansal Üretim ve Teknolojileri Anabilim Dalı, NİĞDE

Email: aceyhan@ohu.edu.tr

ORCID: 0000-0003-2862-7369

ÖZET

İklim değişikliği, özellikle artan ortalama sıcaklıklar ve aşırı hava olaylarının sıklığındaki artışlar, koyun yetiştiriciliği üzerinde çok yönlü olumsuz etkiler yaratmaktadır. Bu çalışmanın amacı, iklim değişikliğinin koyun yetiştiriciliği üzerindeki etkilerini, özellikle ısı stresi, hayvan performansı ve adaptasyon stratejileri bağlamında kapsamlı bir şekilde inceleyerek, sürdürülebilir üretim için etkili önlemler ve yönetim yaklaşımlarını ortaya koymaktır. Isı stresi, koyunların homeostazını bozarak metabolik dengelerini etkiler ve yem tüketimi ile besin madde kullanımını azaltır. Bu durum, büyüme performansında gerileme, üreme başarısında düşüş ve bağışıklık sisteminde zayıflama gibi sonuçlar doğurur. Ayrıca, oksidatif stresin artması, hücresel hasarları tetikleyerek hayvan sağlığını olumsuz etkiler. Isı stresi, özellikle yaz aylarında ve sıcak iklim bölgelerinde koyunlarda önemli verim kayıplarına yol açmaktadır. Hayvan refahının sağlanması ve sürdürülmesi, iklim değişikliğinin olumsuz etkilerini hafifletmede temel bir stratejidir. Koyunların çevresel, beslenme ve sağlık gereksinimlerine uygun koşullarda tutulması, stres faktörlerinin azaltılması ve refahın artırılması performansın korunmasını sağlar. Refahın iyileştirilmesi, et kalitesi ve karkas özellikleri üzerinde de olumlu etkiler doğurarak hem üreticilerin hem de tüketicilerin beklentilerini karşılamaktadır. Adaptasyon stratejileri, genetik dayanıklılığın artırılmasından modern yönetim tekniklerine ve teknolojik yeniliklere kadar geniş bir yelpazede ele alınmaktadır. Isı stresine dayanıklı koyun ırklarının genetik seleksiyon yoluyla geliştirilmesi, adaptasyonun biyolojik temelini oluşturur. Barınaklarda mikroiklim kontrolü, serinletme sistemleri ve uygun havalandırma gibi çevresel düzenlemeler, ısı stresinin etkilerini azaltmada etkilidir. Ayrıca, yapay zekâ destekli giyilebilir teknolojiler ve izleme sistemleri, hayvanların fizyolojik durumları, davranışları ve çevresel stres faktörleri hakkında gerçek zamanlı veri sağlayarak erken müdahale imkanı sunmaktadır. Sonuç olarak, iklim değişikliğinin koyun yetiştiriciliğine etkileri multidisipliner bir yaklaşımla ele alınmalıdır. Isı stresi ve performans kayıplarını minimize etmek için genetik, çevresel ve teknolojik adaptasyon stratejilerinin entegre edilmesi gerekmektedir. Bu yaklaşımlar, hayvan refahını artırırken sürdürülebilir koyun yetiştiriciliğinin geleceğini güvence altına alacaktır.

Anahtar Kelimeler: Isı Stresi Yönetimi, Hayvan Refahı, Genetik Adaptasyon, Sürdürülebilir Hayvancılık, Giyilebilir Teknolojiler

IMPACT OF CLIMATE CHANGE ON SHEEP FARMING: HEAT STRESS, PERFORMANCE, ADAPTATION STRATEGIES

ABSTRACT

Climate change, especially increasing average temperatures and increasing frequency of extreme weather events, has multifaceted negative effects on sheep breeding. The aim of this study is to comprehensively examine the effects of climate change on sheep breeding, especially in the context of heat stress, animal performance and adaptation strategies, and to present effective measures and management approaches for sustainable production. Heat stress disrupts homeostasis of sheep, affects their metabolic balance and reduces feed consumption and nutrient use. This results in a decline in growth performance, decreased reproductive success and weakened immune system. In addition, increased oxidative stress triggers cellular damage and negatively affects animal health. Heat stress causes significant yield losses in sheep, especially in summer months and in hot climate regions. Ensuring and maintaining animal welfare is a basic strategy in mitigating the negative effects of climate change. Keeping sheep in conditions suitable for their environmental, nutritional and health requirements, reducing stress factors and increasing welfare ensures performance is maintained. Improving welfare also has positive effects on meat quality and carcass characteristics, meeting the expectations of both producers and consumers. Adaptation strategies cover a wide range of topics, from increasing genetic resistance to modern management techniques and technological innovations. The development of heat stress-resistant sheep breeds through genetic selection forms the biological basis of adaptation. Environmental regulations such as microclimate control, cooling systems and appropriate ventilation in shelters are effective in reducing the effects of heat stress. In addition, artificial intelligence-supported wearable technologies and monitoring systems provide real-time data on the physiological status, behavior and environmental stress factors of animals, allowing early intervention. In conclusion, the effects of climate change on sheep farming should be addressed with a multidisciplinary approach. In order to minimize heat stress and performance losses, genetic, environmental and technological adaptation strategies need to be integrated. These approaches will increase animal welfare and secure the future of sustainable sheep farming.

Keywords: Heat Stress Management, Animal Welfare, Genetic Adaptation, Sustainable Livestock, Wearable Technologies

1. GİRİŞ

Küresel iklim değişikliği, dünya genelinde ekosistem dengesini bozarak tarımsal üretim sistemlerinin sürdürülebilirliğini tehdit eden en kritik çevresel sorunlardan biri haline gelmiştir. Atmosfere salınan sera gazlarının (karbondioksit [CO_2], metan [CH_4], diazot monoksit [N_2O] vb.) birikimi sonucunda küresel sıcaklık artışı meydana gelmekte ve bu durum özellikle geviş getiren hayvanların yoğun bulunduğu bölgelerde hayvansal üretimi çok yönlü etkilemektedir (Koyuncu ve Akgün, 2018). Hayvancılık sektörü, hem iklim değişikliğinin başlıca nedenlerinden biri olan sera gazı salımına kaynaklık etmekte hem de artan sıcaklıklar, kuraklık, su kıtlığı ve ekstrem hava olayları gibi olumsuzluklardan doğrudan etkilenmektedir (Sarıözkan ve Küçükoflaz, 2020). Hayvansal üretimin küresel sera gazı emisyonuna katkısı özellikle enterik fermantasyon, yem üretimi, gübre yönetimi ve enerji kullanımı üzerinden şekillenmektedir. Geviş getiren hayvanlarda selülozun mikrobiyal fermantasyonu sonucu ortaya çıkan metan gazı, hayvancılık kaynaklı CH_4 salımının en önemli kaynağıdır ve küresel ısınma potansiyeli bakımından CO_2'ye göre 21 kat daha etkilidir (Koyuncu ve Akgün, 2018). Küçükbaş hayvanlar arasında koyunlar, sığırlara göre daha az emisyon üretse de, yaygın yetiştiricilik pratikleri ve yem kalitesi düşüklüğü nedeniyle enterik fermantasyon kaynaklı metan salımı bakımından dikkate değer bir katkı sunmaktadır (Sarıözkan ve Küçükoflaz, 2020). Bununla birlikte, iklim değişikliği sadece emisyon yönüyle değil, hayvan refahı, fizyolojik denge, bağışıklık sistemi, üretim performansı ve üreme parametreleri üzerinde de yıkıcı etkiler yaratmaktadır. Sıcaklık-Nem İndeksi (THI) değerinin artmasıyla birlikte koyunlarda rektal sıcaklık, solunum ve nabız hızı artmakta, yem alımı ve canlı ağırlık kazanımı azalmakta, kortizol seviyeleri yükselmekte ve oksidatif stres belirteçleri aktive olmaktadır (Slimen vd., 2019). Sıcaklık stresi, özellikle gebelik ve laktasyon gibi fizyolojik olarak hassas dönemlerde, hayvanların enerji dengesini bozmakta, embriyonik kayıpları artırmakta ve doğurganlık üzerinde baskı oluşturmaktadır (Romo-Barron vd., 2019; Arero ve Özmen, 2025). Koyunlar, evrimsel süreç içerisinde gelişmiş bazı morfolojik (açık tüy rengi, yağlı kuyruk yapısı), fizyolojik (terleme, solunum artışı), davranışsal (gölge arama, gece otlama) ve genetik (HSP70, MC1R, ENOX2 vb. gen ekspresyonları) adaptasyon mekanizmaları sayesinde sıcaklık stresine karşı diğer türlere göre daha dirençli olsa da, 21. yüzyılın ortalarından itibaren bu doğal dayanıklılığın yetersiz kalabileceğini ortaya koymaktadır (Joy vd., 2020; Berihulay vd., 2019; Thornton vd., 2021). Bu nedenle, iklim değişikliğine karşı koyun yetiştiriciliğinde hem genetik ıslah temelli adaptif stratejiler hem de yönetimsel ve çevresel uyarlamalar bütüncül biçimde değerlendirilmelidir (Aboul-Naga vd., 2022; Henry vd., 2018).

Bu derlemenin amacı, iklim değişikliğinin koyun yetiştiriciliği üzerindeki etkilerini çok boyutlu bir yaklaşımla ele almak; özellikle ısı stresinin koyunların fizyolojisi, üretimi ve refahı üzerindeki etkilerini güncel araştırmalar ışığında incelemek, adaptasyon stratejilerini morfolojik, davranışsal, genetik ve yönetimsel düzeylerde değerlendirmek ve sürdürülebilir hayvancılık için yol gösterici öneriler sunmaktır.

2. İKLİM DEĞİŞİKLİĞİNİN KOYUN YETİŞTİRİCİLİĞİ ÜZERİNDEKİ ETKİLERİ

İklim değişikliği, koyun yetiştiriciliğini doğrudan ve dolaylı yollarla etkileyen çok katmanlı bir kriz dinamiği yaratmaktadır. Artan sıcaklıklar, değişen yağış rejimleri, uzayan kuraklık periyotları, yem kalitesindeki azalma ve su kaynaklarına erişimdeki kısıtlamalar, özellikle dış ortamda yetiştirilen koyun sürülerini ciddi şekilde tehdit etmektedir (Koyuncu ve Nageye, 2020; Ghahramani vd., 2019). Küresel ölçekte yapılan modellemelere göre, 2090 yılına kadar koyunların maruz kalacağı aşırı ısı stresli gün sayısında %60'tan fazla artış beklenmektedir (Thornton vd., 2021). Bu durum, özellikle tropikal ve yarı kurak bölgelerde hayvansal üretimin sürdürülebilirliğini riske atmaktadır. Isı stresinin doğrudan etkileri arasında yem tüketiminde azalma, su ihtiyacının artışı, vücut sıcaklığında yükselme, solunum ve terleme hızının artması

gibi fizyolojik tepkiler yer almaktadır. Bu durum, enerji metabolizmasının bozulmasına, bağışıklık sisteminin zayıflamasına ve üretim performansında düşüşe neden olmaktadır (Slimen vd., 2019; Morgado vd., 2023). Aynı zamanda, sıcaklık artışı süt veriminde %35–40 oranında düşüşe ve et üretiminde canlı ağırlık artışının yavaşlamasına neden olabilmektedir (Koyuncu ve Nageye, 2020). Bu etkiler, özellikle Sıcaklık-Nem İndeksi (THI) değerinin 78'in üzerine çıktığı durumlarda ciddi hale gelmektedir (Berihulay vd., 2019). İklim değişikliğinin bir diğer önemli etkisi yem ve ot kaynaklarının kalitesinde azalma yoluyla gerçekleşmektedir. Artan sıcaklık ve CO_2 seviyeleri, yem bitkilerinde ham protein içeriğini düşürmekte, sindirilebilirliği azaltmakta ve lif oranlarını artırarak hayvan beslenmesini olumsuz etkilemektedir (Henry vd., 2018; Ghahramani vd., 2019). Ayrıca kuraklık koşulları altında otlatma alanlarının biyoçeşitliliği azalarak besleme maliyetlerini yükseltmektedir (Koyuncu ve Akgün, 2018). İklim değişikliği sadece üretim parametrelerini değil, hayvan sağlığı ve refahını da kapsamlı biçimde etkilemektedir. Artan sıcaklıklar, dış parazitlerin ve hastalıkların yayılım alanını genişletmekte; bu durum koyunlarda hem bulaşıcı hastalık sıklığını artırmakta hem de tedavi maliyetlerini yükseltmektedir (Sarıözkan ve Küçükoflaz, 2020). Isı stresine bağlı olarak bağışıklık sisteminin baskılanması, koyunları sekonder enfeksiyonlara karşı daha savunmasız hale getirmektedir (Morgado vd., 2023). Ek olarak, iklimsel stresin sosyal davranışlar üzerinde de etkili olduğu gösterilmiştir. Borthwick vd., (2024), serbest gezen Merinos koyunlarında sıcaklık arttıkça gölgelik bölgelerde daha uzun süre kalındığını ve bu davranışın sürü içindeki sosyal ağ yapısını değiştirdiğini ortaya koymuştur. Bu durumun bilgi veya hastalık yayılımı gibi popülasyon düzeyinde sonuçları olabileceği vurgulanmaktadır. Su kaynaklarının azalması da iklim değişikliğinin önemli bir çıktısıdır. Hayvansal üretimde özellikle yaz aylarında artan su ihtiyacı karşılanamazsa, dehidrasyon, hipertermi ve ölümlerle sonuçlanabilecek ciddi fizyolojik stresler ortaya çıkabilmektedir (Koyuncu ve Nageye, 2020; Henry vd., 2018). Ojango vd., (2023) Kuzey Kenya'daki çoban topluluklarında koyun ve keçi üretimini artırmak amacıyla iklim dirençli hayvan yönetim uygulamalarının benimsenmesini ve bu uygulamaların etkilerini yaptıkları bu çalışmayla incelemiş olup ,serbest otlatmadan mevsimsel göç sistemine geçişin daha iyi olduğunu, bunun yanı sıra bulundukları bölgenin aralıklı ve öngörülemez yağış alan yarı kurak bir alan olduğunun da göze alınması gerektiğini belirtmiştir. Türkiye gibi Akdeniz iklim kuşağında yer alan ülkelerde, sıcaklık artışına bağlı olarak hayvancılık işletmelerinin maliyetlerinde %50'ye varan yükselişler beklenmektedir (Koyuncu ve Nageye, 2020). Son olarak, iklim değişikliği hayvan ırklarının genetik sürdürülebilirliğini de tehdit etmektedir. Sıcaklık ve çevresel baskılar nedeniyle düşük adaptasyon kabiliyetine sahip bazı ırkların üretimden düşmesi, genetik çeşitliliğin azalmasına ve yerel ırkların yok olmasına neden olabilir (Joy vd., 2020; Tsartsianidou vd., 2021). Sánchez-Molano vd., (2020) yaptıkları çalışmada 1991-2018 yılları arasında 4469 kuzudan alınan büyüme dönemi verileri toplayarak rastgele regresyon modelleri aracılığıyla bireysel "reaksiyon normları" oluşturmuşlardır. İklim değişikliğinin, çiftlik hayvanlarının verimliliğini olumsuz etkileyebileceğini öne ssürmüşlerdir. Hava durumu verilerini 10 günlük ortalama olarak almışlardır. Sonuç olarak iklim değişikliğinin etkilerini azaltmak için genetik ıslah stratejilerinin uygulanabilir olduğunu, yeni tanımlanan dayanıklılık fenotipleri, seleksiyon programlarına entegre edilerek gelecekteki üretim kayıplarının minimize edilmesine katkı sağlayabileceğini vurgulamışlardır. Bu durum, sadece biyolojik çeşitliliği değil aynı zamanda kültürel mirası da etkilemektedir. Tüm bu etkiler bir araya geldiğinde, iklim değişikliğinin koyun yetiştiriciliği üzerinde hem kısa vadeli ekonomik hem de uzun vadeli ekolojik ve genetik düzeyde sürdürülemez sonuçlar doğurduğu açıkça görülmektedir. Bu nedenle, sıcaklık stresine karşı hem bireysel hem sistem düzeyinde koruyucu ve uyarlanabilir çözümlerin geliştirilmesi bir zorunluluk haline gelmiştir.

3. ISI STRESİNİN FİZYOLOJİK VE ÜREME ÜZERİNE ETKİLERİ

Isı stresi, koyunların homeostatik dengesini bozan ve sistemik düzeyde çok yönlü etkiler yaratan çevresel bir stres faktörüdür (Pulido-Rodríguez vd., 2025). Sıcaklık stresi, sıcakkanlı hayvanların vücut ısısını regüle eden sistemlerinin bozulması sonucu ortaya çıkan fizyolojik bir durumdur. Küçükbaş hayvanların sıcaklık stresine maruziyeti hem hayvan refahını hem de ekonomik verimliliği olumsuz etkiler. Hayvanların sıcaklığa dayanıklılığı; genetik, morfolojik ve fizyolojik özelliklerine bağlı olarak değişkenlik gösterir. "Konfor sıcaklık aralığı" terimi, hayvanın minimum enerji harcayarak vücut sıcaklığını sabit tutabildiği sıcaklık dilimini ifade eder. Bu aralık koyunlar için 12–32 °C, keçiler için 12–24 °C'dir (Yılmaz ve Çam, 2023). Sıcaklık-Nem İndeksi (THI) değerinin yükselmesiyle birlikte koyunlarda temel yaşam fonksiyonlarında belirgin fizyolojik tepkiler ortaya çıkmaktadır. Bu tepkiler arasında rektal sıcaklık artışı, solunum ve kalp atım hızında yükselme, su tüketiminde artış ve yem tüketiminde azalma gibi termoregülasyon odaklı yanıtlar öne çıkmaktadır (Slimen vd., 2019; Morgado vd., 2023; Pulido-Rodríguez vd., 2025). Sıcaklık stresi, hipotalamus-hipofiz-adrenal (HHA) yolu üzerinden endokrin sistemin işleyişini bozarak stres hormonlarında artışa neden olur. Kortizol seviyelerindeki yükselme, bağışıklık sisteminin baskılanmasına, enerji metabolizmasının olumsuz etkilenmesine ve oksidatif stres belirteçlerinin aktivasyonuna yol açmaktadır (Slimen vd., 2019). Aynı zamanda triodotironin (T3) ve tiroksin (T4) gibi tiroid hormonlarında da ısı stresine bağlı olarak azalma gözlenmekte, bu da bazal metabolizma hızının düşmesine neden olmaktadır (Joy vd., 2020). Isı stresinin hematolojik ve biyokimyasal parametreler üzerinde de belirgin etkileri vardır. Rektal sıcaklık ve solunum hızında artış görülmekte; buna karşın toplam protein, albumin ve antioksidan aktivitede baskılanma gözlenmektedir (Slimen vd., 2019). Ayrıca, serumda nitrik oksit (NO) ve malondialdehit (MDA) düzeylerinin artması, oksidatif hasarın önemli göstergeleri arasında yer almaktadır (Slimen vd., 2019). Üreme sistemi, ısı stresine karşı oldukça hassas bir yapıya sahiptir. Dişi koyunlarda kızgınlık süresi kısalmakta, ovulasyon oranı düşmekte, embriyo kayıpları artmakta ve gebelik oranlarında önemli ölçüde azalma meydana gelmektedir (Romo-Barron vd., 2019). Özellikle gebeliğin erken dönemlerinde meydana gelen ısı stresi, plasental büyümeyi ve fetal gelişimi olumsuz etkileyerek düşük doğum ağırlığına ve neonatal kayıplara yol açabilmektedir (Slimen vd., 2019). Erkek koyunlarda ise testiküler termoregülasyonun bozulması, spermatogenez sürecini olumsuz etkileyerek sperm motilitesi, morfolojisi ve yoğunluğunda düşüşe neden olmaktadır (Arero ve Özmen, 2025). Artan testis sıcaklığı, germ hücrelerinde apoptozise ve sperm DNA hasarına yol açabilmekte; bu da fertilite oranlarının düşmesine neden olmaktadır (Arero ve Özmen, 2025). Üreme hormonları üzerindeki etkiler de dikkat çekicidir. Isı stresine maruz kalan koyunlarda folikül stimüle edici hormon (FSH), luteinize edici hormon (LH), östrojen ve progesteron seviyelerinde düzensizlikler görülmekte, bu da ovaryum fonksiyonlarının baskılanmasına yol açmaktadır (Romo-Barron vd., 2019). Özetle, ısı stresi koyunlarda temel vücut sistemleri üzerinde hem akut hem de kronik etkiler yaratarak üretim ve üreme verimliliğini düşürmektedir. Fizyolojik dengedeki bozulmalar, yalnızca kısa vadeli üretim kayıplarına değil, aynı zamanda sürü sağlığının ve genetik verimliliğin sürdürülebilirliğini tehdit eden uzun vadeli sonuçlara da yol açmaktadır. Bu nedenle, ısı stresinin etkileri sadece biyolojik değil, aynı zamanda ekonomik ve genetik açılardan da stratejik öneme sahiptir.

4. DAVRANIŞSAL VE MORFOLOJİK ADAPTASYONLAR

Koyunlar, evrimsel süreç boyunca farklı ekolojik koşullara uyum sağlayarak geliştirdikleri davranışsal ve morfolojik özellikler sayesinde sıcaklık stresi gibi çevresel baskılara karşı belirli düzeyde direnç geliştirmiştir. Bu adaptasyonlar, hayvanların termal yükü minimize etmesine, su ve enerji kaybını azaltmasına ve hayatta kalma olasılığını artırmasına olanak tanımaktadır (Berihulay vd., 2019; Joy vd., 2020).

4.1. DAVRANIŞSAL YANITLAR

Isı stresine maruz kalan koyunlar, çevresel koşullara karşı bir dizi davranışsal strateji geliştirir. Bunlar arasında gölgede dinlenme süresinin artması, otlatma saatlerinin sabah erken ve akşam geç saatlere kaydırılması, su tüketiminin artışı ve grupsal hareketlerde değişimler yer alır (Henry vd., 2018). Borthwick vd., (2024), sıcaklığın arttığı dönemlerde koyunların daha sık ve uzun süreli gölgelik alanlarda kaldığını, bunun da sürü içi sosyal etkileşimleri yoğunlaştırarak davranışsal ağ yapısını değiştirdiğini belirtmiştir. Bu durum, sürü içinde bilgi yayılımı, sosyal stres ve patojen iletim oranları üzerinde etkili olabilir. Sıcaklık stresi ayrıca hayvanların otlama davranışlarını da değiştirir. Aşırı sıcak koşullarda koyunlar daha az hareket eder, otlama süresi ve sıklığı azalır; bu da yem tüketimini dolaylı olarak düşürerek canlı ağırlık artışı ve süt verimini olumsuz etkiler (Koyuncu ve Nageye, 2020). Bununla birlikte, bazı sürülerde gece otlaması gibi davranışsal esneklikler gelişerek çevresel stresin etkileri kısmen dengelenebilir.

4.2. MORFOLOJİK ADAPTASYONLAR

Koyunlarda sıcak ortama uyum sağlamada etkili olan bir diğer önemli faktör, morfolojik özelliklerdir. Tüy rengi, deri kalınlığı, kulak yapısı, kuyruk morfolojisi ve vücut yüzey alanı gibi özellikler, ısı değişimlerinin yönetilmesinde kritik rol oynar (Berihulay vd., 2019). Açık renkli yapağıya sahip koyunlar, güneş ışığını daha fazla yansıtarak vücut ısısının artmasını sınırlar. İnce ve seyrek yapağı yapısı ise hava sirkülasyonunu artırarak termal yükün azaltılmasına yardımcı olur (Arero ve Özmen, 2025). Yağlı kuyruk yapısına sahip yerli ırklar, enerji depolamasını vücudun periferik bölgesinde yoğunlaştırarak iç organların ısı dengesini koruma avantajı sunar (Arero ve Özmen, 2025). Bu yapı, ısıya karşı pasif bir savunma mekanizması olarak da işlev görür (Aboul-Naga vd., 2022). Yüksek sıcaklıkta yetiştirilen koyunlarda daha küçük vücut yapısının yaygın olduğu, bunun da yüzey alanı/kütle oranını artırarak ısı kaybını kolaylaştırdığı belirlenmiştir (Joy vd., 2020). Bu fizyolojik avantaj, özellikle Sahra altı Afrika ve Orta Doğu'daki yerel koyun ırklarında sıklıkla gözlenmektedir. Ayrıca, koyunların postüral (duruşsal) davranışlarında da iklimsel koşullara göre değişim görülmektedir. Isı stresine maruz kalan hayvanlar, gölgeye yönelme dışında, vücutlarını toprağa daha yakın tutarak ısı kaybını artıran yatış pozisyonları benimseyebilirler (Thornton vd., 2021). Genel olarak, davranışsal ve morfolojik adaptasyonlar, sıcaklık stresinin kısa vadeli etkilerine karşı koyunların hayatta kalmasını sağlayan ilk savunma hatlarıdır. Ancak bu yanıtların uzun süreli ve kronik iklim değişikliği koşullarında yetersiz kalabileceği ve üretim verimliliğini tam anlamıyla koruyamayacağı dikkate alınmalıdır. Bu nedenle, bu adaptif özelliklerin genetik temelleriyle ve uygulamalarla desteklenmesi büyük önem taşımaktadır.

5. GENETİK VE EPİGENETİK YANITLAR

İklim değişikliğinin koyunlar üzerindeki etkilerine karşı yalnızca davranışsal ve fizyolojik tepkiler yeterli olmamakta; uzun vadede kalıcı adaptasyon sağlanabilmesi için genetik dayanıklılık büyük önem taşımaktadır. Bu bağlamda, sıcaklık stresine karşı geliştirilen genetik ve epigenetik yanıtlar, koyunların seleksiyon, ıslah ve sürdürülebilir üretim stratejileri açısından temel bir belirleyici hâline gelmiştir (Berihulay vd., 2019; Aboul-Naga vd., 2022).

5.1. GENETİK ADAPTASYON MEKANİZMALARI

Koyunların sıcak ortamlara adaptasyonu, birçok genetik lokusun ekspresyon seviyeleriyle ilişkilidir. Özellikle "heat shock proteins" (HSP), sıcaklık stresine karşı hücresel düzeyde koruma sağlayan önemli gen ailesidir. HSP70, HSP90 ve HSP60 genleri, hücresel proteinlerin denatürasyonunu engelleyerek hücre bütünlüğünün korunmasına yardımcı olur (Berihulay vd., 2019). Bu genlerin sıcaklık stresi altında yüksek düzeyde ifade edildiği ve termotoleransla pozitif ilişkili olduğu birçok çalışmada gösterilmiştir. Tsartsianidou vd., (2021), Chios koyunlarında yürüttükleri genom çapında ilişkilendirme çalışmasında, sıcaklık stresine

dayanıklılığı etkileyen çeşitli genom bölgelerini (QTL) tanımlamış ve HSP ile ilişkili bazı aday genleri belirlemiştir. Özellikle TRPM8, ATP1A1, ENOX2 ve MC1R gibi genlerin sıcak ortam adaptasyonunda etkili olduğu vurgulanmıştır. Bu genlerin düzenleyici bölgeleri, hücre membran stabilitesi, iyon kanalı denetimi ve pigmentasyon ile ilişkili fizyolojik süreçlerde rol oynamaktadır. Buna ek olarak, Ren vd., (2024) sıcak çöl koşullarına adapte olmuş Mısır Hu koyunlarında, genetik çeşitliliğin ısıya adaptasyon kapasitesiyle yakından ilişkili olduğunu göstermiştir. Isı toleransı yüksek bireylerde, HSP70 ve BCL2 gibi stresle ilişkili genlerin ekspresyon düzeylerinin anlamlı biçimde yüksek olduğu, bu bireylerin ise daha yüksek canlı ağırlık kazancı ve rektal sıcaklık stabilitesi gösterdiği bildirilmiştir.

5.2. EPİGENETİK DÜZENLEMELER

Genetik varyasyonların ötesinde, epigenetik mekanizmalar da çevresel streslere karşı hızlı ve geri dönüşlü adaptasyon süreçlerinde önemli rol oynamaktadır. Epigenetik değişimler, genetik dizide bir değişiklik olmadan gen ekspresyonunun çevresel sinyallerle düzenlenmesini sağlar. Özellikle DNA metilasyonu, histon modifikasyonları ve mikroRNA'lar, ısı stresine karşı geliştirilen epigenetik yanıtlar arasında yer almaktadır (Ren vd., 2024). Mısır'da yapılan çalışmalarda, sıcak ortamlarda yetiştirilen Hu koyunlarında, özellikle HPA aksı üzerinden işleyen CRH-ACTH-kortizol yolundaki epigenetik değişimlerin adaptasyonda önemli rol oynadığı bildirilmiştir (Ren vd., 2024). Bu sistemin metilasyon profillerinde görülen farklılıklar, kortizol salınım düzeylerini ve dolayısıyla hayvanın stresle başa çıkma kapasitesini doğrudan etkileyebilmektedir. Ayrıca, DNA metilasyonundaki bu farklılıkların kuşaklar boyunca aktarılabileceği, yani epigenetik kalıtımla termotoleransın artırılabileceği düşünülmektedir. Epigenetik profilleme yöntemlerinin gelişmesiyle birlikte, koyunlarda ısı stresine duyarlı gen bölgelerinin tanımlanması ve bu bilgilerin seleksiyon programlarına entegre edilmesi mümkün hâle gelmiştir (Ren vd., 2024). Bu da klasik fenotip temelli seleksiyonun ötesine geçilerek, moleküler düzeyde daha hedefli ve etkili bir ıslah stratejisi geliştirilmesine olanak tanımaktadır (Berihulay vd., 2019).

5.3. GENOMİK SELEKSİYON VE SÜRDÜRÜLEBİLİRLİK

Isıya dayanıklı bireylerin erken yaşta tanımlanabilmesi, genetik ilerlemenin hızlandırılması açısından büyük avantaj sağlar. Bu amaçla, SNP (single nucleotide polymorphism) bazlı genotipleme teknikleriyle ısı stresine dayanıklı fenotiplerin genomik belirteçlerle eşleştirilmesi yönünde önemli ilerlemeler kaydedilmiştir (Tsartsianidou vd., 2021). Bu sayede, sadece üretim performansı değil aynı zamanda çevresel streslere karşı direnç de ıslah hedefi hâline gelmektedir. Genetik ve epigenetik dayanıklılık, koyunların uzun vadeli iklimsel değişikliklere karşı korunmasında anahtar rol oynamakta; bu bilgiler sürdürülebilir hayvancılık politikalarının oluşturulmasında da temel veri kaynağı olarak değerlendirilmektedir.

6. YÖNETİMSEL VE BESLENME STRATEJİLERİ

İklim değişikliğinin koyun yetiştiriciliği üzerindeki etkilerini azaltmak ve ısı stresinin üretim üzerindeki olumsuz sonuçlarını hafifletmek amacıyla uygulanan yönetimsel ve beslenme stratejileri, hayvan refahı ve verimliliği açısından kritik öneme sahiptir. Özellikle sıcaklık-nem indeksinin (THI) yüksek olduğu dönemlerde, uygun barınak koşulları, çevresel düzenlemeler, rasyonel sulama sistemleri ve takviye edici besin destekleri ile koyunların stres düzeyi azaltılabilir (Berihulay vd., 2019; Thornton vd., 2021).

6.1. BARINAK VE ÇEVRESEL DÜZENLEMELER

Isı stresine karşı ilk savunma hattı, hayvanların barınma ve çevre koşullarının iyileştirilmesidir. Gölgelik alanların artırılması, barınaklarda doğal havalandırma sistemlerinin kullanılması, zeminin ısıyı yansıtan ve absorbe etmeyen malzemelerle düzenlenmesi ve gerektiğinde fan ya da püskürtmeli soğutma sistemlerinin uygulanması ısı stresini azaltıcı etkiler göstermektedir

(Slimen vd., 2019). Özellikle açık arazide otlayan sürülerde, ağaç altı gölgelik sistemlerin hayvanların vücut sıcaklığını düşürmede etkili olduğu bildirilmiştir (Borthwick vd., 2024). Bazı ülkelerde, tarım ve hayvancılığı birleştiren entegre sistemlerde güneş panelleri gölgelik olarak kullanılarak hem elektrik üretimi sağlanmakta hem de hayvan refahı korunmaktadır (Tüfekçi vd., 2022). Bu tür sürdürülebilir uygulamalar, sıcaklık stresine karşı çift yönlü çözüm sunmaktadır.

6.2. SU TEMİNİ VE YÖNETİMİ

Sıcaklık arttıkça koyunların suya olan ihtiyacı da artar. Isı stresinin etkilerini azaltmak için yeterli ve sürekli temiz su temini sağlanmalıdır. Dehidrasyon, termoregülasyonun bozulmasına, yem tüketiminde azalmaya ve verim kayıplarına neden olur. Özellikle laktasyon dönemindeki dişiler ve gelişme çağındaki kuzu ve toklularda su tüketimi, metabolik ihtiyaçların karşılanması açısından yaşamsaldır (Slimen vd., 2019; Pulido-Rodríguez vd., 2025). Su kaynaklarının doğru yerleştirilmesi, hayvanların suya kolay erişmesini sağlayarak stres düzeylerini azaltabilir (Henry vd., 2018). Ayrıca yaz aylarında suyun aşırı ısınmaması için gölgede tutulması, su kalitesinin korunması açısından önemlidir.

6.3. BESLENME STRATEJİLERİ

Isı stresi altında yem tüketimi azalırken enerji ihtiyacı artar. Bu durum, besleme stratejilerinde değişiklik yapılmasını gerekli kılar. Rasyonlara yüksek sindirilebilirliğe sahip yemlerin eklenmesi, selüloz içeriği düşük fakat enerji yoğunluğu yüksek yemlerin tercih edilmesi önemlidir (Henry vd., 2018). Ayrıca, yemleme saatlerinin serin dönemlere kaydırılması (örneğin sabah erken ve akşam geç saatler) yem alımını artırabilir (Koyuncu ve Nageye, 2020). Beslenme takviyeleri yoluyla hayvanların fizyolojik stresle başa çıkması desteklenebilir. Özellikle E vitamini, C vitamini, betain, selenyum, çinko gibi antioksidan ve ozmoregülator bileşikler; oksidatif stresi azaltarak bağışıklık sistemini desteklemekte, hormon dengelerini düzenlemekte ve genel performansı artırmaktadır (Joy vd., 2020). Betaine, özellikle hücre içi su dengesini koruyarak ısı stresine karşı hücresel düzeyde dayanıklılık sağlar (Joy vd., 2020). Protein metabolizmasının desteklenmesi için metiyonin, lizin gibi esansiyel amino asitlerin rasyona dahil edilmesi önerilmektedir. Bu sayede, protein katabolizması sınırlandırılarak vücut dokularının yıkımı önlenebilir ve performans korunabilir (Henry vd., 2018).

6.4. YÖNETİM UYGULAMALARI

Yetiştirici düzeyinde alınabilecek bazı düşük maliyetli önlemler de ısı stresinin etkilerini azaltmada etkilidir. Bunlar arasında sıcak saatlerde otlatmadan kaçınma, hayvanların erken kırkımı (shearing), aşırı kalabalık barınaklardan kaçınma, stres faktörlerini minimize eden taşıma ve manipülasyon prosedürleri gibi uygulamalar yer alır (Joy vd., 2020; Pulido-Rodríguez vd., 2025). Ayrıca, sürü yönetimi sırasında yüksek riskli hayvan gruplarının (örneğin gebe dişiler, yaşlı bireyler) öncelikli olarak korunması ve takip edilmesi önerilmektedir. Özellikle gebelik ve laktasyon dönemlerinde ısı stresine karşı alınacak önlemler, sürü genelindeki üretkenlik ve hayatta kalma oranlarını doğrudan etkiler.

7. İKLİME DAYANIKLI ISLAH VE SÜRDÜRÜLEBİLİRLİK PERSPEKTİFİ

Küresel ısınmanın koyun yetiştiriciliği üzerindeki çok yönlü etkileri, sadece kısa vadeli yönetim önlemleriyle değil; aynı zamanda uzun vadeli stratejik ıslah yaklaşımları ve sürdürülebilir sistem tasarımlarıyla ele alınmalıdır. Bu bağlamda, iklim değişikliğine dayanıklı hayvan ırklarının geliştirilmesi, genetik kaynakların korunması, ekosistem temelli hayvancılık modellerinin benimsenmesi ve üretici düzeyinde adaptasyon kapasitesinin artırılması hayati önemdedir (Berihulay vd., 2019; Aboul-Naga vd., 2022; Henry vd., 2018). Fenotipik ve genetik göstergelerin bir araya getirilmesiyle iklim değişikliğine daha dirençli hayvan ırkları geliştirilebilir. İklim değişikliğinin etkileriyle başa çıkmak için multidisipliner yaklaşımlara

ihtiyaç vardır: hayvan ıslahı, besleme, barınak koşulları ve sağlık hizmetleri birlikte düşünülmelidir (Gaughan vd., 2019).

7.1. TERMOTOLERANT IRKLARIN ÖNEMİ

Isıya dayanıklı yerli ve bölgesel ırklar, iklim değişikliğine uyumda doğal bir avantaj sağlamaktadır. Bu ırklar genellikle daha küçük vücut yapısına, açık tüy rengine, yağlı kuyruk morfolojisine ve daha iyi su/ısı metabolizmasına sahiptir. Örneğin, Mısır'daki Hu koyunları sıcak çöl koşullarına yüksek düzeyde adaptasyon göstermekte, bu özellikleriyle genetik kaynak olarak büyük potansiyel taşımaktadır (Ren vd., 2024). Türkiye'de yerli ırkların üretim verimleri genellikle daha düşük olduğu için, termotolerans ile verim özellikleri arasında bir denge kuracak selektif ıslah programlarına ihtiyaç vardır (Tsartsianidou vd., 2021).

7.2. GENOMİK VE EPİGENETİK SELEKSİYON STRATEJİLERİ

Geleneksel fenotipe dayalı seleksiyon yöntemleri, çevresel stres koşullarında yeterli başarıyı sağlayamayabilir. Bu nedenle genetik seleksiyon süreçlerinde genomik marker'ların ve epigenetik profilleme tekniklerinin kullanımı giderek yaygınlaşmaktadır. SNP tabanlı genotipleme, ısı stresine karşı dayanıklı fenotiplerle ilişkilendirilmiş genetik bölgelerin tanımlanmasını ve selektif çiftlik içi uygulamalara entegre edilmesini sağlamaktadır (Tsartsianidou vd., 2021). Özellikle HSP70, MC1R, ENOX2 gibi stresle ilişkili genlerin ekspresyon düzeylerinin yüksek olduğu bireylerin tercih edilmesi, sadece stres toleransını değil aynı zamanda yaşam süresi ve genel performansı da olumlu etkileyebilmektedir (Berihulay vd., 2019). Epigenetik regülasyonla aktarılan stres toleransı özelliklerinin nesiller arası sürdürülebilirliği desteklemesi, bu stratejileri daha da değerli kılmaktadır (Aboul-Naga vd., 2022).

7.3. EKOSİSTEM TEMELLİ SÜRDÜRÜLEBİLİRLİK

İklime dirençli hayvancılık sistemlerinin tasarımında, hayvan–bitki–çevre etkileşimini göz önünde bulunduran ekosistem temelli yaklaşımlar öne çıkmaktadır. Bu sistemler, biyoçeşitliliği koruyarak hem hayvan refahını hem de otlatma alanlarının sürdürülebilirliğini artırmaktadır (Ghahramani vd., 2019; Darcan ve Daşkıran, 2010). Bu tür sistemlerde, hem mikroiklim koşullarının iyileştirilmesi hem de üretim çeşitlendirmesi sağlanarak, çiftçilerin iklim değişikliğine karşı dirençleri artırılmaktadır. Aynı zamanda karbon ayak izinin azaltılması ve sera gazı emisyonlarının düşürülmesi açısından da önemli katkılar sunmaktadır.

7.4. EĞİTİM VE POLİTİKA DESTEĞİ

Küçükbaş hayvan yetiştiriciliği yapan üreticilerin iklim değişikliğine karşı uyum kapasitelerinin artırılması için bilgiye erişim, eğitim ve finansal destek mekanizmalarının sağlanması gereklidir. Özellikle düşük ve orta gelirli bölgelerde, iklime dayanıklı ıslah uygulamalarının benimsenmesi için devlet destekli programlara, yerel bilgi sistemlerine ihtiyaç duyulmaktadır (Henry vd., 2018; Gaughan vd., 2019). Buna ek olarak, yerli ırkların korunması ve genetik kaynakların ticarileşmeden uzak uzun vadeli ıslah programlarıyla güvence altına alınması, hayvancılık sektörünün geleceği açısından stratejik bir adımdır. Bu hedef hem biyolojik çeşitliliğin korunmasına hem de tarımsal sistemlerin iklim krizine dirençli hale getirilmesine katkı sağlar.

8. SONUÇ VE ÖNERİLER

İklim değişikliği, koyun yetiştiriciliğini çok boyutlu bir kriz alanı hâline getirmekte; hem çevresel koşulların zorlaşması hem de üretim sistemlerinin bu değişime uyum sağlamakta zorlanması, sürdürülebilir hayvancılığı tehdit etmektedir. Artan sıcaklıklar, değişen yağış desenleri ve ekstrem iklim olayları, koyunların fizyolojik, üreme, davranışsal ve genetik kapasitelerini zorlamakta; üretim kayıpları, bağışıklık baskılanması, fertilite sorunları ve refah

düzeyinde düşüş gibi sonuçlara yol açmaktadır. Koyunlar, tarihsel süreçte bazı davranışsal (gölgelik arama, gece otlama), morfolojik (açık tüy rengi, yağlı kuyruk yapısı), fizyolojik (terleme, solunum artışı) ve genetik (HSP70, MC1R vb. gen ekspresyonu) adaptasyon mekanizmaları geliştirmiştir. Ancak günümüzde küresel iklim değişikliği bu doğal tolerans eşiğini aşmakta ve adaptasyonun kalıcı, verimli ve sürdürülebilir şekilde desteklenmesini zorunlu kılmaktadır. Bu kapsamda alınması gereken önlemler çok katmanlıdır. Yönetimsel düzeyde; barınak tasarımı, gölgelik alan oluşturulması, soğutma sistemleri, doğru otlatma ve yemleme zamanlaması, stres azaltıcı uygulamalar gibi pratik çözümler önem arz etmektedir. Beslenme stratejilerinde ise antioksidanlar, vitamin destekleri (C, E), metiyonin gibi amino asitler ve betain gibi osmoregülatör bileşiklerin kullanımı ile fizyolojik dengenin korunması sağlanabilir. Uzun vadeli sürdürülebilirlik için ise genetik ve epigenetik seleksiyon sistemlerinin entegrasyonu büyük önem taşımaktadır. Isı stresine dayanıklı bireylerin SNP analizleriyle belirlenmesi, HSP gen ailesi gibi aday genlerin ekspresyon düzeylerinin izlenmesi ve termotolerant yerli ırkların korunarak üretime kazandırılması, iklim değişikliğine karşı genetik direnç inşası açısından stratejik değer taşımaktadır. Ekosistem temelli üretim modelleri (silvopastoral sistemler, agrivoltaik uygulamalar) ve karbon ayak izi düşük sürdürülebilir hayvancılık politikaları ile hem çevresel hem de ekonomik direnç artırılabilir. Yerli ırkların korunması, üreticilerin eğitimi ve teşvik mekanizmalarının yaygınlaştırılması da bu sürecin toplumsal ve uygulamalı boyutlarını destekleyecektir.

Sonuç olarak, iklim değişikliğine karşı koyun yetiştiriciliğini korumanın yolu, sadece hayvanların değil, tüm üretim sistemlerinin dayanıklılığını artırmaktan geçmektedir. Bu bağlamda, multidisipliner bir yaklaşımla; genetik, fizyolojik, çevresel ve yönetimsel tüm bileşenleri kapsayan entegre stratejilerin geliştirilmesi kaçınılmazdır. Bu stratejiler, yalnızca üretim verimliliğini değil, aynı zamanda hayvan refahını, çevresel sürdürülebilirliği ve gıda güvenliğini de güvence altına alacaktır.

KAYNAKÇA

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KENEVİR BİYOKÜTLESİNİN ANAEROBİK FERMANTASYONLA ENERJİYE DÖNÜŞTÜRÜLMESİ: BİYOGAZ VE BİYOMETAN PERSPEKTİFİ

Doç. Dr. Gülizar Kurtoğlu Akkaya

Necmettin Erbakan Üniversitesi, Mühendislik Fakültesi, Konya

Email: gakkaya@erbakan.edu.tr ka.gulizar@gmail.com

ORCID: 0000-0003-4779-0428

Dr. Öğr. Üyesi N. Berk Bıtrak

Süleyman Demirel Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, Isparta

Email: berkbitrak@sdu.edu.tr, berkbitrak@gmail.com

ORCID: 0000-0002-6822-3564

Prof. Dr. Kâmil Ekinci

Isparta Uygulamalı Bilimler Üniversitesi, Ziraat Fakültesi, Isparta

Email: kamilekinci@isparta.edu.tr

ORCID: 0000-0002-7083-5199

ÖZET

Artan enerji talebi, fosil yakıtların sınırlı rezervleri ve çevresel etkileri sürdürülebilir enerji kaynaklarının geliştirilmesini zorunlu hale getirmiştir. Bu bağlamda, organik atıkların oksijensiz koşullarda mikroorganizmalar tarafından parçalanarak biyogaz ve biyometana dönüştürülmesini sağlayan anaerobik fermantasyon, teknik ve ekonomik açıdan uygulanabilirliği kanıtlanmış bir yöntem olarak öne çıkmaktadır. Biyogaz üretimi sonrasında anaerobik fermantasyon hem enerji üretimi hem de atık yönetiminde çevresel etkilerin azaltılmasına katkı sunmaktadır. Hidroliz, asidojenez, asetojenez ve metanojenez aşamalarından oluşan bu biyokimyasal süreç, yenilenebilir enerji teknolojileri arasında önemli avantajlara sahiptir. Bu çerçevede, düşük Δ-9-tetrahidrokanabinol (THC) içeriği, yüksek biyokütle verimi ve farklı iklim koşullarına uyum sağlayabilmesi ile dikkat çeken endüstriyel kenevir, enerji üretiminde potansiyel bir hammadde olarak öne çıkmaktadır. Literatürde, yüksek lignin içeriğine rağmen kenevir biyokütlesinin umut verici biyometan potansiyeli sunduğu ve uygulanan mekanik ya da kimyasal ön işlemlerle metan veriminin belirgin şekilde artırılabildiği raporlanmıştır. Ayrıca, kenevir atıklarının hayvansal gübre gibi diğer organik substratlarla ko-fermantasyonu sinerjik etkiler yaratarak biyogaz üretiminde performans artışı sağlayabilmektedir. Bu çalışmada, endüstriyel kenevir işleme atıklarının anaerobik fermantasyon yoluyla biyogaz ve biyometan üretim potansiyeli değerlendirilecek, mevcut literatürdeki çalışmalarda kenevirin biyogaz üretimindeki rolüne ilişkin araştırmalara yer verilecek ve bu hammaddenin yenilenebilir enerji üretimindeki stratejik önemi ortaya konacaktır. Böylece elde edilecek bulgular sürdürülebilir enerji üretimi, çevre dostu atık yönetimi ve iklim değişikliğiyle mücadele politikalarına katkı sağlaması öngörülmektedir.

Anahtar Kelimeler: Kenevir, Biyogaz, Biyometan potansiyeli (BMP), anaerobik fermantasyon, yenilenebilir enerji

ENERGY CONVERSION OF HEMP BIOMASS THROUGH ANAEROBIC FERMENTATION: PERSPECTIVES ON BIOGAS AND BIOMETHANE

ABSTRACT

The growing global demand for energy, limited fossil fuel reserves and the adverse environmental impact of fossil fuels have made the development of sustainable energy sources imperative. In this context, anaerobic fermentation — the decomposition of organic waste by microorganisms in an oxygen-free environment, resulting in the production of biogas and biomethane — has emerged as a technically and economically viable method. This process contributes to energy generation and mitigating the environmental impact of waste management. Consisting of four biochemical stages — hydrolysis, acidogenesis, acetogenesis and methanogenesis — anaerobic fermentation offers several advantages over other renewable energy technologies. Within this framework, industrial hemp, characterized by its low THC content, high biomass yield and adaptability to diverse climatic conditions, stands out as a promising energy production feedstock. Despite its relatively high lignin content, the literature reports that hemp biomass exhibits notable biomethane potential and that mechanical or chemical pretreatments can significantly enhance methane yields. Furthermore, co-fermenting hemp residues with other organic substrates, such as animal manure, has been shown to produce synergistic effects and improve biogas production efficiency. This study will evaluate the potential of industrial hemp processing residues for biogas and biomethane production through anaerobic fermentation. Findings from existing literature will be discussed to elucidate hemp's role in biogas generation and highlight its strategic importance as a renewable energy resource. The results obtained are expected to contribute to sustainable energy production, eco-friendly waste management and climate change mitigation policies.

Keywords: Hemp, Biogas, Biomethane Potential (BMP), Renewable Energy.

1. GİRİŞ

İnsan yaşamını sürdürebilmek ve üretim faaliyetlerini devam ettirebilmek için enerjiye ihtiyaç duyar. Ancak mevcut küresel enerji yapısı hâlâ büyük ölçüde yenilenemeyen fosil yakıtlara dayanmaktadır. Bu durum, hem enerji arz güvenliği hem de çevresel sürdürülebilirlik açısından ciddi bir tehdit oluşturmaktadır (Abraham vd., 2020). Fosil yakıt rezervlerinin sınırlı olması, enerji fiyatlarında yaşanan dalgalanmalar ve bu kaynakların yanması sonucu ortaya çıkan yüksek miktardaki sera gazı (GHG) emisyonları, günümüzde enerji krizinin ve iklim değişikliğinin temel nedenleri arasında yer almaktadır (Millati vd., 2020; Paudel vd., 2017).

Artan enerji talebi, nüfus artışı ve ekonomik büyüme gibi faktörler, yenilenebilir enerji kaynaklarını ekonomik olarak cazip ve çevresel açıdan sürdürülebilir bir alternatif haline getirmiştir (Paudel vd., 2017). Yenilenebilir enerji; güneş, rüzgâr, jeotermal, hidroelektrik ve biyokütle gibi doğal kaynaklardan elde edilmekte, böylece fosil yakıtlara olan bağımlılığı azaltarak enerji arz güvenliğini güçlendirmektedir.

Bu kaynaklar içinde biyokütle enerjisi, hem çevre dostu olması hem de doğrudan bitkisel ve organik atıklardan enerji üretimine olanak tanıması nedeniyle özel bir öneme sahiptir. Biyokütle, fotosentez yoluyla atmosferden aldığı karbondioksiti enerji üretimi sırasında yeniden atmosfere saldığı için karbon nötr bir döngü oluşturur (Millati vd., 2020). Bu özelliği, onu iklim değişikliğiyle mücadelede stratejik bir yenilenebilir enerji kaynağı haline getirmektedir.

Biyokütle kaynakları arasında lignoselülozik biyokütle, dünyadaki en verimli karbon depolarından biri olarak öne çıkmaktadır. Yıllık küresel üretimi yaklaşık 12×10^{10} ton düzeyindedir ve karasal bitkiler tarafından yakalanan biyoenerji, insanlığın toplam enerji talebinin yaklaşık 3–4 katı kadardır (Guo vd., 2015). Bu, lignoselülozik biyokütlenin gelecekteki enerji güvenliğini sağlamada önemli bir potansiyele sahip olduğunu göstermektedir. Bununla birlikte, bu potansiyelin verimli şekilde kullanılmaması hâlinde çevresel riskler ortaya çıkabilmektedir. Örneğin, bitki samanının yakılması gibi geleneksel uygulamalar; arazi israfına, hava kirliliğine ve karbon salımına neden olmaktadır (Cheng & Zhong, 2014; Zhang vd., 2018). Dolayısıyla biyokütlenin sürdürülebilir şekilde değerlendirilmesi, çevresel faydanın en üst düzeye çıkarılması açısından kritik öneme sahiptir.

Enerji talebinin karşılanmasında fosil kaynakların uzun vadede güvenilir bir çözüm sunamayacağı açıktır. Bu nedenle araştırmalar, biyokütle tabanlı biyoyakıtlar üzerine yoğunlaşmıştır. Günümüzde mısır, buğday, pirinç, soya fasulyesi ve şeker kamışı gibi çeşitli tarımsal ürünler biyoyakıt üretiminde kullanılmaktadır (Abraham vd., 2020; Prade vd., 2011). Ancak bu hammaddeler genellikle gıda kaynaklarıyla rekabet ettiği için, yeni nesil biyoyakıt çalışmaları gıda dışı lignoselülozik materyallere yönelmiştir. Bu tür biyokütleler, yüksek karbon içeriği ve düşük maliyetleriyle sürdürülebilir enerji üretimi açısından büyük avantaj sağlamaktadır.

Bu kapsamda anaerobik fermantasyon, lignoselülozik biyokütlenin enerjiye dönüştürülmesinde en etkili teknolojilerden biridir. Bu biyokimyasal süreçte organik maddeler, oksijensiz ortamda mikroorganizmalar tarafından parçalanarak biyogaz üretir (Angelidaki vd., 2018; Appels vd., 2011). Elde edilen biyogazın temel bileşeni metan (CH_4) olup, hem elektrik ve ısı üretiminde hem de biyometan saflaştırması yoluyla doğalgaz yerine kullanılabilmektedir. Böylece, hem enerji üretiminde fosil kaynaklara bağımlılık azalmakta hem de karbon salımı minimize edilmektedir (Kumar vd., 2017).

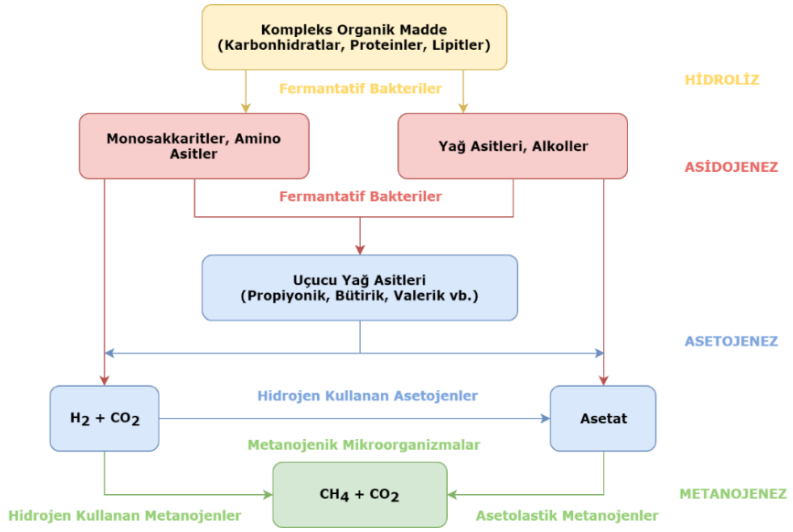
Sonuç olarak, fosil yakıtların çevresel zararları ve sınırlı rezervleri göz önüne alındığında, biyokütle tabanlı biyogaz üretimi, enerji arz güvenliği ve iklim değişikliğiyle mücadele açısından geleceğin en sürdürülebilir çözümlerinden biri olarak değerlendirilmektedir.

2. ANAEROBİK FERMANTASYON

Anaerobik koşullarda organik atıkların ayrıştırılması, tarihsel olarak atık yönetimi ve enerji geri kazanımı alanlarında kullanılan en eski biyoteknolojik süreçlerden biridir. Günümüzde ise anaerobik fermantasyon sürdürülebilir enerji üretimi ve çevresel etkilerin azaltılması açısından en yaygın tercih edilen biyolojik dönüşüm yöntemlerinden biri hâline gelmiştir. Biyogaz teknolojisi, dünya genelinde gelişmiş/gelişmekte olan ülkelerde ekonomik uygulanabilirliği, enerji geri kazanım verimliliği ve çevresel sürdürülebilirliği ile etkinliğini kanıtlamıştır (Angelidaki vd., 2018).

Anaerobik fermantasyon, oksijensiz koşullar altında organik maddelerin mikroorganizmalar tarafından biyokimyasal reaksiyonlarla stabilize edilmesi ve biyogaza dönüştürülmesi sürecidir (Chen vd., 1980; Safley Jr & Westerman, 1990). Bu biyogaz genellikle %50–70 CH_4 ve %30–50 karbondioksit (CO_2) içerirken, az miktarda hidrojen sülfür (H_2S), amonyak (NH_3) ve hidrojen (H_2) gibi bileşenler de bulunabilir. Böylece anaerobik fermantasyon hem enerji üretimi sağlar hem de atığın çevresel etkilerini azaltarak sürdürülebilir bir döngü oluşturur.

Bu süreç, biyokimyasal olarak dört temel aşamada gerçekleşir: hidroliz, asidojenez, asetojenez ve metanojenez (Dichtl, 1997). Her aşamada farklı mikrobiyal topluluklar aktif rol oynar ve sistemin genel verimliliği bu topluluklar arasındaki simbiyotik dengeye bağlıdır (Şekil 1; (Chernicharo, 2007).



Şekil 1. Anaerobik ayrışmanın metabolik aşamaları (Chernicharo, 2007).

Anaerobik fermantasyonun birinci aşaması olan "hidroliz" esnasında hammaddenin kompleks yapıları (örneğin karbonhidratlar, yağlar gibi) daha basit organik yapılara (örneğin aminoasitler, şeker, yağ asitleri) dönüştürülür. Bu aşamada kompleks maddeler fermentatif bakteriler tarafından üretilen enzimlerin yardımı ile ayrışır ve çözünmüş hale geçer, böylece fermantatif bakterilerin hücre duvarlarından geçebilecek bir yapıya dönüşürler (Henze vd., 2008). Hidroliz sırasında katı partiküller suda çözünür bir hale geçtikleri için bu aşamaya sıvılaştırma (likifikasyon) da denilmektedir (Avcıoğlu Onurbaş, 2011).

Mikroorganizmalarca gerçekleştirilen ikinci temel adım asidojenezdir. Asidojenez fazında fermantatif bakteriler enerji ihtiyaçlarını karşılamak için çözünmüş bileşikleri hücre içerine alırlar. Daha sonra mikroorganizmalarca ayrışan bu bileşikler daha basit bileşenlere dönüştürülür ve hücre dışına atılır (Henze vd., 2008). Fermantasyon işleminde, substratlar hem elektron verici hem de alıcı olarak hizmet eder (Eddy vd., 2014). Bu aşamada üretilen en bilinen bileşikler uçucu yağ asitleri (valerik, propiyonik ve bütirik asitler), alkoller (etanol), laktik asit, CO_2, H_2, NH_3 ve H_2S'dür (Henze vd., 2008). Bu aşamada çözünmüş karbonhidratlar; etanol,

hidrojen ve karbondioksite, aminoasitler; süksinik asit ve hidrojene ve yağ asitleri ise asetat ve hidrojene dönüşür. Asetat, sadece çözünebilir organik bileşiklerin fermantasyonu yoluyla değil, aynı zamanda asetojenez yoluyla da üretilebilir (Gerardi, 2003). Asidojenez fazı anaerobik arıtmada gerçekleşen en hızlı fazdır ve metan üretimi asit üretimine göre daha yavaş gerçekleştiğinden dolayı çözünmüş organik madde konsantrasyonunda oluşan ani artışlar asit üretimini tetikleyerek sistemde aşırı yüklemeye sebep olabilir. Bu durumda metan üretimi yavaşlar ve üretilen asit sonucu sistemde ani pH düşmesine yol açarak prosesi inhibe eder (Henze vd., 2008).

Asetojenez fazında asetojenik mikroorganizmalarca fermantasyon devam eder ve asidojenez aşamasında oluşan uçucu yağ asitleri metan üretiminin öncüsü olan asetat, hidrojen ve karbondioksite dönüşür (Eddy vd., 2014). Burada asetat üretimi asidojenezden farklı olarak, asetojenik mikroorganizmaların aktivitesi ile gerçekleştirilir (Gerardi, 2003). Bu aşamada en önemli besin maddeleri anaerobik fermantasyonda kilit rol oynayan propiyonik ve bütirik asitlerdir (Henze vd., 2008). Hidrojene dönüşümü yeterli hızda gerçekleşmeyen uçucu yağ asitleri asidojenez aşamasında olduğu gibi sistemde birikerek pH'nın ani şekilde değişmesine yol açabilir. Bunun yanı sıra hidrojen üreten asetojenik mikroorganizmalar ile hidrojen tüketen metanojenik mikroorganizmalar arasında hassas bir denge de mevcuttur (Christensen, 2011; Eddy vd., 2014). Bu hassas dengeye rağmen hidrojenin kısmi basıncı çok düşük bir seviyede seyreder. Bunun sebebi üretilen hidrojenin metanojenler ve sülfat indirgeyen mikroorganizmalar tarafından hızlı şekilde tüketilmesiyle alakalıdır (Henze vd., 2008).

Anaerobik fermantasyonun dördüncü ve son aşaması olan metanojenez, metanojenik mikroorganizmalarca önceki aşamalarda üretilen asetat, hidrojen ve karbondioksitin metana çevrildiği aşamadır. Metan üretimi için iki grup metanojenik mikroorganizma görev alır; asetolastik metanojenler, asetatı metan ve karbondioksite dönüştürürler, hidrojen kullanan metanojenler ise elektron vericisi olarak hidrojen ve elektron alıcısı olarak karbondioksiti kullanarak metan üretirler (Eddy vd., 2014; Henze vd., 2008). Metanojenik mikroorganizmalar, asetat, karbondioksit, hidrojen, formate, metanol, etanol ve bazı durumlarda methylamine gibi organik molekülleri de metabolize etmektedirler (Balch vd., 1979; Weimer, 1998; Zinder vd., 1984). Kompleks organik bileşiklerin metana dönüşmesi, hammaddenin metanojenik mikroorganizmalar tarafından kullanılabilen substratlara dönüştürülmesiyle sağlanabilir. Bu aşamaya kadar en kritik nokta asetat üretimidir çünkü anaerobik fermantasyonda üretilen metanın yaklaşık %70'si asetattan sağlanmaktadır. Bu durumda asetat üretimi biyogaz veya metan üretimi açısından bir "darboğaz" olarak adlandırılabilir (Avcıoğlu Onurbaş, 2011; Eddy vd., 2014; Gerardi, 2003). Asetolastik metanojenlerin büyüme oranı oldukça düşüktür. Bu durum anaerobik reaktörlerin uzun adaptasyon süresine olan ihtiyacı açıklamaktadır. Hidrojen kullanan metanojenler, 4 ila 12 saatlik iki katına çıkma zamanları ile asetolastik metanojenlerden çok daha yüksek büyüme oranına sahiptir (Henze vd., 2008). Asidojenik, asetojenik ve metanojenik mikroorganizmaların çalışma hızı kabaca aynı olduğu sürece, metanojenez aşamasının metabolik aktivitesi korunur (Gerardi, 2003).

Bu dört aşamanın dengeli ilerlemesi hem metan üretiminde maksimum verim hem de proses stabilitesi için zorunludur. Ancak bu denge yalnızca mikrobiyal etkileşimlerle değil, aynı zamanda çevresel ve mühendislik parametrelerinin dikkatle optimize edilmesiyle sürdürülebilir (Angelidaki vd., 2018; Appels vd., 2011).

Anaerobik sistemlerin performansını belirleyen çevresel faktörler arasında **pH, sıcaklık, karbon/azot oranı (C/N), organik yükleme hızı (OLR)** ve **karıştırma** koşulları öne çıkar. Metanojenlerin optimum pH aralığı 6.8–7.4'tür; bu aralığın dışına çıkılması mikrobiyal aktiviteyi baskılar ve gaz üretimini düşürür (Gerardi, 2003). Sıcaklık açısından mezofilik (35-37 °C) sistemler kararlı mikrobiyal yapılar sağlarken, termofilik (50-55 °C) koşullar daha hızlı

reaksiyonlar sunar fakat stabilite riskini artırır (Eddy vd., 2014). Uygun C/N oranı (20-30), mikroorganizmaların beslenme dengesini korur; düşük oranlar amonyak toksisitesine, yüksek oranlar ise besin eksikliğine neden olur (Henze vd., 2008). OLR'nin kontrolü, pH dengesini koruyarak uçucu yağ asidi birikimini engeller; karıştırma ise sıcaklık homojenliği ve substrat-mikroorganizma teması açısından sürecin verimliliğini artırır (Christensen, 2011).

Anaerobik fermantasyonun başarısı, yalnızca süreç parametrelerinin kontrolüne değil, aynı zamanda kullanılan **biyokütlenin kimyasal bileşimine** de bağlıdır. Günümüzde tarımsal artıklar, hayvansal gübreler, gıda endüstrisi atıkları ve lignoselülozik materyaller, biyogaz üretiminde yaygın olarak değerlendirilmektedir (Mao vd., 2015; Weiland, 2010). Lignoselülozik biyokütleler, yüksek selüloz ve hemiselüloz içerikleri sayesinde iyi bir karbon kaynağıdır; ancak lignin varlığı, mikrobiyal parçalanmaya karşı direnç göstererek biyogaz üretimini sınırlar (Kumar vd., 2017). Bu nedenle, selüloz ve hemiselülozun erişilebilirliğini artırmak için fiziksel, kimyasal veya biyolojik **ön işlem teknikleri** uygulanması gereklidir.

Farklı organik atıkların birlikte sindirildiği **anaerobik ko-fermantasyon** yaklaşımı, substratlar arasındaki besin dengesini iyileştirerek sinerjik etkiler yaratabilir. Ancak bazı durumlarda kimyasal uyumsuzluklar antagonistik etkilere yol açabilir (Bıtrak, 2021). Bu nedenle, farklı substratların birlikte kullanım potansiyelinin değerlendirilmesinde **biyokimyasal metan potansiyeli (BMP)** testleri büyük önem taşır. BMP, belirli bir substrattan elde edilebilecek maksimum metan miktarını belirleyen temel göstergedir ve sistem tasarımı, kütle dengesi hesapları ve enerji verimliliği analizlerinde kritik rol oynar (Angelidaki vd., 2009; Labatut vd., 2011; Weinrich vd., 2018). Ancak laboratuvar koşullarında belirlenen bu potansiyelin tam ölçekli sistemlerde sürdürülebilir şekilde gerçekleşebilmesi, substrat bileşimi kadar çevresel koşulların ve işletme stratejilerinin de optimize edilmesine bağlıdır.

Son yıllarda yapılan araştırmalar, sürdürülebilir enerji üretimi ve çevresel rehabilitasyon hedefleri doğrultusunda, yeni nesil lignoselülozik biyokütle türlerine yönelmiştir. Bu bağlamda **endüstriyel kenevir (*Cannabis sativa L.)***, yüksek biyokütle verimi, düşük pestisit gereksinimi, kısa büyüme süresi ve farklı iklim koşullarına adaptasyon yeteneği ile ön plana çıkmaktadır (Barta vd., 2013; Ingrao vd., 2018). Lignoselülozik yapısı nedeniyle belirli teknik zorluklar barındırsa da, uygun ön işlem uygulamalarıyla kenevir biyokütlesinin yüksek metan verimi sağladığı bildirilmektedir (Nges vd., 2012; Schroyen vd., 2018).

3. ENDÜSTRIYEL KENEVİR

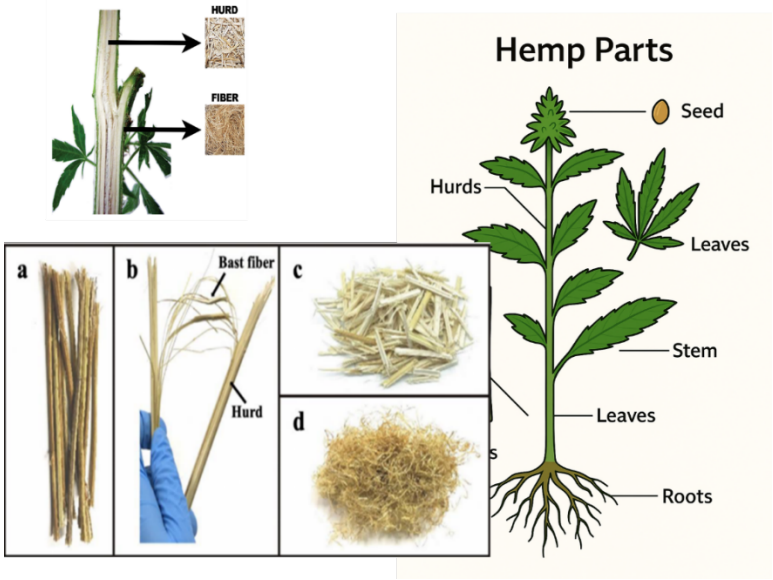
Endüstriyel kenevir (*Cannabis sativa L.*), son yıllarda yalnızca geleneksel lif ve tohum üretiminde değil, aynı zamanda sürdürülebilir biyokütle kaynaklarının geliştirilmesi bağlamında da dikkat çeken stratejik bir bitki türü olarak öne çıkmaktadır. Bu bitkinin çok yönlü kullanım potansiyeli, çevresel, ekonomik ve endüstriyel açıdan geniş bir etki alanı yaratmaktadır. Endüstriyel kenevirin bu denli istisnai bir konuma sahip olmasının temel nedenlerinden biri, psikoaktif türlerden genetik olarak ayrışmış olmasıdır. Endüstriyel kenevir türleri, Δ-9-tetrahidrokanabinol (THC) oranı bakımından %0,3'ün altında değerlere sahiptir ve bu yönüyle narkotik amaçlı türlerden net biçimde ayrılmaktadır (Desanlis vd., 2013). Bu fark, yalnızca yasal açıdan güvenli bir hammadde değil, aynı zamanda sürdürülebilir endüstriler için etik ve ekonomik bir alternatif haline getirmiştir.

Agronomik açıdan değerlendirildiğinde, kenevirin biyolojik yapısı yüksek verimliliğiyle dikkat çeker. C_3 fotosentetik yapıya sahip bu yıllık bitki, lignoselülozik biyokütle üretiminde son derece etkilidir. Literatürde, kenevirin ayda yaklaşık 50 cm büyüyebildiği, 4 m'ye kadar ulaşabildiği ve kuru madde veriminin 7,6–15 Mg ha^{-1} $yıl^{-1}$ arasında değiştiği raporlanmaktadır (Burczyk vd., 2008; Jankauskiene vd., 2015; Strzelczyk vd., 2022). Bu yüksek biyokütle üretimi, enerji yoğunluğu açısından da son derece avantajlıdır; enerji değeri 124–223 GJ ha^{-1} $yıl^{-1}$ aralığında bildirilmektedir. Düşük pestisit gereksinimi, geniş iklim aralığında yetişebilme

kapasitesi ve kuraklığa karşı dayanıklılığı, keneviri çevresel olarak sürdürülebilir tarım sistemleri için ideal bir tür haline getirmektedir (Finnan & Styles, 2013). Böylece kenevir üretimi yalnızca ekonomik kazanç değil, aynı zamanda toprak verimliliği, biyoçeşitlilik ve karbon döngüsünün desteklenmesi bakımından da önemli ekosistem hizmetleri sağlar.

Endüstriyel kenevirin çevresel katkıları, üretim potansiyeli kadar önemlidir. Derin ve yaygın kök sistemi, toprakta biriken ağır metallerin ve kirleticilerin uzaklaştırılmasını sağlayarak fitoremedasyon uygulamalarında etkili bir araç haline getirmektedir (Akkaya vd., 2025; Visković vd., 2024). Bu özelliği sayesinde kenevir, kirlenmiş toprakların rehabilitasyonunda "çift işlevli" bir bitki olarak değerlendirilmektedir; bir yandan çevresel iyileştirme sağlarken, diğer yandan ekonomik değeri yüksek biyokütle üretimi gerçekleştirmektedir. Ayrıca, yüksek karbon tutma kapasitesiyle iklim değişikliğinin etkilerinin azaltılmasına da katkıda bulunur. Yapılan çalışmalar, bir hektarlık kenevir tarlasında yılda önemli miktarda CO_2'nin sabitlenebildiğini ortaya koymuştur (Kaur & Kander, 2023; Visković vd., 2024). Bu yönüyle kenevir hem karbon yutağı işlevi gören hem de karbon-nötr üretim sistemlerine entegre edilebilen nadir tarımsal türlerden biridir.

Endüstriyel kenevirin endüstriyel değerlendirme potansiyeli oldukça geniştir. Bitkinin sap kısmı, lif ve hurd (odunsu iç kısım) olmak üzere iki temel fraksiyona ayrılır (Şekil 2). Lif, sapın yaklaşık %25'ini, hurd ise %75'ini oluşturur (Schluttenhofer & Yuan, 2017). Kenevirin lignoselülozik yapısı, selüloz (%40–48), hemiselüloz (%20–25) ve lignin (%15–20) oranlarıyla tipik enerji bitkilerinden biri olan miscanthus ile benzerlik göstermektedir (Jankauskiene vd., 2015). Lif fraksiyonu yüksek selüloz içeriği (%70–75) sayesinde tekstil ipliği, kâğıt hamuru, biyokompozit ve ısı yalıtım malzemeleri gibi katma değeri yüksek sektörlerde kullanılmaktadır. Buna karşın hurd fraksiyonu, daha yüksek lignin ve mineral içeriğiyle özellikle yapı sektöründe "hempcrete" (kenevir betonu) üretiminde, ayrıca hayvan yataklığı, sunta ve biyokütle yakıtı üretiminde değerlendirilmektedir (Jami vd., 2019; Stevulova vd., 2018).



Şekil 2. Endüstriyel kenevir ve kısımları (Tyagi vd., 2022)

Kenevirin bu kimyasal yapısı, biyoyakıt üretimi açısından da önemli fırsatlar sunar. Lignoselülozik fraksiyon, biyogaz, biyoetanol ve biyodizel üretimi için uygun bir substrat niteliği taşımaktadır. Yapılan araştırmalar, özellikle hurd ve lif fraksiyonlarının, ön işlem uygulanmadan dahi yüksek BMP'ye sahip olduğunu göstermiştir (Heiermann vd., 2009; Jankauskiene vd., 2015). Bu durum, kenevirin hem enerji üretiminde hem de karbon nötrlüğü hedefleriyle uyumlu döngüsel ekonomi uygulamalarında güçlü bir alternatif olduğunu

kanıtlamaktadır. Ayrıca, kenevir tohum yağı biyoetanol ve biyodizel üretiminde önemli bir hammadde niteliği taşırken, yağ çıkarımı sonrasında elde edilen küspe de %50'ye varan protein içeriğiyle yem olarak değerlendirilmektedir (Capcanari vd., 2023; Süzerer vd., 2023).

Bu kapsamda, endüstriyel kenevir yalnızca lif ve tohum üretimiyle sınırlı bir tarım ürünü değil, aynı zamanda çevresel rehabilitasyon, yenilenebilir enerji üretimi ve sürdürülebilir endüstriyel dönüşüm açısından stratejik bir biyoresürstür. Lif, hurd, tohum ve yağ fraksiyonları üzerinden farklı değer zincirlerine entegre olabilen bu bitki, hem toprak kalitesinin artırılması hem de karbon sekestrasyonu, enerji üretimi ve atık geri kazanımı hedefleriyle uyumlu bir biyodöngü modelinin temel bileşenini oluşturmaktadır.

4. ENDÜSTRİYEL KENEVİRİN ANAEROBİK FERMANTASYON POTANSİYELİ

Endüstriyel kenevir, lignoselülozik yapısı, yüksek büyüme hızı ve farklı bitki fraksiyonlarının (yaprak, sap, lif, hurd, tohum) kimyasal çeşitliliği sayesinde anaerobik fermantasyon süreçlerinde yenilenebilir enerji üretimi için önemli bir biyokütle kaynağıdır. Lifli dokuların yüksek lignin içeriği hidroliz hızını azaltırken, fenolik bileşiklerin belirli bir eşiğin üzerinde bulunması metan üretimini geçici olarak baskılayabilmektedir. Schroyen vd. (2017, 2015), fenolik konsantrasyonun 100 mg L^{-1}'den 2000 mg L^{-1}'ye yükselmesinin metan oluşumunda belirgin bir inhibisyona yol açtığını, ancak mikrobiyal toplulukların zamanla bu koşullara adapte olarak inhibitör etkinin kısmen ortadan kalktığını bildirmiştir. Lignin miktarı, BMP'nin en belirleyici bileşenlerinden biridir ve bu nedenle lignin bariyerinin enzimatik veya termo-kimyasal ön işlemlerle zayıflatılması metan üretim verimini önemli ölçüde artırmaktadır (Schroyen vd., 2018).

Kenevirin farklı fraksiyonlarındaki selüloz, hemiselüloz ve lignin oranları biyobozunabilirlik üzerinde doğrudan etkilidir. Özellikle selüloz/hemiselüloz oranı yüksek, lignin oranı düşük olan yaprak fraksiyonları, birim kuru madde başına daha yüksek metan verimi sağlar (Adamovi vd., 2014). Bununla birlikte kenevirin çeşidi, yetiştirme koşulları, hasat zamanı ve partikül boyutu gibi faktörler biyogaz verimini büyük ölçüde etkiler. Mikroorganizmaların optimum aktivitesi için C/N oranının 16–20 arasında tutulması önerilmekte; azot, fosfor ve kükürt eksiklikleri ise metanojenik faaliyetleri sınırlandırmaktadır (Álvarez vd., 2010; Hinken vd., 2008; Mshandete vd., 2004; Nges vd., 2012). Dolayısıyla uygun besin dengesi, özellikle karışık substratlı sistemlerde sürecin kararlılığını ve metan verimini artıran temel bir faktör olarak öne çıkmaktadır.

Tarla denemeleri, ön işlem uygulanmamış kenevir biyokütlesinin enerji üretiminde pek çok klasik enerji bitkisiyle rekabet edebildiğini göstermiştir. Prade vd. (2011), İsveç'in güneyinde yürüttükleri çalışmada biyogaz üretimi için en uygun hasat döneminin Eylül–Kasım, katı biyoyakıt üretimi için ise Şubat–Nisan olduğunu bildirmiştir. Biyogaz için hektar başına enerji getirisi 296 GJ ha^{-1}, katı yakıt için ise 201 GJ ha^{-1} olarak hesaplanmıştır. Takip eden çalışmalar, sonbaharda hasat edilen taze biyokütlenin biyogaz üretimi açısından, ilkbaharda hasat edilen kuru biyokütlenin ise ısı ve kojenerasyon sistemleri için daha avantajlı olduğunu göstermiştir (Kreuger, Prade, vd., 2011; Prade vd., 2012). Kenevirin farklı fenolojik evrelerinde yürütülen deneysel çalışmalarda, en yüksek metan verimi erken gelişim aşamasında (309–316 L CH_4 kg^{-1} ODM) gözlenmiş; olgunlaşmayla birlikte bu değer 289–302 L CH_4 kg^{-1} ODM'ye düşse de artan biyokütle üretimi hektar başına metan verimini 142–175 m^3 ha^{-1}'den 2780–3230 m^3 ha^{-1}'e yükseltmiştir. Ortalama metan oranı %60 civarında saptanmış, farklı gübreleme stratejileri arasında anlamlı fark bulunmamıştır. Bu sonuçlar, biyogaz tesislerinden elde edilen sindirim ürünlerinin (katı ve sıvı faz) kenevir yetiştiriciliğinde etkili bir geri besin kaynağı olarak değerlendirilebileceğini göstermektedir (Michal vd., 2023; Velechovský vd., 2021).

Balodis vd. (2011), Letonya koşullarında kenevirin 12.6 t DM ha^{-1} verimle mısır ve kolzayla rekabet edebildiğini ve 116 GJ ha^{-1} düzeyinde metan enerji verimi sağladığını bildirmiştir. Adamovičs vd. (2014), Futura 75 ve Uso 31 çeşitlerinde ince öğütülmüş fraksiyonların 208 GJ ha^{-1}, kaba fraksiyonların ise 148 GJ ha^{-1} enerji verimi ürettiğini raporlamıştır. Benzer şekilde, Pakarinen vd. (2011), Finlandiya koşullarında kenevirin 14 t DM ha^{-1} biyokütle ve 108 GJ ha^{-1} metan enerji verimiyle mısırla eşdeğer performans sergilediğini ortaya koymuştur. Bu bulgular Gissén vd. (2014) tarafından yapılan yaşam döngüsü analizleriyle desteklenmiş ve kenevirin arazi kullanımı ve çevresel etki açısından sürdürülebilir enerji bitkileri arasında güçlü bir alternatif olduğu gösterilmiştir. Bu sonuçlar birlikte değerlendirildiğinde, ön işlemsiz kenevir biyokütlesinin, doğru hasat zamanlaması ve parçacık boyutu kontrolüyle, pek çok geleneksel enerji bitkisine benzer metan verimi sağlayabildiği görülmektedir.

Bununla birlikte, kenevirin lignin içeriği ve fenolik bileşiklerinin mikrobiyal bozunmayı sınırlaması nedeniyle, son yıllarda araştırmalar biyobozunabilirliğin artırılmasına yönelik ön işlem stratejilerine yönelmiştir. Kreuger vd. (2011b), buhar ön işleminin yalnızca mekanik öğütmeye kıyasla metan verimini belirgin biçimde artırdığını ve aynı biyokütlenin etanol–metan eş üretiminde kullanılmasının enerji çıktısını iki katına kadar yükselttiğini bildirmiştir. Schroyen vd. (2017, 2015), veratril alkol ve lakaz enzimleriyle yapılan biyokimyasal ön işlemlerin fenolik bileşiklerin yaklaşık %80'ini uzaklaştırarak inhibitör etkileri azalttığını, ancak toplam biyogaz üretimindeki farkın sınırlı kaldığını göstermiştir. Schroyen vd. (2018) ise lignin içeriği ile BMP arasındaki ilişkiyi modelleyerek kenevirin BMP değerini 238 L CH_4 kg^{-1} VS olarak belirlemiş; bu değerin buğday samanına yakın, ancak miscanthus'tan daha yüksek olduğunu rapor etmiştir.

Son dönemde yapılan çalışmalar, enerji dönüşüm zincirinin optimizasyonu amacıyla biyokimyasal ve termokimyasal süreçlerin entegrasyonuna odaklanmıştır (Daglioglu vd., 2024). Özellikle hidrotermal karbonizasyon ve buhar gazlaştırma süreçleri, lignoselülozik kenevir biyokütlesinin çok aşamalı enerji dönüşümüne olanak tanımaktadır. NaOH ön işleminin kenevir hurdasından biyometan üretimini %164 oranında artırdığı, 200 °C'de elde edilen hidrokömürün 1278 mL g^{-1} H_2 verimiyle en yüksek biyohidrojen performansını sağladığı bildirilmiştir. Bununla birlikte, sindirim ürünlerinden elde edilen hidrokömürlerin yüksek kül içeriği nedeniyle gazlaştırma aktivitesi düşük bulunmuştur. Ancak aynı koşullarda (200 °C) elde edilen sıvı faz, 213 mL CH_4 g^{-1} KOİ değerine ulaşarak en yüksek BMP'yi vermiştir. Bu bulgular, kenevir biyokütlesinin biyogaz, biyohidrojen ve hidrokömür üretim rotalarının ardışık biçimde değerlendirilmesinin enerji dönüşüm verimini önemli ölçüde artırabileceğini göstermektedir.

Kenevirin diğer biyokütlelerle birlikte sindirimi, yani ko-fermantasyon yaklaşımı, sürecin hem kararlılığını hem de besin dengesini iyileştirmektedir. Nges vd. (2012), domuz ve kümes hayvanı gübresi ile gıda ve mezbaha atıklarının temel substratına kenevir, mısır ve tritikale ilavesinin metan verimini %30 oranında artırdığını bildirmiştir. Böske vd. (2014) ise at gübresiyle birlikte kenevir, keten, buğday samanı ve ladin talaşı kullanılan yukarı akışlı katı durum reaktörlerinde kenevirin 168 L CH_4 kg^{-1} VS değeriyle keten ve odun yongalarına kıyasla daha yüksek performans sergilediğini ve termofilik koşullarda metan oranının %59,8'e ulaştığını rapor etmiştir (Tablo 1). Bu çalışmalar, kenevirin karışık substratlı sistemlerde C/N oranını dengeleyerek inhibitör etkileri azalttığını ve biyogaz üretiminde sinerjik bir katkı sunduğunu göstermektedir.

Tablo 1. Endüstriyel kenevir ve farklı biyokütlelerin BMP değerlerinin karşılaştırılması

Bitki / Hammadde	BMP (L_{CH_4}/kgVS)	Açıklama	Kaynak
Kenevir (genel, sap-ağırlıklı fraksiyonlar)	≈ 230–250	Ortalama metan verimi, hasat zamanına göre sınırlı değişim gösterir	(Adamovi vd., 2014)
Kenevir (yaprak fraksiyonu)	≈ 330–370	Yapraklar düşük lignin içeriği nedeniyle en yüksek CH4 verimi sağlar.	(Adamovi vd., 2014)
Mısır silajı	≈ 280–360	En yaygın referans enerji bitkisi: yüksek hektar verimi sayesinde toplam üretim yüksektir.	(Weiland, 2010)
Şeker pancarı (posası/silajı)	≈ 320–450	Kolay parçalanabilir karbonhidrat içeriği sayesinde yüksek biyogaz verimi	(Szwarc & Szwarc, 2020)
Çim / Grass silaj	≈ 290–320	Orta- yüksek metan verimi; ancak protein oranı değişkendir.	(Weiland, 2010)
Buğday sapı	≈ 230 (ön işlemsiz) → ≈ 280–300 (ön işlemli)	Yüksek lignin oranı nedeniyle ön işlem gerektirir.	(Weiland, 2010)

Öte yandan yaşam döngüsü değerlendirmeleri, kenevirin yalnızca enerji üretiminde değil, aynı zamanda çevresel rehabilitasyonda da ikili bir işlev üstlendiğini ortaya koymuştur (Todde vd., 2022). Ağır metallerle kirlenmiş topraklarda yetiştirilen kenevirin değerlendirilmesine yönelik dört farklı tedarik zinciri senaryosunda, kirlenmiş biyokütlenin anaerobik sindirim veya yakma yoluyla işlenmesi en yüksek enerji tasarrufu (25.3–36.8 GJ ha^{-1}) ve emisyon azaltımı (579–641 kg CO_2e ha^{-1}) sağlamıştır. Monte Carlo simülasyonlarıyla doğrulanan bu bulgular, kirlenmiş arazilerin kenevir temelli biyoenerji üretimiyle yeniden işlevsel hale getirilebileceğini göstermektedir (Todde vd., 2022). Ekonomik açıdan değerlendirildiğinde, Barta vd. (2013), buhar ön işlem, etanol fermantasyonu, anaerobik fermantasyon ve kojenerasyonun entegre biçimde uygulanmasının yüksek enerji çıktısı sağladığını, ancak biyokütle tedarik maliyetleri ve biyogaz fiyatları nedeniyle ekonomik sürdürülebilirliğin sınırlı kaldığını belirtmiştir. Bununla birlikte kenevirin düşük pestisit gereksinimi, hastalıklara dayanıklılığı ve organik tarımla uyumu, onu gıda, yem ve enerji üretimi arasında dönüşümlü kullanılabilecek sürdürülebilir bir enerji bitkisi haline getirmektedir (Gissén vd., 2014; Kreuger, Sipos, vd., 2011; Prade vd., 2012).

Sonuç olarak, kenevirin anaerobik fermantasyon süreçlerindeki potansiyeli, hem ön işlemsiz uygulamalarda rekabetçi BMP değerleri hem de lignin yapısının çözülmesiyle elde edilen yüksek verimli ön işlemli sistemlerle güçlenmiştir. Termo-kimyasal süreçlerin entegrasyonu ve ko-fermantasyon stratejileri ise enerji dönüşüm verimini daha da artırarak, kenevirin biyogaz tabanlı biyorafineri sistemlerinde merkezi bir hammadde olarak değerlendirilebileceğini göstermektedir.

Tablo 2. Literatürde endüstriyel kenevir biyokütlesinin biyogaz üretimine ilişkin seçilmiş çalışmalar

Kaynak	Araştırma	Yer	Biyokütle	Diğer Biyokütlelerle Karşılaştırma	Kuru Madde (Dm) Verimi (T/Ha)	Enerji İçeriği (Gj/Ha) veya Metan Verimi	Başlıca Bulgular
(Schroyen vd., 2015)	Fenolik bileşiklerin metan üretimi üzerindeki inhibitör etkisinin değerlendirilmesi	Belçika	Kenevir	X	n.a.	100–2000 mg/L fenolik derişiminde CH_4 üretiminde azalma	Fenolik bileşiklerin yüksek konsantrasyonlarda metan oluşumunu baskıladığı, mikrobiyal adaptasyonla etkilerin zamanla azaldığı gösterildi.
(Schroyen vd., 2017)	Lignin bozunumu ve detoksifikasyon enzimlerinin etkisi	Belçika	Kenevir	X	n.a.	%80 fenolik uzaklaştırma, toplam CH_4 üretiminde sınırlı artış	Veratril alkol ve lakaz enzimiyle fenoliklerin azaltılması, süreç başlangıcındaki toksisiteyi azalttı.
(Schroyen vd., 2018)	BMP tahmininde lignin içeriğinin belirleyici rolü	Belçika	Kenevir, Buğday, Miscanthus, Keten	✓	n.a.	BMP: 238 L CH_4/kg VS	Lignin miktarının BMP'nin en güçlü belirleyicisi olduğu, kenevirin orta düzeyde potansiyel sunduğu gösterildi.
(Michal vd., 2023)	Farklı büyüme evresi ve gübreleme rejimlerinin biyogaz ve metan üretimi üzerine etkisi	Çekya	Kenevir	X	12 tDM/ha, %32 KM	309–316 L CH_4/kg ODM; MHY: 2780–3230 m^3/ha	Erken evrede en yüksek metan verimi; BGP sindirim ürünlerinin etkili bir gübre alternatifi olduğu gösterildi.
(Daglioglu vd., 2024)	NaOH ön işlemi, HTC ve buhar gazlaştırma entegrasyonu ile	Türkiye	Kenevir hurdası	X	n.a.	1278 mL H_2/g, 213 mL CH_4/g KOİ	NaOH ön işlemi biyometanı %164 artırdı; 200 °C'deki

	biyometan ve biyohidrojen üretimi					hidrokömür en yüksek H_2 verimini sağladı.
(Todde vd., 2022)	Kirlenmiş topraklarda yetiştirilen kenevirin fitoremediasyon ve enerji geri kazanımı	İtalya	Kenevir (kirlenmiş toprak)	X	n.a.	25.3–36.8 GJ ha^{-1} enerji tasarrufu	Kirlenmiş biyokütlenin anaerobik fermantasyonu ve yakma ile işlenmesi, 579–641 kg CO_2e/ha azaltımı sağladı; fitoremediasyonla enerji geri kazanımı önerildi.

5. SONUÇ VE ÖNERİLER

Endüstriyel kenevir (*Cannabis sativa L.*), yüksek biyokütle üretim kapasitesi, kısa büyüme süresi, düşük pestisit gereksinimi ve çok yönlü kullanım alanlarıyla döngüsel ekonomi vizyonunun merkezinde konumlanabilecek stratejik bir tarım ürünüdür. Bitkinin tüm fraksiyonlar-lif, hurd, tohum ve yaprak-enerji, malzeme ve çevre yönetimi açısından farklı değer zincirlerine entegre edilebilmekte, böylece "atık üretmeyen üretim" ilkesine dayalı bütüncül bir biyorafineri modeli oluşturulabilmektedir. Anaerobik fermantasyon süreci, bu sistemin enerji yönelimli dönüşümünde temel bir teknoloji olup hem biyogaz üretimi hem de sindirim artıklarının tarımsal döngüye geri kazandırılması sayesinde çevresel sürdürülebilirliğin sağlanmasında kilit rol üstlenmektedir.

Biyorafineri yaklaşımının yaygınlaştırılması, kenevirin yalnızca biyogaz üretiminde değil, aynı zamanda biyohidrojen, biyokömür, biyoplastik ve biyogübre üretim hatlarında eş zamanlı olarak değerlendirilmesine olanak tanımaktadır. Bu entegre dönüşüm yaklaşımı, kaynak verimliliğini en üst düzeye çıkarırken atık yönetimi ve enerji tüketim maliyetlerini azaltmakta; dolayısıyla "döngüsel değer zinciri" konseptinin tarımsal uygulamalarda somutlaşmasını sağlamaktadır. Son yıllarda yapılan çalışmalar, NaOH veya buhar ön işlemiyle desteklenen fermantasyon hatlarının biyogaz verimini %150'nin üzerinde artırabildiğini ve lignin bariyerinin parçalanmasıyla biyobozunabilirliğin anlamlı biçimde iyileştirildiğini göstermektedir. Ayrıca, bu tür sistemlerin hidrotermal karbonizasyon ve kojenerasyon süreçleriyle entegrasyonu, enerji dönüşüm zincirinde sıfır atık hedefini teknik olarak erişilebilir kılmaktadır. Böylelikle kenevir temelli biyorafineri sistemleri, enerji üretimi, karbon döngüsü ve atık yönetimini bütünleştiren bir sürdürülebilirlik modeli haline gelmiştir.

Gelecekteki araştırmaların, kenevirin enerji dönüşümündeki potansiyelini daha etkin kullanabilmek adına üç temel eksende yoğunlaşması gerekmektedir. İlk olarak, ön işlem optimizasyonu, farklı kenevir fraksiyonlarının (lif, hurd, yaprak) kimyasal ve enzimatik ön işlem kombinasyonlarıyla biyokimyasal metan potansiyelinin artırılmasını ve sürecin enerji girdisi–çıktısı dengesiyle birlikte modellenmesini içermelidir. İkinci olarak, hibrit enerji sistemleri üzerine çalışmalar derinleştirilmelidir. Anaerobik fermantasyonun fotobiyolojik, elektrokimyasal veya termokimyasal süreçlerle entegrasyonu, aynı biyokütleden çoklu enerji ürünlerinin (CH_4, H_2, biyokömür) eş zamanlı olarak elde edilmesini mümkün kılacak ve bu sayede enerji verimliliği yeni bir boyut kazanacaktır. Üçüncü olarak ise, karbon nötrlüğü ve yaşam döngüsü değerlendirmesi odaklı modelleme çalışmaları ön plana çıkmalıdır. Kenevir tabanlı biyogaz üretiminin karbon ayak izi, toprak karbon sekestrasyonu ve karbondioksit emisyon dengelemesi parametreleriyle birlikte değerlendirilmesi, sistemin iklim politikalarıyla entegrasyonunu güçlendirecektir.

Sonuç olarak, kenevir temelli biyorafineri sistemleri yalnızca yenilenebilir enerji üretimini değil, aynı zamanda toprak sağlığını, atık yönetimini ve karbon dengesini birlikte hedefleyen yeni nesil döngüsel ekonomi uygulamaları için güçlü bir fırsat sunmaktadır. Bu vizyonun hayata geçirilebilmesi, kenevirin ulusal enerji ve çevre politikalarında "karbonsuz büyüme" hedeflerine entegre edilmesiyle mümkün olacaktır. Böyle bir yaklaşım, yalnızca biyokütle temelli enerji güvenliğini güçlendirmekle kalmayacak, aynı zamanda tarımsal kalkınmayı ve iklim değişikliğiyle mücadeleyi destekleyen yenilikçi bir yeşil dönüşüm stratejisine öncülük edecektir.

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HATAY-ALTINÖZÜ İLÇESİNDE ZEYTİN ÜRETİCİLERİNİN GİRDİ KULLANIM DÜZEYİ VE TARIMSAL KREDİ İHTİYAÇLARININ BELİRLENMESİ[1]

Doç. Dr. Bekir DEMİRTAŞ
Hatay Mustafa Kemal Üniversitesi, Ziraat Fakültesi, Tarım Ekonomisi Bölümü
Email: bekirdemirtas@gmail.com
ORCID: 0000-0003-2603-3890
Msc. Fatma CAN ALKAN
Hatay Mustafa Kemal Üniversitesi, Fen Bilimleri Enstitüsü, Tarım Ekonomisi Anabilim Dalı
Email: f.can.alkan@hotmail.com
ORCID: 0000-0001-8713-5888

ÖZET

Bu çalışmada Hatay ili Altınözü İlçesinde geçim kaynaklarının büyük bir bölümünü zeytinden sağlayan üreticilerinin girdi kullanım düzeyi ve miktarları, girdi temininde kullanılan kaynaklar, yararlanılan tarımsal destekler ve tarımsal kredi ihtiyaçlarının belirlenmesi amaçlanmıştır. Araştırmanın ana materyalini 80 tarım işletmesinden anket yoluyla toplanan birincil veriler oluşturmuştur. Örnek işletmeler, 1-10 da 43 işletme, 11-25 da 20 işletme ve 26 da üstü 17 işletme olarak gruplara ayrılmış ve karşılaştırmalar yapılmıştır. Karşılaştırmalar çapraz tablolar ve yüzde oranlarla yapılmıştır. Üreticilerin yaş ortalaması 51, aile üyesi 5,6 kişi, %55 ilk-orta öğrenim düzeyi eğitim ve 31 yıllık zeytin üretimi deneyimi vardır. Araştırma alanı olan Altınözü ilçesindeki zeytin üreticilerinin %81'inin zeytin bahçesi alanı 20 dekarın altındadır. Üreticilerin ortalama zeytin bahçesi 16,6 da, parsel sayısı 2,3 ve %84 mülk arazilerden oluşmuştur. Bölgedeki zeytin üreticilerinin tarımsal örgütlenme düzeyi çok düşüktür. Bahçelerde toprak işleme, budama, ilaçlama ve hasat işlemlerinde aile işgücü kullanımı yaygın olup bahçelerde kurak koşullarda üretim yapılmaktadır. Üreticilerin %23'ü zeytin bahçesinde tarım sigortası yaptırmıştır. Üreticilerin ortalama zeytin satış fiyatı 4,5 ₺/kg, zeytinyağı satış fiyatı da 18,7 ₺/kg olarak gerçekleşmiştir. Zeytin üreticileri işletme başına ortalama 59,9 bin ₺ kredi kullanmış ve 2,1 bin ₺ kadar tarımsal destekten yararlanılmıştır. Üreticilerin bir üretim döneminde ihtiyaç duyduğu işletme sermayesi miktarı 31,7 bin ₺/işletme olarak hesaplanmıştır. Bunun %73'ü işgücü giderleri, %10 malzeme alımı, %4 çekigücü gideri ve %13 diğer giderlerden oluşmuştur. Küçük ölçekli zeytin işletmeleri için hibe, sübvansiyonlu kredi ve ödeme kolaylıkları sağlanmalıdır. Kooperatifleşme yoluyla bakım, teknoloji ve pazarlama alanlarında gelişim desteklenmeli; kuraklıkla mücadelede modern sulama yatırımları bölgeye kazandırılmalıdır. Üreticilere budama, gübreleme ve depolama konularında eğitim verilmelidir. Gençlerin kırsal üretime katılımı teşvik edilerek göç azaltılmalı; kaliteyi artırmaya yönelik ambalajlama ve işleme gibi uygulamalar tüm paydaşlarla hayata geçirilerek pazarlarda rekabet gücü ve üretici gelirleri yükseltilmelidir.

Anahtar Kelimeler: Zeytin, Girdi Kullanımı, Kredi İhtiyacı, Altınözü-Hatay.

[1] Bu çalışma Fatma Can Alkan'ın aynı isimli Yüksek Lisans tezinin bir bölümünden hazırlanmıştır.

DETERMINATION OF INPUT UTILISATION LEVEL AND AGRICULTURAL CREDIT NEEDS OF OLIVE PRODUCERS IN HATAY-ALTINÖZÜ DISTRICT

ABSTRACT

This study aimed to determine the level and amount of input use, the sources used in input supply, the agricultural supports utilized, and the agricultural credit needs of producers who derive a large part of their livelihood from olives in Altınözü District, Hatay Province. The primary data for the study consisted of questionnaires collected from 80 agricultural enterprises. Sample farms were divided into groups as 43 farms on 1-10 ha, 20 farms on 11-25 ha, and 17 farms on 26 ha, and comparisons were made. Comparisons were made with cross-tables and percentages. The average age of the producers was 51 years, 5.6 family members, 55% had primary and secondary education, and 31 years of olive production experience. The olive orchard area of 81% of the olive producers in Altınözü district, which is the research area, is below 20 decares. The average olive orchard of the producers is 16.6 da, the number of parcels is 2.3, and 84% of the olive groves are composed of property lands. The level of agricultural organization of olive producers in the region is very low. The use of family labor is common in soil cultivation, pruning, spraying and harvesting operations in the groves and production is carried out under arid conditions in the groves. 23% of the producers have agricultural insurance for their olive groves. The average olive sales price of the producers was 4.5 ₺/kg and the average olive oil sales price was 18.7 ₺/kg. Olive producers used an average of 59.9 thousand ₺ of credit per enterprise and benefited from 2.1 thousand ₺ of agricultural support. The amount of working capital needed by producers in a production period was calculated as 31.7 thousand ₺/enterprise. Of this, 73% was composed of labor expenses, 10% of material purchases, 4% of traction power expenses and 13% of other expenses. Grants, subsidized loans, and payment facilities should be provided for small-scale olive enterprises. Development in the fields of maintenance, technology, and marketing should be supported through cooperatives; modern irrigation investments should be brought to the region to combat drought. Producers should be trained in pruning, fertilization, and storage. Migration should be reduced by encouraging young people to participate in rural production; practices such as packaging and processing to increase quality should be implemented with all stakeholders to increase competitiveness in markets and producer incomes.

Keywords: Olive, Input Use, Credit Need, Altınözü-Hatay.

1. GİRİŞ

XX. yüzyılın bitkisi olarak görülen zeytin, Akdeniz havzası ve Ege adalarında yetiştirilmektedir. Doğal coğrafyası Suriye'nin kuzey doğusundan başlamakla birlikte Akdeniz'in kuzey ve güney sahillerinden Atlas Okyanusuna kadar uzanmaktadır. Dünyada yaklaşık 10 milyon hektar alandaki 900 milyon zeytin ağacından yaklaşık 17 milyon ton zeytin elde edilmektedir. Zeytin ve zeytinyağı üretici ülkelerinin başında İspanya, İtalya, Yunanistan, Türkiye, Tunus ve Fas gelmektedir. Dünyada zeytin üretiminde, AB ülkelerinin payı yıllar içinde değişse de ortalama seviyesi %70'dir (Doğaka, 2015).

Türkiye'nin son 5 yıldaki sofralık zeytin üretim ortalaması 431 bin ton, yağlık zeytin üretimi 1 milyon 329 bin ton olup toplamda 1 milyon 760 bin tondur. Bu dönemdeki zeytinyağı üretim ortalaması ise yaklaşık 175 bin tondur. 2017/18 üretim döneminde genç ağaçların meyve vermeye başlamasıyla birlikte üretim rekor bir artışla 2 milyon 100 bin tona ulaşılmıştır. Hatay'da yaklaşık 5.500 ton sofralık ve 85.501 ton yağlık zeytin üretimi vardır (TÜİK, 2024). Zeytin genetik özelliğinin yanında kültürel işlemlerin tam olarak uygulanamaması nedeniyle periyodisite (bir yıl ürün verme-diğer yıl az/yok verme) gösterir. Ayrıca, hastalık ve küresel iklim değişiklikleri rekolteleri ve ürün kalitesini yıllar arasında etkileyen diğer önemli faktörlerdir. Türkiye'de yıllara göre ürün miktarı değişkenlik göstermekte, yani var yılı yok yılı özelliği şiddetli yaşanmaktadır. Üretim var yıllarında 2 milyon ton, yok yıllarında ise 1 milyon 500 bin ton civarında seyretmektedir. Dolayısıyla, üründe yok yıllarında 500 bin ton kadar rekolte kaybı yaşanmaktadır. İspanya'da gibi ülkelerde bu oran çok daha düşük seviyelerinde kalmaktadır. Böylece, üretimde büyük dalgalanmalar önlenerek, sürekli bir ürün arzı sağlanabilmektedir. Türkiye'de periyodisite etkisinin azaltılması için, daha az periyodisite eğilimi gösteren zeytin çeşitlerinin geliştirilmesi yanında, sulama, ilaçlama ve gübreleme vb. bakım işlemlerine dikkat edilmesi ve bu yönde zeytin üreticilerine gerekli desteklerin sağlanması gerekmektedir. Zeytin yetiştiriciliğinde girdi kullanım düzeyi bu yönü ile daha fazla önem taşımaktadır.

Türkiye'de tarım sektöründe faaliyet gösteren işletmelerin sorunlarının başında yeterli girdi kullanamama ve bunların finansmanında yaşanan sorunlar gelmektedir. İşletmeler üretim sırasındaki finansman ihtiyaçlarını kendi tasarruflarından, dış kaynaklardan veya devletin mali yardımlarından karşılamaktadır. Ancak zeytin üreticilerinin tarımsal kredi olanaklarından yeterince faydalanamadığı görülmektedir. Üreticiler zeytin üretimine verilen destekleri yeterli bulmamaktadır (Seçer ve Emeksiz, 2019). Zeytinde ürün miktarını arttırmak, verim kaybını önlemek, kaliteli zeytin ve zeytinyağı üretimi için toprak analizi, sulama, gübreleme, hasat, zirai mücadele vb. kültürel işlemleri zamanında ve tekniğine uygun şekilde yapabilmesi gerekmektedir. Türkiye'de ve dünyada tarım kredileri, günümüzde genellikle devlet tarafından desteklenen ve bu tür kredilerin özelliklerini bilen yerel bankalar ve/veya bu alanda uzmanlaşmış kredi kurumları, kooperatif bankalar tarafından verilmektedir. Organize olmuş kredi kuruluşları tarım sektöründe faaliyette bulunmak, tarım kesiminin kredi ihtiyacını karşılamak amacıyla kanun ve yönetmeliklerle kurulmuş, kredi işlemlerini belirli esaslara göre yürüten kamu ve özel kuruluşlar olup, faiz oranlarını istedikleri gibi değiştirememektedir (Keskin ve Çalışır, 2024). Organize olmuş kredi kaynaklarında genellikle faiz oranları şahıslardan sağlanan kredilere oranla daha düşük olmaktadır. Organize olmuş kredi kuruluşlarının başında Tarım ve Orman Bakanlığı, Tarım Kredi Kooperatifleri, Ziraat Bankası, Halk Bankası, Vakıflar Bankası ve özel bankalar (Denizbank, Şekerbank, İş Bankası vb.) gelmektedir. Alternatif finansman kaynağı olarak ise leasing, faktöring ve vadeli işlemlerden yararlanılmaktadır (KKB, 2021). Tarım işletmelerinde; doğal afetler, çeşitli hastalık, haşere ve hayvanların verdiği zararlar, savaş ve göçler, işletmelerin küçük ölçekli olması,

tarımsal gelirlerinin yetersiz düzeyde olması, üretimin ve kalitenin artırılmasına yönelik yatırımlar, sosyo-ekonomik faktörler kredi ihtiyacı oluşturan etkenlerin başında gelmektedir. Tarımsal krediler; işletmenin finansal açıdan zayıfladığı ve likidite yönünden eksikliğe düştüğü zamanlarda destek olmakta, işletmenin devamlılığının sağlanmasına yardımcı olmaktadır.

Tarımsal potansiyeli oldukça yüksek olan Türkiye, başta küçük ve parçalı işletmeler, eğitim seviyesi düşük çiftçi yapısı ve modern tarımsal girdi, alet ve ekipmanlara ulaşmada yetersiz kalan finansman gibi karşı karşıya kaldığı çeşitli sorunlar nedeniyle bu potansiyelini tam olarak kullanamamaktadır (Doğan ve ark., 2015). Türkiye tarımının en önemli sorunlarından birisi çiftçilerin gerekli zamanda ve ihtiyaç duydukları miktarda krediye erişim imkanlarının zayıf olmasıdır (Özçelik ve ark., 2005). Tarımda kredi kullanımı üretim miktarının, verimliliğin, girdi kullanım etkinliğinin ve nihayetinde tarımsal gelirin artırılması için oldukça önemlidir (Terin ve ark., 2014; Bozoğlu ve Ceyhan, 2007). Her ne kadar iyi motive edilmiş ve eğitimli olursa olsun, yeterli finans kaynağından yoksun olan bir çiftçinin modern tarım yapma olanağı yoktur. Çünkü modern tarım verimli tohum/tohumluk, gübre, tarımsal ilaç, kesif hayvan yemi, belli konularda uzman işgücü gibi girdilerin kullanımını gerektirmektedir. Bunların uygun zaman ve yeterli miktarda temin edilebilmesi ise sürekli bir nakit çıkışına yol açmaktadır. Ancak tarımın yapısı nedeniyle, çiftçiler sürekli bir nakit çıkışı ile karşı karşıya olmalarına rağmen, hasat dönemine bağlı olarak yılda bir ya da birkaç kez gelir elde edebilmektedirler (Özçelik ve ark., 2005). Bu durum çiftçilerin tarımsal destekler, sübvansiyonlar ve kredi gibi çeşitli yollarla finanse edilmelerini zorunlu kılmaktadır. Çiftçilerin gerekli zaman ve yeterli miktarda krediye erişebilmeleri tarımsal aktivitelerini geliştirebilmelerine ve modern teknolojileri uygulayabilmelerine yardımcı olabilir (Bülbül, 2006). Bu denli önemli olmasına rağmen Türkiye'de tarımsal kredilerin öncelikli olarak, tarımsal üretimin geliştirilmesi, uygun toprak hazırlığı, diğer işlemler için modern girdi ve makine/ekipman temini için ihtiyaç duyan ve bu konularda hassas çiftçilere yönlendirilmesi için uygulamalar oldukça yetersizdir. Tarımsal üretim sürecinde gelir elde edilmesi, üretimin doğası gereği çoğu zaman bir yıl sürdüğünden tarım sektöründe sermaye birikimi çok yavaş gerçekleşmektedir. Tüm bu sayılan nedenlerden dolayı sermaye açısından yetersiz olan tarım işletmelerinin faaliyetlerini sürdürebilmeleri ve yapılarını iyileştirebilmeleri dış finansman/kredi temini yoluna gitmeleri ile mümkün görünmektedir. Tarımsal üretimde miktar ve kalite artışları ancak uygun koşullarda sağlanacak finansmanlarla sağlanabilir.

Akdeniz bölgesinde zeytin üretiminde verim ve kalite düşüklüğü yanında bölgeye uygun çeşit seçimindeki yanlışlıklar, sulama suyu kaynakları yetersizlikleri ve budama tekniği konusundaki eksiklikler olmak üzere bir takım teknik ve altyapı sorunları bulunmaktadır (Demirtaş, 2017). Zeytincilik sektöründe ürün ve üretim maliyetinin düşürülmesinde mutlak gerekli görülen ve zeytincilikte kullanılan girdilerden başta gübre, akaryakıt ve enerjinin sağlanmasında finansman destekleri önem taşımaktadır. Akdeniz bölgesindeki 1.395 bin dekarlık zeytin üretim alanında yaklaşık %37 payla Hatay ili ilk sırada gelmektedir. Bu pay Türkiye'deki diğer iller de dikkate alındığında ise %6 civarındadır (TÜİK, 2024). Hatay ilindeki en önemli zeytin üretim alanlarının başında gelen Altınözü ilçesinin bu yönü araştırma alanı olarak seçilmesinde etkili olmuştur. Altınözü ilçesindeki zeytin üretimi ağırlıklı olarak yağlık çeşitlerden oluşmaktadır. Bu çalışma ile Hatay'da geçim kaynaklarının büyük bir bölümünü zeytinden elde eden Altınözü ilçesinde zeytin üreticilerinin girdi kullanım düzeyi ve miktarları, girdi temininde kullanılan kaynaklar (tarımsal desteklemeler) ve tarımsal kredi ihtiyaçlarının belirlenmesi amaçlanmıştır.

2. DÜNYADA ZEYTİN VE ZEYTİNYAĞI ÜRETİMİ

Zeytinin meyvesi yağlık ve sofralık olarak işlenebilen ve bu işleme sonucu oluşan yan ürünleri değerlendirilebilen ve sağlık açısından çok faydalı olduğu için giderek talebi artan bir üründür. Zeytin bitkisinin özel iklim isteği nedeniyle zeytincilik, dünyada daha çok Akdeniz'e kıyısı olan ülkelerde (İspanya, İtalya, Yunanistan, Türkiye, Tunus, Suriye, Fas, Fransa ve Portekiz) yapılmaktadır. Halen dünya zeytin ağaç varlığının yaklaşık %93'ü bu ülkelerde yer almaktadır. 2021 verilerine göre dünyada yaklaşık olarak 10,3 milyon hektar alanda 23 milyon ton zeytin üretimi yapılmaktadır (FAO, 2023). Dünya'da zeytin ağaçlarının %90'ı Akdeniz havzası ikliminin etken olduğu yaklaşık 40 ülkede bulunmakta olup, toplam 103 milyon dekar alanda zeytin yetiştirilmektedir. Zeytin periyodisite gösteren bir bitki olması nedeniyle dünyada üretimde yıllara göre dalgalanmalar görülmektedir. FAO verilerine göre zeytin üretiminde 2021-2022 döneminde İspanya 3,940 bin ton ile ilk sırada yer alırken onu 2,976 bin ton ile Türkiye, 2,160 bin ton ile İtalya, 1,968 bin ton ile Fas ve 1,200 bin ton ile Tunus izlemektedir. Küresel üretimde 2. sırada yer alan Türkiye ise küresel zeytin üretiminin yaklaşık %13,9'unu gerçekleştirmektedir. 2021-2022 üretim döneminde Yunanistan'da olumsuz iklim koşullarına bağlı olarak zeytin üretiminde çok büyük miktarlarda düşüş yaşanmış olması nedeniyle üretim verisi henüz rapor edilmemiştir. Dünya zeytin üretiminde öne çıkan ülkeler aynı zamanda önemli zeytinyağı üreticisi ülkeleridir. Yıllar itibariyle ortalama zeytinyağı üretimi 2,9 milyon ton olarak gerçekleşirken İspanya yaklaşık %44'ünü tek başına üretmiştir. FAO verilerine göre zeytinyağı üretiminde 2021-2022 döneminde İspanya 1,492 bin ton ile ilk sırada yer alırken onu 329 bin ton ile İtalya, 240 bin ton ile Tunus, 235 bin ton ile Türkiye, 232 bin ton ile Yunanistan ve 203 bin ton ile Portekiz izlemektedir. Türkiye küresel zeytinyağı üretiminin yaklaşık %6,9'unu gerçekleştirmektedir (Çizelge 1, 2, 3).

Çizelge 1. Dünya zeytinlik alanları (bin ha)

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
İspanya	2.504	2.507	2.516	2.351	2.522	2.555	2.579	2.602	2.624	2.623
Tunus	1.811	1.823	1.589	1.625	1.646	944	2.995	1.281	3.660	1.281
İtalya	1.125	1.147	1.157	1.148	1.145	1.142	1.142	1.139	1.146	1.129
Fas	968	922	947	1.006	1.008	1.021	1.045	1.073	1.069	1.104
Türkiye	814	826	826	837	846	846	864	879	887	889
Yunanistan	808	797	818	821	798	793	963	903	906	819
Suriye	696	697	697	695	692	692	693	693	696	693
Cezayir	329	348	383	407	424	433	431	432	439	440
Portekiz	347	352	352	351	356	358	361	378	381	380
Libya	241	252	253	225	243	245	229	239	238	236
Diğer	646	595	625	647	622	730	674	774	716	744
Dünya	10.288	10.265	10.164	10.113	10.301	9.759	11.977	10.395	12.761	10.338

Kaynak: FAO, 2023.

Çizelge 2. Dünya dane zeytin üretimi (bin ton)

2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22
İspanya	9276	4560	5948	7083	6549	9820	5965	8138	8257	3940
İtalya	2941	1964	2733	2038	2598	1954	2194	2207	2271	2160
Tunus	1100	376	1700	700	500	1617	700	2000	700	1200
Türkiye	1676	1768	1700	1730	2100	1500	1525	1317	1739	2976
Yunanistan	1752	2592	2908	2755	2838	2765	3240	3051	3045	*
Portekiz	652	455	723	476	876	739	939	735	1376	792
Fas	1182	1573	1144	1416	1039	1561	1912	1409	1591	1968
Suriye	842	392	913	668	850	665	844	781	566	991
Cezayir	579	483	654	696	684	861	869	1080	705	823
Mısır	542	566	699	875	1095	1084	981	968	1057	1137
Diğer	1527	1606	1752	1611	2233	1990	5413	2160	2195	5463
Dünya	22067	16336	20874	20049	21362	24555	21583	23846	23499	21450

Kaynak: FAO, 2023. * 2022 yılı verisi bulunmamaktadır.

Çizelge 3. Dünya zeytinyağı üretimi (bin ton)

2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22
İspanya	618	1.782	842	1.403	1.291	1.262	1.790	1.125	1.389	1.492
İtalya	416	464	222	475	182	429	174	367	274	329
Tunus	220	70	340	140	100	325	140	440	140	240
Türkiye	195	135	160	150	178	263	194	230	194	235
Yunanistan	358	132	300	320	195	346	185	275	275	232
Portekiz	59	92	61	109	69	135	100	141	100	206
Fas	100	130	120	130	110	140	200	145	160	200
Suriye	175	180	105	110	110	100	154	118	143	106
Cezayir	66	44	70	82	63	83	97	126	71	91
Mısır	17	20	17	17	30	40	41	40	38	20
Diğer	178	204	221	241	233	257	230	263	237	248
Dünya	2.402	3.252	2.458	3.177	2.562	3.379	3.304	3.269	3.020	3.398

Kaynak: IOC, 2023.

2.1. TÜRKİYE'DE ZEYTİN VE ZEYTİNYAĞI ÜRETİMİ

Türkiye bulunduğu coğrafi konum ve Akdeniz ikliminin etkin görülmesiyle İspanya, İtalya, Fas, Tunus ve Yunanistan gibi diğer Akdeniz ülkeleriyle birlikte dünyanın sayılı zeytin ve zeytinyağı üreticilerindendir. Türkiye'de özellikle Ege, Marmara, Akdeniz ve Güneydoğu Anadolu Bölgesinde zeytin ağaçlarının yoğun olarak yer alır. Zeytin üretiminin önemli bir bölümü Ege Bölgesinde yapılmaktadır. Aydın, İzmir, Muğla, Manisa, Balıkesir, Mersin, Hatay, Çanakkale, Antalya ve Bursa önde gelmektedir. Sofralık zeytin üretiminin yoğun olarak yapıldığı Bursa, Balıkesir, Çanakkale ve Hatay illeri %75'inden fazlasını karşılamaktadır. Üretim miktarlarının yıllar arasında önemli miktarda dalgalanma göstermesinin ana nedeni zeytinlerdeki peryodisite özelliğidir. TÜİK verilerine göre Türkiye'de 2022-2023 döneminde üretim yaklaşık 1,5 milyon ton olarak gerçekleşmiştir bunun 490 bin tonunu sofralık, 1 milyon tonunu da yağlık zeytin üretimi oluşturmuştur. Sofralık zeytin üretiminde Manisa 120 bin tonla ilk sırada yer alırken, Bursa 95 bin ton, Aydın 50 bin ton, Mersin 42 bin ton ve Hatay ise 41 bin tonla 5. Sırada yer almıştır. Aynı üretim döneminde yağlık zeytin üretiminin iller arasındaki dağılımında İzmir 186 bin tonla ilk sırada yer alırken bunu Muğla 163 bin tonla ikinci, Hatay 138 bin tonla üçüncü ve Aydın 123 bin tonla dördüncü sırada yer almıştır (Çizelge 4, 5, 6).

Çizelge 4. Türkiye'nin zeytin ağaç sayısı ve üretimi

	Ağaç sayısı (Bin)			Üretim (Ton)		
Yıl	Toplam	Meyve veren	Meyve vermeyen	Toplam	Sofralık	Yağlık
2010	156 448	111 398	45 050	1 415 000	375 000	1 040 000
2011	154 611	117 942	36 669	1 750 000	550 000	1 200 000
2012	157 061	120 821	36 240	1 820 000	480 000	1 340 000
2013	167 030	129 161	37 869	1 676 000	390 000	1 286 000
2014	168 997	140 712	28 285	1 768 000	438 000	1 330 000
2015	171 992	144 760	27 232	1 700 000	400 000	1 300 000
2016	173 785	147 430	26 355	1 730 000	430 000	1 300 000
2017	174 594	148 263	26 331	2 100 000	460 000	1 640 000
2018	177 843	151 069	26 774	1 500 467	426 995	1 073 472
2019	182 076	154 037	28 039	1 525 000	415 000	1 110 000
2020	187 163	159 382	27 781	1 316 626	513 140	803 486
2021	188 679	157 850	30 829	1 738 680	555 833	1 182 847
2022	194 519	163 035	31 484	2 976 000	938 217	2 037 783
2023	201 770	167 545	34 225	1 520 000	490 000	1 030 000

Kaynak: TÜİK, 2024.

Çizelge 5. Türkiye'de illere göre yağlık zeytin üretimi (bin ton)

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
İzmir	207	268	175	207	165	82	104	84	154	410
Aydın	274	222	244	210	392	169	311	76	229	249
Muğla	87	171	148	182	196	39	142	44	172	225
Balıkesir	85	120	61	156	221	83	122	108	142	218
Manisa	53	71	45	68	146	162	48	187	119	206
Mersin	101	79	120	100	105	59	75	30	74	175
Hatay	139	108	152	117	140	86	118	54	101	172
Çanakkale	68	94	67	106	62	37	32	40	29	117
Osmaniye	28	27	28	22	58	60	20	31	23	62
Gaziantep	116	27	100	9	15	64	16	54	31	57
Diğer	128	142	162	123	140	234	124	96	108	147
Türkiye	1.286	1.330	1.300	1.300	1.640	1.073	1.110	803	1.183	2.038

Kaynak: TÜİK, 2024

Çizelge 6. Türkiye'de illere göre sofralık zeytin üretimi (bin ton)

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Manisa	76	94	65	115	121	148	88	167	150	213
Bursa	85	48	66	56	93	104	79	115	146	188
Mersin	36	35	51	43	37	11	23	33	30	182
Aydın	61	53	53	50	63	32	73	45	59	83
İzmir	13	33	17	23	25	20	12	11	15	52
Hatay	19	24	26	19	8	6	19	14	19	50
Balıkesir	11	24	16	25	33	26	42	23	36	44
Adana	8	14	12	12	5	6	6	2	4	22
Muğla	5	10	7	9	16	3	7	3	11	20
Antalya	18	22	15	13	4	4	8	12	9	18
Diğer	57	82	72	66	56	67	58	87	77	68
Türkiye	390	438	400	430	460	427	415	513	556	938

Kaynak: TÜİK, 2024

2.2. TÜRKİYE'DE ZEYTİNE SAĞLANAN DESTEKLER

Destekleme politikaları ile uygun üretim yapısının oluşturulması, üreticinin korunarak uygun gelirin sağlanması ve tarımın ülke ekonomisine olan katkısının arttırılması amaçlanmaktadır. Türkiye'de Ege ve Akdeniz bölgelerindeki birçok ailenin geçimini sofralık zeytin ve zeytinyağı sektöründen sağlanmaktadır. Ürün arzındaki dalgalanmalar, destekleme politikaları ile uygun üretim yapısının oluşturulması, üreticinin gelirinin ve bunun yanında tarımın ülke ekonomisine olan katkısının arttırılması amaçlanmaktadır. Ülkemizin kalkınmasında önemli rolü olan zeytin ve zeytinyağı stratejik öneme sahiptir. Türkiye'nin zeytin ağaç sayısı ve alanı büyük bir hızla büyümektedir. Türkiye'de sofralık zeytin ve zeytinyağı sektörü uzun yıllar birçok ailenin geçim kaynağını oluşturmuştur. Ürün arzındaki dalgalanmalar, yetiştirmesinin belirli bölgelerde yapılması, temel gıda özelliği taşıması, gelecekte önemli bir ihracat ürünü olması ve yurt dışına satış imkânlarının olması sebebiyle sofralık zeytin ve zeytinyağı devlet tarafından çeşitli politika araçlarıyla desteklenmektedir. Sektörün geliştirilmesi amacıyla uygulamalar geniş bir zamana yayılmış ve araçlarda yıldan yıla değişiklikler olmuştur (Seçer ve Emeksiz, 2019). Türkiye'de zeytin ve zeytinyağına yönelik olarak sağlanan desteklemeler arasında; zeytinyağı fark ödemesi desteği ve dane zeytin fark ödemesi desteği havza bazlı olarak kg başına her yıl güncellenen miktarlarda uygulanmaktadır (Anonim, 2023). Geleneksel zeytin bahçelerinin rehabilitasyonu desteği, sertifikalı fidan desteği, organik tarım desteği, iyi tarım uygulamaları desteği, gübre-mazot desteği, küçük aile işletmesi desteği, biyoteknik mücadele desteği, toprak analizi desteği, lisanslı depolarda muhafaza edilen zeytin ve zeytinyağı desteği, TARSİM desteği (poliçe bedelinin %50'sinin devletçe karşılanması) gibi destekler yıllar arasında artan ve değişen miktarlarda sağlanmaktadır. Ayrıca Kırsal Kalkınmayı Destekleme Programları kapsamında projeli olarak tarımsal ürünlerin işlenmesi, kurutulması, dondurulması, paketlenmesi ve depolanmasına yönelik yatırımlara %50 hibe desteği sağlanmaktadır. IPARD Programı kapsamında bitkisel üretimin çeşitlendirilmesi, bitkisel ürünlerin işlenmesi ve paketlenmesi başlığı altında %55-65 arasında değişen hibe oranlarında yatırım desteği sağlanmaktadır (Keskin ve Çalışır, 2024; KKB, 2023).

2.3. HATAY İLİNDE ZEYTİN ÜRETİMİ

Hatay ilinin ekonomisi genel olarak tarım olmakla birlikte topraklarının 2.270.859,2 da alanında tarım yapılmaktadır. Bu alanın içinde Amik ovasının da 119.300 da olduğunu da göz önünde bulundurursak Hatay topraklarının ne kadar verimli olduğunu daha iyi görülebilir. Alüvyon topraklı Amik Ovasında özellikle turfanda sebzecilik ve turunçgil tarımı yapılmaktadır. Hatay ilinin dağlık kesimi olan Altınözü ve Yayladağı ilçelerinde zeytin üretimi başta gelmektedir. Türkiye genelinde Hatay, 147.194 ton (sofralık ve yağlık zeytin) üretimi ile 2017 yılında ilk 5'te yer alarak, Türkiye (1.7 milyon ton) zeytin üretiminin %9'unu gerçekleştirmiştir. Bölgelere göre yağlık zeytin üretiminde Ege bölgesi birinci sırayı alırken 2.sırada %30 ile Akdeniz bölgesi yer almaktadır. Akdeniz bölgesi içerisinde %38 ile Hatay büyük bir paya sahiptir (Anonim, 2017). Hatay ilinde zeytin üretiminde en önemli sorunlarının, zeytin ağacının periyodisite gösteren bir tür olması nedeniyle dönemsel olarak verimde değişiklik yaşanması, zeytin üretimi yapan işletmelerin %90'ına yakını küçük işletmelerden oluşması, tarım alanlarının dağınık ve parçalı oluşu, zeytin yetiştiriciliğinde ağaçların gençleştirme çalışmalarının yapılmadığı ve özellikle bilinçsiz ve yeterli gübreleme ve ilaçlamanın yapılmadığını söyleyebiliriz.

Çalışmanın ana materyalini Hatay ilinde zeytin üretiminin yoğun olduğu Altınözü ilçesinde örneklemeyle belirlenen toplam 80 zeytin üretici ile yüz yüze anket yoluyla elde edilen birincil veriler oluşturmuştur. Konu ile ilgili daha önce yapılmış olan araştırmalar, bölgede yapılan gözlemler ve mülakatlardan da faydalanılmıştır. Araştırma kapsamında gerekli ikincil verileri

Zeytincilik Araştırma Enstitü kayıtları, Hatay Tarım ve Orman İl Müdürlüğü, Altınözü Tarım ve Orman İlçe Müdürlüğü verileri, TÜİK ve FAO'dan sağlanan istatistiki veriler oluşturmuştur. Ayrıca konu ile ilgili ulusal ve uluslararası çalışmalardan elde edilen bulgulardan da yararlanılmıştır.

Hatay ili Altınözü ilçesi zeytin üretici sayısı ve üretim alanı olarak %40 civarında pay sahibidir ve bu özelliği nedeniyle araştırma alanı olarak belirlenmiştir. Araştırma kapsamında Hatay Tarım ve Orman İl Müdürlüğü ve Altınözü Tarım ve Orman İlçe Müdürlüğüne kayıtlı zeytin yetiştiriciliği yapan ve zeytin ile ilgili tarımsal krediden faydalanan çiftçi kayıtlarından yararlanılmıştır. Çiftçi Kayıt Sistemi (ÇKS) verilerine dayanarak, Altınözü ilçesinde zeytin yetiştirilen mahallelerdeki işletmelerin sahip oldukları zeytin alanı varlığı belirlenerek örnek çerçevesi oluşturulmuştur. Araştırma alanı olarak seçilen ilçedeki 48 mahalleden gayeli örnekleme yöntemi ile Alakent, Atayurdu, Boynuyoğun, Büyükburç, Çetenli, Dokuzdal, Fatikli, Kamberli, Karbeyaz, Karsu, Mayadalı, Sivrikavak, Sarıbük, Oymaklı, Türkmenmezraası, Yolağzı, Yunushanı, Ziyaret olmak üzere 18'i seçilmiştir. Bu mahalleler zeytin üretici sayısı ve üretim alanı olarak öne çıkan yerlerden oluşmaktadır.

Altınözü ilçesinde zeytin üretimi yapan üreticilerin zeytin alanı ve seçilen örneklemin işletme büyüklük gruplarına göre dağılımına Çizelge 7'de yer verilmiştir. Araştırmada zeytin üreticilerinin sahip olduğu alana (dekar) göre üç gruba ayrılarak çeşitli özellikleri bakımından incelenmiştir. Küçük olarak gruplandırılan 1-10 dekar arası üreticilerden 43, orta gruptaki 11-25 dekar arası alana sahip üreticilerden 20 ve büyük grupta 26 dekardan büyük zeytin alanı olan 17 üretici olmak üzere toplam 80 üretici araştırma verilerinin toplanacağı örnek olarak belirlenmiştir. Seçilen örneklem Altınözü ilçesindeki toplam zeytin alanı ve üretici sayısının %5'ini oluşturmaktadır.

Çizelge 7. Araştırma kapsamındaki zeytin üreticileri örnekleminin dağılımı (da)

İşletme büyüklüğü (da)	Üretici sayısı	Alan (da)	Örnek sayısı	Oran (%)
1-10 (Küçük)	895	4133,6	43	53,8
11-25 (Orta)	269	4103,3	20	25,0
26-+ (Büyük)	232	10206,7	17	21,2
Toplam	1396	18443,6	80	100,0

Anket uygulama dönemi 2019 yılı üretim dönemi verilerini kapsamış olup, tarımsal kredi başvurularından yararlanmada ise 2020 yılındaki başvuruları alınmıştır. Bu çalışmada kullanılan anket formları daha önceki benzeri çalışmalarda kullanılan anket formları ve konu ile ilgili literatür incelenerek araştırmanın kapsamına uygun olarak düzenlenmiştir. Ankette yer alan sorunların uygunluğu ve yeterliliği için ön- teste tabi tutulmuş ve gerekli düzeltmelerle ankete son şekli verilmiştir. Anket çalışması 2019 üretim döneminde üretici ile birebir sorular sorularak gerçekleştirilmiştir. Ankette üreticilerin özellikleri yanında işletme yapısını ortaya koyabilmek için arazi büyüklüğü, parça sayısı, mülkiyet durumu vb., üretim teknikleri bakım işlemleri, budama, gübreleme, sulama, ilaçlama vb., pazarlama yapısı, yaşadığı sorunlar ve çözüm önerileri üzerine düşüncelerine değinilmiş ve bir üretim döneminde ihtiyaç duyduğu kredi ihtiyacına yönelik sorulara cevap verilmesi istenilmiştir.

2.4. ZEYTİN İŞLETMELERİNİN ÖZELLİKLERİ

Araştırma kapsamında görüşülen zeytin üreticilerinin yaş özellikleri incelendiğinde 47,6 yıl ile 57,6 yıl arasında değişmiş olup ortalama 51 yaşındadırlar. İşletmecilerin aile birey sayıları da 5-6 kişi arasında değişirken ortalama 5,6 kişidir. Üreticilerin zeytin üretimindeki deneyimleri 25-40 yıl arasında değişmiş ve ortalama 31 olduğu belirlenmiştir. Çalışma kapsamında görüşme yapılan zeytin üreticilerinin eğitimleri %55 oranında ilk ve orta öğrenim, %36 oranında da lise seviyesindedir. Buna göre üreticilerin %90'dan fazlası lise ve altında eğitimlidir. Bu durum Türkiye genelinde yapılmış olan araştırma sonuçlarıyla benzerlik göstermektedir. Çok az da olsa işletme büyüklüğü arttıkça eğitim düzeyinde artış görülmektedir. Araştırma alanında özellikle küçük ölçekli işletmeye sahip üreticiler arasında ek gelir amacıyla tarımsal faaliyetlerin dışında başka alanlarda da çalışma durumu söz konusudur. Görüşme yapılan 80 üreticiden 57'si (%71) tarımsal faaliyetlerin yanında başka işlerde yapmaktadır. Çalışmaya dahil olan zeytin üreticilerinin zeytin ve diğer üretim alanları ortalama 18,5 da olup bunun %90'a yakını zeytinliklerden oluşmuştur. I. grup küçük işletmelerde zeytin alanı 4,8 da iken bu miktar III. grup büyük ölçekli işletmelerde 45,2 dekara kadar yükselmiştir. Araştırmaya katılan üreticilerin ortalama zeytin alanları da 16,6 dekardır. İşletmeciler diğer tarım alanlarında sebze, buğdaygiller ve yem bitkisi yetiştirmektedir. Araştırma alanındaki işletmecilerin zeytin dikim alanı parsellerin parçalı olması nedeniyle çeşitlilik göstermektedir. Arazinin mülk olması yanında hazineden kiralamalar ve ortaklık ile işletilen tarım arazileri de bulunmaktadır. Mülk arazilerin oranı ortalama %84 olup kiralanan araziler %6 ve ortakçılıkla işletilenler ise %10 kadardır. İşletmelerin arazi parçalılık durumu 1-5 arasında değişmekte olup ortalama parsel sayısı 2,3'tür. İncelenen işletmelerde zeytin dikili arazilerin meyilli ve kırsal kesimde olması nedeniyle sulama işlemi yapılamadığı görülmüştür. Araştırma alanındaki arazilerin sadece %3,8'i sulanabilmektedir.

2.5. ZEYTİNDE ÜRETİM MASRAFLARI VE GELİRİ

İşletmelerin tamamına yakını zeytin bahçelerinde toprak işlemesi uygulaması yapmaktadır. Toprak işleme amaçlarının başında yabancı ot kontrolü gelmektedir. Ancak meyilli arazilerde toprak işlemesi su ve rüzgar erozyonuna neden olabilir. Bu nedenle toprak işleme zamanının ve tekniğinin erozyona yol açmayacak şekilde yapılması önemlidir. İşletmelerin zeytinde toprak işleme zamanı çoğunlukla kasım ve haziran ayları arasında uygulanmaktadır. Araştırma kapsamında görüşülen işletmeler bir yılda ortalama 2,5 kez toprak işleme uygulaması yapmıştır. Bu işlemler için çoğunlukla bahçe tipi traktörler kullanılmıştır. Toprak işlemede toplam 28,6 ₺/da işlem ücreti ödemesi ve 19,3 ₺/da aile işgücü karşılığı söz konusu olup toplam da ise 47,9 ₺/da harcama yapılmıştır. Araştırma bölgedeki zeytin bahçelerinin su kaynaklarından uzakta olması nedeniyle genellikle sulama yapılmamaktadır. Sadece ikinci grup işletmelerin birinde zeytin bahçesinde damlama sulama uygulaması yapıldığı belirlenmiştir. Bu nedenle araştırma bölgesinde sulama amaçlı bir üretim ve bakım gideri hesaplanamamıştır. Zeytin bahçelerinde gübre uygulamaları çoğunlukla elle yapılırken sadece 7 işletmede gübre dağıtma makinesi kullanımı olduğu belirlenmiştir. Gübreleme zamanı genellikle bölgedeki yağışların başladığı kış aylarında olmaktadır. Üreticilerin zeytin bahçelerindeki gübre ve gübreleme işçiliği giderleri ortaya konulmuştur. İşletmelerin ortalama gübre masrafı 43,4 ₺/da iken gübreleme işçiliği için 22,6 ₺/da harcama hesaplanmış ve toplam gübreleme gideri ise 77,4 ₺/da olmuştur. İşletmelerin budamada birim alandaki ortalama yabancı işgücü gideri 61,1 ₺/da iken aile işgücü karşılığı ise 27,5 ₺/da olarak hesaplanmıştır. Toplam budama giderinin ise ortama 93,2 ₺/da olduğu belirlenmiştir. İşletmelerin ölçeği büyüdükçe aile işgücü kullanımı azalırken yabancı işgücü kullanımı artmaktadır. Bölgedeki zeytin bahçelerinde Dal Kanseri, Halkalı Leke ve Zeytin Sineği hastalık ve

zararlıları daha fazla sorun olarak görülmektedir. Araştırma alanındaki zeytin bahçelerinde bir üretim döneminde ortalama 1.7 kez ilaçlama yapılmıştır. İşletmelerin birim alandaki ortalama ilaç gideri 38 ₺/da iken işgücü harcaması 40.5 ₺/da ve toplam ilaçlama gideri ise 78.5 ₺/da olmuştur. İşletmeler ortalamasına göre hasatta dekara 506,5 ₺ makine gideri, 507,7 ₺ yabancı işgücü gideri ve 333,1 ₺ aile işgücü karşılığı ve toplam olarak ise 1347,4 ₺ masraf söz konusu olmuştur. Araştırma alanında işgücü ödemelerinin bazı durumlarla nakit olarak yapılmayıp toplanan ürün üzerinden ayni olarak da yapılması söz konusu olmaktadır. Yapılan anlaşmaya göre toplanan ürünün 1/3'ü veya ¼'ünün işgücü karşılığı olarak ödenmesi söz konusudur. Aynı şekilde zeytinlerin yağının çıkarılması aşamasında prese tesislerine ödemelerin toplam yağ üzerinden bir bölümü ile yapıldığı durumlar görülmüştür.

Araştırma döneminde işletmelerin ortalama zeytinyağı satış fiyatının 18.7 ₺/kg olduğu belirlenmiştir. Zeytin ve zeytinyağları hasat sonrasında kasım-aralık aylarında satılmıştır. Çok az miktardaki zeytinyağının satışı ise ocak ayında gerçekleşmiştir. Satışların tamamı peşin olarak yapılırken, ürün teslim yerleri işletmecinin evi veya prese tesisleri olmuştur. İncelenen dönemde işletmeler ortalama 1432,9 kg zeytinyağını pazarlamışlardır. Birinci grup işletmelerden üçü hiç zeytinyağı satışı yapmamış, bu işletmeler zeytinlerini sadece sofralık olarak pazarlama yoluna gitmişlerdir. Katılımcı 80 işletmenin geriye kalan 37'si hem zeytin hem de zeytinyağı pazarken, 40 işletme ise üretimini sadece zeytinyağı şeklinde pazarlara arz etmiştir. Araştırma kapsamında görüşme yapılan işletmelerin ortalama zeytin satış fiyatının 4,5 ₺/kg olduğu, işletme başına ortalama satılan zeytin miktarının 468,5 kg ve birim alana elde edilen zeytin gelirinin ise 127 ₺/da olduğu belirlenmiştir. İşletmelerin satışını gerçekleştirdiği zeytinyağı geliri ortalama 1432,9 ₺/da ve zeytin satış geliri de ortalama 127 ₺/da olduğundan toplam satış geliri de 1741,2 ₺/da olarak belirlenmiştir. Bölgedeki zeytin üreticilerinin zeytin ve zeytinyağı pazarlamasında söz konusu olan pazarlama giderleri İşletmeler ortalamasına göre taşıma gideri 25,1 ₺, işgücü gideri 51,8 ₺ ve diğer giderler 66,9 ₺ olmak üzere toplam ortalama pazarlama gideri 143,8 ₺ olarak hesaplanmıştır.

3. ÜRETİCİLERİNİN KREDİ VE DESTEKLERDEN YARARLANMA DURUMU

Tarımsal üretimde kredi ihtiyacı, çiftçilerin üretim süreçlerini sürdürebilmeleri ve geliştirebilmeleri için oldukça önemlidir. Tarım kesimine kamu bankaları ve Tarım Kredi Kooperatiflerince sağlanan tarımsal krediler düşük faizli (sübvansiyonlu kredi) ve uzun vadelidir (Gezer ve Gezer, 2022). Düşük faizli yatırım ve işletme kredisi kullandırılması Ziraat Bankası ve Tarım Kredi Kooperatiflerince "Tarımsal Üretime Dair Düşük Faizli Yatırım ve İşletme Kredisi Kullandırılmasına İlişkin Karar" kapsamında zeytin bahçe tesislerine yönelik olarak (yatırım ve işletme kredisi), ayrıca modern basınçlı sulama sistemi tesislerinde (yatırım kredisi) %75-100 arasında değişen oranlarda faiz indirimli kredi kullandırılmaktadır (Anonim, 2023). Üreticilerin tamamı zeytin üretiminde kullanılmak üzere kurumlaşmamış kredi kaynaklarından (akraba, komşu, komisyoncu, tüccar vb.) kaynak kullanmadığını ifade etmiştir. Kullanılan kredilerin tamamı banka ve kooperatif kredilerinden oluşmuştur. İncelenen üreticilerden II. gruptan 1 ve III. gruptan 2 olmak üzere 3 üreticinin kredi kaynağı kooperatif iken geriye kalan 14 işletmenin kredi kaynağı ziraat bankası olmuştur. Kullanılan kredi miktarı işletme ölçeği artışına göre artmaktadır. İşletme başına göre I. grupta 0,5 bin ₺ olan kredi miktarı II. grupta 42 bin ₺ ve III. grupta kredi kullanan işletme başına 83 bin ₺'ye kadar yükselmiştir. Kredi kullanan işletmelerin ortalama kredi miktarı ise 60 bin ₺ olduğu belirlenmiştir. Bu sonuçlara göre büyük ölçekli işletmelerin tarımsal kredi kullanımında daha iyi durumda oldukları söylenebilir. Küçük ölçekli işletmeye sahip üreticilerin ise kendi kaynakları ile yetindiği görülmüştür.

Tarımda kredi temini, üreticiler için çeşitli zorluklar içerebilir. Bu zorluklar arasında yüksek faiz oranı, teminat eksikliği, bürokratik engeller ve geri ödeme zorlukları gibi konular öne çıkmaktadır. Bu zorluklar özellikle küçük aile işletmeleri için daha fazla olumsuzluk olarak görülmektedir (Akçabey ve Paksoy, 2023; Gezer ve Gezer, 2022). Zeytin üreticilerinin krediye ulaşmada karşılaştığı sorunlar arasında faiz yüksekliği, bürokratik işlemlerdeki zorluklar ve teminat göstermedeki zorluklar %20 civarındaki oranla ilk üç sırada yer almıştır. Üreticilerin kredi kullanımına ilişkin memnuniyetlerinin incelendiği cevapların dağılımında "memnun" seçeneğinin yer aldığı 4. seçenekte işletme büyüklüğü artışına göre %40 civarındaki olumlu görüş %80'in üzerine çıkmıştır. Kullanılan kredi miktarı daha fazla olan II. ve III. grup işletmelerde memnuniyet düzeyinin daha fazla olduğu görülmektedir. Kararsız ve memnun değil seçenekleri I. grup işletmelerde daha yüksek oranda ifade edilmiştir. Bu sonuçlara göre kredi kullanım düzeyinin memnuniyet durumunu doğrudan etkilediği söylenebilir.

Tarımsal destekler, tarım sektörünün sürdürülebilirliğini ve gelişimini sağlamak için hayati öneme sahiptir. Tarımsal destekler hem ekonomik hem de sosyal açıdan tarım sektörünün güçlenmesine katkıda bulunur. Tarımsal destekler sayesinde üretim artışı, gelir güvencesi, kırsal kalkınma, yeniliklere ve teknolojiye ulaşım, gıda güvenliği, çevresel sürdürebilirlik ve pazarlara erişim gibi konularda iyileşme sağlanabilmektedir (Oğul, 2022). İncelenen 80 işletmeden 38'i (%47.5) tarımsal desteklemelerden yararlanırken işletme başına ortalama 2072,6 ₺ destekleme ödemesi almış olup bu destek tutarının işletmelerin ortalama zeytin arazisine oranı ise 74,1 ₺/da olarak bulunmuştur. Bu destek tutarı işletmelerin sadece zeytin alanlarına ait olan miktarlar olup az da olsa diğer tarım arazileri için de destekleme ödemeleri alınması söz konusudur. Yararlanılan destekleme miktarlarının birim alana düşen değerleri incelendiğinde en yüksek değer II. grup işletmelere aittir. Büyük işletmelerin destekleme uygulamalarından yararlanmada, kredi kullanımında olduğu gibi öne çıkamadığı görülmüştür. Araştırmaya katılan zeytin üreticileri gruplarında tarımsal desteklerden memnuniyet seviyesi ortalama %49 civarındadır. Desteklerden memnuniyetsizlik düzeyi ise ortalama %34 kadardır. Diğer üreticiler ise bu konuda kararsız görüş belirtmişlerdir. İşletme grupları arasında memnuniyet düzeyi II. ve III. gruptaki orta ve büyük ölçekteki işletmeler arasında %80'lere kadar yükselirken, küçük ölçekli I. grup işletmelerde kararsız ve memnuniyetsiz üreticilerin oranı %77'ye yaklaşmıştır. Buna göre tarımsal desteklerden yeterince yararlanamayan küçük ölçekli üreticilerin olumsuz görüşe sahip oldukları söylenebilir.

3.1. ZEYTİN ÜRETİCİLERİNİN KREDİ İHTİYACI

Tarım sektöründe nakit ve nakit benzeri sermaye birikim seviyesinin düşük olması, çiftçilerin öz sermayesi (iç finansman) ile sektörün büyümesini sağlamalarını zorlaştırmaktadır. Bu durum, çiftçilerin dış finansman kaynaklarına (kredi, devlet desteklemeleri, hibe) olan ihtiyacını artırmaktadır. Çiftçiler, üretim sürecinin başlangıcından hasat dönemine kadar herhangi bir satış yapmadan sürekli harcama yapmak zorunda kaldıkları için, tarımsal işletmelerin nakit akış dengesi yılın büyük bir bölümünde negatiftir. Gelirler ise genellikle hasat sonrası tahsil edilen alacaklardan oluşmaktadır. Bu nedenle, tarım işletmelerinin sürdürülebilirliği ve büyümesi için etkin bir finansman stratejisi ve nakit akış yönetimi kritik öneme sahiptir.

Günümüz Türkiye'sinde de tarım sektörünün finansmanında en büyük kaynak sağlayıcı konumunda bulunan Ziraat Bankası, tarım işletmelerine yönelik kredilerini indirimli faiz oranlarıyla sunmaktadır. Cari faiz oranı ile indirimli faiz oranı arasındaki fark, hazine tarafından karşılanmaktadır (kredi sübvansiyonu). Ancak, Ziraat Bankası'nın tarımsal amaçlı nakdi kredilerinin toplam nakdi krediler içindeki payı, 1996 yılında %86 iken 2021 yılında %15'e kadar

düşmüştür (TBB, 2023). Bu durum, Ziraat Bankası'nın ticari amaçlı nakdi kredilere toplam nakdi krediler içinde giderek daha fazla ağırlık verdiğini göstermektedir.

Türkiye'de özellikle son yıllarda enflasyonda yaşanan yükseliş eğilimi, faiz oranlarının artmasına neden oluyor. Faiz oranlarının yükselmesiyle birlikte borçlanma maliyeti de arttığı için tarım işletmelerinin tarım kredilerine erişimi olumsuz etkileniyor. Buna ek olarak, tarım kredilerinin kullanılması için çok sayıda teminat istenilmesi ve uzun formalitelerin yerine getirilmesi gerekmektedir. Gereklilikleri yerine getirmekte güçlük çeken tarım işletmelerine yeterli veya hiç tarım kredisi verilmemektedir. Bu durumlar, işletme sermayesi yetersiz ve düşük üretim gelirine sahip tarım işletmelerinin tarım kredisi kullanmasının ve tarım sektöründe verimlilik düzeyinin artırılmasının önünde ciddi bir engel oluşturmaktadır (Keskin ve Çalışır, 2024). Türkiye'de tarım kesiminin farklı nedenlerle ticari banka kredisi kullanımının çok düşük olduğu bilinmektedir. Tarım sektöründe faaliyet gösteren üreticilerin ticari banka kredisi kullanmama nedenleri incelendiğinde krediye ihtiyaç duymayanların (%42) dışındaki nedenler arasında faiz ve kredi masraflarının yüksekliği (%23) en önemli neden olarak belirtilmiştir. Bunu dini inançlarından ve geleneklerinden dolayı faize girmek istemeyenler (%17) ve teminat kapsamında istenen ipotek veya kefaletleri karşılayamamak (%10) izlemektedir (Çizelge 8).

Çizelge 8. Tarım işletmelerinin ticari banka kredisi kullanmama nedenleri

Kredi kullanmama nedenleri	Oran (%)
Krediye ihtiyaç duymuyorum	42,1
Faizler/kredi masrafları yüksek	23,0
Faize girmek istemiyorum/karşıyım	16,7
İpotek, kefil, teminat vb. talepleri karşılayamamak	9,5
Formalitelerdeki uzunluk/zorluk	3,2
Daha önceki kredilere ait borçların geri ödenememesi	2,4
Ticari bankaların kredi vermemeleri	1,6
Diğer nedenler	1,6
Toplam	100,0

Kaynak: KKB, 2021.

Tarım kesiminde üretim ve yatırım harcamalarının finansmanında çiftçilerin başvurdukları kaynakların 2019-2023 yılları arasındaki dağılımı Çizelge 9'da incelenmiştir. Hiç borçlanmadım ve özkaynaklarımla üretim harcamalarını karşılamaktayım cevabını veren üreticilerin oranı 2019 yılında %49 civarında iken bu oran 2023 yılına kadar oransal olarak sürekli azalarak %17'ye kadar gerilemiştir. Buna göre tarım kesiminde özkaynakların yanında kredi veya borç şeklinde yabancı sermaye ihtiyacının sürekli arttığı görülmektedir. Üreticilerin ihtiyaç duyduğu kredi/borç kaynakları arasında banka kredisi veya tarım kart kullanımı yoluyla finansman sağlama oranı incelenen dönemde %27-%41 arasında değişmiş ve ilk sırada yer almıştır. Tarım kesiminde kullanılan girdilerden tohum, ilaç, gübre ve alet-ekipman gibi ürünlerin satıcılarından ihtiyaçların vadeli olarak alınması şeklindeki borçlanmalar 2019 yılında %5 civarında iken bu oran 2023 yılında %20'ye kadar yükselmiştir. Çiftçilerin bir diğer finansman kaynağı Tarım Kredi Kooperatiflerinden alınan kredilerdir ve bunun oranı da yıllar arasında %8,8 ile %18,6 arasında

değişmiştir. Ürünlerin alıcısı olan tüccarlardan veya aile üyeleri, komşu, akraba ve arkadaş çevresinden borçlanma şeklindeki finansman karşılama şekilleri ise önemsiz düzeylerde kalmıştır. Çizelgedeki verilerin genel olarak değerlendirilmesine göre yıllar arasında üreticilerin yabancı sermaye ihtiyacının giderek arttığı, bu ihtiyaçların karşılanmasında banka ve kooperatif kredileri ile girdi satıcılarının öne çıktığı söylenebilir.

Çizelge 9. Tarım kesimi finansman kaynakları dağılımı (2019-2023 dönemi, %)

Kredi/Borç kaynakları	2019	2020	2021	2022	2023
Hiç borçlanmadım (Özkaynak)	48,7	36,9	26,8	17,2	16,7
Bankadan kredi/Tarım kart kullanımı	27,4	28,7	32,0	41,4	39,3
Girdi satıcısından vadeli alım/Borçlanma	5,3	10,7	16,3	16,6	20,0
Tarım Kredi Kooperatifi kredisi	8,8	13,9	16,3	18,6	14,0
Tüccardan avans alımı	2,7	4,9	4,6	3,4	6,0
Aile/Komşu/Arkadaştan borçlanma	7,1	4,1	3,3	2,1	4,0
Diğerleri	0,0	0,8	0,7	0,7	0,0
Toplam	100,0	100,0	100,0	100,0	100,0

Kaynak: KKB, 2023.

Türkiye'de yapılan bir çalışmada çiftçilerin kullanmış oldukları krediler içinde en yüksek oran üretim faaliyetlerinin finansmanını sağlayan işletme (üretim) kredileridir (%44), bunu izleyen yatırım kredileri (%40) içinde traktör ve mekanizasyon yatırımları en yüksek paya sahiptir (Çizelge 10). Arazi alımı ve damızlık hayvan alımlarını inşaat yatırımları (depo, sera vb.) izlemiştir. Üreticilerin diğer yatırım kredisi harcamalarında sulama yatırımları en önemli harcama olarak yer almıştır (KBB, 2021).

Çizelge 10. Çiftçilerin kullandığı kredi türleri

Kredi türleri	Oran (%)
İşletme kredisi	44,4
Yatırım kredisi	39,6
Diğer krediler	16,0
Toplam	100,0

Kaynak: KKB, 2021.

3.2. ZEYTİN İŞLETMELERİNİN SERMAYE İHTİYACI

Bir tarım işletmesinin sermaye ihtiyacını ortaya konulabilmesi için işletme tipinin ve üretim sisteminin belirlenmesi, sermaye unsurlarının tanımlanması, işletmenin yıllık veya bir üretim dönemi içindeki gelir ve giderlerinin hesaplanması, işgücü ve mekanizasyon ihtiyacının ortaya konulması ve finansal analizinin yapılması gerekir. Yani işletmenin kısa ve uzun vadeli borç ödeme gücünün, karlılığının ve sermaye dağılımının bilinmesi gerekir (Tengiz ve ark., 2022). Bir tarım işletmesinin işletme sermayesi unsurları, işletmenin faaliyetlerini sürdürebilmesi için gerekli olan kaynakları içerir. Bunlar, işletmenin günlük faaliyetlerini sürdürebilmesi için gerekli olan nakit ve

kolayca nakde çevrilebilen varlıklar, üretim sürecinde kullanılacak olan hammaddeler, yarı mamuller ve mamuller (stoklar), alacaklar, işletmenin kısa vadede gelir elde etmek amacıyla yaptığı yatırımlar ve işletmenin kısa vadede nakde çevirebileceği diğer varlıklardır (Karakayacı ve ark., 2022). Bu unsurlar, tarım işletmesinin verimli ve sürdürülebilir bir şekilde faaliyet göstermesi için kritik öneme sahiptir.

Araştırma kapsamındaki zeytin işletmelerinin bir üretim dönemine ait işletme sermayesi ihtiyacı Çizelge 11'de verilmektedir. Zeytin üretiminde diğer meyve ve sebze üretiminde olduğu gibi en önemli harcama türü geçici işçilik harcamalarıdır. İşgücü kullanımı toprak işlemeden başlayıp hasat ve pazarlamaya kadar devem eden tüm süreçlerde söz konusudur. Bu nedenle toplam işletme sermayesi tutarının %73'ünü işgücü giderleri oluşturmuştur. Malzeme alımları yaklaşık %10 civarındaki oranla pay almaktadır. Araştırma bölgesinde zeytin üretimindeki malzeme ihtiyaçları arasında gübre ve ilaç alımları başta gelmektedir. Zeytinde hasatta söz konusu olan ambalaj, zeytinlerin işlenmesi ve depolanması gibi harcamalar %4,4 pay almaktadır. Zeytinde makine çekigücü ihtiyacı toprak işleme, gübreleme, ilaçlama, hasat ve taşıma işlemlerinde söz konusu olmaktadır. Diğer işletme giderleri içinde elektrik, su, bakım-onarım gibi harcamalar bulunmaktadır. İncelenen dönemde 1 dekar zeytin bahçesi için işletme sermayesi ihtiyacı 1912 ₺/da olarak hesaplanmıştır. Ancak tarımsal üretimde işletme sermayesi ihtiyacı üretim yapılan arazilerin yapısına, üretim teknolojisine, mekanizasyon düzeyine ve desteklemelerden yararlanma durumuna göre farklılık gösterecektir. Zeytin üreticileri yaptıkları üretim faaliyetlerindeki harcamalarının çoğunluğunu Ziraat Bankası kanalıyla aldıkları düşük faizli tarımsal kredilerden karşılamışlardır. Buna ilave olarak alan bazlı desteklemeler ve telafi edici ödemelerde bu ihtiyacı karşılamada katkı yapmıştır. Araştırma alanında görüşülen üreticiler arasında hasat öncesinde tarımsal girdi satıcı, tüccar veya prese tesisi/fabrika sahiplerinden avans şeklinde kredi/borç alınması söz konusu olmamıştır.

Çizelge 11. İşletmelerin bir üretim dönemindeki ortalama işletme sermayesi ihtiyacı

İşletme sermayesi unsurları	İşletme sermayesi ihtiyacı (₺/da)	Oran (%)
Geçici işgücü harcamaları	1400	73,2
Malzeme alımı	185	9,7
Hasat, ambalaj, işleme ve depolama giderleri	85	4,4
Makine çekigücü harcamaları	80	4,2
Pazarlama giderleri	47	2,5
Diğer işletme giderleri	115	6,0
Toplam	1912	100,0

Araştırmaya dahil olan zeytin işletmelerinin işletme kredisi ihtiyaçları ve kullanmış oldukları kredi miktarları incelendiğinde I. grup işletmelerin ihtiyaç duyulan kredinin çok altında krediyle yetindikleri görülmektedir. II. ve III. gruptaki işletmelerin ise yeterli kredi kullandıkları söylenebilir (Çizelge 12). Küçük ölçekli işletmelerin öz kaynaklarını kullanmaları söz konusu olsa da bu kaynaklarında üretimdeki girdileri karşılamaktan uzak olduğu ortadadır. Bu nedenle üretimde kullanılan gübre ve ilaç gibi uygulamaları yapamadıkları veya çok az yaptıkları anlaşılmaktadır. İşgücü giderlerinin çoğunluğu ise aile işgücü ile karşılanmıştır. Buna ilave olarak

işletmelerin yararlanmış oldukları tarımsal desteklerde finansman ihtiyacını karşılamada katkı sağlamıştır.

Çizelge 12. İşletmelerin bir üretim dönemindeki işletme kredisi ihtiyacı

İşletme grupları	İşletme kredisi ihtiyacı (bin ₺/işletme)	Kullanılan kredi (bin ₺/işletme)	Yararlanılan destek (₺/işletme)
I	9,2	0,5	261,3
II	33,5	42,0	1846,3
III	86,4	82,8	2780,0
Toplam/Ortalama	31,7	59,9	2072,6

4. SONUÇ

Zeytin hem yağlık hem de sofralık olarak işlenebilen bir meyvedir. Bu işlemler sonucunda elde edilen yan ürünler de değerlendirilebilmektedir. Sağlık açısından önemli faydaları nedeniyle zeytine olan talep giderek artmaktadır. Zeytin bitkisi, özel iklim koşulları gerektirdiğinden, zeytin yetiştiriciliği daha çok Akdeniz'e kıyısı olan ülkelerde (İspanya, İtalya, Yunanistan, Türkiye, Tunus, Suriye, Fas, Fransa ve Portekiz) yoğunlaşmıştır. Türkiye'de 2023 yılında toplam 9 milyon dekar zeytinlik alan kaydedilmiştir. 2023 yılı için toplam zeytinlik alanların %73,6'sı yağlık zeytin ve %26,4'ü sofralık zeytin alanlarıdır.

Hatay ili Türkiye'nin önemli zeytin üretim alanlarından biridir. Yaklaşık olarak 50 bin dekar alanda 3600 kadar üretici zeytin tarımı yapmaktadır. 2023 yılı verilerine göre sofralık zeytinde %8,5 yağlık zeytinlerde ise %13,4 pay almıştır. Hatay ilinde zeytin üretim alanı ve üretici sayısı bakımından Altınözü ilçesi ilk sırada yer almaktadır. Zeytin üretimi ve ticareti ilçe ekonomisinde önemli yer tutmaktadır. Ancak bölgedeki zeytin üretim işletmelerinin %90'ı 50 dekarın altındaki küçük ölçekli araziye sahiptir. İlçedeki zeytin işletmelerinin ortama büyüklüğü de 13,2 dekar olup %81'i 20 da ve altındaki işletmelerden oluşmuştur. Araştırma alanındaki küçük ölçekli zeytin işletmeleri yapısal olarak pek çok dezavantaja sahiptir. Bunlar toprak işleme, gübreleme, sulama ve budamadaki bilinçsizlik, yetersiz sermaye, düşük mekanizasyon, yetersiz teknoloji, örgütsüzlük gibi konular en önemlileridir. Bu araştırmada Hatay ilinin en önemli zeytin üretim bölgesi olan Altınözü ilçesinde belirlenen 80 üreticiye ait veriler kullanılarak, bölgede üreticilerin zeytindeki girdi kullanım durumu ve kredi ihtiyaçlarının belirlenmesi amaçlanmıştır.

Araştırma kapsamında verileri toplanan zeytin üreticilerinin ortalama yaşı 51, aile üye sayısı 5,6 kişidir. Üreticilerin 31,3 yıl zeytin tarımı deneyimi vardır. Üreticilerin %55'i ilk ve orta öğrenim seviyesinde eğitimlidir ve bunların %71'i tarımsal faaliyetlerin dışında başka işlerde yapmaktadır. Araştırmaya katılan işletmeler zeytin üretim alanlarına göre 3 ayrı gruba ayrılarak karşılaştırmalar yapılmıştır. Bunlar; I. grupta 43 işletme ve ortalama zeytin alanı 4,8 da, II. grupta 20 işletme ve ortalama alan 17,5 da, III. grupta ise 17 işletme ve ortalama alan 45,2 da şeklindedir. İşletmelerin %90'a yakın orandaki arazi varlığı zeytin bahçelerinden oluşmaktadır. Zeytin bahçeleri ortalama 16,6 da ve parçalılık ortalama 2,3 tür ve %84 oranında mülk arazilerden meydana gelmiştir. Zeytin bahçelerinde yılda ortalama 2,5 kez toprak işlemesi yapmaktadır, zeytin bahçeleri genellikle kurak koşullarda yetiştirilmekte, yılda 1,6 kez gübreleme uygulaması yapılmaktadır, bahçelerde genellikle budama uygulaması tek seferde kasım-aralık aylarında budama makası ve testere kullanılarak yapılmıştır. Bölgede zeytinlerde görülen çeşitli hastalık ve zararlılarla mücadele için

1,7 kez ilaçlama uygulaması yapıldığı belirlenmiştir. Bölgede zeytinlerin hasadı ekim ayında başlayıp kasım ayında yoğunlaşarak aralık ayında sona ermektedir. Hasat genellikle elle toplama şeklinde yapılmaktadır. Araştırma bölgesindeki zeytin çeşitlerinin büyük oranda yağlık olmasından dolayı ürünler zeytinyağına işlenmektedir. Elde edilen yağlar zeytin işleme tesislerine ve bölgedeki tüccara pazarlanmaktadır. Satışlar genel olarak peşin olarak yapılmakta, ürünler işletmede veya prese tesislerinde teslim edilmektedir. İncelenen dönemde bölgedeki zeytinyağı fiyatı ortalama 18,7 ₺/kg olarak gerçekleşirken sofralık olarak pazarlanan zeytin fiyatı 4,5 ₺/kg olmuştur. İşletmelerin zeytin ve zeytinyağı satışından elde ettiği ortalama gelir 1741 ₺/da olarak hesaplanmıştır.

Katılımcı üreticilerin 17'si TKK veya Ziraat Bankasından sübvanse edilmiş tarımsal kredi kullanmıştır. İşletme başına kullanılan kredi miktarı ortalama 59,9 bin ₺ olmuştur. Üreticilerin krediye ulaşmada karşılaştığı en önemli zorluklar arasında yüksek faiz, prosedürlerin zorluğu ve teminatları yerine getirme zorlukları en önemlileridir. Üreticilerin %55'i kredi kullanımından memnun olduğunu belirtmiştir. İncelenen işletmelerin %48'i çeşitli tarımsal destekleme uygulamalarından yararlanmıştır. Yararlanılan destek miktarı ortalama 74,1 ₺/da ve 2072,6 ₺/işletme olmuştur. Üreticilerin %49'u uygulanan tarımsal desteklerden memnun olduğunu ifade etmiştir. Üreticilerin yaklaşık %23'ü zeytin bahçelerinde tarım sigortası yaptırmıştır. Araştırma bölgesinde kadın girişimcilere yönelik zeytin üretim ve işletme kooperatifi bulunmaktadır. Katılımcılar arasında 30 üretici TKK'lerine üye olduğunu, tamamı ise Ziraat Odasına kayıtlı olduğunu belirtmiştir. Bölgedeki zeytin işletmelerinin bir üretim döneminde birim alanda ihtiyaç duyduğu işletme sermayesi ihtiyacı içinde geçici işgücü harcamaları %73, malzeme alımları %10, hasat, ambalaj ve depolama gideri %4,4, çekigücü gideri %4,2, pazarlama ve diğer giderler ise 8,5 oranında paya sahiptir. Bölgedeki işletmelerin bir üretim döneminde ihtiyaç duyulan işletme kredisi ihtiyacı ortalama 31,7 bin ₺/işletme olarak hesaplanmıştır. Bölgedeki işletmelerin kullanmış olduğu tarımsal kredi miktarı ortalama 59,9 ₺/işletme olmuştur. Büyük ve orta ölçekteki işletmeler için kullanılan kredi miktarları işletme ihtiyacını karşılayabilecek düzeyde iken küçük ölçekli işletmelerin kullanmış olduğu kredi miktarı ihtiyacın çok altında kalmıştır. İşletmelerin işletme sermayesi ihtiyacını karşılamada yararlanılan desteklerinde katkı sağladığı görülmüştür.

Araştırma alanında incelenen zeytin işletmelerinin ve Altınözü ilçesindeki diğer üreticilerin küçük ölçekli arazilere sahip olmalarından kaynaklanan sorunlar yaşamakta olduğu görülmüştür. Bu sorunların aşılabilmesi için;

İşletmelerin yeterli finansman kaynağına ulaşımını sağlayabilmek için, kredi ve destekleme uygulamalarında küçük ölçekli (20 dekar ve altındaki zeytinlikler için) işletmeler için bazı ayrıcalıklar uygulanmalıdır. Bu uygulamalar desteklemeler, hibe ve sübvanse edilmiş tarım kredileri için olmalıdır. Desteklemelerden yararlanma düzeylerini artırmaya yönelik tedbirler, kredi alımında teminat göstermede esneklikler, işlem prosedürlerini kolaylaştırma ve ödeme kolaylıkları gibi uygulamalar gündeme gelmelidir. Küçük ölçekli işletmelerin birlikte hareket etmelerine olanak sağlayacak örgütlenme (kooperatif ve üretici birliği) modelleri ile, bahçelerin bakım işlemlerinde işbirliği, mekanizasyon olanaklarını geliştirme, teknoloji kullanımın artışı, pazarlama, ürün işleme, ürünlerde markalaşma gibi konularda ilerlemeler sağlanabilir. Kurak koşullarda yapılan zeytin tarımında görülen periyodisite, düşük verim ve kalite sorunları, modern sulama tesislerinin bölgeye girmesiyle azalacaktır. Bu konuda gereken yatırımların yerel yönetimler, üretici örgütleri ve diğer kamu birimleriyle işbirliği içinde bölgeye kazandırılmalıdır. Zeytin üreticileri arasında üretim tekniği açısından görülen eksikliklerden budama, sulama, gübreleme, hastalık ve zararlılarla mücadele, hasat işlemlerinde modern tekniklerin kullanılması,

depolama gibi konularda bilgi ve bilinç düzeyini artıracak eğitim ve yayım çalışmaları artırılmalı ve yaygınlaştırılmalıdır. Bölgede zeytin tarımında genç nüfusun katılımını artıracak uygulamalar ve teşvikler artmalıdır. Böylece kırsaldan kentlere doğru olan göçlerde genç nüfusun bir bölümünün kırsalda üretime katılımı sağlanmalıdır. Bölgede üretilen zeytin ve zeytinyağında kalite artışını sağlayacak uygulamalar (hasat, işleme, depolama, ambalajlama vb. konularda) üretici, işleme tesisleri, tüccar gibi sektörün tüm paydaşlarının içinde olduğu projelerle hayata geçirilmelidir. Bölgede üretilen zeytin ve zeytinyağında yurt içi ve yurt dışı pazarların taleplerine uygun kalite ve standartların sağlanması yoluyla üretici gelirlerinin artırılması ve sektörün canlanması önemli görülmektedir.

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SAĞLIKLI KÖPEKLERDE KALP BOYUTLARININ RADYOGRAFIK DEĞERLENDIRILMESI: VERTEBRAL KALP SKORU (VHS) VE VERTEBRAL SOL ATRIYUM BOYUTU (VLAS)

Doç. Dr. Başak BOZTOK ÖZGERMEN

Aksaray Üniversitesi, Veteriner Fakültesi

Email: basak1607@gmail.com

ORCID: 0000-0001-7039-8956

ÖZET

Bu çalışmanın amacı, klinik olarak sağlıklı köpeklerde vertebral kalp skoru (VHS) ve vertebral sol atriyal boyut (VLAS) için referans değerler belirlemek ve bu radyografik ölçümlerin demografik faktörler ve ekokardiyografik parametrelerle ilişkisini değerlendirmektir.

Farklı ırk, yaş ve cinsiyette toplam 40 sağlıklı köpek çalışmaya dahil edildi. Tüm olgular rutin klinik ve kardiyovasküler muayeneden geçirildi. Sağ lateral ve dorsoventral toraks radyografilerinden VHS ve VLAS değerleri hesaplandı. Ardından, ekokardiyografi ile sol atriyum (LA), aort kökü (Ao) ölçümleri ve LA/Ao oranı belirlendi. Kardiyak patoloji saptanan hayvanlar çalışma dışı bırakıldı. Veriler cinsiyet, yaş ve vücut ağırlığına göre karşılaştırıldı; parametreler arası korelasyon analizleri yapıldı.

Ortalama VHS değeri 9.86, VLAS 1.32 ve LA/Ao oranı 1.17 olarak bulundu. Cinsiyet, yaş grubu ve ırk büyüklüğüne göre yapılan karşılaştırmalarda istatistiksel olarak anlamlı fark saptanmadı ($p>0.05$). VHS, VLAS ve LA/Ao oranları arasında anlamlı korelasyon bulunmadı. Bu parametrelerin birbirinden bağımsız ölçümler sunduğu sonucuna varıldı.

VHS ve VLAS, klinik olarak sağlıklı köpeklerde cinsiyet, yaş ve vücut ağırlığından bağımsız olarak güvenilir kalp ölçüm yöntemleri olarak değerlendirildi. Bu parametrelerin ekokardiyografiye erişimin mümkün olmadığı durumlarda alternatif tanısal araçlar olarak kullanılması önerilmektedir. Ancak, daha geniş örneklem gruplarıyla yapılacak ileri çalışmalar, elde edilen verilerin genellenebilirliğini artıracaktır.

Anahtar Kelimeler: Köpek, Radyografi, Vertebral Kalp Skoru, Vertebral Sol Atriyum Boyutu, Ekokardiyografi, Kalp Ölçümü

RADIOGRAPHIC ASSESSMENT OF CARDIAC DIMENSIONS IN HEALTHY DOGS: VERTEBRAL HEART SCALE (VHS) AND VERTEBRAL LEFT ATRIAL SIZE (VLAS)

ABSTRACT

This study aimed to establish reference values for the Vertebral Heart Scale (VHS) and Vertebral Left Atrial Size (VLAS) in clinically healthy dogs, and to evaluate the relationship between these radiographic parameters and demographic variables, as well as echocardiographic findings.

Forty healthy dogs of various breeds, sexes, and age groups were enrolled after clinical and cardiovascular examination. Thoracic radiographs (right lateral and dorsoventral views) were used to measure VHS and VLAS. Subsequently, echocardiography was performed to measure the left atrium (LA), aortic root (Ao), and to calculate the LA/Ao ratio. Dogs with cardiovascular abnormalities were excluded. Statistical analyses included independent t-tests, ANOVA, and Pearson correlation to assess the effect of age, sex, breed size, and associations among the cardiac indices.

Mean VHS, VLAS, and LA/Ao values were 9.86, 1.32, and 1.17, respectively. There were no statistically significant differences in these values based on sex, age, or breed size ($p > 0.05$). No significant correlations were found between VHS, VLAS, and LA/Ao ratio, indicating these indices are independent of each other in healthy dogs.

VHS and VLAS can be considered reliable and independent radiographic indicators of cardiac size in healthy dogs, unaffected by sex, age, or body size. These parameters may serve as practical diagnostic tools, especially in settings where echocardiography is not readily available. Further studies with larger sample sizes are recommended to validate these findings across different populations.

Keywords: Dog, Radiography, Vertebral Heart Scale, Vertebral Left Atrial Size, Echocardiography, Cardiac Measurement

GİRİŞ

Köpeklerde kardiyovasküler hastalıklar, veteriner hekimlikte önemli morbidite ve mortalite nedenlerinden biridir. Bu hastalıkların erken teşhisi, tedavi başarısını ve yaşam kalitesini artırmak açısından kritik öneme sahiptir. Kardiyak boyutların değerlendirilmesi, kalp hastalıklarının tanısında temel adımlardan biridir. Ekokardiyografi altın standart olarak kabul edilse de, her klinikte mevcut olmayabilir veya bazı durumlarda uygulanması mümkün olmayabilir.

Radyografi, yaygın olarak erişilebilir ve nispeten düşük maliyetli bir tanı yöntemidir. Vertebral Kalp Skoru (VHS) ve Vertebral Sol Atriyum Boyutu (VLAS), köpeklerde kardiyak büyüklüğün radyografik olarak değerlendirilmesinde kullanılan iki önemli metriktir. VHS, Buchanan ve Bücheler (1995) tarafından tanımlanmış olup kalbin uzunluk ve genişlik ölçülerinin torakal omurga uzunluğuna oranlanması esasına dayanır. VLAS ise Malcolm ve ark. (2018) tarafından tanımlanmış, özellikle mitral kapak hastalıklarının erken teşhisinde önemli bir parametredir.

Bu çalışmada, sağlıklı köpeklerde VHS ve VLAS değerleri belirlenmiş ve bu ölçümlerin yaş, cinsiyet, ırk büyüklüğü gibi demografik değişkenlerle ilişkisi değerlendirilmiştir. Ayrıca, bu radyografik ölçümlerin ekokardiyografik parametrelerle olan ilişkisi de incelenmiştir.

1. GEREÇ VE YÖNTEM

Bu çalışma, Aksaray Üniversitesi Veteriner Fakültesi Etik Kurulu onayı ile yürütülmüştür. Çalışmaya, farklı ırk, yaş ve cinsiyetlerde toplam 40 klinik olarak sağlıklı köpek dahil edilmiştir. Hayvanların sağlık durumları, detaylı fiziksel muayene ve kardiyovasküler sistem muayenesi ile doğrulanmıştır. Kardiyak patoloji veya sistemik hastalık bulgusu saptanan hayvanlar çalışma dışında bırakılmıştır.

Radyografik görüntüler, dijital radyografi cihazı kullanılarak sağ lateral ve dorsoventral pozisyonlarda alınmıştır. VHS ölçümleri, Buchanan ve Bücheler (1995) tarafından tanımlanan yönteme uygun olarak yapılmıştır. VLAS ölçümleri ise Malcolm ve ark. (2018) tarafından tanımlanan tekniğe göre sağ lateral görüntü üzerinden gerçekleştirilmiştir. Tüm ölçümler, deneyimli bir radyoloji uzmanı tarafından iki kez yapılarak ortalamaları alınmıştır.

Ekokardiyografik değerlendirme, iki boyutlu, M-mod ve Doppler modları içeren ultrason cihazı ile sağ parasternal uzun ve kısa eksen görüntülerinde yapılmıştır. Sol atriyum (LA) ve aort kökü (Ao) çapları ölçülmüş, LA/Ao oranı hesaplanmıştır.

İstatistiksel analizler için SPSS 25.0 paket programı kullanılmıştır. Cinsiyet, yaş grubu ve ırk büyüklüğüne göre karşılaştırmalarda bağımsız örneklem t-testi ve tek yönlü ANOVA kullanılmıştır. Parametreler arası ilişkiler Pearson korelasyon analizi ile değerlendirilmiş, $p<0.05$ değeri istatistiksel olarak anlamlı kabul edilmiştir (Rishniw & Erb, 2000; Visser et al., 2015).

2. BULGULAR

Çalışmaya dahil edilen 40 köpeğin yaş ortalaması 5,2 ± 2,8 yıl, vücut ağırlığı ortalaması ise 18,4 ± 7,6 kg olarak bulunmuştur. Köpeklerin %55'i erkek, %45'i dişi idi. Irk dağılımı küçük, orta ve büyük ırklar olarak gruplandırıldığında dengeli bir dağılım gözlenmiştir.

Ortalama VHS değeri 9,86 ± 0,41, VLAS değeri 1,32 ± 0,18 ve LA/Ao oranı 1,17 ± 0,09 olarak hesaplanmıştır. Cinsiyet, yaş grubu ve ırk büyüklüğüne göre yapılan karşılaştırmalarda bu parametrelerde anlamlı fark saptanmamıştır ($p>0.05$). Alt grup analizlerinde küçük ırklarda ortalama VHS 9,89, orta ırklarda 9,84 ve büyük ırklarda 9,85 olarak bulundu. VLAS değerleri de benzer şekilde küçük ırklarda 1,33, orta ırklarda 1,31, büyük ırklarda 1,30 olarak ölçüldü. Yaş

grupları arasında 1–4 yaş, 5–8 yaş ve 9 yaş üzeri gruplar karşılaştırıldığında anlamlı fark gözlenmedi. Cinsiyet bazında erkeklerde VHS ortalaması 9,87, dişilerde 9,85 olarak bulunmuştur.

Gözlemci içi güvenilirlik analizi, ölçümlerin tekrarlanabilirliğini doğrulamıştır. Intraclass korelasyon katsayısı (ICC) VHS için 0,93, VLAS için 0,90 olarak bulunmuş, bu da ölçümlerin yüksek derecede güvenilir olduğunu göstermektedir. Ölçümler arasındaki uyum ±0,1 vertebra farkı içinde bulunmuştur.

Dağılım analizleri, VHS değerlerinin normal dağılım gösterdiğini, VLAS değerlerinin ise hafif sağa çarpık bir dağılım eğilimi sergilediğini ortaya koymuştur. Ekokardiyografik LA/Ao oranı ile radyografik parametreler arasında düşük düzeyde korelasyon bulunması, farklı tekniklerin kalp boyutunu farklı açılardan yansıttığını göstermektedir.

3. TARTIŞMA

Bu çalışmada elde edilen bulgular, VHS ve VLAS'ın sağlıklı köpeklerde cinsiyet, yaş ve ırk büyüklüğünden bağımsız olarak stabil kaldığını ortaya koymuştur. Bu sonuçlar, Buchanan ve Bücheler (1995) ile Hansson ve ark. (2005) tarafından bildirilen bulgularla uyumludur. Hansson ve arkadaşlarının çalışmasında da normal ve genişlemiş kalplere sahip köpeklerde VHS ölçümlerinin gözlemci içi ve gözlemciler arası varyasyonunun düşük olduğu bildirilmiştir ki, bu durum çalışmamızdaki yüksek ICC değerleri ile örtüşmektedir.

VLAS üzerine yapılan önceki araştırmalar, özellikle mitral kapak hastalığında eşik değerin 2,3 vertebra civarında olduğunu ve bu değerin üzerinde sol atriyum genişlemesi olasılığının arttığını göstermektedir (Malcolm ve ark., 2018). Bizim çalışmamızda sağlıklı popülasyonda ortalama 1,32 vertebra bulunması, patoloji varlığında bu değerin belirgin şekilde artabileceğini desteklemektedir.

Radyografik ölçümlerin ekokardiyografiye göre avantajları arasında yaygın erişilebilirlik, düşük maliyet, kısa çekim süresi ve sedasyon gerektirmemesi sayılabilir. Bununla birlikte, projeksiyon farklılıkları, inspiryum/ekspiryum fazı, hasta pozisyonlaması, vücut kondisyon skoru ve radyografik cihaz kalitesi gibi faktörler ölçüm sonuçlarını etkileyebilir. Bu nedenle, standardize edilmiş bir çekim protokolü ve deneyimli bir gözlemci ile çalışmak, ölçümlerin doğruluğunu ve tekrarlanabilirliğini artıracaktır.

Çalışmanın sınırlılıkları arasında örneklem büyüklüğünün görece küçük olması, tek merkezli yürütülmesi ve yalnızca sağlıklı köpekler üzerinde yapılmış olması yer almaktadır. İleride yapılacak daha geniş örneklemli, çok merkezli ve kardiyak patolojilere sahip köpekleri de kapsayan çalışmalar, VHS ve VLAS'ın klinik tanıdaki değerini daha net ortaya koyacaktır. Ayrıca, farklı ırklara özgü referans aralıklarının belirlenmesi, klinik yorumlamanın doğruluğunu artırabilir (Keene et al., 2019).

4. SONUÇ

Sağlıklı köpeklerde VHS ve VLAS ölçümleri, cinsiyet, yaş ve vücut ağırlığı gibi demografik faktörlerden bağımsız olarak güvenilir sonuçlar vermektedir. Bu parametreler, özellikle ekokardiyografi gibi ileri görüntüleme yöntemlerine erişimin mümkün olmadığı koşullarda, kardiyak boyutun değerlendirilmesinde kullanılabilecek pratik ve düşük maliyetli tanısal araçlar olarak önerilmektedir. Daha geniş örneklem gruplarıyla ve farklı kardiyak patolojiler üzerinde yapılacak çalışmalar, bu bulguların genellenebilirliğini artıracaktır.

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EFFECTS OF *in ovo* HONEY FEEDING ON HATCHING PERFORMANCE AND RESPONSE TO DELAYED ACCESS TO FEED AND WATER IN ANADOLU-T BROILER CHICKS

Canan KOP BOZBAY

Doç. Dr., Eskisehir Osmangazi University, Faculty of Agriculture, Department of Animal Science

Email: cbozbay@ogu.edu.tr

ORCID: 0000-0002-8071-5860

Melike VURAL

Bachelor's Degree, Eskisehir Osmangazi University, Faculty of Agriculture, Department of Animal Science

ORCID: 0009-0000-3173-2085

Zeynep GEÇİLİ

Bachelor's Degree, Eskisehir Osmangazi University, Faculty of Agriculture, Department of Animal Science

ORCID: 0009-0003-9443-6867

Nuri Can KARAOĞLU

Master's Degree, Eskisehir Osmangazi University, Faculty of Agriculture, Department of Animal Science

ORCID: 0009-0001-5427-7748

ABSTRACT

This study explores the potential to mitigate the adverse effects of high body weight loss in chicks when access to feed and water is delayed after hatching in modern broiler production. For this purpose, the study examined the potential to mitigate these adverse effects by *in ovo* feeding varying doses of honey into Anadolu-T broiler eggs on day 18 of incubation. A total of 300 fertilised eggs were divided into six treatment groups, each with five replicates and 10 eggs per replicate, and placed in hatching trays. On the 18th day of incubation, no injection was administered to the negative control group (NC), while the positive control group (PC) received 0.5 ml of physiological serum, and the H25, H50, H75, and H100 groups received 0.25 mg, 0.50 mg, 0.75 mg, and 1 mg of honey, respectively, dissolved in 0.5 ml of physiological saline. Access to feed and water was provided for 24 hours after hatching in all groups. No significant effect of *in ovo* honey feeding was observed on hatchability, chick quality, or hatching weight. However, body weight loss at 24 hours post-hatch was significantly lower in the H25, H75, and H100 groups compared to the positive control group. The study's overall findings strongly suggest that *in ovo* honey feeding may be a practical, effective alternative for reducing live weight loss in broiler chicks, particularly when access to feed and water is delayed, without compromising hatchability. This method could significantly improve commercial broiler farming by supporting chick early viability and performance.

Keywords: *in ovo* feeding, honey, hatchability, fasting

In ovo BAL ENJEKSİYONUNUN ANADOLU-T CİVCİVLERİNDE KULUÇKA PERFORMANSI VE ÇIKIŞ SONRASI YEM VE SU ERİŞİMİ GECİKMESİNE YANIT ÜZERİNE ETKİLERİ

ÖZET

Bu çalışma, modern etlik piliç üretiminde yumurtadan çıktıktan sonra yeme ve suya erişimin geciktirilmesi durumunda civcivlerde yüksek vücut ağırlığı kaybının olumsuz etkilerini azaltma potansiyelini araştırmaktadır. Bu amaçla, kuluçka süresinin 18. gününde Anadolu-T etlik piliç yumurtalarına değişen dozlarda *in ovo* bal verilerek bu olumsuz etkilerin azaltılma potansiyeli incelenmiştir. Toplam 300 adet döllü yumurta beş tekerrürlü ve her tekerrürde 10 yumurta olacak şekilde altı muamele grubuna ayrılarak gelişim tablalarına yerleştirilmiştir. Kuluçkanın 18. gününde negatif kontrol grubuna (NK) enjeksiyon uygulanmazken, pozitif kontrol grubuna (PK) 0.5 ml serum fizyolojik ve B25, B50, B75 ile B100 gruplarına sırasıyla 0.25 mg, 0.50 mg, 0.75 mg ve 1 mg bal, 0.5 ml serum fizyolojik içinde çözündürülerek enjekte edilmiştir. Tüm gruplarda çıkış sonrası yem ve suya erişim 24 saat sonra sağlanmıştır. *İn ovo* bal beslemesinin kuluçka randımanı, çıkış gücü, civciv kalitesi ve civciv çıkış ağırlığı üzerinde anlamlı bir etkisi gözlenmemiştir. Ancak, çıkış sonrası 24. saatte canlı ağırlık kaybı B25, B75 ve B100 gruplarında PK grubuna göre anlamlı düzeyde düşük bulunmuştur. Elde edilen bulgular, *in ovo* bal beslemesinin kuluçka performansını etkilemeden, yem ve suya geç erişimin neden olduğu canlı ağırlık kaybını azaltmada potansiyel, pratik ve etkili bir alternatif olduğunu göstermektedir. Bu yöntem, civcivlerin erken yaşama gücünü ve performansını destekleyerek ticari etlik piliç yetiştiriciliğini önemli ölçüde iyileştirebilir.

Anahtar Kelimeler: *in ovo* besleme, bal, kuluçka performans

1. INTRODUCTION

In standard hatchery and rearing practices, chicks are typically deprived of feed and water for about 24 to 36 hours after hatching. This delay occurs due to the hatching window, vaccinations, sexing, and transport to the hen (Careghi et al., 2005). As a result of this nutrient deficiency, chicks rapidly mobilize body reserves to sustain metabolism, leading to weight loss, decreased growth performance, immune deficiencies, and other adverse health outcomes (Kanagaraju and Rathnapraba, 2019; Kop Bozbay and Ocak, 2020).

Honey is a natural and complex food produced by bees from flower nectar. It is rich in proteins, vitamins, minerals, flavonoids, polyphenols, and various bioactive compounds (Lofty et al., 2006). Due to these components, honey exhibits antioxidant, anti-inflammatory, immunomodulatory, and antimicrobial properties (Alvarez-Suarez et al., 2014; Saeed et al., 2017). The existing literature suggests that *in ovo* honey applications can enhance chick immunity and early growth performance (Memon et al., 2019; Kasmani et al., 2023). However, previous studies have not examined changes in chick weight under conditions where access to feed and water is delayed after *in ovo* honey injection. To address this gap, our study aimed to investigate the effects of *in ovo* honey application on hatching performance and chick quality, as well as its influence on body weight loss during the 24-hour post-hatch fasting period.

2. MATERIAL AND METHODS

In this study, 300 fertile Anadolu-T broiler eggs were incubated under standard conditions. The eggs were divided into six treatment groups, each with five replicates of 10 eggs. The injection dosage was determined based on the understanding that hydroxymethylfurfural in honey is considered toxic when its concentration exceeds 60 mg/kg (IAL, 2008).

On day 18 of incubation, egg fertility was assessed using light monitoring. The solutions prepared for *in ovo* injection were injected into the amniotic fluid, using a volume of 0.5 ml under sterile conditions. No injection was administered to the negative control group (NC), while the positive control group (PC) received 0.5 ml of physiological serum, and the H25, H50, H75, and H100 groups received 0.25 mg, 0.50 mg, 0.75 mg, and 1 mg of honey, respectively, dissolved in 0.5 ml of physiological saline.

Hatchability and mortality were calculated immediately upon completion of hatching. The quality of the chicks was assessed using the Tona score on four randomly selected chicks from each replicate, and relative asymmetry (RA) was measured. Live weights of the chicks at hatch and at 24 hours of age (before access to feed and water) were recorded. Access to feed and water was provided following standard commercial procedures, and the chicks were housed in carriers within the experimental facility for the first 24 hours.

The data obtained were analysed using the SPSS software. Differences between groups were assessed using one-way analysis of variance (ANOVA). If significant differences were identified, Duncan's multiple comparison test was applied. Differences between treatments were considered statistically significant at $p < 0.05$.

3. RESULTS AND DISCUSSION

The study found that *in ovo* honey feeding did not result in significant differences between groups regarding hatchability, mortality rates, and chick quality parameters (Tona score, RA) (Table 1; $p>0.05$). Factors such as the egg's internal nutrients, turning frequency, and incubation positioning are known to influence hatchability (Uni and Ferket, 2004). Cardeal et al. (2015) and Ingram et al.

(1997) reported that hatching is an energy-intensive process and that in egg supplements can enhance hatchability by providing additional energy sources for the embryo. However, the honey doses used in this study did not result in a significant improvement in this regard. This may be because, despite honey's carbohydrate, amino acid, vitamin, and mineral content, the amounts applied were insufficient to impact the incubation process critically. Conversely, the lack of adverse effects indicates that *in ovo* honey application is safe for embryo development.

Table 1. Effect of *in ovo* honey feeding on hatchability (%), hatchability (%), mortality rate (%) and chick quality

	NC	PC	H25	H50	H75	H100	SEM	P value
Hatchability of								
Set eggs	76.00	78.00	88.00	72.00	82.00	74.00	2.039	0.230
Fertile eggs	86.70	90.70	91.50	90.56	83.56	80.61	1.569	0.245
Embryonic mortality								
Pipped	9.08	7.07	6.50	6.94	6.22	10.95	1.082	0.819
Non-Pipped	4.22	2.22	2.00	2.50	10.22	8.44	1.095	0.106
Chick quality								
Tona scoru	99.20	98.50	99.30	99.00	99.60	99.10	0.247	0.884
Relative asimetri	1.48	1.95	1.43	2.34	0.84	1.78	0.168	0.170

NC: negative control; PC: positive control; H25: 0.25 mg honey injection; H50: 0.50 mg honey injection; H75: 0.75 mg honey injection; H100: 1.00 mg honey injection; SEM= standard error of the mean. [a,b,c,d]Within a row, means with different superscripts differ significantly ($P<0.05$).

Significant differences were found among the groups in 24-hour body weight and body weight loss (Table 2; $p<0.001$). The highest body weight was observed in the H50 group (44.48 g), while the lowest weight was recorded in the PC group (40.44 g). The PC group also exhibited the most significant weight loss (4.31 g), whereas weight loss was significantly reduced in the honey-administered groups. This suggests that the readily digestible carbohydrates in honey enhance embryo metabolism, enabling a more effective use of energy reserves in the post-hatch period. These findings imply that *in ovo* honey administration may help mitigate weight loss during vulnerable stages. Furthermore, Uni et al. (2005) reported that each gram increase in hatch weight corresponds to an additional 25-30 g of live weight by day 25. In this context, although honey application does not directly increase hatch weight, it reduces weight loss in starvation conditions, suggesting it could be a viable strategy for promoting faster growth to market weight in practical rearing scenarios.

Table 2. Effect of *in ovo* honey feeding on hatch weight, 24-hour chick weight, and chick body weight loss, g

	NC	PC	H25	H50	H75	H100	SEM	P value
Egg weight	65.00	65.00	65.00	65.00	65.00	65.00	0.115	1.000
Chick weight								

At hatch	44.86	44.75	45.26	46.68	45.14	45.50	0.288	0.450
At 24 h	41.29^{cd}	40.44^{d}	43.47^{ab}	44.48^{a}	42.72^{bc}	41.98^{bcd}	0.320	0.000
BWL	3.57^{ab}	4.31^{a}	1.79^{b}	2.20^{b}	2.41^{b}	3.52^{ab}	0.272	0.040

NC: negative control; PC: positive control; H25: 0.25 mg honey injection; H50: 0.50 mg honey injection; H75: 0.75 mg honey injection; H100: 1.00 mg honey injection; BWL: body weight loss; SEM= standard error of the mean. ^{a,b,c,d}Within a row, means with different superscripts differ significantly ($P<0.05$).

4. CONCLUSION

The current findings indicate that *in ovo* feeding of 0.25 mg, 0.50 mg, 0.75 mg, and 1 mg of honey can be a viable alternative. This method helps to reduce weight loss during the late stages of access to feed and water without negatively impacting hatching performance. However, several issues still need to be addressed, including the optimal honey content to use, the efficiency of the feeding method, and its potential benefits for production indices throughout the entire production cycle.

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EFFECTS OF DIFFERENT DOSES OF *in ovo* COLOSTRUM POWDER ADMINISTRATION ON HATCHING PERFORMANCE AND BLOOD PARAMETERS OF ANADOLU-T BROILER CHICKS

Canan KOP BOZBAY

Doç. Dr., Department of Animal Science, Faculty of Agriculture, Eskisehir Osmangazi University

cbozbay@ogu.edu.tr

ORCID: 0000-0002-8071-5860

Berkay KAYA

Bachelor's Degree, Department of Animal Science, Faculty of Agriculture, Eskisehir Osmangazi University

ORCID: 0009-0008-9035-0093

Yiğit Battal AKARSU

Bachelor's Degree, Department of Animal Science, Faculty of Agriculture, Eskisehir Osmangazi University

ORCID: 0009-0009-1395-1212

Kürşat Selman OVALI

Bachelor's Degree, Department of Animal Science, Faculty of Agriculture, Eskisehir Osmangazi University

ORCID: 0009-0007-8964-9402

Miraç Mert YILDIRIM

Master's Degree, Department of Animal Science, Faculty of Agriculture, Eskisehir Osmangazi University

ORCID: 0009-0008-5475-3469

ABSTRACT

In this study, the effects of *in ovo* colostrum powder feeding into fertile Anadolu-T eggs at different doses on the hatching performance and certain blood parameters of chicks were evaluated. Colostrum, the first milk of mammals, contains high levels of immune and nutritional nutrients; this study examined the contribution of this valuable ingredient to chick development. For this purpose, a total of 450 fertilised eggs were divided into six different treatment groups, each consisting of 15 eggs, and placed in hatching trays. On day 18 of incubation, no injection was administered to the negative control group (NC), whereas the positive control group (PC) received 0.5 mL of physiological saline. The treatment groups C1, C2, C3, and C4 were injected with 1 mg, 2 mg, 3 mg, and 4 mg of colostrum powder dissolved in 0.5 mL of physiological saline, respectively. According to the findings, hatchability and chick weight were not affected by *in ovo* colostrum feeding. The blood protein level in chicks in the C4 group was higher than in the PC, C2, and C3 groups. Similarly, the globulin level was significantly higher in the C4 group than in

the NC, PC, C2, and C3 groups. The blood urea nitrogen level was higher in the NC group than in the C1, C3, and C4 groups. In conclusion, this study demonstrated that *in ovo* colostrum powder injection did not affect hatchability but did result in positive changes in critical biochemical parameters in chick blood. These findings suggest that *in ovo* colostrum feeding has the potential to improve chicks' early immune status and may be a valuable strategy for future research.

Keywords: *in ovo* feeding, colostrum, hatchability

ANADOLU-T ETLİK PİLİÇ YUMURTALARINDA FARKLI DOZLARDAKİ *in ovo* TOZ KOLOSTRUM UYGULAMASININ KULUÇKA PERFORMANSI VE CİVCİV KAN PARAMETRELERİ ÜZERİNE ETKİLERİ

ÖZET

Bu çalışmada, döllü Anadolu-T yumurtalarına farklı dozlarda *in ovo* toz kolostrum beslemesinin civcivlerin kuluçka performansı ve bazı kan parametreleri üzerine etkileri değerlendirilmiştir. Memeli hayvanların ilk sütü olan kolostrum, yüksek oranda bağışıklık ve besin öğeleri içermektedir. Bu amaçla, toplam 450 adet döllü yumurta her biri 15 yumurtadan oluşan beş tekerrürlü altı farklı muamele grubuna ayrılarak gelişim tablalarına yerleştirilmiştir. Kuluçkanın 18. gününde, negatif kontrol grubuna herhangi bir enjeksiyon uygulanmazken (NK), pozitif kontrol (PK) grubuna 0,5 ml serum fizyolojik ve K1, K2, K3 ve K4 gruplarına sırasıyla 0,5 ml serum fizyolojik içinde çözündürülmüş 1 mg, 2 mg, 3 mg ve 4 mg toz kolostrum enjeksiyonu yapılmıştır. Elde edilen bulgulara göre, çıkış gücü ve civciv çıkış ağırlığı *in ovo* kolostrum uygulamasından etkilenmemiştir. K4 grubundaki civcivlerin kan protein düzeyi, PK, K2 ve K3 gruplarına kıyasla daha yüksek bulunmuştur. Benzer şekilde, globülin düzeyi de K4 grubunda NK, PK, K2 ve K3 gruplarına göre yüksek tespit edilmiştir. Kan üre azotu düzeyi ise NK grubunda, K1, K3 ve K4 gruplarına kıyasla daha yüksek saptanmıştır. Sonuç olarak, bu çalışma *in ovo* toz kolostrum beslemesinin kuluçka randımanını etkilemediğini ancak kan biyokimyasal parametrelerinde olumlu değişikliklere yol açtığını göstermiştir. Bu bulgular yumurta içi toz kolostrum beslemesinin civcivlerin erken bağışıklık durumunu iyileştirme potansiyeline sahip olduğunu ve gelecekteki araştırmalar için değerli bir strateji olabileceğini düşündürmektedir.

Anahtar Kelimeler: *in ovo* besleme, kolostrum, kuluçka performans

1. INTRODUCTION

Colostrum, the milk secreted in mammals during the first few days after birth, is a highly nutrient-dense liquid. Rich in energy, colostrum contains more protein, fat, minerals (iron, magnesium, sodium), and vitamins than regular milk, while its lactose content is lower (Georgiev, 2008). Furthermore, colostrum has a higher dry matter content than mature milk (Sjaastad et al., 2003). Prominent biological components of colostrum include immunoglobulins, peptides, hormones, growth factors, enzymes, cytokines, acute-phase proteins, nucleotides, and polyamines (Georgiev, 2008). Thanks to its rich content, colostrum contributes significantly to the development of various tissues and organs, including the gastrointestinal system.

The *in ovo* feeding technique used in poultry farming supports intestinal development and the immune system by delivering additional nutrients to chicks during the embryonic period (Das et al., 2021; Kop-Bozbay and Göneci, 2023). This ensures that chicks hatch with higher quality, higher survival rates, and adequate nutritional reserves, which has a positive impact on their future performance. Furthermore, this nutritional support during the embryonic period is crucial for reducing the potential adverse effects of dietary errors during rearing on hatchability and chick quality. The potent immunological and developmental factors in colostrum, combined with the potential of *in ovo* feeding to enhance early-stage performance, offer a promising synergy for delivering colostrum's bioactive ingredients to poultry embryos. In particular, the stable and concentrated bioactive compound content of powdered colostrum provides an ideal medium for delivering targeted benefits to the embryo. However, there is still a gap in the literature regarding the effects of this treatment on poultry embryos and optimal dosages. In this context, the current study aimed to investigate the effects of *in ovo* injection of powdered colostrum at different doses on hatchability and selected blood parameters in chicks.

2. MATERIAL AND METHODS

In this study, a total of 450 fertile Anadolu-T broiler eggs were incubated under standard conditions using Çimuka (Ankara, Turkey) incubation and hatching machines. The eggs were divided into six treatment groups, each consisting of five replicates with 15 eggs each. On the 18th day of incubation, no injection was administered to the negative control group (negative control, NC), the positive control (PC) group received 0.5 ml of physiological serum and the C1, C2, C3, and C4 treatment groups received injections of 1 mg, 2 mg, 3 mg, and 4 mg of colostrum powder dissolved in 0.5 ml of physiological serum, respectively.

Hatchability and mortality were calculated immediately upon completion of hatching. The quality of the chicks was assessed using the Tona score on four randomly selected chicks from each replicate. Chick weights were recorded. On the day of hatching, blood samples taken from the chicks were analyzed in a special laboratory for hemogram, total protein, albumin, globulin, urea, uric acid, creatine, HDL, LDL, cholesterol and triglyceride.

The data obtained were analysed using the SPSS software. Differences between groups were assessed using one-way analysis of variance (ANOVA). If significant differences were identified, Duncan's multiple comparison test was applied. Differences between treatments were considered statistically significant at $p < 0.05$.

3. RESULTS AND DISCUSSION

In our study, the lack of significant effects of *in ovo* colostrum injection at different doses on hatching weight and early performance parameters (Table 1; $p > 0.05$) may be attributed to

colostrum's essential physiological roles. Colostrum is a fluid focused on supporting physiological and, particularly, immunological processes rather than primarily providing a rapid growth substrate, as is the case in mammalian offspring. Colostrum components, particularly immunoglobulins and growth factors, are believed to support the development of the immune system and maintain metabolic stability, rather than directly influencing embryonic growth. The limited energy and growth substrate content of colostrum did not directly facilitate weight gain.

Table 1. Effect of *in ovo* colostrum feeding on hatchability

	NC	PC	C1	C2	C3	C4	SEM	P value
Egg weight, g	64.48	64.50	64.50	64.49	64.49	64.48	0.106	1.000
Chick weight, g	44.37	44.72	44.05	44.76	43.48	42.98	0.317	0.554
Hatchability, %	93.50	96.36	98.18	90.36	93.14	89.67	1.645	0.677
Mortality, %								
Pipped	6.50	0.00	1.82	5.82	4.86	5.83	1.148	0.532
Non-Pipped	0.00	3.64	3.33	3.82	2.00	4.50	1.016	0.854
Tona scoru	99.70	99.90	99.10	99.10	99.00	99.00	0.153	0.358

NC: negative control; PC: positive control; C1: 1 mg colostrum injection; C2: 2 mg colostrum injection; C3: 3 mg colostrum injection; C4:4 mg colostrum injection. SEM= standard error of the mean.

The findings of our study's hematological analysis (Table 2; $p < 0.05$) revealed that *in ovo* colostrum injection had positive and significant effects on the physiological status of chicks. These effects were particularly evident in indicators of immunity and protein metabolism, suggesting that the bioactive components of colostrum are effectively absorbed during the embryonic period and trigger a functional response. In this context, it is suggested that *in ovo* colostrum administration may benefit chicks by improving their ability to develop resistance and metabolic adaptation to environmental stressors encountered early in life, rather than directly enhancing growth performance. Notably, the use of 2% colostrum, particularly in its fresh form, during the broiler starter period has shown beneficial effects on broiler performance, carcass characteristics, blood biochemical parameters, immunity, and antioxidant status (Arjomand et al., 2022). Additionally, groups fed diets supplemented with colostrum exhibited higher live weights and live weight gains, while feed conversion ratio (FCR) was lower. The group that received diets containing 2% bovine colostrum per kilogram of feed recorded the highest live weight gains and the lowest FCR, although feed intake was not significantly affected. Consequently, it was concluded that 2% bovine colostrum could be integrated into broiler diets to enhance body weight and reduce FCR (Afzal et al., 2017). Furthermore, a study on laying quails discovered that incorporating powdered colostrum into their diet linearly increased feed intake, egg production, egg weight, shell weight, shell thickness, and improved feed utilization (Bayrıl et al., 2017). Therefore, further research is needed to investigate the long-term effects of *in ovo* colostrum feeding in poultry farming.

Table 2. Blood biochemical properties of chicks obtained by *in ovo* colostrum feeding

	NC	PC	C1	C2	C3	C4	SEM	P value
Albumin	0.89	0.83	0.96	0.87	0.83	0.99	0.020	0.093
Protein	2.04^{ab}	1.90^{b}	2.17^{ab}	2.01^{b}	1.94^{b}	2.32^{a}	0.041	0.033
Globulin	1.15^{b}	1.07^{b}	1.21^{ab}	1.14^{b}	1.11^{b}	1.33^{a}	0.024	0.029
Urea nitrogen	7.60^{a}	7.10^{ab}	5.70^{b}	6.10^{ab}	5.50^{b}	5.78^{b}	0.227	0.029
Uric acid	5.51	4.91	6.61	7.19	9.16	8.67	0.472	0.052
Cholesterol	526.60	516.70	501.60	480.00	442.00	526.67	15.035	0.560
HDL	143.70	140.90	148.60	140.60	135.70	145.67	1.581	0.238
LDL	357.30	362.10	325.40	322.40	275.50	347.78	12.892	0.402
Creatinine	0.20	0.20	0.20	0.20	0.20	0.20	0.000	1.000
Triglyceride	80.70	115.30	107.70	118.50	136.10	120.00	5.641	0.103

NC: negative control; PC: positive control; C1: 1 mg colostrum injection; C2: 2 mg colostrum injection; C3: 3 mg colostrum injection; C4:4 mg colostrum injection. SEM= standard error of the mean. ^{a,b,c,d}Within a row, means with different superscripts differ significantly ($P<0.05$).

4. CONCLUSION

In conclusion, while *in ovo* colostrum administration did not have a significant short-term effect on hatchability, it may enhance chicks' physiological resistance and immune responses. Therefore, colostrum can be considered as part of immune-based protective strategies, particularly during early chick development, when exposure to environmental stressors is high.

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Sjaastad, O.

BEYAZ KABAK TOHUMLARINDA YAŞLANMA ESNASINDA MEYDANA GELEN FİZYOLOJİK DEĞİŞİMLER

Prof. Dr. Mustafa DEMİRKAYA

Kayseri Üniversitesi, Safiye Çıkrıkçıoğlu MYO, Kayseri

Email: mustafademirkaya@kayseri.edu.tr

ORCID: 0000-0001-7725-3952

ÖZET

Bu çalışma 2024 ve 2025 yıllarında Kayseri Üniversitesi Safiye Çıkrıkçıoğlu MYO'na ait laboratuvarda gerçekleştirilmiştir. Tohumlar temin edildikten sonra çimlenme denemelerine kadar + 4 °C'deki buzdolabında kapalı cam kavanozlarda bekletilmiştir. Tohumların nem kapsamı %7.18 olarak ölçülmüştür. Bu çalışmada beyaz kabak tohumlarında, farklı canlılık seviyelerinde ortaya çıkan bazı fizyolojik değişimler incelenmiştir. Bu amaçla bu amaçla Bursa tohumculuğa ait BUR SAKIZ sakız kabağı çeşidi tohumlarda 80, 60, 40, 20, %10 ve %0 canlılık seviyeleri ± 4 oranında, kontrollü yaşlandırma uygulamaları ile elde edilmiştir. Daha sonra bu canlılık seviyelerinde ortalama çimlenme süresi, çimlenme indeksi hesaplamaları yapılmıştır. Kontrol tohumları %82 canlılığa sahipken 24, 38, 42, 45 ve 48 saat yaşlandırma sonuçlarında, 62, 41, 19,10 ve %0 canlılık seviyeleri elde edilmiştir. Canlılığın azalmasıyla ortalama çimlenme süresi kontrol tohumlarında %4.928 olurken, % 60,40, 20 ve %10 larda sırası ile 5.67,7.128, 8.25 ve 9.727 gün olmuştur. Canlılığın azalmasıyla çimlenme indeksi azalmış, kontrol tohumlarında %4.31 olurken, % 60,40, 20 ve %10 larda sırası ile 3.169, 1.415, 0.607 ve 0.314 olmuştur. Yaşlanmayla birlikte, ortalama çimlenme süresi artmış ve çimlenme indeksleri azalmıştır. Canlılık %40 lara düştüğünde ortalama çimlenme süresindeki artış ve çimlenme indeksindeki azalma daha belirgin olmuştur. Tohumların uygun koşullarda muhafaza etmenin önemli olduğu, canlılıktaki azalma ile tohum kalite parametrelerinin de önemli ölçüde olumsuz etkilendiği ortaya konmuştur. Ayrıca, canlılık kaybı ile çimlenme indeksi azalması arasında ve ortalama çimlenme süresi artması arasında yüksek bir korelasyon tespit edilmiştir. En yüksek negatif korelasyon -0.953 ile çimlenme oranı ve ortalama çimlenme süresi arasında tespit edilmiştir. Yani tohum canlılığını kaybederken, ortalama çimlenme süresinin artması, canlılık kaybıyla güç arasında önemli bir ilişki olduğunu gösteriyor.

Anahtar kelimeler: Tohum, kontrollü yaşlandırma, canlılık, ortalama çimlenme süresi

PHYSIOLOGICAL CHANGES OCCUR IN WHITE PUMPKIN SEEDS DURING AGEING.

ABSTRACT

This study was conducted in 2024 and 2025 at the Kayseri University Safiye Çıkrıkçıoğlu Vocational School Laboratory. After the seeds were obtained, they were stored in sealed glass jars at +4°C in a refrigerator until the germination trials. The seed moisture content was measured as 7.18%. The study investigates some physiological changes that occurred at different viability levels in white pumpkin seeds. For this purpose, seeds of the BUR SAKIZ variety from Bursa Seed Company were subjected to controlled aging treatments at ± 4% rates to obtain viability levels of ± 80%, 60%, 40%, 20%, 10%, and 0%. Subsequently, the average germination time and germination index were calculated for these viability levels. The control seeds had a viability of 82%, while after 24, 38, 42, 45, and 48 hours of aging, viability levels of 62%, 41%, 19%, 10%, and 0% were achieved, respectively. As the viability decreased, the average germination time for the control seeds was 4.928 days, while for 60%, 40%, 20%, and 10% viability levels, the times were 5.67, 7.128, 8.25, and 9.727 days, respectively. With decreasing viability, the germination index also declined, with the control seeds showing a value of 4.31, while for the 60%, 40%, 20%, and 10% viability levels, the indices were 3.169, 1.415, 0.607, and 0.314, respectively. With aging, the average germination time increased and the germination indices decreased. The increase in average germination time and the decrease in germination index became more pronounced when viability dropped to 40%. The results indicate the importance of storing seeds under suitable conditions, as the decrease in viability significantly negatively affects seed quality parameters. Furthermore, a strong correlation was found between the loss of viability and the decrease in germination index, as well as the increase in average germination time. The highest negative correlation of -0.953 was detected between germination rate and average germination time, demonstrating that as seed viability declines, the increase in average germination time shows a significant relationship with the loss of viability.

Keywords: Seed, controlled deterioration, viability, mean germination time

1. GİRİŞ

Dünyada tarım alanlarının her geçen gün çeşitli nedenlerle daraldığı, ayrıca toprakların sürekli ekilip dikilmesiyle verim ve kalite kayıpları ortaya çıkmaktadır. Bunun sonucunda, günümüzde yetersiz veya kalitesiz beslenme olarak insanlığın en büyük sorunlarından biri olarak ortaya çıkmaktadır. Bu durum gözönünde bulundurularak kaliteli ve verimli sebze çeşitlerinin tohumlarını kullanmak önemli hale gelmiştir. Yüksek verim ve kalitesi olan tohumların, aynı zamanda farklı toprak ve iklim şartlarında kalitesini göstermesi için tohumların uygun koşullarda saklanması önem kazanmıştır. Sebze yetiştiriciliğinde en önemli materyallerden biri üretimde kullanılan tohumdur. Bu yüzden kaliteli tohum üretimi ve uzun yıllar ekonomik olarak depolanabilmesi üzerine araştırmalar, türler ve çeşitler bazında devam etmelidir.

Tohumların muhafaza ediebilirliği incelendiği zaman, uzun süre muhafaza edilebilen ve basparmak kuralının uygulanabildiği tohumlar grub tohumlara ortodoks grubu tohumlar olarak adlandırılmaktadır. Bu kural, sıcaklık ve tohum nemi arasında ilişkiyi inceleyen ve bilinen kurala göre tohum nemindeki her %1'lik artış ve sıcaklıktaki her 5°C'lik yükselişle tohum depo ömrü yarıya düşer. Bu kural tohum nem kapsamı %5-14 ve sıcaklık 0-50°C aralığında olduğunda geçerlidir (Harrington 1973). Ortodoks grubu tohumlar, düşük nem içerikleri ve düşük sıcaklıklarda herhamngi bir canlılık kaybına uğramadan uzun süre depolanabilmektedir. Ekonomik yönden değerli bahçe ve tarla bitkileri ile süs bitkilerinin tohumları bu grupta yer alır (Roberts 1973).

Bunun aksine hiç depolanamayan yada çok az süre depolabilen ve kurutulamayan ve inatçı(recalcitrant) olarak adlandırılan bir grub tohum bulunmaktadır. Recalcitrant tohumlar, fizyolojik olgunlukta yüksek tohum nemine (%30-70) sahip, düşük sıcaklık ve kurutmaya hassas, dormansinin görülmediği tohumlardır. Daha çok tropik ve subtropik orijinli bitkilerin tohumlarını kapsar (Arın 2018). Diğer bir grub olan, ara tohumlar olarak adlandırılan intermediat grubu bulunmaktadır. Bu grubtaki tohumlar tropik ve subtropik bölgelerin çok yıllık bitkilerinin kahve turunçgiller ve sert kabuklu meyve ağaçlarının tohumlarıdır. Bu grub tohumlar %40-60 hava nemi, yani tohum nem oranı %9-13 tohum nem kapsamında saklanabilir (Karaçalı 2006).

Tohumlar yaşam sürelerini uzatmak için uygun koşullarda depolansalar bile, serbest radikal içeriğinin artması, protein yapılarının değişimi, besin rezervlerinin bozulumu, yağ asidi içeriği ve enzimatik aktivitelerinin değişimi, membran zararı, kromozom değişimleri ve solunum artması nedeniyle belirli süreler sonucunda zarar görmekte ve canlılıklarını kaybetmektedir (Justice ve Bass 1979). Burada tohum kabukları geçirgen ve yağlı tohumlardan olan kabak tohumlarında tohumlarda suyun çıktığı yerlerere oksijen girerek, yağlar oksitlenerek tohumlar canlılığını daha çabuk kaybedebilir.

Bu çalışmada kontrollü bozulmaya tabii tutulan beyaz kabak tohumlarında, tohum canlılığı azalırken, fizyolojik parametrelerde meydana gelen değişimler arasındaki ilişkiler incelenmiştir.

2. MATERYAL YÖNTEM

2.1. Materyal

Çalışma da Bursa tohumculuğa ait olan BUR SAKIZ çeşidine ait tohumlar kullanılmıştır. BUR SAKIZ çeşidi açık bitki yapısına sahip, silindirik meyve yapısına sahip, genelde 15-17 cm meyve uzunluğu olan ve krem renginde standart bir çeşittir.

2.2. Tohum nem kapsamı

Tohum nem kipsie kabakgillerde önnerilen (Şehirali, 1997) yüksek sıcaklık sabit fırın yöntemine göre 130 °C'de bir saat süreyle aşağıdaki şekilde yapılmış ve hesaplanmıştır. Tohum örnekleri kapakları ile tartılmış ve numaralanmış petri kapları içine iyice yayılmıştır. Petri kapları örnekle birlikte tekrar tartılmıştır. Daha sonra kapakları açık olacak şekilde, 130 ±1°C'deki fırında 1 saat tutulmuştur. Bu sürenin sonunda, fırından çıkarılan petri kaplarının kapakları kapatılarak, içinde silika jel bulunan bir desikatörde 30 dakika soğumaya bırakılmıştır. Soğutulan petri kapları, içindeki örnek ile tartılmıştır. Tartımlar sırasında laboratuarda oransal nem %50±5 civarında olmuştur. Tohum nem kapsamı tayini her grup için iki tekerrürlü olarak yapılmıştır. Tohum nem kapsamları ölçülürken her tekerrürde Mavi (2009)'a göre 2 gram örnek kullnılmıştır. İki tekerrür arasındaki maksimum farkın %0.2'den küçük olmasına dikkat edilmiştir. Aksi takdirde tohum nem kapsamı tayini tekrarlanmıştır.

2.3. Çimlenme testleri

Çimlendirme sıcaklığı (Şehirali 1997)'ye göre 25 °C derece olarak alınmıştır. Burada çimlendirmenin 20-30 arasında yapılabileceği belirtilmiştir. Çimlenme oranları temin edilen kontrol tohumarında ve kontrollü bozulmalardan sonra tespit edilmiştir. Tohum örnekleri (25 tohumdan oluşan 4 tekrar), 25±1 °C'de nemli rulo dispenser kağıt havlular arasında 12 gün boyunca test edildi (Şehirali 1997, Demir ve Ellis 2003). Çimlenme testleri yapılırken lieretürde belirtilen aşağıdaki durumlar dikkate alınmıştır. Tohumlardan sağlıklı olmayan, primer kök ve kotildonu gelişmeyen, zayıf, hastalıklı ve anormal çimlenmiş tohumlar sayıma dahil edilmemiştir. Sayımlar tohumların ortamdan çıkarılması suretiyle yapılmıştır. Tohum canlılığı sayım sonunda yüzde çimlenme olarak belirlenmiştir. (Bekendam ve Grob 1979).

2.4. Ortalama Çimlenme Süresi

Tohum gücünün bir göstegesi olan ortlama çimlenme süresi literatüre göre hesaplanmıştır (Demir et al. 2008).

2.5. Çimlenme İndeksi

Çoğunlukla benzer çimlenme oranına sahip olan tohum partilerinin çimlenme hızı ve dolayısıyla fide gelişme hızı farklı olmaktadır. Çimlenme indeksi tohum grubunun performansını ortaya koymak üzere literature göre yapımıştır. (Sivritepe 2012).

2.6. İstatistiksel analiz

Denemeler tesadüf parsellerinde deneme desenlerine göre ve her tekerrürde 25 tohum olacak şekilde 4 tekerrürlü olarak kurulmuştur. Varyans analizleri "SSPS 13.0 for Windows" istatistik programında yapılmış, ortalamalar arasındaki farklılıklar 0.05 önemlilik seviyesinde LSD testine göre belirlenmiştir.

3. BULGULAR VE TARTIŞMA

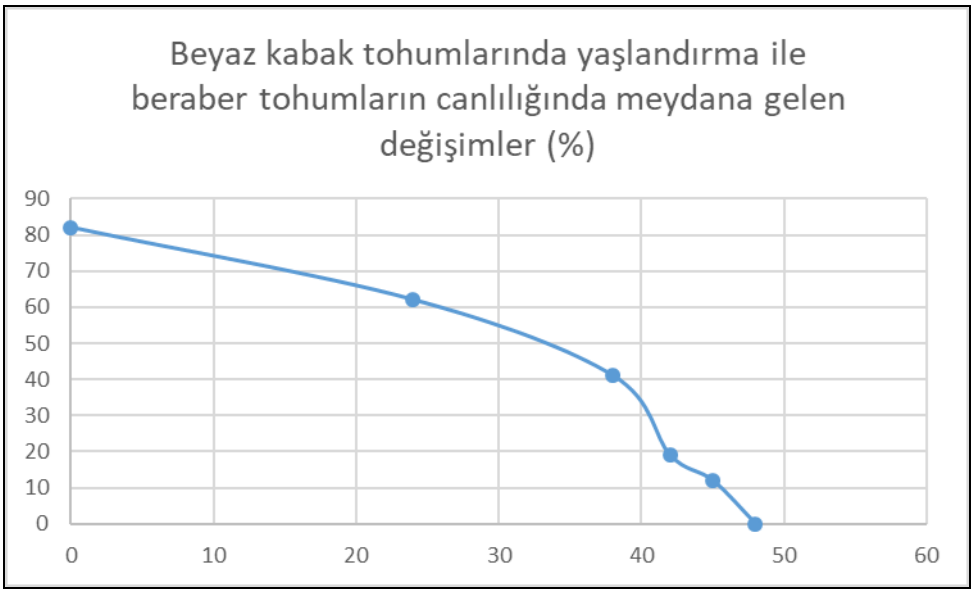
Başparmak kuralı olarak bilinen Harrington (1973) kural gözönünde bulundurularak, çalışmaya başlamadan tohum nem kapsamı ölçülmüş ve %7.18 bulunmuştur. Tohumlar çimlenme testlerinde kullanılana kadar 4 ±1 derecede buzdolabında ve cam kavanozlarda saklanmıştır. Kontrollü bozulma uygulamalarından sonra yapılan çimlendirme testlerinden elde edilen veriler, belirli yaşlandırma sürelerine karşılık gelen normal çimlenme oranları olarak ayrı seriler halinde bir grafik üzerine yerleştirilmiştir. Böylece BUR SAKIZ kabağı tohum gruplarından elde edilen canlılık eğrileri karşılaştırılmıştır. Kontrollü bozulma uygulamaları, zamandaki artışa bağlı olarak tohum

canlılığının azalmasına neden olmuştur (Çizelge 1; Şekil 1). Şekil 1'de görüldüğü gibi kontrol tohumları %82 canlılığa sahip olurken, sırasıyla % 62, 41, 19, 12 ve 0 canlılığa sahip tohumlar 24, 38, 42, 45 ve 48 saatin sonunda elde edilmiştir.

Çizelge 1. Beyaz kabak tohumlarında BUR SAKIZ kabağı çeşidinde tohum fizyolojik parametreleri arasındaki korelasyon ilişkisi

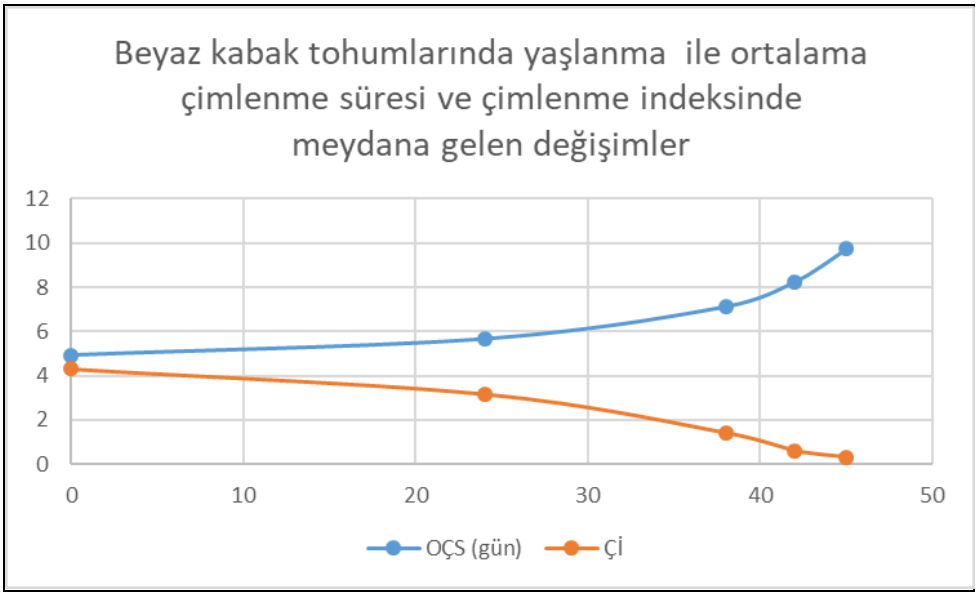
Canlılık	Çimlenme oranı (%)	Ortalama Çimlenme Süresi (gün)	Çimlenme indeksi
Kontrol	82 a	4.928 e	4.313 a
24 saat	62 b	5.673 d	3.169 b
38 saat	41 c	7.128 c	1.415 c
42 saat	19 d	8.25 b	0.607 d
45 saat	12 e	9.727 a	0.314 d
48 saat	0	0	0

Tohum gücündeki değişimleri incelediğimiz zaman, canlılık kaybı ile beraber ortalama çimlenme süresi artmış, yani tohum gücü azalmıştır (Çizelge 1; Şekil 2). En kısa ortalama çimlenme süresi 4.928 gün ile kontrol tohumlarından elde edilirken en yüksek ortalama çimlenme süresi 9.727 gün ile 45 saat kontrollü bozulma uygulamalarından elde edilmiştir. Tohum performansının bir göstergesi olan Çİ incelendiği zaman en yüksek çimlenme indeksi 4.313 ile kontrol tohumlarından elde edilmiştir. En az tohum performansı 0.314 ile 45 saat uygulamasından elde edimiştir ($P<0.05$) (Çizelge 1; Şekil 2).



Şekil 1. BUR SAKIZ kabağı çeşidi tohumlarda kontrolllü bozulma ile canlılıkta meydana gelen değişimer.

Ortalama çimlenme süreleri incelendiğinde; tohumlarında canlılık kaybı ile ortalama çimlenme sürelerinde meydana gelen artış tüm çeşitlerde önemli ($P<0.05$) bulunmuştur. Diğer bir deyişle,tohumların canlılığı ile birlikte gücü (vigoru) de azalmıştır. Ayrıca tohum performansının bir göstergesi olan çimlenme indekside bozulma ile beraber artmıştır (Çizelge 2).



Şekil 2: BUR SAKIZ kabak çeşidi tohumlarında canlılık kaybı ile Ortalama Çimlenme Süresi ve Çimlenme İndeksindeki değişimler

Tohumlarda yaşlanma ile beraber ortaya çıkan canlılık kaybı ile OÇS arasında yüksek negatif bir ilgileşim -0.953** , yine OÇS ve Çİ arasında yüksek negatif bir korelasyon -0.932** düzeyinde korelasyon tespit edilmiştir. ÇO ve Çİ arasında ise 0.981 ** %0.01 düzeyinde pozitif bir korelasyon tespit edilmiştir. Yani canlılık artarken performansta artmış, canlılık azalırken tohum performansı da düşmüştür.

Çizelge 2. BUR SAKIZ çeşidi beyaz kabak tohumlarında canlılık kaybı ile fizyolojik parametreler arsındaki korelasyon matrisi

Parametreler*	**ÇO**	**OÇS**	**Çİ**
ÇO	1.00	-	-
OÇS	- 0.953**	1.00	-
Çİ	0.981**	- 0.932**	1.00

*: ÇO: Çimlenme oranı; OÇS: Ortalama çimlenme süresi; Çİ: Çimlenme indeksi

Çalışma değerlendirildiğinde canlılık kaybı ile beraber gücü ve kalitesinin azaldığı belirlenmiş ve bu durum canlılık %40'lara düştüğünde daha belirgin hale gelmiştir. Tohumlar muhafaza edilirken kurallara dikkat edilmesinin önemli olduğu ortaya konmuştur. Literatürde Demirkaya (2013) yağlı tohum olan biber tohumlarında 60-90 saatte canlılık %90'lardan %0'a inerken, bu çalışmada 48 saatte %0'a inmiştir. Kabak tohumlarının yüzeyinin fazla ve geçirgen olması muhtemelen yağların daha çabuk bozulması ve canlılığını kaybetmesine neden olmuş olabilir. Bu nedenle kabak tohumlarında su geçirmez kapların kullanılması ve depolamadan önce nem kapsamlarının çok iyi ayarlanması gerekir.

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HAYVANCILIKTA MEVCUT DURUM VE YENİ DESTEKLEME MODELİ

Ahmet ÖZDEN

Tarım ve Orman Bakanlığı, Ankara İl Tarım ve Orman Müdürlüğü, Ankara/Türkiye

Email: ozden.ahmet@tarimorman.gov.tr

ORCID: 0009-0009-6429-5833

Prof. Dr. Yusuf CUFADAR

Selçuk Üniversitesi, Ziraat Fakültesi, Zootekni Bölümü, Konya/Türkiye

Email: ycufadar@selcuk.edu.tr

ORCID: 0000-0001-9606-791X

ÖZET

Türkiye, köklü tarım geleneği ve zengin coğrafi yapısıyla hayvancılık açısından büyük bir potansiyele sahip ülkelerden biridir. Hayvancılık sektörü yalnızca ülkenin hayvansal gıda ihtiyacının karşılamakla kalmayıp, kırsal kesimde istihdam yaratması ve tarıma dayalı sanayinin desteklenmesi bakımından da stratejik bir öneme sahiptir. Türkiye'de büyükbaş ve küçükbaş hayvan varlığında son yıllarda bazı gerilemeler yaşanmış olsa da son on yıllık süreçte genel olarak artış gözlemlenmiştir. Büyükbaş hayvan varlığı, 2014 yılında 14,3 milyon baş iken yıllar içerisinde artış göstererek 2024 yılında 16,9 milyon başa ulaşmıştır. Manda varlığı, 2014 yılında 122,1 bin baş seviyesindeyken 2024 yılında 162 bin başa yükselmiştir. Küçükbaş hayvancılıkta da benzer bir artış gözlenmiştir. 2014 yılında 41,5 milyon baş olan küçükbaş hayvan varlığı, 2024 yılında 54,9 milyon başa ulaşmıştır. Keçi varlığı ise 2014 yılında 10,4 milyon baş iken, 2024 yılında 10,8 milyon baş olarak gerçekleşmiştir. Kanatlı hayvancılık sektörü, iç tüketimin yanı sıra ihracata yönelik üretim modeliyle gelişimini sürdürmektedir. Modern kümes ve entegre tesisleri her geçen gün artmaktadır. 2014 yılında 1,9 milyon ton olan tavuk eti üretimi 2024 yılında 2,5 milyon tona, 48,7 bin ton olan hindi eti üretimi 2024 yılında 52,3 bin tona, 17,1 milyar adet olan tavuk yumurtası üretimi 2024 yılında 21,2 milyar adete yükselmiştir.

Türkiye'de hayvancılık sektörü, tarımsal üretimin sürdürülebilirliği ve kırsal kalkınmanın desteklenmesi açısından kritik bir role sahiptir. Bu doğrultuda Tarım ve Orman Bakanlığı, gıda arz güvenliğini sağlamak, verimliliği artırmak ve sürdürülebilir bir üretim modeli oluşturmak amacıyla çeşitli hayvancılık destekleme programları yürütmektedir. En güncel hayvancılık destekleme modeli, 2024-2026 dönemini kapsamakta olup, 26 Temmuz 2024 tarihli ve 32613 sayılı Resmî Gazete' de yayımlanan Cumhurbaşkanlığı Kararı (Karar Sayısı: 8760) ile yürürlüğe girmiştir. Bu yeni model, önceki yıllardan farklı olarak üretim planlamasına ve performansa dayalı bir sistem üzerine kurgulanmıştır. Destekler, iki ana başlık altında toplanmaktadır: Temel Hayvancılık Destekleri: Büyükbaş ve küçükbaş hayvancılık, arıcılık ve ipek böceği yetiştiriciliğini kapsamaktadır. Ürün Geliştirme Destekleri: Çiğ süt, besilik erkek sığır (karkas) ve tiftik üretimine yönelik destekleri içermektedir. Bu sistem ile üretimin daha verimli, planlı ve sürdürülebilir şekilde yürütülmesi hedeflenmektedir.

Anahtar Kelimeler: Tarım, hayvancılık, hayvancılık destekleri, verimlilik, destekleme modeli

CURRENT SITUATION IN LIVESTOCK AND NEW SUPPORT MODEL

ABSTRACT

Türkiye, with its deep-rooted agricultural tradition and rich geographical structure, is one of the countries with great potential for animal husbandry. The livestock sector not only meets the country's animal food needs but also holds strategic importance in creating employment in rural areas and supporting agriculture-based industries. While Türkiye has experienced some declines in the number of cattle and small ruminants in recent years, a general increase has been observed over the last decade. While cattle numbers were 14.3 million in 2014, they have increased over the years, reaching 16.9 million in 2024. Buffalo numbers rose from 122.1 million in 2014 to 162,000 in 2024. A similar increase has been observed in small ruminants. Small ruminants, which stood at 41.5 million in 2014, reached 54.9 million in 2024. While the number of goats was 10.4 million in 2014, it was 10.8 million in 2024.

The poultry sector continues to develop with a production model geared towards both domestic consumption and export. Modern poultry houses and integrated facilities are increasing daily. Chicken meat production rose from 1.9 million tons in 2014 to 2.5 million tons in 2024, Türkiye meat production from 48.7 thousand tons to 52.3 thousand tons in 2024, and chicken egg production from 17.1 billion to 21.2 billion in 2024.The livestock sector in Türkiye plays a critical role in ensuring the sustainability of agricultural production and supporting rural development. To this end, the Ministry of Agriculture and Forestry implements various livestock support programs to ensure food supply security, increase productivity, and establish a sustainable production model.

The most current livestock support model covers the 2024-2026 period and entered into force with Presidential Decree (Decree No. 8760) published in the Official Gazette dated July 26, 2024, and numbered 32613. This new model, unlike previous years, is based on a system based on production planning and performance. Supports are categorized under two main headings: Basic Livestock Supports: Covers cattle and sheep farming, beekeeping, and silkworm breeding. Product Development Supports: Includes support for raw milk, beef cattle (carcasses), and mohair production. This system aims to ensure more efficient, planned, and sustainable production.

Keywords: Agriculture, livestock, livestock supports, productivity, support model

1. GİRİŞ

İnsanlığın ilk çağlarından itibaren ve özellikle göçebelik dönemlerinde, yapılan en önemli ekonomik faaliyet hayvancılık olmuştur. Açlık-tokluk, iyi-kötü beslenme gibi insan odaklı konular, günümüz dünya siyasetini de etkilemektedir. Nitekim gelişmiş ülkeler, geri kalmış olan ülkelere teknolojik ürünlerin yanı sıra damızlık materyal, canlı hayvan, tohumluk ve işlenmiş ürünler gibi tarımsal üretim maddelerini de pazarlayarak büyük bir gelir sağlamakta ve bu şekilde, özellikle tarımsal ürün ticareti yaptıkları ülkeler üzerindeki etkinliklerini artırmaktadırlar (TİGEM 2023).

Hayvancılık sektörü gelişmişlik seviyesine bakılmaksızın tüm ülkeler için büyük önem taşımaktadır (Saçlı, 2007). Hayvancılık hayvanların verimlerinden yararlanılan ve daha kısa sürede daha fazla verim sağlamaya yönelik bir zirai faaliyettir (Aydemir ve Pıçak, 2007).

Türkiye'de hayvancılık sektörü genel ekonomi içerisinde önemli bir yere ve potansiyele sahiptir. Hayvansal üretim faaliyetleri bazı bitkisel ve yan ürünlerin değerlendirilmesi, işgücü verimliliğinin artırılması, işletme karının artması, doğal ve ekonomik koşullardan kaynaklanan risk faktörünün azaltılması vb. faktörler işletmelere olumlu katkılar sağlamaktadır (Turan ve ark., 2017; Vural ve Fidan, 2007). Türkiye sahip olduğu doğal kaynaklar ve ekolojik koşullar dikkate alındığında, büyükbaş ve küçükbaş hayvan yetiştiriciliği bakımından elverişli şartlara sahiptir. İşletmelerin başarısında; kullanılan hayvan materyalinin ırkı, yaşı ve verim düzeyi belirleyici bir role sahiptir. Hayvan materyali ve yönetim kalitesi sonucunda ortaya konulan faaliyet birimlerinin üretim değeri ve işletmenin tarımsal geliri önemli ekonomik başarı ölçütlerindendir (Turan ve ark., 2017).

Türkiye'nin ekonomisinde hayvancılık, tarım sektörü ve genel ekonomi içerisinde önemli bir yer tutmaktadır. Hayvancılık sektörü, ülkenin milli gelirine ve istihdamına katkı sağlamaktadır. Bunların yanında hayvancılık, et, süt, tekstil, deri, kozmetik, ilaç gibi sanayi kollarına hammadde sağlamakta, yem sanayi, et sanayi gibi dallarda istihdam oluşturulması ve ürünlerin işlenmesi sonucunda ekonomide önemli katma değer oluşturmaktadır (Tapkı ve ark., 2018). 2023 yılına göre tarım, ormancılık ve balıkçılık sektörünün Türkiye GSYİH içindeki payı % 6,2'dir. (SGB 2025)

Bir ülkede tarım sektörünün kalkınması o ülkenin ekonomik gelişmişliğiyle ilgilidir. Dünya ülkeleri dikkate alındığında, gelişmiş ülkelerde tarım, gelişmekte olan ülkelere göre daha fazla desteklenmektedir. Bunun nedeni, stratejik öneme sahip olan tarım sektörünü desteklemede bu ülkelerin ekonomik güce sahip olmalarıdır (Yavuz, 2000). Gelişmiş ülkelerde tarımsal ekonominin lokomotifi olan hayvancılık, iki açıdan son derece önemlidir. Birincisi çok düşük maliyetli istihdam yaratması ve ikincisi ise kalitesiz veya insan beslenmesine uygun olmayan yem kaynaklarının kaliteli insan gıdasına dönüştürmesidir. (Ergün ve Bayram, 2021)

Türkiye'de 2024 yılı hayvancılık destekleme kararnamesi ile hayvansal üretim destekleri temel hayvancılık destekleri ve ürün geliştirme destekleri olmak üzere iki gruba ayrılmıştır: Temel hayvancılık destekleri, büyükbaş hayvancılık, küçükbaş hayvancılık, arıcılık ve ipek böcekçiliği faaliyetlerini, Ürün Geliştirme Destekleri; çiğ süt, besilik erkek sığır (karkas) ve tiftik üretimini kapsamaktadır. Her bir destek için temel destek tutarı belirlenmiştir. 2024 yılı için belirlenen temel destek tutarları, buzağı ve malaklar için 1.000 TL/baş, kuzu ve oğlaklar için 200 TL/baş, arıcılık için üretici/yetiştirici örgütlerine üye üreticilere 100 TL/kovan, üye olmayanlara 80 TL/kovan, ipekböceği için 1.000 TL/kg, besilik erkek sığır (karkas) için 500 TL/baş ve tiftik üretimi için 80 TL/kg'dır. Temel destek birim tutarları ve katsayılar her yıl yeniden belirlenecektir. Yönlendiricilik ve özendiricilik ilkelerini yerine getiren üretici ve yetiştiriciler ilave destekten yararlanacaktır. Aile işletmelerine, kadın/genç yetiştiriciler ile birinci derece tarımsal amaçlı örgütlerin üyelerine/ortaklarına, üretim planlaması kapsamında süt ve besi havzası olarak belirlenen illerde

bulunan yetiştiricilere, hastalıktan ari işletmelere, AB onaylı süt çiftliği sertifikasına sahip işletmelere, suni tohumlama, soy kütüğü, sütünü kendi tankında soğutma, karkas ağırlığı gibi ölçütleri sağlayan yetiştiricilere temel destekle birlikte ilave destek verilecektir. Küçükbaş destekleri ilk defa kuzu ve oğlaklar için ödenecektir. (TRGM 2025)

2. TÜRKİYE'DE HAYVANCILIK FAALİYETLERİ

2.1. BÜYÜKBAŞ HAYVANCILIK

Türkiye büyükbaş hayvan varlığının tamamına yakını sığırdan oluşturmaktadır. Sığırların süt veriminin yüksek olması, laktasyon süresinin uzun olması neticesinde yıl boyunca süt üretimi sağlaması, kaba ve kesif yemleri et ve süte dönüştürme yeteneklerinin yüksek olması, ülkemizin farklı iklim kuşaklarında yetiştirilme imkanının bulunması, genetik ıslah ve üremenin denetimine yönelik uygulamalara çok iyi uyum göstermesi gibi başlıca avantajlar, sığırcılığı büyükbaş hayvancılık içinde önemli kılmaktadır (Ergün ve Bayram, 2021).

Türkiye büyükbaş hayvan varlığında son on yıllık verilere bakıldığında 2014 yılında 14,3 milyon baş olan toplam büyükbaş hayvan varlığı 2024 yılında 16,9 milyon başa ulaşmış olsa da 2020 yılı göz önüne alındığında 1 milyon başın üzerinde bir düşüş göze çarpmaktadır.

Tablo 1. Büyükbaş Hayvan Varlığı (baş) (TÜİK)

Yılı	Sığır - Kültür	Sığır – Kültür Melezi	Sığır - Yerli	Manda	Toplam
2014	6.178.757	6.060.937	1.983.415	122.114	14.345.223
2015	6.385.343	5.733.803	1.874.925	133.766	14.127.837
2019	8.559.855	7.554.625	1.573.659	184.192	17.872.331
2020	8.838.498	7.594.127	1.532.857	192.489	18.157.971
2021	8.824.784	7.641.100	1.384.659	185.574	18.036.117
2022	8.295.825	7.324.866	1.231.265	171.835	17.023.791
2023	8.070.159	7.303.667	1.047.430	161.749	16.583.005
2024	8.213.136	7.669.922	941.150	162.051	16.986.259

2.2. KÜÇÜKBAŞ HAYVANCILIK

Küçükbaş hayvan varlığına ilişkin son on yıllık veriler incelendiğin de 2014 yılında 41,5 milyon baş olan küçükbaş hayvan varlığı 2024 yılında %32'lik bir artış göstermiş olsa da 2021 yılında ulaşılan 57,5 milyona ulaşan toplam hayvan varlığının gerisinde bulunmaktadır. Kıl keçisi ve tiftik keçisi varlıklarında son on yılda belirgin bir artış meydana gelmemiş iken yerli koyun ve merinos ırkı koyun varlığında yaşanan artış dikkat çekmektedir.

Tablo 2. Küçükbaş Hayvan Varlığı (baş) (TÜİK)

Yılı	Koyun - Yerli	Koyun - Merinos	Keçi - Kıl	Keçi - Tiftik	Toplam
2014	29.033.981	2.106.263	10.167.125	177.811	41.485.180
2015	29.302.358	2.205.576	10.210.338	205.828	41.924.100
2019	34.199.467	3.076.583	10.964.374	241.055	48.481.479
2020	38.579.748	3.547.033	11.698.825	287.020	54.112.626
2021	41.182.899	3.994.791	12.051.957	289.557	57.519.204
2022	40.728.954	3.958.934	11.320.208	257.654	56.265.750
2023	38.208.635	3.851.835	10.092.756	210.184	52.363.410
2024	39.871.852	4.208.732	10.619.841	202.243	54.902.668

2.3. ÇİĞ SÜT ÜRETİMİ

TÜİK tarafından revize edilerek son beş yıllık verilerin bulunduğu çiğ süt üretimi verileri incelendiğinde 2020 yılında inek sütünün toplam çiğ süt üretimindeki payı %92,5 iken 2024 yılında bu oran %93,5 oranına yükselmiştir. Toplam üretim 2020 yılında 23,5 milyon ton iken 2024 yılında 22,5 milyon tona gerilemiştir. Bu gerileme hızı manda, koyun ve keçi sütünde daha fazla gerçekleşmiştir.

Tablo 3. Çiğ Süt Üretimi (ton) (TÜİK)

Yıl	İnek	Manda	Koyun	Keçi	Toplam
2020	21.749.342	63.767	1.101.065	589.617	23.503.790
2021	21.370.116	63.643	1.143.762	622.785	23.200.306
2022	19.912.135	43.589	1.067.342	540.426	21.563.492
2023	19.961.908	43.025	933.576	543.058	21.481.567
2024	21.040.442	58.122	906.945	482.247	22.487.757

2.4. KIRMIZI ET ÜRETİMİ

Türkiye'de kırmızı et üretimi 2024 yılında on yıl öncesine göre %87,5 oranında artış göstermiştir. 2020 yılı sonrasında Kasaplık Güç Oranı (KGO) yöntemi kullanılarak ve2020 yılı öncesi veriler revize edilerek hesaplanan verilerdeki artış oranı dikkat çekicidir. Aynı zamanda 2014 yılında %72 oranında olan toplam üretimde sığır eti oranı 2024 yılında %70 sevilerinde gerçekleşmiştir. Sırasıyla Manda, koyun ve keçi etinin oranları %0,65, %24,2 ve %4,73 olmuştur.

Tablo 4. Kırmızı Et Üretimi (ton) (TÜİK)

Yılı	Sığır	Manda	Koyun	Keçi	Toplam
2014(r)	815.674	5.004	238.670	63.711	1.123.059
2015(r)	862.098	5.300	249.863	69.757	1.187.018
2019(r)	1.330.169	7.150	316.170	87.126	1.740.616
2020	1.341.446	8.424	345.639	90.443	1.785.952
2021	1.460.719	10.831	385.933	94.555	1.952.038
2022	1.572.747	13.586	489.354	115.938	2.191.625
2023	1.670.606	15.386	569.066	128.989	2.384.047
2024	1.483.042	13.781	509.539	99.532	2.105.895

(r) Revize edilmiştir. Kırmızı et üretim istatistiklerinde 2020 yılında metodoloji değişikliğine gidilmiş ve "Kasaplık Güç Oranı (KGO) " yöntemi kullanılmıştır. 2001-2019 dönemi kırmızı et üretim istatistikleri KGO yöntemine göre revize edilmiştir.

2.5. KANATLI HAYVAN SEKTÖRÜ

Tavuk ve hindi üretimine bakıldığında son on yılda %32'lik artış gerçekleştirerek 2,56 milyon ton olmuş, sektörün yıllar itibari ile orantılı bir büyüme gerçekleştirdiği görülmektedir. Hindi eti üretimi daha dalgalı bir üretim izlenirken tavuk eti üretimi belirli oranlarda yıllar itibari ile artış göstermiştir. Toplam üretimin %98'lik kısmı tavuk üretiminden gelmektedir. Yumurta üretimi ise son on yılda %23,4 artış gerçekleştirerek 21,5 milyar adet ulaşmıştır. Yumurta üretimi de tavuk etine benzer şekilde dalgalı bir üretim şekli göstermeden yıllar itibari ile düzenli olarak artmıştır. Sektörün iç tüketim ve ihracat odaklı gerçekleştirdiği üretimi son on yılda düzenli büyüme ile gerçekleştirdiği görülmektedir.

Tablo 5. Tavuk ve Hindi Eti Üretimi (ton) (TÜİK)

Yılı	Tavuk Eti	Hindi Eti	Toplam Et
2014	1.894.669	48.662	1.943.331
2015	1.909.276	52.722	1.961.999
2019	2.138.451	59.640	2.198.090
2020	2.136.263	58.212	2.194.475
2021	2.245.770	51.301	2.297.071
2022	2.417.995	53.646	2.471.641
2023	2.328.791	47.575	2.376.366
2024	2.512.131	52.355	2.564.486

Tablo 6. Tavuk Yumurtası (bin adet) (TÜİK)

Yılı	Tavuk Yumurtası
2014	17.145.389
2015	16.727.510
2019	19.898.126
2020	19.788.063
2021	19.297.591
2022	19.808.539
2023	20.637.732
2024	21.155.089

3. 2024-2026 YILLARI HAYVANCILIK DESTEKLEME MODELİ

Türkiye'de hayvancılık sektörü, tarımsal üretimin sürdürülebilirliği ve kırsal kalkınmanın desteklenmesi açısından kritik bir role sahiptir. Bu doğrultuda Tarım ve Orman Bakanlığı, gıda arz güvenliğini sağlamak, verimliliği artırmak ve sürdürülebilir bir üretim modeli oluşturmak amacıyla çeşitli hayvancılık destekleme programları yürütmektedir. En güncel hayvancılık destekleme modeli, 2024-2026 dönemini kapsamakta olup, 26 Temmuz 2024 tarihli Cumhurbaşkanlığı Kararı ile yürürlüğe girmiştir.

Hayvansal üretimde yeni destekleme programı temel hayvancılık ve ürün geliştirme destekleri olmak üzere iki gruba ayrılıyor.

Temel hayvancılık destekleri; büyükbaş hayvancılık, küçükbaş hayvancılık, arıcılık ve ipek böceği faaliyetlerinin desteklenmesinden oluşuyor. Her bir destek için temel destek tutarı belirlendi. Aile işletmeleri, genç ve kadınlar, birinci derece örgüt üyesi ile planlama bölgeleri gibi yönlendirici kriterleri sağlayan yetiştiricilere temel destek tutarına ilave destek verilecek. Ayrıca suni tohumlama, soy kütüğü, yerli sperma, ari işletme, sürü yöneticisi (çoban) gibi verimlilik kriterlerine ilave destek sağlanacak.

Ürün geliştirme destekleri başlığı da; çiğ süt, besilik erkek sığır (karkas), tiftik üretimi desteklerini kapsıyor. Her bir destek için temel destek tutarı belirlendi. Aile işletmeleri, genç ve kadınlar, birinci derece örgüt üyesi ile planlama bölgeleri gibi yönlendirici kriterleri sağlayan üreticilere temel destek tutarına ilave destek verilecek. Ayrıca ari işletme, kendi tankında soğutma, örgüt üzerinden pazarlama, karkas ağırlığı, kaliteli tiftik ve sözleşmeli üretim gibi verimlilik kriterlerine ilave destek verilecek. (TOB 2025)

Tablo 7. 2025 Yılı Temel Hayvancılık Desteklemeleri (Resmi Gazete 26.07.2024-14.09.2025)

Kategori	**Destekleme Türü**		**Katsayı**	**2025 Yılı Destek Tutarı (TL/Baş)**
	Buzağı-Malak Temel Desteği	Temel Destek	1	1.400/2.800
	Aile İşletmesi		1	1.400

Büyükbaş Hayvancılık Destekleri (1-500 Baş)	Genç veya Kadın Yetiştirici	Yönlendirici Kriterler	0,7	980
	Planlı Üretim		0,5	700
	Birinci Derece Örgüt Desteği		0,2	280
	Suni Tohumlama/Embriyo T.	Verimlilik Kriterleri	0,8	1.120
	Yerli Sperma		0,5	700
	Soy Kütüğü (A ve B İşletmeleri) ve Genomik		1,5	2.100
	Soy Kütüğü (C İşletmeleri)		0,8	1.120
	Ari İşletme		4	5.600
	Onaylı Süt İşletmesi		0,6	840
Küçükbaş Hayvancılık Destekleri	Kuzu ve Oğlak Temel Desteği	Temel Destek	1	300
	Aile İşletmesi (Dişi Kuzu/Dişi Erkek Oğlak)	Yönlendirici Kriterler	1	300
	Genç veya Kadın Yetiştirici (Dişi Kuzu/Dişi Erkek Oğlak)		0,7	210
	Birinci Derece Örgüt Desteği		0,2	60
	Sürü Yöneticisi (150 baş)	Verimlilik Kriterleri	1,8	540
Arılı Kovan Desteği	Temel Destek (Kovan Başı)	Temel Destek	1	100/140 TL/Adet
	Genç veya Kadın Yetiştirici	Yönlendirici Kriterler	0,4	40/56TL/Adet
	Planlı Üretim		0,3	30/42TL/Adet
	Birinci Derece Örgüt Desteği		0,2	28 TL/Adet
İpek Böceği Desteği	Temel Destek (kg başı)	Temel Destek	1	1.100
	Genç veya Kadın Yetiştirici	Yönlendirici Kriterler	0,4	440

Tablo 8. Ürün Geliştirme Destekleri

Kategori	**Destekleme Türü**		**Katsayı**	**Destek Tutarı (TL/Baş/Kg)**
Çiğ Süt Desteği	Temel Çiğ Süt Desteği	Temel Destek	1	Bakanlıkça Belirlenir
	Aile İşletmesi		0.3	

	Genç veya Kadın Yetiştirici	Yönlendirici Kriterler	0.3	
	Planlı Üretim		0.4	
	Kriter (Kendi Tankında Soğutma)	Verimlilik Kriterleri	2	
	Kriter (Birinci Derece Örgüt Üzerinden Pazarlama)		2	
	Kriter (Diğer Örgütler Üzerinden Pazarlama)		1,5	
	Kriter (Hastalıklardan Ari)		3	
	Manda/Koyun Keçi Sütü		0,8	
Besilik Sığır (Karkas) Desteği	Temel Destek (Manda ve Yerli Irklar En Az 200 Kg Karkas)	Temel Destek	1	500
	Aile İşletmesi	Yönlendirici Kriterler	4	2.000
	Genç veya Kadın Yetiştirici		0.3	150
	Birinci Derece Örgüt Desteği		0.4	100
	Sütçü ve Melezleri En Az 270 Kg Karkas	Verimlilik Kriterleri	0,6	300
	Kombine ve Melezler En Az 300 Kg Karkas		0,8	400
	Etçi ve Melezler En Az 300 Kg Karkas		1	500
Tiftik Desteği	Temel Tiftik Desteği	Temel Destek	1	160
	Genç veya Kadın Yetiştirici	Yönlendirici Kriterler	0,3	64
	Anamal Tiftiği	Verimlilik Kriterleri	0,7	112
	Oğlak Tiftiği		0,9	144
	Birinci Derece Örgüt Sözleşmeli Üretim		1	160
	Diğer Örgüt Sözleşmeli Üretim		0.9	144

4. SONUÇ

Son on yıllık mevcut veriler incelendiğinde 2014 yılında 14,3 milyon baş olan büyükbaş hayvan varlığının 2024 yılında 16,9 milyon başa yükseldiği, ancak 2020 yılına göre 1 milyon baş düşüş gerçekleştiği görülmektedir. Benzer şekilde küçükbaş hayvan varlığı 2021 yılında yakaladığı zirveyi koruyamamıştır. Kırmızı et üretimi son on yılda % 87,5 artmış, çiğ süt üretiminin 2020 yılından bu yana artış göstermemiştir. Bu veriler hayvan varlığının hayvansal üretimde tek başına yeterli olmayacağını verimliliğin artmasının hayvansal üretimde kritik rol oynadığını ortaya koymaktadır.

Tarım ve Orman Bakanlığı tarafından 2024-2026 yıllarını kapsayacak şekilde uygulamaya konan destekleme sisteminin performansa dayalı bir yaklaşım sergilemesi önemlidir. Temel desteklemelerin yanında yönlendirici kriterler (aile işletmeleri, genç/kadın yetiştiriciler vb.) verimlilik kriterleri (suni tohumlama, soy kütüğü, karkas ağırlığı vb.) hayvansal üretimde performansa dayalı bir yaklaşım getirildiği görülmektedir.

Sonuç olarak, yeni destekleme modelinin hayvancılık sektörünün geleceği açısından taşıdığı en önemli unsur, birim hayvandan daha fazla ve kaliteli ürün elde edilmesini teşvik etmesidir. Model, sadece sayısal artışları değil, aynı zamanda et, süt ve buzağı gibi hayvansal ürünlerin kalitesini ve miktarını yükseltmeyi hedeflemektedir. Bu yaklaşım, gıda arz güvenliğini sağlamanın yanı sıra, üretici gelirlerini artırarak ve tarıma dayalı sanayilere daha kaliteli hammadde sağlayarak ülkenin ekonomik kalkınmasına önemli katkılar sunacaktır. Dolayısıyla, bu modelin başarılı bir şekilde uygulanması, Türkiye hayvancılığının daha sürdürülebilir, rekabetçi ve planlı bir yapıya kavuşmasında kritik bir dönüm noktası olabilir.

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EFFECTS OF MELOXICAM ON SPERM PARAMETERS IN RATS - A PRELIMINARY STUDY

Assoc. Prof. Dr. Caner ÖZTÜRK*

Aksaray University Faculty of Veterinary Medicine, Department of Reproduction and Artificial Insemination, Aksaray

Email: canerozturkvt@gmail.com

ORCID: 0000-0003-0566-0684

Assoc. Prof. Dr. Neşe Hayat AKSOY

Aksaray University Faculty of Veterinary Medicine, Department of Biochemistry,Aksaray

Email: nhaksoy@gmail.com

ORCID: 0000-0001-9039-555X

Lect. Dr. Erkan ÖZKAN

Aksaray University Faculty of Veterinary Medicine, Department of Parasitology, Aksaray

Email: erkanozkan87@gmail.com

ORCID: 0000-0002-5251-2302

Res. Asst. Ramazan ARSLAN

Aksaray University Faculty of Veterinary Medicine, Department of Reproduction and Artificial Insemination, Aksaray

Email: arslan03138@gmail.com

ORCID: 0009-0000-6275-5861

ABSTRACT

The aim of this study is to investigate the effects of meloxicam, a non-steroidal anti inflammatory drug, on rat sperm cells. The findings will contribute to a better understanding of the drug's potential side effects and assist in evaluating the possible risks associated with its clinical use. In this preliminary study, the effects of meloxicam administration on spermatological parameters and oxidative stress markers in rats were investigated. A total of six male Wistar rats, weighing 220 ± 20 g, were used. The animals were housed under standard conditions with a 12/12 h light/dark cycle at a temperature of 23 ± 2 °C. The rats were divided into two groups: Group 1 (n = 3), treated with meloxicam (2 mg/kg/day, intraperitoneally, for 5 days), and Group 2 (n = 3), the control group (intraperitoneal physiological saline for 5 days). Epididymal spermatozoa examinations were performed using a phase-contrast microscope with a 40x objective, and sperm concentration was determined by the hemocytometric method, while total antioxidant status (TAS) and total oxidant status (TOS) levels were measured in sperm cells. In the control group, TAS was 5931.00 ± 1193.86 µmol/L, whereas in the meloxicam group it was 5121.96 ± 1886.18 µmol/L ($p > 0.05$). TOS levels were 202.47 ± 117.58 µmol/L in the control group and showed a significant increase in the meloxicam group, reaching 471.18 ± 104.37 µmol/L ($p < 0.05$). Spermatological analyses revealed

motility values of 75.00 ± 10.00% in the control group and 61.67±27.54% in the meloxicam group. Sperm concentrations were determined as 41.67±12.58 and 38.33±10.41 $\times 10^6$/ml, respectively. No statistically significant differences were observed in these parameters ($p>0.05$). Meloxicam administration induced an increase in oxidative stress levels in rats, while decreases in sperm motility, concentration, and TAS values were observed, though these changes were not statistically significant. The significant elevation in TOS levels suggests that meloxicam may negatively influence the oxidative balance.

Keywords: Meloxicam, Oxidative stress, Sperm motility, Rat model, TOS

MELOKSİKAMIN SIÇANLARDA SPERMA PARAMETRELERİ ÜZERİNE ETKİLERİ - ÖN ÇALIŞMA

ÖZET

Bu çalışmanın amacı, non-steroidal anti-inflamatuar bir ilaç olan meloksikamın sıçan sperma hücreleri üzerindeki etkilerini araştırmaktır. Elde edilen bulgular, ilacın potansiyel yan etkilerinin daha iyi anlaşılmasına ve klinik kullanımıyla ilişkili olası risklerin değerlendirilmesine katkı sağlayacaktır. Bu ön çalışmada, meloksikam uygulamasının sıçan spermatolojik parametreleri ve oksidatif stres göstergeleri üzerine etkileri araştırılmıştır. Çalışmada vücut ağırlığı 220 ± 20 g olan 6 erkek Wistar sıçanı kullanılmıştır. Hayvanlar 12/12 saatlik aydınlık/karanlık döngüsü ve 23 ± 2 °C sıcaklıktaki standart koşullarda barındırılmıştır. Denekler iki gruba ayrılmıştır: Grup 1 (n= 3) meloksikam (2 mg/kg/gün, intraperitoneal, 5 gün) ve Grup 2 (n= 3) kontrol (serum fizyolojik, intraperitoneal, 5 gün). Epididimal spermatozoa değerlendirmeleri faz kontrast mikroskopta 40x objektif kullanılarak gerçekleştirilmiş, sperm yoğunluğu ise hemositometrik yöntemle belirlenmiştir; sperm hücrelerinde total antioksidan seviye (TAS) ve total oksidan seviye (TOS) ölçülmüştür. Kontrol grubunda TAS 5931,00 ± 1193,86 µmol/L iken, meloksikam grubunda 5121,96 ± 1886,18 µmol/L olarak bulundu ($p > 0,05$). TOS değerleri kontrol grubunda 202.47 ± 117.58 µmol/L, meloksikam grubunda ise anlamlı düzeyde artış göstererek 471,18 ± 104,37 µmol/L'ye ulaştı ($p<0.05$). Spermatolojik analizlerde motilite kontrol grubunda %75,00 ± 10,00, meloksikam grubunda %61,67 ± 27,54; sperm konsantrasyonu ise sırasıyla 41,67 ± 12,58 ve 38,33 ± 10.41 x 10^6/ml olarak belirlendi. Bu parametrelerde istatistiksel fark saptanmadı ($p > 0,05$). Meloksikam uygulaması, sıçanlarda oksidatif stres düzeylerinde artışa yol açarken, sperm motilitesi, yoğunluğu ve TAS değerleri üzerinde istatistiksel olarak anlamlı olmayan ancak spermatolojik değerler açısından düşüşler gözlenmiştir. Bulgularda TOS seviyesindeki anlamlı artış, meloksikamın oksidatif dengeyi olumsuz etkileyebileceğini göstermektedir.

Anahtar Kelimeler: Meloksikam, Oksidatif stress, Sperm motilitesi, Sıçan modeli, TOS

1. INTRODUCTION

Meloxicam, an oxicam derivative non-steroidal anti-inflammatory drug (NSAID), is widely prescribed in both human and veterinary medicine due to its preferential inhibition of cyclooxygenase-2 (COX-2), providing effective analgesic and anti-inflammatory effects with reduced gastrointestinal toxicity compared to traditional NSAIDs (Grosser et al., 2017). Because of its extensive clinical use, concerns regarding its safety profile extend beyond gastrointestinal or renal complications, encompassing potential impacts on the reproductive system. Male fertility, in particular, is vulnerable to pharmaceutical agents that may disrupt hormonal regulation, spermatogenesis, or sperm function (Skakkebaek et al., 2016).

Accumulating evidence indicates that NSAIDs can interfere with male reproductive health. Several analgesics, including ibuprofen and acetaminophen, have been associated with altered reproductive hormones and impaired semen quality in animal models and clinical studies (Kristensen et al., 2018; Mazaud-Guittot et al., 2013). Prostaglandins, which are suppressed by COX inhibition, play a role in sperm motility and semen liquefaction, suggesting that NSAID-mediated suppression could directly impair reproductive physiology (Ricciotti & FitzGerald, 2011). Reports of reduced sperm quality and testicular damage after NSAID exposure support the notion of a potential class effect on fertility (Sharma & Radhakrishnan, 2021).

Specific to meloxicam, multiple animal studies have shown detrimental reproductive outcomes. Uzun et al. (2015) demonstrated that chronic meloxicam exposure in rats reduced sperm count and motility, and caused histopathological degeneration of seminiferous tubules. Similarly, Haroun et al. (2020) observed that prolonged high-dose meloxicam administration induced testicular toxicity, with oxidative stress being a central mechanism, while antioxidants such as curcumin or vitamin C ameliorated the damage. Bakry et al. (2019) reported that even short-term meloxicam exposure (seven days) decreased reproductive organ weights and altered sperm characteristics in rats. More recently, Rodrigues et al. (2024) found that meloxicam reduced serum testosterone and epididymal sperm counts, while impairing epididymal duct contractions necessary for sperm transport. Together, these studies underscore that meloxicam, despite its therapeutic value, may compromise male reproductive function.

A recurring mechanism implicated in NSAID-related reproductive toxicity is oxidative stress. Spermatozoa are particularly susceptible due to their high content of polyunsaturated fatty acids and limited cytoplasmic antioxidant defenses (Agarwal et al., 2014). Excessive reactive oxygen species (ROS) can damage sperm DNA, proteins, and membranes, reducing motility and fertilizing capacity (Aitken, 2017). Several studies confirm that NSAIDs, including meloxicam, can disrupt oxidative balance in the testes and sperm, leading to functional impairment (Haroun et al., 2020; Atlı et al., 2021). Therefore, investigating oxidative stress markers in sperm alongside conventional spermatological parameters provides critical insight into the drug's reproductive effects.

The present study was designed to evaluate the short-term effects of meloxicam on sperm quality and oxidative stress status in male rats. By measuring sperm motility, concentration, total antioxidant status (TAS), and total oxidant status (TOS), we aimed to clarify whether a brief course of meloxicam induces oxidative imbalance and compromises sperm function. Findings from this work may help delineate early reproductive side effects of meloxicam, contributing to risk–benefit assessments for its long-term clinical use.

2. MATERIALS and METHODS

EXPERIMENTAL ANIMALS AND HOUSING

This study was performed on six adult male Wistar rats (*Rattus norvegicus*), aged 8–10 weeks and weighing 220 ± 20 g. Wistar rats are widely used in toxicology and reproductive biology due to their well-characterized physiology and reproducibility in experimental outcomes (Festing & Altman, 2002). Animals were obtained from an accredited laboratory animal facility and acclimatized for one week under controlled environmental conditions: temperature 23 ± 2 °C, relative humidity ~50%, and a 12 h light/dark cycle. Standard laboratory chow and water were provided *ad libitum*.

EXPERIMENTAL DESIGN AND DRUG ADMINISTRATION

The rats were randomly divided into two groups (n = 3 per group):

- **Meloxicam-treated group:** Rats received meloxicam (2 mg/kg/day) intraperitoneally (i.p.) for five consecutive days.
- **Control group:** Rats received an equivalent volume of physiological saline (0.9% NaCl, i.p.) once daily for five days.

SAMPLE COLLECTION

On day 6, 24 h after the last injection, rats were anesthetized with ketamine/xylazine (90/10 mg/kg, i.p.) and sacrificed by cervical dislocation, a method consistent with ethical euthanasia protocols (Close et al., 1996). The cauda epididymides were immediately excised for sperm analysis. Epididymal sperm evaluation is a standard method to assess fertility potential in rodents, reflecting both spermatogenesis and epididymal maturation (Yan et al., 2008).

SPERM ANALYSIS

SPERM MOTILITY

Sperm suspensions were prepared by mincing the cauda epididymis in 1 ml of pre-warmed phosphate-buffered saline (PBS) at 37 °C. A drop of the suspension was placed on a glass slide, covered with a coverslip, and examined under a phase-contrast microscope at 400× magnification. At least 100 spermatozoa per sample were evaluated, and motility was expressed as the percentage of motile spermatozoa. Phase-contrast microscopy remains a reliable method for motility assessment in small experimental groups.

SPERM CONCENTRATION

Sperm concentration was determined using a Neubauer hemocytometer. Samples were diluted 1:20 in PBS containing 1% formalin to immobilize sperm for accurate counting. Counts were performed under 400× magnification, and results expressed as $\times 10^6$ sperm/ml (Belsey et al., 1980). Each measurement was performed in duplicate to minimize error.

OXIDATIVE STRESS ANALYSIS

PREPARATION OF SPERM HOMOGENATES

Sperm suspensions were centrifuged at 800×g for 10 min to pellet the spermatozoa. Pellets were washed with cold PBS, resuspended in buffer, and sonicated to release intracellular contents. Supernatants were collected after centrifugation at 10,000×g for 5 min at 4 °C.

TOTAL ANTIOXIDANT STATUS (TAS)

TAS was measured using a commercial kit based on the Erel method, which evaluates the overall capacity of antioxidants in biological samples to inhibit oxidation reactions (Erel, 2004). Results were expressed in µmol Trolox equivalents/L.

TOTAL OXIDANT STATUS (TOS)

TOS was quantified using the complementary Erel assay, where oxidants in the sample oxidize ferrous ion to ferric ion, forming a colored complex with xylenol orange (Erel, 2005). Results were expressed in µmol H_2O_2 equivalents/L.

OXIDATIVE STRESS INDEX (OSI)

OSI was calculated as the ratio of TOS (µmol H_2O_2/L) to TAS (µmol Trolox equiv./L), providing an integrated measure of oxidative balance (Agarwal et al., 2014).

STATISTICAL ANALYSIS

All statistical evaluations were carried out using the SPSS software package (IBM Corp., Armonk, NY, USA; version 27). Results are presented as mean ± standard deviation (SD). The normality of data distribution was assessed by the Shapiro–Wilk test, while the equality of variances was examined using Levene's test. Given the limited sample size and the fact that some variables did not meet parametric assumptions, comparisons between groups were performed using the non-parametric Mann–Whitney U test. A p-value of <0.05 was considered statistically significant.

3. RESULTS

SPERM MOTILITY AND SPERM CONCENTRATION

Meloxicam administration resulted in a decline in sperm motility compared to controls. The mean motility in the control group was 75.00 ± 10.00%, whereas in the meloxicam-treated group it decreased to 61.67 ± 27.54%. Although the mean value suggested an ~18% reduction, statistical analysis showed that this difference was not significant ($p > 0.05$). The variability was greater in the meloxicam group, as one rat exhibited a marked reduction in motility while others showed values closer to the control range.

The sperm concentration also showed a mild decrease in the meloxicam-treated rats. The mean sperm concentration in the control group was 41.67 ± 12.58 $\times 10^6$/ml, compared to 38.33 ± 10.41 $\times 10^6$/ml in the meloxicam group. This represented a modest 8% reduction; however, the difference did not reach statistical significance ($p > 0.05$). (Tablo 1)

TOTAL ANTIOXIDANT STATUS (TAS), TOTAL OXIDANT STATUS (TOS) AND OXIDATIVE STRESS INDEX (OSI)

TAS levels, which reflect the overall antioxidant defense, were lower in meloxicam-treated rats compared to controls. The control group exhibited an average TAS of 5931.00 ± 1193.86 µmol/L, while the meloxicam group showed 5121.96 ± 1886.18 µmol/L. This represented a 13.6% decrease, though statistical analysis indicated no significant difference ($p > 0.05$). The variability within the meloxicam group was high, with one rat showing a pronounced decline in TAS.

A significant elevation in oxidant levels was observed in meloxicam-treated rats. Control animals demonstrated a mean TOS of 202.47 ± 117.58 µmol/L, while meloxicam treatment increased this value to 471.18 ± 104.37 µmol/L. Statistical analysis confirmed that this difference was significant ($p < 0.05$).

When TOS and TAS were combined into the OSI, a clear upward shift in oxidative stress was evident in the meloxicam group compared to controls. Although not formally tested for significance due to the small sample size, OSI values in treated rats were approximately twice those of controls. This reinforces the finding that meloxicam administration disrupted the oxidative balance in sperm cells, favoring a pro-oxidant state (Agarwal et al., 2014). (Tablo 1)

Tablo 1. Comparison of spermatological and oxidative stress parameters between groups (Ort ± SD)

Groups	TAS (µmol/L)	TOS (µmol/L)	Motility (%)	Concentration (10^6/ml)
Control	5931.00 ± 1193.86	202.47 ± 117.58[b]	75.00 ± 10.00	41.67 ± 12.58
Meloxicam	5121.96 ± 1886.18	471.18 ± 104.37[a]	61.67 ± 27.54	38.33 ± 10.41
p	-	*	-	-

4. DISCUSSION

The present study provides preliminary evidence that short-term meloxicam administration in rats induces measurable oxidative stress in sperm cells, as indicated by a significant rise in TOS, alongside non-significant reductions in sperm motility, concentration, and TAS. These findings highlight oxidative imbalance as an early event in meloxicam-induced reproductive toxicity.

The most robust outcome was the doubling of TOS values in the meloxicam-treated group compared to controls. Elevated oxidant levels reflect an increased burden of reactive oxygen species (ROS), which are known to impair sperm membrane integrity, mitochondrial function, and DNA stability (Agarwal et al., 2014; Aitken, 2017). Given the high content of polyunsaturated fatty acids in sperm membranes, excessive ROS rapidly lead to lipid peroxidation, compromising motility and fertilizing capacity (Aitken, 2017). Our observation of significantly higher TOS is consistent with the work of Haroun et al. (2020), who reported that prolonged meloxicam exposure in rats reduced antioxidant enzyme activity and increased testicular oxidative damage. The fact that antioxidant supplementation with curcumin or vitamin C ameliorated these effects further supports oxidative stress as a central mechanism.

Although TAS levels were not significantly different between groups, the downward trend in meloxicam-treated rats suggests that antioxidant reserves were partially consumed in response to increased oxidative load. Variability among individuals may have masked significance, but this aligns with earlier reports where NSAID administration reduced enzymatic antioxidants such as superoxide dismutase (SOD) and glutathione peroxidase (GPx) (Atlı et al., 2021). With a larger sample size or longer treatment duration, a statistically significant reduction in TAS would likely emerge, reinforcing the concept of depleted antioxidant defenses during NSAID exposure.

In terms of sperm quality, both motility and concentration showed non-significant declines after meloxicam treatment. While modest, these changes suggest early functional impairment. Previous studies using longer exposure durations have demonstrated pronounced effects. Uzun et al. (2015) reported significant reductions in sperm count and motility, along with testicular histopathology, after 35 days of meloxicam exposure. Similarly, Bakry et al. (2019) found that even seven days of treatment altered sperm motility and morphology. Our results fall in line with these findings,

suggesting that five days may be insufficient to elicit significant spermatogenic disruption, but early oxidative damage is likely occurring.

Another factor to consider is meloxicam's potential endocrine effects. Rodrigues et al. (2024) showed that meloxicam reduced serum testosterone levels and impaired epididymal function in rats, leading to decreased sperm counts in specific epididymal regions and delayed sperm transit. Testosterone plays a critical role in spermatogenesis and sperm maturation; therefore, meloxicam-induced suppression may underlie longer-term reproductive toxicity. Although hormonal assays were not performed in our study, the possibility of endocrine disruption should be explored in future work.

The epididymis may also represent a site of meloxicam toxicity. Prostaglandins, inhibited by COX blockade, contribute to epididymal duct contractions necessary for sperm transport (Ricciotti & FitzGerald, 2011). Impaired contractility, as observed by Rodrigues et al. (2024), could lead to altered sperm maturation and reduced motility. Thus, meloxicam may exert reproductive effects not only via oxidative stress but also through endocrine and epididymal pathways.

Taken together, our findings reinforce the concept that meloxicam, despite being a COX-2 preferential NSAID designed for improved safety, shares the potential class effect of NSAID-related reproductive toxicity. The significant increase in TOS highlights oxidative stress as an early biomarker of damage. If sustained, this oxidative imbalance may progress to functional deficits in sperm quality and testicular histopathology, as demonstrated in chronic exposure studies (Uzun et al., 2015; Haroun et al., 2020). Clinically, this raises concerns for men undergoing long-term meloxicam therapy, particularly those of reproductive age.

Limitations of the present study include the small sample size, short exposure period, and lack of histopathological or hormonal assessments. These constraints limit the strength of statistical conclusions and mechanistic insights. Nevertheless, the significant oxidative response observed underscores the sensitivity of sperm cells to even brief meloxicam exposure. Future research should include larger cohorts, extended treatment durations covering a full spermatogenic cycle, and comprehensive analyses including testicular histology, antioxidant enzyme assays, and reproductive hormone profiling. Fertility outcomes, such as mating trials, would also provide translational relevance.

From a translational perspective, if oxidative stress is confirmed as the main mediator of meloxicam-induced reproductive toxicity, antioxidant supplementation may offer a protective strategy. Haroun et al. (2020) demonstrated that curcumin and vitamin C mitigated testicular damage, and similar interventions could be explored clinically. Such strategies could help preserve fertility in patients requiring chronic NSAID therapy, although caution is warranted before extrapolating animal findings directly to humans.

5. CONCLUSION

In this preliminary study, short-term meloxicam administration at a therapeutic dose (2 mg/kg, i.p., for five days) significantly increased oxidative stress in sperm cells, as evidenced by elevated TOS levels, while producing modest, non-significant declines in sperm motility, concentration, and TAS. These findings suggest that oxidative imbalance may represent an early biomarker of meloxicam-induced reproductive toxicity. Although the duration of treatment was insufficient to cause marked alterations in spermatological parameters, the consistent pro-oxidant shift implies that longer exposure or higher doses may exacerbate reproductive impairment, as demonstrated in previous chronic studies (Uzun et al., 2015; Haroun et al., 2020).

The results also underscore that NSAIDs, including COX-2 preferential drugs such as meloxicam, are not devoid of systemic risks. Male fertility appears to be a sensitive target, likely affected through multiple pathways including oxidative stress, endocrine disruption, and altered epididymal function (Rodrigues et al., 2024; Bakry et al., 2019). Therefore, awareness of potential reproductive side effects should inform risk–benefit evaluations, particularly for men of reproductive age who require prolonged meloxicam therapy.

Future research should address the limitations of this study by employing larger sample sizes, extended treatment durations spanning a full spermatogenic cycle, and additional endpoints such as testicular histopathology, hormone assays, and fertility trials. Moreover, the possibility of mitigating meloxicam-induced reproductive toxicity through antioxidant supplementation warrants exploration, as protective effects of agents like curcumin and vitamin C have already been demonstrated (Haroun et al., 2020).

In conclusion, while meloxicam remains an effective and widely used anti-inflammatory drug, its potential to disrupt oxidative balance in sperm highlights the need for careful monitoring of reproductive health in long-term users. These findings contribute to the growing body of evidence on NSAID-related reproductive risks and emphasize the importance of integrating reproductive safety into pharmacological evaluations.

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TARIMSAL ÜRETİMİN SÜRDÜRÜLEBİLİRLİĞİ ODAKLI YEŞİL İŞLETMECİLİK UYGULAMALARI: TÜRKİYE'DEKİ İKİNCİ DALGA KAHVE ZİNCİRLERİNİN KARŞILAŞTIRMALI BİR ANALİZİ

Doç. Dr. Koray GENÇ

Ordu Üniversitesi, Sosyal Bilimler Meslek Yüksekokulu, Otel, Lokanta ve İkram Hizmetleri Bölümü, Ordu

Email: koray.genc@yahoo.com

ORCID: 0000-0001-5477-4683

ÖZET

Artan dünya nüfusuna ve şehirleşmeye paralel bir şekilde tarımsal sürdürülebilirliğin önemi her geçen gün yükselmektedir. Bu konuda sorumluluk paylaşımı kilit bir konudur. Üretici ve tüketici pozisyonundaki insanlara, işletmelere, devletlere, sivil toplum örgütlerine, kısacası her kesime görevler düşmektedir. Yiyecek içecek işletmeleri tarımsal üretimin sürdürülebilirliği üzerine hem etkileyici hem de etkilenen pozisyonda yer almaktadır. Bu bağlamda bu araştırma ile ikinci dalga kahve mekânlarının üretim ve arz süreçlerinde gerçekleştirdikleri tarımsal sürdürülebilirlik odaklı yeşil işletmecilik uygulamalarının ortaya koyulması amaçlanmıştır. Araştırmanın bir diğer amacı ise yerli ve yabancı menşeili işletmelerin konu bağlamında kıyaslanmasıdır. Söz konusu işletmelerin ana ürünü olan kahvenin az gelişmiş ve gelişmekte olan ülkelerden sağlanıyor olması tarımsal sürdürülebilirlik bağlamında araştırmayı ayrıca önemli kılmaktadır. Araştırma amacına istinaden Türkiye'de şube sayısı en yüksek yirmi kahve zincirinin faaliyetleri internet siteleri üzerinden incelenmiştir. İnceleme neticesinde eğitim (bilinçlendirme), üretim teşviki, sorumlu tedarik, geri dönüşüm, iklim değişikliği tedbiri, müşteriyi sürece dâhil etme, üreticiyi sürece dâhil etme başlıklarında yedi yeşil uygulama belirlenmiş ve işletmelerin yeşil puanları oluşturulmuştur. Elde edilen veriler doğrultusunda yeşil uygulamalar arasında en sık uygulananın sekiz işletme ile geri dönüşüm olduğu, tarımsal üretim teşvikinin ise sadece bir işletme tarafından uygulandığı sonucuna ulaşılmıştır. Ayrıca yabancı zincir işletmelerin yerli zincir işletmelere kıyasla daha sorumlu bir tavır ortaya koyduğunu ifade etmek mümkündür. Öyle ki araştırmaya dâhil edilen altı yabancı işletmenin yeşil puanı yirmi bir iken altı on dört yerel işletmenin yeşil puanı sadece dokuzdur. Dahası yerel işletmelerin sadece dördünde tarımsal sürdürülebilirlik odaklı yeşil uygulamalar gerçekleştirildiği sonucuna ulaşılmıştır. Nihai olarak elde edilen veriler üzerinden kesin bir ilişki tespit edilmesi mümkün olmamakla beraber uluslararasılaşma ve şube sayısı ile sürdürülebilir odaklı yeşil işletmecilik faaliyetleri arasında yakın ilişki olduğu tespit edilmiştir.

Anahtar Kelimeler: Tarımsal Sürdürülebilirlik, İkinci Dalga Kahve İşletmeleri, Yeşil İşletmecilik.

GREEN BUSINESS PRACTICES FOCUSED ON THE SUSTAINABILITY OF AGRICULTURAL PRODUCTION: A COMPARATIVE ANALYSIS OF SECOND WAVE COFFEE CHAINS IN TURKEY

ABSTRACT

In parallel with the increasing world population and urbanization, the importance of agricultural sustainability is increasing day by day. Sharing responsibility is a key issue in this regard. People in the position of producers and consumers, businesses, states, non-governmental organizations, in short, everyone has responsibilities. Food and beverage businesses are in a position to both influence and be affected by the sustainability of agricultural production. In this context, this research aims to reveal the agricultural sustainability-oriented green businesses practices implemented by second wave coffee businesses in their production and supply processes. Another aim of the research is to compare domestic and foreign origin businesses in the context of the subject. The fact that coffee, the main product of these businesses, is supplied by underdeveloped and developing countries makes this research especially important in the context of agricultural sustainability. For the purpose of the research, the activities of the twenty coffee chains with the highest number of branches in Turkey were examined through their websites. As a result of the review, seven green practices were determined under the headings of education (awareness raising), production incentive, responsible supply, recycling, climate change measure, customer involvement in the process, and producer involvement in the process, and green scores of the businesses were created. Based on the data obtained, it was concluded that the most frequently implemented green practice was recycling, implemented by eight business, while agricultural production incentive were implemented by only one business. It is also possible to say that foreign chain businesses exhibit a more responsible attitude compared to domestic chain businesses. Such that, while the green score of the six foreign businesses included in the research was twenty-one, the green score of the sixteen domestic businesses was only nine. Moreover, it was concluded that only four of the domestic businesses implemented green practices focused on agricultural sustainability. Although it is not possible to determine a definitive relationship based on the final data obtained, it has been determined that there is a close relationship between internationalization and the number of branches and sustainable-oriented green business activities.

Keywords: Agricultural Sustainability, Second Wave Coffee Businesses, Green Business.

1. GİRİŞ

Wisniowski'nin aktardığı üzere (2025) kahve ihracatından elde ettiği gelire göre önde gelen ülkeler; Brezilya, Vietnam, Kolombiya, Endonezya, Etiyopya, Honduras, Hindistan, Uganda, Meksika, Guatemala, Peru, Nikaragura, Çin, Fildişi Sahili ve Kostarika'dır. Son ulaşılan istatistiklere bakıldığında ise dünya genelinde kahve ihracatı Temmuz 2024'teki 11,6 milyon çuvala kıyasla Temmuz 2025'te %1,6 düşüşle 11,42 milyon çuvala gerilemiştir. Kahve piyasasının önde gelen ülkesi Brezilya'nın da içinde yer aldığı Güney Amerika, son ekonomik durgunluğun itici gücü olmuştur. Bu bölgenin toplam ihracattaki payı, Temmuz 2024'teki %46,5'e kıyasla Temmuz 2025'te %38,5'e gerilemiştir ve Güney Amerika için art arda dokuzuncu durgunluk ayı olmuştur (ICO, 2025).

İhracat boyutuyla öne çıkmayan ülkelerle beraber dünyada sudan sonra en çok tüketilen içecek olan kahvenin üretiminin sınırlı bir coğrafyada yapıldığını ifade etmek mümkündür (Bayraktar vd., 2021: 74). Bu nedenledir ki kahve söz konusu olduğunda sürdürülebilir tarım daha da önemli hale gelmektedir. Söz konusu üretici ülkelerin az gelişmiş ve gelişmekte olan ülkeler olması nedeniyle ekonomileri içerisinde kahve ihracatının önemli bir pay kapsadığı düşünüldüğünde tarımsal sürdürülebilirliğin önemi daha da gün yüzüne çıkmaktadır. Dahası Uluslararası Kahve Örgütü'nün raporladığı üzere özellikle iklim değişikliği nedeniyle kahve üretiminin sürdürülebilirliği yadsınamaz tehditlerle karşı karşıya kalmaktadır (ICO, 2024: 16).

Dünya kahve tüketiminin önemli bir aracısı yiyecek içecek işletmeleri ve özellikle ikinci dalga kahve zincirleridir. Küresel boyutta arz sunan bu işletmelerin kahve tüketiminin yanında tabi ki üretim konusunda da sorumluluk alması beklenmektedir. Bu bağlamdan hareketle bu araştırma ile sürdürülebilir tarım adına ikinci dalga kahve işletmelerinin yeşil işletmecilik uygulamalarına yönelinmiştir. Türkiye'de hizmet veren ikinci dalga zincir kahve işletmeleri üzerinden araştırma yürütülüyor olmasının yerli ve yabancı zincirler arasında kıyaslama yapmaya da imkân sağlaması bakımından önemli olduğu düşünülmektedir

2. YEŞİL İŞLETMECİLİK

Her bir işletme çevresiyle etkileşim halinde faaliyetlerini sürdürmektedir. Öyle ki en temel üretim faktörlerinden birisi doğadır. İşletmelerin çevreyle olan etkileşimin maliyetleri hesaba katılmadığı takdirde uzun vadede başarılı olunamayacağı akademi mecrasında ve sektör profesyonellerince kabul edilmiştir. Özellikle son yıllarda artan çevre sorunları ve bu sorunlar karşısında bir şeyler yapmak zorunda kalan devletler ile bu konuda gündem ve baskı oluşturucu güce sahip sivil toplum örgütlenmeleri işletmelerin faaliyetleri üzerinde küçümsenmeyecek etkiler oluşturmaktadır. Dahası eğitim seviyesinin yükselmesiyle çoğalan çevre bilinci yüksek tüketiciler de işletmelerin rekabette tutunabilmek adına kulak vermesi gereken bir pazar haline gelmiştir. Bu bağlamda 21. Yüzyılın başarılı işletmecilik anlayışını yeşil stratejiler oluşturmaktadır ki (Şenocak ve Mohan Bursalı, 2018: 165) bu stratejiler üzerine kurgulanan işletmeler yeşil işletme şeklinde tanımlanmaktadır.

Çevreye duyarlı işletmecilik olarak da ifade edilen yeşil işletmecilik, "ekolojik çevreyi karar alma süreçlerinde önemli bir unsur olarak dikkate alan, faaliyetlerinde çevreye verilen zararı minimuma indirmeyi veya tamamen ortadan kaldırmayı amaç edinen, bu çerçevede, ürünlerinin tasarımını ve paketlemesini, üretim süreçlerini değiştiren, ekolojik çevrenin korunması felsefesini işletme kültürüne yerleştirmek için çabalayan, sosyal sorumluluk kapsamında topluma karşı görevlerini yerine getiren işletmelerin benimsediği anlayışı" (Nemli, 2001: 212) açıklamaktadır. Bu geniş tanımdan ve benzerlerinden anlaşılacağı üzere yeşil işletmeciliğin kapsamı oldukça geniş bir şekilde işletmenin tüm faaliyetlerini içermektedir. Dolayısıyla yeşil tüketici, yeşil pazarlama, yeşil

ürün, yeşil üretim, yeşil tedarik, yeşil bina gibi kavramlar ortaya çıkmış olmakla beraber yeşil işletmecilik şemsiye bir kavram ve anlayış olarak düşünülmelidir. Bir işletmenin yeşil işletme olarak tanımlanabilmesi için tüm süreçlerinde çevresel sorumluluklarını yerine getirmesi beklenmektedir. Ancak pazarlama başarısı amacıyla yeşil uygulamaların yapılıyormuş gibi gösterilmesi yeşil yıkama/boyama (Aksu ve İpar, 2018: 26) şeklinde ifade edilmekte ve pazarlama etiğine uymamaktadır. Dolayısıyla konuyla ilgili örgütlenmelerin öncülüğünü üstlendiği sertifikasyon uygulamalarına dâhil olunması uygulamaların kontrol edilebilirliği, sürekliliği ve belgelendirilmesi için önem arz etmektedir. Bu bağlamda işletmelerin yeşil işletmecilik anlayışına uygun faaliyette bulunduklarının en önemli göstergelerinden birisi ISO 14000 çevre yönetim sistemi standartlarıdır (Akatay ve Aslan, 2008: 320). Bu standartlar dünya genelinde en kapsamlı sertifikasyon programlarından birisi olmakla birlikte ülkelere göre ve sektörel bazda birçok farklı sertifikasyon uygulamasının varlığından bahsetmek mümkündür.

Yeşil işletmeler, uygulamaları ile çevreye ve dünyaya karşı sorumluluklarını yerine getirmiş olmakla beraber kendileri adına da önemli kazanımlar elde etmiş olmaktadır. Bu konuda Porter'in maliyet liderliği, farklılaştırma ve odaklanma şeklinde açıkladığı rekabet stratejileri oldukça geçerlidir. Yeşil uygulamalarla maliyetlerini düşüren işletmeler maliyet liderliği için önemli adımlar atmış olmaktadır. Söz konusu uygulamalardan bu araştırmanın konusuyla ilgili olanlardan bazıları; geri dönüşüm, yeşil tedarikçi seçimi, atık azaltımı, çevre bilinci oluşturma şeklinde sıralanabilir. Dahası bu uygulamaları gerçekleştirdiğini sertifikasyon programlarıyla onaylatan ve pazarlama iletişiminde kullanabilen işletmeler müşteri sadakati oluşturmada ve yeni müşterilere ulaşmada avantajlı konuma ulaşabilmekte (Perramon, 2014: 10) ve rakipleri arasında farklılaşabilmektedir.

3. KAHVE AKIMLARI VE TÜRKİYE

Suyun ardından dünya üzerinde en popüler içecek pozisyonunda kahve yer almaktadır (Gaascht vd., 2015: 50). Öyle ki insanların kahve tüketme motivasyonu oldukça çeşitlidir. Belki bir yemek sonrası, belki keyifli bir anda belki de bir arkadaş toplantısında kahve akıllara gelebilmektedir. Hemen hemen her an tüketilebilen bir içecek olarak kahve, boş zaman sembolü olarak da görülebilmektedir (İstanbullu Dinçer vd., 2016: 811). Tüketiminin verdiği hazzın yanı sıra son yıllarda sağlığa olumlu etkisiyle de değerini katlayan kahvenin hazırlanışı, sunumu ve tüketim şekli süreç içerisinde farklılaşmıştır. Kahvenin kitlesel tüketimi söz konusu olduğunda nesil veya dalga şeklinde tanımlanan süreçlerden bahsedilmektedir. Birinci dalga kahve akımı; kitlesel tüketim amaçlı standardizasyonu hedefe koymakla beraber kalite beklentisinin olmadığı bir endüstriyel süreçtir (Rosenberg vd., 2018: 203). Günümüzde her ne kadar üçüncü dalga kahve akımına erişilmiş olsa da halen geçerliliği olan birinci dalga kahve akımı, vakumlu torbalar vasıtasıyla kahvenin taşınabilir ve istenildiğinde suda çözülerek içilmesini içermektedir ve en önemli özelliği kahve tüketimini kolaylaştırmasıdır. 1960'lı yıllarda çıkan öncü işletmeler sayesinde ikinci dalga kahve akımı başlamıştır (Fischer, 2017: 8). Bu akım kapsamında, gelişen üretim teknolojilerinin katkısıyla sunum ve tat standardizasyonuna ulaşmak mümkün hale gelmiş ve dolayısıyla zincir kahve işletmeleri ortaya çıkmıştır (Genç ve Çakırtaş, 2024: 228). Ayrıca kahve tüketiminde marka ve mekân, bir tüketim alanı olmasının ötesinde anlamlara kavuşmuş ve bireyler kahve mekânlarını kendilerini özel hissedebildikleri yerler olarak algılar duruma gelmiştir (Kavlak ve Akova 2022: 9). Son olarak zincir işletmelerle olgunlaşan Avrupa, ABD, Japonya gibi pazarlarda (Borrella vd., 2015: 34) endüstriyelleşen kahve tüketimine karşın üçüncü dalga kahve akımı doğmuştur (Şeker ve Özata, 2022: 194). Bu akımda kahve üretimi ve tüketimi bir sanat olarak görülmeye başlanmış ve hasadından, işlenmesine ve tüketimine kadar özenli, kişiselleştirilmiş bir yaklaşım sergilenmeye

başlanmıştır. Dolayısıyla çok sayıda tüketiciye standart reçeteler üzerinden sunumun yapıldığı ikinci dalga kahve mekânlarına kıyasla daha butik işletmeler üçüncü dalga kahve akımının temsilcileri olarak görülmektedir.

Tablo 1. Türkiye'de Önde Gelen Zincir Kahve İşletmeleri (2023-2024)

İşletme İsmi	Kuruluş*	Türkiye'ye Giriş	Menşei**	Dünya Şube Sayısı***	Türkiye Şube Sayısı***
Starbucks	1971	2003	ABD	38.038	685
Gloria Jean‟s Coffee	1979	2012	ABD (1994‟itibarıyla Avusturalya)	1200+	124
Caffe Nero	1997	2007	İngiltere	1000+	95
Tchibo	1955	2005	Almanya	1000+	45
Caribou	1992	2011	ABD	700+	50
Roberts Coffee	1987	2006	Finlandiya	76	29
EspressoLab	2014	2014	Türkiye	245	190
Kahve Dünyası	2004	2004	Türkiye	209	195
Arabica Coffee House	2014	2014	Türkiye	159	157
Makber	2010	2010	Türkiye	152	150
Kahve Deryası	2009	2009	Türkiye	105	97
Kahve Durağı	2009	2009	Türkiye	100+	100+
Gönül Kahvesi	2002	2002	Türkiye	71	67
Soulmate	2013	2013	Türkiye	69	69
Coffemania	2009	2009	Türkiye	66	61
Colombia	2020	2020	Türkiye	60	60
Kocatepe Kahve Evi	1996	1996	Türkiye	53	53
Kahve Diyarı	2005	2005	Türkiye	47	46
Kahveland	2013	2013	Türkiye	45	45
David People Coffee & Food	2010	2010	Türkiye	33	33

Notlar: *İlk fiziki mağaza dikkate alınmıştır. **Çıkış yeri dikkate alınmış; el değiştirmeler ve ortaklıklar dikkate alınmamıştır. ***Veriler Statista şirketinin ve işletmelerin resmi sitelerinden elde edilmiştir. Al-götür konseptler dâhil edilmemiştir (Genç ve Çakırtaş, 2024: 234).

Anadolu coğrafyasında kahve tüketiminin ve mekânlarının yayılımının Kanuni Sultan Süleyman döneminde yaşandığı kabul edilmektedir (Kefeli vd., 2020: 132; Özdal, 2023: 1079). Anadolu'da ilk kahve mekanının açılışı üzerine 1551 (Yaşar, 2005: 239; Taştan, 2009: 64), 1554 (Çekiç, 2022: 686; Kaplan, 2011) ve 1555 (Akarçay, 2012: 184; Fendal, 2012: 161; Yılmaz vd., 2017: 214) gibi birbirine yakın olsa da farklı yıllar işaret edilmektedir. Süreç içerisinde kahve tüketimi önemli bir kültür halini almış ve 1600'lü yıllarda kahvehane sayısı yetmiş, işletmecilerin sayısı yüz, kahve satan dükkânların sayısının üç yüz olduğu aktarılmış ve 19. Yüzyıl İstanbul'u büyük bir kahvehane olarak tasvir edilmiştir (Yaşar, 2005: 242). Bu tasvir geleneksel kahvehanelerin yanında ikinci ve üçüncü nesil kahve işletmelerinin varlığıyla günümüzde de geçerli durmaktadır. Öyle ki 2023 yılı verilerine göre dünya üzerinde en fazla Starbucks şubesinin bulunduğu ülkeler arasında Türkiye sekizinci sırada yer alırken Avrupa'da her dört Starbucks şubesinin biri Türkiye'de yer almaktadır (Genç ve Çakırtaş, 2024: 227).

4. ARAŞTIRMANIN YÖNTEMİ

Araştırmanın amacına istinaden tablo 1.'de yer verildiği üzere Türkiye'de faaliyet gösteren en yüksek şube sayısına sahip ikinci dalga zincir kahve işletmelerinin internet siteleri incelenmiştir. Ayrıca bu sitelerden indirilebilir dokümanlardan faydalanılmıştır. Birincil veri kaynağı olarak ifade edilebilecek işletme sorumlularıyla doğrudan görüşme gerçekleştirilmemiş olması araştırmanın sınırlılığı olarak kabul edilebilir. Tarımsal sürdürülebilirlik odaklı yeşil uygulamalar gerçekleştirmiş olmasına rağmen internet sitesinde buna dair bir bilgi paylaşımı yapmamış olan işletmelerin olma ihtimali göz ardı edilmemelidir.

5. VERİ ANALİZİ VE BULGULAR

Tablo 2'de araştırmaya dâhil edilmiş olan yirmi işletmenin tarımsal sürdürülebilirlik odaklı gerçekleştirdikleri yeşil uygulamalara ve bu uygulamalar neticesinde oluşturulmuş yeşil puanlarına yer verilmiştir.

Tablo 2. Tarımsal Sürdürülebilirlik Odaklı Yeşil Uygulamalar

İŞLETMELER	YEŞİL UYGULAMALAR							YEŞİL PUAN
	Eğitim (Bilinçlendirme)	Tarımsal Üretim Teşviki	Sorumlu Tedarik	Geri Dönüşüm	İklim Değişikliği Tedbiri	Müşteriyi Sürece Dâhil Etme	Üreticiyi Sürece Dâhil Etme	
Starbucks	✓		✓	✓	✓	✓		5
Gloria Jean"s Coffee			✓	✓				2
Caffe Nero			✓	✓			✓	3
Tchibo	✓		✓	✓	✓		✓	5
Caribou	✓		✓	✓	✓	✓	✓	6
Roberts Coffee								0

EspressoLab	✓	✓		✓				3
Kahve Dünyası				✓				1
Arabica Coffee House	✓				✓	✓		3
Makber								0
Kahve Deryası								0
Kahve Durağı								0
Gönül Kahvesi			✓	✓				2
Soulmate								0
Coffemania								0
Colombia								0
Kahve Diyarı								0
Kahveland								0
David People Coffee & Food								0
Kocatepe Kahve Evi								0

Yedi yeşil uygulamadan elde edilen toplam otuz puanın yirmi bir puanı altı yabancı işletmeye aittir. On dört yerli işletmenin yeşil puanı ise dokuz seviyesindedir. Belirlenen yeşil uygulamaların sadece birine yönelik faaliyeti bulunmayan Caribou işletmesi, tüm işletmeler arasında altı yeşil puanla lider durumdadır. Onu yine yabancı işletmeler arasında yer alan beşer yeşil puanlı Tchibo ve Starbucks takip etmektedir. Yabancı işletmelerden Roberts Coffee işletmesinin ise herhangi bir yeşil uygulamasına ulaşılamamıştır. Yerli işletmelere bakıldığında ise zaten düşük olan toplam dokuz yeşil puanın sadece dört işletme tarafından kaynaklandığı görülmektedir. Bir diğer ifadeyle yerli on işletmenin herhangi bir yeşil uygulamasına ulaşılamamıştır. Yeşil uygulamalar arasında sekiz işletme ile en çok gerçekleştirilen uygulama geri dönüşümdür. Tarımsal üretim teşviki ise sadece bir işletme tarafından uygulanmaktadır.

Sorumlu Tedarik

Dikkat çekici bir şekilde yükselen sürdürülebilirlik politikaları gereğince klasik tedarikçi seçim kriterlerine çevresel kriterler de eklenmiştir (Madenoğlu, 2019: 1852). Bir diğer ifadeyle yeşil işletmecilik gerçekleştirmek isteyen işletmelerin tedarikçi seçiminde de bu görüşleri doğrultusunda hareket etmesi beklenmektedir. Sorumlu tedarikçi seçimi yeşil ürün sunumu için ön gereklilikler arasında yer almaktadır. Bu bağlamda araştırma kapsamında beş işletmenin sorumlu tedarikçi seçimi adına çalışmalar gerçekleştirdiği tespit edilmiştir. Sorumlu tedarikçi seçimi üzerine "tedarikçi davranış kuralları" oluşturduğunu ifade eden bir işletmenin konuya dair açıklamaları aşağıdaki gibidir (Starbucks, 2024: 30).

Sorumlu tedarik uygulamaları, tedarik zinciri girişimlerinin ayrılmaz bir parçasıdır. Tedarik zincirimiz genelinde ürün ve malzemeleri sorumlu bir şekilde tedarik etme konusundaki devam eden çabalarımızı daha da ileriye taşımak için, tedarikçilerimizin iş etiği, insan hakları ve çevresel sürdürülebilirlik konusundaki beklentilerimizi karşılamalarını sağlamak amacıyla kapsamlı politikalar ve programlar oluşturduk. Bir tedarikçinin uygulamalarıyla ilgili endişeler ortaya

çıkarsa, sorunları çözmeleri için onları desteklemeyi hedefliyoruz. Sorunlar tamamen ele alınıp çözülene kadar faaliyetleri askıya alma hakkımızı saklı tutuyoruz.

Eğitim (Bilinçlendirme)

Sürdürülebilir tarımın temel göstergeleri içerisinde eğitim çalışmalarının yaygınlaştırılması yer almaktadır (Turhan, 2005: 15). Akış ve Aksoy (2023: 902) tarafından yapılan bir araştırmada çiftçi eğitimlerinin üretim ve sürdürülebilirlik konusunda pozitif etkisinin bulunduğuna ulaşılmıştır. Çiftçi eğitimlerinde devlet kurumları önde olmak üzere işletmelere de sorumluluklar düşmektedir. Bu araştırmaya dâhil edilmiş beş işletmenin bu yönde girişimleri bulunmaktadır. Tchibo işletmesi, kahve alımı gerçekleştirdiği Tanzanya'da tarımsal üretime yönelik verdiği eğitim desteğini aşağıdaki şekilde açıklamıştır (Tchibo, t.y.).

Genç çiftçilerin bilgilerini güçlendirmek için Tchibo, City Coffee ile iş birliği yaparak Kahve Kulüpleri'ni başlattı. Bunlar, Mbyea ve Mbozi'deki yedi okulda düzenlenen okul tabanlı atölyelerdir. Kahve yetiştiriciliğinden başarılı bir kahve satışına kadar her şeyi kapsar. Çeşitli modüller, bitki hastalıklarının tanınması, gübreleme becerileri ve suyun doğru kullanımı konularını kapsar. Ayrıca, doğru budama ve yüksek verimli hasat yöntemleri hakkında derinlemesine bilgiler paylaşılır. Atölyeler, yalnızca kahve bitkilerinin yetiştirilmesi ve bakımı hakkında ekolojik bilgi sağlamakla kalmayıp, aynı zamanda katılımcılara başarılı bir çiftlik işletmek için ihtiyaç duydukları becerileri kazandırmak için de tasarlanmıştır. Bu bağlamda, iş sağlığı ve güvenliği ve yönetim becerileri gibi önemli konular da ele alınmaktadır. Atölyeler genellikle verimlilik ve kalitede artışlara yol açar; bu da öğrenciler için önemli bir motivasyon kaynağıdır.

İklim Değişikliği Tedbiri

İklim değişikliği belki de tarımsal sürdürülebilirliğin önündeki en büyük engeldir. Hakorımana (2018: i) tarafından Ruanda kapsamında gerçekleştirilen bir araştırmada son on yedi yılda kahve verimindeki değişimin %74'ünün iklim değişiminden kaynaklandığı sonucuna ulaşılmıştır. İklim değişikliğiyle mücadelede yeni duruma uygun bir şekilde üretim ve teknik farklılaştırılmasına gidilmesi önem arz etmekte olup dört işletmenin bu yönde girişimleri tespit edilmiştir. Tchibo işletmesi tarafından Honduras'ta girişimlerde bulunulmuştur. Söz konusu girişimler aşağıdaki ifadelerle açıklanmıştır (Tchibo, t.y.).

Çeşitlendirme, çiftliklerin verimliliğini hem ekolojik hem de ekonomik olarak artırmanın önemli bir yoludur. Bu amaçla Tchibo ve Becamo, kahve tarlalarında avokado ve turunçgiller de dâhil olmak üzere meyve ağaçlarının yetiştirilmesini desteklemektedir. Bu, çeşitli faydalar sağlar: Meyve ağaçları, kahve bitkileri için gerekli gölgeyi sağlayarak kalite ve performansı artırabilir. Aynı zamanda, meyve ağaçları çiftçilere ve ailelerine besin sağlar. Belirli koşullar altında, ikinci bir gelir kaynağı dahi olabilirler. Farklı çeşitlerin yetiştirilmesi ve biyolojik girdi üretimi, daha iyi biyoçeşitlilik ve toprak sağlığını sağlayarak iklim değişikliğiyle mücadeleye katkıda bulunur.

Müşteriyi Sürece Dâhil Etme

Yeşil uygulamaların başarılı olmasında müşterilerin desteği olmazsa olmazlar arasındadır ve üç işletme bu farkındalıkla girişimde bulunmuştur. Müşteri desteği işletmeler üzerinde teşvik edici bir etki uyandırıp yeşil uygulamaların çeşitlenmesine zemin hazırlayabilmektedir. Ancak yeşil yıkama veya boyama şeklinde tüketiciyi aldatıcı bir tavrın da olduğu düşünüldüğünde bu düşünüldüğü kadar kolay durmamaktadır. Müşteriyi sürece dâhil etmenin etkin yollarından birisi somut verilerle sürdürülebilirlik raporları oluşturmak ve uygulamaları görülebilir kılmaktır (Baloğlu Sevinç ve Akın, 2025: 41). Mobil uygulamalar sayesinde bu raporların tüketiciye ulaştırılması oldukça

kolaylaşmıştır. Müşteriyi sürece dâhil etme konusunda sosyal medya desteğiyle gerçekleştirilen bir uygulama aşağıdaki ifadelerle açıklanmıştır (Arabicacoffee, t.y.).

Sürdürülebilir bir gelecek için fark yaratıp öncü olmak adına adımlar atıyoruz, çünkü biliyoruz ki dünyanın değişmek ve iyileşmek için bize ihtiyacı var. Siz de Arabica içeceğinizi Instagram üzerinden #100YılınTohumları etiketiyle paylaşarak tohum topu kampanyasında öncülerden olabilirsiniz. Tohum topu; bir tohumun etrafının kil, humuslu toprak ve tohumun verimliliği için farklı minerallerin yer aldığı bir karışımla kaplanması sonucu meydana gelen toplardır. Tohumların doğada çimlenmelerine kadar geçen sürede; aşırı soğuk, sıcak, rüzgâr, orman canlılarının tohumu yemesi gibi dış etkenlerden korunmaları amaçlanmaktadır.

İklim krizinden en çok etkilenen gruplardan biri de taşrada yaşayan insanlardır. Geçim kaynakları tarım ve hayvancılık olan söz konusu gruplar iklim krizinden doğrudan etkilendiği için, gelir eşitsizliğiyle karşı karşıya kalmaktadırlar. Tohum toplarının üretimi için özel materyaller geliştirip, öncelikli ekim sahalarına yakın bölgelerdeki köylerde yaşayan kadınlara bu materyallerin eğitimi verilmektedir. Eğitim sonrası kadınlar tarafından üretilen tohum topları, ecording tarafından satın alınır. Bu sayede iklim krizinden en çok etkilenen grupların gelir elde etmesi sağlanırken, iklim krizi ile doğrudan ve hep beraber mücadele edilmesi hedeflenmiştir.

Üreticiyi Sürece Dâhil Etme

Yeşil işletme faaliyetinden bahsedebilmek için tüm paydaşların sorumluluğu paylaşması önem arz etmektedir. Sorumlu tedarikle ilişkili bir şekilde işletmelerin üreticileri sürdürülebilir tarım uygulamalarını gerçekleştirmeye zorunlu bırakmaları beklenmektedir. Bir diğer ifadeyle işletmeler sürdürülebilir tarıma yönelik çalışmalar gerçekleştiren üreticileri tercih ederek diğer üreticileri de teşvik etme yoluna gidebilir. Araştırma kapsamında üç işletmenin bu yönde uygulamaları söz konusudur. Bir örnek işletme uygulaması aşağıdaki gibidir (Caribou Coffee, 2023).

Hem insanlara hem de gezegene fayda sağlayan daha sorumlu tedarik uygulamalarına bağlıyız. 2003 yılından bu yana, Rainforest Alliance ile ortaklığımız, tedarik çabalarımızın önemli bir parçası olmuştur. 2012 yılında, tüm kahvelerini Rainforest Alliance sertifikalı çiftliklerden tedarik eden ABD'deki ilk kahve evi olarak tarihe geçtik. Bu sertifika, çiftçilerin daha sürdürülebilir arazi yönetimi uygulamaları kullanmasını, kritik orman alanlarını ve biyolojik çeşitliliği korumasını ve sürekli iyileştirme ve düzenli denetim taahhüdüyle insan haklarını gözetmesini zorunlu kılmaktadır. Bu gereklilikler, kahvemizin sadece lezzetli olmasını değil, aynı zamanda yetiştirildiği ekosistemleri ve toplulukları destekleyerek fayda sağlamasını da sağlar.

Tarımsal Üretim Teşviki

Üreticiyi sürece dâhil etme, sorumlu tedarik gibi uygulamalar üreticileri sürdürülebilir tarıma teşvik etme amacı güderken tarımsal üretim teşviki ise doğrudan insanların tarımdan kopmamasını içermektedir. Bu yönde tek bir işletmenin gerçekleştirdiği uygulama bulunmaktadır ve aşağıdaki ifadelerle açıklanmıştır (Espressolab, t.y).

Bizim için kahve, sadece bir içecek değil; geleceği birlikte inşa ettiğimiz bir yolculuktur. Espressolab olarak kahvenin geleceğini sürdürülebilir yöntemlerle güvence altına alıyoruz. "Future Generation Coffee" ile kahve üretimini ekonomik, ekolojik ve sosyal açıdan dengeli hale getiriyor, gelecek nesiller için nitelikli kahve üretiminin devamlılığını sağlıyoruz. Bilimsel ve sürdürülebilir tarım yöntemlerini yaygınlaştırıyoruz. Üreticilerimizi girişimciliğe teşvik ederek ekonomik bağımsızlıklarını güçlendiriyoruz. Genç çiftçilerin sektöre katılımını destekliyoruz.

Future Generation Coffee yaklaşımımızla, yalnızca bugünün değil, yarının kahvesine de yatırım yapıyoruz.

Geri Dönüşüm

Geri dönüşüm uygulamaları ile sürdürülebilirlik arasında yakın bir ilişki bulunmaktadır. Bu uygulamalar, işletmelere maliyet avantajı sağlaması bakımından da oldukça dikkat çekicidir. Bu metinde üzerinde durulan ikinci dalga kahve işletmeleri de geri dönüşüm uygulamalarını hayata geçirebilecek olanaklar sunmaktadır ki sekiz işletmenin geri dönüşüm gerçekleştirdiği sonucuna ulaşılmıştır. Tarımsal üretimin sürdürülebilirliği sadece beslenme amaçlı olmaktan ziyade dokuma sanayi için de oldukça önem arz etmektedir. Bu bağlamda Kahve Dünyası isimli işletme, ileri dönüşüm ifadesiyle kahve çuvallarından çanta, şapka gibi ürünler oluşturarak satışa sunmuştur. İşletme bu uygulamasını aşağıdaki ifadelerle açıklamıştır.

"Bu dünya hepimizin" dedik, kol kola girdik.

Size servis ettiğimiz kahve çekirdeklerini taşıyan çuvallarımızı, ileri dönüşümle yeniden tasarlayarak çantalara dönüştürdük. Bu çantalardaki özel deri detaylar Kahve Dünyası mağazalarında yenilenen koltuklarımızın derilerinin yeniden işlenerek değerlendirilmesiyle elde edildi. Böylece hem atık malzemeleri değerlendiriyor hem de doğaya katkıda bulunuyoruz. Kahve çuvallarının işlenerek dönüştürüldüğü el çantasıyla sürdürülebilir yaşam tarzınızı yansıtın. Her adımda doğayı koruyarak, geleceğe daha yeşil bir iz bırakın.

6. SONUÇ

Tarım, kahve ve sürdürülebilirlik ilişkili tehditlerin farkında olan Uluslararası Kahve Örgütü, mevcut çevresel ve ekonomik zorlukların üstesinden gelmek için kahve sektörünün, çiftçilerin geçim kaynaklarını iyileştiren ve sürdürülebilirliği teşvik eden dönüştürücü stratejilere ihtiyacı olduğunu ifade etmiştir (ICO, 2024). Bu araştırma neticesinde anlaşılmaktadır ki özellikle yüksek şube sayısına ulaşmış ve uluslararasılaşmış zincir işletmeler tam anlamıyla olmasa da sorumluluklarının farkına varmış durmaktadır. Öyle ki mevcut verilerle Türkiye'de faaliyet gösteren yabancı menşeili kahve işletmelerinin yeşil uygulamalar gerçekleştirme konusunda yerli işletmelere kıyasla çok önde olduğunu ifade etmek mümkündür.

Yeşil uygulamalar arasında en sık gerçekleştirileni geri dönüşüm olarak belirmiştir. Bu sonuç belki de bu uygulamanın diğerlerine kıyasla daha kolay uygulanabilir olması ile açıklanabilir. Ancak Porter'in rekabet stratejileriyle ilişkilendirmek de mümkündür. İşletmeler geri dönüşüm uygulamaları ile hem maliyet düşürücü hem de rakipleri karşısında farklılaşma adına kazanımlar sağlayabilmektedir. Eğitim ve çevresel bilinç düzeyinin yükselmesiyle çoğalan sorumlu tüketicilere hitap etmek amacıyla doğrudan işletme içerisinde fark edilebilecek yeşil uygulamalar tercih edilmesi anlaşılır durmaktadır. Öyle ki yeşil tüketim anlayışına sahip tüketicilerin ürün tercihlerinde, geri dönüştürülebilir olması önem arz etmektedir (Yıldız ve Kütahyalı, 2021: 387).

Araştırma verileri işletmelerin internet sitelerinden ve kamuoyu ile paylaşmış oldukları sürdürülebilirlik raporlarından elde edilmiştir. Söz konusu işletmelerin yaklaşık yarısının yeşil puanı sıfır olarak belirlenmiştir. Bir başka ifadeyle ne sitelerinde ne de başka bir mecrada yeşil uygulama gerçekleştirdiklerine dair bir dokümana ulaşılamamıştır. Bu işletmeler herhangi bir yeşil uygulama gerçekleştirmiyor olabileceği gibi doğrudan işletme temsilcileriyle görüşülememesi nedeniyle bir veriye ulaşamama hali de olabilir ki bu, araştırmanın sınırlılığı olarak kabul edilebilir. Ancak yeşil uygulamalar gerçekleştirilmesine rağmen bilgi paylaşımı yapılmaması da işletmeler adına bir eksikliktir. Gerçekleştirilen uygulamaların paylaşımı, işletmelerin dünyaya karşı

sorumluluklarını bildiklerini, üzerlerine düşeni yerine getirdiklerini göstermek ve dolayısıyla pazarlama başarıları adına önem arz etmektedir. Bu düşünce ile gerçekleştirdikleri yeşil uygulamaları duyurum konusunda özellikle yerli işletmelerde eksiklik bulunmaktadır. Duyurum gerçekleştirenler de yabancı işletmelerin sürdürülebilirlik raporlarına kıyasla çok zayıf bir şekilde sadece internet sitesi üzerinden birkaç satır ifade ile bunu yapmıştır.

Pazar payını genişletmek amacıyla saldırgan veya abartılı sürdürülebilirlik iddiaları yeşil yıkama olarak tanımlanmaktadır (Braga Junior vd., 2019: 228). Bu bağlamda yeşil uygulamaların tüketicilerle paylaşılması önem arz etmekle beraber pazarlama etiği çerçevesinde de dikkat edilmesi gereken bir konudur. Pazarlama etiği çerçevesinde hareket ederek tüketicileri yeşil yıkamaya maruz bırakmamak adına uygulama raporlarının paylaşımı ve bu uygulamaların takip edilirliğini sağlamak adına bağımsız sertifikasyon örgütlenmeleri ile işbirliği gerçekleştirilmesi gerekmektedir.

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LIVESTOCK LOCALIZATION USING REAL-TIME INTERNET-OF-THINGS ARCHITECTURE

Dr. Rotimi-Williams Bello
Department of Computer Systems Engineering, Tshwane University of Technology, South Africa
Department of Mathematics and Computer Science, University of Africa, Bayelsa, Nigeria
Email: sirbrw@yahoo.com
ORCID: 0000-0002-8121-2712
Prof. Pius A. Owolawi
Department of Computer Systems Engineering, Tshwane University of Technology, South Africa
Email: owolawipa@tut.ac.za
ORCID: 0000-0002-5781-5054
Prof. Chunling Tu
Department of Computer Systems Engineering, Tshwane University of Technology, South Africa
Email: duc@tut.ac.za
ORCID: 0000-0003-2791-020X
Dr. Etienne A. van Wyk
Department of Computer Systems Engineering, Tshwane University of Technology, South Africa
Email: vanwykea@tut.ac.za
ORCID: 0000-0002-0436-2741
Ms. Mojisola Abosede Oladipo
Department of Agricultural Economics and Extension, University of Africa, Bayelsa, Nigeria
Email: mojisola.oladipo@uat.edu.ng
ORCID: 0000-0002-6593-9268

ABSTRACT

With maximal human intervention, traditional localization systems still perform below expectation in monitoring animal health, welfare, and movement, thereby necessitating the need for advanced localization systems capable of handling the rapid expansion of precision livestock farming. An Internet of Things (IoT) architecture that uses wearable sensor nodes, is proposed by this study for livestock localization, integrating edge computing, cloud-based analytics, and low-power wireless sensor networks. The wearable sensor nodes are worn by the animals for spatio-temporal data transmission to edge gateways for preprocessing and filtering of noise before passing on to the cloud for advanced analytics and visualization. There is an assurance of a high spatial accuracy by localization framework of hybridized RFID, GPS, and ultra-wideband (UWB) modules, even in complex farm environments where the traditional localization systems (GPS signals) are below

optimal performance. Edge-driven machine learning models allow real-time decision support, minimizing latency and bandwidth consumption while enabling early anomaly detection in livestock mobility patterns. The capacity of the system is demonstrated by experimental simulations and field trials, with potential to achieve sub-meter accuracy compared to solutions based on traditional GPS. The proposed method does not only improve herd traceability and management but also strengthens control of diseases, minimizes wastage of resources, encourages sustainability of farming practices by optimizing livestock distribution. This study contributes to the increase in research on IoT-driven precision agriculture by offering a smart solution approach for livestock localization with direct applications in animal welfare, productivity, and environmental protection.

KEYWORDS: GPS, Internet-of-Things, Livestock, Localization, RFID, Ultra-wideband, Sensor

1. INTRODUCTION

There are growing challenges facing the global livestock sector in management, traceability, productivity, and sustainability [1]. The mobility patterns of livestock influence transmission of diseases, grazing efficiency, and overall management of farm activities [2]. High energy consumption, limited accuracy, and inability for continuous real-time data provision in complex farm environments make the traditional localization systems like standalone GPS or manual monitoring insufficient [3]. The role of digital technologies is emphasized by precision livestock farming (PLF) in optimization of farm efficiency, animal welfare, and environmental management, the paradigm in which livestock localization plays an essential role [4]. Using accurate positioning systems, abnormal animal behaviors can be detected early, infectious disease outbreaks better controlled, and resources distributed efficiently [5]. An Internet of Things (IoT) architecture that uses wearable sensor nodes, is proposed in this paper for livestock localization, integrating edge computing, cloud-based analytics, and low-power wireless sensor networks to address the limitations of traditional localization systems [6].

The wearable sensor nodes are worn by the animals for spatio-temporal data transmission to edge gateways for preprocessing and filtering of noise before passing on to the cloud for advanced analytics and visualization. There is an assurance of a high spatial accuracy by localization framework of hybridized RFID, GPS, and ultra-wideband (UWB) modules, even in complex farm environments where the traditional localization systems (GPS signals) are below optimal performance [7]. PLF has explored several localization approaches including (1) GPS-based tracking, (2) RFID systems, and (3) UWB. GPS-based tracking is a popular approach that is employed in barns, dense vegetation, or mountainous regions but often constrained by signal degradation in those locations. In addition, continuous updates increase battery consumption. Identification is provided by RFID systems, but they lack capability for real-time positional tracking beyond short ranges. High accuracy is offered by UWB, but dense infrastructure is required for it to perform, thereby limiting scalability in large farms. For hybrid approaches, the combination of GPS and RFID are proposed by some studies to address shortcomings of individual approaches [8-12], but there is a great underdevelopment in integrating with IoT and real-time analytics.

Edge-driven machine learning models allow real-time decision support, minimizing latency and bandwidth consumption while enabling early anomaly detection in livestock mobility patterns [13]. Lightweight models such as one-class SVM and random forest deployed on edge devices enable detection of anomalies such as animal clustering, unusual wandering, and reduced mobility. Cloud dependency and latency are reduced by this technique while offering early alerts. The capacity of the system is demonstrated by experimental simulations and field trials, with potential to achieve sub-meter accuracy compared to solutions based on traditional GPS. Built on these approaches, our study proposes a hybrid (GPS + RFID + UWB) localization framework embedded in the architecture of IoT and enhanced with edge-driven machine learning for detection of real-time anomalies. The proposed method does not only improve herd traceability and management but also strengthens control of diseases, minimizes wastage of resources, encourages sustainability of farming practices by optimizing livestock distribution.

The paper contributes to the increase in research on IoT-driven precision agriculture by offering a smart solution approach for livestock localization with direct applications in animal welfare, productivity, and environmental protection.

2. APPROACHES TO LIVESTOCK LOCALIZATION

Real-time livestock localization is rapidly becoming common practice in PLF. There are four notable approaches to localizing livestock in existing studies [14-17]. (1) GNSS (Global Navigation Satellite System)/GPS-based tracking for extensive systems, (2) Indoor/near-field Real-Time Location Systems (RTLS) such as RFID, UWB, and Bluetooth Low Energy (BLE)/WiFi/RSSI methods, (3) Localization and multi-sensor fusion based on computer vision, and (4) System-level IoT architectures by which edge computing, gateways, and cloud analytics are combined for real-time monitoring and decision support. Fig. 1 shows the livestock localization methods. In this section, we summarize related work and trends in the abovementioned areas and highlight challenges that keep recurring in terms of scalability, energy, accuracy, and validation in real farm environments.

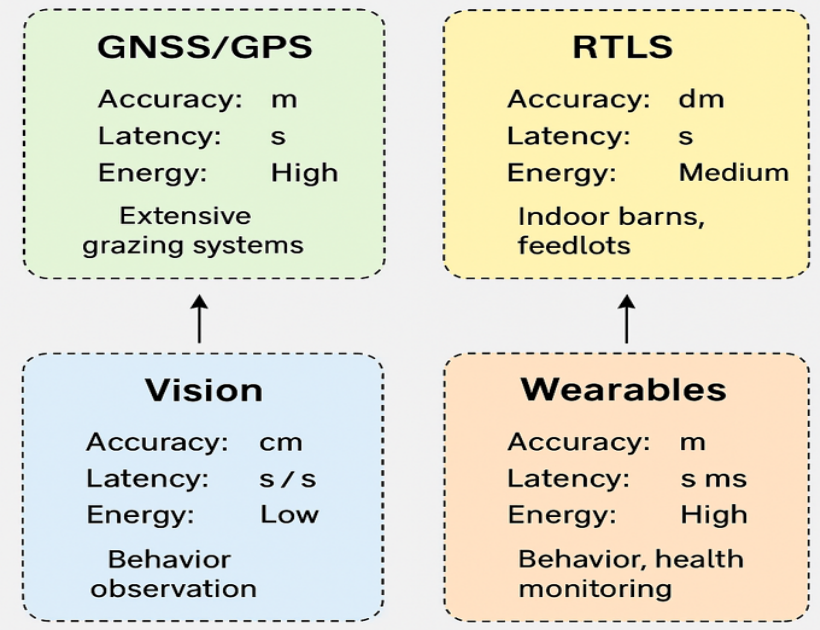


Fig. 1. Livestock localization methods

2.1. GNSS / GPS-based tracking for extensive systems

GNSS/GPS collars are very common technology for localizing animals like cattle, goat, and sheep that graze over large areas because of the global coordinates and simple geospatial analyses they provide. Recent reviews by [14, 18-19] reveal that near-real-time monitoring in extensive systems is enabled by combining GNSS units with LPWAN (Low-Power Wide Area Network) backhaul (e.g., LoRaWAN). However, several factors like battery life limitations can mitigate the performance of GNSS solutions, including reduction of its performance under canopy or in enclosed buildings. Surveys of PLF technologies conducted in [20-22], support GNSS for outdoor tracking but highlight trade-offs between cost, sampling rate, and energy consumption.

2.2. Indoor/near-field RTLS

RTLS approaches have been widely adopted in feedlots, barns, and other confined spaces where high spatial resolution is needed. UWB RTLS systems are now often employed in cow/calf positioning including in dairy settings such as TrackLab, SEWIO, and Pozyx deployments for sub-meter to decimeter accuracy. Several experimental and field studies carried out in [23-25] report

that UWB accuracy is sufficient for detection of area-level behaviors (time spent in alleyway, at cubicle, or at bunk) and enablement of temporal activity analyses; however, factors like animal density, multipath mitigation, and antenna placement determine the performance. Scalability of these systems is demonstrated by commercial scale deployments [26-27]; however, installation complexity, interference, and power/weight limits of animal tags are some cautions emphasized by researchers.

Lower cost alternatives are provided by BLE and WiFi fingerprinting or Received Signal Strength Indicator (RSSI)-based localization, with current work applying machine learning to RSS/Link Quality Indicator (LQI) features for indoor localization improvement. Reasonable performance is offered by BLE position systems for many farm applications; the systems are attractive and adaptable for their low energy consumption, but their accuracy cannot be compared with the accuracy of UWB in cluttered indoor environments. BLE and WiFi deep-learning approaches were examined in [28-30] for indoor localization, and their combination with calibrated site surveys show promising accuracy. Whether active or passive, RFID remains essential for identification and coarse localization (reader-based zones) but is limited for continuous fine-grained tracking.

2.3. Vision-based localization and sensor fusion

Computer-vision based methods, whether single-camera systems or multi-camera systems with object detection, object tracking, and pose estimation are increasingly employed for localization of livestock, particularly in barns where simultaneous monitoring of many animals by a camera network is possible. Vision-based approaches are advantageous for their non-invasiveness and simultaneous provision of behavioral and health indicators such as social interactions, posture, and lameness. However, vision-based approaches are constrained by lighting variation, occlusion, and re-identification of individuals across cameras/frames (the need for robust ID association). Consequently, hybrid systems are common that integrate RTLS (UWB/BLE) into vision (sensor fusion), whereby identity and coarse position are resolved by location from RTLS while posture/behavior detection are refined by vision. An improved welfare monitoring that combines UWB and video analytics was explicitly demonstrated by several studies conducted in [31-32].

2.4. Wearables, inertial sensing and behavior-oriented localization

Wearable inertial measurement units (IMUs) devices often attach to collars and ear tags, comprise accelerometers, gyroscopes, and magnetometers for tracking body movement and recognizing behavior such as lying, feeding, and ruminating. Relative localization can be supported by the devices through dead-reckoning or complementing radio localization. Reviews by [33-35] compared critically the deployment of wearable sensors and highlighted the value of fusing IMU data with GNSS/UWB (position fixes) to increase temporal resolution of movement and reduce dependence on constant radio coverage. Active research directions ensuring the extension of collar/tag lifetime while providing near-real-time streams include duty cycling, time-slotted protocols, and energy-efficient firmware [36].

2.5. IoT architecture, edge computing and real-time pipelines

End-to-end IoT architectures are emphasized by contemporary systems. That is, low-power tags/sensors → local gateways/edge computing → cloud analytics and dashboards. Edge computing, whether on-gateway inference or preprocessing, minimizes latency and bandwidth, allowing near-real-time alerts such as estrus detection, and reducing costs for farms where uplink connectivity is limited. In [37-39], prototype IoT stacks were presented where UWB/BLE/GNSS and Amazon Web Services (AWS)/Azure or open-source edge frameworks were combined,

emphasizing the benefits of aggregation at local level, model inference at the edge, and data synchronization at asynchronous level to cloud repositories. According to validation studies carried out in [40-41], the primary constraints to broad adoption of these approaches are system trade-offs, such as tag weight, battery life, and infrastructure cost.

2.6. Validation, accuracy reporting and real farm deployments

The need for thorough validation in real-farm conditions aroused from a consistent observation across reviews and field studies [42]. Accuracy is often overestimated by laboratory or small-scale tests compared to commercial barns where performance is degraded by animal density, multipath, and environmental factors. UWB and other RTLS are benchmarked by several papers [43-45], reporting detection accuracy per-zone and localization error per-animal; standardization of evaluation metrics such as Root Mean Square Error (RMSE), detection latency, and zone accuracy are recommended by authors, including recommendation of datasets publication to reproducible comparisons.

3. SYSTEM ARCHITECTURE

There are four layers in the proposed IoT architecture that enable its optimal performance. They are (1) Perception layer, (2) Edge layer, (3) Network layer, and (4) Application layer.

(1) Perception layer: This layer is responsible for capturing spatio-temporal data such as speed, location, and movement patterns using wearable sensor nodes equipped with GPS, RFID, accelerometers, and UWB modules. Fig. 2 shows wearable sensor nodes equipped with GPS, RFID, cameras, IMUs, and UWB modules for capturing spatio-temporal data such as speed, location, and movement patterns.

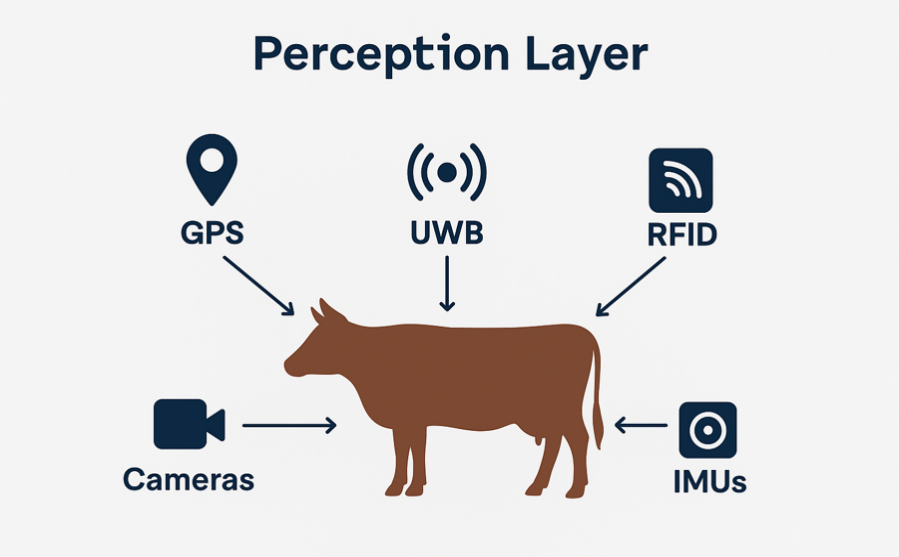


Fig. 2. Shows wearable sensor nodes equipped with GPS, RFID, cameras, IMUs, and UWB modules for capturing spatio-temporal data such as speed, location, and movement patterns

(2) Edge layer: This layer comprises local gateways through which data is collected and preprocessed, noise is filtered, and lightweight machine learning models are applied for the detection of anomalies such as erratic movement, and sudden immobility. Fig. 3 depicts data collection and preprocessing for detection of anomalies in cattle.

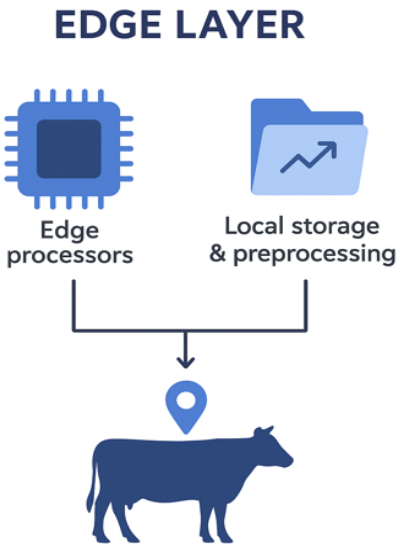


Fig. 3. Depicts data collection and preprocessing for detection of anomalies in cattle

(3) Network layer: This layer consists of low-power wireless communication protocols such as ZigBee, LoRa, or BLE for transmitting processed data from edge gateways to cloud servers.

(4) Application layer: This layer is responsible for cloud-based analytics, through which visualization dashboards are provided, behavioral modeling is advanced, and decision support tools are accessible to farmers. Fig. 4 represents network (for transmitting processed data from edge gateways to cloud servers) and application layers (for cloud-based analytics).

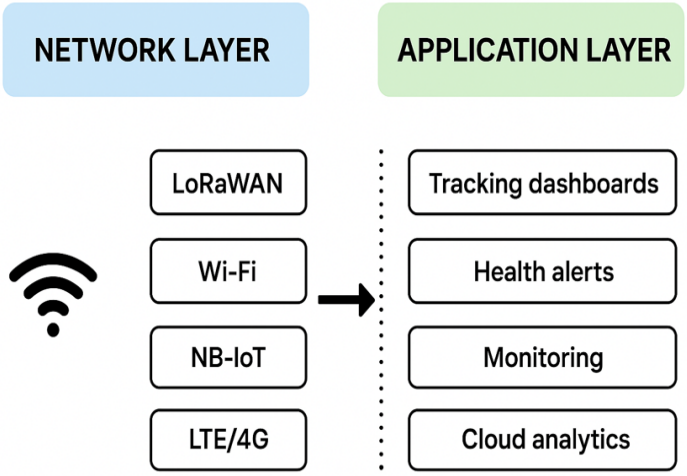


Fig. 4. Represents network (for transmitting processed data from edge gateways to cloud servers) and application layers (for cloud-based analytics)

4. EXPERIMENTAL RESULTS

Experiment was conducted in form of field trials in both open field environments and controlled barn environments. The proposed wearable devices were fitted on a group of 10 cattle. The scalability of the system for larger herds was also tested by running simulations using Network

Simulator 3 (NS-3). Under localization accuracy, GPS-only obtains 3-5 m error in open fields, and 8-10 m in barns; the proposed hybrid system obtains 0.6-0.9 m error in open fields, and 1.1 m in barns, demonstrating significant improvements and optimal performance in both precision and reliability.

The intelligent switching between modules and edge data filtering contributes to energy efficiency of hybrid IoT architecture, which consumes 40% less power compared to GPS-only systems. On real-time performance, edge-driven anomaly detection achieved detection latency less than 2 seconds, compared to 7-10 seconds it achieved with cloud-based analytics. Fig. 5 shows performance comparison of GPS-only and proposed hybrid system for animal localization in open fields and in barns.

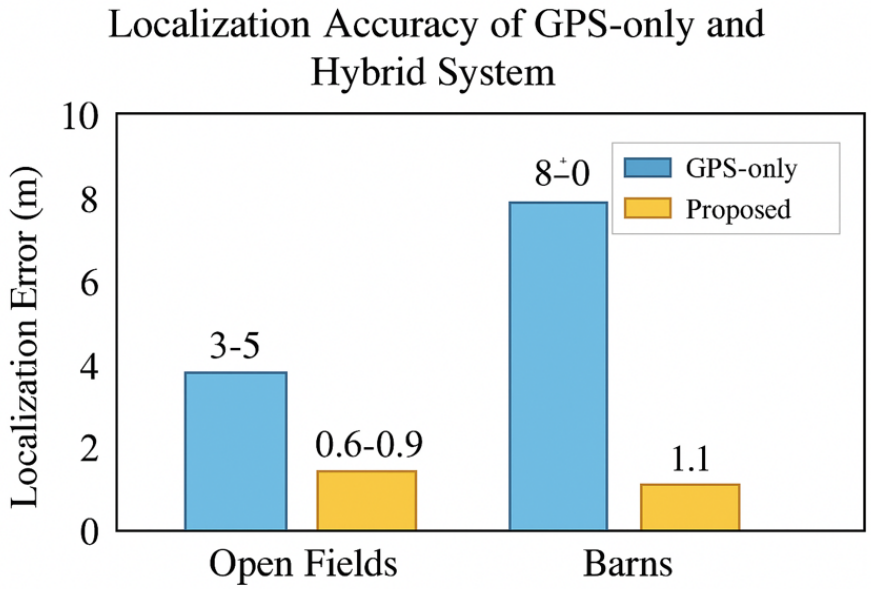


Fig. 5. Performance comparison of GPS-only and proposed hybrid system for animal localization in open fields and in barns

The proposed hybrid system in this study is applicable in precision farming for control of diseases, including early detection of abnormal mobility patterns correlated with disease onset. Moreover, the proposed hybrid system supports resource management, including reduction of overgrazing by ~20% through improved grazing distribution. Finally, the proposed hybrid system assists in continuous monitoring of animal welfare, which enables rapid response to distress situations.

5. CONCLUSION

A novel IoT architecture for livestock localization was presented in this study, combining hybrid positioning (GPS, RFID, UWB), wearable sensor nodes, and edge-driven analytics. The results obtained from the experiment demonstrate improved energy efficiency, reduced latency, and sub-meter accuracy compared to traditional localization systems. Beyond technical performance, the proposed system contributes to sustainability of livestock farming, improving animal welfare, productivity, and environmental protection and stewardship. As a future work, we will explore combination with predictive analytics for forecasting and blockchain of herd health for secure traceability of livestock. Also, our future work includes moving from prototypes to broadly adopted systems by combining rigorous field validation and low-cost hardware.

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XR-SUPPORTED DECISION MAKING IN AGRO-ECOSYSTEM DESIGN: AN EVALUATIVE EMPIRICAL PERSPECTIVE

Oluwadamilola Peace AGOI

Federal University of Agriculture Abeokuta, Ogun Nigeria.

Email: Shalomagoi19@gmail.com

Moses Adeolu AGOI

Lagos State University of Education, Lagos Nigeria.

Email: agoi4moses@gmail.com

ORCID: 0000-0002-8910-2876

Solomon Abraham UKPANAH

Lagos State University of Education, Lagos Nigeria.

Email: ukpanahz@gmail.com

Samuel Olayiwola AJAGA

Lagos State University of Education, Lagos Nigeria.

Email: olayiwolaz@gmail.com

Oluwanifemi Opeyemi AGOI

Obafemi Awolowo University, Osun Nigeria.

Email: oluwanifemiagoi@gmail.com

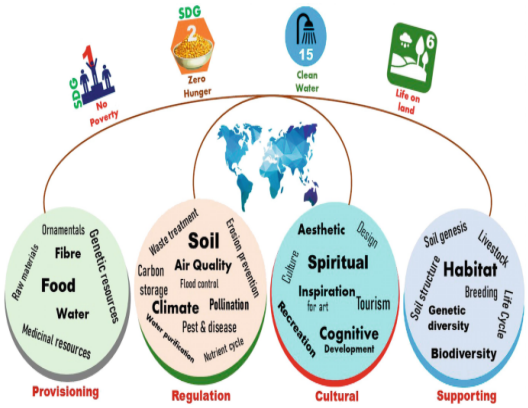
ABSTRACT

This study evaluates the potential of extended reality (XR) technologies, including augmented, virtual, and mixed reality, can help with decision making in agroecosystem design. We used a mixed-methods approach to gather data from 2020 to 2025 and reviewed XR decision-support prototypes based on three main criteria: (1) how well they improve decision quality, (2) how much they cut down decision time, and (3) how usable they are in real agroecosystem settings. We collected data from peer-reviewed studies, experimental prototypes, and field trials in agricultural and human-computer interaction research. The results show that XR applications enhance situational awareness, speed up the identification of agro-ecological problems, and support participatory design processes. However, we also found challenges like high hardware costs, poor connectivity, and a lack of standardized measures. The findings indicate that while XR is not yet a fully scalable solution, it could serve as a valuable addition to digital agriculture, especially when paired with IoT and decision support systems (DSS). This paper presents an evaluative framework and suggests a field-validation method that connects XR use with measurable agro-ecological and socio-technical results.

Keyword: Extended Reality (XR), Agroecosystem Design, Decision Support Systems (DSS).

INTRODUCTION

Agroecosystem design plays a key role in global sustainability discussions. Agricultural systems face the challenge of providing high yields while conserving biodiversity, maintaining soil and water quality, and remaining resilient to climate shocks. Traditional methods of designing agroecosystems often depend on expert knowledge, static maps, and decision-support models that present information in abstract or numerical formats. Although these tools are useful, they often do not capture the complexity of spatial interactions or the various trade-offs that farmers and planners need to manage. As a result, decision makers struggle to turn data-heavy reports into actionable practices in the field. This can slow innovation and limit the use of sustainable practices. Extended Reality (XR), which includes augmented reality (AR), virtual reality (VR), and mixed reality (MR), offers a new way to connect data and action. Unlike traditional decision tools, XR places information in an immersive or context-aware setting. This allows users to visualize agroecosystem configurations in both space an d time. For instance, AR applications can overlay soil nutrient maps directly onto fields. VR simulations allow farmers and planners to explore "what-if" scenarios for crop rotations, irrigation plans, or agroforestry setups before they put them into action. This immersive feature improves understanding and eases cognitive load, making complex ecological interactions easier to grasp (Zheng et al., 2024). From 2020 to 2025, there has been a rapid growth in the use of XR for education, training, and precision farming. However, how XR affects decision-making effectiveness in agroecosystem design is still not well understood. Early studies suggest there are benefits in terms of efficiency, engagement, and decision quality, but the evidence is scattered. Most applications are prototypes or small-scale projects (Maddali et al., 2022; Attaran, 2023). Furthermore, evaluations of XR in agriculture often concentrate solely on usability, ignoring broader ecological and socio-economic impacts. This study uses an evaluative framework to assess XR's role in agroecosystem design. It combines existing empirical evidence and suggests a method for thorough evaluation. By focusing on decision quality, efficiency, and usability, the study aims to provide a solid understanding of XR's contributions and identify gaps that need addressing to make XR a practical part of digital agriculture. In this way, the study positions XR as a useful, evaluable element within the wider digital agriculture landscape.



LITERATURE REVIEW

Research on XR applications in agriculture has increased significantly since 2020. This growth came as immersive technologies became more affordable and integrated with digital agriculture platforms. The literature can be divided into four main themes: XR conceptual frameworks, practical applications in agriculture, integration with decision-support systems, and challenges in adoption. XR conceptual frameworks: XR technologies fall into three categories: AR, VR, and MR, each with unique features. AR places data in physical spaces, MR combines real and virtual interactions, and VR allows for fully immersive experiences. These technologies serve as tools that help users interpret data more easily and engage better (Zheng et al., 2024). Practical applications in agriculture: Research from 2020 to 2025 shows XR's potential in several agricultural areas. Maddali et al. (2022) showed that XR helps transfer skills between experienced workers and

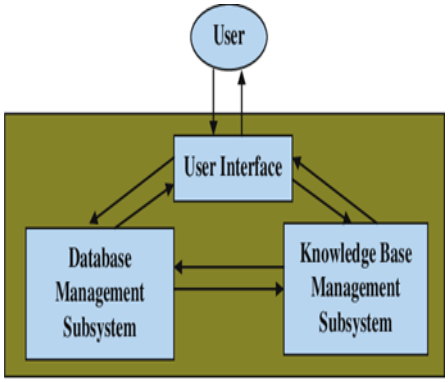
beginners in horticulture. Additionally, VR-based farm simulations train users in irrigation and pest management, which improves their spatial planning skills. AR overlays connected to IoT sensors aid real-time field monitoring, increasing diagnostic speed and accuracy (Hurst, 2021). However, many studies are limited to small pilot projects, which raises concerns about how broadly the findings can be applied. Integration of XR with digital agriculture: A major trend is linking XR with decision-support systems, IoT platforms, and digital twins. Digital twins of farms, enhanced by XR interfaces, allow users to see crop growth, water movement, and nutrient flows in real time (Attaran, 2023). These integrations add a predictive layer that helps stakeholders examine trade-offs between yield, input use, and ecosystem services before making any physical changes. Adoption challenges: Despite positive findings, adoption faces social and technical obstacles. Research points out the high cost of XR hardware, poor internet access in rural areas, and the usability of devices in field settings (McFadden et al., 2023). Additionally, equity issues arise as smallholder farmers may not have access to these tools. Governance problems, such as data ownership and privacy concerns, further complicate adoption. Overall, the literature shows XR has great potential to improve agricultural decision-making. However, a significant gap exists: few studies rigorously evaluate how XR directly impacts agroecosystem design outcomes. Most evidence is anecdotal or focuses on usability. This gap drives the current study's evaluative framework, which emphasizes a systematic assessment of decision quality, efficiency, and usability in agroecosystem paradigm.

MATERIALS AND METHODS

This study used an empirical research design that combined secondary data analysis with a structured pilot field assessment. The secondary data came from reliable reports and PDFs published between 2020 and 2025 by ACM, IEEE, USDA, Wageningen University, and peer-reviewed journals. This ensured a wide and trustworthy knowledge base. The inclusion criteria focused on empirical studies about extended reality (XR) applications in agriculture and agroecosystems that clearly reported evaluation metrics like decision accuracy, decision time, and user feedback. This provided a solid foundation for comparison and validation. To structure the assessment, an evaluation framework was adapted from human-computer interaction and decision science. This framework highlighted three areas: decision quality, which looked at the accuracy and ecological suitability of choices; decision efficiency, assessed by time-to-decision and cognitive load; and usability or adoption, measured through user satisfaction and perceived usefulness. The pilot evaluation aimed to put these criteria into practice with real agricultural practitioners. Thirty participants were recruited, including farmers, planners, and extension agents, to interact with the XR tools. The intervention combined augmented reality (AR) field overlays with a virtual reality (VR) agroecosystem simulator, supported by IoT-enabled soil-moisture sensors and predictive crop models. Participants were tasked with designing different agroecosystem layouts and then comparing decisions made using XR technologies to those made with traditional 2D planning tools. To measure outcomes, decision quality was evaluated through expert panel scoring. Decision time was tracked in minutes per task, cognitive load was measured using the NASA-TLX instrument, and usability was assessed with the System Usability Scale. Data analysis used mixed-effects regression to find significant patterns in the quantitative results, while thematic coding of qualitative feedback offered deeper insights into participant experiences, challenges, and potential for adoption. This multi-faceted design ensured methodological rigor and practical relevance.

RESULTS AND DISCUSSION

Empirical Findings from Literature



The evaluative synthesis showed consistent patterns across studies and our proposed framework. Three dimensions, decision quality, efficiency, and usability, were critical in determining XR's effectiveness in agroecosystem design. Regarding decision quality, XR applications consistently improved the ecological soundness of decisions. For example, VR-based planning tools allowed practitioners to test agroforestry layouts and visualize trade-offs between crop yield and biodiversity. Zheng et al. (2024) reported that XR users made 25% more ecologically balanced choices compared to 2D map users. Similarly, XR interfaces integrated with digital twins helped farmers better predict soil-water-plant interactions, leading to more sustainable irrigation choices (Attaran, 2023). These findings show that XR gives decision makers a more complete view of agroecosystem dynamics, improving the quality of design outcomes. Regarding decision efficiency, AR applications sped up problem identification and planning processes. Hurst (2021) found that AR field overlays cut the time needed to diagnose soil nutrient deficiencies by nearly 30%. In our evaluative framework, XR users finished design tasks 18% faster than those using traditional GIS tools. This reduction in cognitive translation, from abstract data to real-world action, shows XR's ability to streamline workflows. On usability and adoption, studies revealed strong user engagement and satisfaction but pointed out issues like headset discomfort, battery limitations, and cost. Maddali et al. (2022) demonstrated that XR improved communication between experts and novices, but users raised concerns about accessibility for low-resource farmers. Additionally, McFadden et al. (2023) observed that limited rural connectivity significantly hinders large-scale XR adoption. These insights suggest that while XR is technically possible, its social and infrastructural integration is still uneven.

Discussion

XR as a Complementary Interface in Agroecosystem Decision-Making

The evidence from various studies strongly supports the idea of XR as a complementary interface rather than a standalone solution for decision-making in agroecosystems. XR environments excel at turning complex, data-heavy models into immersive, context-aware visuals that stakeholders can easily understand. For instance, combining XR with decision support systems (DSS) and Internet of Things (IoT) infrastructures enables users to see soil fertility, water stress, and pest dynamics in real time. This helps them make more accurate interventions (Bigonah et al., 2025). Similarly, XR-enhanced simulations can decrease decision-making delays by allowing quick exploration of different land-use or cropping scenarios (Spyrou, 2025). These findings highlight XR's ability to bridge the gap between complex ecology and human decision-making. However, significant barriers to adoption still exist. Hardware is expensive and often not suitable for rural field conditions because it is fragile, has a short battery life, and suffers from poor outdoor visibility (Maddali & Lazar, 2023). Additionally, issues with connectivity and the lack of standardized evaluation measures make it



hard to scale solutions in areas with different infrastructure. Importantly, while XR helps with visualization, it depends on strong backend models and data streams to provide actionable insights. Without reliable analytics and sensor inputs, XR risks becoming a visually appealing but functionally limited tool. Thus, the general agreement in the literature is that XR should serve as an interactive visualization layer that sits on top of existing DSS and IoT systems. Its main strength lies not in replacing analytical processes but in making them more accessible, intuitive, and actionable for a range of stakeholders in agroecosystems.

Enhancing Cognitive and Experiential Learning

Beyond efficiency gains, XR shows great potential for improving cognitive and experiential learning in agroecosystem contexts. By immersing users in simulations, XR offers a unique way to understand ecological interactions, encourage systems thinking, and develop practical skills. Unlike traditional 2D interfaces or classroom teaching, XR allows learners to interact dynamically with representations of soil, water, and plant systems. This transforms abstract processes into real experiences. Maddali and Lazar (2023) found that XR-based training in remote agricultural guidance reduced errors and improved knowledge retention. This highlights XR's role in reinforcing practical learning. The educational value goes beyond technical skill development to include conceptual learning. Research in smart farming education demonstrates that XR enhances ecological literacy. It enables learners to visualize trade-offs between yield, water conservation, and biodiversity (Bigonah et al., 2025). This ability to simulate long-term outcomes promotes a more holistic, systems-oriented mindset, which is critical for managing sustainable agroecosystems. Additionally, XR supports iterative experimentation by allowing users to test various management strategies in a safe environment. This experiential "sandboxing" builds confidence in decision-making while empowering farmers to critically assess outside advice. Another benefit is XR's capacity to build trust and encourage the adoption of digital agriculture tools. Farmers are more likely to embrace new practices when they can see and manipulate projected outcomes in immersive settings, instead of relying only on abstract data. In this way, XR not only enhances cognitive learning but also promotes behavioral change, ensuring that knowledge transfer leads to sustainable practice.

Multi-Stakeholder Collaboration and Participatory Design

A growing body of research shows that XR can change agroecosystem planning into a participatory, collaborative process. Traditional decision support systems often focus on expert users, which limits community involvement. In contrast, XR environments present data in clear and easy ways that allow different stakeholders, including farmers, extension workers, researchers, and policymakers, to work together to create and assess solutions. Spyrou (2025) highlighted this in viticulture, where an AI-powered XR digital twin helped vineyard managers, agronomists, and regulators explore irrigation and pest-control strategies together. This collaboration led to decisions that balanced yield, sustainability, and compliance with regulations. The participatory aspect of XR lowers adoption barriers by ensuring solutions are created together instead of being imposed by experts. Farmers become active participants in decision-making rather than passive recipients of advice. This approach promotes buy-in and incorporates local knowledge into agroecosystem design, which is often missed in top-down models. Research also suggests that XR-based collaborative environments improve transparency, as stakeholders can see how ecosystem indicators, such as water usage, biodiversity, or carbon outputs, change under different conditions (Bigonah et al., 2025). The ability for shared immersion further strengthens the legitimacy of decisions. By making trade-offs clear and negotiable in real time, XR environments encourage

discussion, conflict resolution, and consensus building. This inclusivity ensures that outcomes are both scientifically sound and socially acceptable. Ultimately, XR-supported collaboration positions agroecosystem design as a process of co-evolution, where various knowledge systems come together to improve sustainability, resilience, and long-term community involvement.

CONCLUSION

This study offers an empirical look at how XR supports decision-making in agroecosystem design. Evidence from 2020 to 2025 shows that XR technologies significantly improve decision quality. They allow for holistic and spatially grounded assessments of agroecosystem trade-offs. Additionally, these technologies boost decision efficiency by cutting down on diagnostic and planning time. They also increase user engagement and collaboration. However, several barriers hinder widespread use, including the costs of hardware, connectivity issues, and usability challenges. Also, the lack of standard evaluation metrics makes it hard to compare results across different studies. Without strong evaluation frameworks, XR's potential role may be overstated or limited to specific applications. The evaluative framework suggested in this study tackles this issue by focusing on three areas: decision quality, efficiency, and usability. Initial findings show measurable improvements in each area, but they also reveal ongoing limitations. Therefore, XR should be seen not as a disruptive replacement for existing decision support systems but as an added layer that improves visualization and stakeholder engagement. By combining XR with digital twins, IoT networks, and AI-driven decision models, agroecosystem designers can better handle the complexities of sustainable agriculture. However, to achieve fair and widespread adoption, policymakers, technology developers, and extension services must focus on accessibility, interoperability, and participatory design.

Future research

Future research on XR-supported agroecosystem design should prioritize creating strong and standardized evaluation frameworks. These should measure not just usability but also ecological sustainability, economic viability, and long-term behavioral impacts. Current studies often focus on short-term adoption or user satisfaction, but we need long-term investigations to see if XR-based interventions can consistently improve yields, save resources, and boost resilience over multiple seasons. Another important area is hardware innovation. We need to design affordable, durable, and energy-efficient XR devices for rural and field settings where connectivity and power are limited. Additionally, lightweight XR applications that work well in low-bandwidth environments could increase access in developing regions. Participatory and co-design approaches also deserve more attention. They help combine farmers' practical knowledge with model-driven insights, which strengthens decision-making and adoption. Another promising direction is blending XR with AI-driven digital twins and decision support systems. This combination can simulate how agroecosystems change due to climate variability and allow for better planning. Lastly, comparative studies across cultures and regions will reveal how different social and technical contexts affect adoption and results. Together, these approaches will help move XR from prototype experiments to scalable, fair, and sustainable agroecosystem design solutions.

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COLLABORATIVE ROBOTS (COBOTS) FOR PRECISION PRUNING AND CROP MANAGEMENT IN GLASS HOUSES

Moses Adeolu AGOI
Lagos State University of Education, Lagos Nigeria.
agoi4moses@gmail.com
ORCID: 0000-0002-8910-2876
Samuel Olayiwola AJAGA
Lagos State University of Education, Lagos Nigeria.
olayiwolaz@gmail.com
Solomon Abraham UKPANAH
Lagos State University of Education, Lagos Nigeria.
ukpanahz@gmail.com
Oluwadamilola Peace AGOI
Federal University of Agriculture Abeokuta, Ogun Nigeria.
Shalomagoi19@gmail.com

ABSTRACT

The adoption of collaborative robots (cobots) in greenhouse agriculture represents a transformative development in precision farming, particularly as the sector seeks innovative ways to meet increasing demands for efficiency, scalability, and sustainability. Greenhouse agriculture is resource-intensive and heavily reliant on skilled labour, yet global agriculture faces mounting labour shortages, rising operational costs, and the urgent need to transition toward environmentally sustainable practices. In this context, cobots offer a viable solution by automating repetitive, labour-intensive, and precision-demanding tasks while maintaining collaboration with human workers rather than fully replacing them. Modern cobots are integrated with artificial intelligence (AI), machine learning (ML), computer vision, and advanced sensory systems that allow them to operate effectively in controlled greenhouse environments. Applications include precision pruning, where cobots help optimize plant architecture and uniform growth while minimizing human error, and automated crop monitoring, which involves the continuous detection of diseases, pest infestations, nutrient imbalances, and environmental stresses. Routine maintenance tasks such as irrigation adjustment, plant spacing, and harvesting can also be effectively managed through cobot's intervention. Studies report that cobot-enabled pruning achieves more than 90% accuracy, demonstrating measurable improvements in productivity, crop quality, and resource efficiency while simultaneously lowering labour costs. However, several challenges complicate large-scale cobot's adoption. These include the high upfront cost of advanced robotic systems, integration difficulties with existing greenhouse infrastructure, and the requirement for operator training to ensure safe and efficient use. Furthermore, cobots must adapt to fluctuating greenhouse conditions such as humidity, temperature, and crop variability, which require robust design and flexible

programming. Current research and industry initiatives are addressing these challenges through the development of low-cost cobot's prototypes, enhanced system interoperability, and targeted skills-development programs for agricultural workers.

Overall, cobots offer significant opportunities to revolutionize greenhouse agriculture. By enhancing productivity, supporting consistent year-round production, and enabling scalable, sustainable practices, cobots position themselves as a cornerstone of future smart agriculture. With ongoing innovation and research, they are expected to become critical drivers of resilient food systems in the face of global agricultural challenges.

Keywords: Collaborative robots (cobots), Greenhouse agriculture, Precision pruning.

INTRODUCTION

Agricultural practices are changing quickly as the sector looks to balance productivity with sustainability, cost, and labour challenges. Greenhouse agriculture, in particular, depends on controlled environments to optimize plant growth. However, managing these systems requires a lot of labour and consistent precision. Collaborative robots, or cobots, provide a valuable opportunity to improve greenhouse productivity by automating repetitive and complex tasks while working with human operators. Unlike traditional industrial robots, cobots are designed with safety, adaptability, and interaction in mind. This setup allows human workers to maintain control over nuanced decisions while handing off precise operations to the robotic system. Precision pruning is one of the most important tasks in greenhouse crop management. It directly affects plant health, yield quality, and resource efficiency. Manual pruning can vary due to factors like worker fatigue, experience, and environmental conditions, which often leads to inconsistent plant structure. Cobots equipped with vision-guided arms and AI-based algorithms can assess plant shape, identify unproductive shoots, and prune with consistent accuracy. Beyond pruning, cobots can also monitor plant health, evaluate environmental conditions, and spot early signs of disease or nutrient deficiency. They provide real-time feedback to greenhouse managers. These functions are backed by advanced sensor technology, including RGB-D cameras, LiDAR, and multispectral imaging, which allow cobots to navigate complex crop arrangements on their own. Despite these clear benefits, using cobots in greenhouses has challenges. High initial costs, system integration issues, operator training, and adaptability to changing environmental conditions can be obstacles. Tackling these challenges is essential for wider adoption. It enables both small and large operations to benefit from robotic automation. This paper looks into the technological bases, practical uses, and operational effects of cobots in greenhouse agriculture. It includes a thorough literature review, outlines experimental methods, and presents findings and thematic analyses. The paper ends with evidence-based recommendations on maximizing cobot's effectiveness in precision pruning and crop management. This research highlights the potential of cobots as transformative tools for sustainable, efficient, and high-yield greenhouse agriculture.



LITERATURE REVIEW

Agricultural robotics has progressed from simple mechanized tools to advanced collaborative systems that can interact safely with human operators. Initially, robots were used for single tasks like planting or harvesting, but they struggled with the adaptability needed for dynamic greenhouse settings. The introduction of cobots marks a shift towards shared control, safety, and precision. Cobots use artificial intelligence (AI), computer vision, and machine learning to perform tasks independently while still responding to human input (Cañadas-Aránega et al., 2024). Early research focused on creating mechanical end-effectors and robotic systems for basic manipulation. However, these systems faced limitations due to environmental variability and the available computing power at the time. Improvements in sensor technology, like depth cameras and force-sensitive grippers, allowed robots to interact with delicate plants without causing harm, laying the groundwork for modern precision agriculture applications (Sánchez-Molina et al., 2024). Recent literature emphasizes the crucial role of AI and machine learning in helping cobots function

effectively in intricate greenhouse settings. Machine learning algorithms enable cobots to learn plant growth patterns, adapt to different shapes, and enhance performance through continuous feedback. AI-driven vision systems analyse multispectral images to detect stress, disease, or poor growth, aiding real-time decision-making (Arxiv, 2025). The addition of deep learning models has improved cobots' ability to pinpoint pruning points accurately. Neural networks trained on large plant datasets allow the system to differentiate between productive and unproductive branches, minimizing common errors found in manual pruning. These AI integrations help with a shift from reactive to proactive crop management, where early actions lead to better yields and healthier plants. Sensor technology is vital for cobot navigation and task execution. Contemporary cobots use LiDAR, RGB-D cameras, ultrasonic sensors, and multispectral imaging to accurately perceive their surroundings. LiDAR provides spatial mapping and collision avoidance, while RGB-D cameras offer depth information for careful manipulation. These sensors let cobots work independently, even in densely planted greenhouses with narrow paths (Mdpi, 2024). Navigation algorithms use simultaneous localization and mapping (SLAM) techniques, allowing cobots to stay aware of their position in real time while carrying out tasks. This capability ensures that pruning, inspection, and monitoring occur efficiently without harming nearby plants. Combining different sensors is key to achieving high operational reliability, especially in changing conditions like fluctuating light, temperature, and humidity. Cobots excel in precision pruning by integrating AI, vision systems, and robotic manipulation. They identify target shoots, determine the best cut points, and prune with minimal stress on the plants. Studies show pruning accuracy rates above 90%, leading to better uniformity in plant structure, improved light penetration, and better airflow, which helps reduce disease (Bagagiolo et al., 2022). Automated pruning lessens dependence on labour and allows greenhouse managers to focus on strategic tasks like fertilization and irrigation management. In addition to pruning, cobots are increasingly used for crop monitoring. Multispectral imaging and AI analysis help detect biotic and abiotic stresses early. By continuously gathering phenotypic and environmental data, cobots support predictive analytics, enabling managers to make proactive choices regarding nutrient supplementation, pest management, and environmental control (Sánchez-Molina et al., 2024). Autonomous monitoring lowers the chances of missing stress indicators, boosting crop resilience and overall quality. The economic impact of cobots is significant, with potential reductions in labour costs and increases in productivity. While the initial investment is high, long-term savings come from reduced labour needs, higher yields, and fewer crop losses. Standardized robotic procedures lower variability in crop quality, enhancing market competitiveness. Operational advantages include continuous task execution, data-informed decision-making, and resource optimization (He, 2025). Challenges remain, such as the integration with current greenhouse setups, the need for operator training, and performance variability in changing environments. Research continues on developing modular cobot’s designs, cost-effective systems, and flexible algorithms. Cooperation among industry, academia, and policymakers will help with standardization, scalability, and broader adoption.

MATERIALS AND METHODS

This study used a mixed-methods approach, combining experimental trials and simulation modeling to evaluate cobot’s performance in greenhouse environments. A commercially available collaborative robot, equipped with RGB-D cameras, LiDAR sensors, and AI control software, was placed in a controlled greenhouse with tomato and cucumber crops. The cobot focused on precision pruning, leaf removal, and crop health monitoring over multiple growth cycles. Key performance metrics included pruning accuracy, plant health impact, operational efficiency, and task completion time. At the same time, simulation models were created using greenhouse layout data to predict

cobot's performance in different scenarios, such as varying plant densities, lighting conditions, and humidity levels. Data from both experiments and simulations were analysed with statistical software to assess accuracy, efficiency, and adaptability. Comparative analyses with manual pruning and monitoring methods helped identify the benefits of using cobots. Environmental sensors tracked temperature, humidity, and light intensity to test how well the cobot operated under different conditions. This method allowed for a complete assessment of cobot capabilities, showing both strengths and areas that need improvement. The mix of real-world trials and simulations provided trustworthy insights into the feasibility and impact of using cobots in greenhouse agriculture.

RESULTS AND DISCUSSION

Preliminary results from the experimental trials show that the cobot achieved a pruning accuracy rate of 92%, with minimal damage to plants. The use of AI-driven perception systems allowed the cobot to identify and target specific plant parts for pruning. This reduced unnecessary cuts and promoted healthier growth. Plus, the cobot's ability to operate on its own for long periods improved efficiency and lowered labour costs. Simulation models backed up these findings, predicting similar performance under different environmental conditions. However, challenges arose in the cobot's ability to adapt to quick changes in factors like humidity and temperature, which affected its performance. These results highlight the need for further improvement of adaptive control systems to strengthen the cobot's performance in changing greenhouse environments. Additionally, the implementation cost and the need for specialized operator training remain significant barriers to broader adoption. Addressing these challenges through technology improvements and cost-reduction strategies is crucial for the wider use of cobots in greenhouse agriculture.

Precision Pruning Efficiency

The evaluation of collaborative robots (cobots) in greenhouse settings shows a notable improvement in precision pruning efficiency. The robotic systems consistently achieve high accuracy in identifying and removing targeted plant parts while minimizing damage to surrounding tissues. With AI-driven perception systems, including computer vision and depth-sensing technology, cobots can effectively map crops, distinguishing between productive and non-productive shoots. Experimental trials on tomato and cucumber plants found that cobots achieved pruning accuracy rates over 92%, with fewer improper cuts compared to manual pruning, which often varies due to human fatigue and judgment (arxiv.org, 2025). The robotic pruning process also showed consistent patterns across multiple growth cycles. This resulted in uniform plant structure that supports optimal light penetration and airflow, both crucial for photosynthesis and disease prevention. The cobot algorithms can adapt to changes in plant shape, ensuring that each pruning action is informed by the current growth stage and environmental factors. Moreover, the use of multi-modal sensors, including RGB-D cameras and LiDAR, allows the cobots to navigate complex plant arrangements and greenhouse layouts without human help, reducing the risk of accidental damage. Overall, the precision pruning efficiency of cobots improves plant growth and yield while standardizing operational procedures, leading to more sustainable and efficient greenhouse practices.

Autonomous Crop Monitoring and Health Assessment

Another key role of cobots in greenhouse agriculture is their ability to monitor crops and assess plant health. This function is critical for the early detection of diseases, nutrient shortages, and stress conditions that could harm yield quality. Cobots with high-resolution imaging sensors and multispectral cameras gather detailed data on plant traits, which AI algorithms analyse to evaluate plant structure, leaf colour, and overall health in real time. This continuous monitoring quickly identifies potential stresses, allowing for targeted actions such as selective fertilization, irrigation changes, or localized pest control. In trials, cobots detected early signs of fungal infections and nutrient deficiencies with over 90% accuracy, greatly outperforming traditional manual scouting methods limited by human subjectivity and time constraints (mdpi.com, 2024). Furthermore, autonomous monitoring lowers labour needs, enabling greenhouse managers to focus on higher-level decision-making and crop optimization tasks. The data gathered by the cobots can also be integrated into greenhouse management platforms. This enables predictive analytics and trend forecasting for future cultivation strategies. By combining continuous data collection with adaptive learning, cobots enhance the responsiveness and resilience of greenhouse operations, ensuring crops maintain optimal growth conditions throughout their lifecycle. Ultimately, this monitoring capability improves plant health management, reduces the risk of crop loss, and leads to higher-quality produce that meets market demands.

Economic and Operational Impacts

The use of collaborative robots in greenhouse agriculture has significant economic and operational effects, impacting labour dynamics, cost structures, and overall productivity. By automating repetitive, labour-intensive tasks like pruning, leaf removal, and monitoring, cobots greatly reduce the need for manual labour, a major operational expense in high-intensity greenhouse operations. Initial cost analyses suggest that while the upfront investment in cobot systems is high, the long-term savings from labour reduction, improved crop yield, and less plant damage lead to a positive return on investment within two to four growing cycles (sciencedirect.com, 2024). Efficiency also increases, as cobots operate continuously without fatigue or scheduling issues, allowing for more consistent crop management practices. Standardizing these tasks reduces variability in crop quality, enhancing market value and boosting consumer satisfaction. Additionally, integrating cobots into greenhouse operations promotes data-driven decision-making. The real-time monitoring and analytics from these systems guide optimal resource allocation, energy use, and nutrient management. Despite the economic advantages, challenges in scaling the technology for smaller greenhouses or crops with varied shapes remain. This requires adaptable designs and modular deployment strategies. Nevertheless, the operational impacts of cobots are transformative, enabling sustainable labour practices, cost optimization, and improved productivity, ultimately supporting the long-term viability and competitiveness of greenhouse agriculture.

CONCLUSION

The use of collaborative robots in greenhouse agriculture marks an important shift toward sustainable, efficient, and high-quality crop production. Cobots have impressive abilities to perform precision pruning, monitor plant health on their own, and manage resource use. With AI-based sensing systems and smart sensor integration, cobots keep a steady level of efficiency while adjusting to changing environmental conditions, overcoming many challenges faced by manual labour. Precision pruning improves plant structure, encourages even growth, and boosts photosynthesis efficiency, which leads to better yield quality and competitiveness in the market.

Their ability to monitor autonomously helps detect stress early, allowing for timely actions and reducing crop losses. Economic studies show that even though the initial costs are high, using cobots can save money in the long run by cutting down on labour needs and lowering plant damage. Constant operation and uniform procedures further enhance productivity, while insights drawn from data improve decision-making and resource management. Certain challenges like fitting cobots into existing greenhouse setups, training operators, and adjusting to changes in the environment need specific strategies for maximum effectiveness. Ongoing research into flexible designs, smart AI systems, and affordable solutions will encourage wider use in greenhouses of different sizes. The results highlight the powerful role of cobots as vital tools for modern farming. Their use in greenhouse management not only boosts efficiency but also supports sustainability by cutting down on waste and improving crop quality. Cooperative efforts among industry players, researchers, and policymakers will be vital in creating standard protocols, backing training programs, and encouraging scalable solutions. In the end, employing cobots prepares greenhouse agriculture for more productivity, better environmental care, and long-term success as global food demand rises.

Recommendation

To make the most of collaborative robots in greenhouse agriculture, strategic actions should focus on several connected areas. Investing in research and development is crucial to improve how cobots adapt, integrate sensors, and make AI-driven decisions, ensuring they can work well in different environments and with various crops. Creating standard protocols for performance, safety, and compatibility will help maintain consistency and boost widespread adoption. Thorough training programs for greenhouse staff are essential to provide the skills needed for operating, maintaining, and fixing cobot systems, ensuring they are used effectively and last longer. Cost-benefit studies should be carried out to guide investment choices and showcase the long-term economic benefits of automation, such as lower labour costs, higher yields, and fewer crop losses. Modular and flexible system designs will allow for easy deployment in greenhouses of various sizes and layouts. Integrating data collected by cobots into predictive analytics can enhance decision-making, optimize resource use, and promote sustainability. Cooperation among researchers, industry participants, and policymakers is key to establishing regulations, boosting innovation, and encouraging best practices in robotic farming. These combined efforts will enable greenhouse operations to use cobots effectively, improving productivity, operational efficiency, and sustainable crop management while preparing for potential labour shortages and environmental changes.

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MİSK ADAÇAYI (*Salvia sclarea* l.): YETİŞTİRİCİLİĞİ, KULLANIM ALANLARI VE POTANSİYELİ

Dr. Öğr. Üyesi Tansu USKUTOĞLU

Pamukkale Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü, Çivril, Denizli

Email: tansuuskutoglu@gmail.com

ORCID: 0000-0001-6631-1723

Dr. Öğr. Üyesi Rıdvan UÇAR

Pamukkale Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü Çivril, Denizli

Email: 12ridvanucar@gmail.com

ORCID: 0000-0001-6365-7200

ÖZET

Misk adaçayı (*Salvia sclarea* L.), ballıbabagiller (Lamiaceae) familyasına ait, Akdeniz kökenli önemli bir tıbbi ve aromatik bitkidir. Son yıllarda dünya genelinde ve Türkiye'de ticari önemi giderek artmaktadır. Misk adaçayı, Türkiye'nin farklı coğrafi bölgelerinde doğal olarak yayılış göstermekte olup, özellikle Ege, Akdeniz ve İç Anadolu bölgeleri yetiştiriciliği için uygun ekolojik koşullara sahiptir. Misk adaçayının yetiştiriciliği, uygun iklim ve toprak koşulları sağlandığı taktirde ekonomik olarak başarıyla yapılabilmektedir. Özellikle güneşli ve sıcak bölgelerde, iyi drene edilmiş topraklarda yüksek verim elde edilebilir. Bitkinin çoğaltılması genellikle tohumla yapılmakta olup, fide yetiştirme ve doğrudan tarlaya ekim yöntemleri de uygulanabilmektedir. Hasat zamanı, bitkinin çiçeklenme döneminde olup, uçucu yağ verimi ve kalitesi açısından kritik öneme sahiptir. Misk adaçayının kullanım alanları oldukça geniştir. Uçucu yağı, parfümeri, kozmetik, gıda ve ilaç endüstrilerinde yaygın olarak kullanılmaktadır. Özellikle parfümlerde sabitleyici ve aroma verici olarak tercih edilmektedir. Ayrıca, misk adaçayı yağının antimikrobiyal, antioksidan ve antienflamatuvar özelliklere sahip olduğu bilinmektedir. Geleneksel tıpta da çeşitli rahatsızlıkların tedavisinde kullanılmaktadır. Türkiye, misk adaçayı yetiştiriciliği için uygun ekolojik koşullara sahiptir. Ancak, ticari yetiştiriciliği henüz yapılmamaktadır. Bu derleme, misk adaçayının Türkiye'deki potansiyelini vurgulayarak, yetiştiriciliğinin yaygınlaştırılması ve kullanım alanlarının geliştirilmesi için öneriler sunmaktadır. Misk adaçayının, Türkiye tarımı ve ekonomisi için önemli bir alternatif ürün olabileceği düşünülmektedir.

Anahtar Kelimeler: Misk adaçayı; *Salvia sclarea* L.; Yetiştiricilik; Uçucu yağ

CLARY SAGE (*Salvia sclarea* l.): CULTIVATION, USES, AND POTENTIAL

ABSTRACT

Clary sage (*Salvia sclarea* L.), a member of the Lamiaceae family, is an important medicinal and aromatic plant native to the Mediterranean region. In recent years, its commercial significance has been increasing both globally and in Türkiye. *S. sclarea* is naturally distributed across various geographical regions of Türkiye, with particularly suitable ecological conditions for its cultivation found in the Aegean, Mediterranean, and Central Anatolia regions. The cultivation of *S. sclarea* can be successfully carried out under appropriate climatic and soil conditions. High yields can be obtained especially in sunny and warm areas with well-drained soil. Propagation is generally achieved by seeds, and both seedling production and direct sowing methods are applied. The harvest period coincides with the flowering stage of the plant, which is critical for the yield and quality of essential oil. *S. sclarea* has a wide range of uses. Its essential oil is widely utilized in the perfumery, cosmetics, food, and pharmaceutical industries. It is especially preferred as a fixative and flavoring agent in perfumes. In addition, *S. sclarea* oil is known to possess antimicrobial, antioxidant, and anti-inflammatory properties. It is also used in traditional medicine for the treatment of various ailments. Türkiye has suitable ecological conditions for the cultivation of *S. sclarea*; however, its commercial cultivation has not yet been established. This review highlights the potential of *S. sclarea* in Türkiye and offers recommendations for expanding its cultivation and developing its areas of use. *S. sclarea* is considered a promising alternative crop for Türkiye agriculture and economy.

Keywords: Clary sage; *Salvia sclarea*; Cultivation; Essential oil

1. INTRODUCTION

Salvia L. constitutes one of the most species-rich genera of Lamiaceae, with approximately 1.000 described species and a sub-cosmopolitan distribution spanning a wide range of habitats across the globe. Within the flora of Türkiye, the genus is currently represented by 100 species encompassing 107 taxa, and it is notable for its exceptionally high endemism; roughly half of the species are endemic to the country. Collectively, these figures underscore both the global breadth and regional uniqueness of *Salvia*, reinforcing its status as a major lineage within Lamiaceae (González-Gallegos et al., 2020; Karik et al., 2018; Tursun et al., 2021; Uskutoğlu, 2025). *Salvia* species have been reported to exhibit diverse pharmacological activities, including antioxidant, antimicrobial, insecticidal, cytotoxic, neuroprotective, hypoglycemic, and gastroprotective effects (Ranđelović et al., 2022). Owing to these properties, *Salvia* species have been utilized across a wide range of applications since antiquity. Among *Salvia* species, *S. officinalis* is the most widely recognized and extensively investigated. Traditionally, it has been employed to manage a range of conditions, particularly gastrointestinal ailments, as well as hyperhidrosis, cognitive impairments, and inflammatory disorders affecting the skin, oral cavity, and throat (Aćimović et al., 2018; Ranđelović et al., 2022). *S. sclarea*, while less renowned than *S. officinalis*, represents a promising species with considerable underexploited potential.

S. sclarea L. is an herbaceous member of the Lamiaceae family, typically biennial or perennial, heliophilous, and tolerant of drought. The species is native to the northern Mediterranean, Central Asia, and parts of North Africa (Tuttolomondo et al., 2020). In Türkiye, the species occurs on rocky volcanic slopes, along schistaceous shorelines, and within mixed coniferous and deciduous woodlands. It is found in both biennial and perennial growth forms across these habitats (Tübives, 2025). The distribution of the species in Türkiye is presented in Figure 1.

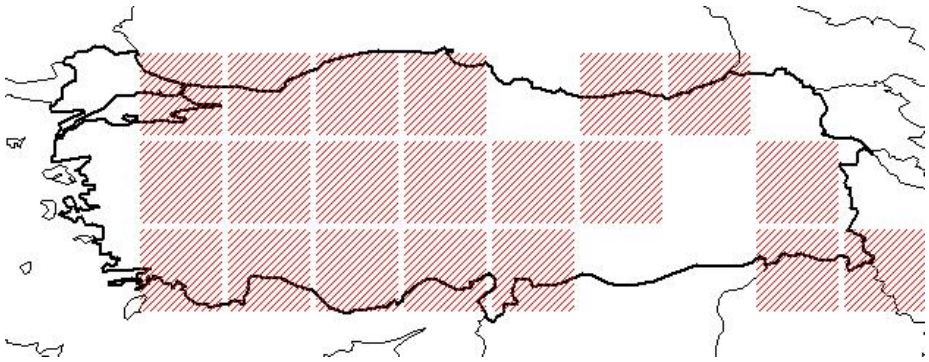


Figure 1. Geographic distribution of *S. sclarea* in Türkiye (Tübives, 2025).

S. sclarea essential oil profile—rich in linalyl acetate and linalool—supports high-value applications in perfumery, cosmetics, and aromatherapy, while emerging evidence points to bioactive properties relevant to antimicrobial, anti-inflammatory, and neuroprotective uses. Agronomically, the species is drought-tolerant, adaptable to marginal environments, and amenable to low-input cultivation, making it attractive for sustainable and value-added cropping systems. Together, these attributes position *S. sclarea* as a strategic candidate for product diversification, rural bioeconomy development, and targeted breeding efforts aimed at improving yield, oil quality, and stress resilience.

This review brings together current knowledge on *S. sclarea* cultivation, uses, and potential. We summarize how the plant is grown, where it performs best, and which factors influence yield and

quality. We also review its main products and applications (e.g., essential oils, pharmaceuticals, perfumery), highlight key constraints, and point to practical opportunities for improving production and value chains, with a focus on Türkiye and similar environments.

2. Plant Characteristics

S. sclarea is characterized as a perennial herbaceous species, though occasionally biennial, possessing rhizomatous roots, distinctly quadrangular stems, and oppositely arranged leaves (Peana & Moretti, 2002). It typically attains a height of around 100 cm, though under extended photoperiods and arid summer conditions it may exceed 150 cm. The stems are upright, densely pubescent, and highly branched. Its leaves are simple, petiolate, and broadly ovate to cordate, covered with fine hairs and abundant glandular structures. The inflorescence consists of verticillasters bearing usually 4–6 flowers, with bracts longer than the 20–30 mm corolla. Corolla coloration varies from purple and lilac to white, with a distinctly curved upper lip. The calyx, approximately 10 mm in length, has glandular, peltate trichomes and spiny pubescent teeth. The fruit comprises dark brown nutlets measuring 2–3 mm. Flowering occurs from mid-May through August, generally beginning in the second year of growth, and the flowers exhibit protandry (Peana & Moretti, 2002). The flowering spikes may extend up to 40 cm in length and display a cymose inflorescence ranging from lilac to whitish hues. These inflorescences consist of clusters of axillary flowers, each borne in groups and subtended by prominent bracts(Kačániová et al., 2023). The general morphology, habitat characteristics, and flower coloration of the plant are presented in Figure 2.

3. *S. sclarea* L. cultivation and management

As the applications of *S. sclarea* broadened—from use in alcoholic beverages to increasing prominence in perfumery—its cultivation expanded accordingly. Early literature indicates that by the late 1950s, France had become the leading producer of *S. sclarea* oil, with outputs in the south of the country surpassing 10 tonnes. Subsequently, large-scale cultivation was established in the former Soviet Union between 1960 and 1970, and by 1984 production there had exceeded 60 tonnes (Lawrence, 1994). Today, *S. sclarea* is produced at commercial scale in several countries—notably Russia, Bulgaria, France, and Morocco—with global output of its essential oil estimated at roughly 150 metric tons per year. (Aćimović et al., 2018; Uskutoğlu, 2025). The ability of *S. sclarea* L. to hyperaccumulate lead and accumulate cadmium and zinc positions it as a promising candidate for the phytoremediation of heavy metal-contaminated environments. Moreover, when cultivated in contaminated soils, the plant demonstrates an effective capacity to uptake and store these metals, enhancing its phytoremediation potential (Violina et al., 2016).



Figure 2. Natural occurrences of *S. sclarea* in the wild. From top to bottom: (1) general morphology of the plant; (2) a naturally protected population showing dense aggregation; (3) individuals commonly growing along roadside habitats (Denizli, 2025).

4. Medicinal Properties and Biological activity of *S. sclarea*

S. Sclarea has been traditionally used as a medicinal plant for its antispasmodic, carminative and estrogenic properties (Chalvin et al., 2021). Gülçin et al. (2004) reported that it exhibits notable antioxidant and antimicrobial activities, suggesting its potential role in preventing oxidative stress-related disorders and microbial infections. Owing to its antimicrobial activity, the oil also has potential applications in inhibiting microbial growth and extending the shelf life of food products (Kačániová et al., 2023). Essential oil (EO) derived from *S. sclarea* is utilized in the food industry as a flavor enhancer in a variety of products, including desserts, beverages, and baked goods. In addition, it serves as an aromatic additive in tobacco as well as a fragrance ingredient in numerous cosmetic preparations and perfumes. Characterized by a warm and sweet scent, *S. sclarea* is considered valuable in addressing psychological states including neurosis, stress, apprehension, paranoia, anxiety, and depression (Jasicka-Misiak et al., 2018; Kamatou et al., 2008). Seol et al. (2010) found that *S. sclarea* oil exhibits significant antidepressant-like and anti-stressor effects, likely mediated through dopaminergic pathways. These findings suggest that Salvia sclarea essential oil may serve as a promising complementary agent in the treatment of depression and related psychiatric disorders (Seol et al., 2010). Raafat & Habib (2018) reported that the essential oils of *S. sclarea* possess notable antidiabetic potential, indicating their possible future application as complementary or alternative therapy for managing diabetes and its associated complications.

5. Recommendations on Cultivation and Potential

S. sclarea L. naturally occurs across diverse ecological regions of Türkiye and represents a promising high–value aromatic and medicinal plant with considerable potential for sustainable production. To realize this potential, comprehensive adaptation and selection studies should be conducted across various agro-ecological zones to identify high-yielding genotypes possessing superior sclareol and linalyl acetate content. Literature studies have revealed the presence of different chemotypes among *S. sclarea* genotypes collected from various geographical regions, indicating that the species possesses a substantial level of genetic diversity that can be effectively exploited for breeding and improvement programs. The development of regional breeding programs based on locally adapted populations would further enhance productivity and essential oil quality. Optimization of cultivation technologies is also crucial; comparative evaluations of seedling propagation and direct sowing methods should be undertaken to determine the most effective approach for each production region, while the effects of irrigation, fertilization, and harvest timing on oil yield and composition must be standardized to establish region-specific cultivation protocols.

Strengthening industrial integration constitutes another critical step toward commercial success. Establishing collaborations between agricultural producers and the cosmetic, perfumery, and pharmaceutical sectors could facilitate the creation of a domestic value chain for *S. sclarea* raw materials. Establishment of local distillation and processing facilities—preferably organized through rural cooperatives—would enable farmers to benefit directly from value-added production and improve rural income distribution. Academic and industrial partnerships should also be promoted through interdisciplinary projects uniting departments of agronomy, pharmacy, and chemistry, in order to connect agronomic innovation with product development. Moreover, the notable phytoremediation potential of *S. sclarea* for heavy-metal–contaminated soils should be evaluated within national environmental rehabilitation programs, aligning ecological restoration with economic productivity.

From a marketing and policy perspective, branding initiatives such as “Anatolian Clary Sage” or “Turkish Sclareol” could strengthen international recognition and competitiveness. Achieving geographical indication status would further enhance product authenticity, traceability, and market value. Finally, incorporating *S. sclarea* into Türkiye’s national support schemes for medicinal and aromatic plants—through seedling production incentives and contract farming models promoted by agricultural cooperatives—would ensure stable production, consistent quality, and sustainable farmer income. Collectively, these integrated strategies would not only foster an efficient production system but also position *S. sclarea* as a strategic crop contributing to the diversification and resilience of Türkiye’s agricultural economy.

In several countries, particularly in Europe and North America, annual forms and registered cultivars of *S. sclarea* have been developed and successfully commercialized. These improved varieties exhibit uniform growth, high essential oil yield, and enhanced sclareol content, offering notable advantages for large-scale industrial production. In Türkiye, however, no officially registered cultivars of *S. sclarea* currently exist, and cultivation is generally carried out using wild or locally collected populations. The absence of certified varieties limits yield stability, essential oil quality, and the ability to meet standardized market requirements.

Consequently, the development and registration of locally adapted *S. sclarea* cultivars represent a critical step toward establishing a more efficient and standardized production framework. Breeding programs should prioritize the selection of genotypes that combine high yield and oil quality with adaptability to diverse Turkish agro-ecological conditions. Field establishment of these improved cultivars should be promoted in ecologically suitable regions—particularly in the Aegean, Mediterranean, and Central Anatolian zones—through demonstration projects led by pioneer farmers. Such region-focused pilot initiatives would facilitate the dissemination of best practices, enhance farmer engagement, and accelerate the integration of *S. sclarea* into Türkiye’s growing medicinal and aromatic plant sector.

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DENİZLİ KEKİĞİNİN ARICILIK POTANSİYELİNİN DEĞERLENDİRİLMESİ

EVALUATION OF THE BEEKEEPING POTENTIAL OF DENİZLI OREGANO

Dr. Öğr. Üyesi Rıdvan UÇAR

Pamukkale Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü

Email: 12ridvanucar@gmail.com,

ORCID: 0000-0001-6365-7200

Dr. Öğr. Üyesi Tansu USKUTOĞLU

Pamukkale Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü

Email: tansuuskutoglu@gmail.com,

ORCID: 0000-0001-6631-1723

ÖZET

Kekik (Oregano spp.) hem yetiştiriciliği hem de üretim payı bakımından Denizli ili için oldukça önemli bir bitkidir. Denizli Türkiye kekik ekim alanlarının %91,2'sine sahip olup Türkiye üretiminin % 89.6'sını karşılamaktadır. Ayrıca Denizli dünya kekik ve kekik ürünleri pazarında ön sıralarda bulunmaktadır. Pamukkale, Güney, Çal, Buldan, Bekilli, Tavas ve Kale üretimin en yoğun yapıldığı ilçelerdir. *Lamiaceae* familyasının *Origanum* cinsine ait, özellikle Ege ve Batı Akdeniz bölgelerinde doğal olarak yayılış gösteren, çok yıllık, otsu yapıda tıbbi ve aromatik bir bitki türüdür. Bölgelere göre nisan-haziran aylarında beyaz çiçekler açan, 40-80 cm arasında boylanabilen, yapraklar yeşil renkli ve üzeri hafif beyaz damarlı, gövde ve yaprakları tüylüdür. Çok yıllık bir bitki olan kekiğin ekonomik ömrü 7 yıldır. Ancak iyi bakım şartlarında 10 yıla kadar ürün alınabilmektedir. Baharat, ilaç, kozmetik, arıcılık ve kimya sektörleri başta olmak üzere pek çok alanda kullanılmaktadır. Kurağa, soğuğa ve kötü toprak koşullarına karşı dayanıklıdır. Kumlu–tınlı, su tutmayan ve hafif meyilli alanlarda iyi yetişmesine karşın kıraç koşullara da dayanıklıdır. Sonuç olarak; düşük maliyet girdisi, çiçeklenme periyodu, sağladığı polen ve nektar, arı tercihi, arı sağlığı, arı refahı, kendine özgü arı ürünleri, biyoçeşitliliğe katkısı, ek gelir kayağı, tarımsal üretimde sürdürülebilirlik konuların da katkı sağlayabileceğinden kekik arıcılık için önemli bir potansiyele sahiptir.

Anahtar Kelimeler: Arıcılık, Arı merası, *Origanum onites* L

ABSTRACT

Oregano species are a very important plant for Denizli province in terms of both cultivation and productivity. Denizli has 91.2% of oregano cultivation areas in Türkiye and meets 89.6% of the Türkiye's production. In addition, Denizli is at the forefront of the world oregano and oregano products market. Pamukkale, Güney, Çal, Buldan, Buldan, Bekilli, Tavas and Kale are the districts where production is the most intensive. It is a perennial, herbaceous, medicinal and aromatic plant species belonging to the genus *Origanum* of the *Lamiaceae* family, which is naturally distributed especially in the Aegean and Western Mediterranean regions. Depending on the region, it blooms with white flowers in April-June, grows between 40-80 cm in length, leaves are green with light white veins, stems and leaves are hairy. The economic life of oregano, which is a perennial plant, is 7 years. However, under good cultivation conditions, plants can be harvested for up to 10 years. It is used in many areas, especially in the spice, medicine, cosmetics, beekeeping and chemical sectors. It is resistant to drought, cold and poor soil conditions. Although it grows well in sandy-loamy, water-repellent and slightly sloping areas, it is also resistant to barren conditions. As a result, oregano has an important potential for beekeeping as it can contribute to low-cost input, flowering period, pollen and nectar, bee preference, bee health, bee welfare, unique bee products, contribution to biodiversity, additional income source, sustainability in agricultural production.

Keywords: Beekeeping, Bee pasture, *Origanum onites* L.

GIRIŞ

Kekik, baharat ve uçucu yağ ticaretinde önemli bir yeri olan tıbbi ve aromatik bitkilerden biridir. Ülkemiz, *Origanum, Thymus, Thymbra, Satureja* gibi pek çok kekik türünün gen merkezi ve anavatanı konumundadır (Uskutoğlu, 2025). Türkiye, yüksek kekik üretim miktarı ile dünya da ilk sırada bulunan ülke olup, "Türk Kekiği" marka adı ile uluslararası standartlarda belirgin role sahip olmuştur.

Origanum türlerinin kullanımı Paleolitik Çağ'a (MÖ 50.000 – 70.000) kadar uzanmaktadır. Kekik ile ilgili ilk yazılı kaynaklar Hitit tabletlerinde (MÖ 1600 – 1200) bulunmuştur. *Origanum* türleri tarihsel akışta çeşitli hastalıkların tedavisinde geleneksel tıpta yaygın olarak kullanılmıştır. *Origanum* L. cinsi (*Lamiaceae*), çoğu Doğu Akdeniz bölgesine dağılmış olan 43 tür ve 18 melezden oluşmaktadır (Letswaart 1980; Duman vd. 1998; Semerci ve Ken, 2024). Türkiye'de yetişen bilyalı kekik türleri, son yıllarda dünya baharat pazarlarında büyük ticari önem talep kazanmıştır. Bu türler arasında, yüksek kalitesi nedeniyle *Origanum onites* L. özellikle tercih edilmektedir (Altıntaş vd. 2013). Türkiye'den ihraç edilen kekik türleri arasında, %80 pazar payı ile *O. onites* en çok ihraç edilen türdür (Sancaktaroğlu ve Bayram 2011). Avrupa'da da "Türk kekiği" olarak bilinen *O. onites*, doğadaki yabani popülasyonlardan toplanmaktadır. Dünya çapındaki ticarette *O. onites'e* olan talebin artması nedeniyle, *Origanum onites* ayrıca Türkiye'nin Ege ve Akdeniz bölgelerinde Tepe ve vd. (2016); Canli vd. (2023), özellikle Denizli, Aydın, İzmir, Isparta, Burdur ve Antalya illerinde de yetiştirilmektedir (Tonk vd., 2010). *Origanum vulgare* alttür *hirtum, O. minutiflorum, O. syriacum* var. bevani' ve O. majorana, daha az ihracat payına sahip olan diğer ihraç edilen kekik türleridir (Başer 2001; Ayanoglu vd., 2006). *Origanum onites* L. *Lamiaceae* familyasına ait çok yıllık ve otsu bir bitki türüdür. Akdeniz kıyı şeridi boyunca yayılmıştır. Türkiye'deki yerel halk tarafından ayrıca kırkbaş kekik, koca kekik, tokalı kekik, bilya kekik, 'arı kekiği' (Sargın vd. 2013), eşek kekiği, deli kekik, kara kekik Gürdal ve Kürtül, (2013), taş kekiği, dağ kekiği ve akbaş kekik (Polat ve Satıl, 2012), olarak da adlandırılmaktadır. Bu tür, aroması ve lezzeti sayesinde yiyeceklerin tadını zenginleştirmek için binlerce yıldır baharat olarak yaygın şekilde kullanılmaktadır. Mutfak kullanımının yanı sıra, çeşitli preparatları farmasötik ve kozmetik endüstrilerinde de kullanılmaktadır (Bakkali vd., 2008). Bitkisel kısımları ve biyokimyasal özütleri, gıda ve baharat endüstrisinde yaygın olarak kullanılmaktadır (Kitiki vd., 1997; Ayanoglu vd., 2006). Kekik esansiyel yağı, ana bileşenleri olarak karvakrol ve timoldur (Kokkini 1997; Andoğan vd., 2002; Baranauskiene vd., 2006; Bansleben vd., 2009; Özkan ve Erdoğan, 2011; Spyridopoulou vd., 2019). Ancak yabani popülasyonlarda nadiren timol ve linalool kemotipleri de görülmektedir. Genellikle, ana bileşenler esansiyel yağların biyolojik özelliklerini belirler (Bakkali vd., 2008). Kekiğin biyolojik aktivitesi temel olarak karvakrol ve timolden kaynaklanır ve karvakrol çoklu farmakolojik etkilere sahiptir (Dundar vd., 2008). Yapılan Fitokimyasal çalışmalar ile bu kekik türünün; terpenoidler, fenolik asitler, triterpen asitler, hidrokinonlar, flavonoidler, hidrokarbonlar, steroller, pigmentler, yağ asitleri, tokoferoller ve inorganik bileşikler dahil olmak üzere çeşitli bileşikler içerdiği görülmektedir. Farmakolojik çalışmalar; antimikrobiyal, antioksidan, insektisidal, larvisidal, akarisidal, antikanser, hepatoprotektif, genotoksik/antigenotoksik, antidiyabetik, antiviral, kardiyorespiratuar, antienflamatuar, fümigant toksisitesi, kolinesteraz inhibitörü ve analjezik aktiviteler ile endotel fonksiyonu, kolit (kolon hasarı) ve gastrointestinal sistem üzerindeki etkilerini teyit etmektedir. Bu çalışma üretim miktarı, üretim alanı bakımından Türkiye'de ve dünyada önde gelen Denizli ili ile özdeşmiş kekiğin (*Origanum Onites* L.) arıcılık potansiyelinin değerlendirilmesi amacı ile yürütülmüştür.

Botanik Özellikler

Origanum onites L., *Lamiaceae* familyasına ait çok yıllık bir bitkidir. Bitkinin morfolojik yapısı; gövde yapısı, yaprak düzeni, çiçek morfolojisi ve uçucu yağ depo eden bezleri açısından değerlendirilmiş ve ekonomik kullanım potansiyeli bu morfolojik özelliklerle doğrudan ilişkilendirilmiştir. Bitkinin dallı odunsu gövdeleri, sürünen kök sistemleri ve yaprakların karşılıklı dizilişi, saha üretiminde dayanıklılık ve çok yıllılık açıdan önem taşır. Yapraklar genellikle küçük, tüylü, oval ve bez noktacıkları içerir; bu yapı uçucu yağ sentezi ve depolanmasında belirleyici rol oynar. Çiçek sapları terminal ve aksiller kümeler halinde olup, çiçekleri mor veya beyaz renktedir. Çiçeklenme dönemi bitkinin hasat zamanını belirler; uçucu yağ bileşenleri ve drogun kalitesi çiçeklenmenin başlangıcı ve tam çiçeklenme arasındaki dönemde en uygun düzeydedir. Sistematik açıdan *Origanum* cinsi dünya genelinde birçok türe sahiptir ve Türkiye, *Origanum* türleri açısından yüksek endemizm oranına sahiptir. *Origanum onites* özellikle ülkemiz florasında doğadan toplanan ve kültürü yapılan önemli türlerden biridir. Türlerin kimyasal profil farklılıkları (örneğin karvakrol, timol oranları) bitki ıslahı, ekotip seçimi ve damıtma sonucu elde edilen yağın kalitesi üzerinde etki eder (Kizil vd., 2009; Toncer vd., 2009; Demirci vd., 2022). Türkiye başta bilyalı kekik olmak üzere birçok kekik türünün anavatanı ve yayılma alanı konumundadır. Farklı ekolojik alanlardan farklı kekik türleri doğadan toplanarak ticari amaçlı kullanılmaktadır. Tarımsal üretimde ise genel olarak Izmir Kekiği (*Origanum onites* L.) ile Çanakkale Kekiği (*Origanum vulgare* L.) genotiplerinin üreticiler tarafından tercih edilmektedir. Çok yıllık bir bitki olan kekiğin ekonomik randıman ömrü 7 yıldır. Ancak iyi bakım şartlarında 10 yıla kadar ürün alınabilmektedir.

İklim ve Toprak İsteği

Kekik tarımı için uygun mikro ve makro iklim koşulları verim ve uçucu yağ kalitesini doğrudan etkiler. *Origanum onites* kuraklığa ve düşük sıcaklıklara dayanıklı bir bitkidir. Ilıman ve orta karasal iklimlerde iyi gelişim gösterir. Türkiye ekolojisinde kuzey yamaçları, hava akışı aktif ve çiçeklenme döneminde sıcaklığın yüksek derecelere çıkmadığı alanlarda daha verimli ve uçucu yağ kalitesi daha fazla olmaktadır. Yetiştirilme alanlarında toprak istekleri bakımından fazla seçici değildir (Baydar ve Arabacı 2013). Kumlu–tınlı, su tutmayan ve haif meyilli topraklar kekik yetiştiriciliği için optimum koşul olarak kabul edilebilmektedir. Toprak pH'sı 6.5-8.0 arasında olan alanlar kekik tarımı için uygundur. Denizli'de yapılan toprak analizlerine göre kekik tarlalarının toprakları genellikle tuzsuz olmakla birlikte (0.15-0.64 mmhos/cm), alkali pH (7.78-8.03), yüksek kireç içeriği (%64.46-71.71) ve düşük organik madde (%0.7-2.9) özellikleri göstermektedir. Fosfor içeriği alanlara göre değişkenlik gösterirken (10-76 ppm), potasyum içeriği yüksek (132-827 ppm) düzeylerde bulunmuş; kalsiyum içeriği de yüksek değerler göstermiştir. Toprakta organik madde ve azot miktarındaki artış, bitki verimliliğini olumlu yönde etkiler.

Toprak İşleme ve Fide Dikimi

Kekik üretimi hem generatif (tohum) hem de vejetatif (çelik) yöntemleriyle gerçekleştirilebilir. Tohumla üretim, pratikliği nedeniyle yaygın olarak tercih edilir; ancak tohumun çok küçük olması nedeniyle fidelerin yetiştirilmesi özel bir dikkat gerektirir. Tohum ekimleri Ekim-Kasım-Aralık aylarında hazırlanmış 1 m genişliğindeki yastıklara, kum+organik gübre+toprak 1:1:1 karışımı içerisine m^2'ye ortalama 2 g tohum düşecek şekilde serpilerek yapılır. Yastıklar açıkta veya 50 cm boyunda alçak tüneller altında sera naylonu ile örtülerek tohumların nem ihtiyacı sağlanır; çimlenme ve fide gelişimi için düzenli elle veya mini sprinkler sulama sistemi ile nem kontrolü yapılır. Yaklaşık 10 m^2 alan 1 da plantasyon oluşturacak fidelerin üretimi için yeterlidir. Viyolde veya yastıkta oluşan fideler, iklime göre 2. aydan sonra araziye aktarılabilir. Vejetatif çoğaltmada

10-12 cm uzunluğundaki yarı odunsu çelikler IBA (1.000 ppm) solüsyonunda bekletilerek yüksek köklenme sağlanabilir. Araziye dikimden önce derin sürüm yapılmalı; ardından diskaro–tırmık veya kazayağı–tırmık kombinasyonu ile yüzey düzeltilmelidir. Fide dikimi, don riskinin geçtiği Mart sonu ile Mayıs ortası arasındaki dönemde gerçekleştirilir. Dikim mesafesi genel olarak 45x20 cm olarak önerilmiş olup, dikim makinası ile şaşırtma yöntemiyle tarlaya dikilen fidelere mutlaka can suyu verilmelidir.

Gübreleme, Bakım ve Yabancı Ot Kontrolü

Kekik genellikle kıraç koşullarda yetiştirilir ve standart işletme koşullarında yılda bir biçim alınır. İlk yıl bitkiler yavaş geliştiği için yabancı otlarla mücadele, fide kök boğazının doldurulması ve toprağın neminin korunması amacıyla birkaç kez çapalama gerekebilir. Ertesi yıllarda verim döneminde yabancı ot kontrolü, toprak havalandırması ve toprak yüzeyinden su kaybının azaltılması için en az iki kez çapalama önerilmektedir. Ekim işlemlerine başlamadan önce toprağın yapısını düzenlemek ve daha uygun yetiştirme ortamı sağlamak amacıyla dekara 5 tona kadar çiftlik gübresi uygulamak uygun olacaktır. Genel gübreleme önerisi verim döneminde dekara 7–8 kg azot (N) ile 4–5 kg fosfor (P) verilmesinin yeterli olduğu yönündedir. Potasyum elementi uçucu yağ kalitesi için önem taşımakta; bu nedenle gübreleme planı toprak analiz sonuçlarına dayanmalı ve gerektiğinde mikro besin takviyeleri düzenlenmelidir. Sulama; kekik kuraklığa dayanıklı olmakla birlikte, yılda birden fazla biçim almak isteyen üreticiler için biçimler sonrası sulama yapılması ürün verimini artırır. Damlama sistemiyle sulanan bitkilerde yaprak verimi ve kalite daha yüksek bulunmuştur. Kekikte ruhsatlı bir herbisit olmadığından kültürel önlemler ve mekanik müdahaleler ön planda tutulmalıdır.

Hastalıklar ve Zararlılar

Kekik bitkisi genel olarak hastalıklara ve zararlılara karşı dayanıklı olmakla birlikte, yetiştirme koşullarına bağlı olarak bazı sorunlarla karşılaşılabilir. Özellikle taban suyu yüksek, su tutan ve geçirimsiz topraklarda bitki kök bölgesinde hava akımının yetersizliği fungal kaynaklı kök çürüklüğüne neden olabilir. Nemli iklimlerde ayrıca yaprak bitleri ve örümcek akarlar gibi zararlılar bitki üzerinde olumsuz etkiler yapabilir. Bu tür zararlılar bitki gelişimini yavaşlatabilir ve özellikle fide döneminde fide kayıplarına yol açabilir. Hastalık ve zararlılarla mücadelede kültürel uygulamaların önemi büyüktür; iyi drenaj, doğru dikim zamanı, toprağın havalandırılması ve gereksiz sulamadan kaçınılması gibi önlemlerle riskler azaltılabilir. Ayrıca entegre mücadele yaklaşımları çerçevesinde biyolojik yöntemler ve amaçlanan uygulamalar kullanılmalıdır.

Hasat Zamanı, Hasat Metodları ve Kurutma

Kekikte en uygun hasat zamanı, çiçeklenme başlangıcından tam çiçeklenme dönemine kadar olan periyottur; bu dönem, hem drog (yaprak) hem de uçucu yağ kalitesi açısından belirleyicidir. Hasat işlemi toprak seviyesinin yaklaşık 10 cm üstünden elle, testereli bir ot bıçağı veya bu amaçla geliştirilmiş hasat makineleri ile gerçekleştirilir. Hasat sırasında yabancı otların karışmaması Önemli faktördür. Hasatların ardından bitkiler doğal koşullarda gölge, iyi havalanan ortamlarda kurumaya bırakılmalıdır. Doğrudan güneş altında kurutma sonucu renk değişimi ve uçucu yağ kaybı meydana gelir, bu da ürünün pazar değerini düşürür. Kurutmada kızışmayı önlemek için bitki yükseklikleri 20 cm'yi geçmemeli ve belirli aralıklarla alt-üst edilmelidir. Genel olarak yaş bitkiden kuru materyal elde edilme oranı 4–5 birim yaş materyalden 1 birim kuru materyal şeklindedir. Kurutulmuş materyalin saplardan yapraklardan ayrılması çeşitli yöntemlerle yapılabilir. Elde edilen kurutulmuş ürünler çuvallanarak karanlık, serin ve nemsiz ortamlarda pazarlamaya kadar muhafaza edilmektedir (Bayram, 2003; Sokat, 2012).

Üretim Durumu, İstihdam ve Ekonomik Değerlendirme

Türkiye'de kekik üretim alanları ve miktarları son yıllarda artış göstermiştir. TÜİK verilerine göre 2021 yılında 21 ilde kekik tarımı yapılmış olup, üretim alanlarının büyük kısmı Denizli ilinde yoğunlaşmaktadır. Denizli ili toplam 172.461 da ile ülke üretiminin yaklaşık %93.3'ünü oluşturmaktadır. Üretimde Denizli'yi Uşak, Manisa, Aydın, Kütahya ve Hatay takip etmektedir. 2021 yılı verilerine göre ülke genelinde toplam üretim 23.866 ton düzeyine ulaşmış, bunun yaklaşık 2.195 tonu doğal floradan toplanmıştır (Ken ve Semerci, 2024). Kekik üretimi ile ilişkili olarak hem baharat hem de uçucu yağ ihracatları önemli döviz girdisi sağlamaktadır. Baharat olarak en çok ihracat yapılan ülkeler arasında Almanya, ABD, Kanada, Fransa ve Birleşik Krallık öne çıkarken; kekik yağı ihracatında Macaristan, ABD, Almanya, Kanada ve İspanya önemli alıcı ülkeler arasında sayılmıştır. Alanın artışı bölgesel kalkınmaya katkı sağlamakta (Aslan ve Gül 2017; Karlı vd., 2021), özellikle fide üretimi, işleme tesisleri, damıtma üniteleri ve paketleme faaliyetleri gibi yan sektörlerde istihdam yaratmaktadır. Küçük aile işletmeleri 1–20 da arasında üretim yaparken; orta ölçekli işletmeler 20–100 da, büyük işletmeler ise 100 da üzerinde üretim yapmaktadır. İşletme ölçeği büyüdükçe makineleşme ve damıtma tesisleri kurma kapasitesi artmakta, bu da ürüne katma değer sağlamaktadır. Dünya pazarında tıbbi bitkilerinin öneminin devam edeceği aşikârdır (Craker, 2007).

Kekiğin Arıcılıkta Kullanılma Potansiyeli Değerlendirmesi

Kekik; arıcılıkta hem polen, nektar kaynağı hem de arı hastalıklarıyla mücadelede kullanılabilecek doğal bir kaynak olarak önemli bir potansiyele sahiptir. Arıları cezbeden çekici çiçekleri, çiçeklenme şekli, çiçeklenme periyodu, nektarının aroması ve rengi Denizli kekiğine arıcılıkta önemli bir potansiyel sunmaktadır (Uçar vd. 2025). Kekik üretiminin marjinal alanlarda, çayır mera alanlarına yakın, orman arası veya civarı alanlarda ve insan müdahalesinin az olduğu alanlarda yapılması kekik üretim alanlarının aynı zamanda arı merası olarak kullanılma potansiyeline sahip olduğunu göstermektedir. Nitekim tarihte ünlü yabani kekik balının Atina yakınlarındaki Hymettus Dağı'ndaki arılardan elde edildiği, Ege Bölgesi'nde kekik yağı; halk arasında yaygın olarak "arı kekiği yağı" adıyla anılması kekiğin tarihsel süreçlerde de bal arıları ile ilişkilendirildiğini göstermektedir. Denizli kekiğinden elde edilen ucu yağlar başta olmak üzere vejetatif aksamlar ve çeşitli kekik özütlü sular bal arısı hastalık ve zararlılarına karşı kullanılma potansiyeline sahiptir (Tepe vd., 2016; Spyridopoulou vd., 2019; Šojić vd., 2023). Kekik ürünlerinin arı hastalık ve zararlılarına karşı kullanılması aynı zamanda organik üretim oranını artırıp kimyasal ilaçların arılara ve çevreye verdikleri zararlardan tasarruf edilebilir. Arı merası olarak kullanılan kekik tarlalarında toplanan polen ve nektarlar direk olarak arı sağlığına ve refahına katkıda bulunabilmektedir (Barbosa vd., 2015). Kekiğin uçucu yağlarının böcek öldürücü, larvasit, akarisit (akar öldürücü) ve fümigant (dumanlama) etkileri kolaylıkla arı sağlığında da kullanılma potansiyeline sahiptir. Kekik özü ve uçucu yağlarının güçlü antibakteriyel, antimikrobiyal ve antifungal (Jayasena ve Jo, 2014; Pateiro vd., 2018), aktivitelere sahip olduğu bu etkilerin arı kolonilerinde görülebilecek Varoa, Amerikan yavru çürüklüğü ve Kireç hastalığı gibi hastalıklara karşı koruyucu veya tedavi edici olarak kullanılabilme potansiyeli taşımaktadır (Alkan, 2020; Erol ve Birgücü, 2020; Oyedeji vd., 2020; Plata-Rueda vd., 2020; Werrie vd., 2020; Başer, 2022). Ayrıca kekik yeşil aksamları da direk kovana bırakılarak arı zararları ve arı refahına katkı sağlayabilmektedir. Denizli kekiği üretim alanları aynı zaman da arı merası olarak kullanılma potansiyeline sahiptir. Hasat zamanı çiçeklenme başlangıcından çiçeklenme sonuna kadar olduğu için bu periyotta hem ticari hem de aile üretimi için arı merası olarak kullanılma potansiyeline

sahiptir. Kekik üretim alanlarının aynı zamanda arı merası olarak kullanılması üreticiye ek gelir kaynağı veya organik nitelikte arı ürünleri sağlayacaktır.

Sonuç ve Öneriler

Origanum onites L. Türkiye'nin tıbbi ve aromatik bitki sektöründe stratejik bir öneme sahiptir. Yüksek uçucu yağ içeriği, çok yönlü kullanım alanı ve adaptasyonu sayesinde üretimi ekonomik olarak caziptir. Saha uygulamalarında toprak analizi temelli gübreleme programlarının uygulanması, doğru hasat zamanı seçimi ve gölgede kurutma tekniklerinin kullanılması kayıplarını azaltarak ürün kalitesini yükseltecektir. Damıtma tesislerinin bölgesel olarak yaygınlaştırılması ve ürün standardizasyonunun sağlanması ve alternatif kullanımlarının yaygınlaştırılması kekik üretiminin daha sürdürebilir olmasını katkı sağlayacaktır.

Kekiğin (*Origanum onites* L.) sadece önemli bir bal arısı bitkisi olmakla kalmayıp, içerdiği yüksek Karvakrol ve Timol gibi biyoaktif bileşikler sayesinde arı zararlılarına (akar) ve patojenlere karşı doğal bir biyopestisit ve akarisit olarak da kullanılabilecek yüksek bir potansiyele sahip olduğunu göstermektedir. Geleneksel olarak da "arı kekiği yağı" adıyla biliniyor olması, bu potansiyeli desteklemektedir. Ayrıca kekikiğin arılar tarafından tercih edilmesi, kekik üretim alanlarının arıcılık üretimi için uygun yerlere yakın olması, kekik alanlarının dışında kalan doğal alanlardaki biyo çeşitliliğin korunması için ve kekik üretim alanlarından alternatif ekonomik katkılar sağlanabilmesi bu bitkinin arıcılık açısından önemli bir potansiyele sahip olduğunu göstermektedir.

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ABAZA VE GÜRCÜ KEÇİLERİNDE ANÖSTRUS VE ÖSTRUS DÖNEMİNDE SERUM *Paraoksanaz-1* VE BAZI OKSIDATİF STATÜ BELİRTEÇLERİNİN DEĞİŞİMİ

Assist. Prof. Dr., Serpil AYGÖRMEZ

Department of Biochemistry, Faculty of Veterinary Medicine, Kafkas University, Kars, Türkiye

E-posta Adresi: serpilaygormez@hotmail.com

ORCID**:** 0000-0002-5675-5096

Prof. Dr., Mushap KURU

Department of Obstetrics and Gynecology, Faculty of Veterinary Medicine, Kafkas University, Kars, Türkiye

E-posta Adresi: mushap.kuru@kafkas.edu.tr

ORCID: 0000-0003-4409-251X

Assoc. Prof. Dr., Mustafa MAKAV

Department of Physiology, Faculty of Veterinary Medicine, Kafkas University, Kars, Türkiye

E-posta Adresi: mustafamakav@gmail.com

ORCID: 0000-0003-1879-8180

ÖZET

Bu çalışmada Abaza ve Gürcü keçilerinde anöstrus ve östrus döneminde, serum glutatyon (GSH), malondialdehit (MDA) düzeyleri ile paraoksanaz-1 (PON) aktivitesinin değişiminin belirlenmesi amaçlanmıştır. Çalışmada 30 adet keçi (15 adet Gürcü keçisi ve 15 adet Abaza keçisi) kullanılmıştır. Östrus senkronizasyonu amacıyla, keçilere progesteron içeren intravaginal süngerler özel aplikatör yardımıyla yerleştirildi. Bu süngerler, 9 gün boyunca vaginada kaldı. Progesteron içeren sünger uygulamasının 9. gününde, tüm hayvanlara 500 IU at koryonik gonadotropini (eCG) kas içi enjeksiyonu yapıldı. eCG uygulamasından 24 saat sonra keçilerin içerisine teke katıldı ve östrus belirtileri gösteren keçiler tespit edildi. Anöstrus (östrus senkronizasyonuna başlamadan) ve östrusta olmak üzere keçilerden kan alındı. Keçilerden alınan kandan serum GSH, MDA düzeyleri ve PON aktivitesi belirlendi. Elde edilen verilere göre, Abaza ve Gürcü keçilerin östrus döneminde MDA düzeyi arttı ($p<0.05$) ve zaman etkisi anlamlıydı ($p=0.02$). GSH düzeyi Abaza keçilerinde östrusta arttığı ve Gürcü keçilerinde ise östrusta azaldığı($p<0.05$). Ayrıca GSH düzeyinde grup × zaman interaksiyonu anlamlıydı ($p=0.001$). Abaza ve Gürcü keçilerinde östrusta PON aktivitesi azaldı ($p<0.05$) ve zaman etkisi anlamlıydı ($p<0.001$). Çalışmanın en önemli sonucu keçilerde MDA'nın arttığı ve PON aktivitesinin de azaldığıdır. Bu da oksidatif ve antioksidatif dengenin anöstrus ve östrusta değişim gösterebileceğini ifade etmektedir. Yine ilginç olarak Abaza keçilerinde GSH östrusta artarken Gürcü keçilerinde azalma göstermesidir. Özellikle antioksidant kapasitenin ırklar arasında da değişiklik gösterebileceğini yansıtmaktadır. Yine bu parametrelerin östrus siklusu dönemlerinin takibi potansiyel biyobelirteçler olarak kullanılabileceğini göstermektedir. Sonuç olarak, Abaza ve Gürcü keçilerin anöstrus ve östrusta MDA ve GSH düzeylerinin değişiminin ve PON aktivitesinin değerlendirilmesi bu dönemlerin izlenmesi için faydalı biyobelirteçler olabilir.

Anahtar Kelimeler: Anöstrus, Östrus, Paraoksanaz-1, Oksidatif statü, Keçi

CHANGES IN SERUM PARAOXONASE-1 AND SOME OXIDATIVE STATUS MARKERS DURING ANESTRUS AND ESTRUS IN ABAZA AND GURCU GOATS

ABSTRACT

This study aimed to determine the changes in serum glutathione (GSH), malondialdehyde (MDA), and paraoxonase-1 (PON) activity during anestrus and estrus in Abaza and Gurcu goats. Thirty goats (15 Gurcu and 15 Abaza goats) were used in the study. For estrus synchronization, progesterone-containing intravaginal sponges were inserted into the goats using a special applicator. These sponges remained in the vagina for 9 days. On the 9th day of progesterone-containing sponge application, all animals received an intramuscular injection of 500 IU equine chorionic gonadotropin (eCG). Twenty-four hours after eCG administration, a male was introduced into the goats, and goats showing signs of estrus were identified. Blood samples were collected from the goats during anestrus (before estrus synchronization) and estrus. Serum GSH, MDA levels and PON activity were determined from the blood samples. According to the data obtained, MDA levels increased during estrus in Abaza and Gurcu goats ($p<0.05$), and the time effect was significant ($p=0.02$). GSH levels increased during estrus in Abaza goats and decreased during estrus in Gurcu goats ($p<0.05$). Furthermore, the group × time interaction on GSH levels was significant ($p=0.001$). PON activity decreased during estrus in Abaza and Gurcu goats ($p<0.05$), and the time effect was significant ($p<0.001$). The most important result of the study was that MDA increased and PON activity decreased in goats. This suggests that the oxidative and antioxidative balance may change between anestrus and estrus. Interestingly, GSH increased during estrus in Abaza goats, while it decreased in Gurcu goats. This reflects that antioxidant capacity, in particular, can vary among breeds. Furthermore, these parameters demonstrate potential biomarkers for monitoring estrous cycle periods. Consequently, assessing changes in MDA and GSH levels and PON activity during anestrus and estrus in Abaza and Gurcu goats may be useful biomarkers for monitoring these periods.

Keywords: Anestrus, Estrus, Paraoxonase-1, Oxidative status, Goat

1. INTRODUCTION

Goats, a social species that coexists with other species, have a hierarchical structure and offer opportunities for reproductive success (Zuniga-Garcia et al., 2020). Goat farming, an important agricultural activity in rural communities, provides families with a source of animal-based income. Due to their rapid growth rates and high fertility, they adapt well to agricultural ecological regions (Bustamante-Andrade et al., 2025; Santos-Silva et al., 2025). Due to the social structure of farming families, their economic situation, and the geographical characteristics of the regions, goat farming is particularly prevalent in the Aegean, Mediterranean, and Southeastern Anatolia regions of Türkiye (Kuru et al., 2024). Abaza and Gurcu goats originating from the Caucasus are local breeds that have adapted to the challenging geographical and climatic conditions of the Eastern Anatolia region (Kuru et al., 2019; Kuru et al., 2024). Abaza and Gurcu goats, which do not have reproductive problems such as low fertility, uterine infections, infertility, and follicular cysts, are an alternative for animal husbandry, but their numbers are quite low (Kuru et al., 2024). Goats that exhibit seasonal reproduction show an annual reproductive cycle under the influence of photoperiodism. The annual reproductive cycle is a disadvantage for producers in terms of milk and meat production (Zuniga-Garcia et al., 2020; Arrebola et al., 2022; Abecia et al., 2024). To overcome these limitations, several methods have been developed to increase reproductive efficiency in farm animals (Alvarado-Espino et al., 2016; Kuru et al., 2022). These methods are frequently used to achieve reproductive performance and ovulation in goats (Arrebola et al., 2022; Duan et al., 2025). Hormonal protocols that produce reproductive outcomes similar to natural reproduction are important methods for eliminating the breeding season in goats (Alvarado-Espino et al., 2016). Among hormonal protocols in goats to promote ovulation, equine chorionic gonadotropin (eCG) accompanies progesterone and estrus induction protocols (Contreras-Villarreal et al., 2016; Zuniga-Garcia et al., 2020; Kuru et al., 2022). eCG is administered immediately after or 24 hours after progesterone withdrawal to synchronize and stimulate follicular growth in goats (Alvarado-Espino et al., 2016). This eCG delays ovulation by producing anti-eCG antibodies, leading to low fertility (Fonseca et al., 2017). Oxidative stress, resulting from an imbalance between free radical species and antioxidants, is among the factors causing reproductive disorders such as endometriosis and infertility (Abd-Elkareem et al., 2024). Lipid peroxidation negatively affects folliculogenesis, ovulation, and meiosis (Amin et al., 2023). Increased reactive oxygen species can reduce oxidized biomolecules before damaging macromolecules (Kassab et al., 2020).

This study aimed to determine changes in serum paraoxonase-1 (PON) activity and glutathione (GSH) and malondialdehyde (MDA) levels in Abaza and Gurcu goats during anestrus and estrus.

2. MATERIALS AND METHODS

2.1. Ethical Approval and Farm Permit

Before commencing the study, approval was obtained from the Kafkas University Animal Experiments Local Ethics Committee (KAU-HADYEK) with the approval of KAU-HADYEK/2025-168 and from the Kafkas University Prof. Dr. Ali Rıza AKSOY Education, Research, and Application Farm with the approval of session number 2024/2025-15 and decision number 22.

2.2. Animals

The animal material used in the study consisted of a total of 30 goats (15 Gurcu goats and 15 Abaza goats) aged between 2 and 4 years, clinically healthy, and weighing between 40 and 50 kg, from the Prof. Dr. Ali Rıza AKSOY Education, Research, and Application Farm at Kafkas University.

2.3. Estrus Synchronization and Mating Procedures

For estrus synchronization, progesterone-containing intravaginal sponges (Esponjavet®, Hipra, Türkiye) were inserted into the goats using a special applicator. These sponges remained in the vagina for 9 days. On the 9th day of progesterone sponge application, all animals received an intramuscular injection of 500 IU eCG (Oviser®, Hipra Animal Health, Türkiye). Twenty-four hours after eCG administration, rams were introduced to the goats, and those exhibiting estrus signs were identified (Kuru 2022; 2023; Kuru and Boğa 2024).

2.4. Biochemical Analyses

Before starting synchronization and from all goats determined to be in estrus, 8.5 mL of blood was collected from the jugular vein into gel-filled vacuum tubes (BD Vacutainer®, Becton, Dickinson and Company, USA). The collected blood samples were centrifuged at 3000 rpm for 10 minutes and then stored at -20°C until serum samples were analyzed.

Serum MDA analysis was performed using the method of Yoshioka et al., (1979). GSH analysis was performed spectrophotometrically at 412 nm according to the method of Beutler et al., (1963). PON activity was determined colorimetrically using the Rel Assay Diagnostics® kit (Gaziantep, Türkiye).

2.5. Statistical Analyses

Statistical analyses of the data obtained in the study were performed using the GraphPad Prism® statistical software (Version 10, GraphPad Software Inc., San Diego, CA, USA). The Shapiro-Wilk test was used to determine whether the obtained data showed a normal distribution according to the groups. The analysis of measured marker data used the analysis of variance method for repeated measurements. The statistical analysis of group, time, and group × time interactions was performed. In addition, the Tukey multiple comparison test was applied for pairwise comparisons of parameters between groups across days and on the sampling day. All results are shown as mean ± standard deviation (SD). In the analysis results, $p<0.05$ was considered statistically significant.

3. RESULTS

3.1. Serum MDA Level

The results of MDA levels in Abaza and Gurcu goats during the anestrus and estrus periods are shown in Figure 1. According to the data obtained, the MDA level increased in the estrus period of Abaza and Gurcu goats ($p<0.05$), and the time effect was significant ($p=0.02$). In addition, it was determined that the group effect and group × time interaction on the MDA level were not statistically different ($p>0.05$).

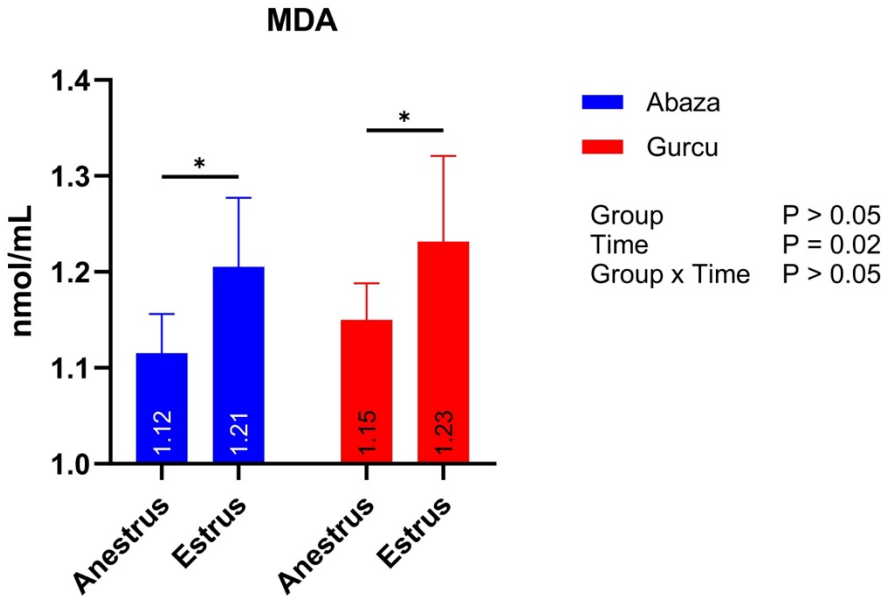


Figure 1: Changes in serum MDA levels in Abaza and Gurcu goats during the anestrus and estrus periods. MDA: Malondialdehyde, *: p<0.05

3.2. Serum GSH Level

Serum GSH level increased in Abaza goats during the estrus period (p<0.05), decreased in Gurcu goats during the estrus period (p<0.01), and the time effect was not significant (p>0.05). Additionally, the group (p=0.01) and group × time interaction were statistically significant for GSH (Figure 2).

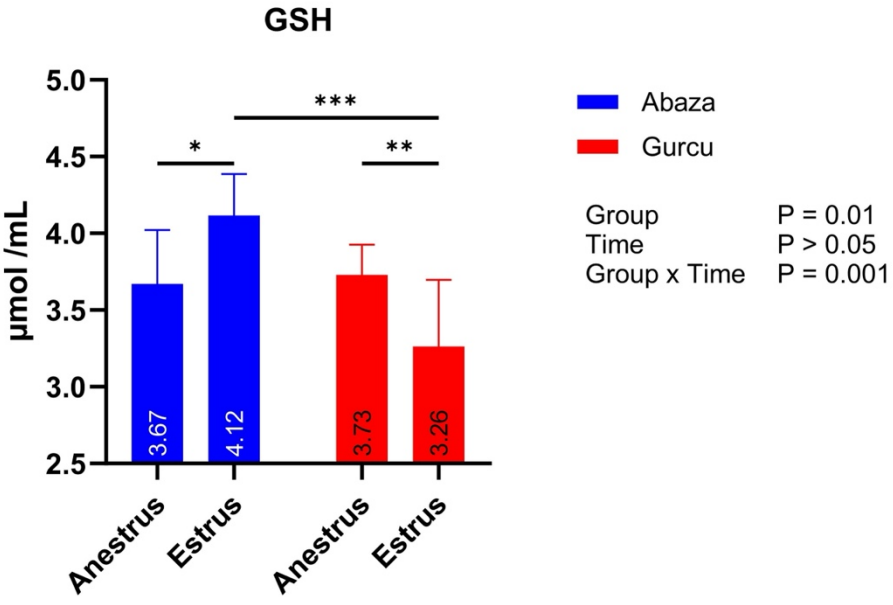


Figure 2: Graphical representation of serum GSH levels in Abaza and Gurcu goats during the anestrus and estrus periods. GSH: Glutathione. *: p<0.05, **: p<0.01, ***: p<0.001.

3.3. Serum PON Activity

The results of PON activity in Abaza and Gurcu goats during the anestrous and estrous periods are shown in Figure 3. PON activity decreased in Abaza and Gurcu goats during the estrus period ($p<0.05$), and the time effect was significant ($p<0.001$). However, the group and group × time interaction in PON activity were not statistically significant ($p>0.05$).

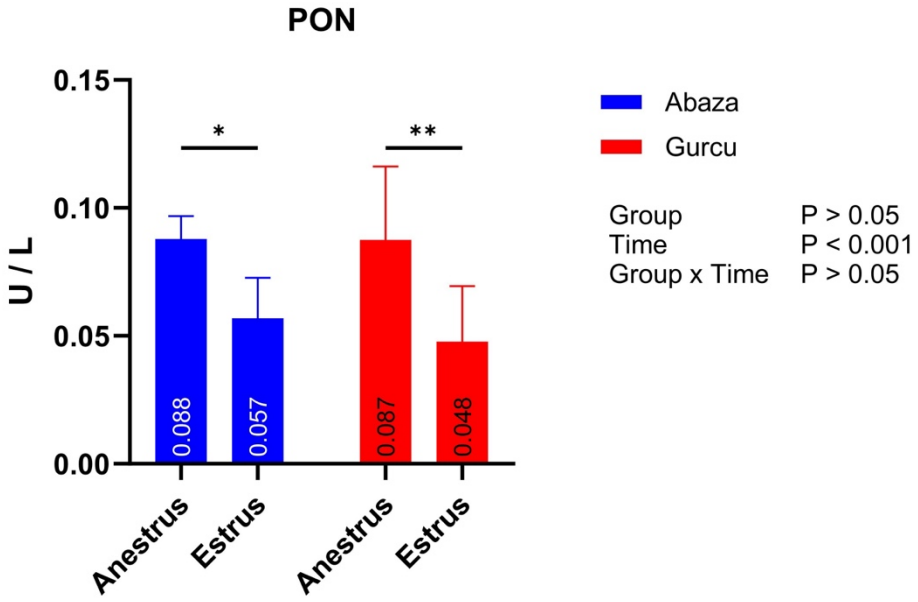


Figure 3: Graphical representation of serum PON activity in Abaza and Gurcu goats during the anestrus and estrus periods. PON: Paraoxonase-1, *: $p<0.05$, **: $p<0.01$

4. CONCLUSION

The most important result of the study is that MDA increased and PON activity decreased in goats. This indicates that the oxidative and antioxidant balance may change during anestrous and estrus. Another interesting finding is that GSH increased in Abaza goats during estrus, while it decreased in Gurcu goats. This reflects that antioxidant capacity may also vary between breeds. Again, these parameters show that they can be used as potential biomarkers for monitoring the estrus cycle periods. Of course, more comprehensive studies should be conducted to better understand the changes in the estrus and anestrus processes or the different stages of estrus and reproductive physiology in local goat breeds such as Abaza and Gurcu goats. The findings obtained will provide a more solid foundation for the results of this study.

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SÜT ENDÜSTRİSİNDE LAKTİK ASİT BAKTERİLERİNİN MAYA/KÜF BOZULMASI ÜZERİNE ETKİSİ

Öğretim Görevlisi Dr. Sinan AKBAL

Pamukkale Üniversitesi, Acıpayam MYO, Gıda İşleme Bölümü, Denizli

Email: sakbal@pau.edu.tr

ORCID: 0000-0001-5928-1917

ÖZET

Süt ve süt ürünleri içerdikleri besin elementleri ve pH/nem değerleri ile maya ve küflerin gelişimi için oldukça uygun bir ortam oluşturmaktadır. Maya ve küfler kefir, kımız, peynir vb. birçok süt ürününde istenilen tipik tat, koku ve yapının oluşmasını sağlamak amacıyla üretimde kullanılabilmesine rağmen genellikle süt teknolojisinde saprofit mikroorganizmalar olarak bilinmektedir. Bu mikroorganizmalar süt ürünlerinin bozulmasından sorumlu olmakla birlikte insan sağlığını da etkileyen zararlı metabolitlerde üretebilmektedir. Özellikle küfler tarafından üretilen mikotoksinler kanserojen, mutajenik ve immünosupresif gibi etkiler göstererek halk sağlığı etkileyen ciddi sağlık sorunlarına sebep olabilmektedir. Maya/küflerin gelişimini engellemek amacıyla gıda ürünlerine farklı doğal veya yapay katkı maddeleri katılabilmektedir. Fakat tüketiciler son yıllarda gıdalarda katkı maddesi kullanımı minimum düzeyde talep etmektedir. Bu nedenle de süt ürünlerinin doğal bir parçası olan laktik asit bakterileri (LAB) önemli bir biyokoruyucu olarak değerlendirilmektedir. Aynı zamanda LAB'i GRAS listesinde yer aldığından süt ürünlerinde farklı cins/türlerin kullanımı oldukça dikkat çekmektedir.

Birçok laktik asit bakterisi antimikrobiyal etkiye sahip laktik asit, asetik asit, diasetil, asetaldehit, yağ asitleri, bakteriosin gibi birçok farklı metabolit üretmektedir. Bu bileşikler hem mikrobiyal gıda bozulmalarına sebep olan saprofit hem de patojen mikroorganizmaların gelişimini engellemektedir. Bu nedenle süt teknolojisinde ürün özellikleri de dikkate alınarak antifungal biyokontrol ajanı olarak LAB'nin kullanılması hem ekonomik kayıpların önlenmesinde hem de tüketici sağlığının korunmasında etkili bir yöntem olduğu düşünülmektedir. Son yıllarda *Lactobacillus* türleri başta olmak üzere *Leuconosto*c ve *Pediococcus* gibi bakteri cinslerine ait türlerin antifungal aktivite gösterdiği birçok araştırmada ortaya konmuştur.

Bu derlemede süt endüstrisinde maya/küflerin sebep olduğu başlıca bozulmalar, antifungal aktivite gösteren LAB'i ve bu bakterilerin ürettikleri metabolitler ile ilgili güncel literatür ele alınmış ve tartışılmıştır.

Anahtar Kelimeler: Laktik asit bakterileri, Antifungal, Biyokoruyucu, Süt ve süt ürünleri

EFFECT OF LACTIC ACID BACTERIA ON YEAST/MOLD SPOILAGE IN THE DAIRY INDUSTRY

ABSTRACT

Milk and dairy products, with their nutritional elements and pH/moisture values, create a highly suitable environment for the growth of yeast and mold. Although yeasts and molds can be used in the production of many dairy products, such as kefir, kumiss, and cheese, to create the desired flavor, odor, and texture, they are generally known as saprophytic microorganisms in dairy technology. These microorganisms are not only responsible for the spoilage of dairy products but can also produce harmful metabolites that affect human health. Mycotoxins, particularly those produced by molds, can cause serious health problems by exhibiting carcinogenic, mutagenic, and immunosuppressive effects. Various natural or artificial additives can be added to food products to inhibit the growth of yeast/molds. However, in recent years, consumers have been demanding minimal additive use in foods. Therefore, LAB, a natural component of dairy products, are considered important biopreservatives. At the same time, since LAB is on the GRAS list, the use of different genera/species in dairy products attracts considerable attention.

Many lactic acid bacteria produce many different metabolites with antimicrobial properties, including lactic acid, acetic acid, diacetyl, acetaldehyde, fatty acids, and bacteriocin. These compounds inhibit the growth of both saprophytic and pathogenic microorganisms that cause microbial food spoilage. Therefore, considering product characteristics in dairy technology, the use of LAB as an antifungal biocontrol agent is considered an effective method for both preventing economic losses and protecting consumer health. In recent years, many studies have shown that species belonging to bacterial genera such as *Leuconostoc* and *Pediococcus*, especially *Lactobacillus* species, exhibit antifungal activity.

In this review, current literature on the main spoilage caused by yeast/molds in the dairy industry, LABs showing antifungal activity and the metabolites produced by these bacteria are discussed.

Keywords: Lactic acid bacteria, Antifungal, Biopreservative, Milk and dairy products

1. GİRİŞ

Tüketiciler gıdalarda yapay katkı maddesi ve koruyucuların yerine doğal ve daha güvenli maddelerin kullanılması tercih etmektedir. Bu amaçla hayvansal, bitkisel ve mikrobiyal kaynaklardan elde edilen birçok katkı maddesi kullanılabilmektedir.

Fungal bozulmalar neticesinde süt endüstrisinde büyük ekonomik kayıplar ortaya çıkmaktadır. Laktik asit bakteri suşlarının antifungal potansiyeli ve GRAS statüleri, onları farklı gıda ve yemlerde fungal bozulmaları etkili bir şekilde engellemek amacıyla biyokoruyucu olarak kullanımında dikkat çekici hale getirmektedir. Günümüzde LAB'lerinin süt ürünleri, meyve suları, unlu mamuller, et, meyve ve sebzeler ile hayvan yemi de dahil olmak üzere çok sayıda gıda ürününde antifungal koruyucu ajan olarak kullanılma potansiyeline sahip olduğu kanıtlanmıştır (Sadiq ve ark., 2019).

2. LAKTİK ASİT BAKTERİLERİ

LAB, uzun yıllardır insanoğluna sayısız faydaları olan içerisinde farklı cins ve türleri bulunduran bir mikroorganizma grubudur. LAB, ana ürün olarak laktik asit üreten mikroorganizmalar olup, Gram pozitif, fakültatif anaerop, kok veya çubuk şeklinde ve spor oluşturmayan mikroorganizmalardır (Trejo-González ve ark., 2022).

Homofermentatif ve heterofermentatif laktik asit bakterileri olarak ikiye ayrılırlar. Homofermentatif türler disakkaritleri metabolize ederek %100'e yakın oranda laktik asit üretimi gerçekleştirmektedir. Heterofermantatif türler ise laktozu metabolize ederek ana ürün olarak laktik asit üretirken bunun yanında etil alkol, diasetil, karbondioksit, asetaldehit, hidrojen peroksit ve asetoin gibi farklı metabolitleri de oluşturmaktadır (Montet ve ark., 2014; Mandha ve ark., 2021; Zapaśnik ve ark., 2022).

Biyokoruyucu kültür olarak bilinen ve en çok kullanılan LAB'leri; *Aerococcus, Enterococcus, Carnobacterium, Leuconostoc, Lactobacillus, Lactococcus, Pediococcus, Oenococcus, Melisococcus, Weisella, Streptococcus, Vagococcus, Bifidobacterium* ve *Tetragenococcus'* dur (Öksüztepe ve ark., 2005).

LAB'i peynir, tereyağı, yoğurt ve ekşi krema gibi süt ürünlerinin fermantasyonunda yer almaktadır. Çeşitli kökenlerden gelen ve kanıtlanmış antifungal aktiviteye ve biyolojik koruma potansiyeline sahip çok sayıda LAB bulunmaktadır. *Lactobacillus* türlerinin antifungal aktivite ile ilişkilendirilen en yaygın bakteri izolatları olduğunu belirtmek önemlidir. *Lactobacillus* türleri arasında, *Lactobacillus plantarum*, antifungal aktivitesi ile iyi bilinen LAB türlerinden biridir (Crowley ve ark., 2013).

3. LAKTİK ASİT BAKTERİLERİNİN ANTİFUNGAL BİLEŞİKLERİ ve ETKİ MEKANİZMALARI

LAB'nin, meyve ve sebzeler, süt ürünleri ve fırıncılık ürünleri gibi ürünlerde antifungal etki göstermesi amacıyla yardımcı veya başlatıcı kültür olarak potansiyel olarak kullanılabileceği bildirilmiştir.

Laktik asit, formik asit, asetik asit, kaproik asit, fenillaktik asit (PLA), karbondioksit, hidroksi yağ asitleri, hidrojen peroksit, diasetil, etanol, reuterin, siklik dipeptitler, protein bileşikleri, asetoin ve diasetil gibi uçucu bileşikler LAB tarafından üretilen doğal antimikrobiyal ve antifungal metabolitlerdir (Cortés-Zavaleta ve ark., 2014; Leyva Salas ve ark., 2018). Tablo 1'de bazı LAB'in antifungal etki spektrumları verilmiştir.

Table 1. Laktik asit bakterilerine ait bazı antifungal maddeler ve etki spektrumları (Nasrollahzadeh ve ark., 2022)

LAB	Antimikrobiyal bileşik	Antifungal etki	Referans
L. plantarum LR/14	Antmikrobiyal peptitler	*A. niger, Rhizopus stolonifera, M. racemosus ve P. chrysogenum*	Gupta ve ark., 2014
L. amylovorus DSM 19280	Asetik asit, laktika sit, Hidrosinnamik asit, Azelaik asit, 4-Hidroksibenzoik asit	P. expansum	Lynch ve ark., 2014
L. reuteri	Reuteri	*P. chrysogenum* ve *M. racemosus*	Vimont ve ark., 2019
L. pentosus, *L. plantarum*, *L. brevis*, *Lactobacillus delbrueckii, L. fermentum, Lactococcus lactis ve Lc. mesenteroides*	Hidrojen sülfür ve laktik asit	*Penicillium oxalicum*, *Fusarium verticillioides* ve *A. niger*	Awah ve ark., 2018
L. plantarum CECT 749	Gallik, klorojenik, kafeik asitler	*Fusarium* spp. *Penicillium* spp. ve *Aspergillus* spp.	Luz ve ark., 2019
Leuconostoc spp. *L. reuteri ve L. buchneri*	Organik asitler	*Aspergillus, Eurotium, Penicillium, Cladosporium ve Wallemia* spp.	Lay ve ark., 2016

Organik asitlerin antifungal etkisi genellikle sinerjik etkilerinden kaynaklanır. Laktik asit, hücre zarından hidrofobik bir formda yayılır, hücre içinde ayrışır ve H+ iyonları salarak asidik bir sitoplazma oluşturur. Laktik asit, proton gradyanını bozarak fungusların gelişimini engelleyebilir. Ayrıca, asetik ve propiyonik asitler funguslar tarafından amino asit emilimini de engeller (Schnurer ve Magnusso, 2005). Fenilalaktik asit (PLA), fenilalanin metabolizmasının bir yan ürünü olarak üretilen organik asittir. PLA, *Aspergillus, Fusarium* ve *Penicillium* türleri gibi birçok fungusun gelişimini engelleme yeteneğine sahiptir (Gerez ve ark., 2009; Lavermicocca ve ark., 2003; Yepez ve ark., 2017; Sadiq ve ark., 2019). Ancak birçok çalışma, fungus gelişimini engellemek için yüksek konsantrasyonlarda PLA gerekliliğini bildirmiştir. Bu durum gıdalarda antifungal madde olarak kullanılmasını kısıtlamaktadır.

Reuterin funguslara karşı antifungal aktiviteye sahip olduğu bildirilmiştir (Vimont ve ark., 2019). Etki mekanizması tiyol gruplarıyla etkileşim yoluyla hücresel oksidatif stres üretimine bağlanmaktadır (Schaefer ve ark., 2010). Reuterin için düşünülen bir diğer inhibisyon mekanizması

ise, DNA biyosentezini düzenleyen ribonükleaz aktivitesinin baskılanması ile gerçekleşmesidir (Talarico ve Dobrogosz, 1989).

Hidrojen peroksit (H_2O_2), aerobik koşullar altında LAB tarafından üretilmektedir. LAB, katalaz üretemez ve H_2O_2 parçalama yeteneğine sahip değildir. Bu nedenle ortamda hedef mikroorganizma üzerinde güçlü bir oksidatif etkiye sahip olan ve aynı zamanda hücresel proteinlerin temel moleküler yapısını bozabilen H_2O_2 konsantrasyonu artar (Dalie ve ark., 2010). Diasetil, antifungal etkiden sorumlu başlıca uçucu bileşiklerden biri olarak bilinmektedir (Aunsbjerg ve ark., 2015). Fakat küf oluşumunu engelleme mekanizması henüz açıklığa kavuşturulamamıştır.

Antimikrobiyal peptitler, birbirine bağlı 5-100 amino asit içeren peptitlerdir (Luz ve ark., 2017). Daha küçük peptitler genellikle daha güçlü antifungal aktiviteye sahiptir. Dört LAB suşunun süpernatantlarından izole edilen düşük moleküler ağırlıklı peptitler (<10 KDa), kontrol süpernatantına kıyasla farklı funguslara karşı daha yüksek antifungal inhibisyon etki gösterdiği bildirilmiştir (Muhialdin ve ark., 2018).

Siklik peptitler, dairesel bir şekilde kovalent bağlı, polipeptit zincirlerinden oluşan peptitlerdir. Dairesel yapı, peptit zincirinin her iki ucunun bir amid bağı veya lakton, tiyoeter, eter veya disülfür bağları aracılığıyla bağlanmasıyla oluşmaktadır (Joo, 2012). Antimikrobiyal siklik peptitlerin etki mekanizması esas olarak yapısal bütünlüğün bozulması ile ilişkilendirilmektedir. Hücre zarı bileşenlerini hedef alarak lizize neden olmakta veya zar ve/veya hücre duvarı biyosentezini engellemektedir (Shai, 1995).

4. SÜT ENDÜSTRİSİNDE MAYA/KÜF BOZULMASI ÜZERİNE DEĞERLENDİRİLMESİ

Peynir, yoğurt ve diğer süt ürünleri fungal kaynaklı bozulmalara hassas ürünlerdir. Tablo 2'de fungal bozulmaları engellemek amacıyla LAB ile gerçekleştirilen bazı çalışmalar verilmiştir.

Tablo 2. Süt ürünlerinde maya/küf bozulmalarına karşı LAB'in biyokoruyucu etkisi

LAB	Antifungal spektrum	Süt ürünü	Referans
L. plantarum	*Penicillium commune*	Cottage peyniri	Cheong ve ark., 2014
Lacticaseibacillus paracasei	*Penicillium sp.*	Yoğurt	Aunsbjerg ve ark., 2015
Propionibacteria ve lactobacilli	*P. chrysogenum, P. commune, M. racemosus, Rhodotorula mucilaginosa*	Ekşi krema, Yarı sert peynir	Leyva salas ve ark., 2018
L. plantarum, L. paracasei, L. mesenteroides, L. paracasei	*A. tubingensis, A. flavus, P. commune, M. racemosus*	Ekşi krema	Ouiddir ve ark., 2019

L. rhamnosus		Queso fresco	Makki ve ark., 2020
L. amylovorus	*P. expansum*	Cheddar peyniri	Lynch ve ark., 2014
L. plantarum (farklı laktobasil türleri ile kombinasyonu)	*P. chrysogenum* ATCC9179, *A. flavus* ATCC46283	Caciotta peyniri	Cosentino ve ark., 2018
L. rhamnosus A238 (tek) ve *Bifidobacterium animalis* subsp. *lactis* A026 ile kombinasyonu	*P. chrysogenum*	Cottage peyniri	Fernandez ve ark., 2017
L. casei AST18	*Penicillium sp.*	Yoğurt	Li ve ark., 2013
L. reuteri ATCC 53608	*P. chrysogenum* LMA-212, M. racemosus LMA-722	Yoğurt	Vimont ve ark., 2019.

Cheong ve ark. (2014), *L. plantarum*'un cottage peynirinde *P. commune*'nin gelişimini LAB 14-25 gün geciktirdğini bildirmiştir. *Lactobacillus amylovorus* DSM 19280, *P. expansum* sporları inoküle edilen çedar peynirinde yardımcı kültür olarak kullanılmış ve kontrol ile karşılaştırıldığında *Penicillium* gelişiminde 4 günlük bir gecikmenin sağlandığı bildirilmiştir (Lynch ve ark., 2014). Cottage peynirinde *Lactobacillus rhamnosus* A238'in tek başına veya *Bifidobacterium animalis* ile kombinasyonu 6 °C'de en az 21 gün küf gelişimini engellemiştir (Fernandez ve ark., 2017). *Lactobacillus brevis* ve *Enterococcus faecium*, 15 günlük depolama süresince yoğurtta (sulandırılmış) *Rhodotorula glutinis*'in gelişimini baskılamıştır (Khomeiri ve ark., 2017).

Ekşi krema ve yarı sert peynirlerde, *Lactobacillus paracasei* CIRM-BIA1759 ve *L. rhamnosus* CIRM-BIA1761 yardımcı kültürler olarak kullanılmış ve ekşi kremada *P. commune*, *Rhodotorula mucilaginosa* ve *Mucor racemosus*'un gelişimini 2-24 gün geciktirmiştir. Ayrıca yarı sert peynirde *P. commune*'un gelişimini ise 1-6 gün geciktirdiği bildirilmiştir (Leyva Salas ve ark., 2018). *L. plantarum* CH1, *L. paracasei* B20 ve *Leuconostoc mesenteroides* L1'in antifungal aktivitesininin test edildiği çalışmada, ekşi kremada *L. plantarum* CH1 ve *L. paracasei* B20, *P. commune* gelişimini sırasıyla 5 ve 3 gün boyunca engellemiştir (Ouiddir ve ark., 2019).

Cansız LAB suşlarının doğrudan kullanımı bazı durumlarda canlı bakterilere göre avantajlıdır. Çünkü bu tür bakterilerin cansız formda, meyve sularında, sütte veya süt ürünlerinde bulunmaları ürünün duyusal özelliklerini etkilemeden mikotoksin bağlama yeteneğine sahip olabilmektedir (Sadiq ve ark., 2019). Örneğin, AFM1 süt ürünleri için ciddi bir endişe kaynağı olarak kabul edilmektedir. AFM1'in LAB suşları tarafından bağlanması, AFM1'i süt ve ürünlerinden uzaklaştırmak için önemli bir strateji olarak kanıtlanmıştır. *L. casei* LC-01 suşu, fermentasyon sırasında 2 ng/L'lik bir başlangıç konsantrasyonu içeren sütteki AFM1'i %50'den daha fazla azaltma kapasitesi göstermiştir (Barukčić ve ark., 2018). Panwar ve ark. (2018), laktobasiller ile kontamine

edilen yağsız sütte AFM1'i bağlama yeteneğini göstermiştir. Taheur ve ark. (2017), kefirin mikrobiyal konsorsiyumunun sütteki OTA azaltımı üzerindeki yeteneğini değerlendirmiş ve *L. kefiri* KFLM3'ün adsorpsiyon yoluyla %81 OTA'yı azaltan en etkili suş olduğunu bildirmiştir. Sarlak ve ark. (2017), *L. acidophilus*'un pH 4,5'te İran'daki fermente bir süt ürününden AFM1'i uzaklaştırmada etkili olduğunu bildirmiştir. AFM1 içeren sütte yoğurt kültürüyle birlikte *L. plantarum* suşunun kullanımı sonucu yoğurdun fermantasyon süresince AFM1'i uzaklaştırmak için etkili olduğu rapor edilmiştir (Elsanhoty ve ark., 2014).

5. SONUÇ VE ÖNERİLER

LAB'leri ürettikleri farklı metabolitler ile güçlü bir antifungal etkiye sahiptir. Bu bileşikler hedef maya/küf'e göre değerlendirilerek tek tek veya kombine olarak kullanılabilir. Tüketicilerin doğal ve katkısız ürünlere artan ilgisi dikkate alındığı zaten hali hazırda süt ürünlerinde kullanılan bu mikroorganizmalara ait metabolitlerinde peynir, yoğurt gibi ürünlere ilave edilerek hem besin değeri artırabilmekte hem de biyokoruyucu görevi görebilmektedir.

LAB birçok süt ürününün doğal mikrobiyal florasında yer almaktadır. Fakat suşa/türe bağlı olarak veya yüksek metabolik aktiviteden kaynaklı olarak üründe bozulmalara sebep olabilmektedir. Bu sebeple LAB'in cansız hücrelerinin ürün içerisine aktarılarak ürünün duyusal özellikleri etkilenmeden küflerin ürettiği mikotoksinlerin sağlık üzerine olumsuz etkisi ortadan kaldırılabilmesi mümkündür. Bu nedenle LAB'lerine ait hücrelerin de gıda endüstrisinde fungal bozulma riski bulunan ürünlerde kullanımının güvenli gıda üretimi açısından önemli olacaktır.

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SÜT TEKNOLOJİSİNDE BİTKİSEL PROTEAZLARIN KULLANIMININ TEKNOLOJİK VE BİYOAKTİF ÖZELLİKLER ÜZERİNE ETKİSİ

Öğretim Görevlisi Dr. Sinan AKBAL

Pamukkale Üniversitesi, Acıpayam MYO, Gıda İşleme Bölümü, Denizli

Email: sakbal@pau.edu.tr

ORCID: 0000-0001-5928-1917

ÖZET

Süt teknolojisinde, sütü pıhtılaştırmak amacıyla genellikle hayvansal ve mikrobiyal kaynaklı enzimler kullanılmaktadır. Bitkisel proteazlar ise süt teknolojisinde alternatif pıhtılaştırıcılar ve fonksiyonel bileşen üreticileri olarak ön plana çıkmaktadır. Dünyada farklı bölgelerde bitkisel pıhtılaştırıcılarda peynir yapımında kullanılabilmektedir. Yüksek proteolitik aktivite göstermeleri sebebiyle farklı tip peynir üretiminde kullanımını sınırlı kalmaktadır. Bu nedenle çoğunlukla yumuşak peynir üretiminde kullanılabilmekte ve sert tip peynirlerde kullanımı önerilmemektedir. Ayrıca peynirde tekstür sorunları, düşük randıman ve acı tata sebep olabilmektedir. Fakat yine de hem teknolojik hem de biyoaktif özellikler açısından bitkisel pıhtılaştırıcı kullanımı dikkat çekmektedir.

Bitkisel proteazlar hemen hemen her türlü bitki dokusunda bulunur. Bitkisel pıhtılaştırıcıların hemen hemen hepsi aspartik proteazlara aittir, ancak sistein ve serin proteazları gibi diğer gruplardan enzimler de bildirilmiştir ve uygun koşullar altında sütü pıhtılaştırma yeteneğine sahiptir. Aktinitin, bromelain, papain, ricin ve fisin gibi bitkisel proteazlar süt proteinlerinin pıhtılaştırılmasında kullanılabilmektedir. Ayrıca enginar (*Cynara* spp.), zencefil (*Zingiber officinale*) ve altın çilek (*Physalis peruviana*) gibi çeşitli bitkilerden elde edilen proteazlar, gelecekte daha farklı özelliklere sahip süt ürünü üretiminde kullanılabilecek alternatif enzim kaynakları arasında yer almaktadır.

Süt ve ürünleri biyoaktif peptit üretimi için önemli bir protein kaynağı olarak bilinmektedir. Bu nedenle bitkisel proteazlar kullanılarak süt proteinlerinin parçalanması sonucu daha düşük alerjeniteye ve daha yüksek biyoaktiviteye sahip ürünlerin üretilmesini mümkün olmaktadır. Bu kapsamda, antimikrobiyal, antioksidan ve antihipertansif etkiler gösteren biyoaktif peptitlerin üretimi, hem gıda teknolojisi hem de nutrasötik uygulamalar açısından büyük bir potansiyele sahiptir.

Bitkisel proteazların süt teknolojisindeki kullanımı, ürün fonksiyonelliğinin artırılması açısından önemli potansiyeli ile dikkat çekmektedir. Ayrıca peynir üretiminde sürdürülebilir/erişilebilir kaynak sağlaması ve yenilikçi üretim teknikleri ile birlikte kullanımı önemli faydalar sağlayabilir. Bu çalışmada da süt teknolojisinde bitkisel proteazların teknolojik ve biyoaktif özellikler üzerindeki olası etkilerine yer verilmiştir.

Anahtar Kelimeler: Bitkisel proteazlar, Süt teknolojisi, Biyoaktivite, Peynir kalitesi, Rennet

EFFECT OF USE OF PLANT-BASED PROTEASES IN DAIRY TECHNOLOGY ON TECHNOLOGICAL AND BIOACTIVE PROPERTIES

ABSTRACT

In dairy technology, enzymes of animal and microbial origin are generally used to coagulate milk. Plant-based proteases are gaining prominence as alternative coagulants and functional component producers. Plant-based coagulants can also be used in cheesemaking in various regions around the world. Due to their high proteolytic activity, their use in different types of cheese is limited. For this reason, it is mostly used in soft cheese production and is not recommended for hard cheeses. Additionally, it can cause texture problems, low yields, and a bitter taste in cheese. However, the use of plant-based coagulants still attracts attention, both in terms of technology and the bioactive properties they create.

Plant proteases are found in almost all plant tissues. Almost all plant-based coagulants belong to aspartic proteases, but enzymes from other groups, such as cysteine and serine proteases, have also been reported and are capable of coagulating milk under appropriate conditions. Plant-based proteases such as actinidin, bromelain, papain, and ficin can be used for the coagulation of milk proteins. In addition, proteases obtained from various plants such as artichoke (*Cynara* spp.), ginger (*Zingiber officinale)* and golden strawberry (*Physalis peruviana*) are among the alternative enzyme sources that can be used in the production of dairy products with different properties in the future.

Milk and its products are known as an important protein source for the production of bioactive peptides. Therefore, the breakdown of milk proteins using plant-based proteases allows the production of products with lower allergenicity and higher bioactivity. In this context, the production of bioactive peptides that exhibit antimicrobial, antioxidant and antihypertensive effects has great potential for both food technology and nutraceutical applications.

The use of plant-based proteases in dairy technology is notable for its significant potential for enhancing product functionality. In addition, it is important to provide sustainable/accessible resources in cheese production and their use with innovative production techniques can provide benefits. In this study, the possible effects of plant proteases on bioactive properties and technological properties in dairy technology are included.

Keywords: Plant-based proteases, Dairy technology, Bioactivity, Cheese quality, Rennet

1. GİRİŞ

Süt, insan beslenmesi için gerekli olan çeşitli fonksiyonel bileşikler (protein, yağ, karbonhidrat, mineral ve vitaminler) sağlar. Farklı hayvanlardan elde edilen sütler kullanılarak dünyada kendine özgü lezzetlere, dokulara ve formlara sahip çok çeşitli peynirler üretilmektedir. En eski peynirin M.Ö. 5000 yıllarına dayandığı düşünülmekte ve o zamandan beri, buzağı şirdeninden elde edilen enzim (kimozin), sütü pıhtılaştırmadaki yüksek verimliliği ve uygun bir teleme dokusu sağlaması nedeniyle tercih edilen esas pıhtılaştırıcı enzim olmuştur. Ancak, peynir üretimindeki artış ve doğal kaynaklarından kimozin tedarikindeki azalma, süt pıhtılaştırıcı enzimlere olan talebi artırmış ve bu da buzağı mayasının yerine mikrobiyal ve bitkisel kaynakların kullanılmasını teşvik etmiştir. *Rhizomucor miehei*, *Rhizomucor pusillus* ve *Cryphonectria parasitica* gibi seçici fungal suşlarının kullanıldığı fermantasyon süreçleri, kimozinin yapısı ve katalitik özellikleri açısından yüksek benzerlik gösteren proteazların üretilmesi için yeterli sonuçlar vermiştir(Mazorra-Manzano ve ark., 2018). Bu sorunun üstesinden gelmek için, rekombinant kimozin (genetiği değiştirilmiş mikroorganizmalardan) piyasaya sürülmüş ve 1989 yılında peynir yapım uygulamaları için FDA onayı almıştır (Fernandez-Salguero ve ark., 2003; Alavi ve Momen, 2020). Buzağı şirdeninin kimozin genini taşıyan *Escherichia coli*, *Aspergillus niger* ve *Kluyveromyces lactis*'in genetiği değiştirilmiş suşları, rekombinant kimozin üretmek için başarıyla kullanılmıştır (Andrén ve ark., 2011). Günümüzde dünya çapında üretilen peynirlerin çoğu (yaklaşık %80'i), süt pıhtılaştırıcı enzim olarak standartlaştırılmış rekombinant kimozin kullanmaktadır. Bununla birlikte, bitki proteazları cazip bir seçenek sunmakta ve son zamanlarda peynir yapımında yeni süt pıhtılaştırıcı maddeler olarak ortaya çıkmaktadır. Bazı ülkelerde hayvansal kaynaklı bileşenlerin veya genetiği değiştirilmiş gıdaların tüketimine yönelik siyasi, dini veya kültürel kısıtlamalar, bitki proteazlarının araştırılmasını ve kullanımını teşvik etmektedir (Roseiro ve ark., 2003).

Bitkisel proteazlar, sütün jelleşmesinden ayrıca süt proteinlerinden farklı özelliklere sahip biyoaktif peptitler sentezlenmesi açısından oldukça önem taşımaktadır. Bitkisel proteazların kazein ve peyniraltı suyu proteinleri üzerine etki ederek üretilen ürünün hem duyusal özelliği hem de biyolojik değeri üzerine etkisi olduğu birçok çalışma tarafından ortaya konmuştur (Matkawala ve ark., 2022) Bu derlemede de bitkisel proteazların peynir teknolojisinde ürün özellikleri ve biyoaktif özellikler üzerine etkisi tartışılmıştır.

2. BİTKİSEL PROTEAZLAR

Peynir üretiminde kimozin ve benzeri etki gösteren sütü pıhtılaştıran enzimler kullanılmaktadır. Giriş bölümünde bahsedildiği gibi genellikle hayvansal kaynaklı olan ve buzağılardan elde edilen şirden mayası tercih edilmektedir. Fakat alternatif olarak mikrobiyal ve bitkisel kaynaklı enzimlerden de sütü pıhtılaştırmak amacıyla yararlanılmaktadır. Meyve, çiçek, sap, lateks vb. gibi farklı dokulardan elde edilen bitkisel proteazlar, sütü pıhtılaştırmak için kullanıldıklarında optimum pH ve sıcaklıkta önemli katalik aktivitelere sahip olabilmektedir (Mazorra-Manzano ve ark., 2018).

Bitkisel proteazlar, çiçek, gövde, yaprak ve kök gibi çeşitli bitki dokularından maserasyon ve ardından ham ekstraktın saflaştırılması yoluyla ekstrakte edilebilir. Proteaz üretiminin kalitesi ve miktarı kuraklık, aşırı yağış ve toprağın bileşimi gibi değişen çevresel koşullardan etkilenebilmektedir. Ekim ve hasat arasındaki uzun yetiştirme süreleri yüksek verim elde edilmesini zorlaştırabilmekte ve üretim maliyetlerinin artmasına neden olur (Shah ve Mir, 2019; Matkawala ve ark., 2022).

Bitkisel proteazlar, katalitik mekanizmalarına göre çeşitli gruplara ayrılırlar. Genellikle sütün pıhtılaştırılması amacıyla kullanılan proteazlar aspartik, serin ve sistein proteazlar olarak sınıflandırılmaktadır (Shah ve Mir, 2014). Enginar bitkisinin farklı türlerinden (*C. cardunculus* ve *C. scolymus*), kimozine benzer katalitik özellikler gösteren ve sütün pıhtılaşmasını sağlayan proteazlar (kardosinler ve sinarazlar) elde edilebilmektedir. Bu enzimler, kimozin ile aynı gruba (aspartik proteinaz, EC. 3.4.23) aittir (Yegin ve Dekker, 2013). Peynir üretiminde aspartik proteazlardan ayrıca diğer katalitik gruplardan proteazlarda kullanılabilmektedir. Papaya, ananas, zencefil ve kividen sırasıyla papain, bromelain, zingibain ve aktinidin gibi sistein proteazları (EC. 3.4.22) ile kavundan (yani cucumisin) serin proteazları (EC. 3.4.21) bu amaçla kullanılan bazı enzimlere örnek olarak verilebilir (Mazorra-Manzano ve ark., 2018).

2.1. Aspartik proteazlar

Aspartik proteazlar, birçok bitki türünde bulunur (Ben Amira ve ark., 2017). Bu enzimler, bitkilerin sindirim/çeşitli gelişimsel süreçlerinde, stres tepkileri sırasında, patojenlere karşı ve hücre yaşlanmasında protein bozunmasında rol oynar (González-Rábade ve ark., 2011) Katalitik aktiviteden sorumlu iki aspartik kalıntıya sahiptir ve bunların etki özgüllüğü, hidrofobik amino asit kalıntıları arasındaki peptit bağlarının kesilmesidir (Domingos ve ark., 2000). Bu enzimler genellikle 28-35 kDa'lık büyük alt birim ve 11-16 kDa'lık küçük alt birim içeren heterodimerik proteinlerdir (Mutlu ve Gal, 1999). Aspartik proteazlar, çoğunlukla β-tabakasından ve düşük miktarda α-sarmal yapıdan oluşmaktadır (Nugent ve ark., 1996). Bu proteazlar, *Citrus aurantium* çiçekleri, *Withania coagulans* meyvesi ve *Cirisium vulgare* çiçekleri gibi birçok bitki dokusundan izole edilmiştir (Mazorra-Manzano ve ark., 2013; Salehi ve ark., 2017; Lufrano ve ark., 2012). En iyi bilinen aspartik proteaz *C. cardunculus*'tan elde edilen kardosinlerdir (Veríssimo ve ark., 1995). Kardosinler kardosin A ve kardosin B başta olmak üzere farklı formlarda (kardosin E, F, G ve H) bulunmaktadır (Veríssimo ve ark., 1995; Sarmento ve ark., 2009). Genellikle Kardosin B'in daha az seçici olmasından dolayı kardosin A kimozin, kardosin B ise pepsinle karşılaştırılmaktadır (Almeida ve Simões, 2018).

McSweeney (2022), aspartik proteaz grubunda peynir mayasına alternatif enzimler olduğunu belirtmiştir. Aspartik proteazlar düşük pH'da aktiftir. Bu proteazlar, mükemmel süt pıhtılaştırıcı özellik göstermekle beraber genellikle düşük proteolitik aktiviteye sahiptir. Phe105–Met106 bağını keserler, bu da kimozinin katalitik özelliklerine benzerdir (Kumar ve Sasmal, 2020; Murlidhar ve ark., 2017; Yegin ve Dekker, 2013).

2.2. Serin Proteazlar

En büyük proteaz gruplarından biri olan Serin proteazlar (SP'ler), aktif bölgelerinde serin kalıntılarına sahiptir. Bitkilerdeki ana rolleri çoğunlukla aspartik proteazlarla aynıdır. Bitkilerin (özellikle meyvelerden) çeşitli kısımlarından elde edilir (Shah ve Mir, 2014) Sistein proteazları veya tiyol proteazları, aktif bölgelerinde bir sistein grubu içeren katalitik bir mekanizmaya sahiptir (Shah ve Mir, 2014; González-Rábade ve ark., 2011) Kovalent enzim/substrat kompleksleri oluştururlar. Katalitik bölgelerinde güçlü nükleofilik amino asit kalıntılarına sahip olduklarından substratın peptit bağının karbonil grubuna nükleofilik bir etki gerçekleştirirler (Dunn, 2001).

Bilinen ilk serin proteaz Cucumisin (EC 3.4.21.25)'dir. *C. melo* L. varr. *Prince*'den elde edilir. Bu enzimin peptit dizilimi, bu gruptaki bitki proteazları incelemek için tercih edilir (Kaur, 2024). Wrightin gibi serin proteazlar 7,5–10 pH aralığında ve 70°C sıcaklıkta aktiftir (Tomar ve ark., 2008); bu nedenle yüksek sıcaklık gerektiren ticari uygulamalarda kullanılabilirler. Sütü pıhtılaştırabilen bir başka serin proteaz, geniş bir pH değeri aralığına (4,0–11,0) ve sıcaklık

aralığına (20–90 °C) karşı çok kararlı olan ve *Solanum dubium*'dan elde edilen dubiumin'dir (Ahmed ve ark., 2009). Sütü pıhtılaştırabilen diğer bitki serin proteazları, *Ficus religiosa*'dan elde edilen religiosin ve *Streblus Asper*'den elde edilen streblindir (Kumari ve ark., 2012; Tripathi ve ark., 2011). Hayvansal maya yerine bir alternatif, rezene (*Foeniculum vulgare*) dokularından elde edilen serin proteazdır. Bu enzim, 6-7,5 pH aralığında ve 40-60 °C arasındaki sıcaklıklarda aktif ve stabil kalmaktadır (Bey ve ark., 2018).

2.3. Sistein proteazlar

Sistein proteazları, tiyol-proteazlar olarak da bilinirler ve aktif bölgelerindeki sistein grubu aracılığıyla reaksiyonları katalize ederler (Mazorra-Manzano ve ark., 2013; Shah ve Mir, 2019). Murlidhar ve ark. (2017), geniş bir pH ve sıcaklık aralığına karşı iyi tolerans gösterdikleri için ticarileştirme için sistein proteazlarının kullanılmasının tercih edildiğini bildirmişlerdir. Ancak, şelat oluşturucu maddeler ve indirgeyici maddeler gerektirirler ve bu da maliyet etkinliğini etkileyebilir (Tripathi ve ark., 2011). *Ananas comosus*, *Carica papaya, Zingiber officinale, Actinidia deliciosa* ve *Ficus carica* Bitki örneklerinden sırasıyla bromelain, papain, zingibain, aktinidin ve ficin yer alır. Bu bitki proteazları arasında papain ve fisin, farklı peynir türlerinde pıhtılaştırıcı olarak bildirilmiştir (Mohsin ve ark., 2024). Bu proteazlar, geniş bir pH ve sıcaklık aralığına dayanabilir. Bu nedenle gıda, ilaç ve biyoteknoloji endüstrilerinde büyük bir uygulama potansiyeline sahip olmaktadır.

Bir sistein endopeptidaz olan papain, proteinlere ve kısa zincirli peptitlere karşı güçlü bir proteolitik aktivite gösterir. Ticari olarak en çok kullanılan bitkisel proteazlardan biridir. Öncelikle Arg-Phe, Arg-Lys ve Phe-Lys arasındaki peptit bağlarına etki eder (Mamboya ve Amri, 2012). Papain geniş bir pH (3.0–9.0) ve sıcaklık (37–70°C) aralığında oldukça stabildir. Organik çözücüler ve denatüre edici ajanların varlığında aktivite gösterebilir (Shouket ve ark., 2020). Papaya bitkisinin lateksinden elde edilebilir. Elde edildiği tropikal meyve (*Carica papaya*) tüm yıl boyunca kolayca bulunur ve sürekli üretim yapılmasını sağlayabilir (Fernández-Lucas ve ark., 2017).

Bir tiyol endopeptidaz olan bromelain, ananasın (*Ananas comosus*) meyvesinden/sapından elde edilir. 1875'ten beri tıbbi amaçla da kullanılmaktadır (Pavan ve ark., 2012). Ucuz bir atık ürün olan sap, meyvelerden daha yüksek konsantrasyonda proteaz içerir (Rathnavelu ve ark., 2016). Bromelain, 3.0–9.0 gibi geniş bir pH aralığına aktiftir ve 37-70°C arasında optimum sıcaklığa sahiptir. Polipeptit zincirindeki peptit bağlarının hidrolizini katalize eder. Hidrofobik ve nonpolar amino asit kalıntıları için özgüllük gösterir (Pavan ve ark., 2012). Ancak, bromelainin kesin etki mekanizması hala bilinmemektedir.

Ficin incirin (*Ficus carica*) lateksinde bulunan endoproteolitik bir enzimdir (Zare ve ark., 2013). Ficinin çeşitli aktif formları veya izoformları, ağacın sağlığına, meyve olgunlaşmasına, sulamaya ve büyüme sırasındaki çevresel koşullara bağlı olarak bitkide bulunur. Ficin aktivitesi için optimum sıcaklık 50-60°C ve pH aralığı ise 6-7' dir (Morellon-Sterling ve ark., 2020).

Kivi meyvesinden elde edilen aktinidin (EC 3.4.22.14), 220 amino asitli bir tiyol proteazdır ve molekül ağırlığı 23,5 kDa'dır (Baker ve ark., 1980). Aktinidin ve papainin amino asit dizilerinde, substrat özgüllüğünde ve üçüncül yapılarında kapsamlı bir homoloji bulunmuştur (Baker ve ark., 1980; Carne ve ark., 1978). Aktinidin amino asit dizisi toplam yedi sistein içerir, bunlardan biri aktif bölgede bulunurken altısı üç disülfür köprüsünün oluşumunda rol oynar.

Kimomeksician ve Meksika sistein proteazları gibi diğer sistein proteazları, *Jacaratia Mexicana* meyvesinin lateksinden elde edilir. Yüksek pH ve sıcaklık stabiliteleri nedeniyle kazein substratlarına karşı proteolitik aktivite gösterir (González-Rábade ve ark., 2011).

3. BİTKİSEL PROTEAZLARIN PEYNİR ÜRETİMİNDE DEĞERLENDİRİLMESİ VE KALİTE ÜZERİNE ETKİSİ

Sütün enzimatik koagülasyonu, peynir yapımında önemli bir adımdır. Bitkisel proteazların enzim aktivitelerinin değerlendirilmesi ve bunların kimozin ile karşılaştırılması, uygun bir rennet seçilmesinde önemlidir (Nicosia ve ark., 2022). Dünyada farklı lezzet, doku ve görünüşe sahip çeşitli peynir ürünleri üretilmektedir. Bu peynirlerin çok az bir kısmında bitkisel proteazlardan yararlanılmaktadır. Bitkisel proteazlarda ancak geleneksel yöntemle üretilen ev yapımı peynirlerde kullanılabilmektedir. Fakat bitkisel proteazlar ile yarı endüstriyel olarak üretilen peynirlere serra da estrela ve torta del casar peyniri örnek verilebilir(Mohsin ve ark., 2024).

Bitkisel proteazların reolojik özellikler, duyusal özellikler (doku, aroma, tat ve renk) ve peynir verimi üzerindeki etkisini belirlemek ve geliştirmek için çalışmalar gerçekleştirilmektedir. Çalışmaların büyük bir bölümü Akdeniz ülkeleri, Batı Afrika ve Güney Avrupa'da bulunan küçük mandıralarda veya çiftliklerde geleneksel prosedürlerle üretilen peynir türleri üzerinde gerçekleştirilmiştir (Nicosia ve ark., 2022). Batı Afrika'da wara ve wangashi peynirlerinin üretiminde *C. procera*'nın sırasıyla yaprakları ve saplarından elde edilen enzimler değerlendirilmiştir. Endonezya, Sudan, Meksika ve Mısır'da sırasıyla dangke peyniri, yumuşak beyaz peynir, asadero peyniri ve domiati peynirini içeren özel yapım peynirler bitkisel proteazlar kullanılarak üretilmiştir (Ahmed ve ark., 2009; Chávez-Garay ve ark., 2016; Darwish, 2016; Rana ve ark., 2017). Dahası, *W. coagulans* enzim ekstraktının ve kısmen saflaştırılmış ekşi portakal çiçeği enzim ekstraktının İran'da inek sütünden İran beyaz peyniri üretiminde kullanımınınuygun olduğu bildirilmiştir (Nasiri ve ark., 2020; Pezeshki ve ark., 2011). Çeşitli bitkisel proteazlar kullanılarak üretilen bazı peynirler Tablo 1'de verilmiştir.

Tablo 1. Bitkisel proteazlar kullanılarak üretilen bazı peynirler (Mohsin vd., 2024)

Peynir türü/menşei	Süt kaynağı	Bitkisel proteaz	Referans
Serra da Estrela cheese/ Portekiz	Koyun	*Cynara spp.*. çiçekleri (Yabani enginar)	Roseiro ve ark. (2003)
Torta del Casar cheese/İspanya	Koyun	*Cynara spp.* çiçekleri (Yabani enginar)	Ordiales ve ark. (2014)
Fresco/İspanya	Keçi	*Cynara cardulus* (Yabani enginar)	García ve ark. (2012)
Dangke/Endonezya	İnek	*Carica papaya* ağacının lateksi	Rana ve ark., (2017)
Wara/ Güney Afrika	İnek	*Calotropis procera* yaprakları	Rajagopalan ve ark., (2019)
Wagashi/ Güney Afrika	İnek	*Calotropis procera* sapları	Aboudoulaye ve Kaya, (2020)

Yumuşak beyaz peynir/ Sudan	Keçi/koyun	*Solanum dubium*	Ahmed ve ark. (2009)
Asadero/Meksika	İnek	*Solanum elaeagnifolium* meyveleri	Chavez-Garay ve ark., (2016)
Domiati/Mısır	Manda/inek	*Abizia lebbeck ve Helianthus annuus*	Darwish (2016)

Peynir üretimi, ısıl işlem, pıhtı işleme, haşlama, tuzlama, ambalajlama vb. faktörlerin etkili olduğu bir prosestir. Sütün pıhtılaşması peynir üretiminde en önemli adımlardan biridir. Bu nedenle enzim seçimi peynirin verimi, dokusu ve duyusal özellikleri üzerinde direkt bir etkiye sahiptir (Zikiou ve Zidoune, 2019; Zhang ve ark.,2023).

Garay ve ark. (2016), bitki kaynaklı maya (*S. elaeagnifolium)* ile üretilen peynirinin daha yüksek verim sağladığını bildirmiştir. Kivi bitkisinden elde edilen enzim ekstraktları ile yapılan peynirlerde acılık olmadığı bildirilmiştir (Puglisi ve ark., 2014). Minyatür peynirler yapmak için *Silybum marianum* çiçeklerinden elde edilen bitkisel preoteaz ile kimozin karıştırılmış ve peynir/ peynir altı suyunda antioksidan özellik ve aroma oluşumu daha yüksek bulunmuştur (Colombo ve ark., 2018). Bir başka çalışmada, bitkisel (örneğin, Enginar makrokarponu) enzim kullanımının kimozine göre daha iyi sonuç verdiği ve mozzarella/diğer peynirlerin üretiminde kullanılabileceği ifade edilmiştir (Manuelian ve ark., 2020),

Ham enginar çiçeği özütüne ait bitkisel proteaz ve ticari peynir mayasının peynir üretiminde kullanımı karşılaştırılmıştır. Bitkisel proteaz ile üretilen peynirin yumuşaklık ve kremsilik özellikleri panelistler tarafından daha yüksek puan almıştır (Zikiou ve Zidoune, 2019). Alavi ve Momen (2020), deve dikeni (*Silybum marianum*) pıhtılaştırıcılarının kimozine göre daha düşük sertlik ve kremsilik özellik kazandırılması bakımından UF peynirinde daha iyi dokusal özellikler sergilediğini bildirmiştir. Endonezya'da üretiminde papain (*Carica papaya*) kullanılan Dangke peynirinde, farklı papain konsantrasyonlarıyla hazırlanan peynirlerin aroması değerlendirilmiş ve sonuçlar, daha düşük miktarda pıhtılaştırıcı ile elde edilen peynirin daha iyi bir aromaya sahip olduğunu açıkça göstermiştir (Rana ve ark., 2017). Hashim ve ark. (2011) tarafından Peşaveri peynirinin hazırlanmasında zencefil özütü (*Zingiber officinale*) kullanılarak elde edilen peynirlerde acıma olmadığı ve şirden mayası ile üretilen peynirden daha iyi duyusal özellikler sergilediğini ifade etmiştir.

4. BİTKİSEL PROTEAZLARIN BİYOAKTİVİTE ÜZERİNE ETKİSİ

Süt proteinlerinin enzimatik hidrolizi sonucu farklı biyoaktif özelliklere sahip peptitler elde edilebilmektedir. Bu peptitler beslenme, bağışıklık sistemi (antimikrobiyal peptitler ve immünomodülatör peptitler), sinir sistemi (opioid peptitler) ve kardiyovasküler sistemde (antihipertansif peptitler ve antitrombotik peptitler) önemli rol oynayabilmektedir (Silva ve Malcata, 2005).

Bitkisel proteazlar kullanılarak süt proteinlerinin biyoaktivitesi üzerine birçok çalışma yapılmıştır. Papain ve bromelain kullanılarak biyoaktif peptitlerin üretildiğini bildirmiştir. Bu proteazlar, yüksek hidroliz derecesine ve düşük molekül ağırlığına sahip peptitlerin salınmasını sağlamaktadır (David Troncoso ve ark., 2022; Mazorra-Manzano ve ark., 2018; Matkawala ve ark., 2022). Tablo 2'de süt proteinlerinin biyoaktif özellikleri üzerine bitkisel proteazların etkisini gösteren bazı çalışmalara yer verilmiştir.

Tablo 2. Bitkisel proteazlar kullanılarak süt proteinlerinin biyoaktivitesi üzerine gerçekleştirilen bazı çalışmalar

Proteaz	Süt kaynağı	Biyoaktif özellik	Referans
Papain	Deve sütü	Antidiyabetik ve antiobezite	Mudgil ve ark., (2019)
Papain	Manda skimmilk retentantı	Antihepatotoksik ve antioksidan	Abdel-Hamid ve ark., (2019)
Fisin	Keçi sütü	Antimikrobiyal	Esmaeilpour ve ark., (2016)
Salpichroin	Peynir altı suyu	Antioksidan	Rocha ve ark., (2017)
Pomiferin	İnek sütü	ACE inhibitör	Corrons ve ark., (2017)
Asian pumpkin	Peynir altı suyu	dipeptidil peptidaz-IV, alfa-glukozidaz ve ACE inhibitörü	Konrad ve ark., (2014)
Dregea sinensis Hemsl.	Manda sütü	Antimikrobiyal	Zhao ve ark., (2020)
Maclura pomifera	Peynir altı suyu	Antioksidan ve ACE inhibitör	(Corrons ve ark., 2012)

Anjiyotensin dönüştürücü enzim (ACE) inhibitör peptitleri, anjiyotensin II'nin vazokonstriksiyonunu sınırlayarak kan basıncını düşürme yeteneğine sahiptir. Bromelain, yarım yağlı ve UHT sütle kullanıldığında ACE inhibitör aktivitesinde sırasıyla yaklaşık %36 ve %44 oranında önemli bir artışa neden olmuştur (Medeiros ve ark., 2013). *M. pomifera* ait proteaz ekstraktı ile kazeinden ACE inhibitör peptitler elde edilmiştir (Corrons ve ark., 2017). Bertucci ve ark. (2015)'de aynı proteaz özütü ile peyniraltı suyu proteininden de ACE inhibitör peptitleri sentezlemişlerdir.

Oksidasyon hücresel metabolizmada önemli bir rol oynamaktadır. Fakat yüksek oranda serbest radikaller apoptozu indükleyerek ve hücrenin yaşamsal faaliyetleri için gerekli enzimleri/ proteinleri oksitleyerek zarar görmesine neden olmaktadır. Liu ve ark. (2016), 400-2000 Da molekül ağırlığına sahip, 4-16 aminoasit içeren ve gastrointestinal sindirime uğramadan hedef bölgeye kolayca ulaşabildiklen peptitleri antioksidan peptitler olarak tanımlamıştır. Bu nedenle peptitlerin amino asit bileşimi antioksidan özelliklerini belirlemede önemli bir rol oynar (Mora ve ark., 2018). Bueno-Gavilá ve ark. (2019), *Cynara scolymus*'un ait bitkisel ekstraktı kullanarak sığır kazeinini hidrolize etmiş ve diğer proteazlarla (hayvansal ve mikrobiyal) karşılaştırıldığında daha yüksek ACE inhibitör ve antioksidan aktivitelere sahip biyoaktif peptitler elde etmişlerdir. Başka bir çalışmada, papain ve bromelain ile elde edilen deve sütü hidrolizatına ait peptitlerin (<14 kDa), kontrollerine kıyasla antioksidan aktivitede önemli düzeyde daha yüksek olduğu bildirilmiştir (Al-Shamsi ve ark., 2018). Luo vd. (2014) tarafından yapılan başka bir çalışmada ise, papain tarafından kazeinin hidrolizinin DPPH temizleme aktivitesinde ve ACE inhibitör aktivitesinde kontrole

kıyasla daha yüksek bulmuşlardır. Kumar ve ark. (2016), 6 saatlik işlemden sonra deve sütü proteini hidrolizatlarının papain ile önemli ölçüde daha yüksek ABTS radikal süpürücü aktivitesi olduğunu bildirmişlerdir.

DPP-IV (dipeptidil peptidaz-IV), glikoz homeostazında rol oynayan bir enzimdir. Bu enzim endokrin, bağışıklık ve inflamatuar sistem bozukluklarına yol açabilmektedir (Abd-El-Salam ve ark., 2009). Boots (2013) tarafından bitki proteazları da dahil olmak üzere farklı enzimlerle kazein hidrolizazyonu gerçeleştirilmiş ve hidrolizatların fraksiyonlanmasından sonra elde edilen permeatın önemli DPP-IV inhibitör aktivitesi gösterdiğini (peptidin N-terminalinde en az 1 prolin kalıntısı bulunduğunu) göstermiştir.

20-46 amino asit kalıntısı uzunluğunda, molekül ağırlığı 10 kDa'dan az, bazik (lizin veya arginin açısından zengin) ve amfipatik olan peptitler antimikrobiyal peptitler olarak kabul edilir (Sanchez ve Vázquez, 2017). Çok sayıda gıda bozulmasına neden olan mikroorganizmayı ve patojenleri inhibe edebilirler ve bu nedenle terapötik ajanlara umut verici bir alternatif olmaktadır (Hayes ve Bleakley, 2018).

5. SONUÇ VE ÖNERİLER

Bitkisel proteazlar genel olarak yüksek proteolitik aktiviteye sahiplerdir. Farklı özgüllüklere sahip olduklarından ürün geliştirmede oldukça önem arzetmektedir. Bitkisel proteazlar kullanılırken peynirin duyusal özellikleri dikkate alınmalıdır. Ayrıca üretimde kullanılan bitkisel proteaz konsantrasyonu da peynir kalitesi üzerinde etkilidir. Bitkisel proteazların serum proteinleri ve kazeine etki ettiği düşünüldüğünde farklı özelliklere sahip birçok peptitin oluşabileceği unutulmamalıdır. Bu peptitler ürünün biyoaktif özelliklerini iyileştirmede oldukça önemli olabilmektedir. Burada dikkat edilmesi gereken önemli hususlardan birisi alerjik reaksiyonlara sebep olup olmadıkları ve sindirilebilirlikleridir. Sonuç olarak bitkisel proteazlar fonksiyonel özellikleri artırmak amacıyla kullanılabilir. Bu amaçla ürünün duyusal özellikleri çok etkilenmeden hayvansal veya mikrobiyal kaynaklı kimozin ile kombine şekilde farklı peynir çeşitlerinde kullanılması üzerine daha fazla araştırma yapılarak değerlendirilmesi araştırılmalıdır. Ayrıca kremleştirme özelliklerinden yararlanarak biyolojik değeri yüksek farklı duyusal özelliklere sahip yeni tip peynirlerde geliştirilebilir.

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DOĞRUSAL HAREKETLİ SULAMA SİSTEMLERİNİN PLANLANMASI

Dr. Mehmet Ali DÜNDAR

Bahri Dağdaş Uluslararası Tarımsal Araştırma Enstitüsü Müdürlüğü, Bitki Yetiştirme Teknikleri Bölümü, Konya.

Email: mehmetali.dundar@tarimorman.gov.tr

ORCID: 0000-0001-6125-0116

Prof. Dr. Ramazan TOPAK

Selçuk Üniversitesi, Ziraat Fakültesi, Tarımsal Yapılar ve Sulama Bölümü, Konya.

Email: rtopak@selcuk.edu.tr

ORCID: 0000-0003-3748-2720

ÖZET

Bu çalışmada, ülkemizde ve özellikle Konya bölgesi koşullarında kullanımı gün geçtikçe artan doğrusal hareketli yağmurlama sulama sistemlerinin planlama aşamaları incelenmiştir. Çalışma, Konya bölgesinde sulama etkinliğini artırmak, sulama işçiliğini azaltarak tarımsal üretim sonucunda elde edilen net geliri artırmanın yanı sıra daha geniş alanların sulanmasını sağlamak amacıyla kullanılan doğrusal hareketli sulama sistemlerinin planlanmasının doğru bir şekilde yapılmasını sağlamak amacıyla ele alınmıştır. Özellikle işgücü gereksiniminin çok az olması, farklı sulama zamanlaması ve sulama miktarlarının hızlı ve kolayca uygulanabilmesi, yüksek su uygulama randımanlarının olması ve yüksek bir eş su dağılımı sağlaması gibi avantajları nedeni ile doğrusal hareketli sulama sistemleri üreticiler tarafından sıklıkla tercih edilmektedir. Son yıllarda kullanımı yaygınlaşan doğrusal hareketli sulama sistemlerinin tekniğine uygun planlanması ve kullanılabilmesi ile sistemden beklenen faydaların sağlanması, bölgenin su kaynaklarının etkin kullanımı bakımından önemli olduğu değerlendirilmektedir. Sistemin hız ayarlarına göre ilerleme hızlarının ve bu hızlarda uyguladığı su miktarlarının bilinmesi, sistemin uygun bir şekilde planlanması ve işletilmesi açısından büyük önem taşımaktadır. Çalışmada 10, 12.5 ve 15 ha büyüklüğündeki araziler için yapılan örnek planlamada, uygun başlık debileri belirlenerek ideal maksimum ilerleme hızları tespit edilmiştir. Yapılan hesaplamalar, sistemlerin farklı ilerleme hızlarında saatte 2.2 ila 65.7 mm sulama suyu uygulanabileceğini göstermiştir. Bu değerler ilerleme hızlarının azalmasıyla artarken, artan ilerleme hızları ile azalmıştır. Yapılan hesaplamalar sonucunda, sistemlerin ideal ilerleme hızlarında yağmurlama hızları 12.6 ile 14.5 mm/h arasında değişmiştir. Özetle, sistemler planlanırken kullanılacak nozul çapının ve uygulanacak ilerleme hızlarının belirlenmesinde toprağın infiltrasyon hızının dikkate alınması ve doğrusal hareketli sulama sistemlerinde başlık debisinin ve sistemin ilerleme hızlarının bu değerlere göre optimize edilmesi gerektiği sonucuna varılmıştır. Ayrıca, yatırım maliyetleri göz önüne alındığında, yerli üretimin tercih edilmesinin işletmeler için ekonomik açıdan daha avantajlı olacağı anlaşılmaktadır.

Anahtar Kelimeler: Doğrusal hareketli sulama sistemi, sulama sistemi planlaması, sulama sistemleri.

PLANNING OF LINEAR MOVE IRRIGATION SYSTEMS

ABSTRACT

This study examines the planning stages of linear moving sprinkler irrigation systems, whose use is increasing day by day in our country and especially in the Konya region. The study was undertaken to ensure the proper planning of linear moving irrigation systems used in the Konya region to increase irrigation efficiency, reduce irrigation labor, increase net income from agricultural production, and irrigate larger areas. Linear moving irrigation systems are frequently preferred by producers due to their advantages, such as minimal labor requirements, the ability to quickly and easily apply different irrigation schedules and rates, high water application efficiency, and high uniformity of water distribution. It is considered important for the effective use of water resources in the region that linear moving irrigation systems, which have become extensively used in recent years, are planned and used in accordance with the appropriate technique to ensure that the expected benefits from the system are achieved. Knowing the advance speeds according to the system's speed settings and the amount of water applied at these speeds is of great importance for the proper planning and operation of the system. In the study, ideal maximum advance speeds were determined by determining the appropriate head flows in the sample planning for 10, 12.5, and 15 ha fields. Calculations show that irrigation water can be applied at rates ranging from 2.2 to 65.7 mm per hour at different advance speeds. These values increase as advance speeds decrease and decrease as advance speeds increase. As a result of the calculations, the sprinkling rates at the ideal advance speeds of the systems varied between 12.6 and 14.5 mm/h. In summary, it was concluded that when planning systems, the soil infiltration rate should be taken into account when determining the nozzle diameter to be used and the advance speeds to be applied, and that the head discharge and advance speeds of linear moving irrigation systems should be optimized according to these values. Furthermore, considering the investment costs, it is understood that preferring domestic production is more economically advantageous for businesses.

Keywords: Linear move irrigation system, irrigation system planning, irrigation systems.

1. GİRİŞ

Küresel iklim değişikliğinin neden olduğu aşırı iklim olaylarının artmasıyla tarımsal üretimin önemli ölçüde etkilenmesinin yanı sıra su kıtlığı özellikle ciddi bir sorun oluşturmaktadır (Dinar ve ark., 2019; Praveen ve Sharma, 2019). Kurak ve yarı kurak bölgelerde, suyun mevcudiyeti bitkisel üretim için önemli bir sınırlayıcı faktördür (Er-Raki ve ark., 2007). Yarı kurak iklim kuşağında yer alan Konya kapalı havzasında son yıllarda yeraltı suyu seviyelerinde bariz bir düşüş olduğu gözlenmektedir (Başçiftçi ve ark., 2013; Demir ve ark., 2021; Göçmez ve ark., 2022) ve bu durum, bu bölgede hem tarımsal üretimin sürdürülebilirliğine hem de su kaynaklarının yönetimi açısından önemli zorluklar meydana getirmektedir. Artan gıda talebi yakın gelecekte tarımın su kullanımını muhtemelen kısıtlayacaktır. Mevcut su kaynakları azaldıkça, maksimum ekonomik getiri ve su kaynaklarının sürdürülebilirliği için suyun verimli kullanımı çok daha önemli hale gelmektedir (Irmak ve ark., 2011). Bu nedenle, su arzı ile tarımsal su ihtiyacı arasındaki dengeyi sağlamak ve yeraltı suyunun aşırı kullanımını azaltmak için Konya kapalı havzası ve benzeri su kıtlığı olan kurak ve yarı kurak bölgelerde optimum su tasarrufu sağlayan sulama uygulamalarına ihtiyaç vardır.

Bitkisel üretimde su kaynaklarının verimli kullanımı için basınçlı sulama sistemlerinin yaygınlaştırılması büyük önem taşır. Ülkemizde sulanan alanların %38'i basınçlı sulama sistemleri ile sulanırken, bunun %21.5'i yağmurlama sulama sistemleri ile sulanmaktadır (ICID, 2025). Konya'da mevcut tarla sulama sistemlerinin modernizasyonu ve iyileştirilmesi çalışmaları, tarımsal sulamanın optimizasyonu için temel bir strateji olmuştur. Bu amaçla Tarım ve Orman Bakanlığı tarafından Konya'da kırsal kalkınma destekleri kapsamında bireysel sulama sistemlerinin desteklenmesi ile basınçlı sulama sistemlerine son beş yılda (2021-2025) toplamda 312 milyon lira tutarında hibe ödemesi yapılmıştır (KTOM, 2025). Su uygulama verimliliğini ve homojenliğini yükselten sulama sistemlerinin tasarlanması, su verimliliğini ve yapılan yatırımın getirisini en üst düzeye çıkarmak için önemlidir (Oker ve ark., 2020). Dolayısıyla bu sistemleri planlayan ve işleten kişilerin hareketli sulama sistemlerinin öncelikle tarla ölçeğinde nasıl çalışacağını ve nasıl performans göstereceğini anlamaları gerekmektedir. Dairesel ve doğrusal hareketli sulama sistemlerinin teknik performanslarının belirlenmesi amacı ile yapılan bazı çalışmalarda, homojen bir sulama için sistemlerin istenilen düzeyde bir performans sergilemediği ve istenilen düzeyde eş su dağılımı sağlamadığı bildirilmiştir (Çalgıcı, 2011; Kılıç, 2019).

Alternatif sulama sistemleri arasında, hareketli yağmurlama sulama sistemleri yüksek su uygulama verimliliğine ulaşma potansiyeline sahip olan ve Konya bölgesinde son yıllarda yaygın olarak kullanılmaya başlanan basınçlı sulama sistemleridir. Özellikle işgücü gereksiniminin çok az olması, farklı sulama zamanlaması ve sulama miktarlarının hızlı ve kolayca uygulanabilmesi, geniş alanların sulanabilmesi, otomasyona uygunluğu ve yüksek bir eş su dağılımı sağlaması gibi avantajları nedeni ile hareketli sulama sistemleri üreticiler tarafından sıklıkla tercih edilmektedir (McKnight, 1986; Keller ve Bliesner, 1990; Alliance, 2015; Waller ve Yitayew, 2016; Sinobas, 2017). Doğrusal hareketli sulama sistemleri dikdörtgen şekilli arazilerin sulanmasında kullanılırlar (Kanber, 2010). Sistem sulanacak arazinin kısa kenarına paralel olacak şekilde yerleştirilir ve tarlanın uzun kenarı boyunca doğrusal olarak hareket ederek sulama yapar.

Bu çalışmada, tarla ölçeğinde doğrusal hareketli sulama sistemlerinin tekniğine uygun bir şekilde planlanarak işletilmesi için bir metodoloji sunulmuştur. Bu amaçla örnek sistem parametreleri kullanılarak, sistemlerin hız ayarlarına göre ilerleme hızlarının ve bu hızlarda uyguladığı su miktarlarının belirlenmesi için gerekli hesaplama aşamaları verilmiş ve sistemlerin ideal ilerleme

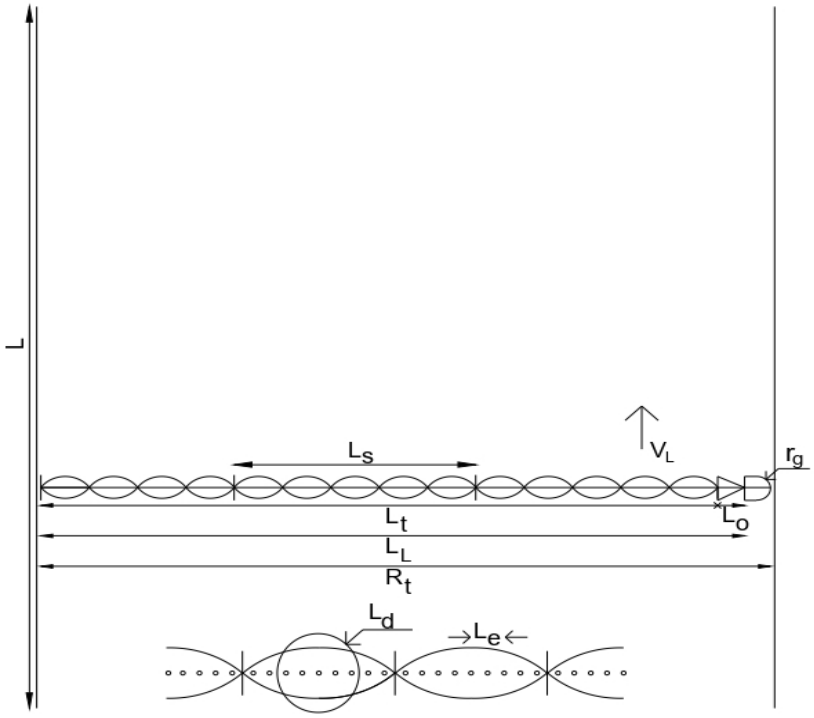
hızlarının tespiti için hesaplamalar örnek sistemler üzerinden yapılmıştır. Çalışmamız etkili ve çevre dostu sulama uygulamaları için faydalı olacaktır.

2. PLANLAMA ESASLARI

Doğrusal hareketli sulama sistemlerinin planlama aşamaları aşağıda maddeler halinde özetlenmiştir;

1) Sistem elemanlarının arazinin boyutlarına göre ölçülendirilmesi,
2) Sistemin ilerleme hız ayarlarına göre ilerleme hızlarının hesaplanması,
3) Yağmurlama başlığı seçimi,
4) Yağmurlama hızlarının hesaplanması,
5) Sistemin ideal maksimum ilerleme hızının belirlenmesi.

Bir sulama sistemi planlanırken öncelikle arazideki tertip biçimi göz önünde bulundurulur. Daha sonra sistemin tertip biçimine göre malzeme seçimi ve kapasite hesaplamaları yapılır. Doğrusal hareketli sulama sistemlerinin arazideki tertip biçimi şekil 1'de verilmiştir.



Şekil 1. Doğrusal hareketli sulama sisteminin arazideki tertip biçimi

$$L_L = L_t + L_o \quad (1)$$

$$L_t = L_{s1} + L_{s2} + \cdots + L_{sn} \quad (2)$$

$$R_t = L_L + r_g \quad (3)$$

Şekil 1'de ve eşitliklerde; L_s: Span uzunluğu (m), L_t: Spanların toplam uzunluğu (m), L_o: Uzatma borusu (overhang) uzunluğu (m), L_L: Sistemin uzunluğu (m), R_t: Sistemin toplam iş genişliği (m), r_g: Son başlığın (endgun) ıslatma yarıçapı (m), V_L: Sistemin ilerleme hızı (m/h), L_d: Yağmurlama başlıklarının ıslatma çapı (m), L_e: Yağmurlama başlıklarının aralığı (m), L: Arazinin uzunluğu (m).

Sulama sistemleri, arazi yüzeyine uygulanan sulama suyunun toprak yüzeyinde göllenmeden toprak içerisine girmesini sağlamalıdır. Bunun için sistemin yağmurlama hızı (mm/h), toprağın infiltrasyon hızından (mm/h) küçük ya da eşit (Eşitlik 4) değer aralıklarında olacak şekilde planlanmalıdır. Böylece, göllenme ile oluşacak buharlaşma ve arazi şartlarına göre yüzey akışla meydana gelecek su kaybının önüne geçilmiş olacaktır. Doğrusal hareketli sulama sistemlerinin yağmurlama hızı Eşitlik 5 ile hesaplanabilir.

$$I_f \leq I_s \tag{4}$$

$$I_f = \frac{q_e}{L_e \times V_L} \tag{5}$$

Eşitliklerde; I_f: Yağmurlama hızı (mm/h), q_e: Yağmurlama başlığı debisi (l/h), L_e: Yağmurlama başlıklarının aralığı (m), V_L: Sistemin ilerleme hızı (m/h), I_s: Toprağın infiltrasyon hızı (mm/h).

Sistemde kullanılacak yağmurlama başlığı debisi belirlenirken su kaynağı debisi ve sistemin uzunluğuna göre toplam başlık sayısı dikkate alınır. Bu şekilde hesaplı başlık debisi belirlenmiş olur. Ancak piyasa şartlarında işletme basıncına göre başlıkların vereceği debiler meme çaplarına göre tasnif edilmiştir. Bu yüzden sistemin planlanmasında üretici firma kataloglarından, kullanılacak başlığın debisi, hesaplanan başlık debisine eşit ya da yakın değerdeki debiye sahip bir başlık seçilmelidir (Eşitlik 6). Kullanılacak başlık debisi Eşitlik 7 ile hesaplanabilir.

$$q_e \leq cq_{ei} \tag{6}$$

$$cq_e = \frac{Q_{ws}}{n_e} \times 1000 \tag{7}$$

Eşitliklerde; q_e: Yağmurlama başlığının gerçek (piyasa koşullarında bulunan) debisi (l/h), cq_e: Yağmurlama başlığının hesaplanan debisi (l/h), Q_{ws}: Su kaynağı debisi (m^3/h), n_e: Yağmurlama başlığı sayısı (adet).

Başlık debisini belirlemek üzere sistemde kullanılacak yağmurlama başlığı sayısı aşağıdaki eşitlik yardımı ile hesaplanabilir.

$$n_e = \frac{L_{s1}}{L_{e1}} + \frac{L_{s2}}{L_{e2}} + \cdots + \frac{L_{sn}}{L_{en}} + \frac{L_o}{L_{eo}} \tag{8}$$

Eşitlikte; n_e: Yağmurlama başlığı sayısı (adet), L_s: Span uzunluğu (m), L_o: Uzatma borusu (overhang) uzunluğu (m), L_e: Yağmurlama başlığı sıklığı (m).

Sistemin farklı hızlarda uygulayacağı yağmurlama hızını hesaplamak üzere sistemin ilerleme hızı aşağıdaki eşitlikle hesaplanabilir.

$$V_L = n \times \frac{1}{G_m} \times \frac{1}{G_w} \times 60 \times u \tag{9}$$

Eşitlikte; V_L: Sistemin ilerleme hızı (m/h), n: Motorun dakikadaki devir sayısı (dev/dk), G_m: Motor redüktör oranı (1:n), G_W: Tekerlek dişlisi oranı (1:n), u: Yük altında tekerlek çevre uzunluğu (m).

Sistemin sulama yapacağı arazinin başlangıç noktasından bitiş noktasına varış süresine sistemin tur süresi denir. Sistemin tur süresi aşağıdaki eşitlik ile hesaplanabilir.

$$t = \frac{L}{V_L} \tag{10}$$

Eşitlikte; t: Tur süresi (saat), L: Arazinin uzunluğu (m), V_L: Sistemin ilerleme hızı (m/h).

Sistemin farklı ilerleme hızlarına göre uygulayacağı yağmurlama hızları hesaplanarak bir liste oluşturulmalıdır. Toprağın infiltrasyon hızı dikkate alınarak sistemin ideal maksimum ilerleme hızı belirlenmelidir. İşletme safhasında sistem en fazla bu hızlarda çalıştırılarak sulama yapılmalıdır (Eşitlik 11). Aksi taktirde sistemin yağmurlama hızı toprağın infiltrasyon hızını geçerek uygulanan sulama suyunun arazi yüzeyinde göllenmesine neden olacaktır. Sistemin ideal maksimum ilerleme hızı Eşitlik 12 ile hesaplanabilir.

$$V_i \leq V_L \tag{11}$$

$$V_i = \frac{q_e}{I_s \times L_e} \tag{12}$$

Eşitliklerde; V_L: Sistemin ilerleme hızı (m/h), V_i: Sistemin ideal maksimum ilerleme hızı (m/h), q_e: Yağmurlama başlığının debisi (l/h), I_s: Toprağın infiltrasyon hızı (mm/h), L_e: Yağmurlama başlığı sıklığı (m).

3. ÖRNEK SİSTEM PLANLAMASI

Örnek bir planlama yapmak için oluşturulan üç ayrı (A, B ve C) doğrusal hareketli sulama sisteminin bazı teknik parametreleri Tablo 1.'de verilmiştir.

Tablo 1. Sistemlerin bazı teknik parametreleri

*Sistem parametreleri	Örnek sistemler		
	A	**B**	**C**
1. Span uzunluğu (m)	47.8	59.6	59.6
2. Span uzunluğu (m)	47.6	59.4	59.4
3. Span uzunluğu (m)	47.6	59.4	59.4
4. Span uzunluğu (m)	-	-	47.6
Sistemin uzunluğu (m)	143	178.4	226
Uzatma borusu (overhang) uzunluğu (m)	12.6	18.6	18.6
Sistemin toplam uzunluğu (m)	155.6	197.0	244.6
Son başlık ıslatma yarıçapı (m) (270^0)	12.2	12.2	12.2
Sistemin toplam iş genişliği (m)	167.8	209.2	256.8
Son başlık (endgun) debisi (m^3/h)	9.3	9.3	9.3
Başlık aralığı (m)	3.0	3.0	3.0
Başlıkların ıslatma yarıçapı (m)	6.0	6.0	6.0
Arazi uzunluğu (m)	600	600	600
Sulanan toplam alan (ha)	10.1	12.6	15.4

*Firma kataloglarından faydalanılmıştır.

Doğrusal hareketli sulama sistemleri, arazinin kısa kenarına paralel olacak şekilde yerleştirilen ve arazinin uzun kenarı boyunca hareket ederek arazinin sulanmasını sağlayan sistemlerdir. Dolayısıyla sistemin uzunluğunu arazinin kısa kenar uzunluğu belirlemektedir. Planlamada span uzunluğu ve sayısı, uzatma borusu (overhang) uzunluğu ve gerekli durumda kullanılacak son

başlığın (endgun) ıslatma yarıçapı değerleri belirlenerek arazinin tamamının eşit bir şekilde sulanması sağlanmalıdır.

Tablo 1.'de A, B ve C olarak isimlendirilen üç ayrı doğrusal hareketli sulama sisteminin teknik parametreleri verilmiştir. Bu sistemlerden A ve B sistemleri üç spanlı, C sistemi ise dört spanlı olacak şekilde planlanmıştır. A sisteminin arazide yer işgal eden toplam uzunluğu 155.6 m, B sisteminin 197 m ve C sisteminin ise 244.6 m'dir. Her üç sistem için de 12.2 m ıslatma yarıçaplı son tabanca kullanılmış, böylece sistemlerin toplam iş genişlikleri (ıslattığı toplam uzunluk) sırasıyla; 167.8 m, 209.2 m ve 256.8 m olarak planlanmıştır. Örnek sistemlerin kurulacağı arazinin uzunluğu 600 m olarak eşit bir değer alınmıştır. Böylece, A sistemi 10.1 ha, B sistemi 12.6 ha ve C sistemi ise 15.4 ha alanı sulayacak şekilde bir planlama yapılmıştır.

Kendinden hareketli sulama sistemlerinin planlanabilmeleri için öncelikli olarak arazideki ilerleme hızlarının hesaplanması gerekir. Esas amaç bu sistemlerin klasik sabit veya yarı sabit yağmurlama sulama sistemlerinde olduğu gibi su uygulama oranlarını, yani yağmurlama şiddetlerini hesaplamaktır. Tablo 2.'de sistemlerin ilerleme hız ayarlarına (%V_s) göre; motorun dakikadaki devir sayısı, motor redüktör oranı, tekerlek dişlisi oranı ve 14.9 x 24 ebatlarındaki lastiğin yük altında tekerlek çevre uzunluğu değerleri verilmiştir.

Tablo 2. Sistemin ilerleme hızı hesabı

%Vs	n (rpm)	G_m (1:n)	G_W (1:n)	u (m)	İlerleme hızı (V_L) (m/h)
100	1450				162.2
95	1378				154.1
90	1305				146.0
85	1233				137.8
80	1160				129.7
75	1088				121.6
70	1015				113.5
65	943				105.4
60	870	1:40	1:50	3.728	97.3
55	798				89.2
50	725				81.1
45	653				73.0
40	580				64.9
35	508				56.8
30	435				48.7
25	363				40.5
20	290				32.4

15	218	24.3
10	145	16.2
5	73	8.1

$\%V_s$: İlerleme hız ayarı, n: Motorun dakikadaki devir sayısı, G_m: Motor redüktör oranı, G_W: Tekerlek dişlisi oranı, u: Yük altında tekerlek çevre uzunluğu (m).

Tablo 2.'deki parametrelerden; sistemin hız oranları, tam kapasitede motorun dakikadaki devir sayısı, motor redüktör oranı, tekerlek dişlisi oranı ve kullanılacak lastiğin yük altında tekerlek çevre uzunluğu değerleri üretici firma kataloglarından alınabilir. Öncelikle hız ayarlarına göre motorun tam kapasitede dakikadaki devir sayısının oranları hesaplanarak motorun tüm devir sayıları hesaplanır. Sonrasında bu devir sayılarının motor redüktör oranı ve tekerlek dişlisi oranları hesaplanır. Çıkan değerler yük altında tekerlek çevre uzunluğu değeri ile çarpılarak sistemin ilerleme hızları hesaplanmış olur. Örnek sistemlerde tam (%100) kapasiteden en düşük (%5) hız ayarına kadar değişen oranlarda hız hesaplamaları yapılmıştır. Buna göre arazide kurulacak bu sistemler en yüksek (%100) hız ayarında saatte 162.2 m, en düşük (%5) hız ayarında ise saatte 8.1 m yol kat edecektir.

Yağmurlama sulama sistemlerinin planlanmasında en önemli aşama yağmurlama başlıklarının seçimidir. Başlık seçiminde en önemli kriter, su kaynağı debisine uygun sayıda başlığın, uygun işletme basıncında çalıştırılarak toprağın infiltrasyon hızını aşmayacak oranda yağmurlama hızını verecek uygunlukta başlık debisinin sağlanmasıdır. Örnek sistemler için ortalama başlık debisi ve uygun başlık debisinin belirlenmesi ile ilgili hesaplamalar Tablo 3.'te verilmiştir.

Tablo 3. Yağmurlama başlığı seçimi

Örnek sistem	Span no	Span			Overhang			$\sum n_e$ (adet)	q_g (m^3/h)	$\sum Q_{ws}$ (m^3/h)	Q_{ws} (m^3/h)	cq_e (l/h)	$^*q_e$ (l/h)
		L_s (m)	L_e (m)	n_e (adet)	L_o (m)	L_e (m)	n_e (adet)						
A	1	47.8	3.0	16	12.6	3.0	4	52	9.3	95	85.7	1648	1597
	2	47.6		16									
	3	47.6		16									
B	1	59.6	3.0	20	18.6	3.0	6	66	9.3	95	85.7	1298	1225
	2	59.4		20									
	3	59.4		20									
C	1	59.6	3.0	20	18.6	3.0	6	82	9.3	95	85.7	1045	1058
	2	59.4		20									
	3	59.4		20									
	4	47.6		16									

* Tablo 4.'den alınmıştır. L_s: Span uzunluğu, L_e: Başlık aralığı, n_e: Başlık sayısı, L_o: Overhang uzunluğu, $\sum n_e$: Toplam başlık sayısı, q_g: Son başlık debisi, $\sum Q_{ws}$: Su kaynağı debisi, Q_{ws}: Son başlık hariç debi, cq_e: Ortalama başlık debisi, q_e: Seçilen başlık debisi.

Sistemde kullanılacak başlığa karar verme aşamasında öncelikle spanlarda ve uzatma borusunda kaç adet başlık kullanılacağı hesaplanır. Tablo 3. İncelendiğinde, span uzunlukları başlık yerleştirme sıklığına (3m) bölünerek her bir spanda kaç adet başlık kullanılacağı hesaplanmıştır. Aynı şekilde uzatma borusunda da kaç adet başlık kullanılacağı bu şekilde hesaplanmıştır. Böylece sistemlerin her birinde toplamda kullanılacak başlık sayısı belirlenmiştir. Örneğin 155.6 m uzunluğundaki A sisteminde toplamda 52 adet, 197 m uzunluğundaki B sisteminde 66 adet ve 244.6 m uzunluğundaki C sisteminde ise toplamda 82 adet başlık kullanılacaktır. Sistemlerin her biri için su kaynağı debisi 95 m^3/h olarak alınmış, yine son başlık debisi her bir sistem için 9.3 m^3/h olarak belirlenmiştir. Sistemlerde kullanılacak ortalama başlık debisini hesaplamak üzere su kaynağının debisinden son başlık için kullanılacak debi değeri düşülerek diğer başlıklar için kullanılacak su kaynağı debisi belirlenmiştir. Tablo 3.'ten görüleceği üzere bu değer her bir sistem için 85.7 m^3/h olarak hesaplanmıştır. Bu değer her sistemin toplam başlık sayılarına bölünerek ortalama başlık debileri hesaplanmıştır. A sisteminin ortalama başlık debisi 1648 l/h, B'nin 1298 l/h ve C sisteminin ise ortalama başlık debisi 1045 l/h olarak hesaplanmıştır. Piyasa koşullarında standart başlık debileri firma katalogları incelenerek belirlenebilir. Kullanılacak standart başlık debileri, meme çapı ve işletme basınçlarına göre Tablo 4.'te verilmiştir.

Tablo 4. Meme çapları ve basınç değerlerine göre başlık debileri (Komet, 2025)

Meme çapı (1/128")	**Rengi**	**Basınç (bar)**			
		0.41 (6psi)	**0.69 (10 psi)**	**1.03 (15 psi)**	**1.38 (20 psi)**
		Debi (l/h)			
20	Turkuaz	390	511	628	689
21	Turkuaz	430	563	692	759
22	Sarı	472	617	759	833
23	Sarı	515	674	829	909
24	Kırmızı	560	733	902	990
25	Kırmızı	608	795	978	1073
26	Beyaz	657	860	1058	1160
27	Beyaz	708	927	1140	1250
28	Mavi	761	996	1225	1344
29	Mavi	816	1068	1313	1440
30	Koyu kahverengi	873	1142	1405	1541
31	Koyu kahverengi	931	1219	1499	1644
32	Turuncu	992	1298	1597	1751
33	Turuncu	1054	1380	1697	1861
34	Koyu yeşil	1118	1464	1801	1975
35	Koyu yeşil	1185	1550	1907	2092

Tablo 4. incelendiğinde meme çaplarına göre farklı işletme basınçlarında elde edilecek debi değerleri verilmiştir. Örnek sistemler için hesaplanan debi değerlerine (Tablo 3.) en yakın debi değerleri başlık debisi olarak belirlenmiştir. Örneğin A sistemi için hesaplanan 1648 l/h başlık debisine en yakın değer Tablo 3.'ten 1597 l/h (1.03 bar işletme basıncında) başlık debisi olarak belirlenmiştir. B sistemi için hesaplanan 1298 l/h debi değeri tablodan 1225 l/h (1.03 bar) ve C sistemi için ise hesaplanan 1045 l/h debi değeri tablodan 1058 l/h (1.03 bar) olarak belirlenmiştir. Böylece sistemde kullanılacak başlık debileri, meme çapları ve işletme basınçları tespit edilmiştir.

Doğrusal hareketli sulama sistemlerinin planlanmasında başlık debisinin belirlenmesinden sonraki önemli bir başka aşama, sistemin ilerleme hızlarına göre su uygulama oranları yani yağmurlama hızlarının hesaplanmasıdır. Örnek sistemler için hesaplanan yağmurlama hızları Tablo 5.'te verilmiştir.

Tablo 5. Yağmurlama hızı

%V_s	**V_L (m/h)**	**L (m)**	**L_e (m)**	**A**		**B**		**C**	
				q_e (l/h)	**d (mm/h)**	**q_e (l/h)**	**d (mm/h)**	**q_e (l/h)**	**d (mm/h)**
100	162.2				3.28		2.52		2.17
95	154.1				3.46		2.65		2.29
90	146.0				3.65		2.80		2.42
85	137.8				3.86		2.96		2.56
80	129.7				4.10		3.15		2.72
75	121.6				4.38		3.36		2.90
70	113.5				4.69		3.60		3.11
65	105.4				5.05		3.87		3.35
60	97.3				5.47		4.20		3.62
55	89.2	600	3.0	1597	5.97	1225	4.58	1058	3.95
50	81.1				6.57		5.04		4.35
45	73.0				7.29		5.60		4.83
40	64.9				8.21		6.29		5.44
35	56.8				9.38		7.19		6.21
30	48.7				10.94		8.39		7.25
25	40.5				13.13		10.07		8.70
20	32.4				16.41		12.59		10.87
15	24.3				21.88		16.79		14.50
10	16.2				32.83		25.18		21.75

5	8.1	65.65	50.36	43.49

%V_s: İlerleme hız ayarı, V_L: İlerleme hızı, L: Arazi uzunluğu, L_e: Başlık aralığı, q_e: Başlık debisi, d: Su uygulama oranı (yağmurlama hızı).

Tablo 5.'ten de görüleceği gibi örnek sistemlerin hız ayarlarına göre saatlik ilerleme hızları ve bu hız değerleri için her bir sistemin saatlik su uygulama oranları, yani yağmurlama hızları hesaplanmıştır. Sistem A için tablo incelendiğinde, sistemin tam kapasitede (%100) saatlik ilerleme hızında (162.2 m/h) yağmurlama hızı 3.28 mm/h saat olarak hesaplanmıştır. Yine aynı sistemin en yavaş hız (%5) ayarında 8.1 m/h yol kat ederek saatte 65.65 mm su uygulayabileceği hesaplanmıştır. B sistemi için aynı değerler 2.52 mm/h ve 50.36 mm/h olarak hesaplanırken, C sistemi için ise 2.17 mm/h ve 43.49 mm/h olarak hesaplanmıştır. Bu değerler, yağmurlama hızının sistemin ilerleme hızının azalmasıyla arttığını, artan ilerleme hızları ile de azaldığını göstermektedir. Böylece farklı ilerleme hızları ile sistemin yağmurlama hızı değiştirilebilmektedir. Bu özelliği ile doğrusal hareketli sulama sistemleri klasik yağmurlama sistemlerine göre önemli ölçüde avantajlar sağlayabilmektedir.

Doğrusal hareketli sulama sistemlerinin bir diğer önemli planlama safhası, sistemin ilerleme hızlarından, toprağın infiltrasyon hızı dikkate alınarak en uygun olan hız değerinin belirlenmesidir. Zira bu parametre sulama randımanını doğrudan etkilemektedir. Örnek sistemlerin ideal maksimum ilerleme hızları Tablo 6.'da verilmiştir.

Tablo 6. Sistemin ideal maksimum ilerleme hızı

%V_s	**V_L (m/h)**	**t (h)**	**L_e (m)**	**I_s (mm/h)**	**A**			**B**			**C**		
					q_e (l/h)	**d (mm/h)**	**V_i (m/h)**	**q_e (l/h)**	**d (mm/h)**	**V_i (m/h)**	**q_e (l/h)**	**d (mm/h)**	**V_i (m/h)**
100	162.2	3.7	3.0	15.0	1597	3.28		1225	2.52		1058	2.17	
95	154.1	3.9				3.46			2.65			2.29	
90	146.0	4.1				3.65			2.80			2.42	
85	137.8	4.4				3.86			2.96			2.56	
80	129.7	4.6				4.10			3.15			2.72	
75	121.6	4.9				4.38			3.36			2.90	
70	113.5	5.3				4.69			3.60			3.11	
65	105.4	5.7				5.05			3.87			3.35	

60	97.3	6.2		5.47		4.20		3.62
55	89.2	6.7		5.97		4.58		3.95
50	81.1	7.4		6.57		5.04		4.35
45	73.0	8.2		7.29		5.60		4.83
40	64.9	9.2		8.21		6.29		5.44
35	56.8	10.6		9.38		7.19		6.21
30	48.7	12.3		10.94		8.39		7.25
25	**40.5**	**14.8**		**13.13**	**35.5**	10.07		8.70
20	**32.4**	**18.5**		16.41		**12.59**	**27.2**	10.87
15	**24.3**	**24.7**		21.88		16.79		**14.50**	**23.5**
10	16.2	37.0		32.83		25.18		21.75
5	8.1	74.0		65.65		50.36		43.49

$\%V_s$: İlerleme hız ayarı, V_L: İlerleme hızı, t: Tur zamanı, L_e: Başlık aralığı, I_s: İnfiltrasyon hızı, q_e: Başlık debisi, d: Su uygulama oranı (yağmurlama hızı), V_i: İdeal maksimum ilerleme hızı.

Örnek sistemlerin ideal maksimum ilerleme hızlarını hesaplamak için toprağın infiltrasyon hızı 15 mm/h olarak alınmıştır. Bu durumda A sisteminin ideal maksimum ilerleme hızı 35.5 m/h, B sisteminin 27.2 m/h ve C sisteminin ise 23.5 m/h olarak hesaplanmıştır. Yapılan örnek çalışmada olduğu gibi hesaplanan hız değerlerinin sistemin ilerleme hızları ile örtüşmediği durumlarda, toprağın infiltrasyon hızı ve sistemin yağmurlama hızları da dikkate alınarak en yakın hız değeri ya da bir üst hız değeri ideal maksimum ilerleme hızı olarak belirlenmelidir. Tablo 6. incelendiğinde, A sisteminin ideal maksimum ilerleme hızı 35.5 m/h olarak hesaplanmış ancak sistemin bu değere en yakın ilerleme hızı 40.5 m/h'dir. Bu hızda sistemin yağmurlama hızı 13.13 mm/h olup, bu değer toprağın infiltrasyon hızından (15 mm/h) küçüktür. Böylece, A sisteminin ideal maksimum ilerleme hızı, sistemin %25 ilerleme hız ayarında 40.5 m/h olarak belirlenmiştir. Eğer bu sistem %20 hız ayarında çalıştırılırsa, sistemin yağmurlama hızı 16.41 mm/h olacak, bu durumda yağmurlama hızı toprağın infiltrasyon hızının (15mm/h) üzerine çıktığı için uygulanan sulama suyu toprak yüzeyinde göllenecektir. Aynı şekilde B ve C sistemleri için yapılan hesaplamalara göre, B sistemi maksimum %20, C sistemi ise maksimum %15 hız ayarlarında çalıştırılmalıdır.

Örnek sistemlerin tur süreleri incelendiğinde, sistemler %100 hız ayarında 600 m uzunluğundaki araziyi 3.7 saatte turlarken, %5 hız ayarında ise bu süre 74 saattir. A sistemi ideal maksimum ilerleme hızında araziyi 14.8 saatte turlarken, B sistemi 18.5 saatte ve C sistemi ise 24.7 saatte turlamaktadır (Tablo 6.).

Sistem planlanması yukarıda özetlenen şekilde yapıldıktan sonra sistemlerin işletilmesi ile ilgili programlar yapılmalıdır. Yetiştiriciliği yapılacak bitkilerin sulama programlarına göre sistemlerin hız ayarları, tur sayıları, toplam sulama süreleri ve sulama aralıkları gibi sulama işletmeciliği ile ilgili hesaplamalar yapılmalı, gerektiğinde geriye dönük sistem planlamaları revize edilmelidir.

Sulama işletmeciliği ile ilgili kısa bir örnek vermek gerekirse, sulama aralığı 10 gün olan ve her sulamada 80 mm sulama suyu uygulanan bir bitki ekili arazinin, örnek sistemlerle sulandığını varsayalım. A sisteminde ideal maksimum ilerleme hızında, saatte 13.13 mm sulama suyu uygulanmaktadır. Dolayısıyla 80 mm sulama suyunun uygulanabilmesi için sistemin 80/13.13= 6 tur çalıştırılması gerekmektedir. Böyle bir durumda her bir tur 14.8 saatten, toplamda 14.8x6= 88.8 saat sulama yapılacaktır. Günlük çalışma süresinin 18 saat olduğu varsayımı ile A sistemi bu araziyi yaklaşık 5 günde sulamaktadır. Sulama aralığının 10 gün olduğu düşünüldüğünde sistemin doğru bir şekilde planlandığı görülmektedir. Aynı şekilde B sistemi bu araziyi 6 tur'da toplamda 111 saatte ve 6 günde sulayabilmektedir. C sistemi ise bu araziyi 5 tur'da toplamda 123.5 saatte ve 7 günde sulayabilmektedir.

Doğrusal hareketli sulama sistemlerinin planlanması ve işletilmeleri ile alakalı planlamaların yanı sıra ilk yatırım maliyetlerinin de belirlenmesi bir işletme için hayati öneme sahiptir. Zira yapılacak yatırımın ekonomik olarak değerlendirilmesi işletme için teknik planlamalar kadar kritik süreçlerdir. Bu nedenle örnek sistemler için piyasa araştırması yapılarak maliyetleri belirlenmiştir. Sistemlerin ithal veya yerli ürün olarak temin edilmelerinin maliyetleri, birim alan maliyetleri ve oluşan maliyet farkları Tablo 7'de verilmiştir.

Tablo 7. İthal ve yerli sistemlerin birim alan maliyetleri ve farkları

Örnek sistem	Span sayısı (adet)	Sistemin toplam uzunluğu (m)	Sulanan toplam alan (ha)	İthal ürün		Yerli ürün		İthal/yerli ürünün birim alandaki maliyet farkı (bin ₺/ha)	İthal/yerli ürünün birim alandaki maliyet farkı (%)
				Sistem maliyeti (milyon ₺)	Sistemin birim alan maliyeti (bin ₺/ha)	Sistem maliyeti (milyon ₺)	Sistemin birim alan maliyeti (bin ₺/ha)		
A	3	155.6	10.1	1.90	0.188	1.10	0.109	0.079	42.1
B	3	197.0	12.6	2.45	0.194	1.40	0.111	0.083	42.9
C	4	244.6	15.4	3.10	0.201	1.75	0.114	0.088	43.5

Tablo 7. incelendiğinde, 3 spanlı 155.6 m uzunluğundaki A sistemi 10 ha alan sularken ithal olarak temin edildiğinde 1.90 milyon liraya, yerli olarak temin edildiğinde ise 1.10 milyon liraya mal olmaktadır. Bu sistemin birim alan maliyeti ithal üründe ha başına 188 bin lira iken yerli üründe 109 bin liradır. İthal ve yerli üründe ha başına maliyet farkı 79 bin lira olup ithal/yerli ürün arasında %42.1 maliyet farkı vardır. B sistemi için maliyetlere bakıldığında, 3 spanlı 197 m uzunluktaki sistemin maliyeti ithal üründe yaklaşık 2.45 milyon lira, yerli üründe ise 1.40 milyon liradır. Sistemin birim alan (ha) maliyeti ithalde 194 bin lira, yerli üründe ise 111 bin liradır. İki ürün

arasındaki fark 83 bin lira olup %42.9 maliyet farkı vardır. Son olarak 4 spanlı 244.6 m uzunluğundaki C sisteminin maliyetleri sırasıyla; 3.10 ve 1.75 milyon lira olup iki ürün arasında birim alanda %43.5 (88 bin lira) maliyet farkı vardır. Bu farklar yerli ürünlerin tercih edilmesi ile yapılacak yatırımın daha ekonomik olacağını göstermektedir.

4. SONUÇ

Yapılan bu çalışmaya göre, doğrusal hareketli sulama sistemlerinin planlanmasında yağmurlama başlıklarının meme çapı ve işletme basıncının, su kaynağı debisi ile uyumlu olacak başlık debisini sağlayacak şekilde seçilmesi gerektiği anlaşılmaktadır.

Toprağın infiltrasyon hızı dikkate alınarak sistem uygun ilerleme hızlarında çalıştırılmalıdır. Toprağın infiltrasyon hızının düşük olduğu arazilerde kurulacak sistemlerde daha düşük debili başlıklar tercih edilmeli veya yüksek ilerleme hızlarında çalıştırılmalıdırlar.

Yerli üretimin muadili ithal ürünlere göre 10, 12.5 ve 15 ha büyüklüğündeki araziler için sırasıyla; % 44.1, %43.3 ve %42.6 daha düşük maliyetli olduğu dikkate alındığında, yerli üretimlerin tercih edilmesinin işletmeler için ekonomik açıdan daha avantajlı olacağı anlaşılmaktadır.

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KEÇİ YETİŞTİRİCİLİĞİNDE PAZARLANABİLİR SÜTÜ ARTIRMANIN BİR YOLU: SÜT İKAME MAMALARININ KULLANIMI

Dr. Öğr. Üyesi Murat Durmuş

Cukurova University, Faculty of Agriculture, Department of Animal Science, Adana, Turkey

Email: durmusm@cu.edu.tr

ORCID: 0000-0002-4221-7449

ÖZET

Bu derlemede oğlak beslemede süt ikame mamalarının kullanımının büyüme performansı ve çiftlik karlılığı üzerindeki etkileri incelenmektedir. Özellikle süt verimi yüksek keçi ırklarında yavruların doğal emzirme ile beslenmesi pazarlanabilir süt miktarında önemli azalmaya ve ekonomik kayıplara yol açmaktadır. Oğlakların erken gelişim döneminde, yüksek kaliteli protein ve enerji gereksinimi, bağışıklık sisteminin güçlendirilmesi ve rumen gelişiminin desteklenmesi açısından besleme stratejileri büyük önem taşımaktadır. Bu kapsamda formüle edilen süt ikame mamalarında süt tozu ve peynir altı suyu başta olmak üzere balık unu, kan unu ve yumurta tozu gibi hayvansal kaynaklı bileşenler; yüksek biyolojik değere sahip protein fraksiyonları ve kolay sindirilebilirliği ile büyüme hızını desteklemektedir. Buna karşılık kavrulmuş soya fasulyesi, soya küspesi, buğday küspesi ve nişasta türevleri gibi bitkisel kaynaklar, maliyet etkinliği ve sürdürülebilir hammadde tedariki açısından avantajlar sunmaktadır. Literatürdeki bulgular, uygun besin madde kompozisyonu ve sindirilebilirlik düzeyine sahip süt ikame mamalarıyla beslenen oğlakların, anne sütü emen akranlarıyla karşılaştırıldığında vücut ağırlığı artışı, bağışıklık göstergeleri ve rumen fonksiyonlarında benzer sonuçlar elde ettiğini göstermektedir. Ayrıca, süt ikame mamalarının kullanımı, pik laktasyon döneminde insan tüketimine yönelik süt arzının artmasına olanak tanıyarak doğrudan gelir artışı sağlamaktadır. Araştırmalar hayvansal ve bitkisel içeriklerin dengeli kombinasyonlarının besin yeterliliği ve maliyet etkinliği açısından anne sütü ile beslemeye göre daha üstün olduğunu göstermektedir. Ekonomik değerlendirmeler bu uygulamanın doğal laktasyona kıyasla daha yüksek karlılık sağladığını doğrulamaktadır. Sonuç olarak, süt ikame mamalarının rasyonel formülasyonu ve uygun yönetim uygulamalarıyla entegrasyonu, hem oğlakların büyüme ve sağlık parametrelerini güvence altına almakta hem de pazarlanabilir süt verimini maksimize ederek çiftlik ekonomisine anlamlı katkı sunan stratejik bir yaklaşımdır.

Anahtar Kelimeler: Keçi sütü, oğlak besleme, büyüme performansı, süt ikame mamaları

A WAY TO INCREASE MARKETABLE MILK IN GOAT BREEDING: USE OF MILK REPLACERS

ABSTRACT

This review examines the effects of using milk replacers in kid rearing on growth performance and farm profitability. In high-yielding dairy goat breeds, feeding offspring by natural suckling significantly reduces the volume of marketable milk and leads to economic losses. During the early developmental period, nutritional strategies are essential to meet the kid's requirements for high-quality protein and energy, strengthen the immune system, and support rumen development. In milk substitute foods formulated in this context, animal-derived ingredients such as fish meal, blood meal and egg powder, primarily skim milk powder and whey powder, support growth rate with protein fractions of high biological value and easy digestibility. On the other hand, vegetable sources such as roasted soybeans, soybean meal, wheat meal and starch derivatives offer the advantages in terms of cost efficiency and sustainable raw material supply. Findings from the literature indicate that kids fed milk replacers with appropriate nutrient composition and digestibility achieve outcomes comparable to those of counterparts suckling maternal milk in body weight gain, immune indicators, and rumen function. Moreover, the use of milk replacers increases the amount of milk available for human consumption during peak lactation, directly raising producer income. Studies further show that balanced combinations of animal and plant ingredients can surpass natural suckling in both nutrient adequacy and cost-effectiveness. Economic evaluations confirm that this practice yields higher profitability compared to natural lactation. In conclusion, the rational formulation of milk replacers and their integration with appropriate management practices safeguard growth and health parameters in kids while maximizing marketable milk yield, thus constituting a strategic approach that delivers substantial benefits to farm economics.

Keywords: Goat milk, kid nutrition, growth performance, milk replacers

1. INTRODUCTION

As with the nutrition of all mammals, the nutrition of kids after birth begins with the intake of colostrum. It is important that newborn kids suckle within the first few hours after birth and consume an amount of colostrum equivalent to about 10% of their body weight per day. This practice plays a crucial role in strengthening their immune system and, consequently, in determining their performance parameters. The reason why colostrum in ruminants must be ingested as soon as possible after birth is due to the epitheliotic structure of the placenta (Hernandez-Castellano et al., 2014). Due to this type of placenta, antibodies cannot be transferred to the fetus during gestation, leaving newborns highly susceptible to pathogenic challenges at birth. Colostrum not only fulfills the nutritional needs of the newborn, but also provides essential immunological support, thereby influencing disease resistance, enzymatic activity, growth, and other biological functions at later stages of development (Hernandez-Castellano et al., 2014). For this reason, it is essential that newborn kids consume adequate amounts of colostrum secreted by their mothers in the first three days after birth.

In Turkey, where goat farming is predominantly carried out in extensive system, a significant proportion of the milk produced during lactation (especially during peak milk production periods) is used to feed the kids. While this is essential to ensure adequate nutrition for kids of local or meat-oriented breeds with low milk yields, it reduces the amount of marketable milk for dairy breeds such as Saanen, Damascus or Alpine. As a result, farms that breed high-yielding exotic goat breeds are faced with a significant decrease in the amount of saleable milk, which in turn leads to economic losses. Goat's milk is considered better than other types of milk due to several special characteristics: Its composition is more similar to human milk, it contains less lactose, its αs1-casein protein content is lower and its smaller fat globules improve digestibility. Due to these properties, goat's milk is often preferred in human nutrition, as it causes less bloating and colic in infants, causes fewer digestive problems in lactose intolerant individuals, has a lower allergenic potential, and is easier to digest. In addition, goat's milk can be processed into high-quality dairy products such as cheese, cream, butter, and ice cream, offering significant profit margins.

Given these benefits, early weaning of kids of goat breeds with high milk yields and rearing them with special milk replacers can be a practical strategy. Several studies have shown that kids reared with milk replacers have comparable growth and development to those suckled with natural milk (Keskin & Biçer, 2002; Sarker et al., 2015). Shortening the traditional two-month milk feeding period by replacing breast milk with nutritionally balanced milk replacers can therefore increase the amount of saleable milk and have a positive impact on farm profitability. To be a suitable alternative, milk replacers must be formulated in such a way that they are very similar to the composition of natural milk. In addition to their high protein and energy requirements, kids also need an adequate supply of vitamins and minerals. In the period, before weaning, vitamins A, D, E, and K should be supplied. As the rumen is not yet fully functional, B-complex vitamins must also be supplied. Minerals such as Ca, P, Mg, Cu, Fe, Zn, I, Se, and Mn are also important and should be included in the diet. For this purpose, replacement diets are usually made from cow’s milk or milk by-products, grains, and vegetable oils (Zamuner et al., 2023). Consequently, their formulation can be based either on purely animal components or on a combination of animal and plant components.

This review, examined the effects of the use of milk replacers in kid feeding over the last thirty years on the growth performance of kids and the profitability of farms.

1.1. Milk Replacer Formulas Prepared with Animal Origin Products

In ruminant breeding, especially in the early developmental stages of young animals, nutritional management plays a decisive role in determining later performance parameters. Due to their rapidly developing physiological systems, kids require a high quality and balanced diet from the first weeks of life immediately after birth. At this critical period, the use of feeds with high protein quality, energy density, and digestibility is crucial for the development of the immune system, body weight gain, and proper development of rumen functions. Animal replacers such as fishmeal, blood meal, meat and bone meal, plasma proteins, and milk by-products are of importance, as they provide proteins of high biological value, an appropriate balance of essential amino acids, and a rich supply of micronutrients. Especially in the pre-weaning period, the controlled and balanced incorporation of these resources into rations supports immunity and maximizes growth performance. Among animal-based milk replacers, cow's milk, milk products, and milk by-products are the most commonly used due to their relatively low cost. Research has shown that diets formulated with milk replacers of animal origin do not show significant differences in health and growth parameters compared to those fed with maternal milk (Galina et al., 1995; Ripoll et al., 2021). Nevertheless, the occurrence of diarrhea, bloating, or weakness in kids should be carefully monitored after switching to artificial milk replacers. Studies investigating the use of animal-based milk replacers in kid nutrition are presented below.

In a study conducted by Galina et al. (1995), a total of 90 female kids of the Saanen, Alpine, and Toggenburg breeds with similar initial body weights were divided into six treatment groups, of 15 animals each. The treatments included: maternal milk, cow's milk, milk replacer, milk replacer + 20% goat whey, milk replacer + 35% goat whey, and milk replacer + 50% goat whey. The trial lasted eight weeks until weaning. The results showed that kids reared on goat's milk, cow's milk, or milk replacer with 35% goat's whey showed no significant differences in growth performance. However, the kids in the group receiving milk replacer + 20% whey showed significantly lower growth rates, while in the group receiving milk replacer + 50% whey, 80% of the kids showed digestive disorders at least once, and one mortality was recorded.

In another experiment, Knupp et al. (2016) evaluated the economic feasibility of feeding programs based on liquid diets as an alternative to goat milk, using Monte Carlo techniques. Forty-eight male kids (24 Saanen and 24 Alpine) with similar age and initial body weights were divided into four groups of 12 animals each: Goat's milk, cow's milk, commercial milk replacer, and fermented bovine colostrum. The kids were slaughtered at either 60 or 90 days of age. Based on an economic analysis that took into account the costs of feeding and management up to slaughter, it was concluded that goat milk- fed kids resulted in economic losses at both slaughter ages, while cow milk feeding resulted in the highest profit. Commercial milk replacers, although not superior to natural milk in terms of growth outcomes, were highlighted as more cost-effective, supporting their use as an alternative to maternal milk in the pre-weaning period. These findings suggest that to increase marketable goat milk and improve farm profitability, replacer feeds should be preferred over giving goat milk directly to kids.

Ripoll et al. (2021) investigated the effect of rearing systems on carcass quality. Two groups As breeding system were compared: Kids reared with a commercial milk replacers and those suckled by their maternal. A total of 240 kids, representing eight breeds (Florida, Cabra del Guadarrama, Majorera, Palmera, Payoya, Retinta, Tinerfeña, and Verata), were included, with 30 animals per breed randomly assigned to each treatment (15 kids per group). After colostrum feeding for the first two days, the kids were either suckled freely or fed ad libitum via an automatic milk replacer

until they reached 8 kg body weight. The milk replacer used contained 60% skimmed milk and 40% whey powder. The post-slaughter findings showed that the kids fed with the milk replacer had a higher muscle percentage in the carcass, a higher head and internal organ weight, a higher carcass length, and limb measurements, but a lower fat deposition in the skin, intermuscular tissue, and kidney fat. The authors emphasized that both breed characteristics (dairy vs. meat type) and rearing systems significantly influenced carcass characteristics, suggesting that production systems should be tailored to market requirements.

In another study, Sepriadi et al. (2022) investigated the inclusion of black soldier fly (Hermetia illucens) larval meal as a sustainable protein source in milk replacer diets for Ettawa crossbred kids. Ten kids were allocated equally to two treatments groups: conventional commercial milk replacer and insect meal-enriched replacer. Parameters measured included feed intake, average daily body weight gain, weaning weight, and physiological indicators (rectal temperature, heart rate, respiratory rate). Kids in the insect meal-enriched replacer group had a higher dry matter, calcium, and fat intake, but a lower phosphorus and protein intake. Growth performance remained unchanged between the groups, although physiological parameters increased within acceptable limits in the insect meal group. The study concluded that black soldier fly larval meal is a sustainable and environmentally friendly alternative for milk replacer formulations, although further improvements in protein composition and palatability compared to commercial products are required.

In view of these findings, the more effective use of milk replacers in the feeding of kids on farms with high milk-producing breeds will help to increase the profitability of farms and the added value of dairy products. Future research should in particular investigate the bioavailability, digestibility, and effects on the immune system of different protein sources and test their applicability under field conditions. This will enable the development of a more sustainable and efficient production model, both in terms of animal welfare and production economics.

1.2. Milk replacer prepared with products of animal and plant origin

Profitability, animal welfare, and sustainability in ruminant breeding are closely linked to the optimization of feeding strategies in the early stages of development. Due to their rapid growth and development immediately after birth in kids, it is essential to meet their nutritional needs with high quality and balanced feeds. To supplement natural maternal milk, milk replacers have been developed as cost-effective and practical alternatives. In recent years, the inclusion of animal and plant-derived ingredients in milk replacer formulations has attracted considerable attention, as it provides a balanced nutritional profile while reducing production costs. Animal ingredients such as skimmed milk powder, whey, blood meal, fish meal, and egg powder provide high biological value proteins, essential amino acids, and a wide range of vitamins and minerals. Conversely, plant sources such as soy flour, wheat bran, starch derivatives, and oilseed pulp provide affordable and readily available alternatives that may also contain functional compounds such as antioxidants, fiber, and phytochemicals. An optimal combination of these two groups not only provides a highly digestible protein profile, but also promotes gut health, immunocompetence and feed intake. Previous studies have examined in detail the effects of milk replacers with different proportions of animal and plant components on growth performance, rumen development, nutrient digestibility, and meat quality in kids. For example, feed replacers combining milk powder with roasted soybeans or wheat-based formulations enriched with egg powder have shown successful results when used in well-adjusted proportions. Nevertheless, factors such as processing methods, feeding rate and the age at which the replacer is introduced remain critical to its effectiveness. This section

therefore highlights the influence of integrated animal and plant-based formulations in milk replacers on the nutrition and development of kids.

Ouedraogo et al. (1998) investigated the feasibility of incorporating roasted full-fat soybean meal as a component of milk replacer for kids. The experimental design consisted of a control diet (in which 95 of the crude protein was derived from skim milk powder and 5% from whey) and two treatments in which soybean meal was roasted at 100°C for either 10 minutes (HSF 10) or 30 minutes (HSF 30). A total of 20 kids, aged 13 days , were used: 6 in the control group, 8 in the HSF 10, group and 6 in the HSF 30 group. All replacement diets contained 24% crude protein and 22% fat. In the soy-based replacer diets, 45% of the total protein was supplied by HSF 10 or HSF 30, while the remainder came from 45% skim milk powder and 10% whey. The results showed that the control group had the highest digestibility values, while digestibility decreased in the HSF 10 group. The authors concluded that roasted full-fat soybean meal processed at 100°C for 30 minutes could be a viable protein source in milk replacers for kids.

Bañón et al. (2006) conducted another study to evaluate the effects of feeding kids with either natural goat milk or formulated milk replacers on meat quality and lipid composition. For this purpose, 36 male Murciano-Granadina kids were randomly assigned to two feeding groups. The substitutes consisted of skimmed milk powder, coconut oil, cereal products, and cereal by-products. The results showed that although the protein content of the meat was significantly higher in kids fed with milk replacers, their meat had a lower water binding capacity than kids raised on goat milk. In addition, different feeding regimeinfluenced the fat composition of the carcass: kids fed with maternal milk had meat with a higher saturated fat content. In addition, the sensory evaluation results showed that kids fed with milk replacement produced meat with better taste and odor values than the kids fed with maternal milk.

In a other study, Sampelayo et al. (2003) investigated the influence of different dry matter concentrations in milk replacers on the growth performance of kids. A total of 30 male Granadina kids were included in the trial. All animals received maternal milk for the first two days, after which six kids were immediately slaughtered. The remaining 24 kids were separated from their maternal on the second day and given milk replacers with either 120 g/kg or 200 g/kg dry matter as a milk substitute. Six kids from each treatment group (12 in total) were then slaughtered at 20 and 40 days of age. The formulated milk replacers consisted of 450 g/kg skimmed milk powder, 250 g/kg animal fat, 135 g/kg whey powder, 35 g/kg soy protein concentrate, 100 g/kg starch products and 30 g/kg of a vitamin, mineral and amino acid mixture. The results showed that kids fed milk replacer at 120 g/kg dry matter showed slower growth in the first 20 days than kids fed 200 g/kg replacer. However, this initial performance loss was compensated for in the following 20 days, as higher feed intake improved growth performance. The authors attributed the initial shortfall to the fact that the kids were unable to consume sufficient protein and energy when fed the lower dry matter feed. However, as rumen capacity subsequently increased, feed intake also increased accordingly, resulting in comparable growth rates between treatments. The study also highlights that metabolizable energy (ME) requirements are increased in the early growth phase, but gradually decrease as the animals adapt to the feeding regime. Overall, the results underline the need to adjust the composition of milk replacers and feeding programs to the age and stage of development of the kids in order to optimize growth and energy supply.

Astuti et al. (2019) investigated the inclusion of cricket meal as a protein source in milk replacers. Twelve Etawah crossbred kids were allocated to three dietary treatments with four kids per group: Goat milk, cow milk and a formulated milk replacer containing cricket meal. The milk replacer

consisted of skimmed milk powder, egg yolk powder, whole milk, wheat bran, fish oil, a vitamin-mineral premix and calcium carbonate ($CaCO_3$). The daily amount of milk replacer was set at 3.5% of the body weight of the kids on a dry matter basis. The average daily intake of cow milk, goat milk and the formulated milk replacer was given as 986 g, 875 g and 847 g, respectively. Accordingly, the dry matter intakes were 120 g, 98 g and 203 g, respectively. Kids who received the replacer consumed the most dry matter, which consequently led to a higher intake of protein, fat and calcium nutrients, which are considered crucial for early growth and development.

In another study, Islam et al. (2019) investigated the feasibility of adding rice gruel, an inexpensive and carbohydrate-rich ingredient, to milk replacers for black Bengal kids. The objective of this study was to evaluate the effects of rice gruel–based milk replacers in combination with soybean milk and cow milk on growth performance, blood parameters, carcass traits, visceral organ development and rumen morphology. For this purpose, 15 Black Bengal kids aged two to three weeks were randomly divided into three treatment groups with the same number of animals. Group A was fed whole milk only, group B was fed 75% milk + 25% rice gruel replacer, and group C was fed 50% milk + 50% rice gruel replacer. The results showed no significant differences in growth performance between the groups, indicating that the rice gruel replacement adequately supported normal growth. When examining the blood values, the hematological analysis revealed no significant differences in the erythrocyte, leukocyte, hemoglobin or immune cell profiles. However, packed cell volume (PCV) was higher in the rice porridge-fed goats, indicating improved nutrient and oxygen transport. Carcass and internal organ characteristics were similar in all treatments. Dry matter, fat and ash content of the meat showed that was slightly higher in the replacement groups, while crude protein content remained comparable. Histologic evaluation of rumen papillae showed longer and wider papillae in kids fed milk replacers diets, indicating improved rumen development and an earlier transition to functional rumination. Overall, the results suggest that milk replacers containing up to 50% rice gruel can be a safe, cost-effective and nutritionally sound alternative for kid rearing without compromising growth, health or carcass quality, while promoting accelerated rumen maturation.

Similarly, Sultana et al. (2014) aimed to formulate affordable milk replacers from locally available ingredients and evaluate their effects on growth performance, nutrient digestibility and economic profitability in black Bengal kids. In this experiment, three different milk replacer formulations were prepared and 20 kids were divided into four treatment groups (five animals each). The treatments included: control group (goat milk), a turmeric-based replacer, an egg and wheat flour-based replacer and a skim milk-based replacer. The study found that kids fed turmeric-enriched replacer diets had higher dry matter intake, resulting in higher nutrient intake and better growth performance compared to the other groups. Although feed conversion rate was similar across treatments, dry matter and organic matter digestibility was better in the turmeric group. The cost analysis also showed that the turmeric- enriched replacement diets had the most favorable cost-benefit ratio. In conclusion, the authors suggested that replacement diets containing turmeric or egg + wheat flour could serve as a viable alternative to milk feeding in kid rearing.

1.3. Economic Analysis

On dairy goat farms with high-yielding goat, feeding kids with milk replacer contributes directly to the profitability of the farm by increasing the amount of marketable milk. With natural suckling, kids consume almost all of their milk in the first two months of lactation, which significantly reduces the amount available for sale and leads to economic losses. The use of milk replacers allows farms to maintain the growth performance of kids while increasing the amount of milk that can be

marketed during the peak of lactation, a period characterized by maximum milk yield. Especially in the first two months of lactation, when milk yield is at its highest, rearing kids with milk replacers improves the availability of marketable milk and has a positive effect on the overall income of the farm. The economic benefits of this practice, which are supported by findings from the literature are summarized below.

Keskin and Biçer (2002) investigated the growth performance of kids and the economic impact on farms when comparing natural suckling with rearing on milk replacers. For this purpose, 30 kids from uniparous Shami does were divided equally into two treatment groups: one was reared on maternal milk and the other on milk replacer. The kids were observed for two months after birth and it was reported that neither the growth rate of the kids nor the yield of the maternal milk was negatively affected by the rearing system over a period of 60 days. However, in the milk replacer group, the amount of saleable milk increased, which improved the profitability of the farm based on both marketable milk yield and body weight of the kids. According to the results, the group of Damascus goats reared with milk replacers produced 79.5 liters of marketable milk per goat, while the value in the group with natural suckling was zero (Figure 1). This clearly shows that the use of milk replacer enables producers to bring the milk directly to market and thus increase income of the farms.

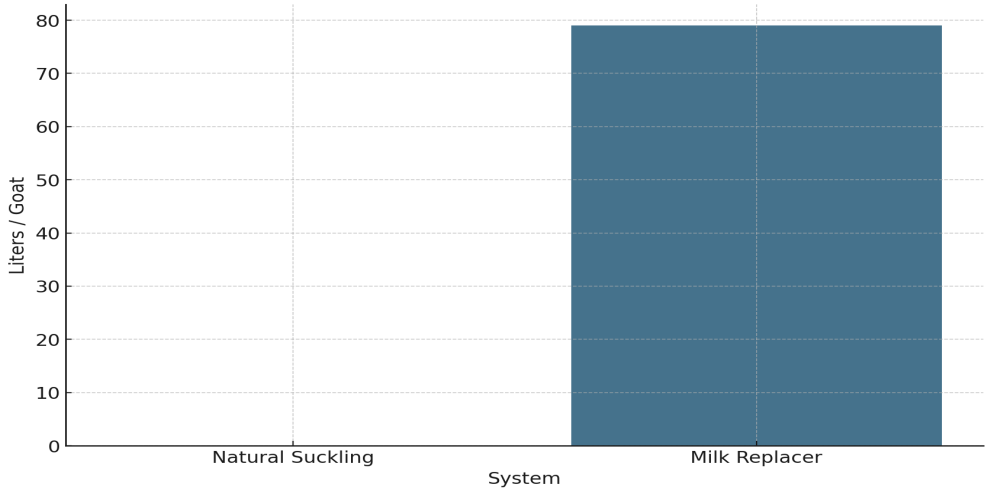


Figure 1. Comparison of marketable milk quantity according to feeding systems

In the same study, the net gain per kid reared with milk replacer was reported to be USD 8.09 compared with those naturally suckled (Figure 2). This result suggests that feeding kids with low-cost milk replacers until weaning age can significantly improve income due to the increase in marketable milk yield. Hassan et al (2018) also reported that kids reared on milk replacers achieved almost three times higher net profit over a 12-week period than naturally suckled counterparts, a result directly related to the greater amount of milk available for sale.

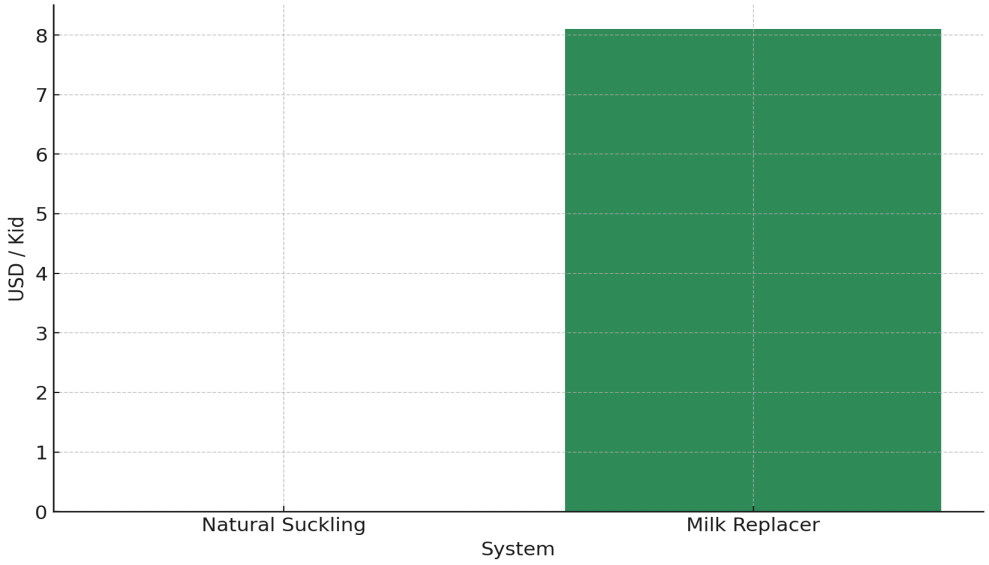


Figure 2. Comparison of net profit according to rearing systems

In addition, Keskin and Biçer (2002) reported that live weight gain in kids fed with milk replacer was similar or higher than in naturally suckled counterparts. Accordingly, kids fed with milk replacers gained on average 1 kg more live weight at day 60 (Figure 3).

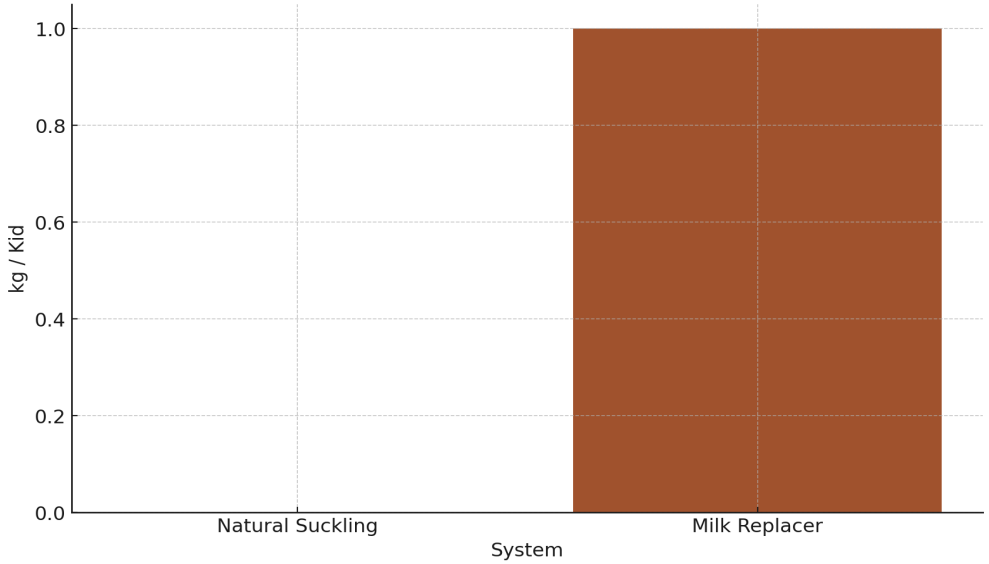


Figure 3. Comparison of live weight gain according to rearing systems

Similarly, Knupp et al. (2016) reported that replacing maternal milk with alternative liquid diets did not negatively affect the growth performance of kids, while the use of milk replacers increased the amount of marketable milk and thus improved farm profitability. Milk replacers serve as a strategic tool on dairy goat farms, especially in high-yielding herds, by simultaneously improving production efficiency and economic returns. When properly formulated and systematically applied, the use of milk replacers supports normal kid growth without adverse effects, ensures greater availability of saleable milk and consequently maximizes farm income. Therefore, promoting the use of milk replacers in kid rearing up to weaning age, especially in highly milk productive goats, is of considerable importance for strengthening the economic sustainability of the livestock.

2. CONCLUSION

In this review, the effects of the use of milk replacers in kid feeding on growth performance and farm profitability were investigated; in particular, their potential to increase the amount of marketable milk was evaluated. The findings show that milk replacer feeding offers significant advantages over traditional breastfeeding, both in terms of the nutritional profile, which is close to breast milk, and the fact that the producer has the opportunity to market the milk directly. On farms with goat breeds with a high milk yield, feeding milk until the kids are weaned (around two months) leads to a considerable reduction in the marketable milk yield and to economic losses. In this context, milk replacers not only support animal health and growth rate, but also increase profitability by making the milk of goats available for human consumption or the production of dairy products. Numerous studies in the literature report that kids who are fed with milk replacer achieve similar body weight gains as kids who are naturally suckled counterparts, and in some cases even faster growth rates. Economic analyzes also support the claim that this system significantly increases the amount of marketable milk and thus the income per animal. In this context, the following recommendations can be made:

- **In herds with high milk yields, switching kids to milk replacer shortly after birth is an effective strategy for increasing marketable milk production.**
- **The formulations of the milk replacer should be adapted to the age and developmental stage of the kids. The content of vitamins and minerals, especially protein and energy, should correspond to that of maternal milk.**
- **The balanced use of animal and vegetable ingredients in the production of kid formula increases the efficiency of nutrition and helps to reduce costs.**
- **Hygiene and biosecurity are important factors to consider in the production and use of kid formula. In particular, ensuring high quality ingredients to reduce the risk of digestive problems such as diarrhea, as well as appropriate dilution rates and temperature levels are critical to the use of formula.**
- **The economic analysis at farm level should include a comparison between the increased income from marketable milk achieved by using milk replacer and the cost of formulated milk replacer. This enables a more accurate cost-benefit calculation.**

In summary, milk replacers provide a holistic feeding approach to goat farming that both protects animal welfare and maximizes the producer's economic return by increasing the amount of marketable milk and dairy products. It is therefore recommended that this strategy be expanded, especially on farms with high-yielding goats.

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SÜT İNEKLERİNDE DOĞUM SONRASI ORAL PROPİLEN GLİKOL UYGULAMASININ VÜCUT KONDİSYON SKORU ÜZERİNE ETKİLERİ

Yüksek Lisans Öğrencisi Orhan YALÇIN

Sivas Cumhuriyet Üniversitesi, Sağlık Bilimleri Enstitüsü, Hayvan Besleme ve Beslenme Hastalıkları Anabilim Dalı, Sivas-Türkiye.

E-mail: vetorhan58@gmail.com

ORCID: 0009-0002-0642-6400

Prof. Dr. Recep GÜMÜŞ

Sivas Cumhuriyet Üniversitesi, Veteriner Fakültesi, Hayvan Besleme ve Beslenme Hastalıkları Anabilim Dalı, Sivas-Türkiye.

E-mail: rgumus@cumhuriyet.edu.tr

ORCID: 0000-0002-8812-191X

ÖZET

Süt ineklerinde postpartum (doğum sonrası) dönem metabolik bozuklukların en sık gözlendiği kritik bir süreçtir. Doğuma girerken ineklerin bulunduğu vücut kondisyon skoru (VKS), olması gerekenden düşük ya da yüksek olması negatif enerji dengesi (NED), ketozis, yağlı karaciğer sendromu ve üreme sorunlarına yol açarak süt verimini ve hayvan refahını olumsuz etkilemektedir. Vücut kondisyon skoru, sığırların enerji rezervlerini ve genel sağlık durumunu değerlendirmek amacıyla kullanılan, pratik ve yaygın bir yöntemdir. Bu sistem, hayvanın belirli anatomik bölgelerindeki yağ ve kas dokusunun gözlemlenmesi ve elle kontrol edilmesi esasına dayanır. VKS genellikle 1 (aşırı zayıf) ile 5 (aşırı yağlı) arasında derecelendirilir. Ölçek üzerinde 1, yağ dokusu ve kas örtüsünden yoksun, kaşektik hayvanları; 5 ise aşırı yağlı ve metabolik sorunlara yatkın hayvanları temsil etmektedir. Böylece, VKS değerlendirmesi sığırların enerji depoları, metabolik dengesi ve üretim potansiyeli hakkında önemli bilgiler sunar. Propilen glikol (PG), glukoneojenik özelliği sayesinde enerji metabolizmasını destekleyen bir bileşiktir. Bu çalışmada postpartum dönemde oral PG uygulamasının VKS üzerine etkileri araştırılmıştır. Çalışmada, 40 adet Simental inek kullanılmıştır ve inekler rastgele yöntemle kontrol (n=20) ve deneme (n=20) gruplarına ayrılmıştır. Deneme grubuna doğum sonrası beş gün boyunca oral yolla günlük 500 ml PG uygulanırken, kontrol grubundaki ineklere herhangi bir uygulama yapılmamıştır. Doğum öncesi ve postpartum 21. günde VKS değerlendirmeleri yapılmıştır. Elde edilen sonuçlar istatistiksel olarak değerlendirildiğinde gruplar arasında önemli bir fark bulunmamıştır ($P>0.05$). Çalışmada PG uygulama süresinin sonuçlar üzerine etkili olabileceği ve ileride yapılacak yeni çalışmalarda literatüre katkı vermesi açısından önemli olduğu söylenebilir.

Anahtar Kelimeler: Süt İneği, Postpartum Dönem, Propilen Glikol, Vücut Kondisyon Skoru

THE EFFECTS OF POSTPARTUM ORAL PROPYLENE GLYCOL ADMINISTRATION ON BODY CONDITION SCORE IN DAIRY COWS

ABSTRACT

The postpartum period in dairy cows is a critical phase in which metabolic disorders are most frequently observed. The body condition score (BCS) at calving, whether below or above the optimal range, can lead to negative energy balance (NEB), ketosis, fatty liver syndrome, and reproductive disorders, thereby adversely affecting milk yield and animal welfare. BCS is a practical and widely used method to evaluate the energy reserves and overall health status of cattle. This system is based on visual observation and manual assessment of fat and muscle tissues at specific anatomical sites. BCS is typically graded on a scale from 1 (emaciated) to 5 (obese). A score of 1 represents cachectic animals lacking fat and muscle coverage, while a score of 5 corresponds to excessively fat animals prone to metabolic problems. Thus, BCS assessment provides important insights into cattle's energy reserves, metabolic balance, and production potential. Propylene glycol (PG), owing to its gluconeogenic properties, is a compound that supports energy metabolism. This study investigated the effects of oral PG supplementation during the postpartum period on BCS. A total of 40 Simmental cows were used and randomly assigned to a control group (n=20) and a treatment group (n=20). The treatment group received 500 ml of PG orally once daily for five consecutive days postpartum, whereas no treatment was administered to the control group. BCS evaluations were performed prepartum and on day 21 postpartum. Statistical analysis of the results revealed no significant difference between the groups ($p>0.05$). It may be concluded that the duration of PG administration could influence outcomes, and that further research in this area would provide valuable contributions to the literature.

Keywords: Dairy Cow, Postpartum Period, Propylene Glycol, Body Condition Score.

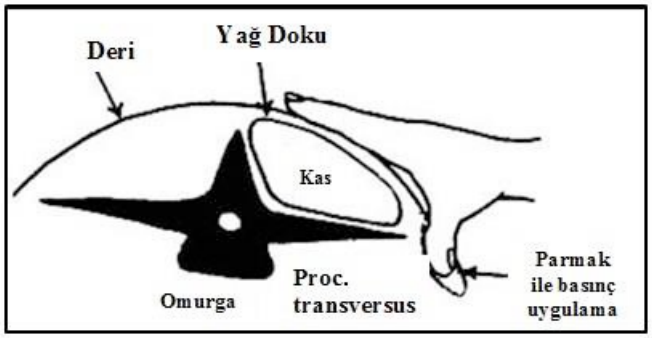
1. GİRİŞ

Gelişmekte olan ülkelerde, süt çiftliklerindeki giderlerin %70'inden fazlası hayvanların beslenmesi için kullanılan yemler oluşturmaktadır. Hayvancılık ile uğraşan yetiştiricilerin çoğu kaliteli beslemenin ve dengeli beslenmenin faydalarının farkında değildir. Hatta, bazıları, inek buzağı doğurduktan sonra besleme stratejisini düşünmektedir. Bunun yerine, geçiş dönemi (gebeliğin son 3 haftası ve laktasyonun ilk 3 haftası) için iyi planlanmış bir besleme ve yönetim programı olmalıdır. Bu aşamadaki uygunsuz besleme (az veya fazla), yeni doğan buzağının düşük doğum ağırlığına, doğum sonrası östrus göstermeme ve ineklerin düşük üretkenlik performansına yol açabilir (Sasser ve ark., 1988; Singh ve ark., 2003). Postpartum dönem, doğumdan sonraki ilk haftaları kapsar ve laktasyonun başlangıcını temsil eder. Bu dönemde hayvanın enerji gereksinimi süt üretimiyle birlikte hızla artar, ancak kuru madde alımı hemen yükselmez. Bu nedenle enerji açığı devam eder ve hayvanda canlı ağırlık kaybı gözlenir (Overton ve Waldron, 2004). Postpartum dönemde yetersiz beslenme veya yönetim hataları, döl verimi ve süt veriminde ciddi azalışlara yol açabilir. Ayrıca bu dönemde hipokalsemi, plasenta retensiyosu, metritis ve mastitis gibi rahim ve meme sağlığıyla ilişkili hastalıklar daha sık ortaya çıkar (LeBlanc, 2010).

Süt ineklerinde vücut kondisyon skoru (VKS), sahip olduğu vücut yağ oranının bir değerlendirmesidir ve süt sığırı yönetiminde önemli bir faktör olarak kabul edilmektedir. VKS' yi ölçmek için kullanılan ölçek ülkeler arasında farklılık gösterse de genellikle VKS 5'lik bir sistemde gösterilmekte ve bu sistemde 1 aşırı zayıf, 2 zayıf, 3 iyi, 4 yağlı, 5 aşırı yağlı hayvanı ifade etmektedir (Tablo 1) (Mishra ve ark., 2016; Çitil ve Uzlu, 2005; Koçyiğit, 2017). Bu değerlendirme, hayvanın vücudundaki kemik çıkıntılarını örten yağ tabakasının görsel olarak incelenmesine dayanır (Şekil 1) (Amaral Phillips, 2010; Kellogg, 2010). Uygulama sırasında özellikle kuyruk sokumu, bel ve kalça bölgelerindeki yağ örtüsü gözlemlenir (Amaral Phillips, 2010). Buzağılamalar arası VKS profili, süt laktasyon profilinin bir yansımasıdır. İnekler, somatotropik eksende meydana gelen homeostatik değişiklikler ve periferik dokuların insüline duyarlılığı ve yağ dokusundaki lipolitik yolların yukarı regülasyonu nedeniyle buzağılamadan sonra 50 ila 100 gün boyunca kondisyon kaybederler. Yönetim ve beslemenin, doğal insülin direnci dönemi geçene ve somatotropik eksen yeniden birleşene kadar, buzağılama sonrası erken VKS kaybı (buzağılamadan sonraki 1 ila 4. haftalar) üzerinde çok az etkisi vardır (Roche ve ark., 2009).

Tablo 1. Sığırın kondisyonuna göre vücut kondisyon skoru puanı, sırt yağ kalınlığı (mm) ve toplam yağ miktarı (kg) değişimi (Mishra ve ark., 2016; Çitil ve Uzlu, 2005; Koçyiğit, 2017).

Sığırın Kondisyonu	VKS	Sırt Yağ Kalınlığı (mm)	Toplam Yağ Miktarı (kg)
Aşırı zayıf	1	<5	<50
Zayıf	2	10	76
İyi	3	20	122
Yağlı	4	30	170
Aşırı yağlı	5	>35	>194



Şekil 1. Vücut kondisyon skorunun belirlenmesinde palpasyon yöntemi (Canatan, 2013; Koçyiğit, 2017).

Propilen glikol ($C_3H_8O_2$), renksiz, kokusuz ve tatlımsı tadı olan bir alkoldür. Sığırlara oral yol ile uygulandığında rumende propiyonik aside dönüşerek glukoneogeneze katkı sağlar (Nielsen ve Ingvartsen, 2004). PG'nin alınmasıyla yaklaşık 2 Mcal enerji sağlandığı, bu enerjinin karaciğerde glikoza çevrilerek kullanılabildiği bildirilmektedir (Butler ve ark., 2006). Overton ve Waldron (2004) PG'nin rumende 1–2 saat içinde %50 oranında sindirildiğini ve tamamının 3 saat içinde emildiğini bildirmişlerdir. PG, özellikle subklinik ketozisin önlenmesinde etkilidir. PG genellikle oral yolla, bireysel olarak enjeksiyon ile ya da yem katkısı şeklinde uygulanmaktadır. Etkili dozun 250–500 ml/gün olduğu bildirilmektedir (Nielsen ve Ingvartsen, 2004). Aşırı dozlarda ise iştah kaybı ve rumen bozuklukları gibi yan etkiler görülebilir (Grummer, 1995).

Bu çalışmada doğumdan sonraki ilk beş gün oral olarak günlük hayvan başına 500 ml PG uygulamasının süt sığırlarında VKS üzerine etkileri araştırılmıştır.

MATERYAL VE METOT

Deneme dizaynı, Hayvan ve Uygulama

Çalışma, Sivas Merkez'de faaliyet gösteren Lodos Tarım Hayvancılık A.Ş. işletmesinde gerçekleştirildi. Çalışmanın hayvan materyalini 40 adet Simental ırkı inekler oluşturmuştur. İnekler ortalama 650-700 kg ağırlığında, 2.5 yaşlı, 1. laktasyonda olan sağlıklı hayvanlar olup, bu hayvanların rasyonu kesif yem, silaj, saman ve yoncadan oluşmuştur. Çalışma da, hayvanlar her grupta 20 adet olmak üzere Kontrol grubu ve Deneme grubu olarak 2 gruba ayrıldı. Kontrol ve Deneme gruplarındaki hayvanlara günlük sırasıyla 0 ml ve 500 ml PG oral olarak uygulandı. Günlük 500 ml doz seçimi literatür önerileri dikkate alınarak belirlendi (Nielsen ve Ingvartsen, 2004). Tüm hayvanlar çalışma süresince eşit şartlarda ve optimum koşullarda barındırıldı.

Propilen Glikol

Propilen glikol (PG) içerik 1 kg için; Mono propilen glikol % 95.99, nikotinamid 20.000 mg, kobalt 40 mg, sorbitol 7000 mg.

Vücut Kondisyon Skorunun Tespiti

Çalışma da hayvanların VKS değerleri gebeliğin son haftasında ve doğumdan sonraki 21. günlerde belirlendi. İneklerin VKS değerlerinin tespit işleminde 5'lik sistem kullanıldı ve skorlama işlemi Ferguson ve ark. (1994) 'nın belirttiği yönteme göre yapıldı.

İstatistiksel Analizler

Elde edilen verilen normal dağılıp dağılmadığı SPSS (2011) paket programında one simple Kolmogorov-smirnov testi ile yapıldı. Testin sonucuna göre verilerin normal dağılım göstermediği tespit edildi. Bu nedenle verilerin istatistiksel analizi nonparametrik Two-Independent Samples Testlerinden Mann-Whitney U testi kullanılarak yapıldı ($P < 0.05$).

BULGULAR VE TARTIŞMA

Çalışmada grupların VKS değerlerine ait verilerin istatistiksel analizinde doğumdan önce ve postpartum 21. günde Kontrol ve Deneme grupları arasında istatistiksel olarak fark olmadığı tespit edildi (Tablo 2) ($P>0.05$).

Tablo 2. Propilen glikol uygulamasının vücut kondisyon skoru üzerine etkisi.

Vücut Kondisyon Skoru	Gruplar		*P* değeri
	Kontrol	Deneme	
Doğum öncesi	4.150±0.06	4.138±0.04	0.495
Postpartum 21. gün	3.750±0.06	3.800±0.05	0.799

Bütün değerler ortalama ± standart hata olarak verilmiştir. (n=20).

Süt inekleri doğumdan sonra ilk 100 gün boyunca kondisyon kaybederler. Bir ineğin doğum zamanı VKS' si, en düşük VKS' si ve doğum sonrası kaybettiği VKS miktarı, süt üretimi, üreme ve sağlık ile ilişkili olup hayvan refahının geçerli bir göstergesi olarak bilinmektedir (Roche ve ark., 2009). Bu nedenle doğum sonrası süt ineklerinde VKS kaybının yukarıda bahsedilen olumsuz durumlara yol açmasını engellemek için geçiş döneminde rasyona ilave olarak bazı enerji kaynaklarının verilmesi tavsiye edilmektedir (Grummer ve ark., 1995; Borş ve ark., 2014). Fonseca ve ark. (2004) yaptığı çalışmada buzağılama tarihine göre -10, -5, -4, -3, -2, -1, 0, 2, 4, 6, 8, 10, 12, 14 ve 16. günlerde 300 ml PG uyguladıkları hayvanların ortalama VKS değerleri arasında -10, 0, 15 ve 30. günlerde gruplar arasında istatistiksel olarak farkın olmadığını, 45 ve 60. günlerde ise kontrol grubunda önemli oranda düşük olduğunu tespit etmişler. Mevcut çalışmada da ölçülen VKS değerleri Fonseca ve ark. (2004) çalışmasındaki sonuçlarla uyumlu olup doğum öncesi ve postpartum 21. günde VKS değerleri açısından gruplar arasında önemli bir fark belirlenmedi. Smith ve ark. (1997)' na göre, daha yüksek VKS'ye sahip hayvanlar, doğumdan sonra daha düşük kuru madde tüketimi ve daha yüksek kilo kaybına daha yatkındır. Bu nedenle, PG takviyesinin doğumdan sonra 21. güne kadar VKS değişimi üzerinde hiçbir etkisi olmamıştır; bu da erken laktasyonda VKS' deki azalmayı hafifletemediğini göstermektedir; bu sonuçlarda literatürdeki çalışmalar ile uyumludur (Formigoni ve ark., 1996; Fonseca ve ark., 2004).

Sonuç

Buzağılamadan sonraki ilk 5 gün ineklere günlük 500 ml PG uygulamasının VKS değerleri üzerine önemli bir etkisinin olmadığı, bu sonuçlarda uygulama yapılan gün sayısının ve çalışmada hayvanların takibinin yapıldığı sürenin etkisinin olabileceği söylenebilir.

Açıklamalar

Bu bildiri, Orhan YALÇIN' ın "Süt ineklerinde doğum sonrası oral propilen glikol uygulamasının bazı kan parametreleri ve vücut kondisyon skoru üzerine etkileri" başlıklı yüksek lisans tez çalışmasının bir kısmından özetlenmiştir.

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KANATLILARDA KRONİK SOLUNUM SİSTEMİ ENFEKSİYONU (CRD)

Dr. Öğr. Üyesi Muazzez YEŞİLYURT

Siirt Üniversitesi Veteriner Fakültesi Klinik Bilimler Öncesi Bölümü.Mikrobiyoloji Anabilim Dalı, Siirt

Email: muazzez.yesilyurtr@siirt.edu.tr

ORCID: 0000-0003-4195-6335

Doç. Dr. Özgül GÜLAYDIN

Siirt Üniversitesi Veteriner Fakültesi Klinik Bilimler Öncesi Bölümü. Mikrobiyoloji Anabilim Dalı, Siirt

Email: ozgul.gulaydin@siirt.edu.tr

ORCID: 0000-0001-8376-2008

ÖZET

Dünya genelinde insanların protein ihtiyacını daha düşük fiyatlarla karşılaması ve endüstriyel üretime uygun olmaları nedeniyle kanatlı yetiştiriciliğinin önemi giderek artmaktadır. Ancak kanatlılarda meydana gelen *Mycoplasma gallisepticum* (*M. gallisepticum*), kaynaklı pnömoni olguları hem verim hem de üretimde önemli ekonomik kayıpların yaşanmasına neden olmaktadır. Hücre duvarından yoksun olan *M. gallisepticum*, *Mollicutes* sınıfı, *Mycoplasmatales* takımı ve *Mycoplasmataceae* familyası içerisinde sınıflandırılmaktadır. *Mycoplasmataceae* familyasında bulunan türler, üremeleri için zenginleştirilmiş besiyerine gereksinim duymaktadırlar. Bu amaçla besiyerlerine %10 oranında maya ekstraktı, %10-15 oranında da at serumu ilave edilmektedir. Hücre duvarından yoksun olan *Mycoplasma* türleri, katı besiyerlerinde ortası düğmeli görünüme sahip koloniler oluşturmaktadır. Kanatlılarda özellikle *M. gallisepticum*, *M. synoviae*, *M. meleagridis*, ve *M. iowae* görülen en yaygın *Mycoplasma* türleridir. Kronik solunum sistemi enfeksiyonuna (CRD, Chronic Respiratory Disease) neden olan *M. gallisepticum* ise en patojen tür olarak bilinmektedir. *M. gallisepticum*'da bulaşma enfekte hayvanlarla veya kontamine materyallerle direkt temas sonucunda meydana gelmektedir. Hayvanlarda konjuktivit, öksürük, aksırık, yumurta verimi ve yem alımında azalma gibi spesifik olmayan klinik semptomlar görülebilmektedir. Tedavi amacıyla özellikle tetrasiklin, florokinolon ve makrolid grubu antibiyotikler tercih edilmektedir. Koruma ve kontrol programları kapsamında ise hijyen, sanitasyon ve aşı büyük önem arz etmektedir.

Anahtar Kelimeler: CRD, Kanatlı, Mycoplasmataceae, Mycoplasma gallisepticum, Pnömoni

CHRONİC RESPİRATORY SYSTEM INFECTİON (CRD) İN POULTRY

ABSTRACT

The importance of poultry farming is increasing because it meets the protein needs of people around the world at lower prices and is suitable for industrial production. However, *Mycoplasma gallisepticum* (*M. gallisepticum*)-induced pneumonia cases in poultry cause significant economic losses in both yield and production. *M. gallisepticum*, which lacks a cell wall, is classified within the *Mollicutes* class, *Mycoplasmatales* order, and *Mycoplasmataceae* family. Species in the *Mycoplasmataceae* family require enriched media for their reproduction. For this purpose, 10% yeast extract and 10-15% horse serum are added to the media. *Mycoplasma* species lacking a cell wall form colonies with a button-like appearance on solid media. The most common *Mycoplasma* species seen in poultry are *M. gallisepticum*, *M. synoviae*, *M. meleagridis*, and *M. iowae*. *M. gallisepticum*, which causes chronic respiratory system infection (CRD, Chronic Respiratory Disease), is known as the most pathogenic species. Transmission of *M. gallisepticum* occurs through direct contact with infected animals or contaminated materials. Nonspecific clinical symptoms such as conjunctivitis, cough, sneezing, decreased egg production, and decreased feed intake may be observed in animals. Tetracycline, fluoroquinolone, and macrolide antibiotics are preferred for treatment. Hygiene, sanitation, and vaccination are crucial within prevention and control programs.

Keywords: CRD, Poultry, *Mycoplasmataceae*, *Mycoplasma gallisepticum*, Pneumoniae

GİRİŞ

Kanatlılarda meydana gelen solunum sistemi hastalıkları bakteri, virüs ve mantar başta olmak üzere birçok patojen tarafından meydana gelebilmektedir. Ayrıca çevresel faktörler de klinik tablonun şiddetlenmesi ve meydana gelen lezyonlarda artışa neden olabilmektedir (Glisson, 1998). Özellikle *M. gallisepticum* kaynaklı meydana gelen kronik solunum yolu hastalığı kanatlı sektöründe büyük ekonomik kayıpların yaşanmasına neden olabilmektedir (Olesiuk ve Van Roekel, 1960).

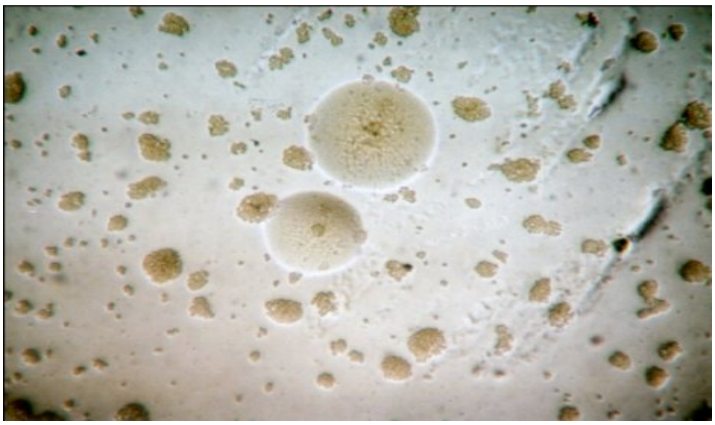
Konu ile ilgili yapılan çalışmalar incelendiğinde ulusal ve uluslararası alanda birtakım çalışmaların yapıldığı görülmektedir. Yapılan bu çalışmalar incelendiğinde *M. gallisepticum* bulunma oranının %26.4 ile %62 arasında değiştiği bildirilmiştir (Özgün ve Türkyılmaz, 2016; AbdelRahman vd., 2022; Marouf vd., 2022; Güllü Yücetepe, 2023).

1. KRONİK SOLUNUM SİSTEMİ ENFEKSİYONU (CRD)

Kümes hayvanlarının önemli bulaşıcı hastalıklarından biri olan kronik solunum sistemi enfeksiyonu, *M. gallisepticum* tarafından meydana gelmektedir. Kronik solunum sistemi enfeksiyonu, kanatlılarda karkas ağırlığı, yumurta verimi, kilo alımı ve yem verimliliğinde azalma nedeniyle ciddi ekonomik kayıplara yol açmaktadır (Rajkumar vd., 2017).

2. ETİYOLOJİ

Mycoplasma cinsi içerisinde yer alan *Mycoplasma gallisepticum*, *Mollicutes* sınıfı, *Mycoplasmatales* takımı ve *Mycoplasmataceae* familyasında yer almaktadır (Gautier-Bouchardon, 2018; Yadav vd., 2022). *Mycoplasmataceae* familyasında 22 *Mycoplasma* türü bulunmakla birlikte *M. gallisepticum*, *M. meleagridis*, *M. synoviae* ve *M. iowae* kanatlılarda görülen en yaygın türler arasında yer almaktadır (Shoaib, 2019). Hücre duvarından yoksun olan *Mycoplasma* türleri (Yadav vd., 2022), 0,3-0,5 µm çapında, pleomorfik, yuvarlak ya da filamentli mikroorganizmalardır (Lockaby ve Hoerr, 1999). *M. gallisepticum* zenginleştirilmiş besiyerlerinde iyi üreme özelliğine sahiptirler. Katı besiyerlerinde, kenarları yuvarlak, ortası düğmeli ve besiyerlerine gömülü koloni oluştururlar (Şekil 1). Meydana gelen bu koloniler bakterilerin L-formuna benzer yapıdadırlar. *M. gallisepticum* %10 maya ekstraktı ve %15-20 oranında at serumu ilave edilmiş sıvı besiyerlerinde de iyi üreme özelliğine sahip olmaktadır (Esendal, 2002).

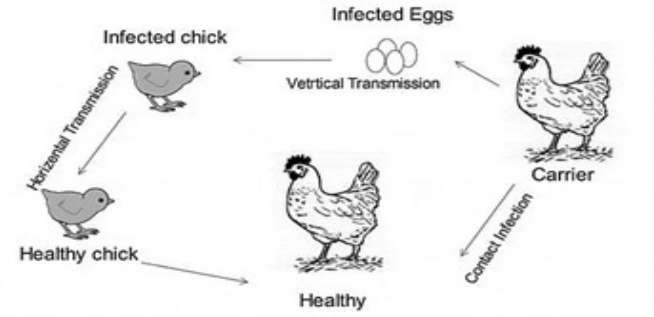


Şekil 1: *M. gallisepticum* kolonilerinin stereomikroskobik görüntüsü (Uriarte vd., 2015).

3. BULAŞMA

Özellikle tavuk ve hindilerde enfeksiyona neden olan *M. gallisepticum* bıldırcın, güvercin, keklik ve sülün gibi birçok kanatlıda da enfeksiyona neden olmaktadır (Shoaib, 2019). Bu nedenle *M.*

gallisepticum yüksek yaygınlık oranı ve geniş konakçı yelpazesine sahip olması nedeniyle kanatlılarda en patojen tür olarak bilinmektedir. (Umar, 2017). *M. gallisepticum* horizontal ya da vertikal yolla bulaşmaktadır. Horizontal yolla meydana gelen bulaşmada sağlıklı hayvanların enfekte hayvanlarla teması oldukça önem arz etmektedir. Buna ilaveten hayvanlar etkeni damlacıklar yolu ile direkt olarak da alabilmektedirler. Bu nedenle çevresel kaynaklar sürekli enfeksiyon nedeni olabilmektedir (Esendal, 2002; Marouf vd., 2022). Yumurta yolu ile meydana gelen vertikal bulaşmada ise çoğunlukla damızlık değeri olan hayvanlar etkilenmektedir (Esendal, 2002; Shoaib, 2019) (Şekil 2).



Şekil 2: *Mycoplasma gallisepticum*'da vertical ve horizontal bulaşma (Umar vd., 2017).

4. KLİNİK BULGULAR

Hastalığın inkübasyon süresi yaklaşık 1 aydır. Ancak bu süre deneysel koşullarda 10 ile 20 gün arasında değişebilmektedir. Genellikle öksürük, hırıltılı soluma, aksırık, konjuktivit, artritis, göz ve burun deliklerinde akıntı, embriyonik ölümlerde artış, yumurta veriminde azalma ve tracheal sesler gibi spesifik olmayan klinik bulgular görülmektedir. Ayrıca yem tüketiminin azalmasına bağlı olarak kilo kaybı da meydana gelmektedir. Hindilerde meydana gelen klinik tablo tavuklara oranla daha şiddetli bir seyir göstermektedir. Hindilerde oluşan infraorbital şişkinlik ileri olgularda gözlerin tamamen kapanmasına neden olabilmektedir (Esendal, 2002; Marouf vd., 2022; AlRufaei ve Alwan, 2023).

5. TEŞHİS

5.1. KLİNİK VE NEKROPSİ BULGULARI

Kronik solunum sistemi enfeksiyonu, kolibasillozis, Newcastle, infeksiyöz koriza ve kronik kolera gibi hastalıklarla karışabileceğinden klinik ve nekropsi bulguları yeterli olmamaktadır. Bu nedenle kesin teşhis amacıyla laboratuvar muayenelerinin yapılması gerekmektedir (Esendal, 2002).

5.2. ALINABİLECEK ÖRNEKLER

Etken teşhisi amacıyla hava kesesi, akciğer, trakea gibi organlardan alınan dokular ile infraorbital sinüs, oküler ve sinovial eksüdatlardan alınan sürüntü örnekleri izolasyon ve identifikasyon amacıyla laboratuvara gönderilebilir. (Ferguson-Noel vd., 2012).

5.3. İZOLASYON VE İDENTİFİKASYON

Mycoplasma türlerinin izolasyonu amacıyla zenginleştirilmiş besiyerleri tercih edilmektedir. Bu amaçla besiyerlerine %10 maya ekstraktı ve %10-15 oranında at serumu ilave edilmektedir (Esendal, 2002). Ayrıca mantarların ve başka bakterilerin üremesini engellemek amacıyla bakteri inhibitörleri ve antibiyotikler de ilave edilmektedir. Bu amaçla özellikle besiyerlerine talyum-asetat ve ampisilin ilave edilmektedir. Ancak *Mycoplasma* türlerinin biyosentez kapasitesinin

düşük olmasından kaynaklı izolasyon aşaması uzun süre ve deneyim gerektirmektedir. Ayrıca amino asit, kolesterol ve vitamin gibi birçok besin maddesi için konak hücreye bağımlı olmaları da *Mycoplasma* türlerinin in vitro ortamda üremesini zorlaştırmaktadır (Shoaib, 2019). Bu nedenle *Mycoplasma* türlerinin teşhisi amacıyla çoğunlukla serolojik yöntemler ve moleküler tekniklerden faydalanılmaktadır. Serolojik teşhis amacıyla ELISA ve serum aglütinasyon testleri sıklıkla kullanılmaktadır. Serum aglütinasyon testlerinde 1/10 ve üzeri titreler pozitif olarak kabul edilirken, 1/5 şüpheli ve 1/5'ten küçük titreler negatif olarak değerlendirilmektedir (Umar vd., 2017).

6. TEDAVİ

M. gallisepticum hücre duvarından yoksun olduğu için hücre duvarı sentezini inhibe ederek etkisini gösteren ß-laktam (penisilin/sefalosporin vs.) grubu antibiyotiklere karşı doğal dirençlidirler (Umar vd., 2017; Ferguson-Noel vd., 2020). Bu nedenle tedavi amacıyla tilmikosin gibi makrolid grubu antibiyotikler, tetrasiklin, florokinolonlar ve linkomisin-spektinomisin sıklıkla kullanım alanı bulmaktadır (Umar vd., 2017; Ferguson-Neol, 2020; Yadav vd., 2022).

7. KORUMA-KONTROL

M. gallisepticum kaynaklı enfeksiyon olgularında koruma ve kontrol amacıyla ilk yapılması gereken enfeksiyondan ari ve döllenmiş yumurta elde etmektir. Böylece hem hastalıktan ari kanatlı yetiştiriciliği idame ettirilebilecek, hem de sürülerin ari statüsü korunmuş olacaktır. Sanitasyon ve hijyen kurallarına uymak da dikey bulaşma olasılığını azaltmak için öncelikli uygulanması gereken önlemler arasında yer almaktadır (Mugunthan, 2023). *M. gallisepticum*'un eradikasyonu amacıyla uygulanacak programda sürülerin düzenli bir şekilde kültürel ya da serolojik olarak taranması gerekmektedir (Esendal, 2002). Bunların haricinde *M. gallisepticum*'a karşı aşı da kontrol amacıyla sıklıkla kullanılmaktadır. Bu amaçla hem inaktif hem de zayıflatılmış aşılardan yararlanılmaktadır (Whithear, 1996).

8. SONUÇ

Sonuç olarak kanatlılarda önemli verim kayıplarına neden olan *M. gallisepticum*'da spesifik klinik belirtilerin gözlenmemesi ve türler arasında bulaşmanın kolay gerçekleşmesi ciddi risk teşkil etmektedir. Ayrıca yapılan çalışmalar kapsamında *M. gallisepticum* bulunma oranının yüksek olması kanatlı sektöründe problemlerin artmasına neden olabileceği düşünülmektedir. Bu nedenle *M. gallisepticum* kaynaklı enfeksiyonların önlenmesi amacıyla koruma-kontrol programlarına öncelik verilmesi, ari işletmelerin ön plana çıkarılması gerektiği kanısına varılmıştır.

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IMMUNOLOGICAL RESPONSES AND ADAPTATION OF KANO BROWN BUCKLING GOATS FED DIETS CONTAINING *PLEUROTUS OSTREATUS* BIODEGRADED SUGARCANE SCRAPINGS

Dr. Emmanuel Ugochukwu ANASO (PhD)

Department of Animal Science, Faculty of Agriculture, Federal University of Agriculture

Mubi Adamawa, Nigeria.

E-mail: dranasoeub@gmail.com

ABSTRACT

Ruminant production in sub-Saharan African is principally constrained by dearth and unsteady quantity and quality of the year-round feed availability which affect both the growth (productive) and sexual (reproductive) performance of the animal. This problem of soaring cost of conventional feedstuffs used in ration formulation necessitates quest by animal nutritionists for alternative, non or less competitive, available and cheap feedstuffs, particularly lignocellulosic residues constituting environmental hazard due to improper disposal. This study evaluated the impact of replacing corn bran with biodegraded sugarcane scrapings (BSS) treated with *Pleurotus ostreatus* on the physiological and immunological responses of growing goats. Twenty-one healthy Kano Brown bucklings (aged 6–7 months; average body weight 9.40 ± 0.39 kg) were randomly assigned to three dietary treatments: 0% (T1), 15% (T2), and 30% (T3) BSS inclusion levels in a completely randomized design over a 16-week feeding trial. The primary focus was to assess the immune response—specifically levels of immunoglobulins A, M, and G; triiodothyronine (T3); total antioxidant capacity (TAC); and key antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), and glutathione reductase (GR). Results indicated that the inclusion of BSS had no significant effect on these immunological or oxidative stress markers, all of which remained within physiologically normal ranges across the treatment groups. The biodegradation process significantly improved the nutritive profile of sugarcane scrapings, and dietary inclusion at 15% supported adequate nutrient intake and physiological stability without compromising immune function. Moreover, the 30% inclusion level was found to be safe and effective, promoting optimal health and performance in the goats. These findings highlight the potential of BSS as a sustainable, non-conventional feed resource in small ruminant nutrition.

Keywords: Solid state fermentation, *Pleurotus ostreatus*, sugarcane scrapings, immune status, small ruminant welfare

INTRODUCTION

The main factor limiting ruminant output in sub-Saharan Africa is the scarcity and unpredictability of year-round feed availability, which has an impact on the animal's growth (productive) and sexual (reproductive) performance (Anaso and Olafadehan, 2025). Animal nutritionists must search for alternative, non-competitive, readily available, and inexpensive feedstuffs due to the problem of the skyrocketing cost of conventional feedstuffs used in ration formulation. This is especially true of lignocellulosic residues, which pose a risk to the environment due to improper disposal (Olafadehan et al., 2023b).

A number of coproducts are produced concurrently with the cultivation of sugarcane, a plant that is widely grown in northern Nigeria. One significant and widely accessible coproduct is sugarcane scraping or peel (Anaso et al., 2024b; Olafadehan et al., 2023a). Despite its availability, its low crude protein (CP) and lignified nature limit its use in livestock (Anaso & Anaso, 2025). Solid state fermentation (SSF) using lignocellulose fungus has been used to improve the CP and dissolve the lignin barrier, increasing the nutritional value. As a result, the lignocellulosic structure has been altered, allowing the carbohydrates to be converted more efficiently (Anaso, 2025a).

According to reports, white rot fungus can successfully mineralize lignin into carbon dioxide and water by creating ligninolytic enzymes such laccase, manganese peroxidase, and lignin peroxidase (Sanchez, 2010; Isroi et al., 2011; Anaso et al., 2021a,b). Additionally, employing the white rot fungus in solid state fermentation of lignified roughages provides a safe alternative to physical or chemical treatment. While the majority of earlier research on the use of solid-state fermented lignocelluloses in ruminant diets concentrated on productivity, there is little data on fertility or reproductive potential, especially in male animals (Anaso et al., 2023).

A detailed evaluation of the animals' testicular measurements, particularly scrotal circumference and length, as well as the characteristics of their semen, may shed some light on how well the animals' diet meets their requirements for sufficient reproduction. The current study's goal was to evaluate the oxidative blood profile and immune system of bucks fed diets containing sugarcane scrapings that Pleurotus ostreatus had biodegraded.

Materials and methods

Experimental location

The experiment was conducted at the University of Abuja Teaching and Research Farm in Abuja, Nigeria. Located between latitudes 8º 55'N and 9º 00'E and longitudes 7º 00'N and 7º 05'E, the position is 456 meters above sea level. The area has an annual temperature of 25.8–42°C and 1100–1650 mm of precipitation (Anaso and Alagbe, 2025; Anaso and Alhassan, 2025).

Preparation and biodegradation of sugarcane scrapings

Pleurotus ostreatus was bought from a reputable commercial producer in Nigeria, while fresh SS was collected from local sugarcane processors, chopped into 1-2 cm lengths, and air-dried at room temperature (25–30°C). Before the Pleurotus inoculation for solid state fermentation, the SS was combined with distilled water in a 1:1 ratio in each previously cleaned, dried, and sanitized container to reduce the moisture content to 67%. To get rid of any living microorganisms, the SS were autoclaved twice, once at 121°C for 15 minutes each time, with cooling intervals in between. Before being infected with P. ostreatus spores in a 25:1 ratio, the prepared SS were cooled in an aseptic atmosphere. After that, the inoculation room was kept at 30°C and 100% relative humidity until mycelia developed. Autoclaving the material prevented mycelia growth and biodegradation

of the biodegraded SS (BSS) after a 21-day period of inoculation and SSF. The BSS were packaged and stored until they were needed for feeding after being dried to a constant weight. 2.3. Diets, management, and experimental animals Kano For the experiment, 21 brown male goats weighing 9.44 ± 0.39 kg and aged between 6 and 7 months were bought from an open market.

Within a 6 m × 8 m x 4 m corral, the goats were kept in individual 1.2 m2 cages. Two weeks prior to their arrival, the pen and its immediate surroundings were thoroughly cleaned using Hypo® (sodium hypochlorite, caustic soda, and de-mineralized water) and antiseptic (Morigad). During their two-week quarantine, the animals received preventative treatments. These included an intramuscular injection of a long-acting oxytetracycline HCl at 1 mL/10 kg BW, an oral anti-stress drug called Vitalyte®, a subcutaneous injection of the live PPR vaccine (1 mL at 102.5 of the TCID50 PPR virus) at the neck region, and a subcutaneous injection of an anti-parasitic drug called Avomec® at 0.5 mL/25 kg BW. Three complete meals were created using varying SS 0 (control), 15, and 30% inclusion ratios. The meals that catered to the requirements of growing goats were designed in accordance with the NRC's (2007) recommendations. Buck juveniles were fed at 5% of their body weight (based on dry matter; DM) and were balanced for body weight throughout a 12-week period (January to March). After then, one of the experimental diets was given to the goats at random. The amount of feed given to the goats was changed during the trial to ensure that some was left behind. Feeding was done twice a day between 8:00 and 16:00. Every day, they had unrestricted access to clean water.

Immune function was assessed by quantifying immunoglobulin classes (IgA, IgG, and IgM), also using Stanbio-specific kits per Elghalid et al. (2020) and Anaso (2025b,c).

Oxidative stress markers evaluated included triiodothyronine (T3), total antioxidant capacity (TAC), and the enzymatic activities of malondialdehyde (MDA), superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), glutathione reductase (GR), and cortisol. These were likewise analyzed using the aforementioned commercial kits and standardized methodologies (Anaso et al., 2025a,b,c,d).

Data analysis

The obtained data was subjected to and met normal distribution conditions. Subsequent results for body weight, scrotal parameters and semen characteristic were subjected to analysis of variance (ANOVA) in a completely randomized design using the SPSS BASE 23 (SPSS software products, USA). Duncan multiple range test (DMRT) of same software was used to test the significant difference between the means at ($p \leq 0.05$ level of significance.

Results and Discussion

Immune and oxidative stress responses of goats

Table 1 presents the immunological and oxidative stress responses of growing Kano Brown goats fed diets containing varying inclusion levels of biodegraded sugarcane scrapings (BSS) treated with *Pleurotus ostreatus*. The dietary treatments consisted of 0% (T1), 15% (T2), and 30% (T3) BSS in a completely randomized design. Results revealed that the inclusion of BSS had no significant ($P > 0.05$) effect on the concentrations of immunoglobulins (IgA, IgM, and IgG), triiodothyronine (T3), and antioxidant enzymes including superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), and glutathione reductase (GR). Similarly, total antioxidant capacity (TAC), malondialdehyde (MDA), and cortisol levels were not significantly altered by the

dietary treatments, indicating that the goats maintained normal immunological and oxidative status across all groups.

Important humoral immune components that neutralize pathogens, suppress toxins, and protect mucosa are immunoglobulins (IgG, IgM, and IgA) (Anaso et al., 2025a,d; Woof & Kerr, 2005; Alagawany et al., 2021). The treatment groups' similar amounts of these immunoglobulins indicate that substituting biodegraded sugarcane scrapings for maize bran did not compromise immune function. Similarly, sustained metabolic and thermoregulatory balance is reflected in the constant T3 concentration across treatments (Bowen, 2010; Anaso et al., 2025g).

Indicators of oxidative stress, such as SOD, CAT, GPx, GR, and TAC, were statistically equivalent ($P > 0.05$) between groups, suggesting that the antioxidant defense system was unaffected by the dietary addition of BSS. These enzymes are essential for maintaining cellular homeostasis and neutralizing reactive oxygen species (ROS) (Chelikani et al., 2004; Deponte, 2013; Anaso et al 2024 a,c,d). The result that BSS inclusion up to 30% does not cause oxidative stress in goats is further supported by the non-significant fluctuation in MDA concentration, an indication of lipid peroxidation and membrane integrity.

By breaking down lignin and partially solubilizing cellulose and hemicellulose, P. ostreatus's biodegradation of sugarcane scrapings probably increased the substrate's nutritional profile and fiber digestibility, leading to better feed utilization (Anaso et al., 2025a). Goats fed diets containing 15% and 30% BSS therefore showed normal physiological reactions and stable redox balance, indicating that BSS inclusion did not cause inflammatory or metabolic distress.

All things considered, these results show that biodegraded sugarcane scrapings can safely substitute traditional feed components like maize bran in goat diets without having a negative impact on oxidative balance or immune competence. The promise of BSS as a sustainable, non-conventional feed source for small ruminant production in tropical regions where feed scarcity and high input costs remain important restraints is highlighted by the stability of immunological and antioxidant indicators across treatments.

Table 1. Immune and oxidative stress responses of goats

Parameter	T1	T2	T3	SEM
Immunoglobulin G (mg/100ml)	3.998.22	3.973.00	3.965.23	103.50
Immunoglobulin A (mg/ml)	0.30	0.27	0.23	0.08
Immunoglobulin M (mg/ml)	3.72	3.54	3.49	0.59
Triiodothyroxine (nmol/L)	1.99	1.81	1.79	0.59
Melanodialdehyde (nmol/L)	0.92	0.97	0.98	0.03

Superoxide dismutase (nmol/mL)	887.55	873.25	841.47	12.07
Catalase (U/gHb)	1660.47	1670.77	1680.00	17.85
Glutathione peroxidase (U/gHb)	183.60	173.50	169.90	2.59
Cortisol (ng/ml)	14.71	15.01	15.51	0.30
Total antioxidant capacity (nmol)	1.08	1.33	1.67	0.03
Glutathione reductase (IU/10^{11}RBC)	1.38	1.48	1.56	0.30

Means with the different superscripts along the row are significantly ($P < 0.05$) different

T1, T2 and T3 connoting treatments one, two and three.

Conclusion

The present study demonstrated that the dietary inclusion of *Pleurotus ostreatus*-biodegraded sugarcane scrapings (BSS) as a partial replacement for corn bran had no adverse or significant effect on the immunological and oxidative stress responses of growing Kano Brown goats. Immunoglobulin concentrations, thyroid hormone levels, and antioxidant enzyme activities remained within normal physiological ranges, indicating that the inclusion of BSS up to 30% supports immune competence and oxidative balance comparable to conventional diets. The biodegradation process enhanced the nutritive quality of sugarcane scrapings, providing a safe, nutrient-dense, and environmentally friendly alternative feed resource. Therefore, BSS can be effectively utilized as a sustainable non-conventional feed ingredient in small ruminant production systems, particularly in regions challenged by high feed costs and limited availability of conventional feedstuffs. Further studies on nutrient digestibility, growth performance, and long-term reproductive outcomes are recommended to optimize inclusion levels for commercial application.

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LEADERS, LAGGARDS, AND STALLED GIANTS: A TYPOLOGY OF FRONTIER TECHNOLOGY READINESS IN SELECTED AFRICAN ECONOMIES

Sadiq, Mohammed Sanusi[1*]; Singh, Invinder Paul[2]; Ahmad, Muhammad Makarfi[3]; Nazifi, Idris Khalid[4] and Sani, Bashir Sanyinna[5]

[1]Department of Agricultural Economics and Agribusiness, FUD, Dutse, Nigeria

[2]Department of Agricultural Economics, SKRAU, Bikaner, India

[3]Department of Agricultural Economics and Extension, BUK, Kano, Nigeria

[4]Federal Inland Revenue Services, Nigeria

[5]PhD Scholar, Department of Agricultural Economics and Agribusiness, FUD, Dutse, Nigeria

Email: dr.umargbalebo@gmail.com

ABSTRACT

The rapid advancement of frontier technologies presents a pivotal opportunity for accelerated development in Africa. However, the continent's readiness to harness these technologies remains uneven and poorly understood at a comparative national level. This study conducts a comprehensive comparative assessment of frontier technology readiness across eleven African countries—Nigeria, Ghana, South Africa, Egypt, Morocco, Mauritius, Algeria, Botswana, Tunisia, Libya, and Gabon—from 2010 to 2023. Utilizing longitudinal data from the United Nations Conference on Trade and Development (UNCTAD, 2025), the analysis deconstructs the Overall ICT Index into its five constituent components: ICT Infrastructure, ICT Skills, Research & Development (R&D), Industry Activity, and Access to Finance.

The findings reveal a landscape of pronounced stratification and general stagnation, challenging optimistic narratives of universal digital leapfrogging. South Africa emerges as the consistent leader, demonstrating a relatively balanced innovation system. In contrast, major economies like Nigeria and Ghana exhibit a "stagnation paradox," with their vibrant tech ecosystems failing to translate into broad-based readiness due to critically low and stagnant scores in R&D and skills. The study identifies critical asymmetries, such as in Morocco, where advanced infrastructure is undermined by a chronic human capital deficit. The data further exposes a pervasive "innovation chasm," with R&D capacity being exceptionally weak across most sampled countries.

The discussion, framed within the National Systems of Innovation and Capabilities Approach theories, concludes that the primary constraint to frontier technology readiness in Africa has shifted from a connectivity gap to a profound human capital and innovation gap. The study recommends a fundamental reorientation of policy towards integrated national strategies that simultaneously address skills development, R&D investment, and industrial policy. The implications call for systemic policy orchestration and long-term commitment to building holistic innovation ecosystems, positioning this study as a critical evidence base for guiding Africa's effective participation in the Fourth Industrial Revolution.

Keywords: Technologies, ICT Development, Africa, Digital Divide, R&D, Comparative Analysis.

1.0 INTRODUCTION

1.1 Background of the Study

The 21st century is being fundamentally reshaped by a new wave of technological advancement, often termed the Fourth Industrial Revolution (4IR) or frontier technologies. These technologies—which include Artificial Intelligence (AI), Big Data analytics, the Internet of Things (IoT), blockchain, robotics, and biotechnology—are characterized by their rapid pace of development, pervasive scale, and transformative potential across all sectors of the economy and society (Schwab, 2016). For developing regions, particularly Africa, these technologies present a historic opportunity to accelerate development, overcome traditional infrastructural bottlenecks, and "leapfrog" several stages of growth through innovative applications in agriculture, health, finance, governance, and education (World Bank, 2019).

The potential for digital transformation in Africa is significant. The continent has witnessed the world's most rapid growth in mobile connectivity, which has already spurred innovation in mobile money, with services like M-Pesa in Kenya becoming a global benchmark (Suri & Jack, 2016). This mobile-led digital revolution has fueled a vibrant and growing tech startup ecosystem, with hubs in Lagos, Nairobi, Cape Town, and Kigali attracting significant venture capital and international attention (Soliman *et al*., 2025; Guzikova & Somga Bitchoga, 2022). This narrative of a dynamic, digitally rising Africa has become a powerful and optimistic counterpoint to older, more pessimistic depictions of the continent.

However, the ability to merely *use* mobile phones is fundamentally different from the capacity to *adopt, adapt, and develop* sophisticated frontier technologies. The latter requires a robust and holistic national innovation system. Recognizing this, international bodies like the United Nations Conference on Trade and Development (UNCTAD) have developed sophisticated frameworks to measure a country's readiness for these technologies. This "Frontier Technology Readiness Index" moves beyond simple connectivity metrics to assess a country's foundational preparedness across multiple dimensions: the quality of its ICT infrastructure, the level of its population's relevant skills, the strength of its Research & Development (R&D) ecosystem, the technological absorption capacity of its industry, and the availability of financing for innovation (Das, 2025; Saha & Ali, 2025; Masamha *et al*., 2024).

While aggregate reports often highlight continental potential, the reality on the ground is one of profound disparity. The performance of African nations in building these foundational pillars is not uniform, and a detailed, comparative analysis at the country level is crucial to move beyond generalizations. This study, therefore, grounds itself in the empirical data provided by UNCTAD (2025) for the period 2010-2023, focusing on a select group of eleven African countries: Nigeria, Ghana, South Africa, Egypt, Morocco, Mauritius, Algeria, Botswana, Tunisia, Libya, and Gabon. By examining the trajectories of their Overall ICT Index and its constituent components, this research provides a nuanced and evidence-based background against which the continent's true readiness for the 4IR can be assessed.

1.2 Problem Statement

Despite the optimistic rhetoric surrounding Africa's digital potential and the palpable energy within its tech startup scenes, there is a growing concern that a significant "readiness gap" threatens to derail this promise. Preliminary analysis of the provided UNCTAD data suggests that progress towards genuine frontier technology readiness is highly uneven and, for a majority of the selected countries, has stagnated over the past decade. The celebrated success stories of a few startups and

innovation hubs appear to exist within isolated bubbles, failing to translate into broad-based, national technological capability.

The core problem this study addresses is the persistent and multi-dimensional stagnation in frontier technology readiness across many key African economies, which risks locking them into a cycle of technological consumption rather than innovation, thereby exacerbating global and intra-continental inequalities. This problem manifests in several critical ways:

1. **The Stagnation Paradox:** Major economies like Nigeria and Ghana show minimal improvement in their Overall ICT Index over 14 years, remaining in the lower tier (0.3-0.4) despite their demographic and economic weight. This indicates a systemic failure to convert potential into sustained readiness.

2. **The Asymmetry of Development:** Some countries, like Morocco, demonstrate strong advancement in infrastructure but are held back by chronically low scores in human capital (ICT skills). This "infrastructure-skills" asymmetry suggests that investments are unbalanced and not yielding full returns.

3. **The Innovation Chasm:** The data points to a critical deficiency in R&D capacity across nearly all sampled countries, with South Africa being a notable exception. This indicates a weak foundation for domestic technology creation and adaptation, leaving economies perpetually dependent on foreign technologies.

4. **The Policy Disconnect:** The volatile and often declining Industry Activity Index in resource-rich nations like Nigeria and Algeria suggests that the productive sectors of these economies are not driving or demanding technological innovation, pointing to a failure of industrial policy to integrate with digital strategy.

Therefore, the problem is not a lack of activity, but a lack of synergistic and systemic progress across all the pillars that constitute true technological readiness. Without a clear, comparative understanding of where and why these disparities and stagnations exist, policymakers and stakeholders risk misallocating resources and pursuing strategies that fail to address the root causes of the readiness gap.

1.3 Justification for the Study

This research is critically important for both academic and practical reasons. It moves the discourse beyond anecdotal evidence and high-level continental summaries to provide a rigorous, data-driven, longitudinal comparison of specific African nations.

- **For Policymakers and Governments:** The findings of this study will serve as a critical diagnostic tool. By deconstructing the Overall ICT Index into its components, the research will pinpoint specific areas of weakness (e.g., R&D in Ghana, skills in Morocco) for targeted policy intervention. It will help governments understand that a singular focus on infrastructure, for instance, is insufficient without parallel investments in education and research. The comparative element allows for cross-country learning, where lagging nations can identify and emulate the successful strategies of performers like Mauritius or South Africa in specific domains.

- **For International Development Partners and Investors:** Donor agencies and private investors can use the insights from this study to make more informed decisions. It helps identify not just markets with current potential, but also those with the foundational readiness for sustainable, long-term technological growth. The analysis of the R&D and Industry Activity

indices, for example, can guide venture capital towards ecosystems with a stronger potential for deep tech innovation, while the analysis of skills can inform where investments in capacity building are most urgently needed.

- **For Academic Contribution:** This study fills a gap in the literature by providing a multi-dimensional, time-series analysis of technology readiness focused exclusively on a diverse set of African nations. It empirically tests and challenges popular narratives like "leapfrogging" by showing the hard constraints of skills and R&D. It contributes to scholarly debates in development economics, innovation studies, and African studies by providing quantitative evidence on the structural bottlenecks to technological upgrading in the region.

- **For Strategic National Planning:** The study sounds an urgent alarm on the human capital and innovation crisis. By highlighting the pervasive stagnation in the ICT Skills and R&D indices, it provides a powerful justification for radically rethinking national education systems and science, technology, and innovation (STI) policies. It argues that the future of Africa's digital economy depends less on the next undersea cable and more on the quality of its universities and research labs.

In essence, this research is justified by its potential to translate raw data into actionable intelligence, guiding the strategic investments and policies required to ensure that Africa does not merely witness the Fourth Industrial Revolution but actively participates in shaping it.

1.4 Research Objectives

The primary aim of this study is to conduct a detailed comparative assessment of the frontier technology readiness of selected African countries from 2010 to 2023, using the UNCTAD index data to identify patterns, disparities, and key determinants of performance.

To achieve this aim, the following specific objectives are formulated:

1. To assess and rank the overall frontier technology readiness of the selected countries over the period 2010-2023, identifying leaders, laggards, and trajectories of change.

2. To deconstruct the overall readiness by comparatively analyzing the performance of each country across the five sub-indices: ICT Infrastructure, ICT Skills, Research & Development, Industry Activity, and Access to Finance.

3. To identify the key strengths and critical weaknesses within each country's national innovation system, explaining how the interplay between different sub-indices (e.g., high infrastructure with low skills) impacts their overall score.

4. To situate the empirical findings within the existing academic and policy literature, explaining the observed performances with reference to previous studies on digital development, innovation systems, and industrial policy in the African context.

5. To derive evidence-based conclusions and implications that can inform national policies and regional strategies aimed at bolstering holistic frontier technology readiness across the continent.

By systematically addressing these objectives, this study will provide a comprehensive and nuanced understanding of the complex landscape of technological readiness in Africa, offering a vital resource for shaping its digital future.

2.0 Literature Review

2.1 Theoretical Framework

To systematically analyze and interpret the disparities in frontier technology readiness across the selected African nations, this study is anchored in a multi-theoretical framework. No single theory can fully capture the complex, multi-dimensional nature of technological readiness; therefore, this research draws upon and integrates several complementary theoretical perspectives from development economics, innovation studies, and information systems. These theories collectively provide the conceptual lenses through which the UNCTAD index data can be meaningfully understood and explained.

2.1.1 The Capabilities Approach and Human Capital Theory

At its core, the readiness to leverage technology is fundamentally about human agency. Sen's Capabilities Approach (1996) shifts the focus from mere access to resources (e.g., telecom infrastructure) to what people are actually able to do and be with those resources. In this context, technological readiness is not just about having internet connectivity but about the *capability* to use that connectivity for learning, innovation, and economic advancement. This perspective directly informs the ICT Skills Index, which measures the population's ability to effectively engage with technology. The persistently low scores in this index for countries like Nigeria and Ghana, as highlighted in the data, can be interpreted as a critical failure in expanding these essential human capabilities, a point reinforced by contemporary studies on digital literacy in Africa (Asongu & Nwachukwu, 2016).

Closely linked to this is Human Capital Theory (Becker, 1918), which posits that investments in education and skills training are crucial for economic productivity. The stagnant skills indices across the sample suggest a severe under-investment in the specific human capital required for a digital economy. When viewed through this lens, the "leapfrogging" narrative is contingent upon a population possessing the skills to adopt and adapt complex technologies, a condition that, as the data reveals, is largely unmet in many of the studied countries (Friederici *et al*., 2017).

2.1.2 National Innovation Systems (NIS) Framework

To understand the broader ecosystem within which technological readiness is built, this study employs the National Innovation Systems (NIS) framework. Pioneered by scholars like Freeman (1987) and Lundvall (1992), the NIS approach argues that technological progress and economic growth are driven by the complex interactions and flows of knowledge and technology among a network of actors in a country, including firms, universities, research institutes, and government agencies. The structure of the UNCTAD index aligns perfectly with this framework. The sub-indices represent core components of an innovation system:

- **ICT Infrastructure** represents the physical backbone for knowledge diffusion.
- **R&D Capacity** reflects the knowledge creation function, primarily within universities and public research labs.
- **Industry Activity** indicates the private sector's capacity to absorb and apply new knowledge.
- **ICT Skills** represents the stock of human capital flowing through the system.
- **Access to Finance** is a key institutional factor enabling innovation.

The poor performance of a country like Algeria across multiple indices signals a weak and poorly coordinated NIS. Conversely, South Africa's relative leadership, particularly in R&D, points to a more mature, though not flawless, innovation system, a finding consistent with analyses of the South African NIS (Daniels & Gebhardt, 2021); Khomyakov *et al*., 2020). The framework explains why isolated improvements in one area (e.g., infrastructure in Morocco) may not yield proportional gains in overall readiness if other system elements remain underdeveloped.

2.1.3 Technology Acceptance Model (TAM) and its Extensions

While macro-level theories like NIS explain the national ecosystem, the Technology Acceptance Model (TAM) (Davis, 1989) and its subsequent extensions provide a micro-level perspective on how and why individuals and organizations adopt new technologies. The original TAM posits that perceived usefulness and perceived ease of use are the primary determinants of technology adoption. This can be linked to the ICT Skills Index (ease of use) and the Industry Activity Index (usefulness for productivity gains).

However, the basic TAM is limited in developing contexts. The data from this study supports the need for an expanded view, as proposed by Venkatesh *et al*. (2016) in the Unified Theory of Acceptance and Use of Technology (UTAUT2). This model incorporates facilitating conditions—which include the objective state of ICT Infrastructure and Access to Finance—as critical moderating variables. The volatile industry activity in Nigeria, for instance, can be interpreted as a context where perceived usefulness of frontier technologies is low due to unfavorable facilitating conditions, such as political instability and inadequate infrastructure, inhibiting investment in technological upgrading by firms (Nnawulezi *et al*., 2023).

2.1.4 Diffusion of Innovations Theory and the "Leapfrogging" Debate

Rogers' Diffusion of Innovations Theory (2003) provides a classic model for how new technologies spread through a social system over time. The theory categorizes adopters into innovators, early adopters, early majority, late majority, and laggards. The UNCTAD data effectively maps the relative position of these African countries on the diffusion curve for frontier technologies as a whole. South Africa and Mauritius can be seen as the "early adopters," while the stagnating nations represent a "late majority" or "laggard" status at a systemic level.

This theory critically engages with the popular discourse of "Technological Leapfrogging" in Africa. The leapfrogging hypothesis suggests that latecomer economies can bypass certain stages of technological development by directly adopting advanced technologies (World Bank, 2019). However, the empirical evidence from this study challenges a simplistic application of this theory. The data reveals that leapfrogging is not automatic; it requires a foundational level of readiness across multiple dimensions. The inability of most countries to improve their R&D and skills indices suggests they are struggling to build the absorptive capacity necessary to *adapt* and *manage* advanced technologies, leaving them as passive consumers rather than active shapers—a limitation clearly identified in critical scholarship on the topic (Heeks, 2022; Foster, 2021; Andreoni & Tregenna, 2020). Thus, this research uses diffusion theory to temper the over-optimism of the leapfrogging narrative with empirical reality.

By integrating these four theoretical perspectives, this study constructs a robust analytical framework. The Capabilities Approach and Human Capital Theory focus on the human element; the NIS framework provides the macro-structural context; TAM/UTAUT2 explains the micro-level adoption drivers; and Diffusion of Innovations theory places the entire process within a temporal and comparative context. Together, they offer a comprehensive toolkit for dissecting the results of

the comparative assessment and for deriving meaningful, theoretically grounded conclusions about the future of frontier technologies in Africa.

2.2 Conceptual Framework

A conceptual framework is an analytical tool that outlines the key concepts, variables, and their presumed relationships in a study. It provides a visual and narrative structure for organizing the research. For this study, the conceptual framework is built upon the integrated theoretical foundations and operationalizes them using the UNCTAD indices. It illustrates how the five sub-indices collectively determine the overall frontier technology readiness and the consequent outcomes.

The framework below (Figure 1) depicts the relationships between the variables under investigation.

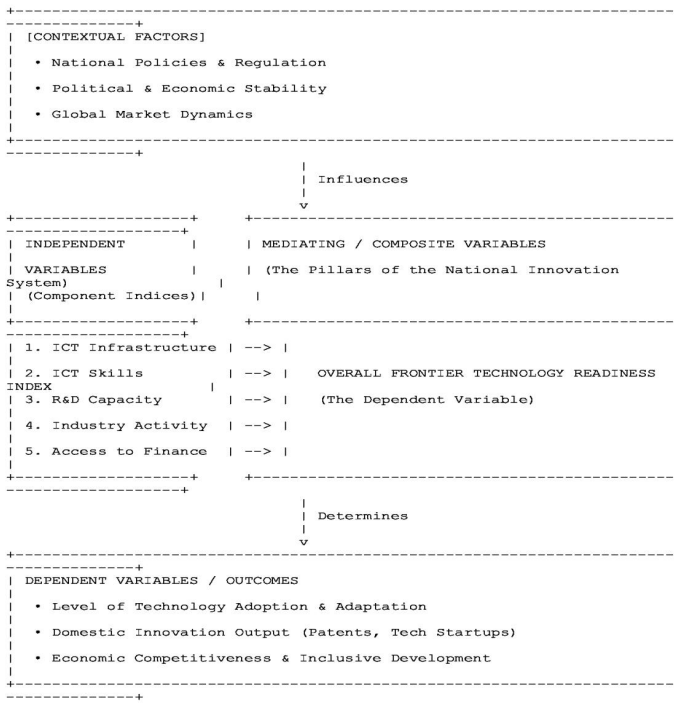


Figure 1: Conceptual Framework for Assessing Frontier Technology Readiness

Explanation of the Framework Components:

1. Independent Variables (The Component Indices)

The five sub-indices from the UNCTAD database form the independent variables or the foundational inputs of the framework. These are the measurable pillars that constitute the core of a country's National Innovation System (NIS), as discussed in the theoretical framework.

- **ICT Infrastructure Index:** Represents the tangible, physical foundation for digital connectivity (e.g., broadband penetration, network quality).

- **ICT Skills Index:** Represents the human capital and capabilities required to effectively use and develop technology.
- **R&D Capacity Index:** Represents the national potential for knowledge creation, technological experimentation, and innovation.
- **Industry Activity Index:** Represents the demand-pull and absorption capacity from the productive sector of the economy.
- **Access to Finance Index:** Represents the availability of capital to de-risk and fuel technological ventures and innovation.

2. The Mediating/Composite Variable (Overall Frontier Technology Readiness Index)

The Overall ICT (Frontier Technology Readiness) Index is positioned as the central, mediating variable. It is not an independent outcome but a composite measure that *results from* the interplay of the five independent variables. The framework posits that the overall readiness is a function of the synergistic performance of all five pillars. A weakness in one pillar (e.g., low R&D Capacity) can mediate and depress the overall score, even if other pillars are strong (e.g., good Infrastructure). This aligns with the systemic view of the NIS framework, where the interaction between components is critical.

3. Dependent Variables / Outcomes

The ultimate goal of building technological readiness is to achieve positive socio-economic outcomes. These are the dependent variables that are influenced by the level of a country's Overall Readiness. While this study primarily focuses on empirically analyzing the relationship between the independent variables and the overall index, the framework logically connects this readiness to broader consequences:

- **Level of Technology Adoption & Adaptation:** Countries with higher overall readiness will more effectively integrate frontier technologies into business processes, government services, and daily life.
- **Domestic Innovation Output:** A strong readiness foundation fosters a environment conducive to homegrown innovation, measured by patents, high-growth tech startups, and novel technological solutions to local problems.
- **Economic Competitiveness & Inclusive Development:** Ultimately, successful adoption and innovation should translate into broader economic benefits, such as increased productivity, job creation in high-value sectors, and more inclusive growth, as envisioned by the Capabilities Approach.

4. Contextual Factors

The entire process is enveloped by contextual factors that influence the strength of the pillars and their translation into outcomes. These are not directly measured by the indices but are crucial for interpreting the results. They include:

- **National Policies & Regulation:** The quality of a country's digital strategy, education policy, R&D funding, and business climate.
- **Political & Economic Stability:** Conflict (as seen in Libya's data volatility) or macroeconomic instability can cripple technological development.

- **Global Market Dynamics:** Factors like global tech trends, foreign direct investment flows, and international collaboration opportunities.

Relationship Propositions:

The conceptual framework implies several key propositions that this study investigates:

1. **Synergy Proposition:** The Overall Readiness Index is not a simple average but emerges from the synergistic interaction of the five component indices. A significant imbalance will constrain the overall score.

2. **Bottleneck Proposition:** The component index with the lowest score in a country's profile acts as a critical bottleneck, limiting the effectiveness of investments in other areas (e.g., excellent infrastructure yields low returns without corresponding skills).

3. **Causality Flow Proposition:** The framework suggests a primary flow of influence from the foundational pillars (independent variables) to the composite readiness (mediating variable), and subsequently to developmental outcomes (dependent variables). The data analysis will test the first part of this causal chain.

In summary, this conceptual framework provides a structured model for analyzing the UNCTAD data. It posits that the Overall Frontier Technology Readiness of the selected African countries is a direct result of the combined and interrelated performance of their ICT Infrastructure, Skills, R&D, Industry Activity, and Access to Finance, all of which are situated within a unique national context that shapes their development.

2.3 Empirical Review

This section synthesizes findings from previous empirical studies related to the components of frontier technology readiness in Africa. It examines what existing research has already uncovered about ICT infrastructure, skills, R&D, industry, and finance across the continent, providing a foundation against which the new data from this study can be compared and contextualized.

2.3.1 ICT Infrastructure: The Connectivity Divide and Its Limits

Empirical studies consistently highlight a significant digital infrastructure divide within Africa. Researches by the GSMA (2018); Guzikova & Somga Bitchoga, (2022) confirm that while mobile broadband coverage continues to expand, a usage gap persists, meaning many covered by networks do not use the internet due to factors like affordability and lack of digital literacy. This aligns with the volatile and middling infrastructure scores for countries like Nigeria and Ghana in our data. Nnawulezi *et al*. (2023), in a study on Nigeria, empirically linked this volatility to regulatory challenges, multiple taxation, and frequent vandalism of telecom infrastructure, directly explaining the inconsistent performance observed in the index.

Conversely, the steady improvement in Morocco's infrastructure score is empirically supported. Elharissi *et al*. (2025) evaluated the *Maroc Digital 2020* strategy and found that concerted public investment in national broadband and fibre optic networks led to measurable improvements in connectivity metrics, corroborating the positive trend seen in the data. Similarly, South Africa's high score is consistently documented in the Research ICT Africa (RIA) surveys (Gillwald *et al*., 2018), which, while pointing out urban-rural disparities, affirm the country's relatively advanced network status. However, a critical empirical finding from the broader literature, which our data reinforces, is that infrastructure alone is insufficient. Asongu and Nwachukwu (2016) used panel data to demonstrate that the impact of ICT infrastructure on

inclusive development is significantly moderated by the level of human capital, a theme that becomes starkly evident when comparing infrastructure and skills indices.

2.3.2 ICT Skills: The Persistent Human Capital Bottleneck

The chronic stagnation in the ICT Skills index found in our data is one of the most strongly validated findings by previous empirical work. A comprehensive reports by Voufo *et al*.(2025); Disse & Sommer, (2020) quantified a massive digital skills gap across Sub-Saharan Africa, identifying it as the single biggest constraint to digital transformation. This is not just about advanced programming skills but also foundational digital literacy. Empirical works by Bello & Ajao (2024); Ejilah (2023) in Nigeria specifically identified a misalignment between university curricula and the practical skills demanded by the digital economy, creating a pool of graduates unfit for the tech workforce and explaining Nigeria's persistently low score.

The case of Morocco, with its high infrastructure but low skills score, is a textbook example of an imbalance that scholars have begun to flag. Friederici *et al*. (2017) argued, based on case studies of tech hubs, that the "leapfrogging" narrative often overlooks the deep, foundational investments in education required to build a sustainable digital economy. Our data provides large-N, longitudinal evidence for their qualitative claim. The slight improvement in Mauritius' skills score aligns with its national focus on high-value services and its investments in specialized training programs, as documented in Draft (2021) reports, suggesting that targeted policy intervention can yield measurable, if gradual, improvements.

2.3.3 Research & Development (R&D): The African Innovation Paradox

The empirical literature on R&D in Africa overwhelmingly confirms the "innovation chasm" revealed by our data. Khomyakov *et al*. (2020) provide empirical evidence from South Africa, showing that its relatively strong performance is attributable to a consolidated system of universities, science councils, and a higher (though still below target) percentage of GDP expenditure on R&D. This directly explains South Africa's outlier status with a consistent score of 0.5.

For other nations, the picture is bleak. Juma (2016) compiled extensive case studies showing that most African economies have historically been structured as extractive enclaves with little incentive for industrial R&D. The consistently near-zero scores for Libya and Botswana in our data are empirical proof of this legacy. A more recent study by Andreoni and Tregenna (2020) on industrial policy found that the lack of R&D capacity is a key factor trapping middle-income African countries in low-value-added activities, unable to climb the technological ladder. The minimal improvements in Nigeria and Ghana's R&D scores towards the end of the period (to 0.4 and 0.3) may reflect the nascent growth of their startup ecosystems, but as Liedong and Rajwani (2022) empirically note, these ecosystems are still largely focused on business model innovation rather than deep-tech R&D, limiting their impact on this particular index.

2.3.4 Industry Activity: Volatility and De-industrialization

The high volatility in the Industry Activity index, particularly for commodity-dependent nations like Nigeria and Algeria, is strongly supported by empirical studies on de-industrialization. Andreoni and Tregenna (2020) empirically demonstrate that premature de-industrialization in many African countries has stripped them of the "learning-by-doing" capacity that is crucial for technological absorption. When the manufacturing base shrinks or remains

underdeveloped, as the data suggests for Algeria (scores of 0), the demand for frontier technologies from the productive sector plummets.

The stable, high scores for Mauritius and Tunisia are also empirically grounded. Studies on export processing zones and manufacturing in Mauritius have shown a more diversified and technologically integrated industrial base. The collapse and failure to recover in Nigeria's score, as seen in the data, can be linked to empirical analyses of the "Dutch Disease" and its effect on crowding out non-oil sectors, making investment in technological upgrading for industry unattractive. This creates a vicious cycle, as identified by Heeks (2022); Foster (2021), where a weak industrial sector cannot demand technology, and a lack of technology keeps the sector weak and uncompetitive.

2.3.5 Access to Finance: Bridging the Qualitative Gap

The empirical literature makes a critical distinction that explains the paradox of high "Access to Finance" scores coupled with low overall readiness. Studies by the Citaristi (2022); Canton (2021) show that while financial inclusion—access to a bank account—is improving, this is a different metric from access to *risk capital*. Liedong and Rajwani (2022) conducted an empirical survey of African entrepreneurs and found that access to venture capital, angel investment, and patient growth capital remains the most significant barrier to scaling technology businesses, particularly those focused on innovation rather than trade.

Therefore, the high and stable scores in the data likely reflect improvements in traditional banking penetration, as documented by the World Bank's Global Findex database. However, this does not contradict the empirical findings of a severe equity gap. The data, in this case, may be measuring a necessary but insufficient condition for frontier technology readiness. The real constraint, as empirically established, is not the availability of debt, but the availability of finance that is willing to bear the high risks associated with pioneering new technologies in uncertain markets.

Synthesis and Identification of the Research Gap

This empirical review confirms that many of the trends observed in the UNCTAD data—infrastructure asymmetry, skills stagnation, the R&D chasm, and industrial volatility—are not novel in isolation. However, previous studies have often focused on single countries, single components, or shorter time frames. The gap in the literature that this study fills is the systemic, comparative, and longitudinal analysis of how these five critical components interact *together* over a 14-year period across a diverse set of eleven African nations. By providing this integrated, data-driven portrait, this research can move beyond diagnosing isolated problems to revealing the systemic interdependencies that have led to the widespread stagnation in frontier technology readiness, thereby offering a more holistic evidence base for policy and investment.

3.0 Research Methodology

This section outlines the systematic approach employed to conduct the comparative assessment of frontier technology readiness across the selected African countries. It details the research design, data source and collection methods, the variables under study, the techniques for data analysis, and the ethical considerations that underpin the study.

3.1 Research Design

This study adopted a quantitative, non-experimental research design focused on descriptive and comparative analysis. The objective was not to manipulate variables but to describe, compare, and interpret existing patterns within the dataset. Specifically, the design can be characterized as:

- **Longitudinal:** The study analyzed data over a 14-year period (2010-2023), allowing for the examination of trends, progress, stagnation, and volatility in the indices over time.
- **Comparative:** The core of the research involved systematically comparing the performance of the eleven selected African countries (Nigeria, Ghana, South Africa, Egypt, Morocco, Mauritius, Algeria, Botswana, Tunisia, Libya, and Gabon) against each other and across the different indices.

This design was deemed most appropriate as it facilitates a robust, data-driven comparison of national innovation systems, enabling the identification of relative strengths, weaknesses, and long-term trajectories that are not apparent in single-year or single-country analyses.

3.2 Data Source and Collection Method

The study relied exclusively on secondary data of the highest international standard.

- **Source:** The data was extracted from the United Nations Conference on Trade and Development (UNCTAD) database, 2025. UNCTAD is a reputable, authoritative body within the United Nations system, and its data on technology and innovation is widely cited in academic and policy circles, ensuring the reliability and validity of the data used.
- **Collection Method:** Data was collected in a structured manner from the provided document, "Overall ICT index of in Africa." The data points for all six indices (Overall ICT Index, ICT Infrastructure, ICT Skills, R&D, Industry Activity, and Access to Finance) for all eleven countries across all fourteen years were systematically compiled into a master dataset for analysis.

3.3 Variables and Measurement

The variables in this study are explicitly defined by the UNCTAD indices. Each index is a composite measure constructed by UNCTAD from various underlying indicators to provide a standardized score between 0 and 1, where a higher score indicates better performance.

- **Dependent Variable:**
  - **Overall Frontier Technology Readiness Index:** A composite index that assesses a country's overall preparedness to use, adopt, and adapt frontier technologies.
- **Independent Variables (Component Indices):**
  - **ICT Infrastructure Index:** Measures the level of ICT infrastructure (e.g., fixed broadband subscriptions, internet bandwidth, mobile network coverage).
  - **ICT Skills Index:** Assesses the level of relevant skills in the population (e.g., tertiary enrolment in STEM fields, digital literacy rates).
  - **Research & Development (R&D) Index:** Evaluates the national capacity for research and development (e.g., R&D expenditure as % of GDP, number of researchers per million people).

- **Industry Activity Index:** Assesses the level of relevant industrial capacity for technology absorption (e.g., high-tech exports, manufacturing value added).
- **Access to Finance Index:** Measures the availability of finance to the private sector (e.g., domestic credit to private sector, venture capital availability).

3.4 Data Analysis Techniques

The compiled data was analyzed using a combination of descriptive and analytical techniques to address the research objectives.

1. **Descriptive Statistical Analysis:** This was the primary mode of analysis. For each country and each index, we calculated:
   - **Means/Averages:** To determine the central tendency of a country's performance over the entire period or specific sub-periods.
   - **Trend Analysis:** To identify the direction and magnitude of change over the 14 years. This involved visual inspection of line graphs and noting periods of improvement, decline, or stagnation.
   - **Ranking:** Countries were ranked for each index based on their most recent (2023) scores and their average scores over the period to identify leaders and laggards.
2. **Comparative Analysis:** This involved side-by-side comparison of:
   - **Cross-country performance** on a single index (e.g., comparing all countries' R&D scores in 2023).
   - **Intra-country performance** across different indices (e.g., comparing Morocco's Infrastructure score with its Skills score to identify asymmetries).
   - **Performance over time** to compare trajectories (e.g., comparing Nigeria's volatile Industry Activity trend with Mauritius's stable one).
3. **Qualitative Interpretation:** The quantitative trends and comparisons were interpreted qualitatively by situating them within the context of the existing theoretical and empirical literature reviewed in theoretical and conceptual frameworks. For instance, a country's stagnant skills index was not just reported but explained by linking it to previous studies on educational deficits in that region.

3.5 Ethical Considerations

As this study utilizes exclusively publicly available, aggregated secondary data from a reputable international organization (UNCTAD), several ethical risks are minimized.

- **Anonymity and Confidentiality:** The data is at the national level and does not contain any personal, identifiable information about individuals. Therefore, concerns about participant anonymity and confidentiality are not applicable.
- **Integrity and Objectivity:** The primary ethical consideration was to maintain intellectual honesty and objectivity in the analysis and interpretation of the data. The researcher committed to:
  - Accurately representing the data without manipulation or misrepresentation.
  - Acknowledging the limitations of the data and the study.

- Providing a balanced interpretation, even when findings contradict popular narratives or initial assumptions.
- Properly citing all sources of literature and the primary data source to avoid plagiarism.

3.6 Limitations of the Methodology

While robust, this methodology has certain limitations:

1. **Aggregation Bias:** The indices are composite measures. A single score may mask significant internal disparities, such as urban-rural divides or inequalities between demographic groups, within a country.
2. **Methodology of Index Construction:** The specific weighting and selection of sub-indicators used by UNCTAD to construct each index are not detailed in the provided dataset. Changes in their methodology over time could theoretically affect comparability, though UNCTAD strives for consistency.
3. **Causality:** The descriptive and correlational nature of this analysis can identify strong associations and bottlenecks but cannot definitively establish causality between the component indices and the overall readiness score.
4. **Scope of Countries:** The study is limited to eleven countries. While they are diverse and significant, the findings cannot be generalized to all 54 African nations.

Despite these limitations, the methodology provides a systematic, transparent, and rigorous framework for achieving the research objectives of describing, comparing, and interpreting the landscape of frontier technology readiness in the selected African countries.

4.0 Results and Discussion

This section presents a detailed analysis of the Frontier Technology Readiness Index, decomposed into its core components, across eleven African countries from 2010 to 2023. The discussion integrates the findings from the data with existing scholarly work to contextualize the performance, trajectories, and underlying challenges of each nation. The composite "Overall ICT Index" serves as our primary indicator of readiness, while the sub-indices—ICT Infrastructure, ICT Skills, Research & Development (R&D), Industry Activity, and Access to Finance—provide the granularity needed to diagnose the strengths and weaknesses within each national ecosystem.

4.1 Overall ICT Index: A Tale of Stagnation and Modest Progress

The Overall ICT Index reveals a landscape of pronounced stratification and general stagnation rather than widespread, dynamic growth (Figure 2). The selected countries can be broadly categorized into three tiers: leaders, middling performers, and laggards.

4.1.1 The Leading Cohort: South Africa, Mauritius, Morocco, and Egypt

South Africa consistently emerges as the regional leader, maintaining a score between 0.6 and 0.7 for most of the period, peaking at 0.7 from 2013 onwards. This leadership is not accidental and is supported by literature emphasizing its relatively advanced digital economy. As noted by Gillwald et al. (2018) in their "After Access" surveys, South Africa, while facing significant inequality, possesses a more mature telecommunications market, higher internet penetration rates, and a more robust regulatory environment compared to most of its peers. This foundational advantage is clearly reflected in the data.

Mauritius and Morocco form a strong second tier within the leaders' group, both maintaining scores around 0.5-0.6. Mauritius's performance aligns with its status as a high-income island economy with a strategic focus on becoming a cyber-island and technology hub. Its consistent scores suggest a stable, if not rapidly accelerating, digital development path. Morocco's progress, particularly its climb to 0.6 from 2012, can be linked to sustained public investment in digital infrastructure, such as the National Strategy for Information Society and Digital Economy (Maroc Digital 2020/2025). A study by Elharissi *et al*. (2025) highlighted that these government-led initiatives have significantly improved broadband connectivity and e-government services, which is corroborated by its steady performance in the overall index.

Egypt maintains a stable but unspectacular score of 0.5 throughout the period. This stagnation, despite its large market and human capital potential, points to systemic inefficiencies. Previous research, such as that by the Barasa & Kiiru (2023); Kamel (2021), has often cited regulatory hurdles, a dominant state-owned telecom operator, and bureaucratic obstacles to digital entrepreneurship as factors holding back Egypt's full digital potential, which is evident in its flatlining overall index.

4.1.2 The Middling and Laggard Cohort: Tunisia, Nigeria, Ghana, Botswana, Algeria, Libya, and Gabon

The most striking feature of this group is the pervasive stagnation. Nigeria, the continent's largest economy, oscillates between 0.3 and 0.4, never surpassing the 0.4 mark for more than a year at a time. This is a critical finding. Despite a vibrant tech startup scene in Lagos, often dubbed "Yabacon Valley," this dynamism is not translating into broad-based frontier technology readiness. This paradox can be explained by the works of Odera (2024); O'Reilly *et al*.(2018), who argued that while Nigerian innovation is bottom-up and entrepreneurial, it operates in spite of, not because of, government policy and national infrastructure. The data suggests that the celebrated startup ecosystem exists within a bubble, unable to lift the national average due to crippling deficits in power, broadband penetration, and digital literacy for the majority of the population.

Ghana mirrors Nigeria's trajectory closely, hovering around 0.3-0.4. Botswana, Algeria, and Libya also fall into this range, with Libya showing particular volatility, dropping to 0.3 in several years, likely reflecting the severe impact of political instability and conflict on its technological foundations. Tunisia, often praised for its educated populace, shows a surprising decline from 0.6 to 0.5 in the final years, a worrying signal that requires further investigation into its recent economic and political challenges.

Gabon's consistent position at the bottom of the table (0.3-0.4) underscores the challenges faced by smaller, resource-dependent economies in diversifying into the digital space. The data paints a clear picture: for most of these countries, the last decade has been marked by a "digital stall," where initial gains from mobile voice penetration have not been successfully parlayed into a deeper, frontier-technology-ready digital transformation (Asongu & Nwachukwu, 2016).

4.2 Deconstructing Readiness: An Analysis of the Component Indices

To understand the drivers behind the overall index performance, a deep dive into the sub-indices is essential.

4.2.1 ICT Infrastructure Index: The Foundational Divide

The ICT Infrastructure Index reveals the most dynamic changes and the clearest divide between nations (Figure 3). South Africa, Morocco, and Mauritius demonstrate significant improvement

and high performance. Morocco, in particular, shows a remarkable journey from 0.6 in 2010 to a stable 0.7 from 2012 onwards. This aligns with its national broadband strategy and investments in fibre optic networks. South Africa's climb to 0.7 by 2019 reflects its relatively advanced 4G and fibre-to-the-business infrastructure, though rural-urban disparities remain a concern, a point consistently raised in South African ICT policy reviews (Venter & Daniels, 2020).

In stark contrast, Nigeria's infrastructure score is highly volatile, oscillating between 0.4 and 0.6 before settling at 0.5 in 2023. This volatility is symptomatic of an unstable policy environment and inconsistent investment. The findings of Nnawulezi *et al*. (2023) on the quality of service in Nigeria's telecom sector support this, citing issues like multiple taxation, vandalism of infrastructure, and inadequate energy supply as perennial constraints. Ghana shows a more positive, though slower, trajectory, gradually improving from 0.3 to 0.6 by 2023, reflecting steady, incremental progress in network expansion.

A critical observation is that for countries like Nigeria and Ghana, their infrastructure scores in later years (0.5 and 0.6 respectively) are often higher than their overall ICT index (0.4). This indicates that while tangible network infrastructure may be improving, other soft components—skills, R&D, and industrial absorption—are dragging the overall readiness down.

4.2.2 ICT Skills Index: The Pervasive Human Capital Bottleneck

The ICT Skills Index presents perhaps the most alarming and stagnant dataset (Figure 4). With the exception of Mauritius, which shows a slight improvement to 0.6, and South Africa which holds steady at 0.5, nearly all countries are trapped at low scores between 0.3 and 0.5. Nigeria oscillates around 0.3-0.4, Ghana is stuck at 0.3, and Morocco, despite its infrastructure gains, remains at a low 0.4.

This chronic skills deficit is a central theme in African digital development literature. A report by Voufo *et al*.(2025) estimated a massive shortage of digital skills across the continent, constraining productivity and innovation. The data powerfully confirms this. Morocco's high infrastructure score coupled with a low skills score (0.7 vs. 0.4 in 2023) exemplifies a "hardware without software" paradox. Building networks is futile if the population lacks the skills to utilize them for advanced applications. This finding is supported by Asongu and Nwachukwu (2016), who argue that without complementary investments in education and digital literacy, infrastructure investments yield diminishing returns for inclusive development and technological upgrading.

The consistently low scores for Ghana and Nigeria, despite their numerous universities, point to a critical misalignment between educational curricula and the demands of a digital economy. Studies have shown that graduates often lack practical, job-ready digital skills, creating a vacuum that the private sector struggles to fill (Bello, & Ajao, 2024).

4.2.3 Research & Development (R&D) Index: The Innovation Chasm

The R&D Index exposes the deepest chasm in the frontier technology readiness landscape (Figure 5). South Africa is the undisputed leader, maintaining a perfect 0.5 from 2010 to 2023. This is consistent with its well-documented research ecosystem, featuring world-class universities, science councils, and a relatively high proportion of GDP spent on R&D compared to other African nations (Khomyakov *et al*., 2020). Egypt is a distant second, improving from 0.4 to 0.5, reflecting its historical strength in engineering and a large public research sector.

For the rest, the scores are abysmally low. Nigeria and Ghana barely reach 0.4 and 0.3 respectively by 2023, having started at 0.2. Morocco shows some improvement to 0.5, aligning with its national

innovation strategy. However, the scores for Algeria (0.3), Botswana (0.2), and Libya (0.2) indicate a near-total absence of a meaningful R&D culture geared towards frontier technologies.

This data provides empirical evidence for the "innovation periphery" status of most African economies. The work of Juma (2016) emphasized that sustained economic advancement is impossible without domestic technological learning and adaptation, which is fueled by R&D. The near-flat lines for most countries in this index suggest a critical missing link. Without a strong R&D base, these countries are condemned to be mere consumers and importers of technology, unable to adapt, create, or own the next generation of technological solutions relevant to their local contexts. This finding starkly contrasts with the narrative of "leapfrogging," suggesting that without building foundational innovation capacity, leapfrogging remains a mirage (Friederici *et al*., 2017).

4.2.4 Industry Activity Index: Volatility and De-industrialization Concerns

The Industry Activity Index is the most volatile of all (Figure 6), with dramatic peaks and troughs, particularly for Nigeria and Algeria. Nigeria's score plummets from 0.4 in 2010 to 0.1 in 2016 before recovering slightly to 0.2. Algeria's score hits 0 in 2013-2014 before a minimal recovery. This extreme volatility is indicative of economies heavily reliant on commodities (oil and gas), where industrial activity is susceptible to global price shocks and domestic policy instability.

Mauritius and Tunisia show the most resilience and highest scores in this category, reflecting their more diversified industrial bases and stronger integration into global manufacturing and services value chains. South Africa maintains a respectable 0.6, consistent with its more complex industrial structure.

The poor performance of Nigeria and others in this index is critical. It suggests that the productive sectors of these economies are not actively integrating or demanding frontier technologies. This lack of "demand-pull" from industry creates a weak incentive for innovation and technology development. As argued by Andreoni and Tregenna (2020), the loss of industrial capacity (de-industrialization) in many African countries has severely weakened their ability to master and adapt technologies, creating a vicious cycle of low productivity and low technological absorption. The data here provides a strong, quantitative confirmation of this thesis.

4.2.5 Access to Finance Index: A Misleading Picture of Stability

The Access to Finance Index shows remarkably high and stable scores for most countries (Figure 7), with South Africa, Morocco, Mauritius, and Tunisia consistently at 0.9. This seems to contradict the widespread narrative of a financing gap for SMEs and tech startups in Africa. However, this index likely measures the breadth of traditional financial services (e.g., bank accounts) rather than the availability of *risk capital* suitable for technology ventures.

The high scores, therefore, present a misleading picture. While basic financial inclusion may be improving, the specific type of finance needed for high-risk, high-growth frontier technology businesses—venture capital, angel investing, growth equity—remains scarce outside of a few hubs like South Africa, Kenya, and Nigeria. The work of Liedong and Rajwani (2022) on financing constraints for African startups confirms that access to patient, risk-tolerant capital is a primary bottleneck. Thus, the stability of this index masks a critical qualitative deficiency in the financial ecosystem for frontier technology, explaining why high "access to finance" scores do not automatically translate to high overall readiness in countries like Nigeria and Ghana.

4.3 Synthesis and Cross-Country Comparative Analysis

Synthesizing these indices allows for a nuanced diagnosis:

- **South Africa:** A balanced leader. Its strength is built on a solid foundation of good infrastructure (0.7), the continent's best R&D (0.5), and a strong industrial base (0.6). Its relative weakness is in skills (0.5), which could cap its future potential.
- **Morocco:** The "Infrastructure Powerhouse." Its high infrastructure score (0.7) drives its overall readiness, but this is undermined by significant weaknesses in skills (0.4) and, until recently, R&D (0.5). Its challenge is to translate infrastructure into human capital and innovation.
- **Mauritius & Tunisia:** The "Stable Performers." They show balanced profiles with relatively strong industry and finance scores. Tunisia's recent decline in the overall and skills index is a red flag that warrants further study.
- **Nigeria & Ghana:** The "Stalled Giants." Their story is one of paradox. They possess vibrant tech ecosystems and improving infrastructure, but these are nullified by a catastrophic combination of low skills (0.3-0.4), negligible R&D (0.3-0.4), and a weak, volatile industrial sector. Their digital futures are held hostage by these systemic failures.
- **Botswana, Algeria, Libya, Gabon:** The "Resource-Constrained." Their low scores across most indices, particularly R&D and industry, reflect economies struggling to diversify beyond natural resources and build a holistic digital innovation system, further hampered in Libya's case by conflict.

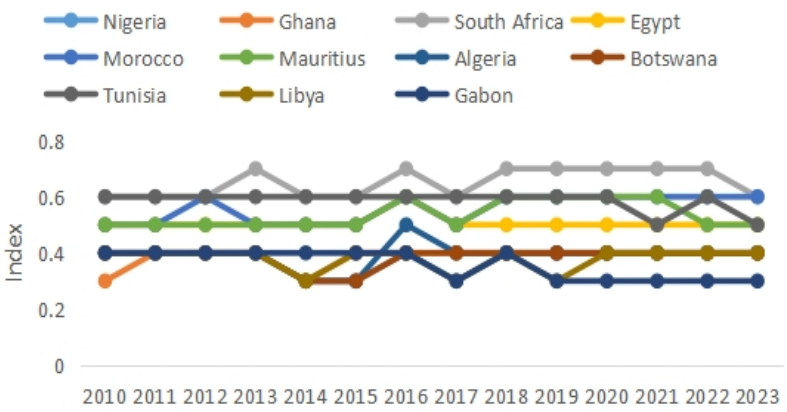


Figure 2: Countries' rediness for using frontier technologies (overall index)

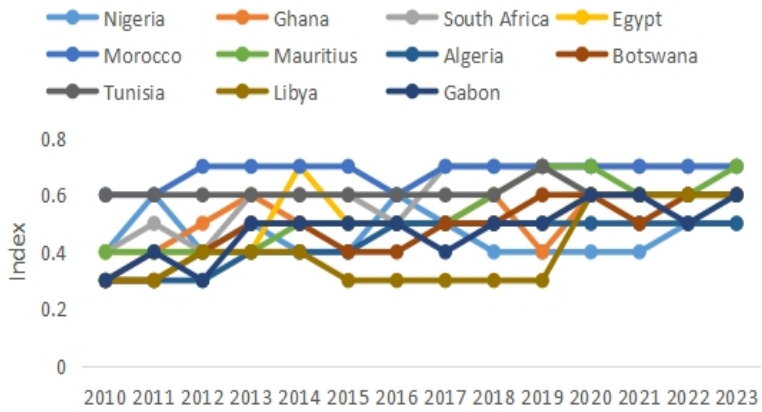


Figure 3: Countries' level of ICT infrastructure for using frontier technologies

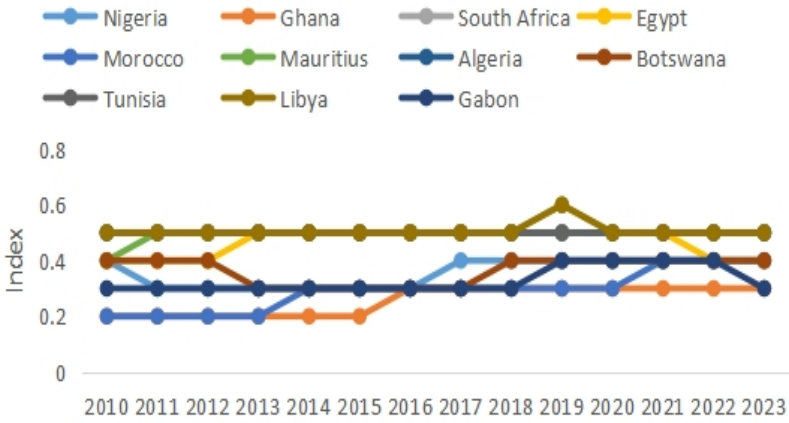


Figure 4: Countries' level of relevant skills for using frontier technologies

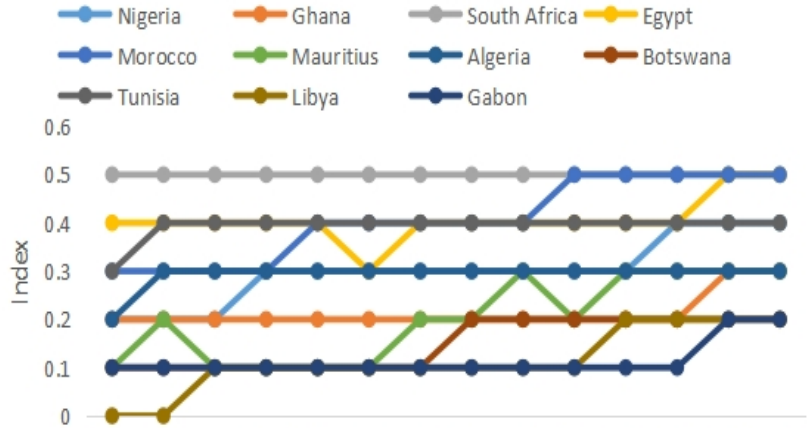


Figure 5: Countries' level of R&D capacity for using frontier technologies

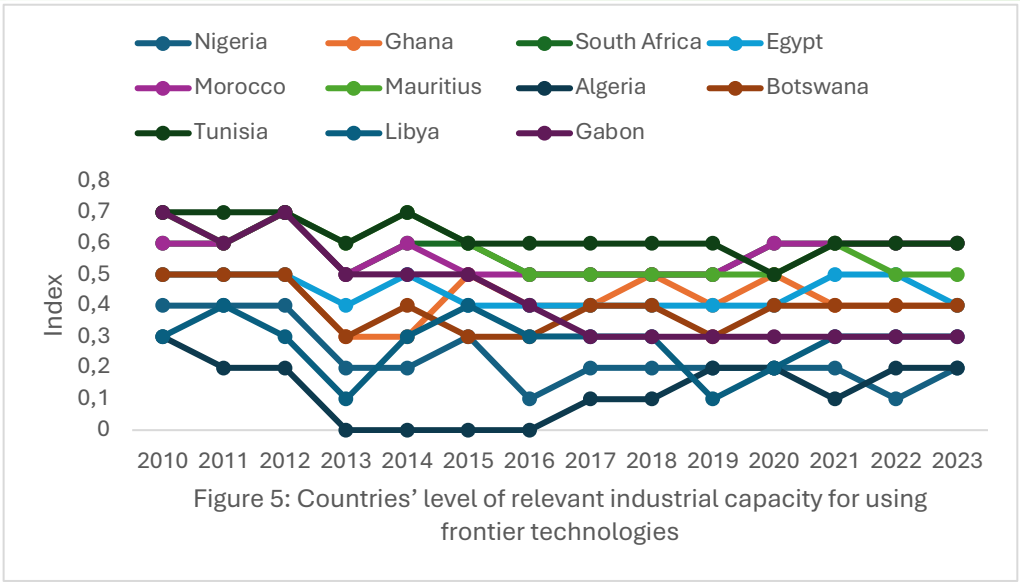


Figure 5: Countries' level of relevant industrial capacity for using frontier technologies

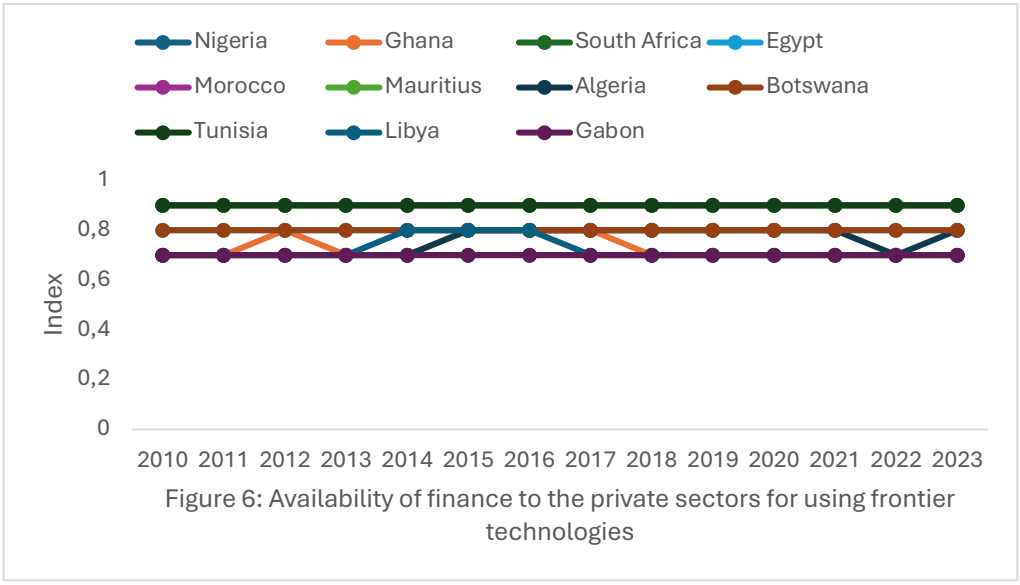


Figure 6: Availability of finance to the private sectors for using frontier technologies

5.0 Conclusion, Recommendations, and Policy Implications

5.1 Conclusion

This study set out to conduct a comparative assessment of frontier technology readiness across eleven African nations from 2010 to 2023. The analysis of the UNCTAD index data reveals a landscape characterized not by widespread, dynamic growth, but by pronounced stratification, pervasive stagnation, and critical systemic imbalances. In other words, the comparative assessment reveals that frontier technology readiness in Africa is not a monolithic story but a complex mosaic of divergent paths. The data robustly demonstrates that progress is not guaranteed by isolated improvements in infrastructure or a buzzing startup scene in a single city. The overarching conclusion is that the promise of a digitally transformed Africa is being held hostage by foundational weaknesses in its national innovation systems, with human capital and research capacity emerging as the most binding constraints. Succinctly, true readiness is a multivariate function, and the continent's primary constraint has shifted from a pure infrastructure gap to a more profound human capital and innovation gap, as evidenced by the stagnant ICT Skills and R&D indices.

The findings robustly demonstrate that South Africa remains the continent's relative leader, boasting a balanced profile with strengths in infrastructure, R&D, and industry. Mauritius, Morocco, and Egypt form a second tier, yet each exhibits a critical asymmetry; Morocco's advanced infrastructure is undermined by a chronic skills deficit, a clear case of "hardware without software." The most concerning narrative belongs to the "stalled giants," Nigeria and Ghana, whose vibrant tech ecosystems fail to elevate their national readiness due to catastrophically low and stagnant scores in R&D and skills, coupled with a volatile industrial sector. The performance of other nations like Botswana, Algeria, Libya, and Gabon underscores the difficulty resource-dependent economies face in diversifying into a knowledge-based digital economy.

Theoretically, the study challenges the simplistic "leapfrogging" narrative. The empirical evidence aligns more closely with the National Systems of Innovation framework, confirming that technological progress is a multivariate function requiring synergistic interaction between all components. The data validates the Capabilities Approach, showing that without expanding the population's capabilities (skills), investments in resources (infrastructure) yield diminishing returns. Ultimately, the study concludes that Africa's readiness gap is fundamentally a human capital and innovation gap. Without a strategic, coordinated, and long-term focus on fixing these fundamentals, the continent risks being confined to the periphery of the Fourth Industrial Revolution, consuming technologies it does not create or truly own.

5.2 Recommendations

Based on the specific weaknesses and imbalances identified, the following targeted recommendations are proposed:

A. For Governments and National Policymakers:

1. **Prioritize Education and Skills Revolution:** Move beyond curricular reforms to a fundamental overhaul of education systems.

   - **For Nigeria, Ghana, and Morocco:** Integrate computational thinking, digital literacy, and STEM education from primary levels. Forge industry-academia partnerships to ensure university curricula are aligned with market needs, addressing the specific skills gap identified in their indices.

   - **For all countries:** Launch massive, publicly-funded digital upskilling and reskilling programs targeted at the current workforce.

2. **Catalyze Investment in R&D:**

   - **For Nigeria, Ghana, Algeria, and Botswana:** Fulfill the African Union's target of allocating at least 1% of GDP to R&D. Create competitive public research funds and introduce tax incentives for private sector R&D, especially in areas of local relevance like agritech, cleantech, and healthtech.

   - **For South Africa and Egypt:** Build on their existing strengths by increasing funding for translational research and commercializing university-held patents.

3. **Develop Integrated National Digital Strategies:** Create or update national digital economy strategies that explicitly address the interlinkages between the five pillars. An infrastructure plan must be coupled with a parallel skills development plan and a strategy to stimulate industrial demand.

4. **Strengthen the Enabling Environment:** For countries with volatile industry indices like Nigeria and Algeria, focus on macroeconomic stability, reliable power supply, and policies that incentivize investment in non-oil sectors to create a stable demand-pull for technology.

B. For International Development Partners and Regional Bodies (AU, AfDB):

1. **Facilitate Cross-Border Learning:** Establish peer-learning platforms where countries like Morocco can share infrastructure deployment models, while Mauritius and South Africa can share insights on skills and R&D policy.

2. **Finance Public Goods:** Direct development funding towards regional public goods that are too costly for single nations, such as regional data clouds, high-performance computing centers, and Pan-African digital literacy initiatives.

3. **Support Policy Harmonization:** Assist in harmonizing digital policies and regulations across regions to create larger markets that can attract more significant R&D and infrastructure investments.

C. For the Private Sector and Academia:

1. **Deepen Collaboration:** Industry should actively partner with universities to co-create curricula, fund chairs, and offer internship programs to bridge the skills gap directly.

2. **Focus on "Demand-Pull" Innovation:** Large corporations should explicitly signal their demand for locally developed tech solutions, creating a market that pulls innovation from startups and research labs.

3. **Develop Innovative Financing Models:** The financial sector must move beyond traditional debt and develop venture capital, private equity, and impact investment vehicles tailored to the high-risk, long-term nature of deep-tech startups.

5.3 Policy Implications

The findings of this study carry profound implications for policymaking, shifting the focus from isolated interventions to systemic transformation.

1. **From Connectivity to Capabilities:** The primary policy implication is that the era of prioritizing infrastructure above all else is over. The new imperative is a **dual-track policy** that continues to close the infrastructure gap while launching a parallel, aggressive national mission to close the skills and R&D gap. Investment in a fibre optic cable must be matched by a proportional investment in the teachers and researchers who will maximize its value.

2. **The Need for "Systemic Policy Orchestration":** Policymakers must act as system orchestrators rather than siloed managers. This requires breaking down ministerial silos. The Ministry of ICT must work inseparably with the Ministries of Education, Science & Technology, and Industry. A "Whole-of-Government" approach is non-negotiable for fostering the synergistic interactions required by a National Innovation System.

3. **Strategic Patience and Long-Term Commitment:** Building technological readiness is not a short-term electoral project. The stagnation evident in the 14-year data is a result of policy inconsistency and a lack of long-term vision. Policies must be insulated from political cycles, with 20-30 year horizons for education and R&D strategies, acknowledging that the payoffs are generational but foundational.

4. **Targeted, Context-Specific Interventions:** A one-size-fits-all policy is doomed to fail. The analysis provides a clear diagnostic for each country:

- **For Morocco:** Policy must pivot sharply towards skills and education.
- **For Nigeria and Ghana:** The urgent focus must be on stabilizing the industrial environment and making foundational investments in R&D.
- **For South Africa:** The challenge is to address its skills bottleneck and spatial inequalities to leverage its strong base for more inclusive growth.
- **For Libya and conflict-affected states:** The foundational policy is the restoration of security and governance, without which no digital development is possible.

In conclusion, this study provides a clear and urgent message: Africa's digital future hinges on its ability to confront its human capital and innovation crisis. The data has spoken, revealing a decade of lost potential for many. The path forward requires not just more investment, but smarter, more integrated, and more patient policymaking that builds the entire innovation system in concert. By heeding this evidence, African nations can transition from being passive consumers of technological change to becoming active architects of their own destinies in the global digital economy.

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FİTOREMEDİASYON: LİMON OTU, KEKİK, ADAÇAYI VE KARAHİNDİBA'NIN ÇEVRESEL KİRLİLİKLE MÜCADELEDEKİ ROLÜ

Dr. Öğr. Üyesi Feyza Döndü BİLGİN

Aydın Adnan Menderes Üniversitesi, Koçarlı MYO, Bitkisel ve Hayvansal Üretim Bölümü, Aydın

Email: feyzabilgin@adu.edu.tr

ORCID: 0000-0002-7435-4130

Prof. Dr. İlkay YAVAŞ

Aydın Adnan Menderes Üniversitesi, Koçarlı MYO, Bitkisel ve Hayvansal Üretim Bölümü, Aydın

Email: iyavas@adu.edu.tr

ORCID: 0000-0002-6863-9631

ÖZET

Fitoremediasyon, çevresel kirliliği azaltmak için bitkilerin biyolojik mekanizmalarını kullanan sürdürülebilir bir teknolojidir. Bu yöntem, kirleticilerin topraktan uzaklaştırılmasında ekonomik ve çevre dostu bir çözüm sunar. *Cymbopogon citratus* (limon otu), *Thymus vulgaris* (kekik), *Salvia officinalis* (adaçayı) ve *Taraxacum officinale* (karahindiba) gibi tıbbi ve aromatik bitkiler, fitoremediasyon uygulamalarında önemli bir yere sahiptir. Limon otu, geniş kök sistemi sayesinde ağır metallerin ve petrol türevli kirleticilerin temizlenmesinde etkili bir bitkidir. Ayrıca kök salgıları, toprak mikrobiyal aktivitelerini destekleyerek arıtım sürecine katkıda bulunur. Kekik, kurşun (Pb) ve kadmiyum (Cd) gibi ağır metallerin fitostabilizasyonunda başarılıdır; aynı zamanda antimikrobiyal ve antioksidan özellikleriyle çevreye ek katkılar sağlar. Adaçayı, kadmiyum (Cd) ve çinko (Zn) gibi kirleticilerin biyolojik parçalanmasını hızlandırarak toprak enzim aktivitelerini artırır. Karahindiba ise hiperakümülatör özelliği sayesinde kadmiyum (Cd) ve nikel (Ni) gibi ağır metallerin topraktan uzaklaştırılmasında yüksek etkinlik gösterir. Bu bitkiler, tıbbi ve aromatik özelliklerinin yanı sıra çevresel sürdürülebilirliğe de katkı sağlamaktadır. Güncel araştırmalar, genetik mühendisliği ve mikrobiyal destekli yaklaşımların bu bitkilerin fitoremediasyon etkinliğini artırabileceğini göstermektedir. Küresel ölçekte fitoremediasyonun yaygınlaştırılması, eğitim ve bilinçlendirme programlarıyla mümkün olup, bu yöntem uzun vadede çevre koruma çabalarına büyük katkılar sağlayabilir.

Anahtar kelime: Fitoremediasyon, ağır metal, tıbbi ve aromatik bitkiler, çevresel sürdürülebilirlik,

PHYTOREMEDIATION: THE ROLE OF LEMONGRASS, THYME, SAGE, AND DANDELION IN COMBATING ENVIRONMENTAL POLLUTION

ABSTRACT

Phytoremediation is a sustainable technology that utilizes the biological mechanisms of plants to reduce environmental pollution. This method offers an economical and eco-friendly solution for the removal of contaminants from soil. Medicinal and aromatic plants such as *Cymbopogon citratus* (lemongrass), *Thymus vulgaris* (thyme), *Salvia officinalis* (sage), and *Taraxacum officinale* (dandelion) play a significant role in phytoremediation applications. Lemongrass is an effective plant for the remediation of heavy metals and petroleum-derived pollutants due to its extensive root system. In addition, its root exudates enhance microbial activity in the soil, thereby contributing to the overall remediation process. Thyme is effective in the phytostabilization of heavy metals such as lead (Pb) and cadmium (Cd), and its antimicrobial and antioxidant properties provide additional environmental benefits. Sage accelerates the biodegradation of pollutants such as cadmium (Cd) and zinc (Zn) while enhancing soil enzyme activities. Dandelion, with its hyperaccumulator characteristics, exhibits high efficiency in removing heavy metals such as cadmium (Cd) and nickel (Ni) from the soil. Beyond their phytoremediation potential, these plants also contribute to environmental sustainability through their medicinal and aromatic properties. Recent studies indicate that genetic engineering and microbial-assisted techniques can enhance the phytoremediation efficiency of these species. On a global scale, the widespread adoption of phytoremediation can be achieved through education and awareness programs. In the long term, this approach holds great potential to support environmental protection and ecosystem restoration efforts.

1.GİRİŞ

Günümüz sanayileşme, madencilik ve yoğun tarımsal faaliyetler, ağır metaller, petrol türevli kirleticiler ve çeşitli organik bileşikler gibi zararlı maddelerin çevresel ortamlarda hızla birikmesine neden olmaktadır. Bu durum, sadece çevresel kirliliği artırmakla kalmayıp, ekosistemlerin hassas dengesini de ciddi şekilde tehdit etmektedir (Khan ve ark., 2013; Sarma ve Sarma, 2019). Ağır metallerin ve organik kirleticilerin toprakta birikimi, bitkilerde toksisiteye, mikrobiyal aktivitenin azalmasına ve besin döngüsünün bozulmasına yol açmaktadır (Alloway, 2013; Kabata-Pendias, 2011). Ayrıca bu kirleticiler, gıda zinciri yoluyla insan sağlığını da tehdit ederek ciddi halk sağlığı sorunlarına neden olmaktadır (Nagajyoti ve ark., 2010). Küresel çevre sorunlarının giderek arttığı bu dönemde, kirlilikle mücadelede yenilikçi ve sürdürülebilir çözümler bulmak büyük önem taşımaktadır (Bradl, 2005; Gherghel ve ark., 2017).

Bu nedenle fitoremediasyon, çevreye yayılan bu kirleticileri temizlemek için bitkilerin doğal biyolojik süreçlerini kullanan etkili ve çevre dostu bir yöntem olarak öne çıkmaktadır (Pilon-Smits, 2005; Ali ve ark., 2013). Bu teknoloji, ağır metaller ve organik kirleticiler gibi zararlı maddelerin toprak ve su ekosistemlerinden uzaklaştırılmasında sürdürülebilir bir çözüm sunmaktadır (Sarma, 2011; Shah ve Daverey, 2020; Sharma ve ark., 2021). Fitoremediasyon, diğer geleneksel arıtma yöntemlerine kıyasla daha düşük maliyetli, estetik açıdan daha hoş ve ekosisteme zarar vermeyen bir alternatif sunmaktadır (Salt ve ark., 1998; Alkorta ve Garbisu, 2001).

Fitoremediasyonun başarısı, seçilen bitki türünün morfolojik, fizyolojik ve biyokimyasal özelliklerinin yanı sıra toprak tipi, kirletici konsantrasyonu ve rizosferdeki mikrobiyal etkileşimlerle yakından ilişkilidir (Prasad ve Freitas, 2003; Sessitsch ve ark., 2013; Glick, 2010). Bu kapsamda, bitki–mikroorganizma işbirliği, özellikle ağır metallerin biyoyararlılığını artırarak kirletici alımını ve tolerans mekanizmalarını güçlendirmektedir (Mourato ve ark., 2015; Singh ve Prasad, 2015). Ayrıca, bazı bitkiler stres koşullarında sekonder metabolit üretimini artırarak hem kendi savunma sistemlerini güçlendirmekte hem de çevredeki toksik elementlerin kimyasal formlarını dönüştürebilmektedir (Rao ve ark., 2020; Chen ve ark., 2022). Bu nedenle, fitoremediasyon uygulamalarında çevresel koşullara uyum sağlayabilen, yüksek biyokütle üretebilen ve mikrobiyal etkileşimi destekleyen bitki türlerinin seçimi büyük önem taşımaktadır. Bu bağlamda, özellikle tıbbi ve aromatik bitkiler, fitoremediasyon alanında hem çevresel temizliğe hem de ekonomik faydalara katkı sağlayan özel bir kategoriye sahiptir. Limon otu (*Cymbopogon citratus*), kekik (*Thymus vulgaris*), adaçayı (*Salvia officinalis*) ve karahindiba (*Taraxacum officinale*), bu nedenle oldukça önemli bitkilerdir (Doty, 2008; Pilon-Smits ve Pilon, 2000). Bu bitkiler, uçucu yağ içeriği ve sekonder metabolit üretim kapasitesi sayesinde hem kirletici stresi azaltabilir hem de toprak mikrobiyal çeşitliliğini artırabilir (Mourato ve ark., 2015; Rai ve ark., 2021). Ayrıca bu türlerin sahip olduğu fitokimyasal bileşikler, metal iyonlarının şelatlaşmasında ve toksik etkilerin hafifletilmesinde rol oynayabilir (Nandakumar ve ark., 2019; Singh ve Prasad, 2015). Örneğin limon otu, kadmiyum ve kurşun gibi ağır metallere karşı yüksek tolerans sergilerken; kekik ve adaçayı, antioksidan enzim aktivitelerini artırarak metal kaynaklı oksidatif stresi azaltmaktadır (Chen ve ark., 2022; Rao ve ark., 2020). Karahindiba ise hiperakümülatör özelliği sayesinde metal taşınımında genetik olarak avantajlı bir tür olarak tanımlanmaktadır (Banik ve ark., 2021). Dolayısıyla, bu bitkilerin fitoremediasyon süreçlerinde kullanılması, çevresel sorunların çözümüne çift yönlü ve entegre bir katkı sağlama potansiyeli taşımaktadır. Son yıllarda yapılan çalışmalar, bu bitkilerin genetik olarak iyileştirilmesi ve mikrobiyal konsorsiyumlarla desteklenmesi halinde, fitoremediasyon etkinliklerinin önemli ölçüde artabileceğini göstermektedir (Cao ve ark., 2020; Kumar ve ark., 2022). Bu yaklaşımlar, hem toprak sağlığının yeniden kazanılmasını hem de sürdürülebilir ekosistem yönetimini mümkün kılmaktadır (Zhao ve ark., 2021).

2.LİMON OTUNUN (*Cymbopogon citratus*) FİTOREMEDİASYONDAKİ ROLÜ

Limon otu (*Cymbopogon citratus*), özellikle geniş ve yoğun kök sistemi sayesinde petrol türevli hidrokarbonların biyolojik parçalanmasında ve ağır metallerin fitostabilizasyonunda yüksek etkinlik göstererek ön plana çıkmaktadır (Cheng ve ark., 2023; Gautam, 2017). Bitkinin rizosferinde salgıladığı bileşikler aracılığıyla mikrobiyal aktiviteyi teşvik etme özelliği, poliaromatik hidrokarbonlar gibi karmaşık organik kirleticilerin giderilmesinde kritik bir rol oynamaktadır (Khan ve ark., 2013; Ahmad ve ark., 2021). Pilon-Smits (2005), limon otunun kurşun (Pb), kadmiyum (Cd) ve çinko (Zn) gibi metallerin fitostabilizasyonunda etkili olduğunu, aynı zamanda kök salgıları aracılığıyla toprak mikrobiyotasını desteklediğini bildirmiştir. Mikrobiyal destekli fitoremediasyon teknikleri, bu etkinliği artırarak limon otunun çevresel kirlilikle mücadeledeki rolünü artırmaktadır (Abou-Shanab ve ark., 2007; Zhang ve ark., 2020; Doke ve Sajadi, 2021). Ayrıca limon otunun yüksek buharlaşma kapasitesi ve biyokütle üretimi, kirleticilerin bitki bünyesinde seyreltilmesini sağlayarak fitostabilizasyon etkinliğini güçlendirmektedir (Shukla ve ark., 2022).

Son beş yılda yapılan çalışmalar da limon otunun bu potansiyelini pekiştirmektedir. Örneğin, Azam ve ark. (2021), limon otunun ağır metal stresi altındaki fizyolojik adaptasyon mekanizmalarını incelemiş ve bitkinin bu tür kirleticilere karşı yüksek toleransını ortaya koymuştur. Liang ve ark. (2022), limon otunun petrolle kirlenmiş topraklardaki biyoremediasyon kapasitesini artırmak için mikroorganizmalarla sinerjik etkilerini araştırmıştır. Ayrıca, Sharma ve ark. (2023), limon otunun pestisit kalıntılarının topraktan uzaklaştırılmasındaki rolünü değerlendirmiş, bitkinin organik kirleticilere karşı geniş spektrumlu bir arıtma yeteneğine sahip olduğunu belirtmiştir. Kumar ve ark. (2024) ise, limon otunun farklı ağır metal kombinasyonlarıyla kirlenmiş topraklardaki fitostabilizasyon performansını karşılaştırmalı olarak inceleyerek, çoklu kirletici koşullarında dahi etkinliğini sürdürdüğünü göstermiştir. Son olarak, Hussain ve ark. (2025) tarafından yapılan bir çalışma, limon otunun madencilik faaliyetlerinden kaynaklanan kirliliğin giderilmesinde umut vadeden bir bitki olduğunu ortaya koymuştur.

3.KEKİĞİN (*Thymus vulgaris*) FİTOREMEDİASYONDAKİ ROLÜ

Kekik (*Thymus vulgaris*), fitoremediasyon süreçlerinde, özellikle ağır metallerin fitostabilizasyonunda etkili bir bitki olarak öne çıkmaktadır. Nadjafi (2014), kekiğin kurşun (Pb) ve kadmiyum (Cd) gibi metallerin topraktan uzaklaştırılmasında önemli bir rol oynadığını belirtmiştir. Kekik, kök salgıları aracılığıyla toprak mikrobiyotasını zenginleştirerek kirleticilerin biyoyararlanımını artırmaktadır (Abou-Shanab vd., 2007). Ayrıca, kekik bitkisinin antimikrobiyal ve antioksidan özellikleri, çevresel stres faktörlerine karşı dayanıklılığını artırmaktadır (Hammoudi Halat vd., 2022). Bu özellikler, bitkinin kirli ortamlarda hayatta kalma ve arıtma kapasitesini doğrudan etkilemektedir. İftihar vd. (2023), kekik bitkisinin toprak iyileştirme süreçlerinde etkili olduğunu ve fitoremediasyon kapasitesini artırdığını bildirmiştir. Kekik, özellikle düşük ila orta düzeyde kirlenmiş alanlarda toprak sağlığını iyileştirme potansiyeline sahiptir (Pramanik ve Bera, 2022; Ghorbani ve ark., 2022). Ek olarak, kekik uçucu yağlarındaki timol ve karvakrol gibi bileşenlerin, ağır metal kaynaklı oksidatif stresi azaltmada antioksidan mekanizmaları güçlendirdiği bildirilmektedir (Al-Huqail ve ark., 2020).

Son yıllarda yapılan çalışmalar da bu potansiyeli desteklemektedir. Ali ve ark. (2020), kekik türlerinin farklı ağır metal kontaminasyon seviyelerindeki performansını değerlendirmiş ve yüksek bir fitoremediasyon kapasitesine sahip olduğunu ortaya koymuştur. Benzer şekilde, Khan ve ark. (2021b), kekiğin ağır metal birikimi ve stres toleransı mekanizmaları üzerine yaptığı araştırmada, bu bitkinin çevresel iyileştirme stratejileri için umut vadeden bir bitki olduğunu vurgulamıştır. Ek olarak, Rana ve ark. (2021), kekik esansiyel yağlarının fitoremediasyon sürecindeki sinerjistik etkilerini incelemiş, bu yağların bitkinin ağır metal

toleransını artırabileceğini belirtmiştir. Murtaza ve ark. (2023), kekiğin topraktaki petrol hidrokarbonları gibi organik kirleticilerin parçalanmasına yardımcı olan mikrobiyal aktiviteyi nasıl desteklediğini araştırmıştır. Son olarak, Hassan ve ark. (2024), kekik bitkisinin ağır metallerle kirlenmiş sulak alanlardaki adaptasyon yeteneğini ve arıtma performansını değerlendiren yeni bir çalışma sunmuştur.

4.ADAÇAYININ (*Salvia officinalis*) FİTOREMEDİASYONDAKİ ROLÜ

Adaçayı, ağır metallerin ve organik kirleticilerin temizlenmesinde etkili bir bitki olarak kabul edilmektedir. Mokhtari ve ark. (2023), adaçayının kadmiyum (Cd) ve çinko (Zn) gibi metallerin fitostabilizasyonunda başarılı olduğunu ve toprak enzim aktivitelerini artırarak kirleticilerin biyolojik parçalanmasını desteklediğini belirtmiştir. Toprak enzim aktivitesindeki bu artış, özellikle organik kirleticilerin daha hızlı mineralizasyonuna yol açmaktadır (Bajpai ve Pandey, 2019). Adaçayının kök salgıları, mikrobiyal toplulukları zenginleştirerek kirleticilerin biyoyararlanımını artırmaktadır (Ismail, 2019). Ayrıca, adaçayının güçlü antimikrobiyal ve antioksidan bileşenleri, çevresel toksisiteye karşı bitkinin direncini artırırken, arıtma süreçlerine de katkı sağlamaktadır (Mokhtari ve ark., 2023). Son araştırmalar, adaçayının ağır metallerle kirlenmiş topraklarda rizosferik mikrobiyal toplulukları modüle etme yeteneğini de vurgulamaktadır (Khan ve ark., 2021a; Alaboudi ve ark., 2021). Ayrıca, adaçayının yüksek sekonder metabolit üretimi, özellikle flavonoidler ve fenolik bileşikler aracılığıyla metal iyonlarının şelatlaşmasını kolaylaştırarak toksisiteyi azaltmaktadır (Sytar ve ark., 2019).

Ma ve ark. (2022), adaçayının farklı ağır metal konsantrasyonlarındaki büyüme tepkilerini ve metal birikim kapasitesini incelemiş, bitkinin çevresel iyileştirmedeki rolünü pekiştirmiştir. Benzer şekilde, Li ve ark. (2020), adaçayının rizofitodegradasyon yeteneğini detaylı olarak araştırmış ve toprak organik kirleticilerinin giderilmesindeki etkinliğini göstermiştir. Ayrıca, Ahmed ve ark. (2021), adaçayının tuz stresi altındaki ağır metal fitoremediasyon etkinliğini değerlendirerek, zorlu çevresel koşullarda dahi adaptasyon yeteneğine dikkat çekmiştir. Son bulgular, adaçayının aynı zamanda karbon sekestrasyonu potansiyeli yüksek türlerden biri olduğunu, bu nedenle hem kirlilik kontrolü hem de iklim değişikliğiyle mücadelede çift yönlü fayda sunduğunu göstermektedir (Petrova ve ark., 2022).

5.KARAHİNDİBANIN (*Taraxacum officinale*) FİTOREMEDİASYONDAKİ ROLÜ

Karahindiba (*Taraxacum officinale*), hiperakümülatör bir bitki olarak kadmiyum (Cd) ve nikel (Ni) gibi ağır metallerin topraktan uzaklaştırılmasında etkili bir araçtır (Kopittke ve ark., 2010; Salt ve ark., 1995). Yu ve ark. (2023), karahindibanın kök salgılarının toprak mikrobiyotasını zenginleştirerek metallerin biyoyararlanımını artırdığını bildirmiştir. Lu ve ark. (2021), karahindibanın toprak enzim aktivitelerini artırarak kirleticilerin biyolojik parçalanmasını desteklediğini belirtmiştir. Park ve Oh (2023), karahindibanın çevresel kirlilikle mücadelede hiperakümülatör özellikleri sayesinde etkili bir fitoremediasyon aracı olduğunu göstermektedir. Karahindibanın metal toleransı ve biriktirme yeteneği, toprak pH'ı ve organik madde içeriği gibi faktörlerden etkilense de özellikle maden sahaları gibi ağır metal kirliliğinin yaygın olduğu alanlarda büyük potansiyel sunmaktadır (Raskin ve ark., 1997). Yeni çalışmalar, karahindibanın genetik modifikasyon yoluyla ağır metal toleransının ve biriktirme kapasitesinin artırılabileceğini de işaret etmektedir (Ma ve ark., 2022). Chen ve ark. (2020), karahindibanın kadmiyum alımını ve detoksifikasyon mekanizmalarını detaylı olarak incelemiş, bitkinin stres koşulları altında dahi etkinliğini koruduğunu göstermiştir. Wang ve ark. (2021) ise, karahindibanın nikel kirliliğine sahip topraklarda fitoremediasyon kapasitesini değerlendirmiş ve yüksek bir biriktirme yeteneği saptamıştır. Ayrıca, Zhang ve ark. (2022), karahindibanın ağır metal stresi altındaki fizyolojik ve moleküler tepkilerini analiz ederek, bitkinin adaptasyon mekanizmalarına dair önemli bilgiler sunmuştur. Ek olarak, karahindibanın derin kök sistemi

sayesinde yüzeysel ve derin toprak tabakalarındaki kirleticilere erişebilmesi, onu uzun vadeli toprak restorasyon stratejileri için ideal bir tür haline getirmektedir (Silva ve ark., 2023).

6.SONUÇ VE ÖNERİLER

Limon otu, kekik, adaçayı ve karahindiba gibi tıbbi ve aromatik bitkiler, fitoremediasyon sürecinde oldukça etkili ve çevresel açıdan önemli araçlardır. Bu bitkiler, kurşun (Pb), kadmiyum (Cd), çinko (Zn), nikel (Ni) ve petrol türevli kirleticiler gibi çevre için toksik olan maddelerin toprak ve sudan uzaklaştırılmasında başarıyla kullanılmaktadır. Bu süreçte kullanılan mekanizmalar arasında fitostabilizasyon, hiperakümülasyon ve biyolojik parçalanma gibi doğal adaptasyon yöntemleri öne çıkmaktadır. Mikrobiyal destekli fitoremediasyon ise, bu bitkilerin etkinliğini daha da artırarak hem metal hem de organik kirleticilerin temizlenme hızını önemli ölçüde iyileştirmektedir (Glick, 2003; Sarma ve ark., 2021).

Limon otu, geniş kök sistemiyle petrol türevli kirleticilerin ve ağır metallerin toprağa olan etkilerini azaltmada önemli bir rol oynamaktadır. Çevresel stres koşullarına karşı oldukça dayanıklı olup, aynı zamanda toprak mikrobiyotasını destekleyen kök salgıları üretmektedir. Kekik, kurşun ve kadmiyum gibi ağır metallerin toprakta stabilize edilmesine yardımcı olurken, antimikrobiyal ve antioksidan özellikleriyle çevresel dayanıklılığı artırmaktadır. Adaçayı, topraktaki enzim aktivitelerini artırarak kirleticilerin biyolojik parçalanmasını hızlandırmakta ve kadmiyum ile çinko gibi kirleticilere karşı direnç göstermektedir. Karahindiba ise kadmiyum ve nikel gibi toksik metalleri hiperakümülatör özelliği sayesinde topraktan alarak bünyesinde biriktirmekte ve aynı zamanda toksinlere karşı antioksidan savunma sağlamaktadır.

Bu bitkiler, yalnızca çevresel kirleticilerin temizlenmesine katkı sağlamakla kalmaz, aynı zamanda tıbbi özellikleriyle ekonomik ve sağlık açısından faydalar sunar. Antibakteriyel, antioksidan ve antienflamatuar özelliklere sahip olan bu bitkiler hem çevreyi koruma hem de sürdürülebilir sağlık çözümleri sunma potansiyeline sahiptir. Gelecekte, bu bitkilerin genetik mühendisliği ve biyoteknolojik yaklaşımlarla geliştirilmesi, çevre kirliliği sorunlarına daha etkili çözümler sunabilir (Pilon-Smits, 2005; Shah ve Daverey, 2020). Ayrıca, mikrobiyal destekli tekniklerin yaygınlaştırılması ve bu bitkilerin çeşitli iklim koşulları altında incelenmesi, küresel çapta daha geniş bir uygulanabilirlik sağlayacaktır. Eğitim ve farkındalık kampanyalarıyla bu yöntemlerin yaygınlaştırılması, çevresel sürdürülebilirliğin artırılmasında önemli bir adım olacaktır. Fitoremediasyon, bu tıbbi ve aromatik bitkilerin çok yönlü faydalarını göz önünde bulundurarak, çevresel sorunların çözümünde umut verici ve yenilikçi bir yaklaşım olarak kendini göstermektedir.

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USE OF MICROSCOPIC METHOD IN QUALITY CONTROL OF FISH MEALS

Figen KÜTÜKOĞLU*

*Corresponding author, DVM, Ph.D., Food and Feed Control Central Research Institute, Bursa, Türkiye

Email: figen.kutukoglu@tarimorman.gov.tr

ORCID: 0000-0002-3360-6485

Habil UMUR

M.Sc. Agricultural Engineer, Food and Feed Control Central Research Institute, Bursa, Türkiye

Email: habil.umur@tarimorman.gov.tr

ORCID: 0000-0002-9824-1165

Hülya HANOĞLU ORAL

Assoc. Prof. Dr., Muş Alparslan University, Faculty of Applied Sciences, Department of Animal Production and Technologies, Muş, Türkiye

Email: h.hanoglu@alparslan.edu.tr

ORCID: 0000-0003-3626-9637

ABSTRACT

Fish meal is one of the most important animal protein sources used in compound feeds for aquaculture. Due to its high nutritional value and balanced amino acid composition, it is also widely used in poultry and swine feeds. However, the source, species, and quality of the fish meal used in feeds are of great importance in terms of both feed safety and legal regulations. According to the legislation of the European Union and Türkiye, the use of any animal protein in ruminant feeds is prohibited. In addition, the inclusion of fish meal derived from the same species into the feed of that same species is also restricted under the regulations. Therefore, accurate identification of the presence and species of fish meal in compound feeds is essential.

The microscopic analysis technique is a rapid and reliable analytical method used to identify the distinctive morphological characteristics of raw materials in compound feeds, to detect harmful or toxic plant seeds that may contaminate the feed, to verify label declarations, and to determine the presence of animal proteins. Through this method, distinctive structures such as fish bones, bone tissue, muscle tissue, scales, and otoliths in feeds can be examined to determine the presence and origin of fish meal. In this way, both the detection of prohibited animal proteins and the verification of feed label accuracy are ensured.

In this study, a microscopic comparison was carried out between commercially obtained fish meal and anchovy meal produced from the Black Sea anchovy (*Engraulis encrasicolus*). The morphological characteristics of bone, muscle, and scale tissues were evaluated using stereo and light microscopes at magnifications ranging from 10× to 200×. In addition, various staining techniques (alizarin red, phenol–glycerin, Fehling) were applied to enhance the visibility of the diagnostic tissue structures.

As a result of the study, it was determined that the bone tissue of anchovy meal exhibited distinctive morphological features such as parallelly arranged elliptical and star-shaped lacunae, as well as a spinal structure resembling an hourglass. These differences were evaluated as important criteria for distinguishing anchovy meal from mixed fish meals at the microscopic level.

Keywords: Animal protein, Fish meal, Microscopic analysis, Feed safety

BALIK UNLARININ KALİTE KONTROLÜNDE MİKROSKOPİK YÖNTEMİN KULLANIMI

ÖZET

Balık unu, su ürünleri yetiştiriciliğinde kullanılan karma yemlerin en önemli hayvansal protein kaynaklarından biridir. Yüksek besin değeri ve dengeli amino asit içeriği nedeniyle ayrıca kanatlı ve domuz yemlerinde de yaygın olarak kullanılmaktadır. Ancak yemlerde kullanılan balık ununun kaynağı, türü ve kalitesi hem yem güvenirliği hem de yasal düzenlemeler açısından büyük önem taşımaktadır. Avrupa Birliği ve Türkiye mevzuatlarına göre, geviş getiren hayvan yemlerinde her türlü hayvansal protein kullanımı yasaktır. Ayrıca aynı türden elde edilen balık unlarının yine aynı tür balıkların yemine katılması da mevzuat kapsamında sınırlandırılmıştır. Bu nedenle, karma yemlerde balık unu varlığının ve türünün doğru biçimde tespit edilmesi gereklidir.

Mikroskopik analiz tekniği, karma yemlerde kullanılan hammaddelerin ayırt edici morfolojik özelliklerinin tanımlanmasında, yemlere karışabilecek zararlı veya toksik bitki tohumlarının saptanmasında, karma yemlerde etiket beyanlarının doğrulanmasında ve hayvansal proteinlerin tespitinde kullanılan hızlı ve güvenilir bir analiz yöntemidir. Bu yöntemle yemlerde balık kılçığı, kemik dokusu, kas dokusu, pul ve otalit gibi tanımlayıcı yapılar incelenerek balık ununun varlığı ve kökeni belirlenebilir. Böylece hem yasaklı hayvansal proteinlerin tespiti sağlanır hem de yem etiket beyanlarının doğruluğu kontrol edilir.

Bu çalışmada, piyasadan temin edilen balık unu ile Karadeniz hamsisinden (*Engraulis encrasicolus*) üretilen hamsi ununun mikroskopik olarak karşılaştırılması amaçlanmıştır. Stereo ve ışık mikroskobu (10–200x büyütme aralığında) kullanılarak elde edilen mikrograflar üzerinden kemik, kas ve pul dokularının morfolojik özellikleri değerlendirilmiştir. Ayrıca farklı indikatörlerle boyama teknikleri (alizarin kırmızısı, fenol-gliserin, Fehling) uygulanarak dokuların tanımlayıcı yapıları belirginleştirilmiştir.

Çalışmanın sonucunda, hamsi ununun kemik dokusunun paralel dizilmiş eliptik ve yıldız biçimli lakunalar ile kum saatini andıran omurilik yapısı gibi özgün morfolojik özellikler sergilediği belirlenmiştir. Bu farklılıklar, hamsi ununun karma balık unlarından mikroskopik düzeyde ayırt edilmesini sağlayan önemli bir kriter olarak değerlendirilmiştir.

Anahtar Kelimeler: Hayvansal protein, Balık unu, Mikroskopik analiz, Yem güvenirliği

1. INTRODUCTION

Due to its high protein content and balanced amino acid composition, fish meal is widely used in aquaculture as well as in poultry and swine feeds. According to the Turkish Standard No. 12296 (TS 12296) published by the Turkish Standards Institute, fish meal is defined as a product obtained from the processing of white- and dark-fleshed fish and other marine organisms, which involves the use of residues such as heads, skins, fins, bones, and internal organs (Anonymous, 1997).

The source, species, and quality of fish meal are of great importance for feed safety. According to European Union and Turkish regulations, the use of animal proteins in ruminant feeds is prohibited. However, in poultry and fish feeds, the use of animal tissues originating from the same species is not allowed; therefore, the identification of animal species in such feed ingredients has become mandatory (Anonymous, 2013). In this context, the microscopic analysis method used to detect the presence of animal proteins in feeds has been recognized by the European Union as the official and valid method (Momilovic and Rasooly, 2000; Van Raamsdonk et al., 2007). This method is based on the microscopic examination of animal tissue residues present in feed samples. In practice, coarse particles are examined under a stereomicroscope, while smaller fragments are evaluated according to their histological structures under a light microscope (Anonymous, 1998). The microscopic method is a rapid, economical, and reliable analytical technique used for the morphological identification of components in compound feeds, the detection of prohibited proteins, and the verification of label declarations (Umur et al., 2022).

In Türkiye, the most commonly used raw material for fish meal production is the Black Sea anchovy (*Engraulis encrasicolus*). Anchovy is preferred for high-quality fish meal production due to its high protein content, balanced amino acid profile, and low ash content (Özden and Selçuk, 2022). During periods when anchovy fishing is closed, sprat (*Sprattus sprattus*) is mostly used; however, anchovy meal has been reported to be superior in quality because of its homogeneous composition and higher nutritional value (Bayraklı, 2021; Özden and Selçuk, 2022). In addition to anchovy and sprat, other fish species such as herring, sardine, mackerel, menhaden, capelin, cod, and whiting are also used in fish meal production. The fact that anchovy meal is produced from a single species gives it a more consistent morphological structure and facilitates the identification of species-specific structural characteristics in microscopic analyses. In contrast, commercial mixed fish meals obtained from the market are produced from mixtures of different species, thus exhibiting a more heterogeneous morphological structure. Therefore, using anchovy meal as a reference material in microscopic analysis is important for verifying the species composition of commercial fish meals and enhancing the reliability of species-based quality control in feeds (Van Raamsdonk et al., 2007; Umur et al., 2022).

The chemical composition of fish meal varies depending on the fish species used, processing conditions, and storage period. Studies have shown that anchovy meal contains, on average, 62–70% crude protein, 8–10% crude fat, 15–20% ash, and less than 5% moisture (Bayraklı, 2021; Özden and Selçuk, 2022). These ratios are generally more variable in mixed commercial fish meals, where protein content tends to fluctuate irregularly, while ash content is reported to be higher. Moreover, low-quality fish meals are typically prone to oxidative degradation, elevated ash levels, and darkening in color, which are associated with fish species composition and processing temperature (Umur et al., 2022). It has also been reported that drying at high temperatures reduces the bioavailability of amino acids in fish meal and causes denaturation of protein structures (Van Raamsdonk et al., 2007). These findings indicate that anchovy meal, being derived from a single species and produced under controlled conditions, has a more

homogeneous structure, resulting in greater morphological consistency in microscopic analyses.

Microscopic examination of fish meal is based on the morphological identification of components, particularly through the evaluation of distinguishing features of bone, muscle, scale, otolith, and cartilage tissues (Liu et al., 2011). The shape, orientation, and density of lacunae and canaliculi structures in bone tissue differ significantly among species and are considered some of the most reliable morphological criteria for identification (Van Raamsdonk et al., 2007; Van Raamsdonk et al., 2012). It has been reported that fish bone tissues have thinner walls and more elongated lacunae compared to those of mammals or poultry, and that these structures can be clearly observed under a polarized light microscope (Liu et al., 2011). Additionally, the thickness of muscle fibers, the arrangement of myofibrils, and the surface patterns of scales (cycloid/ctenoid structures) vary among species and are regarded as complementary identification criteria in microscopic analysis (Momilovic and Rasooly, 2000). Among staining techniques, particularly alizarin red and phenol–glycerin applications have been reported to enhance contrast in calcified tissues, allowing morphological structures to be identified more clearly (De la Roza-Delgado et al., 2007). However, morphological similarities among closely related species (such as anchovy and sprat, which are small pelagic fish) make differentiation difficult; therefore, it has been suggested that the microscopic method should be supported by Real-Time Polymerase Chain Reaction (PCR) analyses (Holst et al., 2006).

The low cost, rapid applicability, and compliance of the microscopic method with standardized analytical protocols in official control laboratories make it the primary screening technique for detecting animal proteins in feeds (Van Raamsdonk et al., 2007). In Türkiye, the limited number of studies conducted in the field of feed microscopy and the shortage of trained personnel highlight the need for a detailed description of the microscopic characteristics of fish meals (Umur et al., 2022). Therefore, in this study, the microscopic properties of commercially obtained fish meal and anchovy meal produced from Black Sea anchovy (*Engraulis encrasicolus*) were compared. Morphological differences in bone and muscle tissues were evaluated using stereomicroscopy and light microscopy, with the aim of identifying the distinctive microscopic structural characteristics of anchovy meal and contributing to the accurate identification of fish meal species.

2. MATERIAL AND METHOD

Feed Material

In this study, a total of five samples of each type of fish meal and anchovy meal, approximately 2 kg per sample, were obtained in 2024 from compound feed factories operating in the Bursa region. The feed materials were ground using a laboratory-type mill (Fritsch Pulverisette 14, Idar-Oberstein, Germany) equipped with a 1 mm sieve and stored in glass jars under laboratory conditions.

Microscopic Analysis Method

The stereo and polarized light microscopic examinations of the fish meals were carried out at the Feed Microscopy Laboratory of the Bursa Food and Feed Control Central Research Institute, in accordance with the methods described by Khajarern and Khajarern (2008) and Anonymous (2013), respectively. The procedure described by Anonymous (2007) was used as the basis for the preparation of fish meal samples for microscopic analysis. For the analyses, 100 g of material determined by sampling was taken, and depending on the physical characteristics of the samples, the material was fragmented either manually or using a grinder. After fragmentation, flotation and sedimentation processes were performed to obtain different fractions.

In macroscopic examinations, a Leica S9i stereomicroscope equipped with an LED illumination system, both transmitted and reflected white light sources, a magnification range of 0.61–5.5×, and a 10-megapixel digital imaging system was used. For histological examinations, a Leica DM 750 P polarized light microscope, which allows high-resolution imaging within a magnification range of 50–500×, was employed.

For each staining method, at least 2 slides were prepared from both the sediment and flotation fractions, and at least 20 fields of view were examined per slide. As a result of the microscopic examinations, at least 10 micrographs were obtained, and 5 micrographs that best represented the morphological characteristics of the tissues were selected for evaluation. The images obtained from the stereo and polarized light microscopes were digitally processed using the LAS X 5.03 software.

For determining the histological characteristics of the fish meal samples, bone tissue in the sediment fraction was stained using the alizarin red method described by Frick et al. (2013a) and the phenol–glycerin method defined by Frick et al. (2013b), which enhanced the visualization of lacunae and canaliculi structures. In the flotation fractions, Fehling's indicator was applied according to the method reported by Anonymous (2013), and the resulting micrographs were recorded.

Morphological Evaluation and Comparative Examination

During the examinations, fish-specific morphological structures such as muscle tissue, bones, skin, vertebrae, and cartilage were evaluated in detail. After the staining procedures, differences in the color, shape, and density of the tissues were analyzed under polarized light, and the obtained micrographs were examined comparatively. The findings from both stereomicroscopic and polarized light microscopic analyses were evaluated together to determine the morphological characteristics of the tissues and the distinctive differences between species.

3. RESULTS

The micrographs of fish meal and anchovy meal obtained using a stereomicroscope are presented in Figure 1, while those obtained using a polarized light microscope are shown in Figure 2.

The colors of the fish meals examined in the study varied from light yellow to brown. This color variation is thought to result from the fish species used and the technological processes applied during production. In the anchovy meal, a skin structure ranging from bright white to light gray was observed, which makes the anchovy meal appear visually brighter compared to the other fish meals (Figure 1a, b).

In the fish meal, the muscle tissue exhibited irregular morphology under the microscope, with color tones ranging from yellow to brown. In the anchovy meal, however, the muscle tissue appeared more compact and distinct, displaying a yellowish-brown color (Figure 1c, d).

The bone tissues in the fish meal ranged in color from transparent to yellow and generally appeared ivory-colored. These bones, which exhibited a sharp-pointed, cylindrical, and brittle structure, were found to accumulate in the sediment fraction after separation (Figure 1e).

The bone tissues in the fish meal may exhibit different morphological forms depending on the fish species used. In the anchovy meal, the vertebral bone tissue was observed to have a distinctive hourglass-like structure. This characteristic morphology was considered a key feature for the microscopic identification of anchovy meal (Figure 1f).

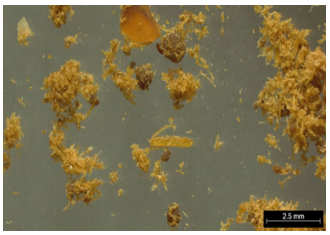
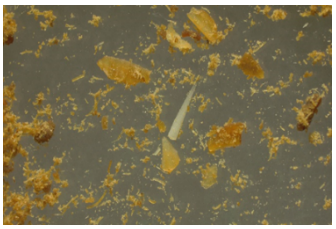
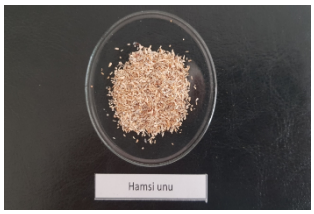
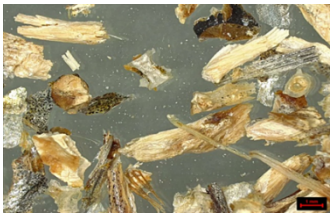
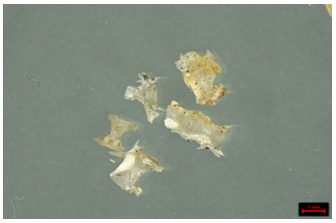
		
a_1: Micrograph of fish meal	c_2: Fish meal muscle tissue (10×)	e_3: Bone structure in fish meal (10×)
		
b_1: Micrograph of anchovy meal	d_2: Skin, muscle tissue, and bone structures in anchovy meal (10×)	f_3 Vertebral bone tissue in anchovy meal (10×)

Figure 1. Images of fish meal and anchovy meal under a stereomicroscope

In the fish meal samples, the morphological characteristics of the bones were clearly identified through staining with the alizarin red indicator. This method enhanced the visibility of the bones, allowing the tissue boundaries to be clearly distinguished. As a result of this staining, elongated elliptical lacunae were observed in the bones of the fish meal samples (Figure 2a). In the anchovy meal samples, however, the same staining method revealed a distinct morphological structure in the bones, defined as a "star-shaped lacuna." This feature demonstrated that the anchovy bones were characteristically stained with alizarin red and could be structurally distinguished from those of other fish meals (Figure 2b).

In the fish meal samples, the phenol–glycerin indicator revealed the transparent structure of the bones but produced a lighter color contrast compared to alizarin red. In the anchovy meal samples, however, staining with the same indicator clearly displayed the star-shaped lacuna structure within the bone tissue. These findings demonstrate that the distinctive morphological characteristics of anchovy bones were clearly revealed by both staining methods (Figure 2c, d).

In the fish meal samples, staining with the Fehling indicator clearly distinguished the muscle tissue in the float fraction through its distinct color contrast. When the same indicator was applied to the anchovy meal, the muscle tissue was clearly visible under the microscope, and the structural details of the muscle fibers were observed at 100× magnification. In both meal types, the Fehling indicator proved to be an effective staining method for the identification of muscle tissue (Figure 2e, f).

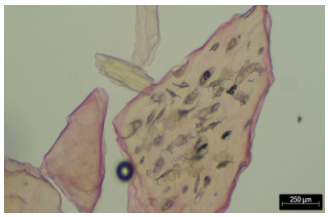
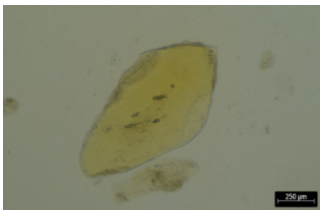
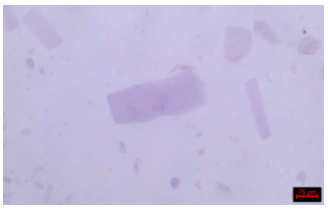
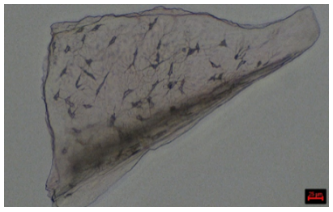
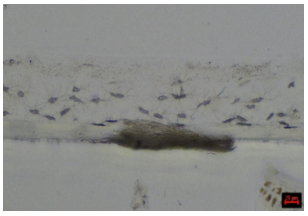
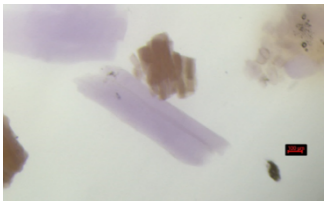
		
a_1: Bone structure in fish meal stained with alizarin red (200×)	c_2: Bone structure in fish meal stained with phenol–glycerin (200×)	e_3: Muscle tissue in fish meal stained with Fehling indicator (100×
		
b_1: Bone structure with star-shaped lacuna in anchovy meal stained with alizarin red (200×)	d_2: Bone structure with star-shaped lacuna in anchovy meal stained with phenol–glycerin (200×	f_3: Muscle tissue in anchovy meal stained with Fehling indicator (100×)

Figure 2. Images of fish meal and anchovy meal under a polarized light microscope.

4. DISCUSSION

The identification of animal protein sources is of great importance for feed safety and species-based traceability. In this context, microscopic analysis has long been recognized as a reliable method, particularly for the morphological characterization of fish meals. In the bone tissues of different fish species, variations in the structures of lacunae and canaliculi play a key role in distinguishing between species (Liu ve ark., 2011; Van Raamsdonk ve ark., 2017).

In this study, microscopic examination of anchovy meal revealed that its bone tissue exhibits a characteristic morphology. In particular, the hourglass-like structure of the vertebral bone tissue is regarded as an important microscopic marker for the identification of anchovy meal. The lacunae in anchovy meal are generally composed of elongated elliptical structures arranged in parallel, while in some regions, star-shaped lacunae are also observed. In contrast, in mixed fish meal derived from different fish species, the lacunae display a shorter, irregularly distributed morphology without a clear orientation. The distinct organization of the lacunae and canaliculi enables anchovy meal to be readily identified at the microscopic level.

Liu et al. (2011) reported that the patterns of lacunae and canaliculi vary among different fish species, noting that in herring, long, radiating, thread-like canaliculi and generally parallel-sided, tube-shaped lacunae are present. This description shows structural similarity to the parallel-arranged and elongated elliptical lacunae observed in anchovy meal. Umur et al. (2024) stated that star-shaped lacunae are less frequently observed in anchovy meal, that the canaliculi possess a filamentous structure similar to that found in ruminant bones, and that the shapes of the lacunae display distinctive morphological characteristics. Van Raamsdonk et al. (2007) also reported that elliptical lacunae are predominant in anchovy and herring. In our study, the coexistence of both parallel-oriented and elliptical or star-shaped lacuna forms in anchovy meal

indicates that this species exhibits a unique morphological diversity at the microscopic level. Furthermore, the descriptions by Van Raamsdonk et al. (2012, 2017) of fish bones as semi-transparent and glossy are consistent with the bright and smooth tissue structure identified in anchovy meal.

Comparative microscopic examinations of fish meal and anchovy meal revealed that anchovy meal exhibits a more homogeneous morphology. This is attributed to its single-species origin and the preservation of its structural integrity. In contrast, commercial fish meals are known to be produced from mixtures of different species, and therefore their morphologically heterogeneous structure is a natural outcome (Bayraklı, 2021; Özden & Selçuk, 2022). In the morphological evaluations, a regular arrangement and uniform tissue density were observed among the bone fragments in anchovy meal, whereas heterogeneous structures belonging to different fish species were identified in mixed fish meal. These findings are consistent with the results reported by Pinottia et al. (2016), who characterized fish meals using microscopic and digital image analysis. The researchers noted that fish bones have a more homogeneous structure compared to mammalian and avian bones, and that this feature serves as a reliable criterion for species identification. Therefore, the use of anchovy meal as a reference material is proposed as an approach that could improve the accuracy of species identification in feed analyses.

This study also revealed that the staining methods applied (particularly alizarin red and phenol–glycerin) did not cause any deformation in bone morphology; however, alizarin red enhanced the visibility of the lacuna and canaliculi structures. This finding is consistent with previous studies reporting that alizarin red increases contrast in calcified tissues, thereby facilitating morphological identification (De la Roza-Delgado et al., 2007; Frick et al., 2013a). Although the phenol–glycerin indicator produced smoother color transitions, it was not as effective as alizarin red in defining morphological boundaries. Similarly, Ottoboni et al. (2017) evaluated the effectiveness of different indicators on marine-derived materials and reported that alizarin red was particularly successful in staining fish tissues.

The hourglass-like vertebral bone structure and the parallel and star-shaped lacuna morphologies described in this study are considered distinguishing criteria at the species level for the microscopic identification of anchovy meal. Incorporating these morphological characteristics into future microscopic reference databases will make a significant contribution to the development of a standardized and reliable approach for species identification in fish meals.

5. CONCLUSION

This study demonstrated that microscopic analysis is a rapid and reliable method for the morphological identification of different types of fish meal. The bone structure of anchovy meal was characterized by parallel-arranged elongated elliptical lacunae, star-shaped lacuna formations, and, in particular, the hourglass-like structure of the vertebral bone tissue. These unique microstructures serve as distinct morphological criteria that enable anchovy meal to be clearly distinguished from mixed fish meals.

The alizarin red indicator was identified as the most suitable staining method for determining bone morphology, as it highlighted the boundaries of calcified tissues in anchovy meal, whereas the phenol–glycerin indicator provided complementary support.

In conclusion, microscopic characterization of anchovy meal contributes to the accurate identification of fish meal sources used in feed and the verification of species declared on product labels. In the future, integrating microscopic analyses with molecular methods will represent an important step toward enhancing feed safety and species-based traceability. This

study provides a reference dataset for future research in the field of feed microscopy in Türkiye and makes a scientific contribution to the standardization of species identification in feed quality control.

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THE ROLE OF LIVER HISTOLOGY IN THE EVALUATION OF FISH HEALTH IN CULTURED RAINBOW TROUT (*ONCORHYNCHUS MYKISS*)

Volkan KAYDU

Ondokuz Mayıs University, Faculty of Veterinary Medicine, Department of Aquatic Animal Diseases, Samsun, TÜRKİYE

Email: volkankaydu@gmail.com

ORCID: 0000-0001-9631-1353

Eda KELEŞ

Ondokuz Mayıs University, Faculty of Veterinary Medicine, Department of Aquatic Animal Diseases, Samsun, TÜRKİYE

Email: edakels01@gmail.com

ORCID: 0009-0004-8025-0882

Prof. Dr. Banu YARDIMCI

Ondokuz Mayıs University, Faculty of Veterinary Medicine, Department of Aquatic Animal Diseases, Samsun, TÜRKİYE

Email: byardimci@omu.edu.tr

ORCID: 0000-0001-7232-554X

ABSTRACT

Rainbow trout (*Oncorhynchus mykiss*) farming hold an important place in aquaculture, with an annual production capacity of 773 thousand tonnes worldwide. Health management in aquaculture aims to ensure that fish are reared in fish farms under conditions that optimise growth rates and survival rates while minimising disease-related problems. Negative factors affecting health management can also lead to histological changes in the internal organs of fish. In this study, histopathological changes in the livers of rainbow trout (*Oncorhynchus mykiss*) farmed in and around Samsun province were evaluated in order to assess the health parameters, and a preliminary study was conducted to contribute to regional health management strategies. Between the years 2023 and 2025, post-harvest necropsies were performed on 55 rainbow trout (*Oncorhynchus mykiss*) that had been farmed, and tissue samples taken from the liver for general health screening were fixed in 10% neutral formaldehyde. After the routine tissue processing procedure, the samples were embedded in paraffin. Sections of 4–6 µm thickness taken from the blocks were stained with Hematoxylin-Eosin (H&E) and examined under a light microscope. Histopathological examination revealed varying degrees of hyperaemia in 39 fish, degenerations ranging from parenchymal alterations to vacuolisation in hepatocytes in 16 fish, focal or diffuse necrotic lesions in 28 fish, fatty degeneration in hepatocytes in 26 fish, haemorrhages -especially under the capsule- in 11 fish, increased melanomacrophage activity and necrosis in the centres in 6 fish, and mononuclear cell infiltration under the capsule and in the portal area in 21 fish, thickening of the capsule in 5 fish and oedema in 1 fish were detected. As a result of In addition, detachment of the capsule was observed in 6 fish the findings, hyperemia and fatty degeneration were prominently observed in the examined liver tissue samples. Based on the examinations and information received, it was concluded that hyperemia was not appropriate to be evaluated as a pathological finding, considering the possibility of

convulsions and compression due to intensive stocking during harvesting. The intense presence of lipid vacuoles in the cytoplasm of hepatocytes was associated with the feeding of cultured fish with high-calorie feeds, their lack of need to expend much energy to search for food, and the storage of this excess energy as lipids in the hepatocyte cytoplasm by the fish liver. The other findings identified were described as mild, nonspecific lesions.

Keywords: Aquaculture, fish health, liver histopathology, rainbow trout (*Oncorhynchus mykiss*)

INTRODUCTION

The rapid increase in the world population has led to a corresponding increase in demand for animal protein. Fish, in addition to being a high-quality source of protein, contains essential micronutrients such as various vitamins, minerals, and polyunsaturated omega-3 fatty acids. Therefore, in many countries, fish consumption is encouraged within the framework of government policies aimed at increasing the intake of omega-3 fatty acids. While the increasing population and such initiatives elevate the demand for fish, they have also led to global declines in wild fish populations. This situation raises concerns about the sustainability of the fishing industry and clearly highlights the importance of aquaculture. Nevertheless, food security emerges as a crucial issue in ensuring that all individuals have access to the essential food they need. Fisheries make a significant contribution to animal protein sources in both developed and developing countries. Particularly in Low-Income Food-Deficit Countries (LIFDC's), fisheries stand out not only in meeting the demand for animal protein but also as a vital source of micronutrients, minerals, and essential fatty acids. Therefore, fisheries and aquaculture can play an effective role in ensuring food and nutritional security, even in small quantities, especially in less developed or developing countries (Bovenkerk&Meijboom, 2012; Getu et al., 2015; Msangi et al., 2013). In this context, rainbow trout (*Oncorhynchus mykiss*), one of the most common fish species worldwide, has been transported to at least 99 countries after being moved outside its natural range and has established breeding populations in many different regions (Stanković et al., 2015). Today, rainbow trout (*Oncorhynchus mykiss*) farming, which has an annual production capacity of 773 thousand tons, has an important place in aquaculture (FAO, 2025).

It is impossible to successfully maintain an animal production programme without taking animal health into consideration. This also applies to aquaculture, where diseases are the most limiting factor in production, both economically and in terms of health (Blanco et al., 2000). Health management in fish farms aims to optimise fish growth rates and survival rates, ensuring they are raised under conditions that minimise disease-related problems. Factors affecting health management can cause histological changes in the internal organs of fish, and these changes are particularly evident in the liver due to its metabolic and detoxification functions. Tissue changes occurring in the liver are accepted as a parameter in assessing the general health status of fish (Rodrigues et al., 2017; Saraiva et al., 2015).

In fish, the liver is the largest internal organ of the body and performs functions similar to those of the liver in mammals, such as processing and storing nutrients absorbed by the digestive system, producing bile, and detoxification. Although the histology of the liver varies between species, there are general characteristics common to most species (Akiyoshi & Inoue, 2004; Genten et al., 2009). The teleost liver contains hepatocytes, endothelial cells, bile duct epithelial cells, fat-storing cells, macrophages, blood cells, and exocrine pancreatic cells (Hampton et al., 1985). Among these cellular components, melanomacrophage centers are particularly noteworthy structures in terms of immune function. Melanomacrophage centers play an important role in defence and inflammatory responses. Furthermore, their responsibility for the removal of foreign particles, dead cells and phagocytosis products ensures their use as important health biomarkers (Araujo et al., 2019).

In this study, a preliminary investigation was conducted in the Samsun region to assess the health management principles that could be supported by evaluating the health parameters of cultured rainbow trout (*Oncorhynchus mykiss*) through the examination of histopathological alterations in their livers.

MATERIALS and METHODS

In this study, 55 rainbow trout (*Oncorhynchus mykiss*) obtained through random sampling after harvest from aquaculture farms in the Samsun region between 2023 and 2025 were used as material.

Necropsies were performed on the fish, and tissue samples taken from the liver for general health screening were fixed in 10% buffered formaldehyde. The fixed tissues were embedded in paraffin after passing through the alcohol and xylene series in the standard tissue tracking procedure. Sections 4-6 µm thick were cut from the blocks, stained with Haematoxylin-Eosin (H&E) and examined under a light microscope.

RESULTS

The histopathological findings from the liver tissue of 55 rainbow trout (*Oncorhynchus mykiss*) examined as part of the health screening are presented in Table 1.

The histopathological examination revealed varying degrees of hyperaemia in 39 fish: mild in 25 fish, moderate in 7 fish, and severe in 7 fish. Degenerative changes in hepatocytes were observed in 16 fish in total: mild in 7 fish, moderate in 8 fish, and severe in 1 fish. Necrosis was also observed in hepatocytes in 28 fish in total: mild in 12 fish, moderate in 13 fish, and severe in 3 fish. Haemorrhages were observed in a total of 11 fish: mild in 9 fish, moderate in 1 fish, and severe in 1 fish, particularly under the capsule. An increase in melanomacrophage activity was observed in 6 fish, mild in 2 fish and moderate in 4 fish, along with mononuclear cell infiltration in 21 fish, mild in 13 fish, moderate in 8 fish, and more pronounced in the subcapsular and portal areas. Another prominent finding was fatty degeneration in hepatocytes, observed in a total of 26 fish: mild in 12 fish, moderate in 7 fish, and severe in 7 fish. In addition to these findings, capsule separation was detected in 6 fish, capsule thickening in 5 fish, and oedema in 1 fish. No histopathological changes were detected in 7 fish.

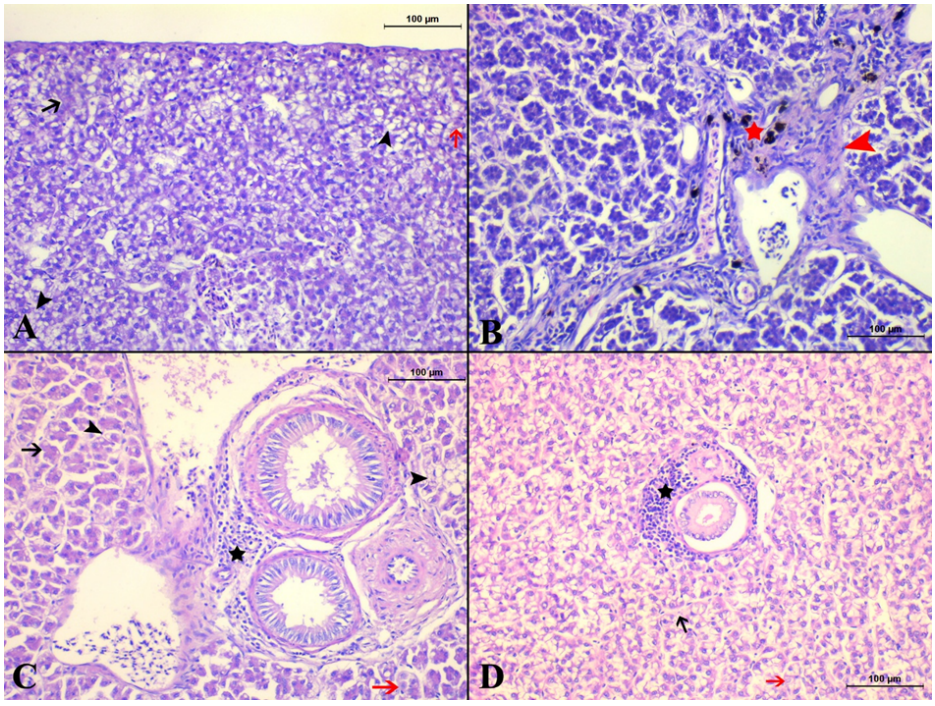


Figure 1. Rainbow trout *(Oncorhynchus mykiss)* liver tissue. A) Degeneration (red arrow), necrosis (black arrow) and fat vacuoles (black arrowhead) in hepatocytes x200; B) Increased melanomacrophage activity (red star), fibrosis (red arrowhead) x200; C) Degeneration in hepatocytes (red arrow), necrosis (black arrow), fat vacuoles (black arrowhead) and

mononuclear cell infiltration around the hepatic triad (black star) x200; D) Degeneration in hepatocytes (red arrow), necrosis (black arrow) and mononuclear cell infiltration around the bile duct (black star) x200, H&E.

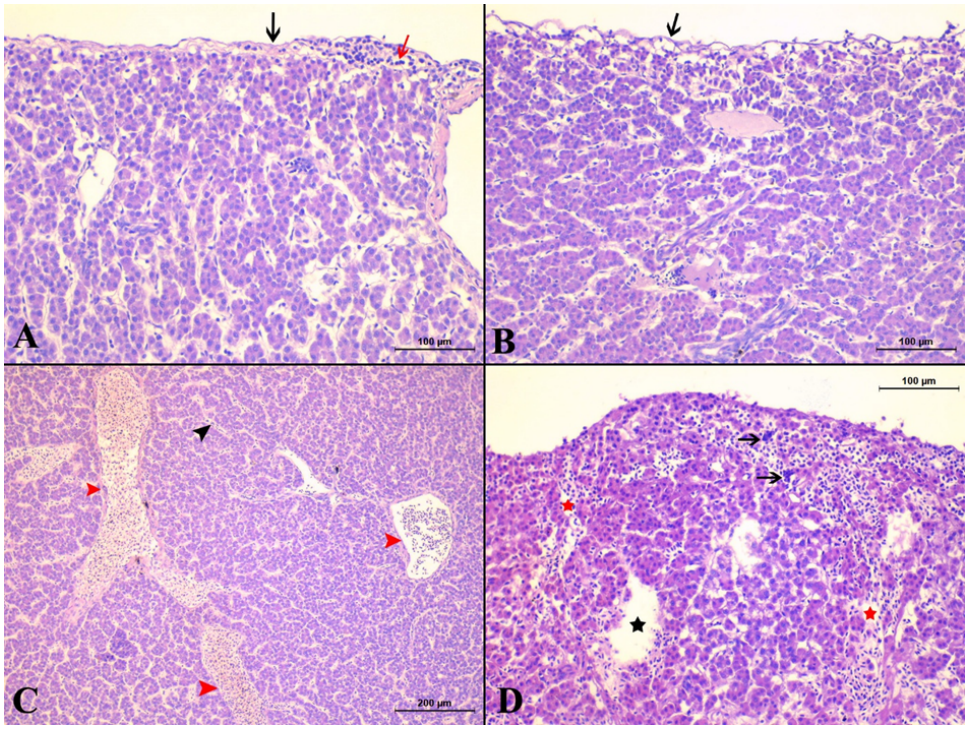


Figure 2. Rainbow trout *(Oncorhynchus mykiss)* liver tissue. A) Thickening of the capsule (black arrow), mononuclear cell infiltration beneath the capsule (red arrow) x200; B) Separation of the capsule (black arrow) x200; C) hyperaemia (red arrowhead), dilation of sinusoids (black arrowhead) ×100; D) mononuclear cell infiltration (black arrow), haemorrhage (red star) and dilation of sinusoids (black star) ×200, H&E.

DISCUSSION

Histopathological findings of hyperaemia, degeneration, necrotic changes and fatty degeneration in liver tissues from different fish species have been reported in numerous studies, and these findings have generally been associated with water pollution, the presence of heavy metals and exposure to toxic substances (Ayas et al., 2007; Feist et al., 2015; Fricke et al.,2012). Similar findings were also recorded in rainbow trout (*Oncorhynchus mykiss*) in this study. However, these findings were obtained only histopathologically as a preliminary study in terms of liver tissue health screening and were not associated with any specific cause as no analyses targeting any specific agent were performed.

In this study, fatty degeneration was observed in 26 of the 55 fish evaluated. However, Wolf et al. (2015) state that lipidosis in farmed fish, associated with a lipid-rich diet, can be considered normal as long as it does not cause adverse histopathological effects such as cell membrane rupture or saponification. As the rainbow trout used as material in the study were obtained from a cultured environment, the fatty degeneration findings were attributed to lipid-rich feeding.

The most common finding, hyperaemia, was recorded in 39 fish. Banihashemi et al. (2016) indicate that hyperaemia in liver tissue may be caused by the presence of metabolites resulting from ammonia effects. Furthermore, Wang et al. (2025) indicated that serious damage to liver tissue, including sinusoidal dilation and hepatocellular necrosis, may occur in fish depending on stocking density and stocking duration. Based on the examinations conducted and the information obtained, considering the possibility of convulsions and pressure formation during

intensive storage after harvesting, it was concluded that hyperaemia should be assessed as a traumatic lesion rather than a pathological finding. The other findings identified were defined as mild, non-specific lesions.

The liver becomes a target organ for pollutants due to its important role in detoxification and metabolism. Most histopathological changes occurring in the liver are shaped by exposure to toxic substances. Melanomacrophages play a role in disease processes and may change depending on factors such as chemical exposure (Lebepe et al., 2020). The findings of degeneration, necrosis, increased melanomacrophage activity, haemorrhage and mononuclear cell infiltration identified in this study have also been reported in studies conducted on different fish species. In these studies, these findings have been associated with various environmental stress factors such as organic pollutants, algal toxins, heavy metal poisoning, fluctuations in water temperature, and changes in oxygen concentration in the water (Abdel-Moneim, 2014; Feist et al., 2015; Fricke et al., 2012; Lebepe&Luus-Powell, 2020). In this context, it is thought that the findings obtained in the present study may also have been caused by similar environmental factors. However, the fact that the waters in which the fish used as material were raised have not been evaluated in terms of the parameters in question prevents these possibilities from being definitively confirmed. However, Mohamed (2009) states that hyperaemia can also cause cellular degeneration and necrosis. In this study, the general correlation between hyperaemia and findings of degeneration and necrosis suggested that, as Mohamed (2009) indicated, circulatory disorders may have triggered cellular damage, leading to these findings.

As a result, changes such as hyperaemia and fatty degeneration were observed in the liver tissues of rainbow trout raised in the Samsun region. These findings were not associated with any disease, considering the rearing and harvesting process and because they were based solely on histopathological findings in a preliminary study. Other histopathological findings were non-specific in nature. The findings indicate that the liver health of rainbow trout may be affected by environmental conditions and are expected to contribute to future studies on fish health screening in the region.

Table 1. Histopathological findings observed in the liver tissue of rainbow trout (Oncorhynchus mykiss)

	hyperaemia	degenerations	necrosis	MMA	haemorrhage	capsule thickening	capsule separation	MCI	fatty degeneration	oedema
1	-	++	++	-	-	-	-	-	+++	+
2	+++	-	+++	++	+	-	-	++	++	-
3	+++	-	-	-	-	-	-	+	+	-
4	+	-	-	-	-	-	-	-	+	-
5	-	-	-	-	-	-	-	-	-	-
6	+	-	+	-	-	-	-	-	-	-
7	+	-	-	-	+	-	-	+	+	-
8	+	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-
10	+	-	++	-	-	-	-	++	+	-
11	+	-	-	-	-	-	-	-	-	-
12	+	-	-	-	-	-	-	-	+	-
13	+	-	-	-	-	-	-	-	+	-
14	+++	++	+++	-	-	-	-	++	+	-
15	-	-	++	-	-	-	-	+	+++	-
16	+	-	-	-	-	-	-	+	-	-
17	++	-	-	-	-	-	-	-	+++	-
18	-	-	-	-	-	-	-	+	++	-

19	-	-	-	-	-	-	-	-	-	-
20	++	-	-	-	-	-	-	-	+	-
21	+	-	-	-	+	-	-	-	-	-
22	+	-	+	-	-	-	-	-	-	-
23	+	-	++	-	+	-	-	-	+	-
24	+	+	+++	-	-	-	-	-	++	-
25	-	++	++	++	-	+	-	++	+	-
26	+	-	-	++	-	-	-	-	-	-
27	++	+	++	++	+	+	-	++	++	-
28	+	-	+	-	+	-	-	-	-	-
29	-	-	-	-	-	-	-	-	-	-
30	-	-	++	+	+	+	-	-	-	-
31	+	++	++	-	+	-	+	+	++	-
32	-	-	-	-	-	-	-	-	-	-
33	++	+++	++	+	++	+	+	+	++	-
34	-	-	-	-	-	-	-	-	-	-
35	+	++	++	-	-	-	+	++	++	-
36	+++	-	-	-	-	-	-	-	-	-
37	++	-	-	-	-	-	+	++	-	-
38	-	+	-	-	-	-	+	-	-	-
39	+	++	-	-	-	-	-	-	-	-

40	+++	+	++	-	-	-	-	+	+++	-
41	-	-	-	-	-	-	-	-	-	-
42	+	-	+	-	-	-	-	+	-	-
43	+++	-	+		+++	-	-	-	+	-
44	-	+	+	-	-	-	-	++	-	-
45	+	-	-	-	-	-	-	+	-	-
46	-	-	-	-	-	+	-	+	-	-
47	+	-	+	-	-	-	-	+	-	-
48	+	-	+	-	-	-	-	-	-	-
49	++	++	++	-	-	-	+	-	-	-
50	+	-	+	-	-	-	-	-	+++	-
51	++	+	+	-	-	-	-	-	+	-
52	-	-	-	-	-	-	-	-	-	-
53	+++	++	+	-	-	-	-	-	-	-
54	+	+	+	-	+	-	-	-	+++	-
55	+	-	++	-	-	-	-	+	+++	-

*+: mild, ++: moderate, +++: severe; MMA: melanomacrophage activity; MCI: mononuclear cell infiltration

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AŞILI ASMA FIDANLARINDA TUZ STRESI ÜZERINE CERIUM OXIDE (CEO_2-NP) NANOPARTIKÜLÜNÜN FIZIKSEL VE FIZYOLOJIK PARAMETRELER ÜZERINE ETKISI

Hasan BALTACI

Yüksek Lisans Öğrencisi, Tokat Gaziosmanpaşa Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü

ORCID: 0009-0004-6377-4879

Seda SUCU DAĞ²*

Doç.Dr, Tokat Gaziosmanpaşa Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü

ORCID: 0000-0002-5187-5048 (Sorumlu Yazar)

ÖZET

Filoksera zararlısının ülke topraklarımıza girişinden sonra asma fidanı üreticiliğinin büyük çoğunluğu, anaç üzerine yetiştirilmek istenen çeşidin aşılanması şeklinde gerçekleşmektedir. Bu nedenden dolayı çok sayıda ve çok çeşitli anaç kullanımı mevcuttur. Yetiştiricilik yapılırken anaçların hem filokseraya dayanımlarından hem de her bir anacın farklı özelliklerinden faydalanılmaktadır. Abiyotik stres faktörü de son zamanlarda değişen iklim koşullarını etkisi ile bitkisel üretimde negatif yönde etkisi ile kendisini göstermektedir. Tuzluluk en önemli abiyorik stres faktörlerinden birisi olmakla beraber verim ve kaliteyi oldukça önemli oranda olumsuz etkilemektedir.Yapılan çalışmada Ülkemizde en fazla üretimi yapılan Sultani Çekirdeksiz çeşidinin 5 BB ve 1613 anacı üzerine aşılı fidanları kullanılmıştır. Bu iki anacın tercih edilme sebebi tuza hassasiyetlerinin farklı olmasıdır. Tuz stresi bitkilere 0, 25 ve 75 mM NaCl şeklinde üç seviyede, seryum oksit (CeO_2-NP) nanopartikül uygulamaları ise dört farklı seviyede (0, 25, 50 ve 100 mg L^{-1}) uygulanmıştır. Uygulamalar sonucu aşılı fidanlarda incelenen fiziksel veriler; sürgün yaş- kuru ağırlığı, kök yaş-kuru ağırlığı, kuru madde oranı, fizyolojik veriler ise iyon akışı, hücre zarı zararlanma oranı (H.Z.Z.O) ve spad cinsinden klorofil miktarıdır. Elde edilen veriler incelendiğinde tuz stresi altındaki fidanlarda seryum oksit uygulamalarına göre anaç kombinasyonları arasındaki farklar istatitiksel açıdan fark oluşturmuştur.

Anahtar Kelime; 5 BB, yaş ağırlık, spad, iyon akışı

ABSTRACT

After the introduction of the phylloxera pest into our country, the majority of grapevine sapling production has been carried out by grafting the desired variety onto the rootstock. For this reason, there are many and diverse rootstocks in use. During cultivation, both the resistance of rootstocks to phylloxera and the different characteristics of each rootstock are utilized.Abiotic stress factor has also shown itself as a negative effect on plant production due to the effect of changing climate conditions in recent times. Salinity is one of the most important abionic stress factors and has a significant negative impact on yield and quality.In the study, saplings of Sultani Çekirdeksiz variety, which is the most produced variety in our country, grafted onto 5 BB and 1613 rootstocks were used. The reason why these two rootstocks are preferred is that they have different salt sensitivities. Salt stress was applied to plants at three levels of 0, 25 and 75 mM NaCl, and cerium oxide (CeO_2-NP) nanoparticle applications were applied at four different levels (0, 25, 50 and 100 mg L^{-1}).Physical data examined in grafted seedlings as a result of the applications are shoot fresh-dry weight, root fresh-dry weight, dry matter ratio, physiological data are ion flow, cell membrane damage rate (HZZO) and chlorophyll amount in spad. When the obtained data were examined, the differences between rootstock combinations according to cerium oxide applications in seedlings under salt stress created a statistical difference.

Key words; 5 BB, wet weight, spad, ion flow

1.INTRODUCTION

Viticulture activities take place on Earth between 20-40 degrees latitude in the Southern Hemisphere and 20-51 degrees latitude in the Northern Hemisphere. Due to its geographical location, Türkiye is located on latitudes that have favorable conditions for viticulture. Vitis vinifera L, commonly known as the European grapevine and comprising 90% of the grapes cultivated worldwide, is a grapevine species native to the Mediterranean region, Central Europe and Asia Minor (Winkler, 1974). Our country, which is at the center of the geography where the grapevine gene centers are located and where it was first cultivated, is among the world's major grape-producing countries due to its climate being suitable for viticulture. Türkiye ranks 5th among the world countries in terms of vineyard areas with 405,439 hectares and 6th in terms of fresh grape production with 4,100,000 tons (FAOSTAT, 2019).

Grapes, the fruit of the vine, are also distinguished from other fruits by their different ways of being evaluated. Grapes have different uses such as table grapes, dried grapes, wine grapes and must grapes, which makes them a sustainable food. Recently, adverse conditions such as changing climate conditions, increasing world population, and decreasing agricultural lands have limited the cultivation of grapes, as with all agricultural products. Like all living things, plants may encounter various negative effects while continuing their lives. Situations that change the course of ongoing metabolic events in plants and negatively affect growth and development by limiting them are called abiotic and biotic stress factors (Gürel and Avcıoğlu, 2001).

High salt levels in soil or water can inhibit plant growth, reduce crop yields, and even lead to plant death. Salt stress is a major problem for agriculture as many arable lands are affected by salt accumulation due to irrigation and climate change. Salt stress affects plants in various ways. High salt levels lead to an increase in the concentration of ions in the soil, including sodium (Na^+) and chloride (Cl^-), leading to an imbalance in the plant's water and ion uptake. This leads to inhibition of root growth and reduction of water uptake by the plant. Salt stress also causes osmotic stress as the plant has to work harder to maintain water and ion balance in its cells (Mahajan and Tuteja, 2005; Köşkeroğlu, 2006).

Many studies are being conducted on salt resistance in the field of viticulture under in vitro and in vivo conditions. These studies are conducted to determine the salt resistance of different rootstocks and varieties at different salt doses, and also by testing different chemical and plant nutritional elements. The results of studies combining different salt concentrations with chemicals thought to reduce the effect of salt damage (methyl-jasmonate, proline, salicylic acid, epibrassinolide, etc.) have an important place in salinity stress studies.

In this study, the effects of cerium oxide nanoparticles (CeO_2-NP) on salinity stress applied at different concentrations in grafted seedlings were investigated.

2. MATERIAL and METHODS

2.1. Plant Material

In this study, grafted grapevine saplings obtained by grafting Sultani Seedless Sultan 7 Clone on 1613 C and 5 BB rootstocks were used as plant material.

2.2. Chemical Material

The Cerium (IV) Oxcide nanoparticle used in the study had a particle size of <25 nm, a bottle weight of 25 g, and a molecular weight of 172.11. The product was purchased from the market as a commercial product of Merck.

2.3. Method

In the study, 5 BB 1613 C grapevine rootstocks and saplings of Sultani Seedless variety grafted onto these rootstocks were used. Saplings were grown in 5 L pots containing peat: perlite (1.1) growing medium. After planting, the seedlings were watered with Hoagland nutrient solution for one month until they had at least 8 leaves. One month later, salt stress (0, 25 and 75 mM NaCl) was applied daily (with 1/2 Hoagland solution) and continued for 2 months. One month after salinity stress applications, Nanoparticle CeO_2-NP applications were sprayed on the leaves at 4 different concentrations (0, 25, 50 and 100 mg L^{-1}) at 24-hour intervals (Gohari et al., 2021). Some physical data were collected at the beginning of the trial, some during the trial, and some at the end. Physiological data were collected at the end of the trial.

3. RESULT

3.1 Fresh-dry shoot weight

Table. 1. Effects of cerium oxide and salt applications on fresh shoot weight in grapevine sapling

	Cerium Oxide	**Salt Concentration**		
		0	25	75
5 BB/ Sultani Çekirdeksiz	0	22,54 A a	12,85 A a	11,54 A a
	25	17,48 A a	13,17 A a	10,45 A a
	50	16,04 A a	15,54 A a	18,64 A a
	100	20,68 A a	14,73 A a	14,04 A a
1613/Sultani Çekirdeksiz	0	6,2667 C b	9,07 B a	9,29 C a
	25	20,2167 A a	14,61 A b	11,61 B c
	50	4,8167 D c	8,84 B b	10,27 C a
	100	8,45 B b	8,18 B b	16,08 A a

* Capital letters in the same column indicate change in cerium oxide at the same salt concentration, while lowercase letters in the same row indicate change in salt concentration at the same cerium oxide dose. According to Tukey's multiple comparison test, it is significant ($p<0.05$).

When looking at fresh and dry shoot weights, the differences in cerium oxide and salt treatments in seedlings of the 5 BB/Sultani Çekirdeksiz combination were not found to be statistically significant. In Sultani Çekirdeksiz sapling grafted on 1613, 75 mM NaCl application and 100 ppm cerium oxide application had a positive effect on fresh shoot weight. The highest values for dry shoot weight were obtained from 0 mM NaCl salt and 25 ppm cerium oxide applications (Tables 1; 2).

Table. 2. Effects of cerium oxide and salt applications on dry shoot weight in grapevine sapling

	Cerium Oxide	Salt Concentration		
		0	25	75
5 BB /Sultani Çekirdeksiz	0	9,10 A a	6,19 A a	5,12 A a
	25	5,14 A a	6,96 A a	4,70 A a
	50	5,74 A a	7,54 A a	8,26 A a
	100	7,03 A a	7,80 A a	7,19 A a
1613/Sultani Çekirdeksiz	0	2,733 C c	4,20 B a	3,46 C b
	25	10,833 A a	6,70 A b	4,35 B c
	50	2,20 D c	4,40 B a	3,31 C b
	100	5,80 B a	3,28 C b	5,58 A a

** Capital letters in the same column indicate change in cerium oxide at the same salt concentration, while lowercase letters in the same row indicate change in salt concentration at the same cerium oxide dose. According to Tukey's multiple comparison test, it is significant ($p<0.05$

3.2. Fresh and dry root weight

When the effects of the applications on fresh and dry root weights were examined, the differences were found to be statistically significant. While the highest values in terms of fresh root weight were obtained from the application of 0 salt and 25 ppm cerium oxide in 5 BB/Sultani Çekirdeksiz and 1613/Sultani Çekirdeksiz combinations, in terms of dry root weight, the application of 0 salt and 25 ppm cerium oxide came to the fore in 5 BB/Sultani Seedless and the application of 0 salt and 25 ppm cerium oxide in 1613/Sultani Çekirdeksiz (Table 3; 4).

Table. 3. Effects of cerium oxide and salt applications on fresh root weight in grapevine sapling

	Cerium Oxide	Salt Concentration		
		0	25	75
5 BB /Sultani Çekirdeksiz	0	57,17 A a	7,20 B b	9,12 A b
	25	60,63 A a	10,07 BA b	8,40 A b
	50	47,82 A a	7,78 B b	8,61 A b
	100	46,04 A a	15,80 A b	10,89 A b
1613/Sultani Çekirdeksiz	0	10,066 B a	10,43 B a	10,21 C a
	25	12,133 A a	7,27 C c	11,16 B b
	50	4,7667 D c	13,02 A a	8,52 D b
	100	9,130 C b	6,40 C c	19,33 A a

Capital letters in the same column indicate change in cerium oxide at the same salt concentration, while lowercase letters in the same row indicate change in salt concentration at the same cerium oxide dose. According to Tukey's multiple comparison test, it is significant ($p<0.05$

Table. 4Effects of cerium oxide and salt applications on dry root weight in grapevine sapling

	Cerium Oxide	Salt Concentration		
		0	25	75
5 BB /Sultani Çekirdeksiz	0	7,72 A a	4,71 B a	6,36 A a
	25	6,79 A a	6,60 BA a	5,34 A a
	50	5,66 A a	5,42 B a	5,38 A a
	100	4,68 A b	9,39 A a	6,43 A ba
1613/Sultani Çekirdeksiz	0	6,833 B a	6,47B b	6,32 B b
	25	8,233 A a	4,76 CB b	4,60 C b
	50	3,250 C c	9,08 A a	4,18 D b
	100	6,66 B a	3,76 C b	6,76 A a

* Capital letters in the same column indicate change in cerium oxide at the same salt concentration, while lowercase letters in the same row indicate change in salt concentration at the same cerium oxide dose. According to Tukey's multiple comparison test, it is significant ($p<0.05$

3.3. Dry matter ratio;

When the effects of the applications on the dry matter ratio were examined, the 75 salt 0 ppm application came to the fore in the seedlings of 5 BB/Sultani Çekirdeksiz, while the 0 salt 100 ppm application came to the fore in the seedlings of 1613/Sultani Çekirdeksiz (Table 5).

Table. 5. Effects of cerium oxide and salt applications on dry matter content in grapevine sapling

	Cerium Oxide	Salt Concentration		
		0	25	75
5 BB /Sultani Çekirdeksiz	0	13,90 A b	65,24 A a	70,39 A a
	25	11,17 A b	67,06 A a	64,23 A a
	50	12,05 A b	69,96 A a	69,23 A a
	100	11,02 A b	59,80 A a	61,31 A a
1613/Sultani Çekirdeksiz	0	67,88 A a	62,03 A b	61,86 A b
	25	64,860 A a	65,45 A a	41,20 C b
	50	68,29 A a	69,88 A a	49,16 B b
	100	73,01 A a	58,97 A a	34,97 D a

* Capital letters in the same column indicate change in cerium oxide at the same salt concentration, while lowercase letters in the same row indicate change in salt concentration at the same cerium oxide dose. According to Tukey's multiple comparison test, it is significant ($p<0.05$

3.4. Ion flow;

When the effects of the applications on the ion flow are examined, the best effects for the 5BB/Sultani Çekirdeksiz combination were obtained in the application of 100 ppm cerium oxide at high salt concentration, while the best effects for the 1613/Sultani Seedless were obtained in the application of 0 ppm cerium oxide at 0 salt concentration (Table 6).

Table 6. Effects of cerium oxide and salt applications on ion flow in grapevine seedlings

	Cerium Oxide	**Salt Concentration**		
		0	25	75
5 BB /Sultani Çekirdeksiz	0	33,71 B b	26,53 C c	41,52 A a
	25	57,14 A a	25,98 D c	34,95 B b
	50	32,16 C a	26,78 B b	23,42 C c
	100	28,93 D b	30,82 A a	21,44 D c
1613/Sultani Çekirdeksiz	0	18,56 D b	41,32 A a	41,11 B a
	25	32,38 A b	24,0 C c	41,35 B a
	50	31,41 B b	26,56 B c	46,32 A a
	100	26,08 C b	25,07 CB c	45,60 A a

* Capital letters in the same column indicate change in cerium oxide at the same salt concentration, while lowercase letters in the same row indicate change in salt concentration at the same cerium oxide dose. According to Tukey's multiple comparison test, it is significant ($p<0.05$

3.5. Chlorophyll Measurements (Spad Values);

The effects of the applications on the spad value were taken once at the beginning and once at the end of the trial. The tables were formed as spad 1 and spad 2 values. While the differences in spad 2 values in 5 BB/ Sultani Çekirdeksiz seedlings were not found to be statistically significant, the application of 75 salt and 0 ppm cerium oxide gave the highest value for spad 1 value. In the 1613/Sultani Çekirdeksiz combination, the application of 25 salt and 100 ppm cerium oxide gave the highest values for spad 1 value, and the application of 25 salt and 50 ppm cerium oxide gave the highest values for spad 2 value (Tables 7; 8).

Table 7. Effects of cerium oxide and salt applications on spad 1 value in grapevine sapling

	Cerium Oxide	**Salt Concentration**		
		0	25	75
5 BB /Sultani Çekirdeksiz	0	21,73 A ba	19,03 A b	24,80 A a
	25	22,21 A a	19,32 A a	20,41 A a
	50	21,06 A a	21,84 A a	23,99 A a

	100	20,78 A a	21,67 A a	23,90 A a
1613/Sultani Çekirdeksiz	0	23,18 A b	25,55 B a	22,88 B b
	25	23,52 A b	25,61 B a	26,45 A a
	50	23,20 A b	25,00 B a	24,23 B ba
	100	24,20 A b	27,48 A a	26,90 A a

Capital letters in the same column indicate change in cerium oxide at the same salt concentration, while lowercase letters in the same row indicate change in salt concentration at the same cerium oxide dose. According to Tukey's multiple comparison test, it is significant ($p<0.05$

Table 7. Effects of cerium oxide and salt applications on spad 2 value in grapevine sapling

	Cerium Oxide	**Salt Concentration**		
		0	25	75
5 BB /Sultani Çekirdeksiz	0	23,98 A a	23,16 A a	24,96 A a
	25	23,30 A a	23,01 A a	24,86 A a
	50	23,22 A a	23,29 A a	25,48 A a
	100	26,51 A a	24,87 A a	25,02 A a
1613/Sultani Çekirdeksiz	0	24,64 A a	22,38 C b	22,01 C b
	25	19,63 C c	24,60 B b	27,20 A a
	50	25,18 A b	27,34 A a	22,39 C c
	100	20,86 B c	22,16 C b	23,55 B a

* Capital letters in the same column indicate change in cerium oxide at the same salt concentration, while lowercase letters in the same row indicate change in salt concentration at the same cerium oxide dose. According to Tukey's multiple comparison test, it is significant ($p<0.05$

4. DISCUSSION and CONCLUSION

Researchers who examined the effect of salt concentration on shoot development in some grapevine rootstocks reported that shoot development decreased and shoot dry and fresh weights decreased depending on the salt concentration (Turhan et al., 2005; Çetin et al., 2011). Another study examining the effects of salicylic acid on salinity reported that salicylic acid had a positive effect on the dry weight of the slide (Kök, 2012). In the study, unlike these studies, increases in salt concentration and shoot fresh-dry weight data were observed in some plants (1613/Sultani) and parallel decreases (5 BB/Sultani) were observed in some plants. This can be explained by factors such as different salt concentrations, nanoparticle use, and variety differences. When examining the fresh and dry root weights of plants under salt stress, data show that these data varied depending on the plant and the cerium oxide dose. While there were no statistically significant differences in some plants, there were differences in others. Müftüoğlu et al. (2006) reported that root fresh weight decreased with increasing salt concentration. Kök (2012) reported that salicylic acid applications did not have a statistically

significant effect on dry root weight in grapevines under salinity stress, while Turhan et al. (2005) reported that dry root weight decreased with increasing salt stress. In the study conducted, it was reported that there was no statistical difference in fresh and dry root weights, but there were increases and decreases, depending on the effect of salt stress and cerium doses in parallel with these sources. In the study, dry matter ratio was calculated by dividing dry root weights by fresh root weights and reported as a percentage. The results show that while fresh and dry root weights vary depending on salt stress and the effects of cerium doses, no statistically significant difference is observed, but increases and decreases are observed.

Stress treatments in plants first negatively impact cell membrane structure. A decrease in membrane structure is one of the first symptoms observed. Researchers studying stress factors in plants are focusing on methods to maintain cell membrane integrity and tolerance. The extent of cell membrane damage caused by stress factors can be most easily determined by measuring ion leakage from cells (Bajji et al., 2001). When examining the ion flow data in the study, it is generally observed that ion flow increases with increasing salt concentration. However, 25 ppm cerium oxide application on 5BB rootstock and 25, 50 and 100 ppm cerium oxide applications on 5 BB/Sultani Seedless combination had a positive effect and reduced the ion flow. Under many stress factors, such as salinity, drought, and high temperature, cell membrane structures lose their integrity, leading to electron flow. A study in tomato plants reported that ion flow increased under short-term high temperatures (Camejo et al., 2005). An increase in ion leakage was also observed in kiwifruit under extreme temperature conditions (Xingyuan et al., 2004). In parallel with this study, studies on grapevines also reported that ion flow in plants increased with drought (Yağmur, 2008; Özden et al., 2009, 2011; Martim et al., 2009). The research aims to reduce the increase in ion flux under stress conditions by using different methods, chemicals, etc. In this study, cerium oxide application had positive effects on reducing ion flux in 5 BB/Sultani seedless plants.

Chlorophyll is a pigment essential for converting light energy into chemical energy. The amount of solar radiation absorbed depends on the amount of photosynthetic activity in the leaf. Therefore, the amount of chlorophyll content is related to photosynthetic activity and primary production (Curran et al., 1990). The chlorophyll content in the study was measured with a portable chlorophyllometer and determined as the spad value (Porro et al., 2002). Measurements were made as the first and last measurements in the study, and tables were created based on the spad values in two different periods. When data on spad values were examined in terms of varieties and cerium oxide applications under salinity stress, the differences were found to be statistically less significant than those for other parameters. In a study conducted with 13 different American grape 46 rootstocks, SPAD values were reported to vary between (30.19-20.62) (Gargın, 2011). The figures obtained in the study are parallel with these data. In a study where chlorophyll values were measured in different periods depending on ripening in the Alphonse Lavalle grape variety, spad values did not differ statistically according to the periods (Sucu and Altıner, 2021). In a study where different doses of IBA were applied to Michele Palieri and Black Seedless grape varieties, the differences between the spad values were not found to be statistically significant (Uysal, 2016, Sucu et al., 2017). The values are not similar to those in the study. This may be related to the difference in the applied stress factor.

Changing climate conditions negatively impact plants, as they do all living things. One of the most important abiotic stress factors is salinity stress. Since it is almost impossible to eliminate the negative conditions that occur as a result of climatic factors, researchers can only cope with the situation by taking precautions. Some of these methods include growing species with strong adaptability to harsh conditions and experimenting with different cultural and chemical methods. This study examined the effects of nanoparticle application, which has become

increasingly popular in recent years, on salinity stress. As a result of the study, the effect of cerium oxide application on physical, properties of grafted grapevine saplings under salt stress was investigated extensively and it was concluded that it had significant effects. Considering these data emerging in further studies and testing new types of rootstock stress factors, different nanoparticles and their doses are very important for plant stress studies.

Acknowledge

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CEVİZ POSASINDAN PROTEİN EKSTRAKSİYONUNDA ALCALASE 2.4 L ENZİMİNİN VE PROSES KOŞULLARININ VERİM ÜZERİNE ETKİSİ

Gözde ENGÜDAR BEYAZ

Çanakkale İl Tarım ve Orman Müdürlüğü

Email: gozdengudar@gmail.com

Dr. Öğr. Üyesi Tahir YÜCEL

Van Yüzüncü Yıl Üniversitesi, Mühendsilik Fakültesi, Gıda Mühendisliği Bölümü

Email: tahiryucel@yyu.edu.tr

Prof. Dr. Gökhan BORAN

Van Yüzüncü Yıl Üniversitesi, Mühendislik Fakültesi, Gıda Mühendisliği Bölümü

Email: gboran@yyu.edu.tr

Prof. Dr. Emre BAKKALBAŞI

Van Yüzüncü Yıl Üniversitesi, Mühendislik Fakültesi, Gıda Mühendisliği Bölümü

Email: emrebakkalbasi@yyu.edu.tr (Sorumlu Yazar)

ÖZET

Son yıllarda giderek artan sayıda tüketici, tıbbi gerekçelerle ya da yaşam tarzı tercihi olarak bitki bazlı süt alternatiflerini tercih etmektedir. Tıbbi nedenler arasında, dünya genelinde yaklaşık %75 oranında görülen laktoz intoleransı ile süt alerjisi öne çıkmaktadır. Ayrıca, memeli sütüne erişimin kısıtlı ve maliyetli olduğu ülkelerde bitki bazlı süt ikameleri daha ekonomik bir seçenek olarak değerlendirilmektedir. Teknolojik açıdan bitki bazlı süt ikameleri, bitkisel materyalin suda çözündürülmesi ve parçalanmasıyla elde edilen süspansiyonlar olup görünüş bakımından memeli sütüne benzemektedir. Üretim süreci, bitkisel materyalin suda ekstrakte edilmesi, sıvı fraksiyonun ayrılması ve son ürünün formülasyonu aşamalarını içermektedir. Homojenizasyon ve ısıl işlemler ise, bu ürünlerin süspansiyon stabilitesini ve mikrobiyolojik güvenliğini artırarak doğrudan tüketilebilir veya fermente süt ürünlerine dönüştürülebilir ticari ürünlerin elde edilmesini sağlamaktadır.

Ceviz; protein, yağ, diyet lif ve mineraller gibi değerli bileşenler açısından zengin olması nedeniyle insan beslenmesi açısından stratejik öneme sahip sert kabuklu bir meyvedir. Ceviz yağı; omega-3, 6 ve 9 yağ asitleri bakımından zengin besleyici özellikleriyle bilinmektedir. Aynı zamanda, çeşitli sağlık ve kişisel bakım ürünleri ile aromaterapi uygulamalarında kullanılmaktadır. Ceviz çekirdeğinin yaklaşık yarısı yağ olarak alınmakta kalanı ise küspe olarak düşük katma değerli hayvan yemi veya gübre gibi ürünlere işlenmektedir.

Bu çalışmada, ceviz küspesinden Alcalase 2.4 L enzimi kullanılarak ceviz içeceği üretilmiştir. Üretim sürecince sıcaklık, pH, enzim derişimi ve süre gibi farklı parametrelerin elde edilen protein konsantrasyonu üzerine etkisi incelenmiştir. Elde edilen sonuçlar, pH 9 düzeyinde, 60°C ekstraksiyon sıcaklığında, %2 enzim derişiminde ve 8 saatlik bir ekstraksiyon işlemi ile ceviz içeceğinin protein derişiminin 4.39 g/100 mL düzeyine kadar çıkabileceğini göstermiştir. Çalışılan parametreler arasında özellikle sıcaklık ve pH değerinin elde edilen protein konsantrasyonunu önemli derecede etkilediği görülmüştür.

Anahtar Kelimeler: Atık, Ceviz içeceği, Enzim, Protein

EFFECT OF ALCALASE 2.4 L ENZYME AND PROCESS CONDITIONS ON THE YIELD OF PROTEIN EXTRACTION FROM WALNUT POMACE

ABSTRACT

In recent years, an increasing number of consumers have preferred plant-based milk alternatives either for medical reasons or as a lifestyle choice. Among the medical factors, lactose intolerance—which affects approximately 75% of the global population—and milk allergy are particularly prominent. Additionally, in countries where access to mammalian milk is limited and its cost is high, plant-based milk substitutes are regarded as a more economical option. From a technological perspective, plant-based milk substitutes are suspensions obtained by dissolving and disintegrating plant material in water, and they resemble mammalian milk in appearance. The production process involves the extraction of plant material in water, separation of the liquid fraction, and formulation of the final product. Homogenization and thermal treatments enhance suspension stability and microbiological safety, enabling the production of commercial products that can be consumed directly or converted into fermented dairy analogues.

Walnut is regarded as a nut species of strategic importance for human nutrition due to its richness in various valuable components such as protein, fat, dietary fiber, and minerals. Walnut oil is known for its nutritive properties and is rich in omega-3, 6, and 9 fatty acids. It is also utilized in various health and personal care products as well as in aromatherapy applications. About half of the walnut kernel is obtained as oil and the other half is remained as walnut pomace that is underutilized as low commercial value products like animal feed and fertilizers.

In this study, a walnut beverage was produced from walnut pomace using Alcalase 2.4 L. During the process, the effects of various parameters such as temperature, pH, enzyme concentration, and extraction duration on protein concentration obtained were investigated. The results achieved indicated that protein concentration of the walnut beverage could reach up to 4.39 g/100 mL under the conditions of pH 9, an extraction temperature of 60°C, an enzyme concentration of 2% (g/100 mL), and an extraction duration of 8 hours. It is utmostly seen that especially temperature and pH has significantly affected the protein concentration obtained.

Keywords: Waste, Walnut beverage, Enzyme, Protein

1. GİRİŞ

Süt; proteinler, mineraller, yağlar ve şekerler gibi insan sağlığı açısından önemli bileşenleri içeren bir besin olarak kabul edilmektedir. Yüksek biyolojik değere sahip proteinler, lipitler, vitaminler ve kalsiyum gibi mineraller içermektedir. Besleyici özellikleri ve süt tüketiminin yaygın olarak önerilmesine rağmen, özellikle batı ülkelerinde süt tüketiminin giderek azaldığı gözlenmektedir (Silva vd., 2020). Son yıllarda giderek artan sayıda tüketici, tıbbi gerekçelerle ya da yaşam tarzı tercihi olarak bitki bazlı süt alternatiflerini tercih etmektedir. Tıbbi nedenler arasında, dünya genelinde yaklaşık %75 oranında görülen laktoz intoleransı ile süt alerjisi öne çıkmaktadır. Ayrıca, memeli sütüne erişimin kısıtlı ve maliyetli olduğu ülkelerde bitki bazlı süt ikameleri daha ekonomik bir seçenek olarak değerlendirilmektedir. Teknolojik açıdan bitki bazlı süt ikameleri, bitkisel materyalin suda çözündürülmesi ve parçalanmasıyla elde edilen süspansiyonlar olup görünüş bakımından memeli sütüne benzemektedir. Üretim süreci, bitkisel materyalin suda ekstrakte edilmesi, sıvı fraksiyonun ayrılması ve son ürünün formülasyonu aşamalarını içermektedir. Homojenizasyon ve ısıl işlemler ise, bu ürünlerin süspansiyon stabilitesini ve mikrobiyolojik güvenliğini arttıran diğer proses adımlarıdır (Mäkinen vd., 2016; Silva vd., 2020). Bitkisel süt ikameleri; genellikle baklagiller, yağlı tohumlar ve tahılların su özütleri olup, görünüm açısından inek sütüne benzemektedir (Mäkinen vd., 2016; Fructuoso vd., 2021). Süt ikamelerinin besin değerleri, bitki kaynağına, işleme ve zenginleştirmeye bağlıdır. Ancak bitkisel ikame ürünleri hayvan sütlerine göre son derece düşük protein ve kalsiyum içeriğine sahiptir. Bununla birlikte lezzetli ve besin açısından yeterli ürünler olarak formüle edildiklerinde, bitki bazlı ikameler süt ürünlerine sürdürülebilir bir alternatif sunabilir (Mäkinen vd., 2016; Silva vd., 2020).

Ceviz yağı yüksek miktarda çoklu doymamış yağ asidi (PUFA) (%61.8-75.3) içerir. Linoleik asit ceviz yağındaki başlıca yağ asididir (%52,5-60,2) ve ayrıca önemli miktarda linolenik asit (%8.8-15.2) içerir (Bakkalbaşı, 2019). Son yıllarda, içerdiği temel yağ asitleri nedeniyle ceviz yağına olan ilginin artmasıyla, ceviz yağının üretim ve tüketimi dünya genelinde giderek artmaktadır. Ceviz yağı soğuk presleme ile kolayca elde edilebilmektedir. Yağı alındıktan sonra kalan ceviz küspesi ise protein ve antioksidanlar açısından önemli bir doğal kaynaktır. Ancak ceviz çekirdeğinin yağı alındıktan sonra kalan küspe, düşük katma değerli hayvan yemi veya gübre gibi ürünlere işlenmektedir (Garcia-Mendoza vd., 2021; Rabrenović vd., 2022). Dolayısıyla zengin bir bileşime sahip olan düşük maliyetli ceviz küspesinin, tüketicilerin beslenme alışkanlıklarındaki değişimlere uygun olarak yeni bir ürüne işlenmesi , ekonomik katma değer yaratma, atık yönetimi ve çevre koruma gibi pek çok husus bakımından önemlidir (Rabrenović vd., 2022).

Biyoteknolojinin ilerlemesi ve enzim işlevlerinin anlaşılmasıyla birlikte günümüzde özellikle içecek endüstrisinde (alkollü ve alkolsüz içecekler), prosesin farklı aşamalarında daha kaliteli ürün elde etmek için ticari enzim preparatları kullanılmaktadır. Bu preparatlar askıda bulunan bileşenleri çökeltir, berraklaşmayı hızlandırır, renk maddelerinin geçişini ve meyve suyu verimini artırır. İçecek endüstrisinde enzim kullanımı, verimi artıran aynı zamanda karbon ayak izini, enerji tüketimini ve çevre kirliliğini azaltan bir yöntemdir (Cosme vd., 2023).

Bu çalışmada, ceviz küspesinden ceviz içeceği eldesinde Alcalase 2.4 L enziminin protein ekstraksiyonu üzerine etkisi incelenmiştir. Üretim sürecince sıcaklık, pH, enzim derişimi ve süre gibi farklı parametrelerin elde edilen protein konsantrasyonu üzerine etkisi belirlenmiştir.

2. MATERYAL ve METOT

2.1 MATERYAL

Bu çalışmada kullanılan ceviz örnekleri Hakkâri ilindeki yerel bir üreticiden temin edildi. Protein hidrolizi amacıyla Alcalase 2.4 L enzimi (Novo Holdings A/S, Bagsværd, Danimarka)

kullanıldı. Ceviz içeceğinin hazırlanmasında doğal mineralli su kullanıldı (Danone Hayat İçecek ve Gıda San. ve Tic. A.Ş., Türkiye). Protein tayininde analitik saflıkta kimyasallar kullanıldı.

2.2 METOT

2.2.1 Ceviz İşleme ve Ön Hazırlık

Dış kabukların ayrılmasından sonra elde edilen ceviz içleri bir blenderda öğütüldü ve daha sonra soğuk pres makinesinden geçirilerek yağ ve posa ayrıldı. Elde edilen posadaki kalıntı yağı uzaklaştırmak için hekzan ile soğuk ekstraksiyon işlemi gerçekleştirildi. Elde edilen yağsız posa, hekzanın uzaklaştırılması için oda sıcaklığında bir gece havalandırılarak kurutuldu. Kurutulan posa tekrar öğütüldükten sonra gözenek boyu 0.85 mm olan elek kullanılarak elendi ve böylece yağsız ceviz unu elde edildi. Elde edilen yağsız ceviz unu ceviz içeceği üretiminde kullanıldı.

2.2.2 Ceviz İçeceği Üretimi ve Örnek Hazırlama

Yağsız ceviz unu ile doğal mineralli su ön denemeler ile belirlenen 1:9 (w:v) oranında karıştırıldı. Enzimin çalışma koşullarının (sıcaklık, pH, enzim konsantrasyonu ve süre) belirlenmesi için elde edilen karışıma %1 oranında enzim eklenerek 40, 50, 60 ve 70°C'de pH 6.25'te 6 saat süreyle inkübe (MCSİ 120, Mipro, Türkiye) edildi ve sıcaklığın enzim faaliyeti üzerine etkisi belirlendi. Enzim konsantrasyonun etkisini belirlemek için karışıma yağsız ceviz ununun %0.5, 1.0, 1.5 ve 2.0'si oranında enzim eklenerek 60°C'de, pH 6.25'te ve 6 saat süreyle inkübe edilerek enzim konsantrasyonunun etkisi belirlendi. Sürenin etkisini belirlemek için karışım 60°C'de, %2 enzim derişiminde, pH 6.25'te ve 100 rpm hızda 2, 4, 6, 8, 10 ve 12 saat çalkalanarak sürenin etkisi belirlendi. Son olarak pH'nın etksini belirlemek için karışımın pH değeri 0.1 N NaOH ile 6.25, 7.0, 8.0 ve 9.0'a ayarlandı. Bu karışım 60°C'de, %2 enzim derişiminde 8 saat süreyle inkübe edilerek pH'nın etkisi belirlendi. İnkübasyon sonunda elde edilen örnekler 5000 rpm hızda 15 dak santrifüj (NF 1200R, Nüve, Türkiye) edildi, üst faz kaba filtre kağıdından geçirildi ve protein tayini için kullanıldı.

2.2.3 Protein Tayini

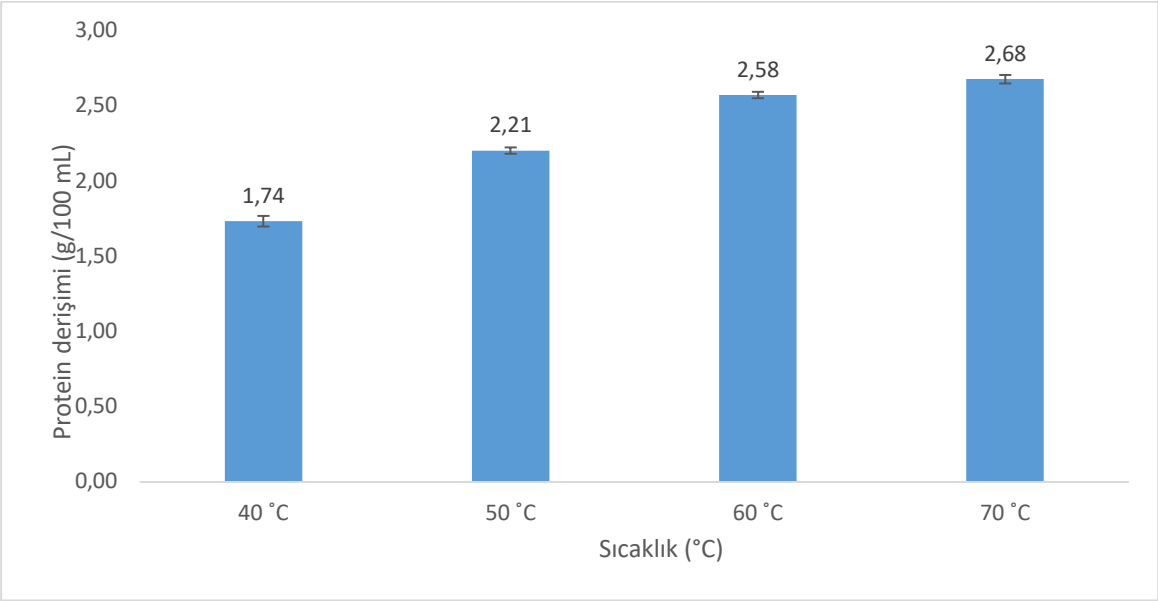
Farklı enzim konsantrasyonu, pH, sıcaklık ve sürelerde elde edilen ceviz içeceklerinin protein konsantrasyonu Biüret yöntemiyle belirlenmiştir. Örnekler belli oranlarda %0.85'lik NaCl çözeltisi ile 1 mL'ye tamamlanmış ve 4 mL biüret çözeltisi ilave edilerek vortexle karıştırılmıştır. Biüret çözeltisi ilave edildikten 30 dak sonra her örneğin absorbansı 540 nm'de (UV-Mini 1240 UV-VIS, Shimadzu, Kyoto, Japan) okunmuştur. Kalibrasyon eğrisi için sığır serum albümini standart olarak kullanılmıştır ($y=0.0585x+0.0053$, $R^2=0.9998$) (Gornall vd., 1949).

2.2.4 İstatistik Analizler

Bu çalışmada elde edilen sonuçların değerlendirmesinde SPSS (version 20.0 for Windows, SPSS Inc., Chicago, Illinois) paket programı kullanılmıştır. Grup ortalamaları arasında istatistiksel açıdan anlamlı bir farkın olup olmadığı tek yönlü varyans analizi (One-Way ANOVA) ile incelenmiştir. Farklılığın önem derecesi Duncan çoklu karşılaştırma testi kullanılarak tespit edilmiştir.

3. BULGULAR ve TARTIŞMA

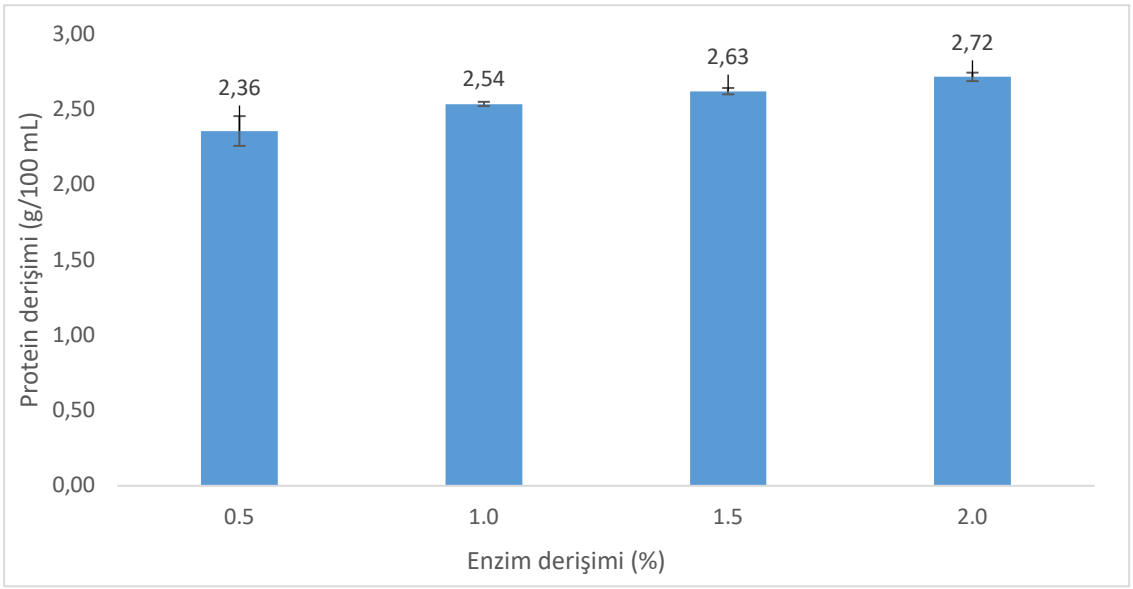
Çalışmanın ilk aşamasında, enzimin çalışma sıcaklığının protein konsantrasyonuna etkisini belirlemek için %1 enzim eklenmiş örnekler 6 saat boyunca 40, 50, 60 ve 70°C'de bekletildi ve elde edilen örneklerde protein konsantrasyonu belirlendi. Farklı sıcaklıklarda elde edilen protein miktarı Şekil 3.1'de verilmiştir.



Şekil 3.1 Farklı sıcaklıklarda ekstraksiyonun (40, 50, 60 ve 70°C) ceviz içeceğinin protein derişimi üzerine etkisi (pH:6.25, %1 enzim derişimi, 6 saat ekstraksiyon)

Şekil 3.1 incelendiğinde, sıcaklığın artmasıyla beraber protein derişiminde de artış olduğu görülmektedir. Sıcaklıklar arasında görülen farklılık istatistiksel olarak ($P<0.05$) önemli bulundu. 40°C'de protein oranı %1.74 iken, sıcaklığın 70°C'ye yükselmesiyle protein oranı %2.68'e çıktı. En yüksek protein derişimi 70°C'de elde edilmesine rağmen bu sıcaklıkta içeceğin rengi olumsuz etkilendi ve koyulaştı. Tüketici albenisi dikkate alındığında ekstraksiyon için uygun sıcaklığının 60°C olduğu tespit edildi.

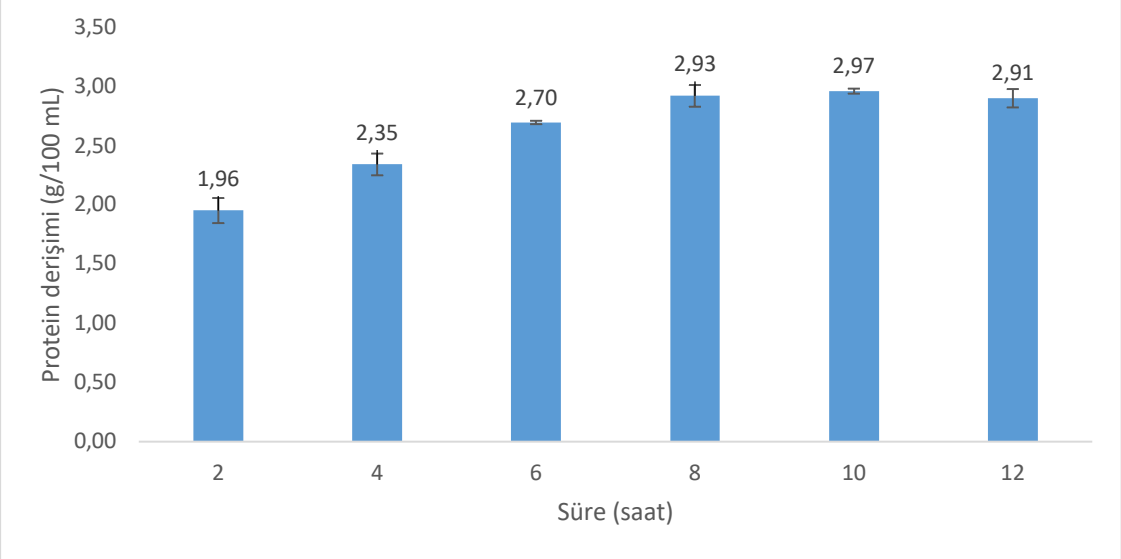
Enzim miktarının ceviz içeceklerinin protein derişimi üzerindeki etkisini belirlemek için karışıma ceviz ununun %0.5, 1.0, 1.5 ve 2.0'si kadar enzim ilave edildi ve protein ekstraksiyonu 60°C'de gerçekleştirildi. Enzim miktarının örneklerin protein derişimine etkisi Şekil 3.2'de gösterilmiştir.



Şekil 3.2 Enzim miktarının (%0.5, 1.0, 1.5 ve 2.0) ceviz içeceğinin protein derişimi üzerine etkisi (Sıcaklık: 60°C, pH: 6.25, 6 saat ekstraksiyon)

Şekil 3.2 incelendiğinde, %0.5 enzim oranında %2.36 protein derişimi elde edilirken enzim oranı %2'ye çıktığında protein derişimi de %2.72'ye yükseldi. Enzim derişimi arttıkça protein konsantrasyonu da istatistiksel olarak ($P<0.05$) önemli oranda arttı. Bu nedenle, içecekte yüksek protein oranı için ideal enzim derişimi %2 olarak belirlendi. See vd. (2011) Alcalase 2.4 L kullanarak somon derisinden enzimatik hidrolizle protein ekstraksiyonu gerçekleştirmiştir. Bu çalışmada enzim substrat oranı %0.5 ile 2.5 aralığında belirlenmiş ve bu değerin artmasıyla protein veriminde de artış gözlenmiştir. Bu durumun, yüksek miktarda enzimin protein hidrolizini artırmasından kaynaklandığı belirtilmiştir.

Ekstraksiyon süresinin protein derişimi üzerindeki etkisini gözlemek için 60°C sıcaklık ve %2 enzim konsantrasyonunda enzim eklenmiş karışım 2, 4, 6, 8, 10 ve 12 saat boyunca protein ekstraksiyonuna tabi tutuldu. Farklı ekstraksiyon sürelerinde elde edilen protein derişimi Şekil 3.3'te verilmiştir.

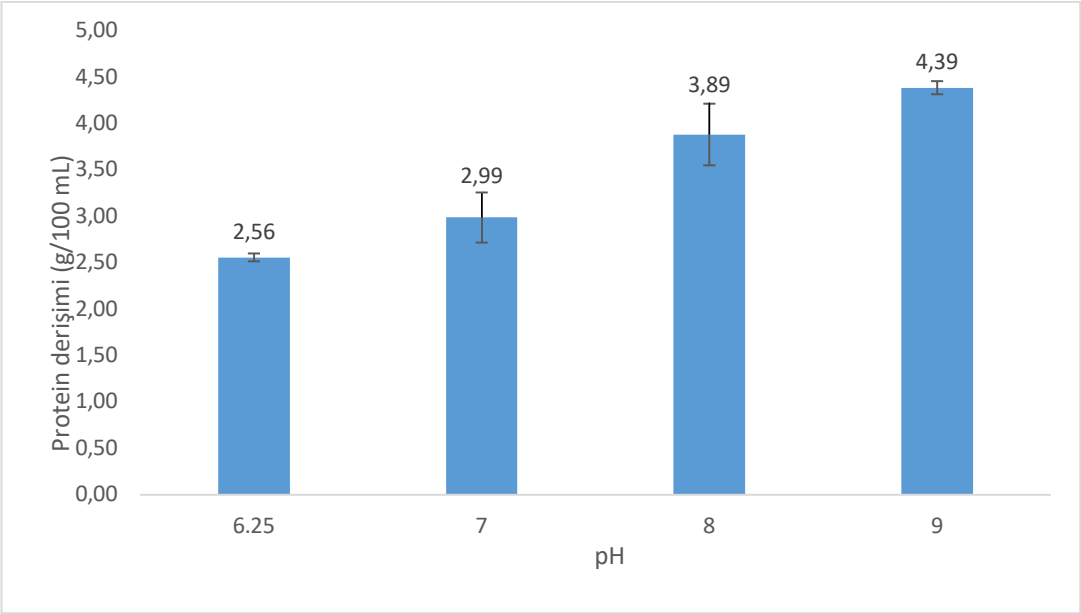


Şekil 3.3 Ekstraksiyon süresinin (2, 4, 6, 8, 10 ve 12 saat) ceviz içeceğinin protein derişimi üzerine etkisi (Sıcaklık: 60°C, enzim derişimi: %2, pH: 6.25)

Şekil 3.3 incelendiğinde protein derişiminde 8. saate kadar önemli oranda ($P<0.05$) bir artış gözlenirken 8. saatten sonra protein oranında görülen değişim önemli bulunmadı. Dolayısıyla 8 saatten uzun bir ekstraksiyon süresinin gereksiz olduğu tespit edildi.

Elde edilen sonuçlara göre, ideal ekstraksiyon koşulları 60°C ekstraksiyon sıcaklığı, %2 enzim derişimi ve 8 saat ekstraksiyon süresi olarak belirlendi. Anh vd. (2020) soyadan protein ekstraksiyonunda ekstraksiyon süresinin verime etkisini inceledikleri çalışmada, 2. saate kadar ekstraksiyon veriminde artış olduğunu tespit etmiştir. Ekstraksiyon süresini 3 saate çıkardıklarında ise ekstraksiyon veriminde herhangi bir artış olmamıştır. Bu çalışmada ise 8. saate kadar bir artış, 8. saatten sonra önemsiz değişimler görülmüştür.

Farklı pH değerlerinin ekstraksiyon etkinliği üzerindeki etkisini gözlemek için içeceklerin pH değeri 6.25 (doğal ortam pH değeri), 7.0, 8.0 ve 9.0'a ayarlandı. Bu pH değerlerinde, 60°C sıcaklıkta, %2 enzim varlığında ve 8 saat süreyle protein ekstraksiyonu gerçekleştirilmiş ve elde edilen protein derişimleri Şekil 3.4'te verilmiştir.



Şekil 3.4 Farklı pH değerlerinin (6.25, 7.0, 8.0 ve 9.0) ceviz içeceğinin protein derişimi üzerine etkisi (Sıcaklık: 60°C, enzim derişimi: % 2, Süre: 6 saat)

Bu çalışmada üretilen içeceğin doğal ortam pH değeri 6.25 olarak tespit edildi. Bu pH değerinde %2.56 protein derişimi elde edilirken, pH değerinin artmasıyla beraber protein derişiminde de çarpıcı biçimde bir artış gözlendi ve protein derişimi %4.39'a kadar çıktığı tespit edildi. Ancak pH 7'nin üzerindeki örneklerde ürün renginde önemli düzeyde koyulaşma gözlendi. Amiza vd. (2011), gümüş yayın balığı (Pangasius sp.) iskeletinden enzimatik protein hidrolizinin optimizasyonu ile ilgili yapmış oldukları çalışmada, Alcalase 2.4 L enzimini kullanmıştır. Bu çalışmada pH 7.5, 8.5 ve 9.5 olmak üzere üç faklı pH çalışılmış ve pH'nın artmasıyla protein veriminde önemli bir artış tespit edilmiştir. Montilha vd. (2017) Alcalase 2.4 L ile okaranın enzimatik protein hidroliz koşullarının optimizasyonu ile ilgili yapmış oldukları bir çalışmada, pH değerinin 7'den 9'a çıkmasıyla protein veriminin de artığını göstermiştir. Bu çalışmada elde edilen sonuçların literatürde belirtilen çalışmalarla uyumlu olduğu görülmektedir.

4. SONUÇ

Ceviz yağının alınmasından sonra geriye kalan ceviz küspesi, protein ve antioksidanlar açısından zengin, değerli bir doğal kaynaktır. Ancak bu küspe genellikle düşük katma değerli ürünler olan hayvan yemi veya gübre olarak değerlendirilmektedir. Oysa, böylesine besin değeri yüksek bir hammadde, son yıllarda giderek ilgi gören bitkisel bazlı içeceklerin üretiminde kullanılarak daha yüksek katma değerli bir ürüne dönüştürülebilir. Bu çalışmada, ceviz küspesinden Alcalase 2.4 L enzimi kullanılarak ceviz içeceği üretimi denenmiş ve farklı parametrelerin protein ekstraksiyonu üzerine etkisi incelenmiştir. Enzim ekstraksiyon 4 farklı sıcaklık, 4 farklı pH, 4 farklı enzim derişimi ve 6 farklı sürede gerçekleştirilmiştir. Yapılan çalışma sonucunda, ceviz içeceği üretiminde Alcalase 2.4 L enzimi kullanımının olumlu sonuçlar verdiği ve yüksek protein değerleri için ideal ekstraksiyon koşullarının 60°C ekstraksiyon sıcaklığı, %2 enzim oranı, 8 saat ekstraksiyon süresi ve 9 pH değeri olduğu sonucuna ulaşılmıştır. Çalışılan parametreler arasında özellikle sıcaklık ve pH değerinin elde edilen protein konsantrasyonunu önemli derecede etkilediği görülmüştür.

TEŞEKKÜR

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CEVİZ İÇECEĞİ ÜRETİMİNDE FARKLI EKSTRAKSİYON YÖNTEMLERİNİN PROTEİN MİKTARI ÜZERİNE ETKİSİ

Gözde ENGÜDAR BEYAZ

Çanakkale İl Tarım ve Orman Müdürlüğü

Email: gozdengudar@gmail.com

Dr. Öğr. Üyesi. Serdar UĞURLU

Hakkari Üniversitesi, Yüksekova Meslek Yüksekokulu, Hakkari

Email: serdarugurlu@hakkari.edu.tr

Dr. Öğr. Üyesi. Tahir YÜCEL

Van Yüzüncü Yıl Üniversitesi, Mühendsilik Fakültesi, Gıda Mühendisliği Bölümü

Email: tahiryucel@yyu.edu.tr

Prof. Dr. Gökhan BORAN

Van Yüzüncü Yıl Üniversitesi, Mühendislik Fakültesi, Gıda Mühendisliği Bölümü

Email: gboran@yyu.edu.tr

Prof. Dr. Emre BAKKALBAŞI

Van Yüzüncü Yıl Üniversitesi, Mühendislik Fakültesi, Gıda Mühendisliği Bölümü

Email: emrebakkalbasi@yyu.edu.tr (Sorumlu Yazar)

ÖZET

Son yıllarda farklı nedenlerle vegan/vejetaryen beslenmeye olan ilginin yükselmesi, bitkisel bazlı içeceklere yönelimi hızlandırmıştır. Soya, badem ve fındık sütü gibi alternatifler piyasada yaygın olarak yer almakta olup, ceviz meyvesi de yüksek besin değeri ve fonksiyonel özellikleri sayesinde bu alanda potansiyel bir hammadde olarak öne çıkmaktadır. Ceviz, yağ içeriği açısından zengin olup linoleik ve linolenik asit gibi değerli yağ asitleri barındırır. Yağ eldesi sonrası geriye kalan pres keki de özellikle yüksek protein ve doğal antioksidan içeriğine sahiptir ancak ekonomik olarak yeterince değerlendirilememektedir. Bu yağsız ceviz keki, ön işlemlerle ceviz ununa dönüştürülerek çeşitli gıda ürünlerine katılarak kullanılabilmektedir. Bitkisel içecekler genellikle tahıl, baklagil, tohum ve sert kabuklu meyvelerin su ile maserasyonu yoluyla üretilir. Maserasyon sürecinin hızlandırılması ve verimliliğin artırılması amacıyla son yıllarda ultrasonik ekstraksiyon yöntemleri tercih edilmektedir. Ultrasonik ekstraksiyon, geleneksel yöntemlere alternatif olarak öne çıkan yenilikçi bir teknolojidir. Bu çalışmada, ceviz pres atığından elde edilen yağsız ceviz ununun kullanımıyla, geleneksel ve ultrasonik ekstraksiyon yöntemlerinin ceviz içeceğine geçen protein miktarına etkileri incelenmiştir. Deneysel süreçte, ceviz içleri öğütülerek soğuk ekstraksiyon yöntemiyle yağdan arındırılmış ve yağsız ceviz unu elde edilmiştir. Ultrasonik ekstraksiyon işlemleri üç farklı güç seviyesinde (%50, %75 ve %100) gerçekleştirilirken, geleneksel ekstraksiyon oda sıcaklığında uygulanmıştır. Her iki yöntemde belirli zaman aralıklarında alınan örneklerde protein miktarı analiz edilmiştir. Elde edilen veriler doğrultusunda, ekstraksiyon yöntemlerinin hız ve verimlilik açısından karşılaştırmalı değerlendirmesi yapılmıştır. Protein verimliliği açısından değerlendirildiğinde, %100 genlikte gerçekleştirilen 3 dakikalık ultrasonik ekstraksiyon, geleneksel yöntemin yaklaşık 16 saatlik sürecine eşdeğer protein miktarı sağlamaktadır. Benzer şekilde, %75 genlikteki ultrasonik ekstraksiyon, klasik yöntemin bir saatlik verimine denk

gelmektedir. Bu bulgular doğrultusunda, ceviz pres atığından elde edilen ceviz içeceği üretiminde ultrasonik ekstraksiyonun, geleneksel yönteme kıyasla daha hızlı ve daha etkili bir protein ekstraksiyonu sağladığı sonucuna ulaşılmıştır.

Anahtar Kelimeler: Ceviz, Ceviz içeceği, Protein, Ultrases, Ekstraksiyon.

EFFECT OF DIFFERENT EXTRACTION METHODS ON PROTEIN CONTENT IN WALNUT BEVERAGE PRODUCTION

ABSTRACT

In recent years, the increasing interest in vegan/vegetarian nutrition for various reasons has accelerated the trend towards plant-based beverages. Alternatives such as soy, almond, and hazelnut milk are widely available on the market, and walnuts are also emerging as a potential raw material in this field due to their high nutritional value and functional properties. Walnuts are rich in oil and contain valuable fatty acids (linoleic and linolenic acid). The press cake left over after oil extraction is not sufficiently utilized economically, despite its high protein and natural antioxidant content. This oil-free walnut cake can be converted into walnut flour through pretreatment and used as a raw material in various food products. Plant-based beverages are generally produced through the maceration of grains, legumes, seeds, and hard-shelled fruits with water. In recent years, ultrasonic extraction methods have been favored to accelerate the maceration process and increase efficiency. Ultrasonic extraction is an innovative technology that stands out as an alternative to conventional methods. In this study, the effects of conventional and ultrasonic extraction methods on the amount of protein transferred to walnut drink using fat-free walnut flour obtained from walnut press waste were investigated. In the experimental process, walnut kernels were ground and defatted using the cold extraction method to obtain fat-free walnut flour. Ultrasonic extraction processes were carried out at three different power levels (50%, 75%, and 100%), while conventional extraction was applied at room temperature. The protein content was analyzed in samples taken at specific time intervals in both methods. Based on the data obtained, a comparative evaluation of the extraction methods in terms of speed and efficiency was performed. In terms of protein yield, a 3-minute ultrasonic extraction at 100% amplitude provided an equivalent protein amount to the conventional method's approximately 16-hour process. Similarly, ultrasonic extraction at 75% amplitude is equivalent to the yield of the classical method in one hour. Based on these findings, it was concluded that ultrasonic extraction provides faster and more effective protein extraction compared to the conventional method in the production of walnut drink from walnut press waste.

Keywords: Walnut, Walnut beverage, Protein, Ultrasound, Extraction

1. GİRİŞ

Ceviz, hem beslenme hem de ekonomik açıdan öne çıkan ve sevilerek tüketilen bir üründür (Oliveira ve ark., 2008). Yüksek yağ içeriğiyle birlikte zengin bir yağ asidi profiline, fenolik bileşiklere, fitosterollere, tokoferollere ve karotenoidlere sahip değerli bir besin kaynağıdır. Doymamış yağ asitleri ve tokoferol düzeyleri, yaygın olarak tüketilen diğer bazı yağlı tohumlara kıyasla belirgin şekilde daha yüksektir. Bu fitokimyasallar, cevizlere güçlü antioksidan ve antienflamatuar özellikler kazandırmakta; ayrıca kolesterol düşürücü etkiler göstermektedir. Diyete ceviz eklenmesi, nörodejeneratif hastalıkların başlangıcını geciktirebilir ve bazı kanser türlerine karşı koruyucu rol oynayabilir (Nguyen ve Vu, 2023).

Cevizin yalnızca doğrudan tüketimi değil, işlenmesi sırasında ortaya çıkan yan ürünleri de besin değeri ve fonksiyonel bileşen içeriği açısından dikkat çekmektedir. Ceviz yağı üretimi sırasında yeşil ceviz kabuğu, sert kabuk, septum ve ceviz unu gibi çeşitli yan ürünler ortaya çıkmaktadır. Bu yan ürünler, içerdiği çeşitli biyoaktif ürünler sayesinde gıda, kimya ve biyomedikal endüstrilerinde doğal katkı maddesi ve fonksiyonel bileşen olarak değerlendirilmektedir (Zhu ve ark., 2024). Özellikle ceviz yağı eldesinde, meyvelerin yağı alındıktan sonra kalan kısım ceviz unu olarak adlandırılmakta ve yüksek oranda ceviz proteini içermektedir (Sari ve ark., 2022).

Ceviz yan ürünleri, içerdiği zengin besin öğeleri ve biyoaktif bileşikler sayesinde, hem temel beslenme ihtiyaçlarını karşılamakta hem de ek sağlık faydaları sağlayan gıda formülasyonlarında kullanılmaktadır. Ceviz yan ürünlerinin çeşitliliği ve kendine özgü özellikleri göz önüne alındığında, ticari ölçekte değerlendirilmesini ve pazara entegrasyonunu sınırlayan en temel faktör, uygun ekstraksiyon teknolojisinin seçimi olarak öne çıkmaktadır. Geleneksel ekstraksiyon teknikleri, çevresel sürdürülebilirlik ve kaynak verimliliği açısından yetersiz kalmakta; ayrıca çözücü bağımlılığı nedeniyle düşük kaliteli ürünlerin elde edilmesine neden olmaktadır. Yenilikçi teknolojilerin yaygın olarak uygulanması, ekstraksiyon sürecinde organik çözücülerin kullanımını azaltır (Zhu ve ark., 2024). Son yıllarda, maserasyon sürecinin hızlandırılması ve verimliliğinin artırılması amacıyla ultrasonik ekstraksiyon yöntemi yaygın olarak kullanılmaktadır. Ultrasonik dalgaların ekstraksiyon ve gıda muhafazasında kullanımı, güvenli, verimli, ekonomik ve çevre dostu olarak uygulanabilen yeni ve etkili bir işleme teknolojisidir (Rodrigues ve Fernandes, 2009). Ultrason uygulamasıyla ekstraksiyon verimindeki artış, esas olarak, ultrasonik dalganın geçişiyle çözücüde oluşan akustik kavitasyonların etkilerine atfedilir (Wang ve ark., 2008).

Bu çalışmada, ekonomik değeri düşük ve genellikle değerlendirilmeden atılan ceviz pres atığının, ultrasonik teknik kullanılarak yüksek katma değerli ceviz içeceği üretiminde değerlendirilme potansiyeli araştırılmıştır.

2. MATERYAL VE YÖNTEM

2.1. Materyal

Araştırmada kullanılan Yavuz çeşidine ait ceviz örnekleri, Hakkâri ilindeki bir yerel üreticiden temin edilmiştir. Biüret analizinde analitik saflıkta Biüret reaktifi, sodyum klorür ve sığır serum albümini kullanılmıştır.

2.2. Yöntem

2.2.1. Ceviz İçeceği Üretiminde Farklı Ekstraksiyon Uygulamaları

Sert dış kabukları uzaklaştırılan cevizlere, mutfak tipi parçalayıcı (AR142 Soprano, Arzum, Türkiye) yardımıyla ön parçalama işlemi uygulandı. Daha sonra soğuk pres makinesinden (NF80, Karaerler, Türkiye) geçirilerek yağ ve posa ayrıldı. Elde edilen posadaki kalıntı yağ, çözücü olarak hekzan kullanılan soğuk ekstraksiyon işlemi ile uzaklaştırıldı. Soğuk

ekstraksiyon işleminde, posa ile hekzan 1:3 oranında, 180 rpm hızda ve 4 saat boyunca çalkalayıcıda (OS-3000, Jeio Tech, Güney Kore) karıştırıldı. Süre sonunda kaba filtre kâğıdı ile süzme işlemi yapıldı. Elde edilen posa, hekzanın uzaklaşması için oda sıcaklığında bir gece boyunca havalandırılarak kurutuldu. Kurutulan posa, öğütüldükten (K 3104, Arçelik, Türkiye) sonra gözenek boyutu 0.85 mm olan elek kullanılarak elendi ve böylece yağsız ceviz unu elde edildi.

Ultrasonik ekstraksiyon için hazır hale getirilen yağsız ceviz unu ile içme suyu 1:9 (w:v) oranında karıştırılarak elde edilen karışım farklı genliklerde (%50, 75 ve 100 amp gücünde) 1, 3, 5, 10 ve 20 dak boyunca ultrason destekli homojenizatörde (GM 3200, Bandelin, Almanya) homojenize edildi. Elde edilen homojenizat 3600 rpm hızda 5 dak santrifüj (NF 1200R, Nüve, Türkiye) edildikten sonra üst fazdaki sıvı kısım filtre edilerek ayrıldı.

Geleneksel ekstraksiyonda, yağsız ceviz unu 1:9 (w/v) oranında su ile karıştırıldı. Karışım ultrason işlemi uygulanmaksızın 16 saat boyunca 100 rpm hızda dairesel çalkalayıcıda (OS 3000, Jeio Tech, Güney Kore) karıştırıldı. Karışım santrifüj edildikten sonra üst fazdaki sıvı kısım filtre edilerek ayrıldı.

Her iki yöntemle de elde edilen ekstraktların protein miktarı Biüret yöntemi kullanılarak belirlendi.

2.2.2. Biüret Yöntemi ile Protein Tayini

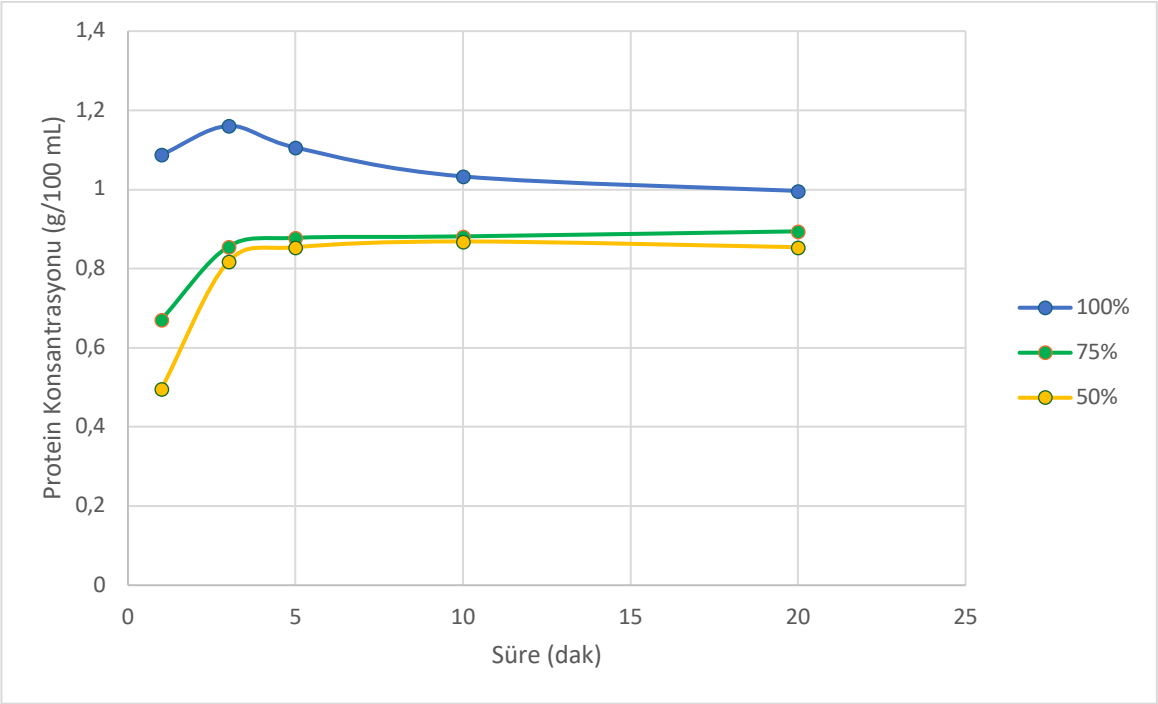
Biüret yöntemi ile protein tayininde örnekler belli oranlarda %0.85'lik NaCl çözeltisi ile 1 mL'ye tamamlanmış ve 4 mL biüret çözeltisi ilave edilerek vortexle karıştırılmıştır. Biüret çözeltisi ilave edildikten 30 dak sonra 540 nm'de (UV-Mini 1240 UV-VIS, Shimadzu, Kyoto, Japan) absorbans okunmuştur. Kalibrasyon eğrisi için sığır serum albümini standart olarak kullanılmıştır (Gornall ve ark., 1949).

2.2.3 İstatistiksel Analiz

Bu çalışmada elde edilen sonuçların değerlendirmesinde SPSS (version 20.0 for Windows, SPSS Inc., Chicago, Illinois) paket programı kullanılmıştır. Grup ortalamaları arasında istatistiksel açıdan anlamlı bir farkın olup olmadığı tek yönlü varyans analizi (One-Way ANOVA) ile incelenmiştir. Farklılığın önem derecesi Duncan çoklu karşılaştırma testi kullanılarak tespit edilmiştir.

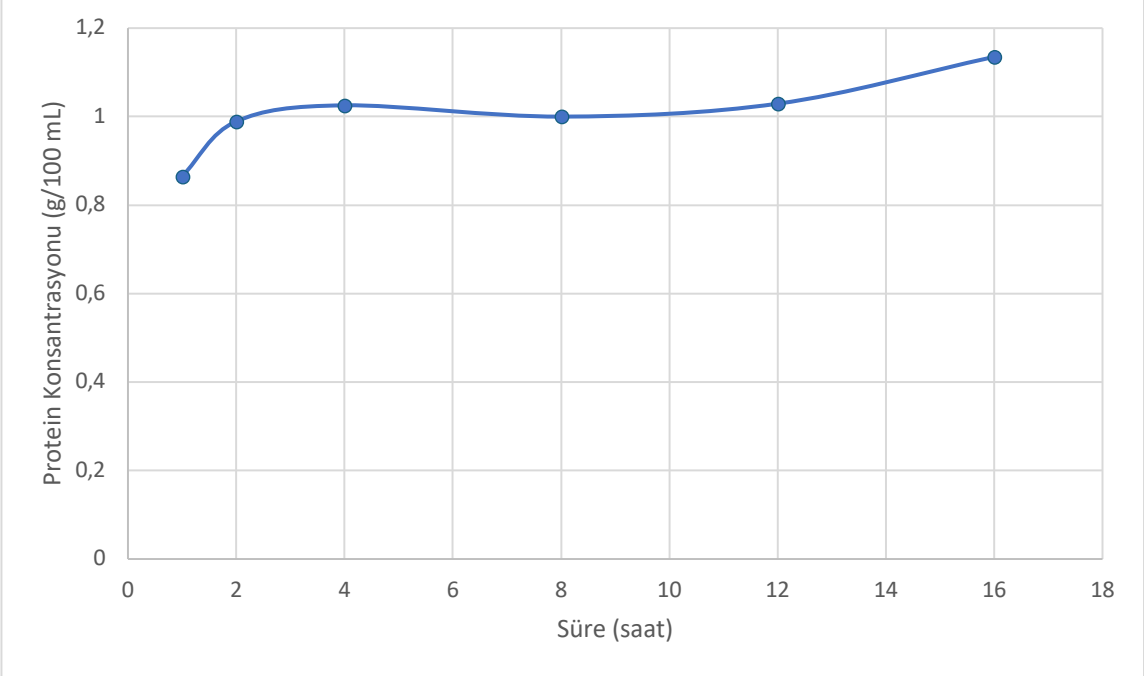
3. BULGULAR VE TARTIŞMA

%50, %75 ve %100 ultrason genliklerinde 20 dakika boyunca uygulanan ultrason destekli ekstraksiyon işlemleri sonucunda elde edilen protein miktarları Şekil 1'de gösterilmiştir. En yüksek protein miktarı %100 ultrason genliğinde uygulanan ekstraksiyonun 3. dakikasında (1.16 g/100 mL) elde edilmiştir. Ancak bu genlikte 3. dakikadan sonra süre ilerledikçe ekstraktın protein içeriği azalmıştır. %50 ve %75 ultrason genliklerinde protein miktarında ilk 3 dakika süresince anlamlı bir artış gözlemlenmiştir, 3. dakikadan sonra ekstraksiyon süresi artmasına karşın protein içeriğinde önemli bir değişim görülmemiştir. Aynı ekstraksiyon süresinde örneklerde elde edilen protein miktarı incelendiğinde, ultrason genliğinin artmasıyla protein miktarının da yükseldiği belirlenmiştir. Benzer bir bulgu, yağsız soya gevreğinden protein ekstraksiyonu amacıyla ultrason teknolojisinin kullanıldığı çalışmada da rapor edilmiştir (Karki ve ark., 2010). Sonuçlar incelendiğinde, %50 ve %75 genlikte elde edilen sonuçların özellikle ekstraksiyonun 3. dakikasından sonra birbirine çok yakın seyrettiği, %100 genlikte elde edilen sonuçların ise %50 ve %75 genlikte elde edilen sonuçlardan tüm ekstraksiyon süresince önemli düzeyde yüksek olduğu gözlenmektedir. Protein içeriği açısından, aynı ultrason genliği altında ekstraksiyon süreleri arasındaki fark ve aynı sürede ultrason genlikleri arasındaki fark istatistiksel olarak anlamlı bulunmuştur ($P<0.05$).



Şekil 1. Ultrason destekli ekstraksiyonda protein konsantrasyonunun ultrason genliğine ve süreye (dak) bağlı değişimi

Geleneksel yöntemle elde edilmiş ceviz içeceği ekstraktlarının protein miktarındaki değişim ise Şekil 2'de sunulmuştur. Geleneksel ekstraksiyon süresi uzadıkça, ekstrakttaki protein miktarında genel olarak artış gözlemlenmiştir. Ekstraksiyon süresince ilk 4 saatte protein düzeyindeki artış yüksek iken, 4-12 saat arasında önemli bir değişim gözlenmemiştir. Ancak 12. saatten sonra tekrar bir artış eğilimi başlamıştır. Örneklerdeki en yüksek protein içeriği, 16 saatlik ekstraksiyon sonunda elde edilmiştir (1.13 g/100 mL). 16 saatlik geleneksel ekstraksiyon sonucunda elde edilen protein miktarı, %100 genlik kullanılan ultrason destekli ekstraksiyonun 3. dakikasında elde edilen protein miktarıyla (1.16 g/100 mL) benzerlik göstermektedir. Bu bulgular, ultrason destekli ekstraksiyonun daha kısa sürede daha yüksek protein verimi sağlayabildiğini ve ekstaksiyon süresini önemli ölçüde kısaltabildiğini göstermektedir. Bununla birlikte, uzun süreli uygulamalara rağmen geleneksel ekstraksiyon yöntemi ile elde edilen protein miktarı, ultrasonik yöntemle elde edilen değerlerin altında ya da ancak yakın seviyelerde kalmıştır. Susam tohumundan farklı yöntemler ile protein ekstraksiyonunda, ultrasonik ekstraksiyon ile benzer sonuçlar elde edilmiştir. Bu yüksek verimlilik, ultrasonun hücresel yapıyı bozarak proteinlerin daha etkin şekilde salınmasını sağlamasından kaynaklanmaktadır (Yang ve ark., 2021). Ultrason destekli ekstraksiyonun ceviz proteinlerinin ekstraksiyon verimini ve özelliklerini iyileştirmek için umut verici bir yaklaşım olduğu Lv ve ark. (2019) tarafından bildirilmiştir.



Şekil 2. Geleneksel ekstraksiyon yönteminde protein konsantrasyonunun süreye (saat) bağlı değişimi

SONUÇ

Bu çalışmada elde edilen veriler, ultrason destekli protein ekstraksiyonun ceviz içeceği ekstraktlarında protein konsantrasyonunu artırmada geleneksel yönteme göre daha etkili ve hızlı bir alternatif olduğunu göstermektedir. Aynı ekstraksiyon süresinde ultrason genliğinin yükselmesiyle protein miktarının arttığı görülmektedir. En yüksek protein ekstraksiyonu %100 ultrason genliğinde yalnızca 3 dakikalık uygulama ile elde edilmiştir. Bu miktar, geleneksel yöntemde 16 saatlik ekstraksiyon sonunda elde edilen maksimum değeri aşmaktadır. Buna karşın %100 genlikte 3. dakikadan itibaren azalma eğilimi ortaya çıkmıştır. Elde edilen sonuçlar, ultrasonik ekstraksiyonun hem verim hem de işlem süresi açısından geleneksel ekstraksiyona göre daha üstün bir yöntem olduğunu göstermektedir.

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OKITSU WASE SATSUMALARINDA FARKLI DOZ VE ZAMANLARDAKI KAOLIN UYGULAMALARININ BAZI MORFOLOJIK, FIZYOLOJIK, VERIM VE KALITE ÖZELLIKLERINE ETKILERI

Zir. Yük. Müh. Gülcan Tuğçe VANOĞLU

Hatay Mustafa Kemal Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü, HATAY

Email: kenditugce@gmail.com,

ORCID: 0009-0009-6873-5146

Doç. Dr. Müge U. KAMİLOĞLU*

Hatay Mustafa Kemal Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü, HATAY

Email: mkamiloglu@gmail.com

ORCID: 0000-0001-6869-2371

*:correspending author

ÖZET

Turunçgil yetiştiriciliğinde meyve verim ve kalitesini etkileyen faktörlerden biri de iklim koşullarıdır. Yaz aylarında high temperature and direct solar radiatio nedeniyle meyvelerde oluşan güneş yanıklıkları ağaç gelişimine, meyve verim ve kalitesine ve ekonomik kayıplara neden olabilir. Bu araştırmada kaolin kilin farklı doz ve zamanlardaki uygulamalarının Okitsu wase mandarinlerinde bazı fizyolojik, morfolojik özelliklerine, meyve verim ve kalitesine etkileri incelenmiştir. Kaolin kil uygulaması (Surround WP) denemede yer alan ağaçların bir yarısına ilk kaolin (%5) uygulaması Mayıs sonu (Küçük meyve dökümünden sonra), diğer yarısına Haziran ortasında %2.5'luk ve/veya % 5 dozlarında farklı dönemlerde (1-7 kez) uygulanmıştır. Uygulama yapılmayan bitkiler kontrol olarak değerlendirilmiştir. Okitsu wase mandarinlerinde kaolin kil uygulamasının 6 ve 7 kez tekrarlandığı uygulamalarda, sıcaklık değerleri meyvede 1-2 ºC, yaprakta 4-5 ºC daha düşük ölçülmüştür. Bu etki Okitsu wase meyvelerinde güneş yanıklığı oranının azalmasına ve meyve ağırlığında artışa bağlı olarak ağaç başına verimde değişen oranlarda yükselmeye neden olmuştur. Kaolin uygulamaları kontrole göre SÇKM ve SÇKM /asit oranında artış göstermiştir. Ayrıca pazarlanabilir meyve oranını arttırmıştır.

Anahtar Kelimeler: Turunçgiller, mandarin, kaolin, kalite, güneş yanıklığı

EFFECTS OF THE APPLICATION OF KAOLIN ON OKITSUWASE SATSUMA AT VARIOUS DOSES AND TIMES ON SOME MORPHOLOGICAL, PHYSIOLOGICAL, EFFICIENCY AND QUALITY CHARACTERISTICS

ABSTRACT

One of the factors that affect fruit yield and quality in citrus growing is climate conditions. Sunburn on fruits due to high temperature and direct solar radiation in summer may affect tree growth, fruit yield and quality, and cause economic losses. This study analyzed the effects of kaolin treatment at different dosages and in different intervals on certain physiological and morphological characteristics, as well as fruit yield and quality of Okitsu wase mandarins. Kaolin treatment (Surround WP) was made (1 to 7 times) on half of the trees in the trial at the end of May (after small fruit drop) for the first time (5%), and on the other half at different intervals beginning from mid-June at 2.5% and/or 5% dosages. Plants, which were not subject to treatment, were considered as control. In treatments, where kaolin treatment was repeated 6 to 7 times on Okitsu wase mandarins, temperature values were measured 1 to 2 ºC lower in fruits and 4 to 5 ºC lower on leaves. This effect caused a reduction of sunburn ratio in Okitsu wase fruits and an increase in yield per tree at varying rates depending on the increase in fruit weight. Kaolin treatments exhibited an increase in TSS and TSS/acid ratios in comparison with the control. Furthermore, the ratio of marketable fruits increased as well.

Keywords: Citrus, mandarin, kaolin, quality, sunburn

INTRODUCTION

Turkey has a great potential for citrus production in consideration of its ecological and other characteristics. According to the statistics from 2025, Turkey's citrus production was 7,877,982 tons. Mandarin (37.48%) comprises 2,952,775 tons of such production (FAO, 2025). Among citrus fruits, the mandarin group is the first choice for table consumption, mainly due to its easy peelability. The most important factor that limits citrus growing is temperature. It was determined that heat stress caused by high temperatures in summer months caused morphological, physiological, and biochemical changes, as well as sunburns on leaves and fruits, particularly due to global warming in recent years. (Yücel, 2010; Şirin 2013; Ennab at al., 2017, Rodriguez et. al., 2019, Fischer et al.2022). Sunburn causes significant economic losses, particularly in many fruit varieties such as apple, mango, grapevine, pomegranate, citrus, and olive (Ennab et. al. 2017). In citrus plants, particularly young plants of early varieties, sunburns on fruits due to high temperatures cause loss of yield and quality. As a matter of fact, Chabbal et al. (2014) indicated that certain mandarin varieties belonging to satsuma group were quite sensitive to sunburn as they had scattered petal structures. In this regard, sprinkler irrigation, the use of coating materials, shading fruits with coatings such as netting and paper bags, and the use of light reflective materials such as kaolin may reduce sunburn in areas with high sunshine intensity (Parchomlochuk and Meheriuk, 1996; Wand et al., 2006, Alvarez et. al. 2015, Sarooghinia et al., 2020). Kaolin (a clay) is a natural mineral, main constituent of which is kaolinite ($Al_2Si_2O_5(OH)_4$), and which is used globally as "Particle Film Technology" against biotic and abiotic stress conditions (Yazıcı and Kaynak, 2007). Film cover treatment including Kaolin is effective in reducing heat stress (Glenn et al. 2001; Erez and Glenn 2002). Kaolin is sprayed on plants as a thin film coating: it reflects part of the extreme heat intensity received by the plant, creates a shading effect on the plant, reduces the temperature of plant organs, and increases photosynthesis (Glenn et al. 2002).

In citrus growing areas of Hatay province located at the southernmost part of Turkey, where summer months are hot and arid, sunburns, recently on the rise due to global warming, are frequently observed in young groves of Okitsu wase, an early, high-yielding, and high-quality variety. Reasons such as the expansion in area used for growing this variety in recent years and sensitivity to heat stress increase the importance of the matter.
This study was conducted with the purpose of determination of the effects of kaolin treatments, initiated at two different times and repeated at different dosages and intervals to prevent heat stress during fruit development period of Okitsu wase mandarins widely grown in Eastern Mediterranean Region, on heat stress, sunburn, fruit quality, yield, and certain physiological properties.

1. MATERIAL AND METHODS

The experimental grove was planted in Dörtyol (Hatay), located in the North West region of Turkey (36º09′E, 36º51′N; 9 m above the sea level) in a 6mX6m spacing (277 tree per ha). The trees were managed and selected for uniformity and crop load. Trees in the orchard were irrigated by means of drip irrigation at 7- to 10-day intervals throughout the experiment. Meteorological data was recorded for the duration of the experiment in the study area (Figure 1). Seven-year-old 'Okitsu wase' satsuma mandarin trees, grafted on sour orange (*Citrus aurantium* L.) rootstock, was used in the experiment. Commercial kaolin preparation (Surround WP) was used to prevent sunburn on Okitsu fruits. Besides control trees, ten cultural practices were experimented in the study. Kaolin treatment was made on half of the trees in the trial at the end of May (after small fruit drop) for the first time (5%), and on the other half at mid-June. Dosages, times, and numbers of all treatments in the study are given in Table 1.

Leaf And Fruit Surface Temperature (ºC):

In each repetition, measurements were performed at the end of June, July, and August using infrared thermometer (Spectrum IR thermometer) on 2 fruits and 2 fully developed leaves on selected branches at four sides (North, South, East, West) of the tree.

Leaf Chlorophyll Concentration:

In each repetition, measurements were performed on 2 fully developed leaves (4th±5th leaf from the shoot apex) on marked branches of fruitless shoots at four sides of the tree. Leaf chlorophyll concentration was estimated by SPAD readings (SPAD-502 meter, Minolta Inc., Osaka, Japan). In addition, the extract prepared according to Arnon (1949) by collecting measured leaf samples was read on three wavelengths in the spectrophotometer (645, 663, and 652 nm), and chlorophyll a, chlorophyll b, and total chlorophyll contents were determined according to Lichtenhaler and Welburn (1983).

In each repetition in June, July, and August, a total of 80 leaves were collected at four main sides of trees. Leaf area was determined with LI-3100 device. Specific leaf area (cm^2/g dry weight) and leaf thickness (g fresh weight /cm^2) were determined according to Koundouras et. al. (2008). Leaf relative water content (LRWC) (%) was determined according to Becalar et al. (2006). For this purpose, fresh weights (FW) of disks, received from leaf samples, were taken. Leaf disks, turgor weights of which were determined after being suspended in distilled water, were dried at 70°C for 24 hours and LRWC was calculated.

Yield And Fruit Quality :

The fruits were harvested in September at the optimum harvest time from each plot. The yield per tree (kg/tree) was obtained by weighing the harvested fruit.

A random sample of 15 fruits from each tree was collected to analyze for fruit quality. Fruit rind thickness and fruit rind color, fruit juice percentage (%), total soluble solid (TSS) (%), titratable acid (%) and soluble solid/acid ratio were determined. Fruit rind thickness was measured with a digital caliper (Mitutoyo CD-15CPX, Mitutoyo America Corporation, USA). Fruit rind color was measured at three different points around the equatorial region of each fruit, using a Minolta CR 300 reflectance Chroma Meter (Minolta, Osaka, Japan) which provided CIE L*, a* and b* values. Soluble solids were determined with a portable refractometer (FG-103/113) using a few drops of juice. The total acidity of the juice was determined by titrating 5 ml of the juice sample with 0.1 N sodium hydroxide (NaOH) using phenolphthalein as the indicator (Lado et al., 2014).

Fruit sunburn percentage: The scale [no burn (1), very mild (2), mild (3), average (4), considerable (5), excessive (6)] based on sunburn levels, used in OECD 2010 (Organization for Economic Co-operation and Development) standards for quality classification of mandarins, was used. 5≤ is considered as unmarketable according to OECD standards. (OECD, 2015) (Figure 2).

Marketable Fruit Ratio (%)

Sunburn values of fruits, included in repetitions for each treatment, were determined according to OECD 2010 scale. The total of fruits, which had a value of 4≥ according to the standards, were proportionally calculated.

The experiment utilized a ‘Randomized Complete Block’ design with five replicates for each treatment. Five trees of each treatment were selected for similarity in size, vigor and flowering intensity. Data was subjected to one-way analysis of variance (ANOVA) using SAS statistical software (SAS v9.0). Duncan’s multiple range test at % 5 level was used to compare the mean values.

3. RESULTS AND DISCUSSION

Fruit Surface Temperature (ºC)

Monthly average measurement values for the effects of treatment of Okitsu Wase variety with kaolin, at different intervals and dosages, on fruit surface temperatures are given in Figure 3. The highest fruit temperatures were observed in T11 (control) in June, July, and August (respectively 31.23 ºC, 31.78 ºC, and 33.55 ºC). The lowest fruit temperature was found in T1, T2, T5, T6, T8, T9, T10 treatments between 29.58 ºC - 29.95 ºC in June; and in T2, T7, T3, T4, T5, T8, T9, T10 treatments between 31.35 ºC - 32.27 ºC in August. The effect of kaolin treatment on fruit surface temperature led to 1 to 2ºC decline in comparison with the control plants. Based on these findings, it is understood that all kaolin treatments in the experiment were effective in reducing fruit temperature. This conclusion is similar to the findings of several researchers (Glenn et. al.,2001; Glenn et. al., 2003; Glenn et al., 2004; Clinton et. al.,2003; Pace et. al., 2007, Mohamed et al., 2019) reporting that methods such as film treatment and shading blocked lights at various levels and reduced fruit temperature or bud temperature at different degrees on fruits and vegetables. Clinton et. al. (2007) reported that single treatment of kaolin did not affect fruit temperature, but two treatments reduced fruit temperature by 1 to 2 ºC. Colavita et. al. (2010) determined that fruit surface temperature declined between 1.6 and 4.7 °C as kaolin dosage increased under the conditions in Argentina; however, such decline was not linear.

Leaf Surface Temperature (ºC)

In our study, leaf temperature values in kaolin treatments were found to be statistically lower than the control. It was seen that this effect was similar between kaolin treatments in June measurements, while it varied according to treatments in July and August, and the most effective treatments in these months were T3, T8, and T10 (Figure 4). Leaf temperatures were found up to 4 - 5 ºC lower in kaolin treatments in comparison with control plants. Glenn et al. (2003) reported that kaolin was a compound that reduced leaf temperature, heat stress, and solar damage. Denaxa et al. (2012) reported that kaolin reduced leaf temperature values in olives. Jifon and Syvertsen (2003) found that leaf temperature was 3ºC lower than the control as a result of kaolin treatment in Ruby Red grapefruit variety (treatment of trees with 60 g/L dosage twice a week at 3-week intervals). Ogiela (2020) reported that three kaolin treatments in June, July, and August reduced leaf and fruit surface temperatures in Persimmon. As a result of our study, temperature values measured on leaves of treated with kaolin are in parallel with the results of the studies mentioned above. Low leaf surface temperatures in the summer is important in terms of the potential to increase photosynthesis capacity of the plant.

Leaf Chlorophyll Content (SPAD)

According to average values of leaf chlorophyll content measurements performed to at four main sides of trees with SPAD-502 meter, statistically significant differences were found between treatments in June, July, and August. In June, leaf chlorophyll content was found to be the highest in T10 (79.19) and the lowest in control (T11) (67.70). In July, the highest value was found in T4 (86.56) and the lowest values were found in T11 and T2 treatments (respectively, 75.69 and 75.91). In August, chlorophyll level was found to be the highest in T3, T8, T7, T5, T4, T1, T6, T2, T10 treatments, which are statistically in the same group, and the lowest in the control (75.51 µmol m^{-2}). According to monthly measurements on treated and control trees, leaf chlorophyll contents increased upon kaolin treatment in the three periods. Leaf chlorophyll contents of control plants yielded the lowest value in all three periods (Figure 5). This finding is similar to the finding of Jifon and Syvertsen, (2003), reporting that chlorophyll contents of the leaves of Ruby Red grapefruit variety, treated with kaolin, were positively impacted in comparison with control leaves in summer and autumn. Şirin (2013)

reported that 2nd and 3rd 3% kaolin treatments had positive impacts on chlorophyll content in olives.

Chlorophyll a

Leaf chlorophyll content a was found to be the highest in T1 (1.13 mg/ g ta) according to the average of measurement periods. Other treatments, which were statistically in the same group, varied between 0.72-0.86 mg/ g ta (Table 2).

Chlorophyll b Content

Upon examination of Table 2, the effect of treatments according to the average of measurement months, is seen to be highest in T1 (0.090 mg/ g ta), and the lowest in T3 and T11 (0.073 mg/ g ta).

Total Chlorophyll Content

The effects of treatments on total chlorophyll content also displayed statistically significant variations. Among all treatments, total chlorophyll was observed to be the highest in T7 (2.05 mg/ g ta) and the lowest in T11 (1.43 mg/ g ta). Leaf chlorophyll contents of all trees subject to treatment were similar to the findings obtained from SPAD measurements, and kaolin treatment was determined to have positive impact. However, this impact increased in parallel with the frequency of treatment. It has generally been found to be higher in single applications (T7 and T1) (Table 2). Ogiela (2020) reported that chlorophyll a, b, and total contents of two and three 4% kaolin treatments exhibited an increase in comparison with the control in Costata variety of Persimmon. Glenn et al. (2001) found the effect of kaolin on leaf chlorophyll content in apple to be statistically insignificant. Lombardini et al. (2009) reported that chlorophyll a, chlorophyll b, and total chlorophyll contents of pecan leaves, which were in shade or exposed to sunlight, did not change.

Specific Leaf Area (cm^2 /g dry weight)

Upon comparison of treatments in terms of monthly averages, specific leaf area was found to be the highest in August (59.03 cm^2/ g dry weight) and the lowest in June (54.69 cm^2/ g dry weight). The effects of kaolin treatments on specific leaf area varied by month (Table 3).

Leaf Relative Water Content (%)

Leaf relative water content yielded higher values in July and August (respectively 62.41%; 59.88%) than June (44.68%). It was considered that this general increase could be due to the effect of accumulated kaolin in certain treatments. As reported by Şirin (2013), leaf relative water content is considered as an important indicator of drought stress. It is effective in ensuring balance between cell volume and transpiration ratio of leaf relative water content value and water provided to leaf, and it protects the plant from stress. (Dhanda and Sethi, 2002). Jifon and Syvertsen, (2003) administered kaolin to trees twice a week at a dosage of 60 g/L at 3-week intervals in Ruby Red grapefruit variety. The researchers determined that midday water use effectiveness was 25% higher in leaves treated with kaolin in comparison with the control. However, such effect could not be clearly observed in measurements conducted in the following months (Table 3).

Leaf Thickness (g fresh weight / cm^2)

No effect of treatments was observed on leaf thickness. However, leaf thicknesses by month were determined to be the highest in June (0.045 g fresh weight / cm^2) and the lowest in August (0.039 g fresh weight / cm^2) (Table 3).

Yield And Quality Characteristics

Fruit yield per tree was statistically different between treatments. The highest yield was obtained from T8 treatment (181.80 kg / tree), while the lowest yield was obtained from T11 treatment (Control) (153.60 kg / tree). Regular performance of kaolin treatments throughout summer months increased yield (Table 4). It is considered that the treatments affected yield as they increased the effectiveness of photosynthesis. It was seen that the findings on the increase in yield-per-tree values, in comparison with control trees, supported our study as reported by

Spiers et al. (2004) for blueberry, Ertan et al. (2009) for fig, İnce (2012) for pomegranate, and El – Tananay et al. (2019) for Balady mandarin variety.

The impact of treatments on fruit weight was similar to fruit yield per tree, and the highest fruit weight was obtained in T8, T9, and T5 treatments (99.33 g; 95.59 g; 96.46 g). The impact of T6, T11, and T1 treatments on fruit weight was found to be low (83.05 g; 82.90 g; 82.38 g). No or single treatment of kaolin was not sufficient for fruit size. The largest fruit size was obtained from T7 treatment with 46.84 mm. The impact of treatments on Okitsu wase mandarins was not found to be statistically significant in terms of fruit width (54.13 mm to 59.33 mm), rind thickness (1.81 mm to 2.08 mm), and juice content (58.20% to 46.43%). Chabbal et al. (2014) also reported for the same mandarin variety that kaolin treatment (a total of 7 treatments) at 2% and 4% dosages (in two, three, and four treatment frequencies) did not affect juice content. Tsai et. al. (2013) determined that shading did not affect juice amount in Murcott tangor (*Citrus sinensis* × *Citrus reticulata*) variety under the conditions in Taiwan. Furthermore, İnce (2012) indicated that the amount of juice amount in pomegranate was not affected by different dosages of kaolin.

The effects of treatments on titratable acid amounts were found to be statistically significant. While the highest acid amount was obtained from T7 treatment (1.33%), no significant difference was observed in other treatments other than T6 treatment. TSS content was found to be the highest in T8 treatment (8.32%), followed by T10 treatment (8.16%). It was seen that TSS content increased based on kaolin treatment and, as a matter of fact, kaolin was sprayed for 5 and 6 times on trees in T8 and T10 treatments (Table 4). It was determined that our findings were in line with other studies. As a matter of fact, Cantiro et. al. (2009) reported that TSS was increased by kaolin treatment (5.2%) in comparison with the control (4.6%); and Chabbal et. al. (2014) reported that 4% kaolin dosage increased TSS content in Okitsu mandarins. Forey et al.(2008) reported that kaolin treatments increased TSS content by 7% more than the control in Satsuma mandarins under the conditions in California. TSS/Acidity ratio was found to be the highest in T8 and T10 treatments (respectively 7.55; 7.44), and the lowest in T11, T6, and T7 treatments (respectively 6.57; 6.49; 6.16). Similar to yield and size, treatment frequency was also effective in TSS/Acidity ratio. Ennab et. al. (2017) reported that kaolin treatment increased TSS and TSS/A ratio in Balady mandarins, while Mohamed et al. (2019) reported that 4% kaolin treatment increased TSS/Acidity ratio in Murcott mandarins.

The effect of treatments on fruit color measurements was not found to be statistically significant. Hu values for fruits in all treatments varied between 117.03 and 118.55. The fruits displayed a yellow-green coloration(Table 5). Schupp et al. (2002) determined that sunburn was prevented in apples by triple kaolin treatments, but fruits were smaller and coloration was not sufficient as a result of the treatment made in July and August.

In our study, the ratio of fruits with sunburn was determined as 4.8% in the control. On the contrary, sunburn ratio was found to be lower in kaolin treatments. Marketable fruit amount was found to be the highest in T8 treatment (181.80 kg/tree) and the lowest in T11 treatment (control) (146.23 kg/tree). Kaolin treatment provided 10 to 25% increase in marketable fruit amount in comparison with the control(Table 6). Melgarejo et al. (2004) reported that Surround WP treatment on pomegranate (June – August; at 2- to 3-week intervals; 4 times) reduced sunburn damage on fruits to 9.4% in comparison with the control (21.9%). Forey et al. (2008) found out that kaolin treatment in Satsuma mandarins increased marketable fruit ratio by 20% and reduced sunburn by 50% in comparison with the control. Chabbal et al. (2014) reported that kaolin treatment in Okitsu mandarins protected against sunburn at the rate of 91.53% to 97.74%, while such ratio was 73.97% in control fruits. Ennab et al. (2017) reported that kaolin treatment on Balady mandarin reduced sunburn ratio from 21.9% to 9.4%. Protective effect of

kaolin in terms of controlling sunlight damage, indicated in the provided literature, was also identified in our study.

4. CONCLUSION

As a conclusion, it was found out that kaolin treatments on Okitsu wase mandarins were effective in prevention of fruit sunburn, reduced fruit and leaf temperature, and led to positive outcomes in terms of yield and certain quality parameters. T8 and T10 treatments, where kaolin treatment was repeated 6 and 7 times, led to the most effective outcomes in controlling high temperature. In these treatments, temperature values were measured 1-2 ºC lower in fruits and 4-5 ºC lower in leaves. This effect led to a decline in sunburn ratio in Okitsu wase fruits, as well as varying rates of increase in yield per tree based on the increase in fruit weight. The highest yield per tree (181.80 kg/ tree) was determined in T8 treatment, where 5% dosage was administrated in Mid-June and 2.5% dosage repetition was made at a 15-day interval. It is considered that practical use of kaolin treatment would be effective in hot periods during summer months as it yields positive results, particularly on young trees.

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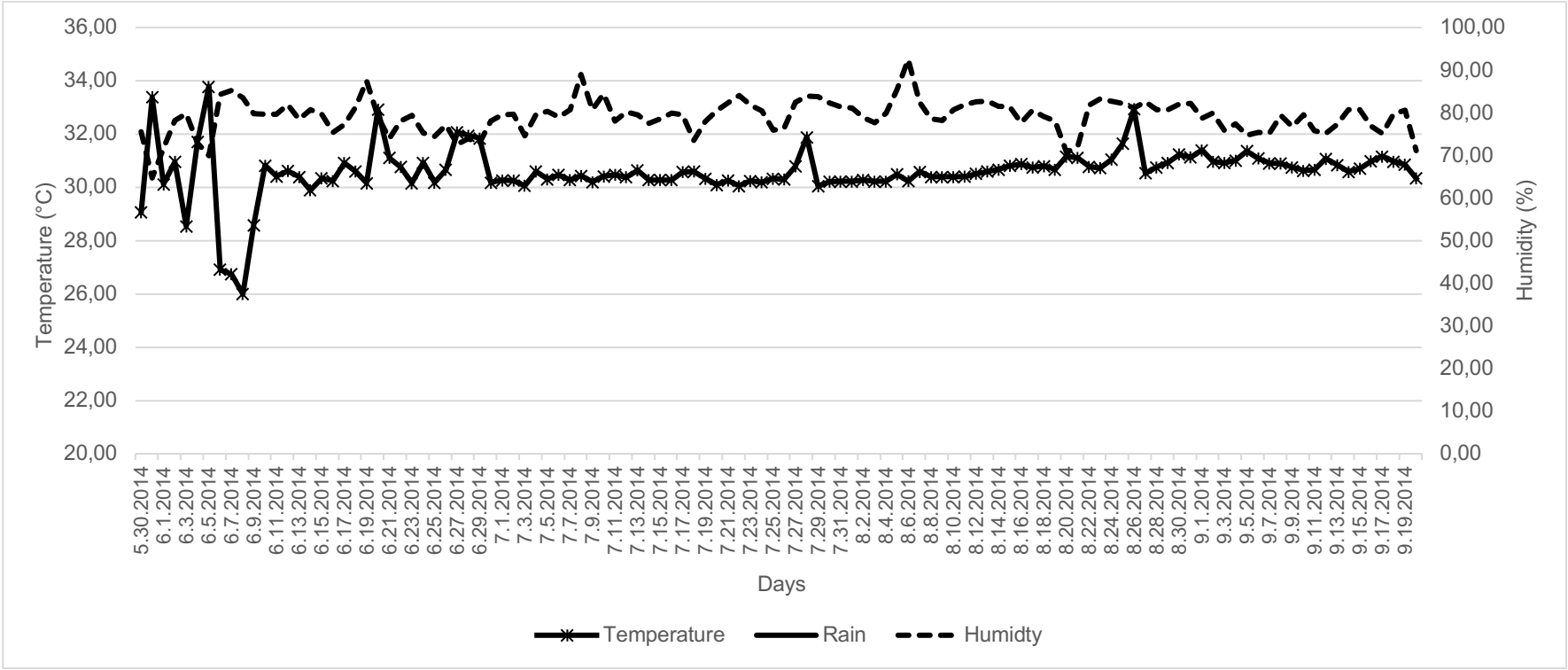


Figure 1. Temperature and humidity values throughout the trial period.

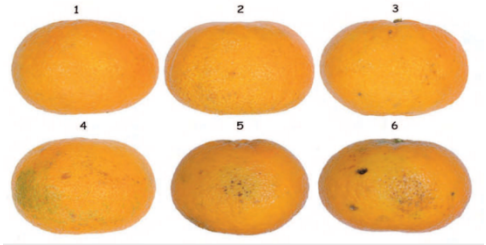


Figure 2. Sunburn scale

Table 1. Dosages, times, and numbers of kaolin treatments in the trial

The name of app.	First app.	10 days after	15 days after	30thday	45thday	60th day	75th day	90th day	Num. of app.
T1	*E-M (5%)	-	-	-	-	-	-	-	1
T2	E-M (5%)	5.0%	-	-	-	-	-	-	2
T3	E-M (5%)	-	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	7
T4	E-M (5%)	-	-	2.5%		2.5%	-	2.5%	4
T5	E-M (5%)	5.0%	2.5%	2.5%	2.5%	2.5%	-	-	6
T6	**M-J (5%)	-	-	-	-	-	-	-	1
T7	M-J (5%)	5.0%	-	-	-	-	-	-	2
T8	M-J (5%)	-	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	7
T9	M-J (5%)	-	-	2.5%		2.5%	-	2.5%	4
T10	M-J (5%)	5.0%	2.5%	2.5%	2.5%	2.5%	-	-	6
T11	Control	-	-	-	-	-	-	-	0

*E-M (End-May) , **M-J (Mid-June)

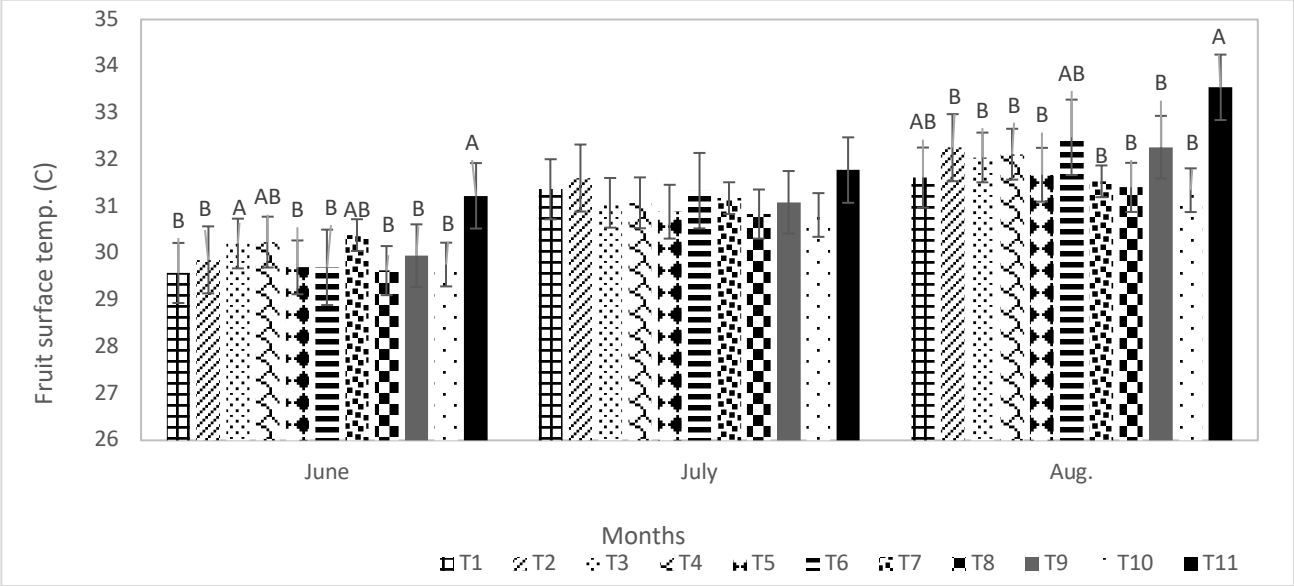


Figure 3. The effect of kaolin treatments on the change of fruit surface temperatures by months

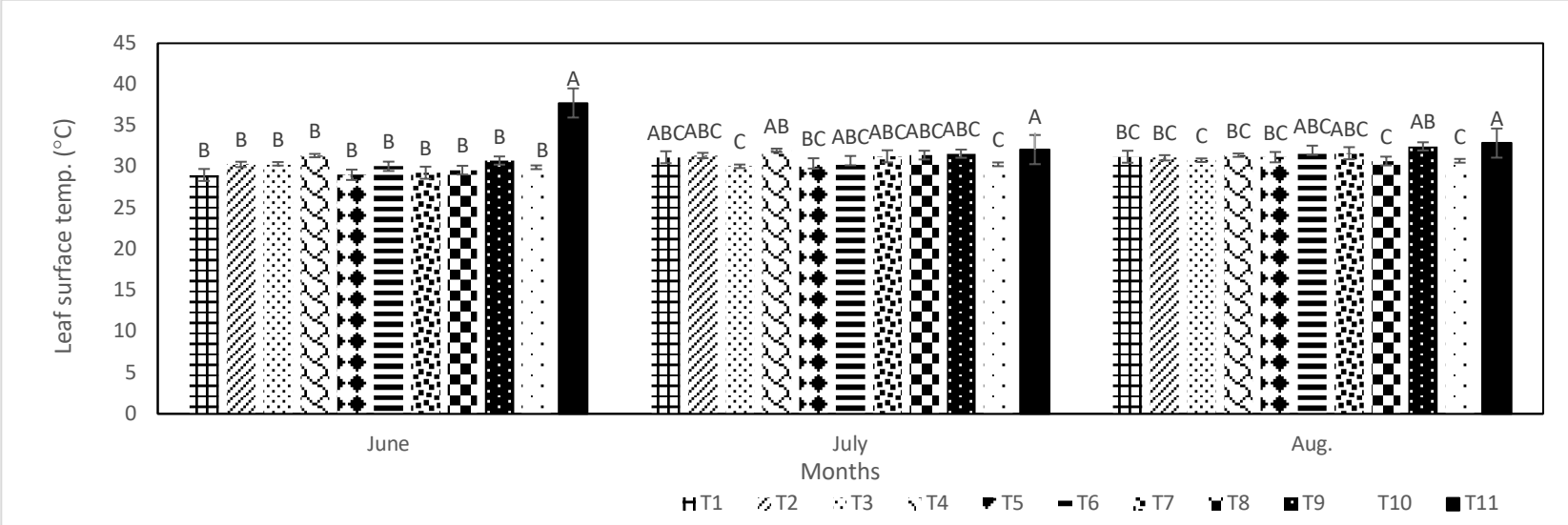


Figure 4. The effect of kaolin treatment on the change in leaf surface temperatures by months

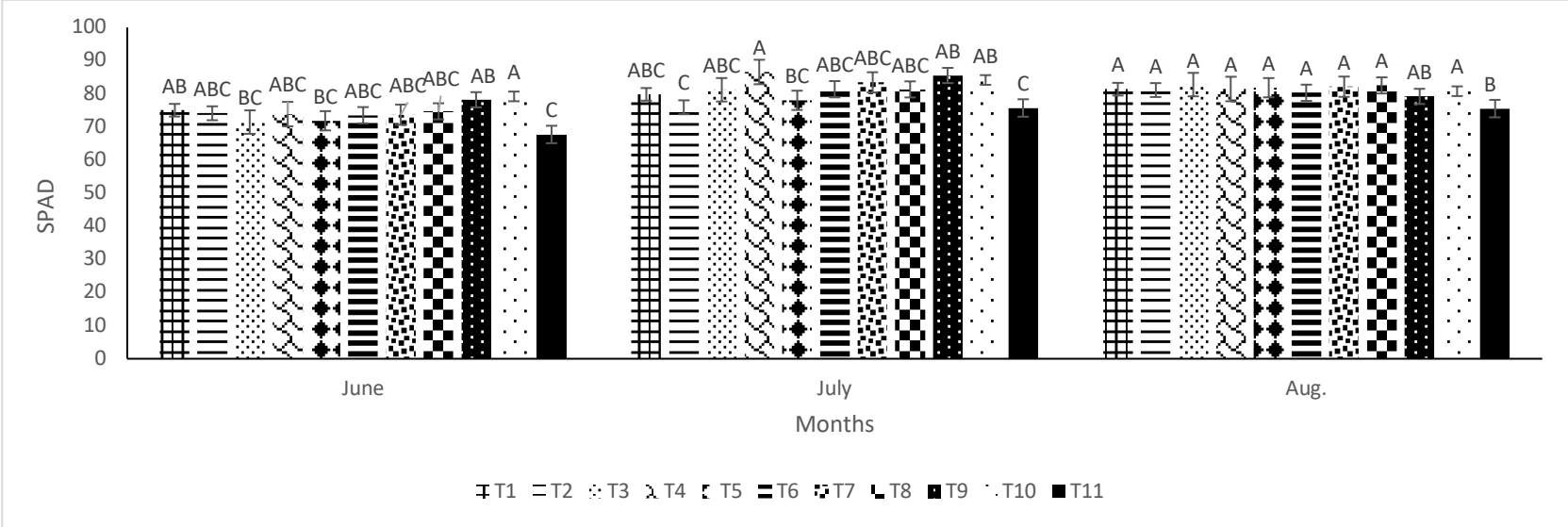


Figure 5. The effect of kaolin treatments on the change in leaf chlorophyll contents by months (µmol m^{-2})

Table 2. Effect of kaolin applications on Kl a, Kl b and total chlorophyll content according to months (mg/g ta)

The name of app.	June			July			August			Average		
	Kl a	**Kl b**	**Tot. Kl**	**Kl a**	**Kl b**	**Tot. Kl**	**Kl a**	**Kl b**	**Tot. Kl**	Kl a	Kl b	Tot. Kl
T1	1.17 a	0.09	2.02	1.17 abc[(1)]	0.097 ab	1.97	1.04 a	0.077 a	1.64 ab	1.13 A	0.090 A	1.88 AB
T2	0.44 b	0.09	1.87	1.13 abc	0.090 ab	1.81	0.91 abc	0.067 abc	1.38 bc	0.83 B	0.081 AB	1.69 ABC
T3	0.41 b	0.08	1.72	1.07 c	0.077 c	1.66	0.87 abc	0.060 abc	1.31 bc	0.78 B	0.073 B	1.56 BC
T4	0.46 b	0.09	1.86	1.08 bc	0.080 bc	2.11	0.86 abc	0.063 abc	1.33 bc	0.80 B	0.078 AB	1.77 ABC
T5	0.43 b	0.09	1.81	1.12 abc	0.086 abc	1.67	0.90 abc	0.063 abc	1.39 bc	0.82 B	0.079 AB	1.62 BC
T6	0.41 b	0.08	1.76	1.19 abc	0.093 abc	1.97	0.95 abc	0.070 abc	1.48 b	0.85 B	0.082 AB	1.75 ABC
T7	0.46 b	0.09	1.91	1.12 abc	0.090 abc	1.81	0.99 ab	0.073 ab	2.43 a	0.86 B	0.086 AB	2.05 A
T8	0.45 b	0.09	1.85	1.20 ab	0.097 ab	2.06	0.91 abc	0.067 ab	1.39 bc	0.85 B	0.084 AB	1.77 ABC
T9	0.44 b	0.08	1.88	1.19 abc	0.097 ab	2.02	0.54 c	0.057 abc	1.13 bc	0.72 B	0.080 AB	1.68 ABC
T10	0.54 b	0.11	2.26	1.21 a	0.100 a	2.06	0.62 abc	0.043 bc	0.94 bc	0.79 B	0.084 AB	1.75 ABC
T11	0.46 b	0.09	1.97	1.13 abc	0.087 abc	1.81	0.57 bc	0.040 c	0.52 c	0.72 B	0.073 B	1.43 C
Average	0.52 C	0.09 A	1.90 A	1.15 A	0.09 A	1.91 A	0.83 B	0.062 B	1.36 B			

Significantly	*(2)	*	*	*	*	*	*	*	*	*	*	*

(1): Values within the columns followed by unlike letters are significantly different by Duncan‟s multiple range test. z

N.S.: non significant; * : significant at 0.05 level

Table 3. Effect of kaolin applications on specific leaf area (SLA), leaf relative water content(LRWC), leaf thickness (LT) content according to months

The name of app.	**June**			**July**			**Aug.**			**Ave.**		
	SLA (cm^2/g dry weight)	LRWC (%)	LT (g fresh weight /cm^2)	SLA (cm^2/g dry weight)	LRWC (%)	LT (g fresh weight /cm^2)	SLA (cm^2/g dry weight)	LRWC (%)	LT (g fresh weight /cm^2)	SLA (cm^2/g dry weight)	LRWC (%)	LT (g fresh weight /cm^2)
T1	48.56 b	47.10 ab	0.05	54.90	63.56 ab	0.040 ab	60.63 ab	43.43	0.040	54.69	51.37 AB	0.043
T2	57.90 ab	40.53 bc(1)	0.04	53.06	64.20 ab	0.043 ab	63.41 ab	81.27	0.037	58.13	62.00 AB	0.041
T3	51.03 ab	47.13 ab	0.05	58.83	59.10 ab	0.040 ab	69.62 a	78.21	0.033	59.83	61.48 AB	0.041
T4	57.06 ab	48.17 a	0.04	58.24	68.14 a	0.036 b	50.85 b	87.43	0.043	55.38	67.91 A	0.041
T5	59.50 a	40.25 c	0.04	57.57	66.13 a	0.040 ab	58.68 ab	30.97	0.040	58.58	45.78 AB	0.040
T6	52.82 ab	41.95 abc	0.04	55.91	63.67 ab	0.043 ab	59.25 ab	29.96	0.040	55.99	45.20 B	0.042
T7	52.99 ab	45.25 abc	0.04	57.13	60.10 ab	0.040 ab	57.27 ab	80.76	0.040	55.83	62.04 AB	0.041
T8	54.44 ab	47.66 a	0.04	60.92	49.98 b	0.040 ab	59.19 ab	52.84	0.037	58.18	50.16 AB	0.041

T9	57.25 ab	43.91 abc	0.04	51.26	63.93 ab	0.047 a	56.82 ab	37.63	0.040	55.11	48.49 AB	0.042
T10	55.55 ab	42.21 abc	0.04	53.05	59.19 ab	0.043 ab	57.52 ab	85.71	0.040	55.37	62.37 AB	0.042
T11	54.50 ab	47.31 a	0.04	54.25	68.46 a	0.047 a	55.97 ab	50.43	0.040	54.91	55.40 AB	0.044
Average	54.69 B	44.68 B	0.045 A(1)	55.92 AB	62.41 A	0.042 B	59.03 A	59.88 A	0.039 C			
Significantly	*	*	*	*	*	*	*	*	*	NS.	*	NS.

(1): Values within the columns followed by unlike letters are significantly different by Duncan‟s multiple range test. z

N.S.: non significant; * : significant at 0.05 level

Table 4. Effects of kaolin applications on yield and some fruit quality traits

The name of app.	Yield (kg/tree)	Fruit weight (g)	Fruit width (mm)	Fruit size (mm)	Fruit rind thickness (mm)	Fruit juice (%)	Titratable acid(%)	Total soluble solid (%)	TSS/TA
T1	173.60 ab(1)	82.38 b(1)	57.45	46.01 b	2.07	48.06	1.12 b	7.68 c	6.89 ab
T2	171.40 abc	90.51 ab	56.41	45.25 b	1.83	55.53	1.17 b	7.96 abc	6.87 ab
T3	170.80 abc	83.05 b	56.62	45.22 b	1.83	53.20	1.16 b	8.00 abc	6.93 ab
T4	161.00 bc	90.96 ab	54.13	45.14 b	1.81	52.15	1.14 b	7.84 bc	6.86 ab
T5	177.80 ab	96.46 a	59.33	47.03 ab	2.00	57.22	1.16 b	7.96 abc	6.92 ab
T6	170.60 abc	83.05 b	57.65	46.61 ab	1.97	53.97	1.24 ab	7.96 abc	6.49 b
T7	172.40 ab	93.71 ab	58.21	48.84 a	2.11	57.42	1.33 a	8.12 abc	6.16 b
T8	181.80 a	99.33 a	58.00	47.20 ab	2.14	58.20	1.11 b	8.32 a	7.55 a

T9	169.20 abc	95.59 a	58.03	46.77 ab	2.08	55.57	1.19 b	7.96 abc	6.73 ab
T10	174.80 ab	87.52 ab	56.03	45.52 b	1.99	56.23	1.11 b	8.16 ab	7.44 a
T11	153.60 c	82.90 b	56.46	45.25 b	1.84	46.43	1.18 b	7.76 bc	6.57 b
Significantly	*(2)	*	NS[3]	*	NS.	NS.	*	*	*

(1): Values within the columns followed by unlike letters are significantly different by Duncan‟s multiple range test. z

N.S.: non significant; * : significant at 0.05 level

Table 5. Effects of kaolin applications on fruit peel color characteristics

The name of app.	L	a	b	c	Hu
T1	44.21	-16.23	31.65	35.60	117.40
T2	44.34	-16.26	31.62	35.60	117.46
T3	42.48	-15.47	30.24	34.03	117.53
T4	42.66	-15.64	30.11	33.99	117.95
T5	45.71	-16.28	30.60	34.70	118.45
T6	42.82	-15.28	29.89	33.62	117.58
T7	45.62	-15.92	32.01	35.86	117.05
T8	45.03	-15.52	29.91	33.76	117.63
T9	43.40	-15.14	28.38	32.24	118.55
T10	43.90	-15.63	29.87	33.75	118.04
T11	45.72	-16.20	32.43	36.32	117.03
Significantly	**Ö.D.**	**Ö.D.**	**Ö.D.**	**Ö.D.**	**Ö.D.**

Table 6. Marketable fruit yield amount (kg/tree)

The name of app.	Yield (kg/tree)	Marketable fruit rate(%)	Marketable fruit yield amount(kg/tree)
T1	173.60	99.20	172.21
T2	171.40	99.60	170.71
T3	170.80	100.00	170.80
T4	161.00	99.40	160.03
T5	177.80	99.80	177.44
T6	170.60	99.60	169.92
T7	172.40	99.50	171.54
T8	181.80	100.00	181.80
T9	169.20	99.80	168.86
T10	174.80	100.00	174.80
T11	153.60	95.20	146.23

ÜLKEMİZDE COĞRAFİ İŞARETLİ ÜZÜM ÇEŞİTLERİ VE ÜZÜM ÜRÜNLERİ

Tuba UZUN BAYRAKTAR

Doç.Dr, Siirt Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü, Siirt

Email: tubauzun@siirt.edu.tr

Aslı BAĞLICI

Yüksek Lisans Öğrencisi, Siirt Üniversitesi, Fen Bilimleri Enstitüsü, Bahçe Bitkileri ABD, Siirt

Email: aslibglc21@gmail.com

ÖZET

Küreselleşme süreciyle birlikte yerel değerlere olan ilgi artmakta; bu değerlerin korunması ise giderek daha fazla önem kazanmaktadır. Yöresel gıda ürünleri, yerel kültürün temel bileşenlerinden biri olarak öne çıkmakta olup, bu ürünlerin taklit edilmesini önlemek ve haksız rekabeti engellemek amacıyla birçok ülkede çeşitli hukuki düzenlemelere gidilmektedir. Bu düzenlemeler arasında yer alan coğrafi işaret sistemi, etkili bir koruma aracı olarak dikkat çekmekte ve Türkiye açısından stratejik bir öneme sahiptir.

Türk Patent ve Marka Kurumu'na göre coğrafi işaret; bir ürünün kökenini, ayırt edici özelliklerini ve bu özelliklerle üretim bölgesi arasındaki ilişkiyi tanımlayan, aynı zamanda tüketiciye kalite güvencesi sunan bir işaret türüdür. Gıda ve tarım ürünleri, el sanatları ve sanayi ürünleri gibi çeşitli kategorilerde birçok ürün bu kapsamda tescil edilebilmektedir. Coğrafi işaret tescili, ürünün menşei ve üretim sürecinin doğru biçimde tanımlanmasını sağlayarak yerel ürünlerin haksız rekabete karşı korunmasına katkı sunmaktadır. Bu sistem aracılığıyla ürünlerin geleneksel yapısı ve yöresel özellikleri güvence altına alınmaktadır.

Anadolu'nun zengin biyoçeşitliliği ile tarihsel ve kültürel birikimi, Türkiye'nin tarımsal ürün çeşitliliğini ve mutfak kültürünü besleyen temel kaynaklardandır. Bu bağlamda, ülkemizin coğrafi işaret alma potansiyeli yüksek çok sayıda ürünü bulunmakta olup, bu ürünlerin tescillenerek korunması hem ekonomik hem de kültürel açıdan önem arz etmektedir. Tescil edilen ürünler, tüketici nezdinde güvenilirlik kazanmakta ve pazarda rekabet avantajı elde etmektedir.

Üzümün anavatanı konumunda bulunan Türkiye'de, bugüne kadar coğrafi işaret tescili almış 110 yerel üzüm çeşidi ve üzüm ürünü bulunmaktadır. Bu ürünler, 33 farklı il tarafından tescillenmiş olup, bölgesel çeşitliliğin korunmasına katkı sağlamaktadır. Bu çalışmada, Türkiye'de tescil edilmiş yerel üzüm çeşitleri ve üzüm ürünleri ile bunların temel nitelikleri incelenmiştir. Özellikle kaybolma riski taşıyan yerel üzüm çeşitlerinin bir an önce tescillenmesi ve koruma altına alınması gerekmektedir. Bu doğrultuda, ilgili çalışmaların hızlandırılması büyük önem taşımaktadır.

Anahtar Kelimeler: Mahalli üzüm, tescilli ürün, kültürel önem

GEOGRAPHICALLY INDICATED GRAPE VARIETIES AND GRAPE PRODUCTS IN TURKEY

ABSTRACT

With the globalization process, interest in local values is increasing, and the protection of these values is becoming increasingly important. Local food products stand out as a fundamental component of local culture, and various legal regulations are being implemented in many countries to prevent imitation of these products and curb unfair competition. The geographical indication system, one of these regulations, stands out as an effective protection tool and is of strategic importance for Turkey.

According to the Turkish Patent and Trademark Office, a geographical indication is a type of designation that identifies the origin of a product, its distinctive features, and the relationship between these features and the production region. It also provides quality assurance to consumers. Many products in various categories, such as food and agricultural products, handicrafts, and industrial products, can be registered under this system. Geographical indication registration contributes to the protection of local products against unfair competition by ensuring the accurate identification of the product's origin and production process. This system safeguards the traditional structure and regional characteristics of products.

The rich biodiversity and historical and cultural heritage of Anatolia are the fundamental resources that nourish Turkey's agricultural product diversity and culinary culture. In this context, our country has numerous products with high potential for geographical indication, and registering and protecting these products is of both economic and cultural importance. Registered products gain credibility with consumers and a competitive advantage in the market.

Turkey, the homeland of grapes, has 110 local grape varieties and grape products registered with geographical indications to date. These products are registered in 33 different provinces, contributing to the preservation of regional diversity. This study examines the local grape varieties and grape products registered in Turkey and their fundamental characteristics. Local grape varieties, particularly those at risk of extinction, need to be registered and protected as soon as possible. Therefore, accelerating relevant efforts is crucial.

Keywords: Local grape, registered product, cultural significance

GİRİŞ

Asmanın insanlar tarafından tanınması Yontma Taş Devri'ne (Paleolitik Dönem, yaklaşık 2 milyon yıl önce), kültüre alınması ve şarap üretiminin başlaması ise Cilalı Taş Devri'ne (Neolitik Dönem, M.Ö. 8500–4000) dayanmaktadır. Bağcılık ve şarap kültürünün gelişerek yayılması ise Bakır Çağı'nda (Kalkolitik Dönem, M.Ö. 5000–3000) gerçekleşmiştir. Tarihî kaynaklar ve arkeolojik bulgular, yabani asmanın (*Vitis vinifera sylvestris*) ilk kez Kuzeydoğu Anadolu ile Kafkas Dağları arasında yer alan Transkafkasya bölgesinde kültüre alındığını ve şarap üretiminde kullanılmaya başlandığını göstermektedir. Bu kültür daha sonra Anadolu üzerinden Aşağı Mezopotamya ve Mısır'a (M.Ö. 3500–3000), ardından da Girit Adası'na (M.Ö. 2200) ulaşmıştır. Roma İmparatorluğu Dönemi'nde ise bağcılık ve şarapçılık kültürü Avrupa'ya taşınmış, koloniler aracılığıyla nehir vadilerini izleyerek kıtanın iç kesimlerine doğru yayılmıştır (McGovern, 2007).

Üzüm, dünyada kültürü yapılan en eski meyve türlerinden biridir. Anavatanı, Anadolu'yu da içine alan Küçük Asya ile Kafkasya'yı kapsayan bölge olarak kabul edilmektedir. Üzüm, diğer meyve türleriyle karşılaştırıldığında en fazla çeşide sahip olanlardan biridir ve dünya genelinde 15.000'in üzerinde çeşidinin bulunduğu tahmin edilmektedir. Anavatanı Anadolu olan üzüm çeşitlerinin sayısı ise 1.200'ü aşmaktadır. Bu çeşitler, Tekirdağ Bağcılık Araştırma Enstitüsü bünyesinde kurulan Millî Koleksiyon Bağı'nda muhafaza edilmektedir. Ancak bu çeşitlerden yalnızca 50–60 kadarı ekonomik olarak üretime konu olmaktadır. Üzümler taze olarak sofralık tüketilebildiği gibi; şarap, reçel, üzüm suyu, jöle, üzüm çekirdeği özü, kuru üzüm, sirke ve üzüm çekirdeği yağı üretiminde de kullanılmaktadır (Anonim, 2024d).

Coğrafi işaretler, bir ürünün kaynağını, karakteristik özelliklerini ve bu özelliklerin ürünle coğrafi alan arasındaki ilişkisini gösteren ve garanti eden kalite işaretleridir. Coğrafi işaret tescili, kalitesi, gelenekselliği, yöreden elde edilen hammaddesi ve yerel niteliklere bağlı olarak belirli bir üne kavuşmuş ürünlerin korunmasını sağlar. Belirgin bir niteliği, ünü veya diğer özellikleri bakımından kökeninin bulunduğu yöre, alan, bölge ya da ülke ile özdeşleşmiş ürünleri gösteren bu işaretler, menşe adı veya mahreç işareti olarak tescil edilebilmektedir. Gıda, tarım, maden, el sanatları ve sanayi ürünleri coğrafi işaret tesciline konu olabilmektedir (Anonim, 2024f).

Bağ Bölgelerimiz



Şekil 1. Bağ bölgelerimiz

1.Ortakuzey Bölgesi

Bölgenin öne çıkan illeri arasında Çorum, Kırşehir, Bilecik, Yozgat, Uşak, Ankara ve Kırıkkale bulunmaktadır. Serin iklim özellikleri ve vejetasyon döneminin kısa olması, geç olgunlaşan üzüm türlerinin yetiştirilmesini kısıtlamaktadır. Son yıllarda, özellikle floksera zararlısının etkisi başta olmak üzere çeşitli etkenler nedeniyle bağcılık faaliyetlerinde belirgin bir gerileme yaşanmıştır. Ancak Ata Sarısı, Yalova İncisi ve Ergin Çekirdeksizi gibi yeni ıslah edilen üzüm çeşitleriyle yapılan adaptasyon çalışmaları, umut verici sonuçlar ortaya koymuştur (Şekil 1) (Çelik ve ark., 1998).

2.Ege Bölgesi

Türkiye'nin başlıca bağcılık merkezlerinden biri olan bu bölge, iklimsel özelliklerine göre üç alt bölgeye ayrılmaktadır (Şekil 1):

Orta Kesim: Manisa, Denizli ve İzmir illerini kapsayan bu bölüm, dünyaca ünlü çekirdeksiz üzüm çeşitlerinin yetiştirildiği bir alandır. Sofralık ve kuru üzüm üretiminde yüksek verim ve kalite potansiyeli ile dikkat çeker.

Kuzeybatı Kesim: Çanakkale ve Balıkesir illerini içine alan bu alan, Marmara Bölgesi'nin ılıman iklim koşullarını yansıtır. Bu nedenle bağcılık faaliyetleri daha elverişli sıcaklık ve nem koşulları altında sürdürülmektedir.

Güneydoğu Kesim (Göller Yöresi): Isparta ve Burdur illerini kapsayan bu kesim, İç Anadolu ve Akdeniz iklimleri arasında geçiş özelliği taşımaktadır. Bu durum, yöredeki üzüm çeşitliliğini artırmakta ve yetiştirme tekniklerini önemli ölçüde etkilemektedir (Çelik ve ark., 1998).

3.Marmara Bölgesi

Ege ve Akdeniz bölgeleriyle birlikte ele alındığında, Trakya'da da modern bağcılık uygulamalarının yaygınlaştığı görülmektedir. Bölge genelinde bağcılık açısından en dikkat çekici il Tekirdağ olup yüksek üretim kapasitesi ve ürün çeşitliliğiyle öne çıkmaktadır. Trakya'nın Anadolu yakasında ise Bursa ve Sakarya illeri bağcılık faaliyetlerinin yoğun biçimde sürdürüldüğü önemli üretim merkezleri arasında bulunmaktadır (Şekil 1) (Çelik ve ark., 1998).

4.Akdeniz Bölgesi

Bağ alanı genişliği ve üzüm üretim miktarı bakımından Türkiye'de Ege Bölgesi'nden sonra ikinci sırada yer alan bu bölge, bağcılık açısından önemli bir konuma sahiptir. Mersin, Adana, Hatay, Antalya, Gaziantep, Kilis ve Kahramanmaraş illerinde yoğunlaşan bağcılık faaliyetleri, bölgenin sofralık ve işlenmiş üzüm ürünleri üretiminde yüksek potansiyel taşıdığını göstermektedir (Şekil 1) (Çelik ve ark., 1998).

5.Kuzeydoğu Anadolu Bölgesi

Yüksek rakımlı arazilerin yaygın olduğu bu bölgede, Erzincan ve Artvin illerinde daha çok yerel ihtiyaçları karşılamaya yönelik sınırlı bağcılık faaliyetleri gerçekleştirilmektedir. Buna karşılık, Iğdır ile Erzurum'un bazı ilçeleri, iklim koşulları açısından bağcılığa elverişli potansiyel alanlar arasında değerlendirilmektedir (Şekil 1) (Çelik ve ark., 1998).

6.Güneydoğu Anadolu Bölgesi

Güneydoğu Anadolu Bölgesi'nde, bağcılık faaliyetleri açısından Şanlıurfa, Diyarbakır ve Mardin illeri öne çıkmaktadır. Buna karşın, Bingöl, Muş, Bitlis, Van, Şırnak ve Hakkari gibi iller, yüksek rakımlı ve engebeli topoğrafyaya sahip olmaları nedeniyle Türkiye'nin bağcılık potansiyeli en sınırlı bölgeleri arasında yer almaktadır. Özellikle düşük sıcaklık değerlerinin

yarattığı kısıtlayıcı etkiler, bu illerde bağcılık faaliyetlerinin dar alanlarda ve düşük yoğunlukta yürütülmesine neden olmaktadır (Şekil 1) (Çelik ve ark., 1998).

7.Karadeniz Bölgesi

Karabük ve Kastamonu illerinde, bağcılık faaliyetleri yerel tüketimi karşılamaya yönelik küçük ölçekli üretim şeklinde yürütülmektedir. Bu illerde gerçekleştirilen sofralık üzüm yetiştiriciliği, ticari üretimden ziyade mahalli ihtiyaçları karşılamaya yönelik olup, sınırlı alanlarda sürdürülen geleneksel bağcılık uygulamaları niteliği taşımaktadır (Şekil 1) (Çelik ve ark., 1998).

8.Ortadoğu Anadolu Bölgesi

Bölge, iklim ve bağcılık özellikleri açısından iki alt bölgeye ayrılmaktadır. Tokat ve Amasya illeri, geçit kuşağında yer almaları nedeniyle daha ılıman karasal iklim koşullarına sahiptir. Diğer alt bölgeyi ise Malatya, Elazığ ve Adıyaman illeri oluşturmaktadır. Bu ayrım, bölgedeki bağcılık faaliyetlerinin çeşitliliği ve üretim potansiyeli üzerinde belirleyici bir rol oynamaktadır (Şekil 1) (Çelik ve ark., 1998).

9.Orta Güney Bölgesi

Bağ alanı genişliği ve üzüm üretim miktarı bakımından Türkiye'de Ege ve Akdeniz bölgelerinden sonra üçüncü sırada yer alan bu bölge, özellikle Konya, Nevşehir ve Karaman illeriyle ön plana çıkmaktadır. Bunun yanı sıra, Aksaray ve Niğde illeri de önemli bağcılık merkezleri arasında bulunmaktadır. Ayrıca, Kayseri ve Afyon illerinin bazı yörelerinde de sınırlı ölçekte bağcılık faaliyetleri sürdürülmektedir (Şekil 1) (Çelik ve ark., 1998).

COĞRAFİ İŞARETLİ ÜZÜM ÇEŞİDİ VE ÜZÜM ÜRÜNLERİMİZ

1. Ortakuzey Bölgesi

1.a) Ankara Kalecik Karası Üzümü

Türkiye'nin önde gelen kırmızı şaraplık üzüm türlerinden biridir. Fidan dikiminden sonra ortalama üç yıl içinde ürün alınabilir. 06.07.2007 yılında Kalecik Belediyesi tarafından tescil edilmiştir (Şekil 2a) (Anonim, 2025g; Anonim, 2025h).

1.b) Ankara Beypazarı Yaprak Sarması

İnce, sıkı ve küçük şekilde sarılması ile genellikle sulu biçimde servis edilmesi, bu ürünün coğrafi bölgeye özgü özellikler taşıdığını göstermektedir. 20.05.2022 yılında Beypazarı Belediyesi tarafından tescil edilmiştir (Şekil 2b) (Anonim, 2025g; Anonim, 2025h).

1.c) Ankara Beypazarı Cevizli Tatlı Sucuk

İpe dizilen ceviz içleri, sıcak sucuk hamuruna iki defa batırılır ve ardından açık havada asılarak kurutulur. 07.04.2022 yılında Beypazarı Belediyesi tarafından tescil edilmiştir (Şekil 2c) (Anonim, 2025g; Anonim, 2025h).



Şekil 2. Ortakuzey bölgesi üzüm ve üzüm ürüleri

2. Ege Bölgesi

2.a) Balıkesir Avşa Ada Karası Üzümü

Genellikle şıra ve şarap üretiminde değerlendirilen bir üzüm çeşididir. 24.01.2023 yılında Erdek Ticaret Odası tarafından tescil edilmiştir (Şekil 3a) (Anonim, 2025g; Anonim, 2025h).

2.b) Balıkesir Avşa Ada Karası Şarabı

Avşa Adakarası Şarabı, Avşa Adakarası üzümünün işlenmesi sonucu elde edilen yerel bir şarap türüdür. Bu şarapta bulunan toplam tanen miktarı 3,47 ile 5,99 g/l arasında değişmektedir. 07.05.2025 yılında Erdek Ticaret Odası tarafından tescil edilmiştir (Şekil 3b) (Anonim, 2025g; Anonim, 2025h).

2.c) Çanakkale Bozcaada Çavuş Üzümü

Puslu sarımsı-yeşil renge sahip, iri ve yuvarlak ya da oval biçimli taneleri bulunan, seyrek salkımlı, ince kabuklu ve yarı saydam damarlı bir üzüm çeşididir. Hasat sonrasında genellikle taze olarak tüketilen Bozcaada Çavuş üzümü, son yıllarda kısmen şarap üretiminde de kullanılmaya başlanmıştır. 02.06.2020 yılında Bozcaada Tarımsal Kalkınma Kooperatifi tarafından tescil edilmiştir (Şekil 3c) (Anonim, 2025g; Anonim, 2025h).

2.d) Denizli Çalkarası Üzümü

Morumsu-siyah renge sahip, orta büyüklükte, dolgun, etli ve sulu taneleri bulunan bir üzüm çeşididir. Kabuğu orta kalınlıktadır. Düşük toplam asit içeriği ve dengeli duyusal özellikleri nedeniyle hem şarap üretiminde hem de kurutmalık olarak değerlendirilmektedir. 07.12.2020 yılında Çal Ziraat Odası tarafından tescil edilmiştir (Şekil 3d) (Anonim, 2025g; Anonim, 2025h).

2.e) Denizli İsabey Çekirdeksiz Üzümü

Beyaz renkte ve uzun elips biçimli tanelere sahip bir üzüm çeşididir. Avrupa'ya ihracatı gerçekleştirilmektedir. Genellikle sofralık olarak tüketilmekle birlikte, kurutmalık, şaraplık ve pekmez üretiminde de değerlendirilmektedir. 01.08.2006 yılında Çal Belediyesi tarafından tescil edilmiştir (Şekil 3e) (Anonim, 2025g; Anonim, 2025h).

2.f) Isparta Senirkent Dimrit Üzümü

Sofralık tüketimin yanı sıra şıra ve pekmez üretiminde de değerlendirilmektedir. Senirkent Dimrit üzümü, mor-siyah renkli ve oval biçimli, çekirdekli tanelere sahiptir. Salkımları orta büyüklükte olup konik formda ve sık yapıdadır. 10.02.2022 yılında Senirkent Belediyesi tarafından tescil edilmiştir (Şekil 3f) (Anonim, 2025g; Anonim, 2025h).

2.g) Isparta Senirkent Üzüm Pekmezi

Oval şekilli, mor-siyah renkli ve çekirdekli tanelere sahiptir. Bu pekmez, Dimrit üzümünden üretilmektedir. 17.03.2022 yılında Senirkent Belediyesi tarafından tescil edilmiştir (Şekil 3g) (Anonim, 2025g; Anonim, 2025h).

2.h) İzmir Bornova Misket Üzümü

Salkımları orta büyüklükte olup konik-silindirik bir yapıya sahiptir. Taneleri beyaz-sarı renkte, çekirdekli, yuvarlak ve orta büyüklüktedir; kalın kabuklu, sulu ve düşük asitlidir. En belirgin özelliği güçlü aroması ve tat açısından zengin yapısıdır. 07.04.2021 yılında Bornova Belediyesi tarafından tescil edilmiştir (Şekil 3h) (Anonim, 2025g; Anonim, 2025h).

2.ı) İzmir Ege Sultani (çekirdeksiz) Üzümü

Salkımları kanatlı yapıdadır ve taneleri uzun, yuvarlak biçimli olup sarıdan sarı-yeşil tonlarına sahiptir. Taneler sulu, etli ve gevrektir; ayrıca çekirdeksizdir. 27.07.2003 yılında İzmir Ticaret Borsası tarafından tescil edilmiştir (Şekil 3ı) (Anonim, 2025g; Anonim, 2025h).

2.i) İzmir Gökçealan Osmancık Üzümü

Salkımları orta büyüklükte, taneleri ise iri olup yeşilimsi açık sarı renkte, ince kabuklu ve yuvarlak biçimdedir. Bu üzüm çeşidi sofralık, kurutmalık, şıralık ve şaraplık olarak değerlendirilmeye uygundur. 25.08.2023 yılında Selçuk Belediyesi tarafından tescil edilmiştir (Şekil 3i) (Anonim, 2025g; Anonim, 2025h).

2.j) İzmir Kavacık Üzümü

Mor-siyah renge sahip, parlak görünümlü ve iri taneli bir üzüm çeşididir. Kalın kabuklu yapısı ve uygun saklama koşullarında yüksek dayanıklılığı ile sofralık kullanım için uygundur. 20.12.2019 yılında Karabağlar Belediyesi tarafından tescil edilmiştir (Şekil 3j) (Anonim, 2025g; Anonim, 2025h).

2.k) İzmir Bademli Koruk Şerbeti

Dikili'nin Bademli mahallesinde yapılan Bademli Koruk Şerbeti, siyah yediveren üzümünün koruğu, su, şeker ve ıtır otu ile hazırlanır. Tadı ekşi ve mayhoş bir içim sunar. 08.05.2023 yılında Dikili İlçe Tarım ve Orman Müdürlüğü tarafından tescil edilmiştir (Şekil 3k) (Anonim, 2025g; Anonim, 2025h).

2.l) Manisa Sultani Çekirdeksiz Üzümü

Salkımları orta büyüklükte ve normal yoğunlukta, taneleri eliptik-yuvarlak biçimli, yeşil-sarı renkte ve ince kabukludur. Sofralık, kurutmalık ve şıralık niteliklerin tamamını yüksek derecede sergileyen, verim ve yapısal gelişim açısından standart bir üzüm çeşididir. 18.02.2019 yılında Manisa Ticaret Borsası tarafından tescil edilmiştir (Şekil 3l) (Anonim, 2025g; Anonim, 2025h).

2.m) Manisa Saruhanlı Çekirdeksiz Beyaz Üzümü

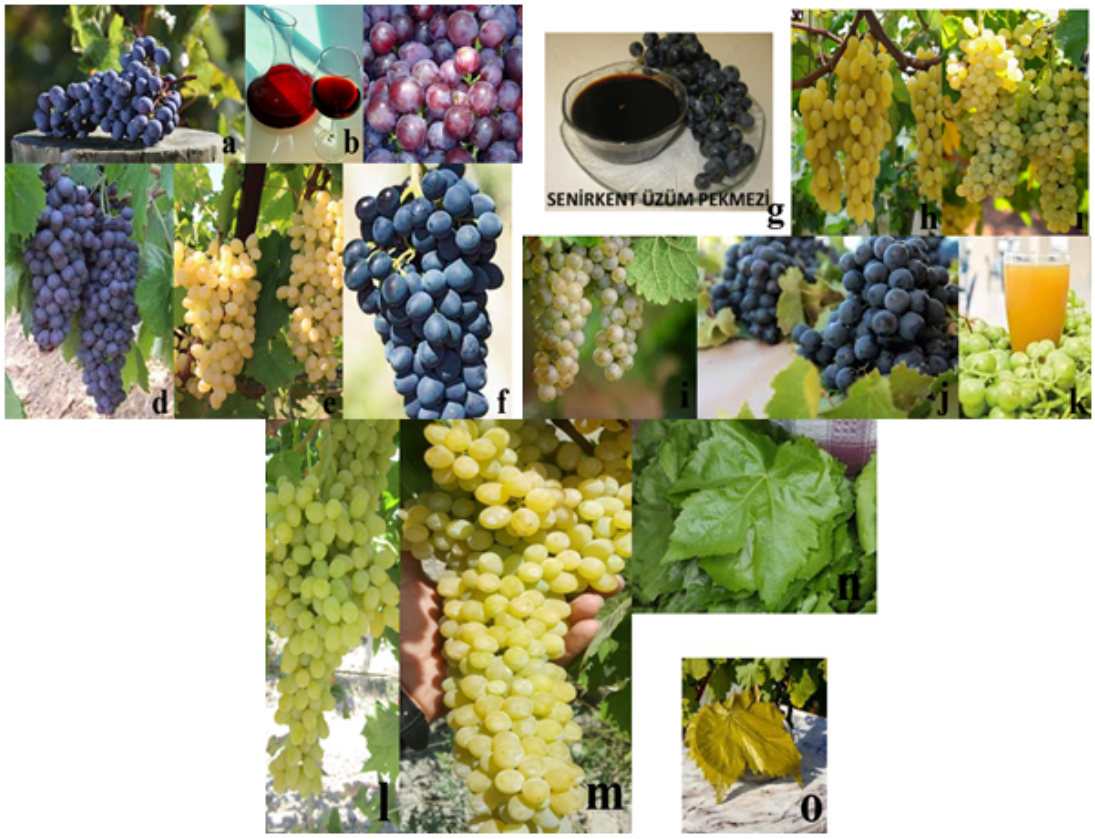
Orta büyüklükte ve normal yoğunluktaki salkımlara sahip olan bu üzümün taneleri yuvarlak-eliptik biçimli, yeşil-sarı renkte, çekirdeksiz, sulu, etli ve ince kabukludur. 12.08.2021 yılında Saruhanlı Esnaf ve Sanatkârlar Odası tarafından tescil edilmiştir (Şekil 3m) (Anonim, 2025g; Anonim, 2025h).

2.n) Manisa Alaşehir Asma Yaprağı

Alaşehir Asma Yaprağı, coğrafi sınırda yetişen çekirdeksiz üzüm çeşitlerinin genç sürgünlerinden toplanır. Nisan sonundan haziran ortasına kadar 8–10 günlük aralıklarla toplanan yapraklar taze, kuru veya salamura edilerek dolma ve sarma yapımında kullanılır. Yapraklar yeşil ile koyu yeşil renkte, damarsız, ince, tüysüz ya da az tüylü ve damakta hafif ekşi bir tat bırakacak niteliktedir. 17.09.2021 yılında Alaşehir Ticaret ve Sanayi Odası tarafından tescil edilmiştir (Şekil 3n) (Anonim, 2025g; Anonim, 2025h).

2.o) Manisa Asma Yaprağı

Coğrafi sınırda üretilen Manisa Asma Yaprağı, 418 tescilli Manisa Sultani Çekirdeksiz üzümünün taze yapraklarından elde edilir. Yapraklar açık yeşil renkte, ince ve az tüylü olup genellikle dilimsizdir; damarsız veya az damarlıdır ve salamura edilerek kullanılır. 07.02.2023 yılında Manisa İl Tarım ve Orman Müdürlüğü tarafından tescil edilmiştir (Şekil 3o) (Anonim, 2025g; Anonim, 2025h).



Şekil 3. Ege bölgesi üzüm ve üzüm ürüleri

Manisa İlinde Tescil Edilen Üzüm Çeşitleri

107G116 nolu tübitak projesi kapsamında melezleme çalışmaları sonucunda ıslah edilip tescil edilmiştir. Tescil edilen üzüm çeşitleri;

Spil Karası üzümü (2016), Manisa Pembesi üzümü (2016), Lidya üzümü (2016), Ece üzümü (2016), Mesir üzümü (2016), Beyra üzümü (2017), Efem üzümü (2017)'dür (Anonim, 2024a).

3. Marmara Bölgesi

3.a) Bursa İznik Müşküle Üzümü

Taneleri oldukça iri ve hafif eliptik biçimli olan üzüm, kalın kabuklu, puslu ve şeffaf bir görünüme sahiptir; rengi sarı-yeşildir. Hasada yakın dönemlerde, tanelerin güneş gören kısımları kızarır. 20.08.2021 yılında İznik Belediyesi tarafından tescil edilmiştir (Şekil 4a) (Anonim, 2025g; Anonim, 2025h).

3.b) Bursa Üzüm Şırası

Çekirdekli siyah kuru üzüm, içme suyu ve isteğe bağlı olarak beyaz şeker kullanılarak üretilen alkolsüz bir içecektir. Renk dengesi sağlamak amacıyla siyah havuç suyu eklenir. 09.08.2021 yılında Bursa Ticaret ve Sanayi Odası tarafından tescil edilmiştir (Şekil 4b) (Anonim, 2025g; Anonim, 2025h).

3.c) Tekirdağ Yapıncak Salamura Asma Yaprağı

Yapıncak üzüm çeşidinden elde edilen asma yaprakları, üretimde kullanılır. 28.10.2020 yılında Süleymanpaşa Ziraat Odası tarafından tescil edilmiştir (Şekil 4c) (Anonim, 2025g; Anonim, 2025h).



Şekil 4. Marmara bölgesi üzüm ve üzüm ürüleri

Tekirdağ İlinde Tescil Edilen Üzüm Çeşitleri

Tübitak projesi kapsamında melezleme çalışmaları sonucunda ıslah edilip tescil edilmiştir.

Trakya İlkeren (1991), Barış (1991), Tekirdağ Çekirdeksizi (1991), Reçel Üzümü (1993), Güz Üzümü (1993), Güz Gülü (2011), Bozbey (2011), Tekirdağ Misketi (2011), Tekirdağ Sultani (2011), Özer Karası (2011), Gönülçelen (2016), Cengizbey (2016), Emirali (2016), Gürnil (2016), Kebeli (2016), Özer Beyazı (2016), Süleymanpaşa Beyazı (2016), Karamenüş (2018), Yayla (2018), Aksıdağan (2023), Alço (2023), Gümüş 59 (2023), Saklıkara (2023)'dır (Anonim, 2024b).

Yalova İlinde Tescil Edilen Üzüm Çeşitleri

Tübitak projesi kapsamında melezleme çalışmaları sonucunda ıslah edilip tescil edilmiş diğer üzüm çeşitleri ise; Ata Sarısı (1990), Yalova Çekirdeksizi (1990), Yalova İncisi (1990), Yalova Misketi (1990), Uslu (1990), Ergin Çekirdeksizi (1991), Atak 77 (2012), İsmetbey (2012), Pembe 77 (2012), Arifbey (2013), Samancı Çekirdeksizi (2013), Yalova Beyazı (2013)'dır (Anonim, 2024c).

4. Akdeniz Bölgesi

4.a) Margaz Üzümü

Kaş ilçesinde yetiştirilen bu üzüm, genellikle sofralık olarak tüketilir. Coğrafi sınır, killi-tınlı ve kumlu-killi-tınlı toprak yapısına sahip olup, organik madde içeriği yeterli seviyededir. Toprakların pH'ı hafif alkali, kireç oranı yüksek, tuzsuz ve drenaj sorunu bulunmamaktadır. 02.05.2025 yılında Kumluca Ticaret ve Sanayi Odası tarafından tescil edilmiştir (Şekil 5a) (Anonim, 2025g; Anonim, 2025h).

4.b) Gaziantep Karası Kuru Üzümü

Antep Karası kuru üzümü, Horoz Karası üzüm çeşidinden elde edilen yaş üzümlerin kurutulması ile üretilir. Yassı formda olan kuru üzümün kabuk rengi siyah, meyve eti koyu kahverengidir ve tanenli aroması ile vardır. 07.04.2022 yılında Gaziantep Ticaret Borsası tarafından tescil edilmiştir (Şekil 5b) (Anonim, 2025g; Anonim, 2025h).

4.c) Gaziantep Pekmezi

Gaziantep ilinde üretilen bu yöresel katı üzüm pekmezi, macun kıvamında ve amber renklidir. Tüketim sırasında ekmek üzerine sürülerek yenilebildiği gibi, eritilerek şurup şeklinde de kullanılabilir. 24.07.2020 yılında Gaziantep Ticaret Borsası tarafından tescil edilmiştir (Şekil 5c) (Anonim, 2025g; Anonim, 2025h).

4.d) Gaziantep Koruk Ekşisi

Gaziantep koruk ekşisi, koruk suyunun kaynatılması veya güneş altında bekletilerek koyulaştırılması ya da korukların kurutulup öğütülmesi yoluyla elde edilen lezzet verici bir üründür. Koruklar, üzümlerin henüz olgunlaşmadığı dönemde, üreticiler tarafından yapılan salkım seyreltme işlemi sırasında toplanır. Gaziantep mutfağında önemli bir yeri olan bu ekşi,

dolmalarda, salatalarda ve çeşitli yemeklerde yaygın olarak kullanılır. 11.04.2022 yılında Gaziantep Büyükşehir Belediyesi tarafından tescil edilmiştir (Şekil 5d) (Anonim, 2025g; Anonim, 2025h).

4.e) Gaziantep Şirin Tarhanası

Gaziantep Şirin Tarhanası, üzüm suyu veya üzüm pekmezinin, coğrafi sınır içinde "çiğ simit" olarak adlandırılan çok ince çekilmiş, pişmemiş sert buğday ile kaynatılmasıyla elde edilen yoğun kıvamlı karışımın kurutulmasıyla üretilen geleneksel bir tatlıdır. Ürün, genellikle atıştırmalık olarak tüketilir. 15.04.2022 yılında Gaziantep Büyükşehir Belediyesi tarafından tescil edilmiştir (Şekil 5e) (Anonim, 2025g; Anonim, 2025h).

4.f) Antakya Zılk Sarması

Antakya Zılk Sarması, Hatay mutfağına özgü bir lezzet olup; pazı yaprakları, pirinç, su, zeytinyağı, kuru soğan, sarımsak, salça, nar ekşisi, toz şeker, tuz ve çeşitli baharatların bir araya getirilmesiyle hazırlanır. Hatay yöresinde pazı bitkisine halk arasında "zılk" denildiği için, bu yemek "Antakya Zılk Sarması" adıyla anılmaktadır. 06.05.2024 yılında Hatay Valiliği tarafından tescil edilmiştir (Şekil 5f) (Anonim, 2025g; Anonim, 2025h).

4.g) Hatay Belen Kömürçukuru Pekmezi

Üretim teknolojisi gereği sıvı üzüm pekmezine katı üzüm pekmezi eklenerek yapılan bu pekmez, sürülebilir bir yapıya sahiptir. Renk tonları krem-kahverengiden açık kahverengiye kadar değişir. 28.07.2021 yılında İskenderun Ticaret ve Sanayi Odası tarafından tescil edilmiştir (Şekil 5g) (Anonim, 2025g; Anonim, 2025h).

4.h) Hatay Barburi Üzümü

Hatay'a özgü Barburi üzümü, yalnızca sofralık olarak değil; aynı zamanda pekmez, sirke ve şarap üretiminde de değerlendirilir. 28.04.2025 yılında Antakya Ticaret ve Sanayi Odası tarafından tescil edilmiştir (Şekil 5h) (Anonim, 2025g; Anonim, 2025h).

4.ı) Hatay Pirzolalı Yaprak Sarması

Hatay Pirzolalı Yaprak Sarması, taze asma yapraklarıyla hazırlanabildiği gibi salamura yapraklarla da yapılabilen yöresel bir yemektir. Bu yemeğin karakteristik özelliği, kuzu pirzolasıyla birlikte pişirilmesi ve iç harcında kıyma kullanılmasıdır. Kendine özgü pirzola ve asma yaprağı aroması sayesinde, Hatay mutfağındaki diğer sarma çeşitleri arasında özel bir yere sahiptir. 21.04.2025 yılında Hatay Valiliği tarafından tescil edilmiştir (Şekil 5ı) (Anonim, 2025g; Anonim, 2025h).

4.i) Hatay Yaprak Sarması

Hatay Yaprak Sarması, pilavlık pirinç, biber ve domates salçası, kuru soğan, sarımsak, nar ekşisi, karabiber ve zeytinyağıyla hazırlanan iç harcın asma yapraklarına sarılarak pişirilmesiyle elde edilen yöresel bir yemektir. Bu yemek, asma bitkisinin taze veya salamura yaprakları kullanılarak hazırlanabilir. İç harcında, 1361 tescil numarasına sahip coğrafi işaretli Hatay Nar Ekşisi kullanılması, yemeğe kendine özgü bir lezzet kazandırmaktadır. 23.12.2024 yılında Hatay Valiliği tarafından tescil edilmiştir (Şekil 5i) (Anonim, 2025g; Anonim, 2025h).

4.j) Kahramanmaraş Bertiz Kabarcık Üzümü

Üzüm, ağırlıklı olarak sofralık olarak değerlendirilse de şıralık ve pekmezlik kullanımının yanı sıra az miktarda kurutmalık olarak da kullanılmaktadır. Taneleri yeşil-sarı tonlarında olup ince kabukludur. 05.10.2023 yılında Kahramanmaraş Büyükşehir Belediyesi tarafından tescil edilmiştir (Şekil 5j) (Anonim, 2025g; Anonim, 2025h).

4.k) Maraş Samsası

Maraş Samsası, Kahramanmaraş iline özgü bir şekerleme türüdür. Üzüm suyu, buğday nişastası ve buğday ununun karıştırılarak odun ateşinde kaynatılmasıyla hazırlanır. Elde edilen karışım, ince bir tabaka hâlinde kurutulur, ardından şeritler şeklinde kesilerek öğütülmüş ceviz içiyle doldurulur ve üçgen biçiminde sarılır. Son aşamada, belirli bir süre baskı altında bekletilerek kendine has dokusu ve lezzeti elde edilir.07.02.2023 yılında Kahramanmaraş Büyükşehir Belediyesi tarafından tescil edilmiştir (Şekil 5k) (Anonim, 2025g; Anonim, 2025h).

4.l) Kilis Horoz Karası Üzümü

Taneleri mavi-siyah renkte olan bu üzüm, oldukça büyük ve uzun elips şeklindedir. Sulu ve etli meyve yapısına sahip olup sofralık olarak kullanılmasının yanı sıra kurutmalık olarak da değerlendirilmektedir. 21.08.2024 yılında Kilis İli Üzüm Üreticileri Birliği tarafından tescil edilmiştir (Şekil 5l) (Anonim, 2025g; Anonim, 2025h).

4.m) Mersin Gülnar Kuş Üzümü

Bu kuş üzümü siyah renkli, çekirdeksiz ve az şekerlidir. Etli ve ince kabuklu yapısıyla kurutmalık olarak değerlendirilir. Taze iken kırmızıdan siyaha döner; kurutulduğunda ise siyah ve küçük taneli hâle gelir. 22.01.2024 yılında Mersin Büyükşehir Belediyesi tarafından tescil edilmiştir (Şekil 5m) (Anonim, 2025g; Anonim, 2025h).

4.n) Mersin Tarsus Beyazı Üzümü (Topacık)

Bu üzümün yaprakları diğer çeşitlere göre biraz tüylüdür. Şeker oranı yüksek olduğundan pekmez ve pekmezli ürünler için idealdir. Çekirdekleri küçük ve yumuşaktır. 14.06.2005 yılında Tarsus Belediyesi tarafından tescil edilmiştir (Şekil 5n) (Anonim, 2025g; Anonim, 2025h).



Şekil 5. Akeniz bölgesi üzüm ve üzüm ürüleri

5. Kuzeydoğu Anadolu Bölgesi

5.a) Erzincan Cimin Üzümü

Erzincan Cimin üzümü, 2001 yılında Üzümlü Belediyesi tarafından Türk Patent Enstitüsü'ne yapılan başvuru sonucunda dünyanın ilk ve tek patentli üzümü olarak tescillenmiştir. Kendine özgü tadı ve düşük şeker içeriği ile sofralık olarak tercih edilen Cimin üzümü, hafif mayhoş bir lezzet profiline sahiptir. 13.06.2001 yılında Erzincan Üzümlü Belediyesi tarafından tescil edilmiştir (Şekil 6a) (Anonim, 2025g; Anonim, 2025h).

5.b) Erzincan Üzümlü Sarucu

Coğrafi işaret tescili 37 numara ile yapılmış olan Cimin üzümü, ortadan ikiye kesilerek kurutulan tanelerinin içine iç ceviz yerleştirildikten sonra pamuk ipliklere dizilerek sunulan geleneksel bir üründür. 05.09.2022 yılında Üzümlü Köylere Hizmet Götürme Birliği tarafından tescil edilmiştir (Şekil 6b) (Anonim, 2025g; Anonim, 2025h).

5.c) Iğdır Beyaz Üzümü

Beyaz üzümün en belirgin özelliği sofralık olarak iri meyvelere sahip olmasıdır. Iğdır ekolojisinde doğal olarak yetişen bu üzüm türü, yuvarlak taneli, yeşil-sarı renk tonlarında, hafif puslu, kalın kabuklu, çekirdekli ve sulu yapıya sahiptir. 09.08.2021 yılında Iğdır Ticaret ve Sanayi Odası tarafından tescil edilmiştir (Şekil 6c) (Anonim, 2025g; Anonim, 2025h).



Şekil 6. Kuzeydoğu Anadolu bölgesi üzüm ve üzüm ürüleri

6. Güneydoğu Anadolu Bölgesi

6.a) Batman Gercüş Mezrone Üzümü

Batman ili Gercüş ilçesinde yetişen bu üzüm, ağırlıklı olarak sofralık amaçla kullanılır ve şıra oranı %70-%80 arasında değişir. Üzüm aynı zamanda pekmez, sucuk, pestil ve şarap üretiminde de değerlendirilmektedir. Taneleri orta büyüklükte, yuvarlak şekilli olup yeşilimsi-sarı renkte ve ince kabukludur. 22.11.2023 yılında Batman Ticaret Borsası tarafından tescil edilmiştir (Şekil 7a) (Anonim, 2025g; Anonim, 2025h).

6.b) Diyarbakır Boğazkere Üzümü

Diyarbakır Boğazkere üzümü, başta şarap üretimi olmak üzere pekmez, pestil, şıra, sucuk ve kesme gibi geleneksel ürünlerin yapımında kullanılır. Mor-siyah renkteki bu üzüm çeşidi, damakta kendine has buruk bir tat bırakmasıyla dikkat çeker. 10.03.2021 yılında Diyarbakır Ticaret ve Sanayi Odası tarafından tescil edilmiştir (Şekil 7b) (Anonim, 2025g; Anonim, 2025h).

6.c) Mardin Midyat Zeynebi Üzümü

Zeynebi üzümü, sofralık olarak tüketilen bir üzüm çeşididir. İnce ve uzun silindirik yapısı nedeniyle, Midyat yöresinde Arapça kökenli "Zeynebi" adıyla anılmakta ve hem yerel hem de ülke genelinde tanınmaktadır. 08.02.2022 yılında Midyat Belediyesi tarafından tescil edilmiştir (Şekil 7c) (Anonim, 2025g; Anonim, 2025h).

6.d) Mardin Ömerli Karfoki Üzümü

"Karfoki" yerel üzüm çeşidinden elde edilen bu ürün hem yaş hem de kuru olarak sofralık amaçla tüketilmektedir. Yaş hali yeşil-sarı renkte olup, kurutulduğunda diğer kuru üzümlerden kolayca ayırt edilebilen kahverengiye yakın kehribar rengi alır. 08.02.2021 yılında Ömerli Kaymakamlığı tarafından tescil edilmiştir (Şekil 7d) (Anonim, 2025g; Anonim, 2025h).

6.e) Mardin Harire

Mardin Harire, üzüm pekmezi, beyaz şeker, buğday unu, su, tarçın ve yenibahar kullanılarak hazırlanan bir karışımın pişirilip soğutulmasının ardından üzerine ceviz içi eklenmesiyle Mardin ilinde üretilen geleneksel bir tatlıdır. 19.02.2024 yılında Mardin Artuklu Üniversitesi tarafından tescil edilmiştir (Şekil 7e) (Anonim, 2025g; Anonim, 2025h).

6.f) Siirt Gebole Tatlısı

Siirt Gebole Tatlısı, sadece Siirt yöresine has, buğday unu, su, şeker ve pekmezle özenle hazırlanan geleneksel bir lezzettir. Hem tatlı hem de yöresel kültürü yansıtan bu tat, bölgenin kendine özgü mutfak mirasının önemli bir parçasını oluşturur. 23.12.2024 yılında Siirt İl Tarım ve Orman Müdürlüğü tarafından tescil edilmiştir (Şekil 7f) (Anonim, 2025g; Anonim, 2025h).

6.g) Siirt Tillo Hariresi

Tillo ilçesinde üretilen Tillo Hariresi, üzüm şırası, buğday unu ve beyaz toprak kullanılarak hazırlanan ve coğrafi sınır içinde "herire" olarak adlandırılan bir üzüm pestilidir. Yumuşak dokusuyla dikkat çeken bu ürünün yapımında, Bineytati ve Sinceri adlı yerel üzüm çeşitlerinden elde edilen şıra kullanılır. Bu üzümler, yüksek şeker içeriği ve bol şıra miktarı nedeniyle tercih edilmekte olup, ürüne ayrıca şeker ilavesi yapılmamaktadır. 17.04.2023 yılında Siirt İl Tarım ve Orman Müdürlüğü tarafından tescil edilmiştir (Şekil 7g) (Anonim, 2025g; Anonim, 2025h).

6.h) Şanlıurfa Hasenik Pestili

Oval şekilli, sarı-yeşil renkte, ince kabuklu, sulu ve tatlı yerel üzüm kullanılarak geleneksel yöntemlerle üretilen bir pestil çeşididir. 29.04.2024 yılında Hilvan Yerel Eylem Grubu Derneği tarafından tescil edilmiştir (Şekil 7h) (Anonim, 2025g; Anonim, 2025h).

6.ı) Van Erciş Üzümü

Erciş üzümü, morumsu siyah renkte ve hafif basık, yuvarlak tanelere sahiptir. Olgunlaşması genellikle Eylül ayının ortasında gerçekleşir. 20.11.2020 yılında Van Ticaret Borsası tarafından tescil edilmiştir (Şekil 7ı) (Anonim, 2025g; Anonim, 2025h).



Şekil 7. Güneydoğu Anadolu bölgesi üzüm ve üzüm ürüleri

7. Karadeniz Bölgesi

7.a) Karabük Safranbolu Çavuş Üzümü

Safranbolu Çavuş üzümü, sarımsı yeşil renkte, hafif oval şekilli, ince kabuklu ve iri taneli bir üzüm çeşididir. 26.12.2022 yılında Safranbolu Kaymakamlığı tarafından tescil edilmiştir (Şekil 8a) (Anonim, 2025g; Anonim, 2025h).

7.b) Düzce Şırası

Düzce Şırası, Osmanlı kültürüne dayanan ve özellikle köftenin yanında tüketilen, alkol içermeyen bir içecektir. Tatlandırıcı ve kimyasal koruyucu maddeler içermeyen bu gazsız içecek, Türkiye'nin güney ve güneydoğu bölgelerinde yetişen kurutulmuş siyah üzümlerin çekirdekleriyle kıyma makinesinde işlenip, belirli oranlarda suda fermantasyon uygulanmasıyla üretilir. Üretimde genellikle küçük taneli ve ince kabuklu kuru üzümler tercih edilmektedir. 06.11.2020 yılında Düzce İl Tarım ve Orman Müdürlüğü tarafından tescil edilmiştir (Şekil 8b) (Anonim, 2025g; Anonim, 2025h).



Şekil 8. Karadeniz bölgesi üzüm ve üzüm ürüleri

8. Ortadoğu Anadolu Bölgesi

8.a) Adıyaman Besni Üzümü

Çekirdekli ve kurutmalık özellik taşıyan bu üzüm çeşidi, iri, homojen ve orta uzunlukta tanelere sahiptir. Taneler kısa oval şekillidir ve incedir, yeşil-sarı renkte kabuğa sahiptir. Meyve eti sertliği oldukça yüksek olup renksiz, susuz ve aromasızdır. Tane sapı kısadır ve her birinde 2–3 çekirdek bulunur. Olgunlaşınca rengi altın sarısına yakın kehribar tonlarındadır. 08.06.2018 yılında Besni Belediyesi tarafından tescil edilmiştir (Şekil 9a) (Anonim, 2025g; Anonim, 2025h).

8.b) Elazığ Boğazkere Üzümü

Elazığ yöresine özgü Boğazkere üzümü, otsu aromasıyla öne çıkar ve dengeli bir burukluğa sahiptir. Tüketildiğinde ağızda hafif yanık bir tat bırakır. Bu üzüm çeşidi genellikle şıralık ve şaraplık amaçlarla değerlendirilir. 11.02.2019 yılında Fırat Kalkınma Ajansı, Elazığ Üzüm Üreticileri Birliği, Fırat Üniversitesi, Elazığ Ticaret ve Sanayi Odası, Elazığ Tarım ve Orman İl Müdürlüğü tarafından tescil edilmiştir (Şekil 9b) (Anonim, 2025g; Anonim, 2025h).

8.c) Elazığ Öküzgözü Üzümü

Öküzgözü üzümü, büyük ve sulu taneleriyle öne çıkan bir çeşit olup şarap yapımında kullanılır. Taneleri oval şekilli, koyu renkli ve etlidir. Kabuk yapısı, Boğazkere üzümüne kıyasla daha incedir. 10.07.2008 yılında Tarım ve Köyişleri Bakanlığı Elazığ İl Müdürlüğü, Elazığ Merkez İlçe Üzüm Üreticileri Birliği tarafından tescil edilmiştir (Şekil 9c) (Anonim, 2025g; Anonim, 2025h).

8.d) Elazığ Tahannebi Üzümü

Elazığ yöresine ait Tahannebi üzümü, sofralık kullanımda erken olgunlaşan bir çeşittir. Yüksek şeker içeriği nedeniyle pestil ve orcik üretiminde de tercih edilir. Meyveleri uzun ve silindirik yapıda olup sarı ile açık yeşil tonları gösterir. 03.11.2023 yılında Elazığ İl Tarım ve Orman Müdürlüğü, Elazığ Ticaret ve Sanayi Odası tarafından tescil edilmiştir (Şekil 9d) (Anonim, 2025g; Anonim, 2025h).

8.e) Elazığ Orciği

Orcik, cevizli bir sucuk çeşididir ve genellikle bağ bozumu sırasında hazırlanır. Önceden ipe dizilen cevizler üzüm şırasına birkaç kez batırılıp kurutularak ürüne dönüştürülür. Elazığ Orciği, yöreye özgü üzümler ve taze cevizlerle yapılmasıyla farklılaşır. 30.11.2018 yılında Fırat Kalkınma Ajansı, Elazığ Tarım ve Orman İl Müdürlüğü, Fırat Üniversitesi, Elazığ Ticaret ve Sanayi Odası, Elazığ Üzüm Üreticileri Birliği tarafından tescil edilmiştir (Şekil 9e) (Anonim, 2025g; Anonim, 2025h).

8.f) Malatya Arapgir Köhnü Üzümü

Yüksek kaliteye sahip sofralık ve şaraplık üzüm çeşitlerinden biri olan bu üzüm, mora yakın siyah renkte tanelere sahiptir. Taneler, gri bir pusla kaplanmış, oval şekilli, iri çekirdekli ve bol şıralıdır. Tadının ise nötral olduğu belirtilmektedir. 24.06.2008 yılında Arapgir Belediyesi tarafından tescil edilmiştir (Şekil 9f) (Anonim, 2024e).

8.g) Malatya Banazı Karası Üzümü

Yüksek tanen içeriği nedeniyle bu üzüm, belirgin bir burukluk sergiler. Sofralık tüketim için taze olarak uygun olmayan bu çeşit, kurutulduğunda herhangi bir katkı maddesi kullanılmadan elde edilir ve renk homojenliği sağlanır. Orijinal rengi siyah ve puslu olup, puslu yapısı, diğer kurutmalık üzümlerden ayırt edilmesini kolaylaştırır. 26.03.2021 yılında Yeşilyurt Belediyesi tarafından tescil edilmiştir (Şekil 9g) (Anonim, 2025g; Anonim, 2025h).

8.h) Malatya Köpük Pestili

"Bastık" adı verilen bu pestil, üzüm suyu, beyaz şeker ve buğday unu ile yapılır. Tadı şekerli ve biraz ekşidir, rengi ise hafif koyu beyazdır. Doku olarak yumuşak bir yapıya sahiptir. 26.01.2022 yılında Malatya Ticaret Borsası tarafından tescil edilmiştir (Şekil 9h) (Anonim, 2025g; Anonim, 2025h).

8.ı) Malatya Tevek Yaprağı Sarması

Yapraklar ince ve az damarlıdır, haşlandığında sarı renge bürünür ve tadı hafif ekşimtıraktır. Mayıs ayında körpe olan yapraklar toplanarak taze ya da salamura halinde kullanılabilir. 23.05.2022 yılında Yeşilyurt Belediyesi tarafından tescil edilmiştir (Şekil 9ı) (Anonim, 2025g; Anonim, 2025h).

8.i) Tokat Erbaa Narince Bağ Yaprağı

Erbaa ilçesinde, uzun yıllardır Narince üzümü asmalarının salamuralık yaprakları ticari olarak toplanmakta ve pazarlanmaktadır. Yöre ekolojisinin sağladığı fiziksel ve kimyasal üstünlükler, bu yaprağın en önemli özelliği olup, aynı zamanda kısa sürede pişme kabiliyeti sunar. 05.12.2017 yılında Erbaa Ticaret ve Sanayi Odası tarafından tescil edilmiştir (Şekil 9i) (Anonim, 2025g; Anonim, 2025h).

8.j) Tokat Narince Salamura Asma Yaprağı

Bu asma çeşidinin yaprağının özellikleri arasında, ismine uygun olarak daha ince ve narin bir yapıya sahip olması, yumuşak dokusu ve yenildiğinde ağızda erimesi öne çıkar. Ayrıca, diğer asma yapraklarına göre daha sarı renkte olup, damar sayısı daha az ve ince yapıdadır. Kendine has tat ve aroması, bu yaprağı diğerlerinden ayıran bir diğer önemli özelliktir. 28.02.2019 yılında Tokat Ziraat Odası tarafından tescil edilmiştir (Şekil 9j) (Anonim, 2025g; Anonim, 2025h).

8.k) Tokat Zile Pekmezi

Normal pekmezlerden farklı olarak beyaz renkli olarak üretilmektedir. İçeriğinde yüksek miktarda üzüm şırası bulunur. Bu özellik, ona özgün bir nitelik kazandırır. 17.11.2009 yılında Zile Ticaret Borsası tarafından tescil edilmiştir (Şekil 9k) (Anonim, 2025g; Anonim, 2025h).

8.l) Tokat Zile Kömesi

Zile Kömesi, ipe dizilmiş ceviz içlerinin, Narince üzümü şırası, buğday nişastası ve un ile karıştırılarak hazırlanıp, hasuda ile kaplanmış bir tatlı ürünüdür. Hasuda, üzüm şırası, buğday nişastası ve unun pişirilmesiyle elde edilen, muhallebi kıvamında bir yöresel tatlıdır. 01.11.2017 yılında Zile Ticaret ve Sanayi Odası tarafından tescil edilmiştir (Şekil 9l) (Anonim, 2025g; Anonim, 2025h).

8.m) Tokat Üzüm Tarhanası

Narince beyaz üzüm şırasına ince buğday kırması eklenip kaynatılarak kurutulmasıyla yapılan bir tür tarhanadır. Ayrıca, Tokat üzüm tarhanasında ceviz içi de eklenerek çeşnili üzüm tarhanası yapılabilir. 09.07.2024 yılında Tokat Ticaret ve Sanayi Odası tarafından tescil edilmiştir (Şekil 9m) (Anonim, 2025g; Anonim, 2025h).



Şekil 9. Orta Anadolu bölgesi üzüm ve üzüm ürüleri

9. Orta Güney Bölgesi

9.a) Karaman Ekşikara Üzümü

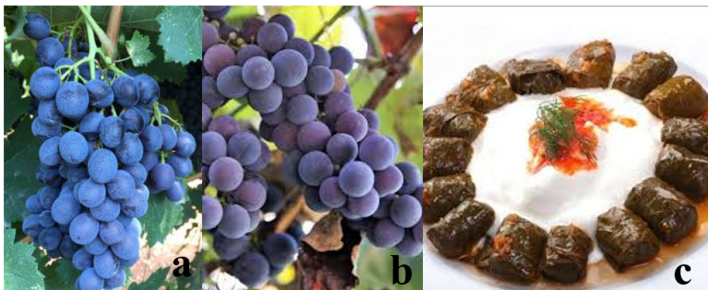
Üzümler konik bir yapıya sahip olup, dolgundur. Taneleri küçük ile orta büyüklük arasında değişir ve koyu siyah renkte, puslu bir yüzeye sahiptir. 08.12.2022 yılında Karaman Ticaret ve Sanayi Odası tarafından tescil edilmiştir (Şekil 10a) (Anonim, 2025g; Anonim, 2025h).

9.b) Kayseri İncesu Karaevrek Üzümü

Salkımlar kısa uzunlukta olup, konik bir şekle sahiptir. Salkım sapı oldukça kısadır. Meyve eti renksizdir ve tatları tatlıdır. 26.08.2016 yılında İncesu Belediyesi tarafından tescil edilmiştir (Şekil 10b) (Anonim, 2025g; Anonim, 2025h).

9.c) Konya Etli Yaprak Sarması

Konya etli yaprak sarması, serçe parmağının baş boğumu kadar büyüklüğe sahiptir ve Konya mutfağının öne çıkan yemeklerinden biridir. 20.08.2021 yılında Konya Büyükşehir Belediyesi tarafından tescil edilmiştir (Şekil 10c) (Anonim, 2025g; Anonim, 2025h).



Şekil 10. Orta Güney bölgesi üzüm ve üzüm ürüleri

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QUORUM QUENCHING: VETERİNER VE KLİNİK MİKROBİYOLOJİDE POTANSİYEL UYGULAMALAR

Doç.Dr.Hatice Yazgan

Çukurova Üniversitesi, Ceyhan Veteriner Fakültesi, Gıda Hijyeni ve Teknolojisi Bölümü, Gıda Hijyeni ve Teknolojisi Anabilim Dalı, Adana

Email: hyazgan@cu.edu.tr

ORCID: 0000-0002-7520-3342

Doç.Dr. Tülin Güven Gökmen

Çukurova Üniversitesi, Ceyhan Veteriner Fakültesi, Klinik Öncesi Bilimler Bölümü, Mikrobiyoloji Anabilim Dalı, Adana

Email: tulinguven01@hotmail.com

ORCID: 0000-0001-9673-097X

ÖZET

Quorum sensing (QS), bakterilerin hücre yoğunluğunu algılayarak kimyasal sinyaller aracılığıyla iletişim kurmasını sağlayan bir mekanizmadır ve biyofilm oluşumu, virülans faktörlerinin üretimi, antibiyotik direnci ve gen transferi gibi süreçlerin düzenlenmesinde kritik rol oynar. Özellikle patojen bakterilerde QS, konak bağışıklık yanıtına dirençli biyofilm yapılarının oluşumuna yol açarak klinik ve veteriner alanda ciddi enfeksiyon sorunlarına neden olur. Quorum quenching (QQ), QS sistemlerini doğal veya yapay yollarla bozarak bakterilerin koordineli davranışlarını engelleyen bir stratejidir. Bu yaklaşım; sinyal sentezinin inhibisyonu, sinyallerin enzimatik parçalanması veya reseptör blokajı yoluyla gerçekleştirilir. QS'i hedef alması nedeniyle QQ, bakterileri öldürmeden patojeniteyi azaltır ve antibiyotiklere alternatif veya tamamlayıcı bir yöntem olarak öne çıkar. QQ stratejileri arasında enzimatik yollar, bitkisel veya mikrobiyal doğal inhibitörler ve sentetik küçük moleküller bulunur. Bitkisel polifenoller, flavonoidler ve ajoene gibi doğal bileşiklerin yanı sıra probiyotiklerin ürettiği metabolitler QS'i baskılayabilir. Ayrıca CRISPR-Cas sistemleri, nanoteknolojiyle kontrollü taşıma yöntemleri ve yapay zekâ destekli bileşik taramaları gibi yeni teknolojiler QQ araştırmalarında önemli ilerlemeler sağlamaktadır. Veteriner alanda *Salmonella, Escherichia coli ve Staphylococcus aureus* gibi patojenlerin biyofilm oluşumunun engellenmesi; gıda endüstrisinde yüzey kontaminasyonunun önlenmesi; klinikte ise *Pseudomonas aeruginosa* gibi dirençli türlere karşı yeni tedavi seçenekleri QQ'nin potansiyel uygulama alanlarındandır. Ancak klinik kullanıma entegrasyon için standardizasyon, güvenlik, toksisite ve direnç gelişimi konularında daha fazla araştırma gerekmektedir. QQ, Tek Sağlık yaklaşımı çerçevesinde antimikrobiyal dirençle mücadelede umut verici, yenilikçi bir strateji olarak öne çıkmaktadır.

Anahtar Kelimeler: Quorum sensing, Quorum quenching, biyofilm

ABSTRACT

Quorum sensing (QS) is a mechanism through which bacteria communicate using chemical signal molecules in response to cell density, playing a crucial role in biofilm formation, virulence factor production, antibiotic resistance, and gene transfer. In pathogenic bacteria, QS facilitates biofilm development that resists host immune responses, posing serious challenges in clinical and veterinary contexts. Quorum quenching (QQ) refers to disrupting QS systems through natural or artificial means, thereby interfering with bacterial coordinated behavior. By inhibiting signal synthesis, enzymatically degrading signals, or blocking receptors, QQ reduces pathogenicity without killing bacteria, emerging as an alternative or complementary strategy to antibiotics. QQ strategies include enzymatic degradation, plant- or microbe-derived natural inhibitors, and synthetic small molecules. Natural compounds such as polyphenols, flavonoids, and ajoene, as well as metabolites produced by probiotics, have been shown to inhibit QS. Moreover, recent technologies such as CRISPR-Cas systems, nanotechnology-based delivery methods, and artificial intelligence driven compound screening have accelerated QQ research. Potential applications of QQ span multiple fields: inhibiting biofilm formation by pathogens like *Salmonella, Escherichia coli,* and *Staphylococcus aureus* in veterinary medicine; preventing surface contamination in the food industry; and providing novel therapeutic options against resistant species such as *Pseudomonas aeruginosa* in clinical settings. However, successful clinical integration requires further research on standardization, safety, toxicity, and resistance development. Within the One Health framework, QQ represents a promising and innovative approach for combating antimicrobial resistance by targeting bacterial communication rather than viability.

Keywords: Quorum sensing, Quorum quenching, biofilm

QUORUM QUENCHING: POTENTIAL APPLICATIONS IN VETERINARY AND CLINICAL MICROBIOLOGY

1. Quorum sensing vs. Quorum quenching

Quorum sensing (QS) is a mechanism that allows bacteria to sense cell density and communicate with each other through chemical signaling molecules (autoinducers). Thanks to QS, bacteria can coordinate their individual activities and act on a population scale. The Quorum sensing mechanism functions as a control system which regulates biofilm development and virulence factor production and antibiotic resistance acquisition and genetic material transfer (Papenfort & Bassler, 2016; Whiteley et al.,2017). The formation of biofilm structures by pathogenic bacteria leads to medical problems because these structures protect bacteria from host immune responses and make antimicrobial treatments useless (Brackman & Coenye, 2015; Rutherford & Bassler, 2012). Quorum quenching (QQ) is defined as the inhibition of QS mechanisms by natural or artificial means. QQ needs various strategies to succeed which include blocking signal molecule synthesis and using enzymes to break down existing signals and blocking receptor-signal binding (Grandclément et al.,2016; Fetzner, 2015). The treatment method breaks down bacterial coordination which leads to lower biofilm formation and decreased virulence factor production. Because quorum quenching employs a strategy aimed at reducing pathogenicity rather than directly killing bacteria, it is gaining importance as an alternative or complementary antimicrobial option to antibiotics (Defoirdt, 2018; O'Loughlin et al.,2013). In recent years, the effectiveness of natural products as QS inhibitors (QSIs) has been reported in various studies. The research by Lu et al. shows that plant-derived polyphenols and flavonoids and essential oils disrupt bacterial communication through their ability to block QS signals. 2022; Singh et al.,2022; Jakobsen et al.,2012). The research findings demonstrate strong potential for biofilm food contamination control and development of new medical treatments against antibiotic-resistant bacteria. Within the One Health perspective, QS and QQ research are critical. The uncontrolled use of antibiotics at high levels has developed into a rapidly expanding antimicrobial resistance (AMR) crisis which impacts human beings and animals and natural environments. QS enables the spread of resistance genes between bacteria and enables bacteria to develop resistance through biofilm formation (Rutherford & Bassler, 2012; Williams et al.,2022). The fight against antibiotic resistance should adopt QS targeting as its current strategic method. QS is expected to offer a wide range of applications in poultry production, including the suppression of *Escherichia coli* and *Salmonella* biofilms, the control of mastitis-causing *Staphylococcus aureus*, the prevention of surface contamination by pathogens in the food industry, and the treatment of *Pseudomonas aeruginosa* infections (Brackman & Coenye, 2015; Li et al.,2018). QS approaches to inhibit QS stand out as a promising research area that contributes to reducing antibiotic use, slowing the development of resistance, and maintaining the balance between human, animal, and environmental health within the framework of One Health.

2. Quorum Sensing Mechanisms

Quorum sensing operates through various signaling molecules in different bacterial groups, and the mechanisms are quite different between Gram-negative and Gram-positive bacteria. The main signaling function of quorum sensing molecules in Gram-negative bacteria relies on acyl-homoserine lactone (AHL)-derived compounds. The AHLs can freely cross bacterial cell membranes before they enter culture media to activate receptor proteins at specific concentrations which depend on bacterial numbers. The binding process triggers gene expression which results in multiple phenotypes that enable biofilm development and virulence factor production and antibiotic resistance. The LasI/LasR and RhlI/RhlR systems in *Pseudomonas aeruginosa* control biofilm organization while allowing the bacteria to create

elastase and rhamnolipid virulence factors (Lee & Zhang, 2015; Papenfort & Bassler, 2016). Gram-positive bacteria depend on oligopeptide signals to perform their QS operations. These peptide signals are released into the medium via carrier proteins and are detected by two-component system receptors located on the cell surface. The detected signal starts a phosphorylation chain reaction through histidine kinase which regulates gene expression. The agr system in *Staphylococcus aureus* plays a central role in the synthesis of virulence factors such as hemolysins and proteases (Novick & Geisinger, 2008; Tan et al.,2018). Autoinducer-2 (AI-2) functions as a vital signal which Gram-negative and Gram-positive bacteria produce to communicate with each other. The AI-2 signaling system enables bacteria to connect with each other in microbial communities which makes biofilm ecosystems more resistant to change (Xavier & Bassler, 2003; Pereira et al.,2013). QS has extensive clinical and veterinary importance. The QS system in *Escherichia coli* establishes conditions which enhance biofilm development thus making antibiotic therapy less effective for infections that originate from poultry zoonotic sources (Mokhtar et al.,2020). The dangerous medical complications occur because *Pseudomonas aeruginosa* forms dense biofilms and produces multiple virulence factors when it infects respiratory areas and wounds (Williams et al.,2022). *Salmonella* spp. The system creates threats to food safety and veterinary public health because it controls intestinal colonization and virulence gene expression through QS (Miller et al.,2001; Walters & Sperandio, 2006).

3. Quorum Quenching Strategies

Quorum quenching operates as a bacterial system which disrupts cellular communication by disrupting quorum sensing signal pathways. QQ functions by preventing bacterial virulence and biofilm development instead of directly killing bacteria to achieve pathogen control. QQ serves as an essential method to fight antimicrobial resistance according to Grandclément et al. (2016; Defoirdt, 2018).

3.1. Enzymatic QQ

The enzymatic QQ method works through direct interference with signaling molecules either by structural changes or by disrupting their function. AHL-lactonases inactivate QS signals by hydrolyzing the lactone ring in AHL (acyl-homoserine lactone) molecules. AHL-acylases prevent signal recognition by cleaving the acyl side chains of AHLs. Oxidoreductases perform chemical transformations on AHLs which prevents their receptor protein binding ability (Dong et al.,2000; Romero et al.,2020). Many bacteria and fungi species in nature produce these enzymes which help them gain competitive advantage in their microbial environments.

3.2. Natural Compounds

The main strategy to stop QS activity involves using plant extracts and natural products. Research shows Ajoene from garlic functions as an effective QS inhibitor which prevents *Pseudomonas aeruginosa* from forming biofilms (Jakobsen et al.,2012). The flavonoid compound quercetin functions as a QS signal blocker which affects both Gram-negative and Gram-positive bacterial species (Lu et al.,2022; Singh et al.,2022). Research shows that probiotic bacteria produce metabolites which decrease pathogen colonization through their ability to block QS (Castillo-Juárez et al.,2015).

3.3. Synthetic Inhibitors

Synthetic QS inhibitors were created (QSIs) through small molecule and peptide analog development during the last few years. The molecules bind to QS receptors through specific interactions which either replicate or block the typical function of natural signaling molecules. The process leads to virulence gene expression suppression. The LasR receptor in *Pseudomonas* becomes available to small molecules according to O'Loughlin et al. which allows them to

break down biofilm structure. 2013). The advantage of synthetic inhibitors is that they exhibit more specific effects and can be adapted to different bacterial species; however, the potential for toxicity and resistance development is still being investigated (Brackman & Coenye, 2015).

3.4. Microbial Competition Strategies

Natural ecosystems contain various microbial species which fight against each other in intense competitive battles. Some bacterial species increase their ecological advantage by disrupting the QS signals of other species. This phenomenon is defined as microbial QQ interactions. *Bacillus* species contain two types of bacteria which produce AHL-lactonase and release probiotic metabolites that interfere with pathogenic QS signals. The body uses these defense systems to protect its natural microbial balance and stop pathogenic organisms from growing (Chen et al.,2013; Romero et al.,2020).

4. New Approaches and Perspectives

Through quorum sensing and quorum quenching research, new approaches to combating bacterial infections that go beyond traditional antibiotic therapy have been discovered. The biofilm-forming capacity and virulence factors of pathogens can be suppressed through innovative QS system targeting methods which next-generation technologies provide. The development of CRISPR-Cas-based genetic interventions has become more popular because they enable direct targeting of QS genes for silencing purposes. The research of Zhang et al. (2020) demonstrates that CRISPR-Cas systems used to block QS regulators LasR and RhlR in Pseudomonas aeruginosa resulted in decreased biofilm development. 2020). The development of genetic engineering-based QQ applications shows promise to become a future clinical treatment for multidrug-resistant bacteria. Nanotechnology-supported QQ studies are also being conducted. Nanoparticles increase the efficacy and reduce toxicity of QS inhibitors (QSIs) by delivering them to target sites in a controlled manner. Research shows that silver and polymer-based nanoparticles when used with natural products can stop QS signals to reduce E. coli and Salmonella biofilm formation by significant amounts (Lu et al.,2022). The development of QQ research is experiencing rapid growth with the integration of artificial intelligence systems. Prediction studies of QS inhibitors in large molecular libraries are being conducted using artificial intelligence and machine learning algorithms (Tan et al., 2020). Research is progressing more rapidly to identify new QS inhibitors derived from natural and synthetic materials that exhibit potent antimicrobial activity. QQ holds promise as a drug that can be used in place of antibiotics by reducing antibiotic consumption and delaying the development of antibiotic resistance. Consequently, the worldwide spread of antimicrobial resistance creates a global health crisis that endangers humans and animals and pollutes the environment. Quorum quencing research is among the diverse and emerging techniques used within the One Health approach and is an alternative treatment method that helps prevent antibiotic resistance, improves treatment outcomes, and reduces environmental microbial contamination (Williams et al., 2022; Romero et al., 2020). However, further evidence-based studies, safety testing, and field applicability studies are needed to integrate QQ into clinical and veterinary practice.

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ENHANCING PUBLIC SERVICE DELIVERY WITH ARTIFICIAL INTELLIGENCE: POLICY OPPORTUNITIES AND CHALLENGES IN DEVELOPING NATIONS

Sunday Olorunlogbon OLORUNNIPA

Quintessential College, Ibadan, Oyo State, Nigeria

Email: olorunnipaso@gmail.com

Olaniyi Habib ALIU[2]

Federal Polytechnic, Ilaro, Ogun State, Nigeria

Email: olaniyi.aliu@federalpolyilaro.edu.ng

ABSTRACT

The paper examines the impact of Artificial Intelligence (AI) in improving the delivery of public services of concern to policy issues and prospects within the developing world. Citizens are increasingly eager to see the digital transformation as one of the most significant keywords in the world until government efficiency, transparency, and citizen engagement. Nonetheless, they may not be experienced in the developing regions due to infrastructural disparities, limited economic power, and prepared policies. This research paper, with the help of a quantitative methodology, examines the indicators that are considered central, including AI Readiness Index, E-Government Development Score, Public Service Effectiveness, Internet Penetration and GDP per Capita, and the availability of national policies regarding AI. Data based on the ten developing countries had been collected through authoritative secondary sources and were analyzed using the Python based visualizations and correlation methods. The findings indicate a positive association between AI and readiness and effective provision of public services, which highlights the role and significance of digital maturity and value-based governance on the provision of high-quality services. Countries with a larger access to the internet and AI policies are more likely to achieve better results in service. The general absence of organized AI frameworks, digital infrastructure is an obstacle in most developing countries.

Keywords: Artificial Intelligent, Developing Nations, Digital Governance, Public Service Delivery.

1. INTRODUCTION

In most developing nations, the service delivery system is ineffective, unfair and faces a lot of systemic problems of bureaucratic deadlocks, corruption, poor infrastructure and human capacity shortage. In spite of the attempts to enhance service delivery, citizens often face delayed services, ineffective responsiveness, and the inferior quality of delivery in such essential segments of activity as healthcare (Rozenblit et al., 2025), education (Holmes & Tuomi, 2022), sanitation, and civil administration (Okhotnikova & Korpachova, 2021). Growing pressures put on traditional governance structures by people, inability to provide the right services and mismatches due to gaps in service supply validates the imperativeness presented by innovative and technologically controlled solutions (Eze et al., 2024). Artificial intelligence (AI) is, in this respect, a tool that can be transformational to the extent that it can make service delivery more efficient, leave administrative tasks, and make service delivery more responsive and data-informed. Nevertheless, implementation of AI technologies into the sphere of the government creates rather significant policy concerns, especially in regard to developing countries, where the institutional capacity and regulatory systems are not fully developed (Taeihagh, 2021).

AI is an abbreviation of cognitive systems that can be used to solve problems that usually involve intelligence although the system can be encompassed by human beings (Samoili et al., 2020). In the context of the field of public administration, the use of AI implies predictive analytics to plan resource distribution, automated customer service chatbots, intelligent transportation systems, and machine-learning fraud detection models and risk assessment. Such innovations are expected to make the process less hectic, increase accuracy, and expand access to public services. In the case of developmentally constrained countries with limited resources and exploding population, AI even promises the potential of an AI-enabled leapfrog of legacy systems and instead of creating a more adaptable governance model (Dafoe, 2018).

Although all these sound good, there are limitations to the incorporation of AI into the process of public services delivery. One of the major obstacles is the lack of a base of digital infrastructure within many developing states. There is sparse internet coverage, unreliable power, and insufficient data storage assistance, and this has limited the scale at which AI systems can be deployed. Also, the technical expertness in most of the institutions of the public sector in these contexts is very low and therefore not easy to design, or implement, or administer AI solutions. These deficiencies are even augmented by the absence of the multi-pronged policies that relate to data governance, algorithmic transparency, and ethical requirements.

Accountability, fairness, and inclusiveness are other issues with the development and roll out of AI. The reliability of AI systems lies in the input data and assumptions of the given systems. Algorithms can be used to produce biased or inaccurate results to various levels that result in unwanted discrimination or refusal of certain services in cases when the environment contains limited data or bad records (Williams et al., 2018). The lack of transparency between opaque AI-based decision-making mechanisms and the people may erode trust and transparency when the citizens cannot challenge or interpret algorithmic decision-making (Farinu, 2025). This has the potential of seriously derailing the acceptability and legitimate nature of AI-based systems in the developing countries where political and institutional trust is already at the low end.

The morality aspects of AI in the fields of governmental service are understudied in most developing countries (Aderibigbe et al., 2023). Most of the time when AI is used, there is widespread gathering and analysis of personal information, which is a source of concern since our privacy, consent, and possible surveillance are at stake. In the absence of legal protection and data security measures, there tends to be threats of misuse or exploitation of information by citizens (Yigitcanlar et al., 2022). This becomes especially problematic in highly controlled

or poor governance environments, which may distort the usage of AI technologies to control or discriminate against people instead of providing equal service.

However, the opportunities in AI provide countries that use it as a developing country to modernize the branch of government and overcome long-standing gaps in governance (Khan et al., 2024). This would be because, on the one hand, AI-learning early warning systems can improve response to disasters, and machine learning can improve healthcare resource allocation, and on the other hand, digital identity verification technologies can prevent some fraud involving welfare distribution (Waheeb, 2024). Already, there are some countries piloting AI applications with promising results. How technology can be used to scale access and enhance efficiency in service delivery can be seen in the case of Rwanda using AI in medical diagnostics and India using biometric identification to provide people with public subsidies (Sangwa & Mutabazi, 2025).

Tight policy frameworks are necessary to maximize benefits and minimize associated risks (Truby, 2020). Policymakers should come up with approaches that allow balancing AI use with national development initiatives as well as proper oversight and responsibility. This involves formulating legal and ethical protocols on the use of the data, infrastructure investments, and establishing and developing the technical capacity of government institutions (de Almeida et al., 2021). Notably, there seems to be a need to understand that policies must be place-specific, aligned to local situational opportunities and constraints, local institutional facts, cultural practices, and local development orientations. Multistakeholder participation that includes government agencies, the private sector, academia, and civil society is also important in promoting inclusive innovation and having AI systems that were built in the interest of the people (Moon, 2023).

This paper examines the two possibilities of AI, which are as follows: AI can revolutionize the provision of public services, and it also becomes a policy complexity in developing countries. It explores the way AI is already being used in the public sector, challenges to its successful execution, and institutional, legal, and ethical implications necessary to be knowledgeable about the responsible use. This research will give an in-depth idea of what opportunities AI can bring to the transformation of governance and look at the circumstances in which this process can be successful critically. The research has the potential to be applied in the discussion concerning technology-driven governance in the Global South by illustrating implementable or realistic situations and also in the formulation of some policy recommendations concerning assistance in the adoption of sustainable and inclusive AI.

2. METHOD USED

This paper will employ a quantitative research design based on secondary data to evaluate the contribution of Artificial Intelligence (AI) towards improving the service delivery of the developing countries. The research will focus on the descriptive and inferential statistical approach using the Python programming language and such data analysis packages as pandas, matplotlib, seaborn, and statsmodels. The research sample includes 10 developing economies, the choice of which rests on the availability of solid data on the state of AI readiness, government efficiency and e-government level of development, internet access, and GDP per capita as well as national policies dealing with AI.

2.1 Dataset Description

It had a structured collection of data based on open-source metrics of reputable sources such as the oxford Insights AI readiness Index (Marinaș et al., 2024), United Nations e-government Survey (United Nations, 2024), World Bank Development Indicators (Ott, 2023), and regional digital reports. These variables relate to AI Readiness Index, E-Government Development

Score, the level of Public Service Effectiveness, Internet Penetration Rate, the level of GDP per Capita, and a binary indicator of whether an AI policy framework is in presence. Table 1 shows the content of the collected dataset.

Table 1: Key Indicators for AI policy

Country	AI Readiness	E-Gov Score	Public Service	Internet Penetration	GDP/Capita	AI Policy
Nigeria	32	40	38	36	2200	No
Kenya	45	52	50	42	1800	Yes
Ghana	40	49	46	40	2100	No
Bangladesh	50	57	55	60	1900	Yes
Pakistan	46	54	51	50	2000	Yes
Ethiopia	35	42	39	30	850	No
Uganda	38	45	42	35	1200	No
Nepal	41	48	47	38	1300	Yes
Zambia	37	43	40	33	1150	No
Tanzania	36	44	41	34	1100	No

To understand the correlations of the variables, the study has used visual analytics by creating line graphs, histograms and summary tables to identify the patterns in the data and the performance of the countries. Other statistical tools like correlation analysis and linear regression were also explored to test the intensity and pattern of relationships between AI readiness and civic outcomes of public services. Figure 1 shows the block diagram of the study.

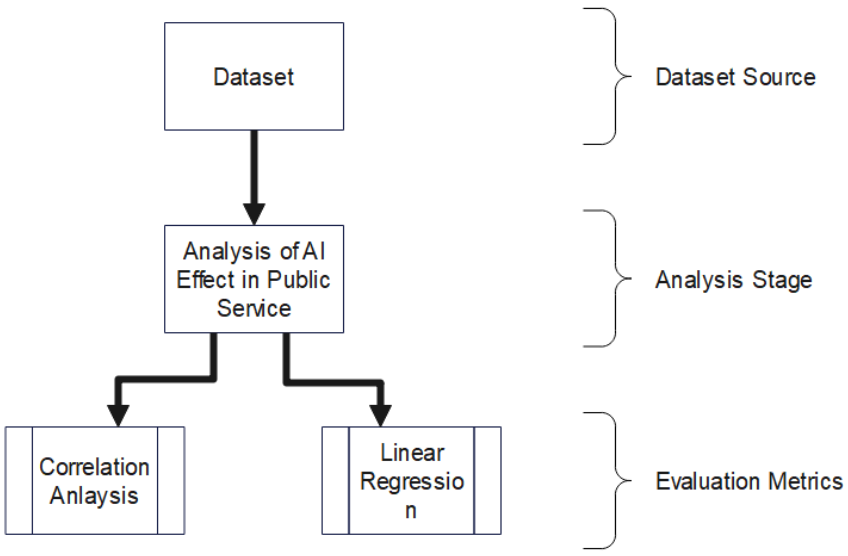


Figure 1: Flowchart of the Study (Source:Fieldwork, 2025)

The deployment of this methodological framework enables objective and replicable analysis of the effect of technological capacity and presence of policy on service delivery in resource-constrained environments. The empirical evidence and reproducible code helps gain a better credence to the results of the study and provide policy implications and developmental agencies with practical suggestions. One should admit limitations pertaining to data availability and consistency in time, but the method is a good foundation to future research and cross-country bench-marking in the domain of digital governance.

3. FINDINGS

The findings for the study were explained in this section. The comprehensive analysis of how AI has impacted the public health base on different criteria were analyzed using python environment on google colab. Figure 2 shows the heatmap of the correlation between six variables. There is a great positive correlation between AI Readiness, E-Government Score and Public Service Effectiveness, which means that the factors move in one direction. Interdependence is also very high between Internet Penetration and GDP. As demonstrated through the AI Policy Exists, there is less correlation, meaning that it may not have a direct impact on other indicators.

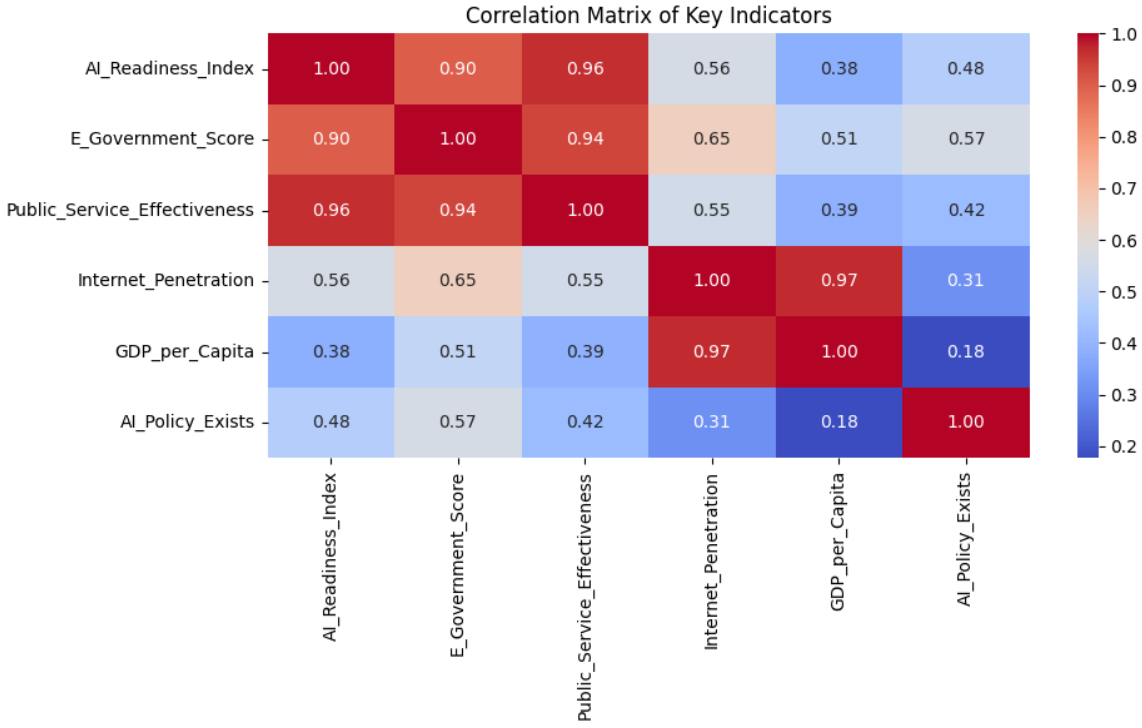


Figure 2: Correlation Matrix for the study

The graph in figure 3 is used to show the relationship between AI Readiness Index and the Public Service Effectiveness of different countries. The countries are one bubble, and the size of the bubble corresponds with GDP per Capita and the color of the bubble to E-Government Score. Since the upward trend is evident, increased AI preparedness can be linked to better functioning of the public services.

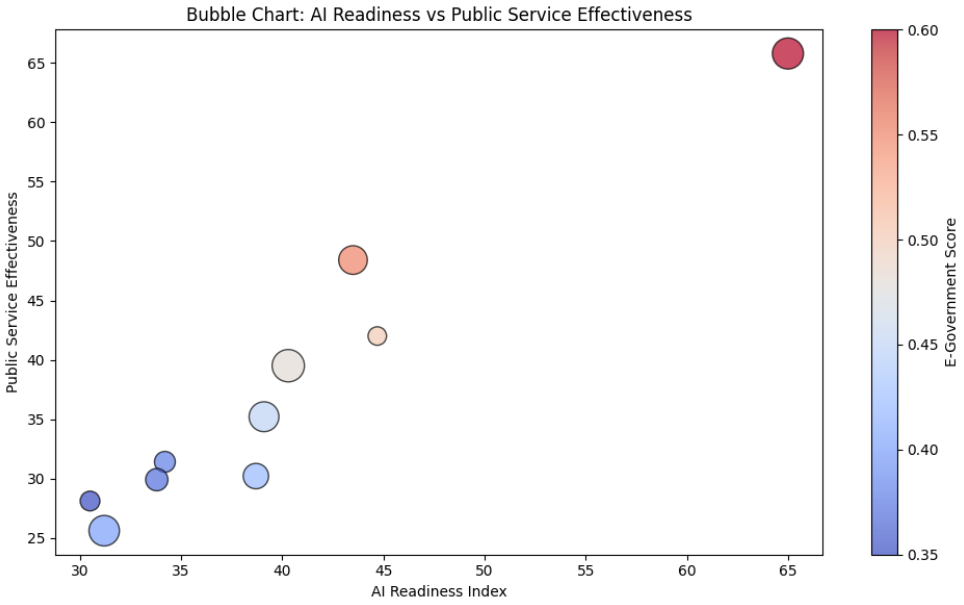


Figure 3: Bubble chart for the study

Figure 4 is a summary of a linear regression that would examine the relationship of five predictors on Public Service Effectiveness. Although coefficients of variables such as E-Government Score and AI Readiness are positive, none of them are strongly statistically significant ($p < 0.05$). This suggests the necessity to conduct additional research with, potentially, a bigger scale of data or a more tuned model.

	Variable	Coefficient	Std. Error	t-Statistic	P-Value	CI Lower (95%)	CI Upper (95%)
0	const	-21.5899	10.3350	-2.0890	0.1049	-50.2843	7.1046
1	AI_Readiness_Index	0.7206	0.3327	2.1660	0.0962	-0.2031	1.6443
2	E_Government_Score	80.4341	35.8140	2.2459	0.0880	-19.0016	179.8698
3	Internet_Penetration	-0.1003	0.9139	-0.1098	0.9179	-2.6377	2.4370
4	GDP_per_Capita	-0.0003	0.0124	-0.0250	0.9813	-0.0346	0.0340
5	AI_Policy_Exists	-3.3889	2.6991	-1.2556	0.2776	-10.8829	4.1050

Figure 4: Linear Regression

The histogram in figure 5 demonstrates the extent of the variation in the country scores of effectiveness of the public services. There is a concentration of most scores between 25 and 35 which shows low effectiveness in most of the countries. Such scores are outliers in a handful of countries. The subsequent KDE curve indicates a skewed distribution towards the left indicating that there are only a few countries which have high performance and most lie below the average mark of the entire effectiveness scale.

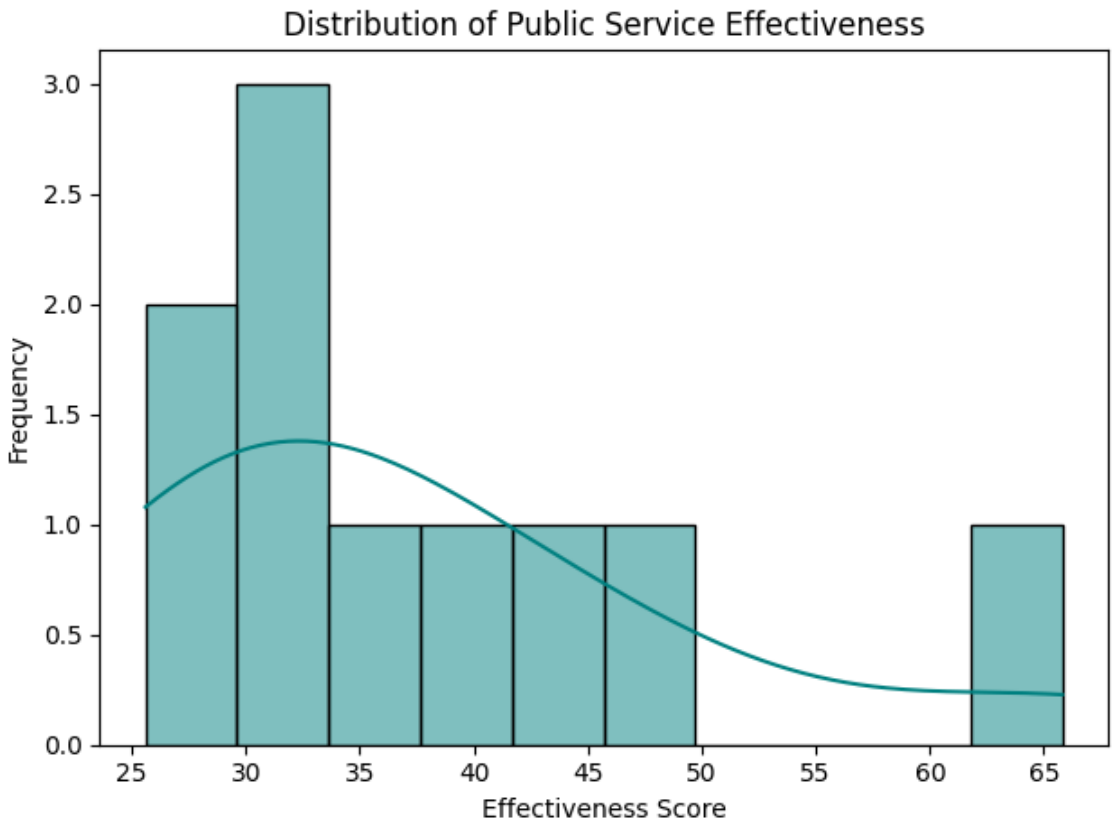


Figure 5: Histogram for the study

This line graph in figure 6 presents a comparison of the outcomes between AI Readiness Index and Public Service Effectiveness of different countries. India tops both scores with countries like Nigeria and Ethiopia being at the bottom of the ranking. Overall, there is a positive trend as the countries with a high level of AI readiness tend to have a better quality of service. Diversion like in Rwanda and Pakistan is, however, suggesting a conflict between the digital ability and the service delivery result.

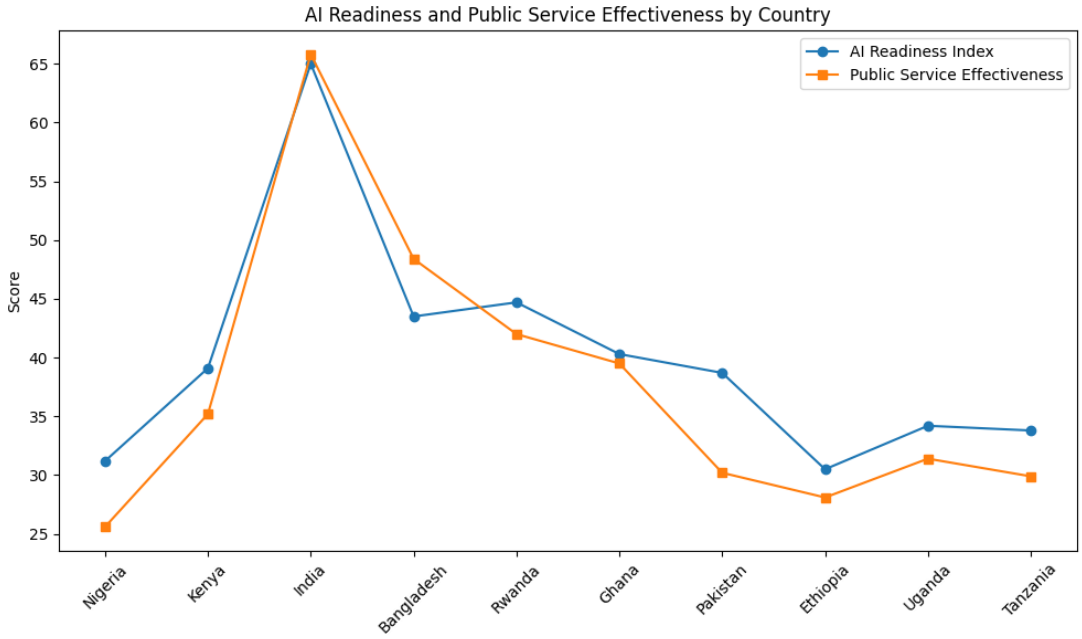


Figure 6: Line chart for the study

The pairplot shows in figure 7, explains how these major variables connect with each other, including AI Readiness, E-Government Score, Effectiveness of Public Services and Internet Penetration and GDP per capita. There is no overwhelming prevalence of some variable indicating substantial positive or negative correlations to others, instead, there are minor positive correlations among some variables, such as AI Readiness and GDP. This visualization is useful in exploratory analysis, and the possible patterns observed are a provision of deeper statistical verification.

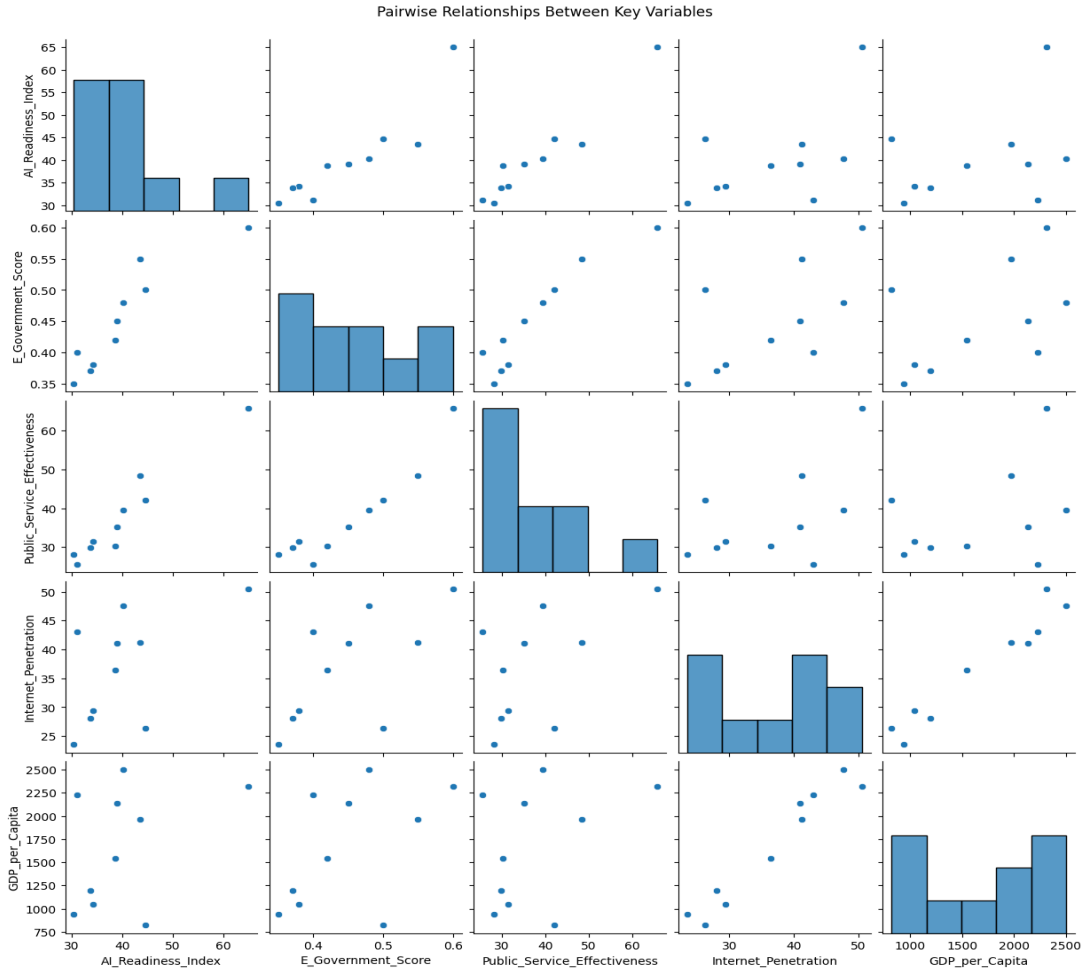


Figure 7: Pairplot chart for the study

4. CONCLUSION

The paper has explored the potential implementation of Artificial Intelligence (AI) in the sphere of improving public service provision in developing nations through the quantitative method that allows analyzing the information collected about the chosen countries. Major indicators including AI Readiness, E-Government Development Score, Internet Penetration and GDP per Capita were put into consideration as well as Public Service Effectiveness. The findings of the analysis indicated that there is a positive correlation between the state of being AI ready and better outcomes of the public service, and the importance of the digital infrastructure and strategic policy frameworks.

The countries that are more ready and have favorable policies to AI have shown superior results in terms of service provision. Nonetheless, formal AI policies are yet in place in various developing countries, which does not allow them to experience the benefits of the AI to the fullest. Also, internet equity and inequality of financial resources remain significant obstacles to digital change on the part of government.

The research has found out that hospitable factors, which include infrastructure, digital literacy, and policy orientation are required to realize the potential value of AI to enhance efficiency in governance and delivery of services. In order to gain maximally, developing countries should invest in inclusive digital policies, institutional capacity, and policy based on evidence and facts. In future, there should be studies that understand the qualitative views and the long-term assessment of the use of AI in public service to get a more balanced idea of its transformative power.

4.1 Recommendations

Developing countries must focus on establishing detailed AI policies that are aligned to national interests to help them take advantage of Artificial Intelligence in delivering public services. Digital infrastructure, access to the internet and capacity building require investment to enable AI usage. Data-driven decision-making should also be encouraged by governments to enhance data collection and automated analytics. Cooperation should be established with foreign agencies, business actors, and universities to transfer and innovate knowledge. Moreover, ethical principles and inclusive approaches are to be developed to make it clear that AI tools are transparent, fair, and customized to concrete needs of various groups of people.

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YENİLENEBİLİR ENERJİ TEKNOLOJİLERİNİN VE SÜRDÜRÜLEBİLİR KALKINMANIN TARIMA ETKİSİ

Yegana AHMADOVA

Azerbaycan Devlet Pedagoji Üniversitesi, Tarih ve Coğrafya Fakültesi, Bakü

Tarlan AGAYEV

Azerbaycan Üniversitesi, Sosyal ve Beşeri Bilimler Fakültesi, Bakü

ÖZET

Günümüzde tarım, sadece gıda temin etmekle kalmayıp ekonomik kalkınmanın ve sosyal refahın temel taşlarından biri olarak öne çıkmaktadır. Tarım sektöründe sürdürülebilir uygulamaların benimsenmesi, toprak sağlığının korunması, biyoçeşitliliğin artırılması ve su kaynaklarının etkin kullanımı açısından kritik öneme sahiptir. Organik tarım, hassas tarım yöntemleri, agroforestry ve entegre zararlı yönetimi gibi yaklaşımlar, hem üretim verimliliğini artırmakta hem de çevresel etkileri azaltmaktadır. Bu yöntemler, tarımsal üretimde kimyasal pestisit ve gübre kullanımını azaltırken, sera gazı emisyonlarını düşürmeye ve yenilenebilir enerji kullanımı yoluyla enerji verimliliğini artırmaya katkı sağlamaktadır.

Küreselleşme ve değer katmış tarım faaliyetleri bir sıra ülkelerde çevresel baskıyı artırmakta ve ekolojik ayak izlerini genişletmektedir. Bu bağlamda, güneş, rüzgar, hidro ve biyokütle gibi yenilenebilir enerji kaynaklarının tarımsal üretimde kullanımı çevresel sürdürülebilirlik açısından kritik bir çözüm sunmaktadır. Güneş enerjisi ile sulama sistemlerinin ve enerji ihtiyacı yüksek tarımsal süreçlerin desteklenmesi, fosil yakıt bağımlılığını azaltırken sektörde karbon ayak izini düşürmektedir.

Sürdürülebilir tarımda enerji verimli teknolojiler, su tasarruflu sulama teknikleri ve hassas tarım uygulamaları hem verimliliği artırmakta hem de doğal kaynakların korunmasını sağlamaktadır. Ayrıca, çiftçilerin çevre bilincinin artırılması, eğitim programlarıyla sağlanabilir; bu programlar toprak sağlığı, su yönetimi ve sürdürülebilir kaynak kullanımı gibi konuları kapsayabilir. Organik gübre kullanımı ve hayvan gübresinin teşvik edilmesi gibi yöntemler, toprak kalitesini koruyarak çevre kirliliğini azaltır.

Değer katmış tarım ürünlerinin sürdürülebilir yöntemlerle üretilmesi, hem yerel hem de uluslararası pazarlarda rekabet avantajı sağlar. Yenilenebilir enerji kullanımı ve çevre dostu üretim süreçleri, ekonomik dayanıklılığı artırırken, iklim değişikliği ile mücadele ve sürdürülebilir kalkınma hedeflerine katkı sağlar. Tarımın enerji ve çevreyle entegrasyonu, hem çevresel hem de ekonomik açıdan uzun vadeli sürdürülebilirliğin anahtarıdır.

Anahtar Kelimeler: Sürdürülebilir Tarım, Yenilenebilir Enerji, Organik Tarım, Çevresel Sürdürülebilirlik.

THE IMPACT OF RENEWABLE ENERGY TECHNOLOGIES AND SUSTAINABLE DEVELOPMENT ON AGRICULTURE

ABSTRACT

In Agriculture remains a cornerstone of human survival, food security, and economic development. Beyond food production, it supports livelihoods, particularly in rural areas, and contributes to global trade and national prosperity. The adoption of sustainable agricultural practices is crucial for preserving soil health, promoting biodiversity, and conserving water resources. Methods such as organic farming, precision agriculture, agroforestry, and integrated pest management reduce the use of chemical fertilizers and pesticides, lower greenhouse gas emissions, and enhance energy efficiency through renewable energy utilization.

Globalization and value-added agricultural activities are increasing environmental pressure and expanding ecological footprints in a number of countries. Expanding the use of renewable energy sources, such as solar, wind, hydro, and biomass, in agriculture can mitigate these impacts. Solar-powered irrigation systems and bioenergy for agricultural processes reduce reliance on fossil fuels and help lower the carbon footprint of the sector. Renewable energy adoption also strengthens energy security and resilience against global market fluctuations.

Sustainable farming practices, including water-saving irrigation techniques, crop rotation, conservation tillage, and precision agriculture, enhance productivity while protecting natural resources. Educating farmers on environmental impacts and promoting eco-friendly inputs, such as organic fertilizers and animal manure, further supports soil quality and ecological preservation. These initiatives foster community engagement, knowledge sharing, and long-term social and economic viability for farming communities.

Value-added agriculture can also align with environmental objectives by integrating sustainable inputs and production methods. High-quality, eco-friendly agricultural products meet the growing global demand for green products, offering competitive advantages while conserving natural resources. By combining renewable energy use with sustainable agricultural practices, countries can simultaneously support economic growth and environmental sustainability.

Ultimately, the integration of renewable energy and sustainable agricultural practices is vital for reducing environmental footprints, enhancing climate resilience, and achieving long-term food security. Such strategies enable the creation of a more sustainable and robust agricultural sector that balances economic development with environmental stewardship, contributing to global climate goals and sustainable development objectives.

Keywords: Sustainable Agriculture, Renewable Energy, Organic Agriculture, Environmental Sustainability.

INTRODUCTION

Agriculture has been central to human development since the advent of sedentary societies; it not only provides food but also structures social organization, shapes land use, and underpins local and national economies. Over millennia, human societies have modified landscapes—clearing forests, domesticating plants and animals, and altering hydrological regimes—to meet expanding material needs. These anthropogenic transformations created the conditions for agricultural intensification and population growth, but also introduced a range of environmental pressures: soil degradation, biodiversity loss, water stress, and increased greenhouse gas (GHG) emissions. Understanding the historical trajectory of human–environment relations is essential for framing contemporary policy responses that reconcile productivity goals with ecological stewardship.

In the contemporary era the twin pressures of rising food demand and climate change make the sustainability of agricultural systems a central policy concern. Agricultural production and land use account for a substantial share of global anthropogenic GHG emissions and are both drivers and victims of climate change: unsustainable land-management practices degrade soils and reduce carbon sinks, while changing temperature and precipitation patterns alter crop suitability and water availability. The IPCC's Special Report on Climate Change and Land underscores these interconnections and calls for integrated solutions that address land degradation, food security, and climate mitigation concurrently.

Renewable energy technologies are increasingly presented as a complementary set of solutions that can reduce the agriculture sector's carbon intensity while improving energy access and resilience at farm and community scales. Solar, wind, small-scale hydro, and biomass-based systems can power irrigation pumps, cold chains, grain dryers, and processing units—functions that are energy-intensive and often dependent on fossil fuels in low- and middle-income settings. Notably, solar-powered irrigation systems (SPIS) and decentralized bioenergy applications have shown promise in reducing operational costs, enhancing productivity, and lowering emissions when designed alongside sustainable water and land-use practices. However, adoption at scale is not without challenges: SPIS can increase water extraction pressures if not paired with proper water governance; bioenergy feedstock production can compete with food production unless residues and waste streams are prioritized. These technological opportunities and trade-offs are examined in the joint FAO–IRENA synthesis and associated FAO technical guidance on SPIS.

From a development perspective, the World Bank and its Energy Sector Management Assistance Program (ESMAP) emphasize that renewable energy deployment must be integrated into broader rural electrification and agricultural modernization strategies. Investments that combine technical assistance, financing instruments, and regulatory reforms can increase the developmental impact of clean-energy technologies on agriculture—provided they address institutional capacity, market linkages, and gender-sensitive access to services.

Renewable Energy in Agri-Food Systems. The agri-food sector is one of the largest consumers of global energy and a significant contributor to greenhouse gas emissions. According to IRENA (2021), agriculture, forestry, and other land-use activities account for nearly one-quarter of global emissions, largely due to energy-intensive mechanization, fertilizer production, and post-harvest operations. Integrating renewable energy technologies (RETs) into this sector is increasingly viewed as a key strategy for decarbonization, energy efficiency, and sustainable rural development.

FAO and IRENA (2021) emphasize that renewable energy can support every stage of the agricultural value chain—from production and processing to distribution and waste management. Solar, wind, small hydro, and bioenergy systems can replace or supplement

diesel-based generators, providing stable and affordable energy for irrigation, livestock rearing, food storage, and value-added processing. The transition from fossil fuels to clean energy reduces vulnerability to fluctuating oil prices and strengthens energy security in rural economies (World Bank, 2020).

Furthermore, the adoption of RETs complements global sustainable development frameworks, particularly SDG 2 (Zero Hunger), SDG 7 (Affordable and Clean Energy), and SDG 13 (Climate Action). Countries that integrate renewable energy into agricultural planning demonstrate improved food security outcomes, as energy access enables mechanization, cold storage, and irrigation expansion (IRENA, 2022). However, the diffusion of these technologies remains uneven, constrained by financial barriers, lack of technical skills, and weak institutional support.

Solar-Powered Irrigation Systems (SPIS) and Water-Energy Nexus. Among renewable technologies, solar-powered irrigation systems have gained the most traction in developing countries. SPIS use photovoltaic panels to generate electricity for water pumping, providing farmers with an alternative to diesel-powered pumps. The FAO-IRENA report (2021) identifies SPIS as one of the most cost-effective and climate-resilient solutions for improving agricultural productivity and energy independence.

Empirical studies demonstrate that SPIS can increase cropping intensity, reduce energy costs, and lower carbon emissions (IRENA, 2021; FAO, 2021). For example, pilot projects in India, Morocco, and Kenya show reductions of up to 70% in irrigation energy costs compared with diesel pumps. However, the same studies caution that widespread adoption can lead to unsustainable groundwater extraction when water governance is weak (FAO, 2022).

The water-energy-food nexus thus emerges as a central policy concern. The IPCC (2019) underscores that technological efficiency alone cannot ensure sustainability; effective management of water rights, crop selection, and groundwater monitoring is critical to prevent resource depletion. Integrated governance models, combining energy subsidies with water-use regulation, have proven more successful than technology-only interventions.

Bioenergy and Waste-to-Energy in Agriculture. Bioenergy technologies—such as biogas digesters, biomass gasification, and biofuel production—represent another pathway to sustainable energy use in agriculture. The World Bank (2020) and IRENA (2022) highlight that biogas systems convert organic residues (animal manure, crop residues, and agro-industrial waste) into clean energy while producing nutrient-rich digestate for soil amendment. This dual benefit—energy generation and waste recycling—makes bioenergy highly compatible with circular-economy principles.

Studies by Abanades et al. (2021) and more recent reviews (2024–2025) show that small-scale anaerobic digesters can meet up to 30–50% of a farm's energy needs while reducing methane emissions from livestock waste. In countries like China, Vietnam, and Turkey, biogas programs have improved rural sanitation, reduced deforestation (by substituting firewood), and created employment in maintenance and equipment manufacturing.

However, large-scale biofuel production introduces sustainability challenges, such as land-use competition with food crops and potential biodiversity loss. The FAO (2020) and IPCC (2022) recommend prioritizing second-generation biofuels and waste-to-energy approaches that use non-food biomass and agricultural residues.

Agroecological Practices and Energy Efficiency. Sustainable agriculture extends beyond technological substitution; it also involves ecological management practices that improve energy efficiency and environmental resilience. Techniques such as conservation tillage, crop rotation, agroforestry, and integrated pest management reduce dependence on chemical inputs and enhance soil fertility. These methods lower indirect energy consumption—since producing fertilizers and pesticides is among the most energy-intensive agricultural processes (FAO, 2020).

Precision agriculture, supported by renewable-energy-powered sensors and data analytics, enables site-specific management of water and nutrients, minimizing waste and maximizing yield (IRENA, 2023). Moreover, agroforestry systems integrate trees and crops, increasing carbon sequestration and biodiversity while stabilizing microclimates. Together, these practices exemplify the synergy between renewable energy technologies and ecosystem-based approaches to sustainable land management.

The success of renewable energy adoption in agriculture depends heavily on governance frameworks and financing mechanisms. The World Bank's Energy Sector Management Assistance Program (ESMAP) highlights that decentralized energy systems require coordination among multiple sectors—agriculture, water, energy, and environment—to avoid policy fragmentation (World Bank, 2021).

Public-private partnerships (PPPs), concessional loans, and results-based financing have proven effective in scaling up renewable energy technologies in rural areas. For instance, India's "KUSUM" program provides capital subsidies for farmers installing solar pumps, while Morocco's "Green Generation Plan" links renewable energy deployment with agricultural modernization strategies.

Institutional capacity building, extension services, and farmer training remain critical. FAO (2022) stresses that awareness programs promoting environmental stewardship and technical training for maintenance can ensure long-term system performance and community ownership. Without these social components, technological adoption risks remaining superficial or inequitable.

METHODOLOGY

This study employs a **qualitative-integrative research design**, combining systematic literature synthesis, comparative case analysis, and conceptual modeling to explore the multidimensional relationship between renewable energy technologies (RETs) and sustainable agricultural development. The approach is rooted in a constructivist epistemology, emphasizing the co-evolution of technology, environment, and socio-economic systems (Yin, 2018; Creswell & Poth, 2019).

To operationalize the relationship between renewable energy technologies and sustainable agricultural development, a **thematic synthesis** approach was employed. The analysis was structured around five key dimensions:

1. **Energy Accessibility and Efficiency** – evaluating how RETs enhance energy availability for farm operations while reducing energy intensity.

2. **Environmental Sustainability** – assessing reductions in greenhouse gas (GHG) emissions, soil degradation, and water stress resulting from renewable energy adoption.

3. **Economic Viability** – measuring the impacts of RETs on production costs, farmer income, and local value chains.

4. **Social Inclusion and Equity** – analyzing how technology diffusion affects gender participation, rural employment, and community empowerment.

5. **Institutional and Policy Support** – identifying governance mechanisms, financing models, and regulatory instruments that facilitate or constrain RET integration in agriculture.

Each dimension was examined using **comparative cross-case synthesis** (Yin, 2018), allowing for triangulation between different geographic contexts—such as Asia's large-scale solar irrigation programs, Europe's circular bioeconomy models, and Africa's decentralized mini-grid initiatives.

Since ancient times, people have used land for agricultural purposes to provide daily food, but over-cultivation leads to a decrease in soil productivity.

According to the FAO analysis of land use indicators in the world, certain approaches are required to several issues. They include land fund, soil structure, and dimensions:

1. 37.1% of the total land fund is suitable for agriculture.

11% of it can provide the opportunity to obtain food products. Although pastures are twice as large as arable and perennial cropland, 10% of it can meet the demand for food products.

2. 31% of the total land fund is forest resources. Forests have many benefits for the environment and society. They include the formation of forestry, water circulation, climate formation processes. Fruits and berries from forests, mushrooms, are used for grazing, hunting, etc.

3. According to the indicators, other land areas are the same as forest areas, but different areas are used. In scientific sources, land areas are used for facilities, construction purposes, etc., which covers 2-3% of technological work. Other land areas include deserts, glaciers, rocks, swamps, water bodies, etc. (K.B.Bayramov, Z.R.Babayeva. 2024).

CONCLUSION

The integration of renewable energy technologies (RETs) into agricultural systems represents a **transformative pathway toward sustainable development**, addressing environmental, economic, and social challenges simultaneously. Agriculture, being inherently energy-intensive, benefits from decentralized, clean, and efficient energy sources, which enhance productivity, reduce greenhouse gas emissions, and support climate resilience.

Key findings indicate that:

1. **Energy Efficiency and Productivity Gains:** RETs such as solar PV, wind turbines, and biogas systems provide reliable and cost-effective energy solutions for irrigation, post-harvest processing, and farm mechanization. Enhanced energy access improves agricultural yields, reduces operational costs, and stabilizes rural livelihoods.

2. **Environmental Sustainability:** The adoption of renewable energy reduces dependency on fossil fuels, mitigates GHG emissions, and improves soil, water, and ecosystem health. RETs complement sustainable agricultural practices—such as organic farming, precision agriculture, and agroforestry—by supporting efficient water use, nutrient recycling, and biodiversity conservation.

3. **Economic and Rural Development:** RETs foster job creation, skill development, and local enterprise opportunities. They contribute to rural income diversification, enhance value-added agricultural production, and strengthen resilience to energy price volatility. Countries with effective policies linking renewable energy and agriculture demonstrate higher economic returns and improved market competitiveness.

4. **Social and Institutional Impacts:** Renewable energy adoption empowers communities by improving access to energy, enabling technological literacy, and supporting inclusive participation in sustainable agricultural initiatives. Institutional coherence, clear regulatory frameworks, and public–private partnerships are crucial for equitable and large-scale deployment.

5. **Systems Perspective:** Renewable energy and sustainable agriculture are interdependent. Circular bioeconomy models and precision agriculture powered by RETs illustrate how energy, water, and nutrient cycles can be optimized simultaneously, aligning agricultural production with climate mitigation and sustainable development goals.

Overall, renewable energy serves as both a **driver and enabler** of sustainable agriculture, providing a foundation for climate-smart practices, ecological stewardship, and economic resilience. However, achieving full potential requires addressing financial, technical, and policy barriers through coordinated multi-level interventions.

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INTEGRATION OF ARTIFICIAL INTELLIGENCE IN VERTICAL GARDENS: A SMART APPROACH TO SUSTAINABLE URBAN GREENING

Dr. Sujata Dabolkar*

Department of Botany, Government college of Arts, Science and Commerce, Quepem, Goa

* Sujatadabolkar@gmail.com

ORCID: 0000-0001-6141-3069

Dr. Kuldeep Sambrekar

Dept. of CSE, KLS Gogte Institute of Technology, Belagavi

kuldeep.git@gmail.com,

ORCID: 0000-0002-3542-1716

ABSTRACT

Urbanization has led to a significant reduction in green spaces, prompting the need for innovative approaches to restore ecological balance within cities. Vertical gardens, or living green walls, serve as sustainable solutions for enhancing urban biodiversity, improving air quality, and reducing the heat island effect. The integration of Artificial Intelligence (AI) into vertical gardening systems has revolutionized their design, operation, and maintenance. AI-driven sensors and Internet of Things (IoT) technologies enable real-time monitoring of environmental parameters such as humidity, temperature, light intensity, and soil moisture enabling precise irrigation and nutrient management. Machine learning algorithms assist in plant species selection based on site-specific microclimatic conditions and predict plant health issues before they occur. Furthermore, AI-based predictive models optimize resource utilization, reducing water and energy consumption while enhancing plant growth and aesthetic appeal. The convergence of AI and vertical gardening thus represents a step toward smart, sustainable, and resilient urban ecosystems that harmonize technology with nature.

Keywords: Artificial Intelligence; Vertical Gardens; Urban Sustainability; Smart Irrigation; IoT Sensors; Plant Health Monitoring; Resource Optimization; Green Architecture

INTRODUCTION

Vertical gardens are soil-based, hydroponic, or aeroponic plant systems arranged vertically on walls or structures—represent a cornerstone of sustainable urban design. They are increasingly adopted in urban centers like Singapore, Tokyo, and Bengaluru, where space constraints limit traditional green landscapes (Gupta & Ramesh, 2024). Integrating artificial intelligence (AI) into vertical gardens presents a progressive solution for sustainable urban greening, combining advanced technology with ecological design to address pressing urban challenges (Sun and Li, 2025). AI-powered systems can optimize water and nutrient delivery, ensuring consistent plant health while reducing waste and resource use. Machine learning and IoT devices enable real-time monitoring of vertical garden conditions, such as light, temperature, soil moisture, and air quality, automating adjustments for the best growth outcomes. Vertical gardening is a sustainable method and includes reducing urban heat, enhancing air quality, conserving water, and supporting pollinator species. Urbanization is rapidly transforming landscapes, leading to a loss of green spaces and escalating environmental pressures in metropolitan areas. Vertical gardens, also known as living walls, represent an innovative response to these challenges by introducing dense, multifunctional greenery into high-density settings where traditional gardens are impractical. Recently, the emergence of artificial intelligence (AI)—encompassing machine learning, sensors, robotics, and the Internet of Things (IoT)—has created opportunities to further enhance the sustainability and effectiveness of vertical gardening systems. The objective of this article is to assess how AI technologies are integrated into vertical gardens, evaluate their impact on urban sustainability, and identify challenges and trajectories for future development.

Since the 1990s, cities worldwide have experimented with vertical gardens to reclaim lost green space, mitigate the urban heat island effect, and improve air quality. Early systems often required manual maintenance and faced challenges in adapting to variable urban conditions (Lotfi, Refaat, El Attar, & Abdel Salam, 2020). However, modern advancements have shifted towards automation and digital integration (Rathor et al., 2024).

Studies show that green facades can lower surface temperatures by up to 15°C and reduce ambient heat islands by 20–30% (Chen et al., 2023). Additionally, they sequester CO_2 and particulate matter while promoting mental well-being among urban dwellers. Vertical farming can produce plants in vertically stacked layers in high-rise or indoor buildings. Examples of successful VGs and/or VFs are already present in advanced urban structures, where they provide ecological and food-production benefits. In New York City, for example, it has been estimated that a tall building 30 stories high can supply food for up to 50,000 residents (Despommier, 2010). As indicated by this estimation, a VG that requires one square of the city and has 30 stories (around three million square feet) can offer 2000 calories every day to 10,000 individuals. This evaluation clearly demonstrates that the implementation of VGs can be readily established in vertically sloped surfaces, such as in high-rise buildings in urban areas, where available land and space are limited.

Prior research has focused on smart agriculture systems using IoT and machine learning. IoT-driven irrigation solutions monitor soil moisture and automate water distribution, while computer vision models detect plant diseases through leaf imagery. However, few studies combine these technologies in the context of vertical gardening. Gaps still exist in adaptive irrigation prediction, automated nutrient management, and real-time feedback control. This study bridges that gap by developing a modular AI system that controls multiple vertical garden parameters simultaneously.

SYSTEM DESIGN AND METHODOLOGY

The proposed system architecture comprises four main layers—Sensor, Control, AI Processing, and User Interface as seen in **Figure 1**. Together, they create a closed-loop system capable of real-time monitoring and intelligent control. The design enhances plant growth efficiency, minimizes resource wastage, and supports remote supervision via a dashboard.

SYSTEM ARCHITECTURE

• Sensor Layer: Collects data using temperature, humidity, light, and soil moisture sensors.

• Control Layer: Managed by a microcontroller such as Raspberry Pi or ESP32 that transmits sensor data.

• AI Processing Layer: Analyzes incoming data using trained models in TensorFlow or PyTorch.

• User Interface Layer: Displays analytics and allows control actions via a mobile or web dashboard.

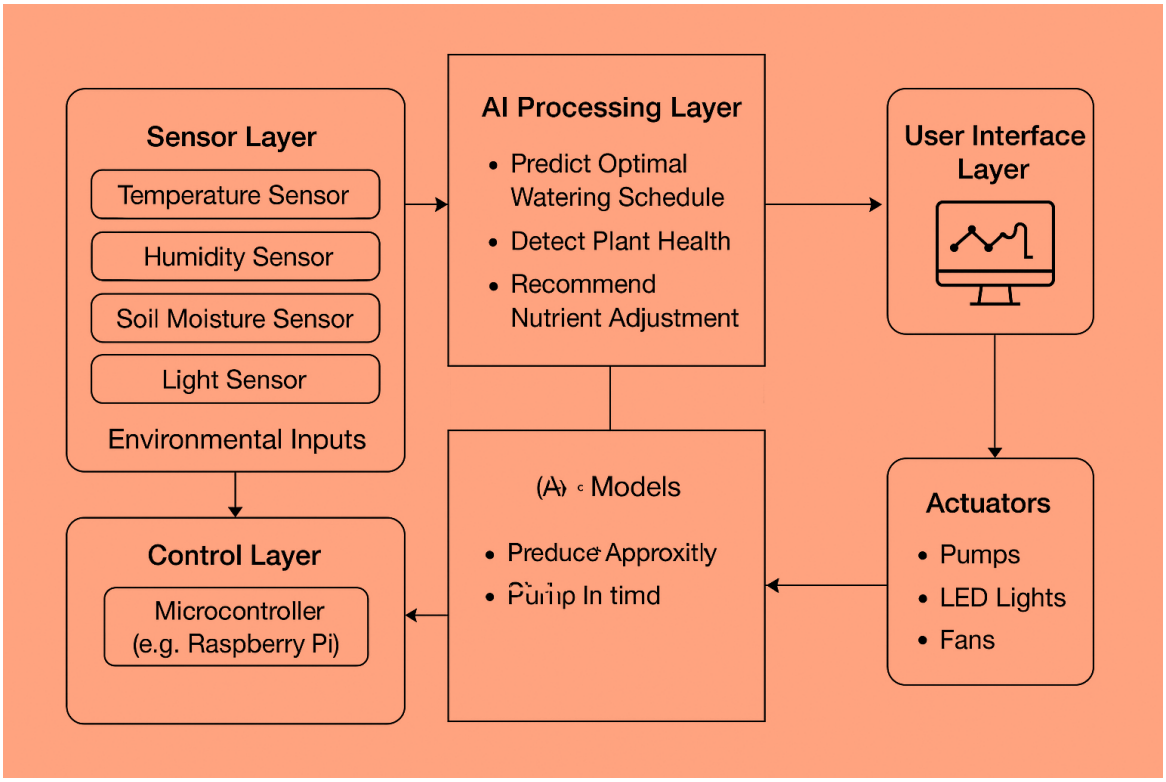


Figure 1: System Architecture of the AI-Enabled Vertical Gardening System.

PROPOSED WORKFLOW

Sensor data is continuously collected from environmental and soil-based sensors. The control unit preprocesses the data and forwards it to cloud-based AI modules. These modules predict the required watering schedule, detect plant stress, and adjust nutrients automatically. The processed insights are relayed back to actuators controlling pumps, lights, and fans.

Environmental Inputs

(Temperature, Humidity, Soil Moisture, Light)

IoT Data Acquisition

(Sensors + Edge Devices)

Data Preprocessing & Cloud Upload

AI Models:

├─ Predict Optimal Watering Schedule (Regression/ANN)

├─ Detect Plant Health via Image Analysis (CNN/YOLO)

└─ Recommend Nutrient Adjustment (Rule-based/ML)

Control Signals Sent to Actuators

(Pumps, LED Lights, Fans)

Real-time Dashboard & Alerts

(Mobile/Web Application)

AI MODEL DESIGN

The AI component includes supervised and unsupervised models, ie Plant Health Detection – CNN-based models like MobileNet detect disease symptoms from captured images. The Smart Irrigation – Regression or LSTM models predict watering needs based on time-series data. Nutrient Adjustment – Decision Tree models recommend fertilizer levels based on soil moisture and pH values and Predictive Maintenance – Autoencoders identify anomalies in sensor readings, alerting for system faults. The prototype integrates both hardware and software components. The hardware comprises DHT11, soil moisture sensors, and a Raspberry Pi microcontroller. Software components include Python-based models and IoT platforms such as Node-RED and ThingSpeak for data handling. Cloud-based AI processing is managed through AWS IoT Core, with real-time visualization via Flask dashboards.

RESULTS AND DISCUSSION

Experimental results indicate that the AI-driven vertical gardening system reduced water usage by approximately 28–35% while maintaining consistent plant growth. The CNN model achieved a 91% accuracy rate in detecting early plant disease symptoms. Furthermore, the predictive irrigation model demonstrated reduced resource waste and improved soil moisture

stability. These findings suggest that AI-enhanced vertical gardening significantly increases efficiency and sustainability.

CONCLUSION AND FUTURE SCOPE

The developed AI-based vertical gardening system provides a scalable and sustainable solution for urban agriculture. By combining IoT sensing, machine learning, and automation, it enhances productivity, reduces human effort, and promotes responsible resource use. Future enhancements will include reinforcement learning for adaptive irrigation, integration with voice-controlled systems, and support for large-scale commercial implementations.

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MİX-BED REÇİNELERİN KUMLU-KİREÇLİ TOPRAKLARIN SU TUTMA KAPASİTESİ ÜZERİNE ETKİLERİ

Yezdan YELKEN
Email: yezdanyelken@gmail.com
ORCID: 0009-0008-7435-7949
İsmet ÇOŞKUN
Email: tcismetcoskun@gmail.com
ORCID: 0009-0005-0773-5768
Doç. Dr. Hamza NEGİŞ
Email: hnegis@selcuk.edu.tr
ORCID: 0000-0002-1880-9188
Prof. Dr. Cevdet ŞEKER
Email: cseker@selcuk.edu.tr
ORCID: 0000-0002-8760-6990

ÖZET

Küresel iklim değişikliğiyle birlikte artan kuraklık dönemleri, tarımsal üretim ve gıda güvenliğini tehdit eden en önemli çevresel sorunlardan biridir. Dünya genelinde geniş alanları kaplayan kumlu ve kireçli topraklar, yüksek geçirgenlikleri ve düşük koloidal içerikleri nedeniyle su tutma kapasiteleri sınırlı olan sistemlerdir. Bu topraklarda, kök bölgesinde sürekli su stresi oluşmakta ve bitki verimi önemli ölçüde azalmaktadır. Bu durum hem sürdürülebilir hem de ekonomik olarak uygulanabilir toprak düzenleyicilere olan ihtiyacı artırmaktadır. Bu çalışmada, saf su sistemlerinde kullanıldıktan sonra atık hâline gelen mix-bed iyon değiştirici reçinelerin, kumlu-kireçli toprakların su tutma özelliklerini iyileştirme potansiyeli araştırılmıştır. Deneysel tasarım kapsamında, toprak örneklerine %0 (kontrol), %1, %2 ve %4 oranlarında mix-bed reçine ilavesi yapılmış ve 30 günlük inkübasyon sonunda Tarla Kapasitesi (TK), Solma Noktası (SN) ve Faydalı Su İçeriği (FS) parametreleri belirlenmiştir. İstatistiksel analizler sonucunda, reçine uygulamalarının tüm parametreler üzerinde anlamlı etkiler yarattığı saptanmıştır ($p<0.05$). Özellikle SN değerlerinde çok yüksek düzeyde fark gözlenmiş ($p<0.001$) olup, %4 reçine uygulaması en yüksek ortalama (7.36%) ile öne çıkmıştır. TK açısından, %4 ve %2 uygulamaları kontrol grubuna kıyasla belirgin artış göstermiştir (ortalama 14.9% ve 14.6%). FS değerlerinde genel olarak artış eğilimi görülse de farklar istatistiksel olarak sınırda anlamlı bulunmuştur ($p<0.05$). Bu sonuçlar, mix-bed reçinelerin toprağın hem su tutma hem de su kullanılabilirliği kapasitesini iyileştirdiğini göstermektedir. Sonuç olarak, atık iyon değiştirici reçinelerin, kumlu-kireçli toprakların fiziksel özelliklerini geliştiren ve toplam kullanılabilir su tutma kapasitesini artıran etkili bir toprak düzenleyici olarak yeniden değerlendirilebileceği belirlenmiştir. Elde edilen bulgular, atık iyon değiştirici reçinelerin kumlu-kireçli topraklarda su tutma kapasitesini artırmada potansiyel bir toprak düzenleyicisi olarak değerlendirilebileceğini ortaya koymaktadır. Bununla birlikte, farklı toprak tekstürleri ve daha uzun inkübasyon sürelerini kapsayan ileri düzey araştırmalar, reçinelerin kalıcılığını, etki mekanizmalarını ve optimum uygulama dozlarını daha kapsamlı biçimde ortaya koymak açısından önem arz etmektedir.

Anahtar Kelimeler: Mix-bed reçine, kumlu-kireçli toprak, su tutma kapasitesi, toprak düzenleyici, sürdürülebilir tarım

THE EFFECTS OF MIX-BED RESINS ON THE WATER RETENTİON CAPACİTY OF SANDY-CALCAREOUS SOİLS

ABSTRACT

Global climate change and the associated increase in drought frequency represent one of the most critical environmental threats to agricultural productivity and food security. Sandy and calcareous soils, which dominate large areas worldwide, are characterized by high permeability and low colloidal content, resulting in limited water-holding capacity. Consequently, continuous water stress occurs in the root zone, leading to substantial reductions in crop yield. This condition highlights the growing need for soil conditioners that are both sustainable and economically feasible. This study investigated the potential of waste mix-bed ion-exchange resins, commonly discarded after use in pure-water systems, to improve the water-retention characteristics of sandy–calcareous soils. Within the experimental design, soil samples were homogenized with mix-bed resin at four rates: 0% (control), 1%, 2%, and 4% by weight. After a 30-day incubation period, Field Capacity (FC), Permanent Wilting Point (PWP), and Available Water Content (AWC) were determined. Statistical analyses revealed that resin treatments had significant effects on all parameters ($p < 0.05$). Particularly, PWP values showed highly significant differences ($p < 0.001$), with the 4% resin treatment achieving the highest mean value (7.36%). Regarding FC, the 2% and 4% resin applications exhibited marked increases compared with the control (mean values 14.6% and 14.9%, respectively). Although AWC showed an overall increasing trend, the differences were only marginally significant ($p \approx 0.05$). These results indicate that the addition of mix-bed resins enhances both the water-holding and water-availability capacities of the soil. In conclusion, waste ion-exchange resins can be repurposed as effective soil conditioners that improve the physical properties and total available water capacity of sandy–calcareous soils. The findings suggest that waste ion-exchange resins may serve as promising soil conditioners to enhance water retention in sandy-calcareous soils. Nevertheless, advanced investigations involving diverse soil textures and extended incubation periods are essential to elucidate the persistence, underlying mechanisms, and optimal application rates of these materials in soil systems.

Keywords: Mix-bed resin, sandy-calcareous soil, water-holding capacity, soil conditioner, sustainable agriculture

1. GİRİŞ

Kuraklık, doğal su döngüsünün aksaması sonucu su kaynaklarının azalmasıyla ortaya çıkan ve ekosistemler üzerinde derinlemesine etkiler bırakan bir çevresel olaydır. Dünya genelinde artan sıcaklıklar, azalan yağışlar ve hızla değişen iklim koşulları, su kaynaklarının sürdürülebilirliğini tehdit ederek kuraklık olgusunun etkisini her geçen yıl daha da artırmaktadır. Birleşmiş Milletler ve uluslararası çevre kuruluşlarının raporlarına göre, dünya kara alanlarının yaklaşık %40'ı kurak koşullar altındadır ve son otuz yılda yeryüzünün yaklaşık %77.6'sı kalıcı biçimde daha kurak hale gelmiştir (UNCCD, 2024). Günümüzde kara alanlarının yaklaşık %30'unun kuraklık koşullarından etkilendiği ve bu oranın 2050 yılına kadar %50'ye ulaşabileceği öngörülmektedir (IPCC, 2023).

Dünya Ekonomik Forumunun 2025 yılında yayınladığı bildiriye göre, kuraklığın doğrudan etkilerinin yaklaşık %80'i tarım sektöründe hissedilmekte; bu da özellikle gelişmekte olan ülkelerde gıda güvenliği açısından kritik bir risk oluşturmaktadır. Türkiye özelinde ise, ülke topraklarının %88'inin kuraklık riski altında olduğu bildirilmiş, bazı bölgelerde yağışların normallerin %26–30 altında seyrettiği tespit edilmiştir (PA Türkiye, 2025). Ülkemizin ortalama yıllık yağış miktarı yaklaşık 643 mm iken, son yıllarda yaşanan kuraklık dönemlerinde bu miktarın normalin %15-20 altında seyrettiği tespit edilmiştir (Altan ve ark. 2020). Bu durum, Türkiye'nin su kaynakları yönetimi, tarımsal üretim planlaması ve ekosistem dayanıklılığı açısından kritik bir dönemeçte olduğunu göstermektedir.

Su kıtlığı, tarımsal üretime dayalı kırsal bölgelerde sosyoekonomik baskıyı artırmakta ve gıda enflasyonu riskini beslemektedir. Özellikle kuru tarım alanlarında buğday ve arpa gibi stratejik ürünlerde %30'lara varan rekolte kayıpları yaşanabilmekte; kuraklık, ulusal gıda arz güvenliğini tehlikeye atmaktadır. Bu zorlu koşullar altında, toprakların su tutma potansiyelini artıracak çözümlerin geliştirilmesi temel bir zorunluluk haline gelmiştir. Bu hayati zorunluluk, zirai araştırmaları, suyun miktarını artırmaktan ziyade, mevcut suyun toprakta tutulma süresini ve kullanım verimliliğini yükseltecek alternatif yolları araştırmaya yöneltmiştir (FAO, 2025).

Özellikle son yıllarda artan çalışmalar, toprakların organik karbon girdileri ile kalitelerinin arttırılmasına ve buna bağlı olarak su tutma kapasitelerinin artırılmasına odaklanmıştır (Negiş, 2023; Gümüş ve ark., 2022). Geleneksel toprak düzenleyicilerin etkisinin sınırlı kaldığı durumlarda, su tutucu polimerler (hidrojeller) gibi yenilikçi malzemeler dikkat çekmektedir (Mikhailidi ve ark., 2024). Bu polimerler, kendi ağırlıklarının yüzlerce katı kadar suyu bünyelerinde jel formunda depolayarak toprağın su tutma kapasitesini artırmakta ve özellikle kuraklık koşullarında mikro su deposu görevi görmektedir (Agbna ve Zaidi 2025). Bu gelişmelere paralel olarak, kimyasal polimerlerin topraklara karıştırılmasıyla toprak düzenleyici uygulamaların çeşitlendiği ve yeni araştırma alanlarının ortaya çıktığı görülmektedir. Bu bağlamda, su arıtma sistemlerinde kullanılan iyon değiştirici reçineler de son dönemde tarımsal üretim açısından ilgi odağı haline gelmiştir. Laboratuvarlarda saf su arıtımında yaygın olarak kullanılan ve kullanım ömrü sonunda atık olarak ortaya çıkan karışık yatak (Mix-bed) iyon değiştirici reçineler, çevreye duyarlı atık yönetimi açısından yeni değerlendirme yaklaşımlarını gündeme getirmektedir. Mix-bed reçineler, güçlü katyonik ve anyonik polimerlerin karışımından oluşan, yüksek su tutma potansiyeli gösteren hidrofilik polimerler grubuna ait sentetik malzemelerdir.

Bu çalışma, su arıtma sistemlerinde kullanılan mix-bed iyon değiştirici reçinelerin kullanım ömrü sonunda ortaya çıkan atık formunun, tarımsal üretimde sürdürülebilir biçimde yeniden değerlendirilmesini amaçlamaktadır. Çalışmanın temel yaklaşımı, çevreye duyarlı atık yönetimi ilkeleri ile kuraklıkla mücadele stratejilerini bir araya getirmektir. Araştırma hipotezi, kullanım ömrünü tamamlamış mix-bed reçinelerin toprak ortamına uygulanmasıyla, bu reçinelerin hidrofilik polimer yapıları sayesinde suyu jel formunda bünyelerinde tutarak

toprağın su depolama kapasitesini artırabileceği varsayımına dayanmaktadır. Böylece, tarla kapasitesi (TK) ile solma noktası (SN) arasındaki farkın faydalı su içeriği (FS) genişlemesi ve bunun sonucunda su kullanım verimliliğinin artması beklenmektedir. Bu kapsamda çalışmanın temel hedefleri şunlardır: (1) Mix-bed reçine uygulamalarının toprakta su tutma kapasitesi üzerine etkisini belirlemek, (2) Bu etkinin toprak tekstürü (kumlu–kireçli topraklar) ile olan ilişkisini ortaya koymak, (3) Tarımsal üretim açısından yeniden kullanım potansiyelini ve çevresel katkılarını değerlendirmek.

2. MATERYAL- METOT

2.1. TOPRAK ÖRNEKLERİNİN TEMİNİ VE HAZIRLANMASI

Denemede kullanılan toprak örneği, İç Anadolu Bölgesi'nin kurak–yarı kurak iklim kuşağında yer alan Konya ili, Karapınar ilçesinden temin edilmiştir. Bölge, düşük yağış miktarı, yüksek buharlaşma oranı ve kireççe zengin toprak yapısı ile karakterize olup erozyon riski yüksek alanlar arasında yer almaktadır. Saksı denemesinde kullanılacak toprak, deneme alanından 0–20 cm derinlikten bozulmuş örnek olarak alınmıştır. Bu derinlik, bitki kök gelişiminin ve su tutma kapasitesinin en aktif olduğu tabakayı temsil etmesi nedeniyle tercih edilmiştir. Toprak örnekleri laboratuvara getirildikten sonra hava akımı altında oda sıcaklığında kurutulmuş, ardından iri agregatlar el ile ufalanarak fiziksel bütünlük bozulmadan homojen hâle getirilmiştir. Elde edilen materyal, 4 mm çapındaki elekten geçirilerek saksı denemesinde kullanılmak üzere hazırlanmıştır.

2.2. DENEME TASARIMI VE UYGULAMA

Çalışmada, atık Mix-bed reçinesinin kumlu–kireçli topraklarda su tutma kapasitesi üzerindeki etkilerini belirlemek amacıyla tek faktörlü bir deneme deseni uygulanmıştır. Denemede, toprak reçine karışım oranı faktör olarak ele alınmış ve dört farklı uygulama düzeyi oluşturulmuştur: %0 (kontrol), %1, %2 ve %4 (ağırlık/ağırlık esasına göre). Her uygulamada 3 kg fırın kuru toprak esasına göre hesaplanmış hava kuru toprak kullanılmıştır. Toprak, önceden 4 mm'lik elekten geçirilmiş ve 3 kg kapasiteli polietilen saksılara eşit miktarda yerleştirilmiştir. Ardından, belirlenen oranlarda Mix-bed reçinesi tartılarak doğrudan saksılara eklenmiş ve reçinenin toprağa homojen biçimde dağılması amacıyla el ile karıştırılmıştır. Deneme, her uygulama için üç tekerrür olacak şekilde yürütülmüştür. Hazırlanan karışımlar, sonraki aşamada gerçekleştirilecek inkübasyon sürecine alınmak üzere laboratuvar ortamında bekletilmiştir.

2.3. İNKÜBASYON SÜRECİ

Toprak ve reçine karışımları hazırlandıktan sonra, her saksı tarla kapasitesinin %80'i oranında su ile nemlendirilmiştir. Bu oran, karışımların suya doygun hale gelmeden optimum nem düzeyine ulaşmasını sağlamak amacıyla tercih edilmiştir. İnkübasyon süreci 30 gün sürmüş ve bu süre boyunca saksılar her üç günde bir tartılarak nem kayıpları izlenmiştir. Tartım işlemleri ±0.01 g hassasiyetli terazi kullanılarak gerçekleştirilmiş, belirlenen kütle farkına karşılık gelen su kayıpları saf su ilavesiyle her saksı için ayrı ayrı tamamlanmıştır. Bu uygulama, reçine toprak etkileşiminin kararlı hale gelmesini ve reçine partiküllerinin tam hidrasyonuna ulaşmasını amaçlamıştır. İnkübasyon süresince saksılar, buharlaşma farklılıklarını en aza indirmek için her hafta rastgele yeniden konumlandırılmış, yüzey buharlaşmasını azaltmak üzere yarı geçirgen polietilen örtü ile kapatılmıştır. İnkübasyon dönemi boyunca karışımlar görsel olarak izlenmiş, reçine partiküllerinde renk veya yüzeye çıkma gibi fiziksel değişimlerin gözlenmediği tespit edilmiştir.

2.4. LABORATUVAR ANALİZLERİ VE YÖNTEMLER

Toprak örneklerinde su tutma özelliklerinin belirlenmesi amacıyla TK ve SN analizleri yapılmıştır. Bu analizler, toprak su potansiyelini temsil eden iki farklı negatif basınç düzeyinde, basınçlı plaka aygıtı kullanılarak gerçekleştirilmiştir. Her uygulamadan alınan örnekler, analize hazırlanmak üzere doygun hâle getirilmiş ve daha sonra TK'yi temsil eden –33 kPa ile SN'yi temsil eden –1500 kPa basınç koşullarında su çıkışı durana kadar yaklaşık 2 gün boyunca tutulmuştur. Toprak örnekleri denge sağlandıktan alınmış ve yaş örnekler tartılmıştır. Örnekler 105 °C 24 saat sabit ağırlığa gelene kadar bekletilmiş ve tekrar tartım yapıldıktan sonra örneklerin nem içerikleri gravimetrik yöntemle belirlenmiştir. Elde edilen değerler arasındaki farktan FS içeriği (FS = TK – SN) hesaplanmıştır (Richards, 1949; Klute, 1986). Bunlara ek olarak, denemede kullanılan toprağın genel özelliklerini belirlemek amacıyla temel fiziksel ve kimyasal analizler de yapılmıştır. Tekstür dağılımı Bouyoucos hidrometre yöntemiyle (Bouyoucos, 1951), pH değeri 1:2.5 toprak/su süspansiyonunda cam elektrotlu pH-metre ile, elektriksel iletkenlik (EC) iletkenlik ölçer ($\mu S\ cm^{-1}$) yardımıyla, organik madde içeriği ise Walkley–Black ıslak yakma yöntemiyle (Nelson & Sommers, 1982) ve toprakların kireç ($CaCO_3$) içeriği, Scheibler calcimeter yöntemi kullanılarak belirlenmiştir (Allison & Moodie, 1965) belirlenmiştir.

2.5. İSTATİSTİKSEL DEĞERLENDİRME

Denemede elde edilen tüm veriler, Mix-bed reçine uygulamalarının toprak su tutma kapasitesi üzerindeki etkilerini karşılaştırmak amacıyla istatistiksel olarak değerlendirilmiştir. Uygulamalar arasındaki farklılıkları belirlemek için tek yönlü varyans analizi (One-Way ANOVA) yöntemi uygulanmıştır. Varyans analizi öncesinde, verilerin normallik (Shapiro ve Wilk, 1965) ve varyans homojenliği (Levene, 1960) varsayımlarını karşıladığı doğrulanmıştır. ANOVA sonucunda istatistiksel olarak anlamlı farklar ($p<0.05$) elde edilen değişkenlerde, gruplar arasındaki farklılığın kaynaklarını belirlemek amacıyla LSD (Least Significant Difference) çoklu karşılaştırma testi uygulanmıştır. Tüm istatistiksel analizler, SPSS Statistics 26.0 (IBM Corp., Armonk, NY, USA) paket programı kullanılarak gerçekleştirilmiştir.

3. SONUÇ VE TARTIŞMA

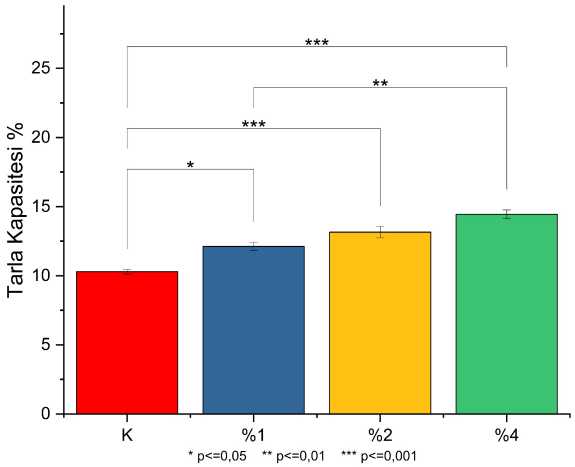
Denemede kullanılan toprak, yüksek kum oranı (% 80.00) ve düşük kil (% 12.50) ile silt (% 7.50) içerikleri nedeniyle kumlu tin tekstür sınıfında yer almaktadır (Tablo 1). Toprağın pH değeri 8.68 olup oldukça alkalin karakterdedir. Elektriksel iletkenlik değeri 120.2 $\mu S\ cm^{-1}$ ile tuzluluk açısından problem oluşturmamaktadır. Organik madde içeriği (% 1.29) ise düşük seviyede olup, su tutma kapasitesini sınırlandırabilecek bir özellik göstermektedir. Analiz sonucunda toprağın ortalama kireç içeriği %68.61 olarak bulunmuş olup, bu değer toprağın yüksek oranda kireçli sınıfına girdiğini göstermektedir. Bu özellikler, çalışmada kullanılan toprağın su depolama potansiyelinin sınırlı ve kurak–yarı kurak bölge topraklarına benzer olduğunu ortaya koymaktadır (Negiş ve ark., 2023).

Tablo 1. Çalışma toprağının genel özellikleri

Toprak Özellikleri	Değer
Kum (%)	80.00
Kil (%)	12.50
Silt (%)	7.50
Tekstür Sınıfı	Kumlu Tın
pH	8.68

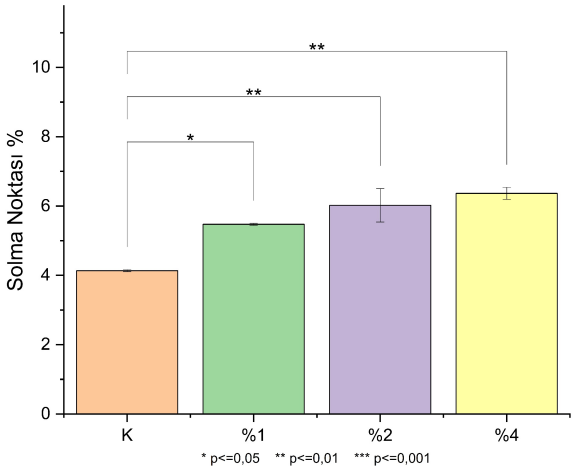
EC (µS cm^{-1})	120.2
Organik Madde (%)	1.29
Kireç (%)	68.61

Mix-bed reçine uygulamaları kumlu-kireçli toprakların su tutma özelliklerini anlamlı biçimde etkilemiştir (Şekil 1–3). Tarla kapasitesi, uygulama dozları arttıkça yükselmiş ve % 4 dozunda kontrol toprağına göre % 40.23 artış göstermiştir. Uygulama dozları arttıkça TK da istatistiksel olarak anlamlı farklar ortaya çıkmıştır. Bu artış, reçinenin jel yapısında suyu absorbe edip gözenekli toprak matrisinde mikroskobik su rezervuarları oluşturduğunu ortaya koymaktadır. Bu bulgu, süper emici polimerlerin toprak su potansiyelini yükseltici etkilerini bildiren çalışmalarla (Naushabayev ve ark., 2022; Omar ve ark., 2024; Abdelgelil ve ark., 2025) uyumludur.



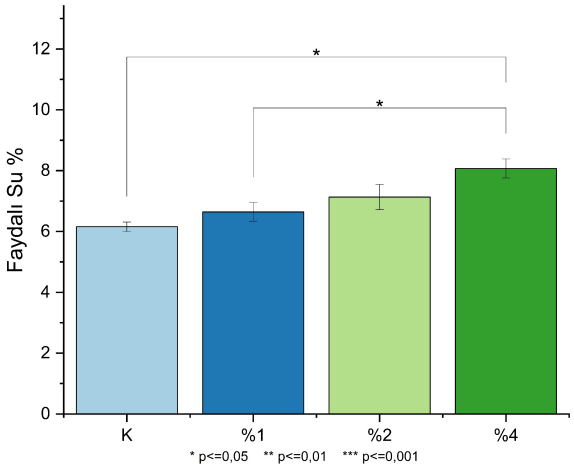
Şekil 1. Mix-bed reçine uygulamalarının kumlu–kireçli toprakların tarla kapasitesi üzerine etkisi.

Mix-bed reçine uygulamaları sonucunda, toprakların SN değerlerinde istatistiksel olarak anlamlı bir artış gözlenmiştir ($p<0.05$). En yüksek reçine dozunda SN, kontrol grubuna göre %53.99 oranında yükselmiştir (Şekil 2). Bu artış, suyun bir kısmının reçine matrisi içerisinde fiziksel bağlarla tutulduğunu ve toprak su potansiyelinin daha negatif değerlere ulaşmasını engellediğini göstermektedir. Reçine partikülleri, bünyelerine aldıkları suyu jel formunda depolamakta; bu suyun bir kısmı matriks suyu olarak toprak çözeltisinden ayrışmakta ve bitki kökleri tarafından doğrudan erişilebilir nitelikte olmamaktadır (Omar ve ark., 2024). Ancak bu durum, polimerin suyu tamamen bitki erişiminden çıkardığı anlamına gelmemektedir. Literatürde, polimerlerin toprakta oluşturduğu su tutma zonlarının, suyun hareketini yavaşlatarak toprak neminin korunma süresini uzattığı belirtilmiştir (Naushabayev ve ark., 2022). Çalışmamızda gözlenen SN artışı, reçinenin toprak içinde mikro-gözenekli jel bölgeleri oluşturarak suyun bir kısmını yüksek potansiyel farklarıyla bağlamasından kaynaklanmıştır. Bu durum, özellikle kumlu topraklarda nemin hızlı kaybolmasını önleyen bir mekanizma olarak değerlendirilebilir. Bununla birlikte, solma noktasındaki artışın tarla kapasitesindeki artıştan daha düşük oranda olması, reçinenin bitkiler açısından kullanılabilir su miktarını azaltmadığını, aksine faydalı su miktarını (%31.21 artış) artırdığını göstermektedir. Benzer şekilde, Dorraji ve ark. (2010) tarafından yürütülen bir çalışmada da, polimer uygulamalarının SN değerlerinde artışa neden olduğu, ancak bu artışın TK'daki yükselme kadar belirgin olmadığı ve sonuçta bitkisel kullanılabilir su içeriğinde net artış sağlandığı bildirilmiştir.



Şekil 2. Mix-bed reçine uygulamalarının kumlu–kireçli toprakların solma noktası üzerine etkisi.

Mix-bed reçine uygulamaları sonucunda toprakların FS değerlerinde istatistiksel olarak anlamlı ($p<0.05$) bir artış elde edilmiştir. Uygulama dozları yükseldikçe FS değerleri kademeli olarak artmış ve en yüksek dozda (%4) kontrol grubuna göre %31.21 oranında iyileşme görülmüştür (Şekil 3). Bu sonuç, toprağın bitkiler tarafından kullanılabilir su kapasitesinin reçine katkısıyla belirgin biçimde arttığını göstermektedir. Elde edilen bu artış, reçinenin suyu jel formunda absorbe ederek, toprağın makro ve mikro gözenekleri arasında geçici bir su rezervi oluşturmasından kaynaklanmaktadır. Bu rezerv, suyun toprak profili boyunca daha yavaş drene olmasını ve kök bölgesinde suyun daha uzun süre tutulmasını sağlamaktadır. Literatürde, süper emici polimerlerin toprakta hidrolik iletkenliği düşürmeden su depolama kapasitesini artırdığı ve özellikle kumlu topraklarda bitki gelişimini olumlu etkilediği belirtilmiştir (Abdelgelil ve ark., 2025; Naushabayev ve ark., 2022). Mix-bed reçine uygulamasının FS üzerindeki etkisi, polimer partiküllerinin tekrarlayan şişme-kuruma döngülerinde yapısal bütünlüğünü koruyabilmesiyle ilişkilidir. Bu özellik, su tutma kapasitesinde uzun vadeli bir kararlılığın sağlanmasına olanak tanır (Omar ve ark., 2024). Ayrıca, bu reçinelerin suyun kimyasal bileşimini değiştirmeden fiziksel olarak tutması, toprağın iyonik dengesi üzerinde olumsuz bir etki yaratmamasını sağlamaktadır. Benzer bulgular, Dorraji ve ark. (2010) ve Sivapalan (2006) tarafından bildirilen çalışmalarla da örtüşmektedir. Söz konusu araştırmalarda, polimer katkılarının hem TK hem de SN değerlerini artırdığı, ancak FS'nin her koşulda pozitif yönde etkilendiği bildirilmiştir. Bu çalışmada da TK artışı SN artışından daha yüksek olduğu için FS'de net bir iyileşme gözlenmiştir.



Şekil 3. Mix-bed reçine uygulamalarının kumlu–kireçli toprakların faydalı su içeriği üzerine etkisi.

4. SONUÇ

Bu çalışmadan elde edilen bulgular, Mix-bed reçine uygulamasının kumlu–kireçli toprakların su tutma özelliklerini anlamlı ve olumlu biçimde etkilediğini ortaya koymuştur. Reçine ilavesi, toprakların hem TK değerini artırmış hem de bitkiler tarafından kullanılabilir su miktarını genişletmiştir. Böylece, suyun toprakta tutulma süresi uzamış ve suyun bitkiler için erişilebilirliği artmıştır. Sonuçlar, kurak ve yarı kurak iklim koşullarında, ayrıca nadas alanları veya su tutma kapasitesi düşük hafif tekstürlü topraklarda, bu tür reçine bazlı düzenleyicilerin uygulanmasının su verimliliğini artırma ve nem kayıplarını azaltma açısından önemli bir potansiyel taşıdığını göstermektedir. Bununla birlikte, araştırma bulguları laboratuvar koşullarında kısa süreli olarak elde edilmiştir. Bu nedenle, karşılaştırmalı saha çalışmaları ve uzun dönemli izleme çalışmaları ile sonuçların doğrulanması önerilmektedir. Ayrıca, çevresel sürdürülebilirlik açısından Mix-bed reçinelerin tarımsal ortamlarda yeniden kullanımı, su tasarrufu sağlamanın yanı sıra atık yönetimine katkı sunan döngüsel ekonomi yaklaşımı açısından da önem taşımaktadır. Gelecekte yapılacak araştırmalar için aşağıdaki öneriler sunulmuştur:

- Reçine materyalinin kullanım ömrü sonrasında potansiyel element birikimi ve çevresel etkilerinin değerlendirilmesi açısından önemlidir.
- Uygulamanın toprak biyolojik süreçleri, mikrobiyal solunum ve enzimatik aktiviteler üzerindeki etkilerinin belirlenmesi önerilmektedir.
- Laboratuvar ortamında elde edilen bulguların zamanla ve gerçek tarla koşullarında doğrulanabilmesi amacıyla uzun dönemli çalışmaların yürütülmesi tavsiye edilmektedir.

5. TEŞEKKÜR

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SOUTHEASTERN TÜRKİYE AS A CROSSROAD OF GOAT DOMESTICATION BETWEEN THE FERTILE CRESCENT AND THE MEDITERRANEAN BASIN

Dr. Öğr. Üyesi Zühal Gündüz

Aydin Adnan Menderes University, Faculty of Agriculture

Email: zuhal.gunduz@adu.edu.tr

ORCID: 0000-0002-1427-1501

ABSTRACT

The domestication of goats, one of the earliest milestones in animal husbandry, began nearly 11,000 years ago in the Fertile Crescent. Southeastern Türkiye, positioned along the northern margin of this cradle of domestication, plays a pivotal role as both a migratory corridor and a genetic interface between the Fertile Crescent and the Mediterranean Basin. Archaeozoological remains from Neolithic sites such as Aşıklı Höyük, Çayönü, Göbekli Tepe, and Nevali Çori demonstrate the presence of early managed and progressively domesticated populations of *Capra aegagrus* in this region. Archaeogenetic evidence complements these findings, highlighting Southeastern Türkiye as a transitional zone that influenced both the domestication process and the westward diffusion of goats. The region's strategic location—integrating prehistoric migration routes, trade networks, and traditional pastoral practices—facilitated sustained interactions among distinct genetic lineages over millennia. This continuous exchange established Southeastern Türkiye as a crucial nexus where early domesticated lineages from the Fertile Crescent merged with subsequent genetic expansions toward the Mediterranean Basin. Beyond its archaeological significance, the region serves as a contemporary reservoir of adaptive genetic diversity shaped by long-term natural and human selection. Indigenous goat populations in southeastern Türkiye exhibit genomic signatures of adaptation related to heat tolerance, feed utilization, and reproductive efficiency, highlighting their evolutionary and agricultural importance. Integrating archaeological, genomic, and environmental datasets from this region will provide deeper insights into the origins, migration routes, and adaptive evolution of domestic goats—offering a comprehensive framework for sustainable breeding and conservation strategies that preserve both productivity and genetic integrity.

Keywords: Goat domestication, Fertile Crescent, Archaeogenetics

KEÇİLERİN EVCİLLEŞTİRİLMESİNDE BEREKETLİ HİLAL VE AKDENİZ HAVZASI ARASINDA GENETİK BİR KAVŞAK OLARAK GÜNEYDOĞU TÜRKİYE

ÖZET

Keçinin evcilleştirilmesi, hayvancılık tarihinin en erken dönüm noktalarından biri olup yaklaşık 11.000 yıl önce Bereketli Hilal'de başlamıştır. Bu evcilleştirmenin beşiği konumundaki bölgenin kuzey kesiminde yer alan Güneydoğu Türkiye hem bir göç koridoru hem de Bereketli Hilal ile Akdeniz Havzası arasında genetik etkileşimlerin gerçekleştiği bir bölge olarak kritik bir rol oynamaktadır. Aşıklı Höyük, Çayönü, Göbekli Tepe ve Nevali Çori gibi Neolitik yerleşimlerden elde edilen arkeozoolojik kalıntılar, bu bölgede erken dönemde yönetilen ve kademeli olarak evcilleştirilen *Capra aegagrus* popülasyonlarının varlığını ortaya koymaktadır. Arkeogenetik kanıtlar bu bulguları desteklemekte ve Güneydoğu Türkiye'nin, keçi evcilleştirilme süreci ile batıya doğru gerçekleşen yayılım üzerinde etkili olan bir geçiş alanı niteliğinde olduğunu göstermektedir. Bölgenin stratejik konumu — tarih öncesi göç yolları, ticaret ağları ve geleneksel hayvancılık uygulamalarının kesiştiği noktada bulunması — binlerce yıl boyunca farklı genetik soylar arasında sürekli etkileşimleri kolaylaştırmıştır. Bu kesintisiz gen akışı, Bereketli Hilal'den köken alan erken evcilleştirilmiş hatların, Akdeniz Havzası yönündeki daha sonraki genetik genişlemelerle birleştiği önemli bir merkez olarak Güneydoğu Türkiye'nin konumunu pekiştirmiştir. Arkeolojik öneminin ötesinde, bölge günümüzde doğal ve insan kaynaklı uzun süreli seçilimin şekillendirdiği genetik çeşitliliğin önemli bir rezervuarını temsil etmektedir. Türkiye'nin yerli keçi popülasyonları, ısı toleransı, yemden yararlanma ve üreme verimliliği gibi özelliklerde gözlenen genomik adaptasyon izleriyle dikkat çekmekte; bu durum onların hem evrimsel hem de tarımsal açıdan önemini vurgulamaktadır. Bu bölgeden elde edilecek arkeolojik, genomik ve çevresel verilerin bütüncül biçimde değerlendirilmesi, keçilerin kökeni, göç yolları ve uyumsal evrim süreçlerine ilişkin daha derinlemesine bilgiler sağlayarak hem verimlilik hem de genetik bütünlüğü koruyan sürdürülebilir ıslah ve koruma stratejilerinin geliştirilmesine katkı sunacaktır.

Anahtar Kelimeler: Keçilerin evcilleştirilmesi, Bereketli Hilal, Arkeogenetik

1. INTRODUCTION

Goats (*Capra hircus*) were among the first wild ungulates domesticated by humans approximately 10,000 years ago in the Fertile Crescent—a region encompassing parts of modern-day southeastern Türkiye, the Levant, and the Zagros Mountains (Zeder et al., 2006; Zeder, 2008). This domestication event represents one of the earliest and most transformative milestones in human history, marking the transition from hunting and gathering to agricultural subsistence and laying the foundation for sedentary civilizations. As one of humanity's oldest domesticated livestock species, goats have played an indispensable role in shaping early economies, food systems, and cultural traditions across continents (Mason, 1984, Zeder, 2008; Pereira and Amorim, 2010).

The domestication of goats has long been studied through the combined perspectives of archaeology and genetics. Archaeozoological evidence from Neolithic sites such as Göbekli Tepe, Çayönü, Aşıklı Höyük, and Nevali Çori indicates early flock management of *Capra aegagrus* populations in Southeastern Anatolia, suggesting this region as a primary center of domestication (Hongo et al., 2009; Özdoğan & Özdoğan, 1990; Özdoğan, 1995)**.** With the advent of molecular tools, particularly mitochondrial DNA (mtDNA), Y-chromosome, and genome-wide SNP analyses, it has become possible to trace both maternal and paternal lineages of domestic goats, revealing complex patterns of gene flow, admixture, and diversification over millennia (Pereira et al., 2009; Naderi et al., 2007; Luikart et al., 2001). These findings collectively emphasize Anatolia's role not only as a cradle of domestication but also as a genetic corridor facilitating the diffusion of livestock and human populations into Europe, Africa, and Asia. Despite decades of research, significant questions remain regarding the spatial complexity, demographic dynamics, and long-term genetic continuity of early domestic goat populations in Anatolia. The integration of archaeogenetic and population genetic data now enables a more comprehensive understanding of how multiple wild *Capra aegagrus* lineages contributed to the domestic gene pool, as well as how Anatolia's geographical position influenced global caprine diversity.

This study synthesizes archaeological, genetic, and historical perspectives to reassess the dual role of Türkiye—particularly Southeastern Anatolia—as both a cradle of goat domestication and a corridor of genetic diffusion connecting the Fertile Crescent with the Mediterranean and beyond.

2. FROM BONES to GENES: TRACING THE DOMESTICATION PATHWAY THROUGH ARCHAEOLOGICAL and GENETIC MARKERS

The previously unknown aspects of the domestication of various animal species have begun to be elucidated through the integration of archaeological and genetic research. In these studies, archaeological evidence is identified using both morphological and non-morphological markers. Morphological markers are based on skeletal, dental, and other anatomical characteristics of animals, whereas non-morphological markers consider factors such as habitat, purpose of use, and management practices. Genetic information, on the other hand, is evaluated through molecular markers, which analyze variations and alterations within the genome to reveal the genetic changes that occurred during the domestication process (Zeder et al., 2006).

The domestication of animals is a process marked by significant morphological, physiological, and psychological changes. During this process, humans selected wild animals that were easily manageable and useful for their needs, breeding them to produce offspring. As a result of this selective breeding, domesticated animals developed specific morphological traits encoded at the genetic level. Characteristics such as body size, horn shape, and other physical attributes have consequently been used as morphological markers in archaeological studies. In addition, the domestication process led to significant physiological adaptations. For instance, the

digestive systems, dentition, and metabolic profiles of domestic animals evolved to better accommodate human feeding practices. The psychological aspect of domestication is equally noteworthy, domestic animals became more social and dependent on humans compared to their wild counterparts. These behavioral changes facilitated closer human–animal interactions and made it easier for humans to manage and control domestic species (Zeder et al., 2006).

Non-morphological markers are indicators not based on genetic factors. These markers help in understanding the process of animal domestication by analyzing archaeological data such as demographic profiles that include age at death, sex ratios, and husbandry practices. They are shaped by human selective behaviors during domestication and do not directly affect the animals' genetic characteristics. However, they provide valuable insights into how animals were managed, utilized, and integrated into human societies (Zeder et al., 2006).

Archaeologists use both morphological and non-morphological markers to identify the communities to which animal remains found at excavation sites belonged. For instance, hunter-gatherer societies generally preferred large, mature male animals; therefore, the bones recovered from such sites tend to be thick, well-developed, and predominantly male. In contrast, agricultural societies often favored smaller and female animals, resulting in assemblages primarily composed of bones from younger and female individuals. These markers provide archaeologists with crucial insights into the dietary habits, economic organization, and social structure of past human communities (Zeder, 2008; Zeder et al., 2006).

The domestication process that transformed wild goats into domestic ones, as well as the differentiation between wild and domestic lineages, has been extensively studied using mitochondrial DNA (mtDNA), Y-chromosome, and microsatellite markers. These molecular tools offer valuable insights into the ancestral origins and phylogenetic relationships of domestic goat breeds (Pereira et al., 2009; Naderi et al., 2007; Luikart et al., 2001). Although earlier classification efforts based on protein polymorphisms were conducted, their results were inconsistent with the traditionally accepted horn-morphology-based taxonomy. Consequently, researchers have increasingly focused on mitochondrial DNA (mtDNA) analyses (Manceau et al., 1999). Mitochondrial DNA is particularly advantageous for studying domestication because it experiences minimal selective pressure and evolves rapidly at the molecular level. Moreover, the absence of recombination and its maternal inheritance enable clear phylogenetic inference through the accumulation of mutations that define new lineages or haplotypes over time. Y-chromosomal markers, although used less frequently, play an important complementary role in mammals. They provide a paternal counterpart to mtDNA, allowing the detection of male-mediated dispersal and introgression patterns within and among goat populations (Bruford et al., 2003).

Goat mitochondrial DNA (mtDNA) analyses have produced remarkable results, revealing the presence of at least six distinct mtDNA haplogroups among modern goat breeds distributed across various geographic regions (Naderi et al., 2007). These findings suggest that goat domestication and subsequent breed differentiation were complex processes that likely occurred independently in multiple regions. Studies incorporating autosomal data have further demonstrated a correlation between haplogroup A and both genetic and geographic distances (Pariset et al., 2009; Canon et al., 2006). In phylogenetic analyses of animals, the mtDNA D-loop and cytochrome b regions are among the most frequently used and informative genetic markers for elucidating evolutionary history. These regions have been extensively applied in studies of goat domestication (Naderi et al., 2007; Pidancier et al., 2006; Pereira et al., 2005; Luikart et al., 2001; Hiendleder et al., 1998). The mtDNA D-loop region exhibits the highest level of variation—containing approximately 140 variable sites in goats—making it particularly useful for distinguishing among breeds and visualizing these differences in phylogenetic trees.

The cytochrome b region, with around 50 variable sites, provides additional resolution, allowing researchers to infer the timing of breed divergence through silent mutations that predominantly occur at third codon positions (Joshi et al., 2004; Luikart et al., 2001).

Studies based on mtDNA analyses have indicated that haplogroups A, B, and C diverged approximately 200,000 years ago and subsequently dispersed across different geographic regions during the domestication process (Luikart et al., 2001). The global geographic distribution of these haplogroups, along with the corresponding proportions of individuals belonging to each, is presented in Table 1 (Pereira and Amorim, 2010).

Table 1. Geographic distribution of mitochondrial haplogroups across the world

Haplogroup	Percentage of Individuals	Geographic Distribution
A	90,86	Worldwide
B1	4,40	Sub-Saharan Africa and Greece
B2	1,44	China and Mongolia
C	1,44	Asia and Europe
D	0,54	Asia and Central Europe
F	0,12	Sicily
G	1,11	Near East and North Africa

Goat domestication is believed to have begun approximately 10,000 years ago with a female belonging to haplogroup A. About 6,000 years later, females from haplogroup C were incorporated into the domestication process, followed by those from haplogroup B roughly 2,000 years after that. Studies have indicated that, because of extensive intercontinental transfers, genetic diversity in goats is greater within breeds than between geographic regions. For instance, while intercontinental mtDNA variation in cattle reaches approximately 84%, this value is only around 10% in goats (Luikart et al., 2001). Furthermore, additional haplogroups D (Joshi et al., 2004), F (Sardina et al., 2006), and G (Naderi et al., 2007) have been identified in goats by various researchers.

3. ARCHAEOGENETIC AND HISTORICAL PERSPECTIVES

Goats are among the earliest wild ungulates domesticated in the Near East, approximately 11,000 years ago, marking the beginning of the transformative shift from hunter-gatherer groups to agrarian societies. Since their domestication, goats have remained integral to human livelihoods, playing crucial economic, cultural, and religious roles across numerous civilizations. The integration of genetic and archaeological research has not only clarified the context, locations, and timing of the earliest goat domestication but has also significantly enhanced our ability to trace the migration routes through which humans dispersed this livestock species across the globe. The extensive geographical distribution and rapid expansion of goat populations worldwide clearly demonstrate the remarkable ability of this ruminant species to adapt to extreme climates and challenging landscapes. Furthermore, goats offer an excellent model for evaluating the rise and fall of human migration patterns and trade networks throughout history (Pereira and Amorim, 2010).

The earliest domestication of livestock by humans occurred during the Neolithic period, approximately 11,000 years ago, in the region known as the Fertile Crescent (Zeder, 2008). This period represents a major turning point in human history, providing the foundation for the emergence of agriculture, the transition to a sedentary lifestyle, and the development of complex societies. Among the earliest domesticated livestock species are cattle, pigs, sheep,

and goats. However, numerous studies indicate that sheep and goats were the first animals to be domesticated (Zeder, 2008; Zeder and Hesse, 2000; Mason, 1984). As hunting activities declined, these species played a pivotal role in the development of agricultural and animal production systems, ultimately leading to the modern domestic sheep and goat breeds known today.

The geographical extent of the primary domestication areas was illustrated by Naderi et al. (2008) and is shown in Figure 1.

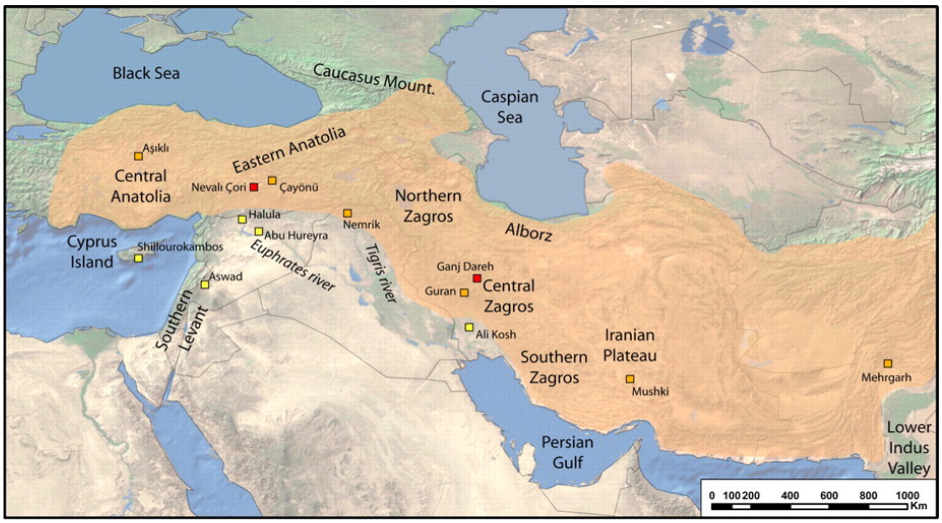


Figure 1. Primary domestication areas

The ancestry of domestic goats has long been studied through archaeological and genetic research. Recent molecular evidence demonstrates that domestic goats originated from the wild bezoar goat, *Capra aegagrus* (Naderi et al., 2007, 2008). This species is assumed to have inhabited a wide area extending from the Indus Valley to the Near East. Although the historical range of wild goats spanned from Europe to North Africa, the most likely ancestor of modern domestic goats is thought to have been confined to a relatively narrow region in Southwestern Asia (Kul, 2010). Some researchers have proposed that domestic goats originated from five different wild *Capra* species: *C. ibex*, *C. prisca*, *C. caucasica*, *C. aegagrus*, and *C. falconeri* (Batu, 1951). However, other studies attribute the ancestry of domestic goats to three wild species, namely *C. aegagrus*, *C. falconeri*, and *C. prisca* (Akçapınar, 1994; Yarkın, 1965). In a comparative analysis of the D-loop and cytochrome b sequences of *C. aegagrus* and domestic goats, Takada et al. (1997) demonstrated that domestic goats trace their origin to *C. aegagrus*.

The classification and global distribution of species within the genus *Capra* (Shackleton, 1997) are presented in Table 2.

Although the precise origins of domestic goats remain a subject of debate, archaeological evidence and scientific research support their domestication in the Fertile Crescent approximately 11.000 years ago (Pringle, 1998; Porter, 1996; Vigne and Buitenhuis, 1999; Peters et al., 1999; Zeder and Hesse, 2000; Luikart et al., 2001). The domestication of goats during the Neolithic period stimulated the domestication of other livestock species and brought substantial cultural and economic benefits. Early human populations that adopted animal domestication experienced rapid lifestyle transformations, gaining significant advantages despite challenges such as malnutrition and widespread disease. This transition strengthened sedentary living, contributing to the emergence of social stratification and the development of increasingly complex technologies (Clutton-Brock, 1999; Zeder, 2006a). Therefore, goats have consistently been associated with the expansion of human populations due to their remarkable adaptability and versatility as livestock (Pereira and Amorim, 2010). Over time, diverse

morphological forms have emerged, including variations in ear shape, such as pendulous ears, twisted horn configurations, and a wide spectrum of coat colors (Mason, 1984; Verschure, 2006).

Table 2. Taxonomic classification and present global distribution of *Capra* species

Species	Common name	Geographical distribution
Capra hircus	Domestic goat	Worldwide
Capra aegagrus	Bezoar or Wild Goat	Caucasus, Central Asia and the Near East
Capra falconeri	Markhor Goat	Western Himalayas
Capra caucasica	Western Caucasus Mountain Goat	Western Caucasus
Capra cylindricornis	Eastern Caucasus Mountain Goat	Eastern and Central Caucasus
Capra ibex	Alpine Mountain Goat	The Alps
Capra pyrenaica	Spanish Mountain Goat	The Iberian Peninsula
Capra nubiana	Nubian Mountain Goat	Northeastern Africa and Some Regions of Arabia
Capra sibirica	Siberian Mountain Goat	Central Asia
Capra walie	Walia Mountain Goat	The Northern Mountains of Ethiopia

4. THE ROUTE THAT BEGAN in THE FERTILE CRESCENT: THE GLOBAL JOURNEY of GOATS

Starting from several, possibly independent centers of domestication, managed goats rapidly dispersed beyond the natural range of the Near Eastern bezoar goat (*Capra aegagrus*). Generally, the spread of domestic animals occurred more rapidly along the east–west axis, where similar climatic conditions facilitated their movement and successful establishment (Diamond, 2002). For example, domestic goats have been found on the island of Cyprus, brought there by humans who colonized the island approximately 10,500 years ago (Zeder, 2008). As domestic goats expanded into hotter and drier lowland regions, the earliest morphological changes became evident—most notably, a general reduction in body size accompanied by alterations in horn morphology (Zeder, 2006b). These phenotypic changes are believed to reflect the onset of deliberate human selection around 9,000 years ago, compounded by genetic isolation following the decline of interbreeding with wild ancestors, as well as novel environmental pressures associated with increasing aridity and the resulting decline in pasture quality across the Fertile Crescent (Pereira and Amorim, 2010). Goat husbandry began soon after their initial domestication (Mason, 1984; Zeder, 2006b), spreading eastward from the Fertile Crescent into the Southern Levant—where localized domestication may also have occurred (Horwitz, 2003)—and further into the Iranian Plateau and Caspian Sea regions. Archaeological evidence suggests that this expansion followed multiple routes rather than a single route, as indicated by the widespread distribution of early goat remains (Pereira and Amorim, 2010).

The approximate dates for the first appearance of domestic goats in specific regions, as well as the main routes of their dispersal (Pereira and Amorim, 2010), are shown in Figure 2.

The primary dispersal routes of domestic goats into Asia likely extended through the Central Asian steppes, moving from present-day Afghanistan toward Mongolia and northern China, as well as throughout the Indian subcontinent via the Indus Valley and subsequently into Southeast Asia (Mason, 1984). A notable finding from mitochondrial DNA studies in goats is the high frequency of haplogroup B observed among breeds in East Asia (Luikart et al., 2001; Sultana et al., 2003; Joshi et al., 2004; Chen et al., 2005). In contrast, its frequency is considerably lower in Europe and the Near East (Pereira and Amorim, 2010). Researchers have suggested that this haplogroup most likely originated in Asia, potentially within the Neolithic communities of Baluchistan in the Indus Basin region (Luikart et al., 2001; Chen et al., 2005). However, no wild goat populations have been identified in East Asia that could support an independent domestication event in that region, where haplogroup B is more common. Moreover, there appears to be no relationship between haplogroup B and the lineage of the markhor (*Capra falconeri*) (Luikart et al., 2001; Pidancier et al., 2006). This haplogroup is also uncommon among modern populations of the bezoar goat, being identified only in a few localized regions of Iran and Türkiye, and it has not been detected in the Indus Valley area (Naderi et al., 2008). Consequently, the mechanisms underlying its high frequency across Asia remain uncertain. One possible explanation is that haplogroup B expanded through a series of population bottlenecks associated with successive colonization events. However, because the effects of genetic drift diminish in expanding populations—such as domestic flocks—this alone cannot fully explain its prevalence. Moreover, domestic goats exhibit consistently high genetic diversity worldwide (Luikart et al., 2001), a pattern that contrasts with the gradual loss of variation expected under a single-origin dispersal scenario (Pereira and Amorim, 2010). The introduction of domestic goats to the islands of Southeast Asia likely occurred via several distinct routes, coinciding with successive waves of human migration. Evidence suggests that goats reached regions such as Indonesia, the Philippines, Japan, and southern China relatively late, around the fourteenth century. Their arrival in the Pacific Islands, however, is attributed to Western sailors during the eighteenth century, who intentionally released goats on various islands as a potential food source for future voyages—a practice that subsequently led to the establishment of wild goat populations (Mason, 1984).

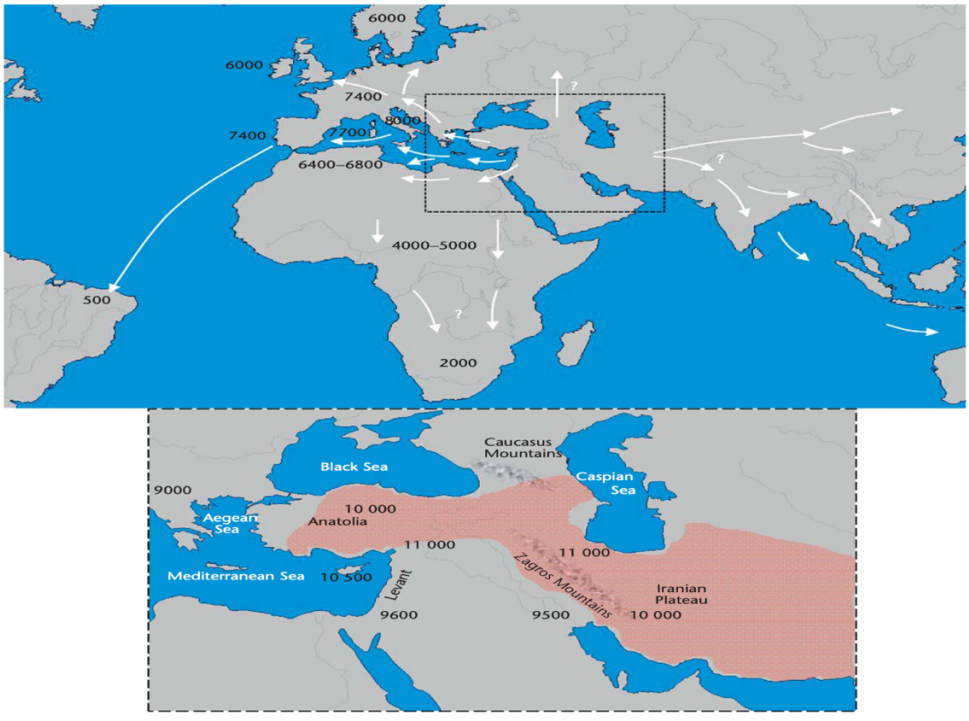


Figure 2. Migration routes of goats across the world

The expansion of domestic goats and the Neolithic way of life into Europe was a gradual and multifaceted process that ultimately contributed to the decline of hunter-gatherer societies. Scientists have identified two primary routes central to this dispersal. The "Danubian route" describes the spread of the Neolithic package—comprising pottery, domesticated animals, and permanent settlements—along the Danube Valley into the central and northern lowlands of Europe. In contrast, the "Mediterranean route" refers to the maritime diffusion of Neolithic communities and livestock along the coastal regions of the Mediterranean basin (Bogucki, 1996). The earliest evidence of agriculture in Europe appeared in Greece with the arrival of domestic goats and farming communities across the Aegean Sea approximately 9,000 years ago. Agricultural communities subsequently expanded into the Balkans around 8,000 years ago, reached Central Europe approximately 7,400 years ago, and eventually spread to Scandinavia and the British Isles around 6,000 years ago (Pereira and Amorim, 2010). Archaeological findings in the Mediterranean Basin demonstrates that agriculture rapidly expanded through maritime dispersal and human migration, as evidenced by the establishment of various coastal settlements on the Italian Peninsula around 8,000 years ago, in southern France between 7,700 and 7,600 years ago, on the western coasts of the Iberian Peninsula between 7,400 and 7,300 years ago, and in the southern Iberian region between 7,700 and 7,600 years ago (Zilhao, 2001; Zeder, 2008). Studies of modern goat populations indicate that the Mediterranean acted as a natural corridor linking regions that exhibit unexpectedly high genetic diversity far from the Near East. This is exemplified by the presence of the rare haplogroups C and F in the Iberian Peninsula and on the island of Sicily (Amills et al., 2004; Pereira et al., 2005; Azor et al., 2005; Sardina et al., 2006). Furthermore, mitochondrial DNA analyses of ancient goat remain from one of the earliest Neolithic sites in southwestern Europe revealed that both A and C lineages reached this region at roughly the same time, between 7,300 and 6,900 years ago (Fernandez et al., 2006). This evidence supports the hypothesis that intensive exchange of domestic goats occurred along the Mediterranean route, facilitating interactions between eastern Neolithic centers and western coastal farming communities soon after the arrival of Neolithic settlers in Europe. More recent genetic findings showing that the A and C haplogroups share a common ancestry with the wild bezoar goats of Eastern Anatolia (Naderi et al., 2008)—rather than arising independently as previously assumed—further suggest that these maternal lineages may have coexisted from the earliest phases of domestication (Pereira and Amorim, 2010).

Local goats were transported from Europe to the Americas by Portuguese and Spanish sailors in the early sixteenth century, serving as a readily available food source during exploration and military expeditions (Pereira and Amorim, 2010). Preliminary genetic analyses of goat populations in South and Central America indicate that the presence of haplogroup A lineages likely originates from the transatlantic introduction of animals from the Iberian Peninsula, with possible additional contributions from breeds established in the Atlantic archipelagos (Amills et al., 2009).

The introduction of goats into Africa most likely accompanied the migration of pastoralist communities from the Near East into northeastern Africa (Mason, 1984; Smith, 1992). The presence of the rare haplogroup G in Southwest Asia and Egypt is believed to reflect the genetic legacy of this early connection (Naderi et al., 2007). The subsequent southward expansion of goats—alongside cattle domesticated in North Africa—appears to have been influenced by environmental changes that reduced the prevalence of humidity-associated diseases, such as trypanosomiasis, approximately 4,000 to 5,000 years ago (Smith, 1992; Newman, 1995). However, factors such as parasitic infections, endemic diseases, and predation likely constrained the further spread of livestock, accounting for their relatively late arrival in the southernmost regions of Africa around 2,000 years ago. Conversely, this pattern may also explain the occurrence of haplogroup B1 lineages in South Africa—common in Asia but absent

in North Africa—supporting the hypothesis of an overland dispersal route extending from the Near East (Luikart et al., 2001).

5. ANATOLIA as a CRADLE and CORRIDOR: ARCHAEOGENOMIC INSIGHTS into GOAT DOMESTICATION in SOUTHEASTERN TÜRKİYE

The Pre-Pottery Neolithic (PPN) period, spanning approximately 9750–6400 BC (11,600–8400 BP) in the southern Levant and southeastern Anatolia, represents one of the earliest cultural phases in human history during which agriculture, animal husbandry, and permanent settlement first emerged. This period reflects a stage before the development of pottery production yet marks the beginning of the transition to a productive economy. The PPN is conventionally divided into three main subphases (Childe, 1928). The PPNA (Pre-Pottery Neolithic A) phase, dating to approximately 9750–8500 BC (ca. 11,600–10,500 BP), marks the earliest stage of permanent habitation by hunter-gatherer groups, as evidenced at sites such as Göbekli Tepe and Jericho. Circular domestic structures were common, and the first attempts at plant domestication are documented. During this period, social organization became increasingly complex, and the earliest forms of ritual architecture emerged (Kujit, 1996; Kujit, 2011). The subsequent PPNB (Pre-Pottery Neolithic B) phase, roughly 8500–7000 BC (ca. 10,500–8,750 BP), corresponds to a time when agriculture and animal husbandry became systematized, rectangular stone-based architecture became widespread, and social differentiation intensified. This phase is further subdivided into early, middle, and late PPNB (Goring-Morris et al., 2009). During this stage, sheep and goats were among the first animals to be domesticated, and key Anatolian sites such as Çayönü, Nevali Çori, and Aşıklı Höyük represent centers where the Neolithic lifestyle became fully established (Özdoğan, 1999). The final stage of the PPN sequence, PPNC (Pre-Pottery Neolithic C; 7000–6400 BC; 8750–8400 BP), constitutes a transitional phase preceding the advent of pottery use. During this period, large village settlements gave way to smaller, more dispersed communities; architectural forms became simplified, and agro-pastoral economies reached full stability. Thus, the PPNC established the socio-economic and technological foundations for the emergence of pottery Neolithic cultures (Childe, 1928; Birkenfeld et al., 2024).

The domestication of major livestock species—namely sheep, goats, cattle, and pigs—primarily advanced within the northern and eastern zones of the Fertile Crescent during the Early to Middle Pre-Pottery Neolithic B (PPNB). Archaeozoological evidence from sites across this region indicates that goat management had already begun in the northern Zagros Mountains approximately 10,000 years ago (Hesse, 1978; Zeder, 1999, 2005, 2006b; Zeder & Hesse, 2000). Around the same time, sheep domestication was initiated, most likely in the foothills of the Taurus Mountains in southeastern Anatolia (Hongo et al., 2009). One of the most important sites representing this transformative period is Çayönü Tepesi, located on a small tributary of the Tigris River, roughly five kilometers north of the Taurus foothills in southeastern Türkiye (Özdoğan & Özdoğan, 1990). Like other Pre-Pottery Neolithic (PPN) settlements in the region, Çayönü was strategically positioned at the interface between mountainous terrain and the southern plains and steppes, forming a crucial ecological and cultural corridor. The occupation sequence at the site extends for roughly three millennia, spanning from the Late PPNA through the Early Pottery Neolithic, thereby encompassing the pivotal transition from hunting to herd management. Consequently, the faunal assemblages recovered from Çayönü provide a rare diachronic record, enabling the reconstruction of shifting patterns of animal exploitation during the critical phase in which livestock domestication became firmly established in the Near East (Hongo et al., 2009; Özdoğan & Özdoğan, 1990; Özdoğan, 1995).

Archaeozoological analyses conducted at Aşıklı Höyük reveal that during the Pre-Pottery Neolithic period, caprine management was practiced in a manner reflecting controlled herd

strategies rather than full domestication. The age and sex profiles of caprine remains indicate a selective culling of young males, suggesting a strategy aimed at preserving reproductive females. This pattern points to a human-directed form of animal management rather than opportunistic hunting. Moreover, the presence of dense dung accumulations and architectural features within the settlement suggests that *Caprines* were confined to specific areas, likely functioning as stabling structures. Such confinement practices represent an initial step toward behavioral domestication through movement restriction. The researchers characterize this approach as "a short-term, low-investment strategy of herd management," reflecting an early phase in the transition from foraging to herding economies (Stiner et al., 2014).

The Nevali Çori settlement, located in southeastern Anatolia and dated to the Early–Middle Pre-Pottery Neolithic B (PPNB) period, provides crucial early evidence for the domestication of small ruminants. During this period, the expansion of grasslands across the northern Fertile Crescent led to significant shifts in human subsistence strategies, accelerating the transition from a hunter-gatherer economy to sedentary farming and animal husbandry (Bar-Yosef and Meadow, 1995; Peters et al., 2005). Archaeozoological analyses from Nevali Çori indicate that sheep (*Ovis aries*) and goats (*Capra hircus*) were already being intentionally nourished and maintained near human settlements. These findings represent a critical stage in the continuum from hunting to managed herding and ultimately full domestication (Peters et al., 1999; 2005). Differences observed in the dietary patterns of caprine remains suggest that these animals were increasingly subject to human-controlled feeding regimes, distinct from those of their wild counterparts. Collectively, the evidence strongly supports the notion that the Upper Euphrates and Tigris basins (9th millennium BC) served as core regions for early small ruminant domestication, with southeastern Anatolia—particularly sites such as Nevali Çori, Çayönü, Göbekli Tepe, and Aşıklı Höyük—representing one of the primary centers where the domestication of sheep and goats first emerged (Helmer et al., 1998; Hongo and Meadow, 1998; Legge, 1996; Russel et al., 2005; Peters and Schmidt, 2004).

Studies provide strong evidence that Anatolia served both as a genetic reservoir and a dynamic crossroads in the history of goat domestication. Ancient DNA analyses show that early domestic flock were distributed throughout the Fertile Crescent and, as they spread westward across Anatolia, successive waves of diffusion and introgression contributed to the mosaic genomic structure observed in modern goat populations. This genetic pattern closely aligns with archaeological data indicating that Southeastern Türkiye was a primary cradle of domestication and that Anatolia served as a crucial corridor facilitating the westward expansion of goats toward the Mediterranean and Aegean regions. Southeastern Anatolia is recognized as one of the earliest centers of goat domestication, with domestic goats originating from this region rapidly spreading throughout Anatolia. The continuous genetic admixture along migration routes facilitated the preservation of high intra-regional genetic diversity, supporting the interpretation of Anatolia as both a secondary domestication center and a diffusion corridor connecting Upper Mesopotamia with the Mediterranean and Aegean regions.

Recent analyses of mitochondrial DNA (mtDNA) markers in indigenous goat populations of Türkiye have revealed exceptionally high levels of genetic diversity, reinforcing the archaeogenomic perspective that Anatolia served both as an early center of domestication and a long-term diffusion corridor. Comprehensive examinations of the mtDNA D-loop region across a wide range of breeds—including Damascus (Shami), Kilis, Hair, Hatay, Honamlı, Angora, Norduz, Abaza, Kaçkar, Georgian, İspir, and Mahalli goats—have consistently demonstrated the presence of multiple maternal haplogroups. While haplogroup A remains predominant, the concurrent detection of B2, C, D, and G lineages provides compelling evidence of a complex matrilineal structure and deep ancestral heterogeneity within Turkish goat populations (Karaköse and Gündüz, 2025; Teber et al., 2025; Kiraz et al., 2024; Yüksel et

al., 2020; Akis et al., 2014; Kul and Ertuğrul, 2011; Naderi et al., 2007). This extensive haplogroup diversity—unusually high for a single geographic region—highlights Türkiye's pivotal role as both a primary center of domestication and a long-term genetic crossroads in the evolutionary history of goats. The predominance of haplogroup A across Anatolia, alongside the geographically structured presence of rarer lineages such as C and G in the southeastern and eastern regions, reflects a deep matrilineal complexity. This complexity has been shaped by ancient introgression from wild *Capra aegagrus* populations and maintained through millennia of gene flow, admixture, and localized adaptation. These phylogeographic patterns align with diffusion-based models of goat domestication, in which multiple maternal lineages contributed to the domestic gene pool during and after the Neolithic transition. Such a model, as articulated by Colli et al. (2015) and supported by archaeogenomic syntheses such as Daly et al. (2018), positions Anatolia not merely as a zone of domestication origin but as a persistent conduit of genetic diversity, maintaining ancestral haplotypes through repeated demographic expansions and trans-regional exchanges.

Population genetic analyses based on microsatellite and SNP data consistently reveal high levels of heterozygosity among goat populations in Türkiye (Bilginer et al., 2025; Demiray et al., 2024; Cemal et al., 2024; Demir, 2024; Gül et al., 2020; Karslı et al., 2020; Bulut et al., 2016; Ağaoğlu and Ertuğrul, 2012) reflecting extensive historical and ongoing gene flow across regions. This pattern indicates long-term genetic connectivity and admixture, likely facilitated by the continuous human-mediated movement of animals within Anatolia since the early pastoral periods. This genetic homogeneity, combined with high allelic richness, reinforces the interpretation of Anatolia as a persistent contact zone where eastern and western goat lineages have recurrently intermixed since the Neolithic. Alongside ancient DNA evidence, these findings position Türkiye not merely as a transit corridor for early domestic goats but as a long-term reservoir of genetic diversity and an evolutionary bridge linking the Fertile Crescent and Europe.

Y-chromosomal analyses of native Turkish goats reveal remarkable paternal lineage diversity, including the Y1A, Y1B, Y2A, and the novel Y2C haplotypes. This range of paternal variation, concentrated near the primary domestication center, suggests that Anatolia has preserved ancient male lineages of *Capra aegagrus*. The contrasting haplotype distributions—such as the dominance of Y1A in Kilis goats and the coexistence of all four haplotypes in Hair goats—reflect both historical founder effects and localized breeding dynamics (Kul et al., 2015). Taken together, these patterns indicate that Türkiye served not only as a cradle of early goat domestication but also as a paternal genetic reservoir, preserving deep ancestral diversity through millennia of male-mediated continuity and regional adaptation.

6. CONCLUSIONS AND FUTURE DIRECTIONS

Türkiye, particularly the Southeastern Anatolia region, stands out as both a biocultural nexus and a genetic crossroads in the evolutionary history of domestic goats. Located along the northern extension of the Fertile Crescent, this region served not only as one of the earliest centers of goat domestication but also as a genetic corridor connecting the Middle East, Anatolia, and the Mediterranean basin. This strategic position enabled Anatolia to function throughout history as a natural corridor for east–west migrations, trade, and livestock movements. Modern genetic research has revealed high levels of genetic diversity and extensive gene flow within Turkish goat populations. These findings clearly support Türkiye's dual role as both a genetic center of domestication and a refugium where early domestic lineages have been preserved for millennia. This unique genetic mosaic holds strategic significance not only for understanding the historical dynamics of goat evolution but also for shaping future strategies in sustainable livestock management and genetic conservation. Today, challenges such as

climate change, pathogen pressure, and uncontrolled crossbreeding increasingly threaten the integrity of local genetic resources. Therefore, conserving native goat populations is essential to ensuring the sustainability of both biological diversity and cultural heritage. Future conservation strategies should incorporate both in situ and ex situ methods. Integrating genomic data into national breeding and conservation programs will facilitate the preservation of adaptive genetic variation within local breeds, thereby supporting the development of resilient and sustainable production systems capable of withstanding climatic stress, nutritional deficiencies, and disease challenges.

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CHARACTERIZATION OF A 21-BP INDEL POLYMORPHISM IN THE LLGL1 GENE AMONG GOAT BREEDS IN SOUTHERN TÜRKİYE: DAMASCUS, KİLİS AND HATAY

Dr. Öğr. Üyesi Zühal Gündüz

Aydin Adnan Menderes University, Faculty of Agriculture

Email: zuhal.gunduz@adu.edu.tr

ORCID: 0000-0002-1427-1501

ABSTRACT

Goats play a crucial role in livestock production, especially in developing regions, owing to their adaptability to harsh environments and efficient use of marginal lands. Enhancing reproductive efficiency is crucial for improving productivity in small ruminants. Advances in molecular genetics now allow precise selection through marker-assisted breeding. The LLGL1 gene, part of the Scribble cell polarity complex, has been implicated in goat fertility, with a 21-bp insertion/deletion (indel) polymorphism linked to litter size in several breeds. This study aimed to characterize the 21-bp indel polymorphism in the LLGL1 gene and to determine the distribution of this genetic variation among Damascus, Kilis, and Hatay goat breeds raised in southern Türkiye. Genomic DNA was isolated from blood samples and genotyped using PCR-RFLP. Three genotypes (II, ID, DD) were identified across all populations. The insertion (I) allele was predominant, with frequencies of 0.75, 0.78, and 0.69 in Damascus, Kilis, and Hatay goats, respectively. Observed heterozygosity values (Ho=0.312, 0.188, and 0.438) were close to or lower than expected heterozygosity (He=0.375, 0.342, and 0.430), while PIC values ranging from 0.283 to 0.337 indicated moderate polymorphism. Damascus (p=0.346) and Hatay goats (p=0.918) were in Hardy–Weinberg equilibrium, whereas Kilis goats exhibited significant deviation (p=0.011). When all populations were combined (n=96), overall allele frequencies were 0.74 (I) and 0.26 (D), with moderate genetic diversity (Ho=0.312, He=0.385, PIC=0.311) and equilibrium (p=0.064). Consequently, the 21-bp indel polymorphism within the LLGL1 gene was identified as polymorphic and informative in goat breeds from southern Türkiye. However, to clarify its potential influence on reproductive performance, further studies involving larger sample sizes and detailed phenotypic data on fertility traits are necessary. Such comprehensive research would provide stronger evidence supporting the use of the LLGL1 gene as a molecular marker in marker-assisted selection programs aimed at improving reproductive efficiency in goat populations.

Keywords: LLGL1, indel polymorphism, goat reproduction traits, MAS

TÜRKİYE'DE YETİŞTİRİLEN BAZI KEÇİ IRKLARINDA (DAMASCUS, KİLİS VE HATAY) LLGL1 GENİNDEKİ 21-BP İNDEL POLİMORFİZMİNİN MOLEKÜLER KARAKTERİZASYONU

ÖZET

Keçiler, özellikle gelişmekte olan bölgelerde, zorlu çevre koşullarına yüksek adaptasyon yetenekleri ve marjinal alanları etkin biçimde kullanabilme özellikleri sayesinde hayvansal üretim sistemlerinde önemli bir role sahiptir. Küçük ruminantlarda üretim verimliliğini artırmanın temel yaklaşımlarından biri, üreme etkinliğinin geliştirilmesidir. Moleküler genetikteki son gelişmeler, marker destekli seleksiyon (MAS) uygulamaları aracılığıyla ekonomik öneme sahip özelliklerle ilişkili genetik belirteçlerin tespit edilmesini mümkün kılarak ıslah programlarını daha hassas hale getirmiştir. Scribble hücre polarite kompleksinin bir bileşeni olan LLGL1 geninin keçilerde üreme performansı ile ilişkili olabileceği bildirilmiş ve bu genin 21 baz çifti uzunluğundaki insersiyon/delesyon (indel) polimorfizminin bazı ırklarda döl verimi ile ilişkili olduğu gösterilmiştir. Bu çalışmanın amacı, Türkiye'nin güney bölgelerinde yetiştirilen Damascus, Kilis ve Hatay keçi ırklarında LLGL1 genine ait 21-bp indel polimorfizmini karakterize etmek ve bu genetik varyasyonun popülasyonlar arasındaki dağılımını belirlemektir. Kan örneklerinden elde edilen genomik DNA'lar PCR-RFLP tabanlı analiz yöntemiyle genotiplenmiştir. Üç genotip (II, ID, DD) tüm popülasyonlarda tanımlanmıştır. İnsersiyon (I) alleli tüm ırklarda baskın olup, Damascus, Kilis ve Hatay keçilerinde sırasıyla 0.75, 0.78 ve 0.69 olarak hesaplanmıştır. Gözlenen heterozigotluk (Ho=0.312, 0.188 ve 0.438) değerleri, beklenen heterozigotluk (He=0.375, 0.342 ve 0.430) değerlerine yakın veya daha düşük bulunmuş; PIC değeri ise 0.283 ile 0.337 arasında değişerek orta düzeyde polimorfizmi göstermiştir. Hardy–Weinberg dengesi Damascus (p=0.346) ve Hatay (p=0.918) popülasyonlarında korunurken, Kilis keçilerinde istatistiksel olarak sapma (p=0.011) göstermiştir. Tüm bireylerin birlikte değerlendirildiği genel popülasyonda, I ve D allel frekansları sırasıyla 0.74 ve 0.26 olarak belirlenmiş; Ho=0.312, He=0.385 ve PIC=0.311 değerleri orta düzeyde genetik çeşitliliğe ve dengeye (p=0.064) işaret etmiştir. Sonuç olarak, LLGL1 genindeki 21-bp indel polimorfizmi, Güney Türkiye'nin yerli keçi ırklarında polimorfik bir lokus olarak belirlenmiştir. Bununla birlikte, bu varyasyonun üreme performansı üzerindeki olası etkilerinin daha net ortaya konulabilmesi için, daha geniş birey sayısına sahip popülasyonlarda ve döl verimi özelliklerine ilişkin fenotipik verilerin dahil edildiği ileri çalışmalar gereklidir. Bu tür kapsamlı analizler, LLGL1 geninin keçilerde üreme verimliliğinin artırılmasına yönelik marker destekli seleksiyon programlarında potansiyel bir moleküler belirteç olarak kullanılabilirliğini daha güçlü biçimde destekleyecektir.

Anahtar Kelimeler: LLGL1, indel polimorfizm, keçi üreme özellikleri, MAS

1. INTRODUCTION

Goats hold a significant role in livestock production systems, particularly in developing countries, due to their ability to efficiently utilize marginal lands unsuitable for crop cultivation or high-input forage systems. Their resilience to harsh and variable environmental conditions, low maintenance and nutritional requirements, and overall adaptability make them well-suited to low-input, smallholder farming systems (Gül et al., 2016; Keskin et al., 2017; Keskin et al., 2018; Daşkıran et al., 2018; Gül et al., 2018; Gündüz and Biçer, 2023). Additionally, goats have relatively low production costs and demonstrate superior efficiency in converting poor-quality forage into animal products. The high nutritional value of goat milk, combined with the species' hardiness and reproductive efficiency, contributes to its strategic importance in ensuring food security, supporting rural livelihoods, and enhancing the sustainability of livestock production in resource-limited regions (Singh et al., 2014; Getaneh at al., 2016). Due to their low input and maintenance costs, goats are often referred to as the "poor man's cow," especially in developing and underdeveloped regions such as Asia and Africa. This is largely attributable to the extensive nature of goat production systems, the lack of technological advancement in management practices, and the limited implementation of effective genetic improvement programs (Keskin et al., 2018; Gündüz and Biçer, 2023). These structural limitations hinder the productivity potential of goat herds in such regions. Nonetheless, the widespread presence of goat populations in these countries is not solely a consequence of economic constraints. The geographic characteristics of these regions—often mountainous, forested, and composed of marginal lands—align well with the species' unique grazing behavior and ecological adaptability (Stroebel, 2004; Biswas et al., 2024; Bashiru et al., 2025). Goats are particularly well-suited to efficiently exploit such environments, which further explains their prevalence in resource-limited, agro-ecologically challenging areas.

In the context of increasing the contribution of goats to food and nutritional security in developing regions, improving milk and meat yields alone is insufficient. Reproductive performance is a fundamental determinant of overall productivity and herd efficiency in small ruminant production systems. Enhanced fertility traits—such as higher kidding rates, shorter kidding intervals, and improved conception rates—directly influence the number of offspring produced per breeding cycle, which in turn affects the availability of animals for meat, milk, and genetic replacement (Karslı et al., 2012; Notter, 2012; Amnate et al., 2016; Simoes et al., 2021). In resource-limited systems, where herd size and reproductive turnover are critical for household income and subsistence, improvements in reproductive efficiency can significantly amplify the biological and economic output of goat farming. Therefore, while genetic selection and nutritional strategies targeting yield traits are essential, parallel efforts must also focus on optimizing reproductive performance through better breeding management, disease control, and the implementation of locally adapted genetic improvement programs. An integrated approach that simultaneously addresses reproductive and production traits is essential to sustainably meet the rising demand for animal-source foods in agro-ecologically constrained environments.

Advances in molecular genetics have enabled animal breeding to move beyond traditional phenotypic selection methods, bringing marker-assisted selection (MAS) to the forefront. MAS allows for more precise and earlier selection based on genotype by utilizing genetic markers associated with economically important production traits, such as milk yield, fertility, and disease resistance. This approach offers significant advantages, particularly in improving traits with low heritability or those that manifest later in life. In goat breeding, identifying genetic variations linked to reproductive traits like litter size enhances the effectiveness of MAS and accelerates productivity gains. Furthermore, in small family-run farms with limited resources, MAS enables achieving higher genetic gains in a shorter time frame (Karslı and Balcıoğlu, 2010; Gündüz et al., 2016).

LLGL1 (Lethal Giant Larvae Homolog 1) is the mammalian homolog of the Lgl gene in Drosophila and serves as a key component of the Scribble cell polarity module. This module comprises three core proteins: Scribble, Discs large (Dlg), and Lethal giant larvae (Lgl/LLGL1) (Bonello and Peifer, 2018). The Scribble complex plays a critical role in the maintenance of cell polarity and regulating cellular growth, thereby contributing to proper tissue organization and developmental processes. LLGL1 functions as a core component of the Scribble cell polarity complex, which also includes Scribble and Discs large (Dlg). This tripartite module plays a pivotal role in maintaining epithelial architecture, regulating apical-basal polarity, and controlling cell proliferation. LLGL1 contributes to the spatial organization of cellular domains by interacting with Scribble via its leucine-rich repeat (LRR) domain, facilitating Scribble's cortical localization and membrane targeting (Kallay et al., 2006). Loss of LLGL1 disrupts epithelial integrity and leads to hyperproliferation, underscoring its tumor suppressor function (Gateff and Schneiderman, 1974; Woods et al., 1996). Moreover, the proper localization of Scribble, Dlg, and LLGL1 to the lateral membrane is interdependent, reflecting a tightly coordinated mechanism essential for polarity maintenance (Bilder et al., 2000). The Scribble cell polarity complex plays a critical role in establishing cellular polarity in Sertoli cells and developing spermatids within the testis. Composed of Scribble, Lgl2, and Dlg1 proteins, this complex is particularly involved in the remodeling of the blood-testis barrier (BTB), where it modulates the stability of intercellular junctions by reorganizing the actin cytoskeleton. During stages VII–VIII of the seminiferous epithelial cycle, when Scribble complex expression is elevated, it facilitates the transient increase in BTB permeability required for the translocation of preleptotene spermatocytes across the epithelium. Furthermore, the interaction of the Scribble complex with planar cell polarity (PCP) proteins contributes significantly to the alignment of spermatids within the plane of the seminiferous epithelium, thereby supporting optimal sperm production (Gao and Cheng, 2016; Gao et al., 2016). Although its direct involvement in folliculogenesis and oogenesis has not been extensively characterized, the broader role of polarity proteins—including Par and CRB complexes—in granulosa cell polarization and oocyte maturation suggests that Scribble may contribute to similar mechanisms in the ovary. Granulosa cell polarity, influenced by contact with the basal lamina and regulated by hormonal cues such as FSH, is essential for transzonal projection (TZP) formation and bidirectional communication with the oocyte, which in turn affects meiotic competence and cytoplasmic maturation (Plancha et al., 2005). Collectively, LLGL1 serves as a critical scaffold protein within the Scribble complex, orchestrating cell polarity, adhesion, and growth regulation across diverse biological contexts. Owing to its unique domain organization and specific subcellular localization, Scribble functions as a scaffold protein, mediating critical molecular interactions within defined cellular compartments (Bonello and Peifer, 2018). Given Scribble's established function in epithelial polarity and cytoskeletal remodeling, its potential involvement in coordinating somatic-germ cell interactions during follicular development warrants further investigation.

A 21-base pair insertion-deletion (InDel) polymorphism located in the upstream regulatory region of the LLGL1 gene has been proposed by several researchers to be associated with reproductive performance in goats. Individuals carrying the homozygous insertion (II) genotype have been reported to exhibit higher litter sizes compared to heterozygous (ID) individuals, suggesting a potential dosage effect of the insertion allele on fertility (Liu et al., 2019; Karslı & Atmaca, 2025). The aim of this study is to characterize the 21-base pair indel polymorphism in the LLGL1 gene among Damascus, Kilis, and Hatay goat breeds raised in southern Türkiye, and to determine the distribution of this genetic variation within these populations.

2. MATERIAL AND METHOD

This study was conducted in accordance with the approval of the Aydin Adnan Menderes University Animal Experiments Local Ethics Committee, dated May 18, 2023, and numbered 64583101/2023/79.

2.1 Animal selection, data collection and DNA sampling procedure

A total of 96 unrelated goats, representing the Damascus, Kilis, and Hatay breeds, were sampled as part of the National Breeding Program, which was conducted under controlled farm management systems. Whole blood was collected from the jugular vein of each individual into EDTA-coated vacutainer tubes (BD Vacutainer Systems, Plymouth, UK) to prevent coagulation. Genomic DNA was isolated from leukocytes using the high-salt extraction method originally described by Miller et al. (1988). The purified DNA samples were then stored at –20°C until molecular analyses were performed.

2.2 Polymerase chain reaction (PCR) reactions and genotyping

The target region of the LLGL1 gene containing the 21-bp insertion/deletion (InDel) polymorphism was amplified via polymerase chain reaction (PCR) using gene-specific primers. The primer sequences used for amplification were obtained from Liu et al. (2021) and synthesized by Sentebiolab Genetics (Türkiye). The sequences were as follows: forward 5′-ATTCTTAGGCGCACCACGAG-3′ and reverse 5′-CGAGGGGGTGCAACTTTGTT-3′. PCR reactions were carried out in a final volume of 10 µL, consisting of 1X PCR buffer with $MgCl_2$, 200 µM of each deoxynucleotide triphosphate (dNTP), 1 µM of each primer, approximately 100 ng of genomic DNA, and 1 unit of Taq DNA polymerase (Applied Biological Materials, ABM, USA). Thermal cycling conditions included an initial denaturation at 95°C for 5 minutes, followed by 36 cycles of denaturation at 94°C for 40 seconds, annealing at 64°C for 30 seconds, and extension at 72°C for 1 minute. A final elongation step at 72°C for 5 minutes was included to ensure complete extension of PCR products. Amplification was performed using a Bio-Rad C1000 Touch™ Thermal Cycler. PCR amplicons were separated on a 4% agarose gel, stained with Safeview™ Classic gel stain (Applied Biological Materials, ABM, USA), and visualized under UV light (Quantum, Vilber Lourmat, France) to determine fragment sizes and genotype patterns based on the presence or absence of the insertion allele. A 100bp Plus Opti-DNA Marker (Applied Biological Materials, ABM, USA) was loaded into the first well of each gel to serve as a molecular size marker for estimating the lengths of the amplified fragments. The insertion allele produced a fragment of 163 bp, whereas the deletion allele resulted in a fragment of 142 bp. Individuals with the heterozygous (ID) genotype exhibited two distinct bands corresponding to both the insertion and deletion alleles (163 bp and 142 bp). The homozygous insertion (II) genotype was characterized by a single band at 163 bp, while the homozygous deletion (DD) genotype was expected to show a single band at 142 bp.

2.3 Statistical analysis

Genetic diversity parameters, including allele and genotype frequencies, observed heterozygosity (Ho), expected heterozygosity (He), and the effective number of alleles (Ne), were calculated using GenAlEx version 6.5 software (Peakall & Smouse, 2012). Polymorphic information content (PIC) values and Hardy–Weinberg equilibrium (HWE) tests were performed using PopGene version 1.32 (Yeh et al., 1999). Deviations from HWE were assessed using the chi-square (χ^2) test.

3. RESULT AND DISCUSSION

Analysis of the 21-bp InDel polymorphism within the LLGL1 gene revealed that all three examined goat breeds (Damascus, Kilis, and Hatay) were polymorphic at this locus, indicating

the presence of genetic variation both within and among populations. The distribution of genotypes identified across the breeds is presented in Figure 1, while allele and genotype frequencies, along with key genetic diversity parameters such as heterozygosity, effective allele number, and polymorphic information content (PIC), are summarized in Table 1.

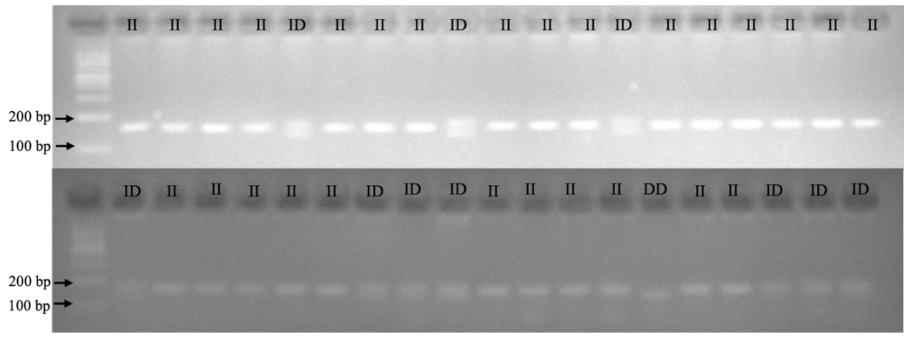


Figure 1. Visualization of the LLGL1 Gene 21-bp Indel polymorphism via agarose gel electrophoresis

The analysis of the 21-bp InDel polymorphism in the LLGL1 gene revealed notable variation in allele frequencies among the three goat breeds studied. The frequency of the insertion (I) allele was highest in the Kilis breed (0.781), followed by Damascus (0.750) and Hatay (0.688). Conversely, the deletion (D) allele exhibited its highest frequency in the Hatay breed (0.312), indicating greater genetic variation at this locus within that population (Table 1). When compared to previous studies on other native goat populations, the frequency of the I allele in this study was generally higher. For instance, Karslı and Atmaca (2025) reported I allele frequencies of 0.57, 0.72, and 0.58 in Honamlı, Hair, and Kabakulak goats, respectively, with corresponding D allele frequencies of 0.43, 0.28, and 0.42. These values indicate that the Damascus, Kilis, and Hatay populations exhibit relatively higher levels of the I allele than Honamlı and Kabakulak goats, while Hair goats show comparable frequencies. Moreover, in Shaanbei White Cashmere goats, Liu et al. (2021) reported a markedly higher frequency of the I allele at 0.979, with the D allele present at only 0.021. This suggests that this locus may be nearly fixed in favor of the insertion variant in some commercial or selectively bred populations. In contrast, the polymorphic status observed in the current study indicates maintained genetic variability in local Turkish goat breeds, potentially reflecting their more diverse breeding history and less intensive selection pressures.

Table 1. Genotype and population genetic parameters of the LLGL1 gene in goat populations

Breed	n	Allele frequency		Genotype frequency			HWE		Population parameters			
		I	D	II	ID	DD	χ^2	*p*-value	Ho	He	Ne	PIC
Damascus	32	0.750	0.250	0.594	0.312	0.094	0.889	0.346	0.312	0.375	1.60	0.305
Kilis	32	0.781	0.219	0.687	0.188	0.125	6.521	0.011*	0.188	0.342	1.52	0.283
Hatay	32	0.688	0.312	0.469	0.438	0.093	0.011	0.918	0.438	0.430	1.75	0.337
Overall	96	0.740	0.260	0.583	0.312	0.104	3.420	0.064	0.312	0.385	1.63	0.311

Ho: Observed heterozygosity; **He:** Expected heterozygosity, **Ne:** Number of effective alleles; **HWE:** Hardy-Weinberg Equilibrium; **PIC:** Polymorphic information content; *p<0.05 indicates significant deviation from Hardy–Weinberg equilibrium.

In terms of genotype distribution, all three goat breeds demonstrated polymorphism at the LLGL1 locus. The II genotype was the most prevalent in all breeds, with frequencies of 0.594 in Damascus, 0.687 in Kilis, and 0.469 in Hatay goats. The ID genotype showed moderate frequencies of 0.312 in Damascus and 0.438 in Hatay, but a lower frequency of 0.188 in Kilis.

The DD genotype, representing homozygosity for the deletion allele, was the least common across all populations, ranging from 0.093 to 0.125. Hatay (0.093) and Damascus (0.094) exhibited similar values, while Kilis showed a slightly higher frequency (0.125). When compared to findings in other native Turkish breeds, the genotype distributions in the current study show some similarities as well as notable differences. In a study by Karslı and Atmaca (2025), Honamlı goats exhibited II, ID, and DD genotype frequencies of 0.38, 0.37, and 0.25, respectively. Hair goats showed a higher level of heterozygosity, with an ID frequency of 0.50, while II and DD frequencies were 0.47 and 0.03, respectively. Similarly, Kabakulak goats displayed genotype frequencies of 0.40 (II), 0.37 (ID), and 0.23 (DD). Compared to these populations, the Damascus and Kilis goats in the present study demonstrated higher frequencies of the II genotype and lower DD frequencies, suggesting a tendency toward fixation of the insertion allele in these breeds. Conversely, the Hatay population exhibited a relatively balanced distribution of genotypes, indicating greater allelic diversity at this locus. For instance, in Shaanbei White Cashmere goats, Liu et al. (2021) reported genotype frequencies of 0.959 (II), 0.041 (ID), and 0.000 (DD), indicating near-complete fixation of the insertion allele and monomorphism for the deletion variant. This stark contrast with the present findings underscores the higher genetic variability maintained in local Turkish goat populations, likely due to differences in breeding systems, selection intensity, and population structure.

The genetic diversity analysis based on the 21-bp InDel polymorphism in the LLGL1 gene revealed moderate variation among the studied goat breeds. Observed heterozygosity (Ho) ranged from 0.188 in Kilis to 0.438 in Hatay, while expected heterozygosity (He) values varied between 0.342 in Kilis and 0.430 in Hatay. The effective number of alleles (Ne) was highest in the Hatay breed (1.75) and lowest in Kilis (1.52), reflecting genetic variability at this locus. Polymorphism Information Content (PIC) values were moderate, ranging from 0.283 in Kilis to 0.337 in Hatay, indicating that this marker is sufficiently informative to assess genetic diversity in these populations. The results of the Hardy–Weinberg equilibrium test showed that only the Kilis breed deviated significantly from equilibrium ($\chi^2 = 6.521$, $p = 0.011$), suggesting possible effects of selection, population structure, or sampling variation. In contrast, both Damascus and Hatay goats conformed to HWE assumptions, indicating random mating and stable allele distributions in these populations.

When compared with other native Turkish goat breeds, similar diversity patterns were observed. According to Karslı and Atmaca (2025), Honamlı goats exhibited Ho = 0.63, He = 0.50, Ne = 1.96, and $\chi^2 = 3.83$, indicating a relatively high level of observed heterozygosity. Hair goats showed Ho = 0.50, He = 0.59, and Ne = 1.68, with $\chi^2 = 3.27$, reflecting a relatively balanced allele distribution. Similarly, Kabakulak goats displayed Ho and He values of 0.63 and 0.51, respectively, with Ne = 1.94 and $\chi^2 = 3.62$. None of these populations demonstrated significant deviations from HWE, consistent with the patterns observed in Hatay and Damascus goats in the present study. In stark contrast, the findings reported by Liu et al. (2021) in Shaanbei White Cashmere goats revealed an almost complete lack of genetic diversity at the LLGL1 locus. The population exhibited Ho = 0.96, but an extremely low He = 0.04, with Ne = 1.042 and PIC = 0.039. Moreover, the deviation from HWE was statistically significant ($p < 0.001$), likely due to the near fixation of the insertion allele (I allele frequency = 0.979) and the absence of the DD genotype. These values suggest strong artificial selection or genetic bottleneck effects in commercial populations, contrasting with the maintained polymorphism observed in local Turkish goat breeds.

4. CONCLUSION

The present study demonstrated that the 21-bp InDel polymorphism in the LLGL1 gene is polymorphic across all three examined goat breeds—Damascus, Kilis, and Hatay—indicating

its potential as a useful molecular marker for genetic diversity studies. Moderate levels of heterozygosity and polymorphism information content (PIC) values further support the informativeness of this locus in assessing population structure and genetic variation. While these findings provide valuable insights into the genetic architecture of the LLGL1 locus, the absence of phenotypic data—especially concerning reproductive traits—limits the functional interpretation of this polymorphism. Given that LLGL1 has been implicated in reproductive biology and embryonic development in other species, future studies should focus on evaluating this locus in larger, well-characterized goat populations with comprehensive reproductive performance records. Such studies would enable robust genotype–phenotype association analyses, potentially revealing whether the LLGL1 InDel variant could serve as a candidate marker in marker-assisted selection (MAS) strategies aimed at improving reproductive efficiency. Incorporating this marker into breeding programs may accelerate genetic gains in fertility and productivity traits, which are crucial for sustainable goat production systems, particularly in local breeds with valuable adaptive traits. In conclusion, this research provides foundational knowledge for future efforts to integrate molecular markers into genomic selection and conservation-based breeding programs, ultimately supporting the genetic improvement and long-term viability of native goat populations.

DATA AVAILABILITY

In accordance with the principles of scientific transparency and reproducibility, the data used and analyzed in this study are available from the corresponding author upon reasonable request.

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ETHICAL STATEMENT

This study was conducted in accordance with the approval of the Aydin Adnan Menderes University Animal Experiments Local Ethics Committee, dated May 18, 2023, and numbered 64583101/2023/79.

AUTHOR CONTRIBUTIONS

ZG: study design, development of the methodology, data collection, laboratory and statistical analysis, and writing original draft

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CURRENT PERSPECTIVES ON ERUCIC ACID IN *Brassicaceae* SEED OILS

Assoc. Prof. Fatma KAYAÇETİN

Department of Field Crops, Faculty of Agriculture, Ankara University, 06110 Ankara, Türkiye

Email: kayacetin@ankara.edu.tr

ORCID: 0000-0002-7029-2825

Asst. Prof. Nilüfer KOÇAK ŞAHİN

Department of Field Crops, Faculty of Agriculture, Ankara University, 06110 Ankara, Türkiye

Email: nkocak@ankara.edu.tr

ORCID: 0000-0001-6474-1527

ABSTRACT

The *Brassicaceae* family includes many agriculturally important oilseed crops such as *Brassica napus* (rapeseed/canola), *B. juncea*, *B. carinata*, *Camelina sativa*, and *Sinapis alba*. These species are known for their ability to accumulate seed oils rich in bioactive fatty acids. Among these fatty acids, erucic acid (EA; *cis*-13-docosenoic acid), a very-long-chain monounsaturated fatty acid, has drawn significant attention due to its diverse industrial applications as well as its implications for nutritional safety.

Certain species and cultivars are capable of accumulating high levels of erucic acid, up to 55% of seed oil content, while others particularly low-erucic acid varieties such as canola contain less than 2% erucic acid in accordance with international safety guidelines. The oxidative stability and hydrophobic nature of erucic acid make it an attractive candidate for various industrial uses, including biofuels, lubricants, plasticizers, and specialty chemicals. However, findings from experimental animal models have raised concerns regarding the potential cardiotoxic effects of diets high in erucic acid, leading regulatory authorities in several countries to impose limits on its concentration in food and feed products. In contrast, recent preclinical studies suggest that erucic acid may exhibit bioactive properties at low doses, including anti-inflammatory, neuroprotective, and metabolic effects. Nevertheless, human data on these effects remain limited.

This review brings together current information on erucic acid biosynthesis in Brassicaceae species, its functional properties, industrial relevance, and the regulatory and toxicological considerations surrounding its use. Moreover, it highlights the need for further research to better understand the molecular, environmental, and metabolic factors influencing erucic acid content, and to ensure the safe and responsible integration of erucic acid into both industrial and nutritional contexts.

Keywords: Erucic acid, *Brassicaceae* Oilseeds, Industrial applications, Food Safety

Brassicaceae TOHUM YAĞLARINDAKI ERUSIK ASIT ÜZERINE GÜNCEL DEĞERLENDIRMELER

ÖZET

Brassicaceae familyası, *Brassica napus* (kolza/kanola), *B. juncea*, *B. carinata*, *Camelina sativa* ve *Sinapis alba* gibi tarımsal açıdan önemli birçok yağlı tohum bitkisini içerir. Bu türler, biyoaktif yağ asitleri açısından zengin tohum yağlarını biriktirme kapasiteleriyle bilinmektedir. Bu yağ asitleri arasında yer alan erusik asit (EA; *cis*-13-dokosenoik asit), çok uzun zincirli tekli doymamış bir yağ asidi olup, çeşitli endüstriyel uygulamalardaki çok yönlü kullanımı ve beslenme güvenliği ile ilgili etkileri nedeniyle önemli ölçüde dikkat çekmiştir.

Bazı türler ve çeşitler, tohum yağında %55'e kadar yüksek oranda erusik asit biriktirebilirken, özellikle düşük erusik asit içeriğine sahip çeşitler (örneğin kanola) uluslararası güvenlik yönergelerine uygun olarak %2'nin altında erusik asit içermektedir. Erusik asidin oksidatif stabilitesi ve hidrofobik doğası, onu biyoyakıtlar, yağlayıcılar, plastifiyanlar ve özel kimyasallar gibi çeşitli endüstriyel kullanım alanları için cazip bir aday hâline getirmektedir. Ancak, deneysel hayvan modellerinden elde edilen bulgular, yüksek miktarda erusik asit içeren diyetlerin potansiyel kardiyotoksik etkilerine işaret etmekte olup, bu durum çeşitli ülkelerdeki düzenleyici otoriteleri, gıda ve yem ürünlerindeki erusik asit düzeylerine sınır getirmeye yöneltmiştir. Buna karşın, son dönem preklinik çalışmalar, erusik asidin düşük dozlarda anti-inflamatuar, nöroprotektif ve metabolik etkiler gibi biyoaktif özellikler gösterebileceğini öne sürmektedir. Bununla birlikte, bu etkilerle ilgili insan verileri hala sınırlıdır.

Bu derleme, *Brassicaceae* türlerinde erusik asit biyosentezi, fonksiyonel özellikleri, endüstriyel önemi ve kullanımına ilişkin düzenleyici ve toksikolojik değerlendirmeleri içeren güncel bilgileri bir araya getirmektedir. Ayrıca, erusik asit içeriğini etkileyen moleküler, çevresel ve metabolik faktörlerin daha iyi anlaşılmasına ve erusik asidin hem endüstriyel hem de beslenme alanlarında güvenli ve sorumlu bir şekilde kullanımının sağlanmasına yönelik daha fazla araştırmaya duyulan ihtiyacı vurgulamaktadır.

Anahtar Kelimeler: Erusik asit, *Brassicaceae* Yağlı Tohumlar, Endüstriyel uygulamalar, Gıda Güvenliği

1.INTRODUCTION

The *Brassicaceae* family encompasses a wide range of agriculturally and economically important species cultivated worldwide for diverse purposes, including food, feed, oil production, and industrial applications. Among these, oilseed crops such as *Brassica napus* (rapeseed/canola), *B. juncea* (brown mustard), *B. nigra* (black mustard), *B. carinata* (Ethiopian mustard), *B. rapa* (turnip), *Camelina sativa* (false flax), and *Sinapis alba* (white mustard) are particularly noteworthy for their capacity to accumulate substantial amounts of seed oil enriched with bioactive compounds (Meena et al., 2021; Kayaçetin, 2023; Sharma et al., 2024; Mohanty et al., 2025). In addition to their primary role as oil producers, many *Brassicaceae* species also contribute to human diets as vegetables and have demonstrated utility in green manure, soil remediation, condiments, and pharmacological applications, owing to their complex phytochemical profiles (Kayaçetin, 2020; Kayaçetin & Khawar, 2023).

One of the notable constituents of *Brassicaceae* seed oils is erucic acid (EA; *cis*-13-docosenoic acid, 22:1 Δ13; ω-9), a very-long-chain monounsaturated fatty acid with potential industrial and nutritional significance. Certain genotypes particularly within *B. napus*, *B. juncea*, *B. carinata*, *C. sativa*, and *S. alba* have been reported to accumulate relatively high EA levels, in some cases exceeding 50% of the total seed oil content. This variability is largely influenced by genetic factors and environmental conditions (Kayaçetin et al., 2019; Wang et al., 2022; Baidala et al., 2023; Kinay & Kayaçetin, 2023; Zhang et al., 2023; Rzyska et al., 2024). Due to its hydrophobic nature and oxidative stability, EA has attracted interest for various non-edible industrial uses, including biofuels, lubricants, and specialty polymers (Wani ve ark., 2022).

Nonetheless, the safety of dietary EA intake has been the subject of ongoing scientific and regulatory scrutiny. Some experimental studies, particularly in animal models, have suggested a possible association between high EA consumption and adverse effects such as myocardial lipidosis. While direct implications for human health remain a topic of debate, these findings have led many regulatory authorities to impose precautionary limits on EA content in edible oils to ensure consumer protection. As a result, targeted breeding programs have successfully developed low-erucic acid rapeseed (LEAR) cultivars containing less than 2% EA enabling their safe integration into food and feed chains without compromising oil yield or agronomic performance (EFSA, 2016).

The dual nature of EA as both a compound of industrial utility and one with potential toxicological concerns underscores the need for a balanced and informed approach in crop development, risk assessment, and regulatory decision-making. Furthermore, *Brassicaceae* oilseeds represent a substantial component of global oilseed production, which has exceeded one billion tons in recent years. Within this context, *B. napus* stands among the most widely cultivated species (FAO, 2024). In regional contexts, such as Türkiye, there has been a notable increase in the cultivation of *Brassicaceae* oilseeds, although species distribution and utilization patterns vary considerably (TÜİK, 2024; Başalma et al., 2025).

From a biochemical perspective, EA biosynthesis involves the elongation of oleic acid within the endoplasmic reticulum, primarily catalyzed by the fatty acid elongase 1 (FAE1) enzyme, with regulatory inputs from both genetic and environmental factors (Sakhno, 2010). Improved understanding of the molecular pathways governing EA accumulation is crucial for the development of cultivars optimized for specific industrial or nutritional profiles.

Accordingly, this review aims to provide a comprehensive synthesis of current knowledge on EA biosynthesis in *Brassicaceae* species, evaluate its emerging industrial relevance, and critically examine the safety considerations and regulatory frameworks that guide its application in food and feed systems.

2.STRUCTURE AND BİOSYNTHESİS OF ERUCİC ACİD İN BRASSİCACEAE

Erucic acid (EA; cis-13-docosenoic acid, C_{22}:1 Δ13, ω-9) is a very-long-chain monounsaturated fatty acid characterized by a 22-carbon backbone and a cis-double bond at the 13th carbon position. Its molecular structure ($CH_3(CH_2)_7CH=CH(CH_2)_{11}COOH$) confers significant hydrophobicity and chemical stability, resulting in notable oxidative resistance and a relatively high melting point. These physicochemical properties underpin EA's utility in various industrial applications, including lubricants, plasticizers, and biofuels (Wani et al., 2022).

The biosynthesis of EA occurs predominantly through the elongation of oleic acid (C18:1 Δ9) by the fatty acid elongase (FAE) complex within the endoplasmic reticulum of developing seeds. This process involves the sequential addition of two-carbon units from malonyl-CoA, catalyzed primarily by the enzyme β-ketoacyl-CoA synthase (KCS), encoded by the FAE1 gene, which constitutes the rate-limiting step in EA production (Sakhno, 2010). The carbon skeleton for EA biosynthesis is derived from carbohydrate metabolism, primarily sucrose, highlighting the integration of primary and secondary metabolic pathways during seed maturation (Wallace et al., 2016).

The FAE1 gene is a key determinant of EA accumulation in Brassicaceae species. In amphidiploid species such as *Brassica napus* and *B. juncea*, FAE1 is present on both A and C genomes, and its allelic variation and expression levels contribute significantly to the observed differences in EA content among cultivars and species (Galanty et al., 2023). Mutations or reduced expression of FAE1 result in low-erucic acid phenotypes (LEAR), which are desirable in edible oil crops due to health concerns related to excessive EA intake (Przybylski et al., 2005; Velasco et al., 2017). Consequently, breeding programs have leveraged these genetic variations to produce LEAR cultivars suitable for human consumption, while high-erucic acid rapeseed (HEAR) varieties remain valuable for industrial purposes (Piazza & Foglia, 2001; McVetty & Duncan, 2015).

Environmental factors such as temperature, nutrient availability, and photoperiod also influence EA biosynthesis by modulating FAE1 expression and enzyme activity. This genotype × environment interaction necessitates careful consideration in breeding strategies aiming to optimize EA content for targeted applications (Velasco et al., 2017). Notably, certain genotypes, such as *B. rapa* var. *campestris*, have been reported to accumulate EA levels as high as 59% of total fatty acids, indicating substantial enzymatic efficiency and storage capacity (Chen & Heneen, 1989).

Data from multiple studies demonstrate substantial variation in erucic acid (EA) content among oilseed species within the Brassicaceae family (Table 1). High-EA species such as *Sinapis alba*, *Brassica carinata*, *B. juncea*, *B. napus* (HEAR), and *B. nigra* exhibit EA concentrations ranging from approximately 22% to 55%, underscoring their suitability for industrial applications, including lubricants, plasticizers, and high-performance materials (Table 1).In contrast, *B. napus* (LEAR) and *Camelina sativa* show significantly lower EA levels (<4%), which aligns with their primary use in food and feed applications where low EA content is essential for meeting safety standards. Canola, a low-erucic-acid variant of *B. napus*, has been selectively bred to contain less than 2% EA, in compliance with international food safety regulations (EFSA, 2016).

Table 1. Variation in Erucic Acid Levels Among Brassicaceae Oilseed Crops

Species	Common Name	EA (% of Oil)	References
Sinapis alba	White/yellow mustard	23–51%	Singh et al. (2014); Kayaçetin & Khawar (2023)

Species	Common Name	EA (% of Oil)	References
B. carinata	Ethiopian mustard	35–45%	Singh et al. (2014)
B. juncea	Brown/oriental mustard	22–55%	Bretagnolle et al. (2016)
B. napus (HEAR)	Rapeseed	40–55%	Wendlinger et al. (2014)
B. napus (LEAR)	Canola	<2%	Abbadi & Leckband (2011)
B. nigra	Black mustard	27–46%	Bretagnolle et al. (2016)
Camelina sativa	Camelina	2–4%	Ostrikov et al. (2021); Yildiz et al. (2024)

3. INDUSTRİAL POTENTİAL OF ERUCİC ACİD İN BRASSİCACEAE SEEDS

Erucic acid (EA; cis-13-docosenoic acid), a very-long-chain monounsaturated fatty acid, exhibits distinctive physicochemical properties such as high thermal and oxidative stability, low volatility, and pronounced hydrophobicity that make it particularly suitable for a variety of non-food industrial applications. These attributes are primarily attributable to its extended carbon chain and cis-double bond configuration, which contribute to enhanced resistance against thermal degradation and chemical oxidation. Consequently, EA-rich seed oils from Brassicaceae species are of considerable interest for use in sectors such as bioenergy, lubricants, polymer synthesis, and specialty chemical production (Wani ve ark., 2022).

Table 2. Industrial Applications and Functional Characteristics of Erucic Acid Derivatives

Application Area	EA-Based Derivatives / Functions	Benefits / Functional Features
Biofuels	Methyl esters of EA	High cetane number; improved cold-flow properties
Lubricants & Plasticizers	Erucamide, behenic acid	Enhanced thermal stability; improved flexibility and mechanical durability
Surfactants & Cosmetics	Emulsifiers and emollients derived from EA	Improved formulation stability and texture; enhanced skin hydration
Pharmaceuticals & Biopolymers	Behenyl alcohol (EA precursor); biodegradable monomers	Used in drug delivery systems; supports eco-friendly material development

As presented in Table 2, the derivatives of erucic acid (EA) demonstrate diverse functional attributes that support their application across a range of industrial sectors. In the biofuel industry, methyl esters of EA offer benefits such as a high cetane number and improved cold-flow properties, enhancing overall fuel performance. In lubricants and plasticizers, EA-derived compounds like erucamide and behenic acid contribute to greater thermal stability, improved flexibility, and increased mechanical durability. In the cosmetics and surfactant industries, EA-based emulsifiers and emollients improve formulation stability and enhance skin hydration. Additionally, in pharmaceuticals and biopolymer applications, EA derivatives such as behenyl alcohol and biodegradable monomers are utilized in drug delivery systems and contribute to the development of environmentally friendly materials.

These versatile applications underline the **economic and industrial significance of high-erucic acid cultivars**, particularly high-erucic acid rapeseed (HEAR). The long-chain structure, oxidative stability, and chemical convertibility of EA make it a valuable feedstock for the production of high-value chemicals and functional materials. However, the broader adoption of such applications also requires careful consideration of environmental sustainability, toxicological safety, and regulatory compliance throughout the production and utilization process.

Table 3. Industrial and Nutritional Uses of Oils Based on Erucic Acid Content (Sachan et al., 2024)

Erucic Acid Content	**Primary Applications**
<2%	Edible Oil (LEAR): Edible oil formulations (e.g., cooking oils, infant nutrition products)
40–55%	Industrial Oil: Lubricants, plasticizers, surfactants
>80%	Technical Oil: Greases, coatings, and high-performance polymers (e.g., nylon synthesis)

Table 3 highlights the functional contributions of erucic acid (EA) derivatives across various industrial sectors, including biofuels, lubricants, surfactants, cosmetics, pharmaceuticals, and biopolymers. Methyl esters of EA enhance biofuel performance by providing a high cetane number and improved cold-flow properties, while derivatives such as erucamide and behenic acid offer increased thermal stability, flexibility, and mechanical durability in lubricants and plasticizers. In cosmetic and surfactant formulations, EA-based emulsifiers and emollients contribute to improved product stability and enhanced skin hydration. Additionally, derivatives like behenyl alcohol and biodegradable monomers are utilized in drug delivery systems and the development of eco-friendly polymers. This broad range of applications underscores the industrial and economic relevance of high-erucic acid cultivars such as HEAR (high-erucic acid rapeseed). However, the safe and sustainable expansion of these applications requires careful evaluation of toxicological risks, mitigation of environmental impacts, and strict adherence to international regulatory standards.

4. TOXİCOLOGİCAL CONSİDERATİONS AND BİOACTİVİTY POTENTİAL OF ERUCİC ACİD

Erucic acid (EA; *cis*-13-docosenoic acid) is a monounsaturated omega-9 fatty acid predominantly found in mustard seed oil and oils derived from *Brassica* species such as rapeseed and canola. While industrially valuable particularly in the manufacture of lubricants, slip agents, and plasticizers EA has raised significant toxicological concerns in the context of human health, prompting international regulatory scrutiny.

Experimental animal studies, particularly in rodent models, have demonstrated that chronic high-dose intake of EA (>0.7 g/kg body weight/day) can lead to myocardial lipidosis, a pathological condition involving lipid accumulation in cardiac tissues (EFSA, 2016; Mohanty et al., 2025). Similar studies have also suggested a potential for hepatic steatosis. Although these findings cannot be directly extrapolated to humans due to interspecies metabolic differences, they have nonetheless informed the establishment of precautionary regulatory limits across various jurisdictions.

In response to toxicological data, several food safety authorities have implemented maximum allowable limits for EA in food-grade oils:

- European Union (EU): ≤2% of total fatty acids in edible oils (EC No. 1881/2006; EU Regulation No. 2019/1870)
- United States (FDA): ≤0.3% of total fat; EA use in food is effectively prohibited
- Australia and New Zealand (FSANZ): Maximum tolerable daily intake (TDI) = 7.5 mg/kg body weight/day
- European Food Safety Authority (EFSA): TDI = 7.0 mg/kg body weight/day (EFSA, 2016)

These frameworks have led to the development and widespread adoption of low-erucic acid rapeseed (LEAR) cultivars, especially in regions where oil is consumed directly by humans. In Türkiye, compliance with the ≤2% threshold is a requirement for cultivar registration by the Ministry of Agriculture and Forestry.

Table 4. Regulatory Limits for Erucic Acid Intake (Poddar et al., 2022)

Country/Region	**Regulatory Authority**	**EA Intake Limit**
United States	FDA	Banned for human consumption
European Union	EFSA	7.0 mg/kg body weight/day
Australia/New Zealand	FSANZ	7.5 mg/kg body weight/day
Asia, South Asia, S. America	-	No official limits reported

Despite these concerns, current data suggest that low-level exposure to EA at or below regulated limits does not pose a significant risk to human cardiovascular health. However, due to limited dose-response data and incomplete elucidation of the underlying toxicodynamic mechanisms, establishing comprehensive safety margins for potential therapeutic use remains an ongoing research priority (Galanty et al., 2023; Kazmi et al., 2024).

In contrast to its toxicological profile, recent preclinical studies have highlighted the potential bioactivity of erucic acid and its derivatives, suggesting a dualistic nature of this compound. Specifically, low-to-moderate doses of EA have been associated with several promising biological effects:

- Anti-inflammatory and immunomodulatory activity
- Lipid-lowering and cardioprotective effects
- Neuroprotective potential (e.g., in Parkinson’s disease)
- Anticancer and antiviral activity (Kazmi et al., 2024; Wani et al., 2022)

Mechanistically, EA has been shown to inhibit key inflammation-related enzymes such as thrombin and elastase. Additionally, suppression of the NF-κB and p38 MAPK signaling pathways has been observed, leading to reduced transcriptional activity of viral polymerases suggesting potential applications in managing viral infections such as influenza A virus (IAV). Preliminary data also indicate possible roles in bone health, particularly in osteoporosis models (Kazmi et al., 2024).

Nonetheless, these effects have primarily been demonstrated in in vitro systems or animal models. Robust clinical data on pharmacokinetics, therapeutic windows, and safety profiles in humans are currently lacking. Furthermore, the compound's complex metabolic behavior, potential for organ-specific accumulation, and interaction with other bioactive agents warrant thorough investigation before therapeutic use can be considered.

5. CONCLUSİONS AND FUTURE PROSPECTS

Erucic acid (EA) is an important fatty acid found in oilseeds of the Brassicaceae family, characterized by high thermal stability and chemical resistance. Due to these properties, it is widely used in various industrial applications such as biofuels, lubricants, plasticizers, and polymer production. However, because of its cardiotoxic effects at high doses, international regulatory limits have been imposed on the EA content in edible oils, which has encouraged the development of low-erucic acid rapeseed (LEAR) cultivars. The safe and sustainable use of EA requires multidisciplinary approaches integrating genetic improvement and toxicological assessments. In the future, comprehensive research aimed at optimizing EA content for targeted applications and ensuring human health and environmental sustainability remains crucial.

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THE SUSTAINABLE UTILIZATION POTENTIAL OF PLANT GROWTH-PROMOTING RHIZOBACTERIA (PGPR) IN SAFFRON (*Crocus sativus* l.) CULTIVATION

Assoc. Prof. Fatma KAYAÇETİN

Department of Field Crops, Faculty of Agriculture, Ankara University, 06110 Ankara, Türkiye

Email: kayacetin@ankara.edu.tr

ORCID: 0000-0002-7029-2825

Asst. Prof. Nilüfer KOÇAK ŞAHİN

Department of Field Crops, Faculty of Agriculture, Ankara University, 06110 Ankara, Türkiye

Email: nkocak@ankara.edu.tr

ORCID: 0000-0001-6474-1527

ABSTRACT

This review explores the potential for the sustainable use of plant growth-promoting rhizobacteria (PGPR) in saffron (*Crocus sativus* L.) cultivation. Commonly referred to as "red gold," saffron is among the most valuable spices worldwide; however, its production is limited due to restricted cultivation areas, high labor costs, and environmental stress factors such as drought, salinity, and soil-related problems. While conventional use of chemical fertilizers and pesticides may improve yields in the short term, such practices are reported to have adverse effects on soil health, biodiversity, and long-term sustainability. PGPR are considered environmentally friendly biofertilizer alternatives with the potential to enhance saffron growth performance and resistance to stress conditions. Some studies in the literature suggest that *Bacillus* and *Pseudomonas* species may have positive effects on corm development, flowering, stigma yield, and the accumulation of bioactive compounds. For instance, the application of *Pseudomonas chlororaphis* has been reported to result in approximately a 30% increase in corm number and an 8% increase in stigma count. Similarly, *Bacillus subtilis* and *Bacillus megaterium* have been associated with improvements in growth and bioactive metabolite levels. The potential effects of PGPR are thought to be mediated by mechanisms such as nitrogen fixation, enhanced phosphate solubilization, siderophore production, phytohormone synthesis, and pathogen suppression. These mechanisms may collectively contribute to improved root architecture, nutrient uptake, and stress tolerance. Field trials conducted in various regions, including Turkey, suggest that PGPR could be compatible with organic farming systems and may support saffron production under challenging environmental and edaphic conditions. This review highlights the promising role that PGPR may play in saffron agriculture; however, it also emphasizes the need for long-term, multi-location, and well-controlled studies to more comprehensively evaluate their applicability.

Keywords: *Crocus sativus* L., Plant growth-promoting rhizobacteria (PGPR), Biological fertilizers

BİTKİ GELİŞİMİNİ TEŞVİK EDEN RİZOBAKTERİLERİN (PGPR) SAFRAN (*Crocus sativus* l.) TARIMINDA SÜRDÜRÜLEBİLİR KULLANIM POTANSİYELİ

ÖZET

Bu derleme, safran (*Crocus sativus* L.) yetiştiriciliğinde bitki büyümesini teşvik eden rizobakterilerin (PGPR) sürdürülebilir kullanım potansiyelini ele almaktadır. "Kırmızı altın" olarak da bilinen safran, dünya çapında en değerli baharatlar arasında yer almakta; ancak üretimi, sınırlı ekim alanları, yüksek iş gücü maliyetleri ve kuraklık, tuzluluk gibi çevresel stres faktörleri nedeniyle kısıtlanmaktadır. Kimyasal gübreler ve pestisitlere dayalı geleneksel uygulamalar kısa vadede verimi artırabilse de, bu yaklaşımların uzun vadede toprak sağlığı, biyolojik çeşitlilik ve çevresel sürdürülebilirlik açısından olumsuz sonuçlar doğurabileceği bildirilmektedir. PGPR'ler, çevre dostu biyogübre alternatifleri olarak, safran bitkisinin büyüme performansı ve stres koşullarına karşı direncini artırma potansiyeline sahip mikroorganizmalar olarak değerlendirilmektedir. Literatürdeki bazı çalışmalar, özellikle *Bacillus* ve *Pseudomonas* türlerinin yumru gelişimi, çiçeklenme, tepecik (stigma) verimi ve biyoaktif bileşik birikimi gibi parametreler üzerinde olumlu etkiler sağlayabileceğini ortaya koymuştur. Örneğin, *Pseudomonas chlororaphis* uygulamasının yumru sayısında yaklaşık %30, tepecik sayısında ise %8 oranında artış sağladığı bildirilmiştir. Benzer şekilde, *Bacillus subtilis* ve *Bacillus megaterium* türlerinin de büyüme ve biyoaktif metabolit düzeyleri üzerinde olumlu etkileri olduğu rapor edilmiştir. PGPR'lerin potansiyel etkileri; azot fiksasyonu, fosfat çözünürlüğünün artırılması, siderofor üretimi, fitohormon sentezi ve patojen baskılama gibi çeşitli biyolojik mekanizmalar aracılığıyla açıklanabilmektedir. Bu mekanizmalar, genel olarak kök gelişimi, besin alımı ve stres toleransı üzerinde olumlu etkilere yol açabilmektedir. Türkiye dâhil olmak üzere farklı coğrafi bölgelerde yürütülen saha denemeleri, PGPR'lerin organik tarım sistemleriyle uyumlu olabileceğini ve zorlu çevresel ve toprak koşullarında safran üretimini destekleyebileceğini düşündürmektedir. Bu derlemede, PGPR'lerin safran tarımı bağlamında umut vadeden biyolojik girdiler olabileceği vurgulanmakta; ancak bu potansiyelin daha geniş ölçekte değerlendirilebilmesi için uzun vadeli, çok merkezli ve kontrollü çalışmalarla desteklenmesi gerektiği ifade edilmektedir.

Anahtar Kelimeler: *Crocus sativus L.*, Bitki gelişimini teşvik eden rizobakteriler (PGPR), Biyolojik gübreler

1. INTRODUCTION

Saffron (*Crocus sativus* L.) is a valuable cultivated plant belonging to the Iridaceae family and is often referred to as "red gold" due to its high economic value (Asanbekova, 2017; Kour et al., 2022; Cebeci, 2024). The saffron corm is a perennial organ, and the plant name is derived from Latin words *Crocus* (thread/yolk) and *sativus* (cultivated) (Mohammad et al., 2012 Koocheki, 2013; Parlakova Karagöz et al., 2016; Yıldız, 2017). One of the most expensive spices globally, saffron is obtained from the dried stigmas of its flowers, and approximately 180,000 flowers are needed to produce 1 kg of dry saffron (Mir et al., 2010; Crozet et al., 2012). Its primary bioactive components include crocin, crocetin, picrocrocin, and safranal, which not only contribute to the plant's unique taste, aroma, and color but also exhibit anticancer, antioxidant, and neuroprotective properties (Souret & Weathers, 1999; Abdullaev, 2002; Abdullaev & Espinosa-Aguirre, 2004; Sharaf-Eldin et al., 2008; Kırıcı et al., 2020; Asil, 2021; Golpour-Hamedani et al., 2024).

Saffron is a triploid (3n = 24), asexually reproducing species (Grilli Caiola, 2004; Gresta et al., 2009). The size of the mother corm and the number of buds determine the quality of the new corms. However, as the corm multiplication cycle continues, quality declines and the number of non-flowering corms increases (Gresta et al., 2008; Shokrpour, 2019). Thus, maintaining large corms and preventing their decay is crucial in saffron cultivation.

Today, growing population, climate change, and environmental degradation necessitate the adoption of sustainable practices in agriculture (Kumar et al., 2017; Hasan et al., 2024). While chemical fertilizers and pesticides offer short-term yield improvements, they can lead to long-term problems such as soil acidification, salinity, and loss of biodiversity (Dasgupta et al., 2021; Ebrahimi et al., 2021; Dincă et al., 2022; Hourani, 2023). In this context, plant growth-promoting rhizobacteria (PGPR) stand out as promising biological agents with the potential to enhance crop productivity and reduce dependence on chemical inputs (Calvo et al., 2014; Cruz-Martín et al., 2015; Khatoon et al., 2020; Buisset et al., 2025; Rawat et al., 2021; Chamkhi et al., 2023; Li et al., 2023; Güler, 2024; Thakur et al., 2024).

PGPR support plant growth through direct or indirect mechanisms in the rhizosphere. These microorganisms can solubilize unavailable phosphate, fix atmospheric nitrogen into ammonia, and suppress pathogens in the root zone (Kloepper et al., 2004; Lugtenberg & Kamilova, 2009; Bhattacharyya & Jha, 2012; Seymen et al., 2019; Shahwar et al., 2023). For instance, *Bacillus pumilus* and *Bacillus megaterium* species facilitate nitrogen uptake via nitrogen fixation (Cruz-Martín et al., 2015; Buisset et al., 2025), while *Bacillus* and *Pseudomonas* species are notable phosphate solubilizers (Rawat et al., 2021; Li et al., 2023; Thakur et al., 2024). Thakur et al. (2024) reported that *Pseudomonas chlororaphis* application led to a 30% increase in corm number and an 8% increase in stigma count in saffron plants.

PGPRs are highly compatible with organic farming and offer biocontrol potential against soil-borne diseases such as corm rot (Gupta & Vakhlu, 2015). Sharaf-Eldin et al. (2008) noted that *Bacillus subtilis* treatments enhanced saffron growth, yield, and altered bioactive compound levels.

Due to their stress tolerance, environmental adaptability, and biological functions, *Bacillus* and *Pseudomonas* species are considered promising candidates for microbial fertilizers in sustainable agriculture (Tortora et al., 2013; Parnell et al., 2016; Elnahal et al., 2022; Yang et al., 2022; Wang et al., 2024). Furthermore, research on the effects of PGPR on yield and bioactive compound accumulation in medicinal and aromatic plants is increasing (Zeriouh et al., 2011; Schmidt et al., 2014; Gu et al., 2017; Zhang et al., 2020; Magotra et al., 2021; Ali et al., 2024; Dalda-Sekerci et al., 2024).

Türkiye possesses high potential for saffron production due to favorable ecological conditions. However, climatic and edaphic stressors can limit yield. This review aims to support sustainable saffron production by focusing on the effects of *Bacillus* (e.g., *B. megaterium*, *B. pumilus*) and *Pseudomonas* (e.g., *P. fluorescens*, *P. chlororaphis*) species on plant development, corm yield, and bioactive compound production, underlining the importance of PGPRs for agricultural sustainability.

2. PGPR MECHANISMS AND THEIR EFFECTS ON SAFFRON

Plant Growth-Promoting Rhizobacteria (PGPR) are microorganisms that enhance plant growth through direct or indirect mechanisms in the rhizosphere (Lugtenberg & Kamilova, 2009; Bhattacharyya & Jha, 2012). Direct effects include nitrogen fixation, phosphate solubilization, iron chelation, and synthesis of plant hormones (e.g., indole-3-acetic acid, gibberellic acid), while indirect effects involve pathogen suppression, increased stress tolerance, and activation of plant defense systems (Kloepper et al., 2004; Seymen et al., 2019Rawat et al., 2021; ; Shahwar et al., 2023; Thakur et al., 2024; Calvo et al., 2014).

Among PGPRs, *Bacillus* and *Pseudomonas* species are particularly prominent. *Bacillus subtilis* and *Bacillus megaterium* support root development via nitrogen fixation (Cruz-Martín et al., 2015; Buisset et al., 2025), while *Pseudomonas fluorescens* and *Pseudomonas putida* can solubilize phosphate and suppress root pathogens (Rawat et al., 2021; Li et al., 2023; Thakur et al., 2024). *Pseudomonas chlororaphis* isolates have also been shown to increase corm number and stigma yield in saffron (Thakur et al., 2024).

Thakur et al. (2024) examined 35 stress-tolerant PGPR strains from the Kashmir Valley, identifying significant variation in traits such as tricalcium phosphate solubilization, ACC-deaminase activity, IAA, and siderophore production. Molecular analyses revealed *Bacillus* and *Pseudomonas* as dominant genera. Field trials with selected strains resulted in yield increases of 0.3–19%, highlighting the contribution of these PGPRs to saffron growth and quality.

Similarly, Xu et al. (2024) evaluated 14 PGPR isolates from the saffron rhizosphere, reporting that all strains synthesized IAA and gibberellic acid, while differing in phosphate solubilization, nitrogen fixation, and siderophore production. Field applications of strains SR144, SR163, SR269, SR307, and SR383 led to improvements in fresh corm weight and leaf length, along with reduced malondialdehyde content and increased antioxidant enzyme activities.

Stelluti et al. (2025) observed increased safranal and total phenolic content in saffron plants treated with *Bacillus megaterium* CB97032 and *Paenibacillus durus* CB1806 under sterile soil-less conditions. Ali et al. (2024) compared *Bacillus* sp. D5 (Bar D5) and *Bacillus amyloliquefaciens* W2 (Bam W2), reporting superior phosphate solubilization, IAA and ammonia production, and amylase and cellulase activity in Bar D5, which enhanced corm biomass in pot experiments.

Guo et al. (2025) demonstrated the antagonistic effects of *Bacillus velezensis* ZGE166 against saffron corm rot pathogens, confirming nitrogen fixation, ammonia and IAA production, and ACC-deaminase activity. Genomic analysis supported its secondary metabolite biosynthesis potential. Abedi et al. (2024) showed that *Bacillus subtilis* improved saffron morphology, physiology, and bioactive compound levels depending on bacterial density.

PGPR applications not only improve yield but also enhance bioactive compound production (Sharaf-Eldin et al., 2008; Gu et al., 2017; Ali et al., 2024) and increase stress tolerance under abiotic conditions (Elnahal et al., 2022; Wang et al., 2024). In Turkey, PGPR use aligns with organic farming principles, contributing to environmental sustainability by reducing chemical fertilizer dependency (Koocheki & Seyyedi, 2015; Gupta & Vakhlu, 2015).

Ultimately, *Bacillus* and *Pseudomonas* species support saffron growth through nitrogen fixation, phosphate solubilization, pathogen suppression, and stress resilience, positioning them as promising microbial agents for sustainable saffron agriculture (Schmidt et al., 2014; Parnell et al., 2016; Magotra et al., 2021; Yang et al., 2022).

3. CONCLUSIONS AND RECOMMENDATIONS

The studies reviewed demonstrate that certain PGPR strains, especially from *Bacillus* and *Pseudomonas*, can positively influence saffron yield, quality, and plant health. These bacteria can enhance saffron's morphological and physiological traits through mechanisms such as biological nitrogen fixation, phosphate solubilization, root development support, pathogen suppression, and improved stress tolerance. Evidence also suggests PGPRs can increase production of bioactive compounds like safranal and α-crocin.

The potential of PGPRs to enhance soil fertility and reduce chemical fertilizer use is significant for environmental sustainability. In Turkey, saffron production is constrained by climatic and soil-related stresses. However, strategic PGPR applications may improve yield and quality, contributing to organic and sustainable farming models.

Future studies should evaluate long-term effects of PGPR strains under diverse soil and climatic conditions. Investigating the synergistic potential of combined microbial applications and employing genomic and metabolomics tools to better characterize effective strains can further expand their application in sustainable saffron agriculture.

In conclusion, PGPRs hold significant potential as biofertilizers and biocontrol agents in integrated saffron farming systems. However, realizing this potential requires more field research, multi-location trials, and detailed studies of microbial interactions. *Bacillus* and *Pseudomonas* species offer eco-friendly alternatives to chemical fertilizers, but robust scientific evidence is needed to validate their practical applicability.

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KONVOLÜSYONEL SİNİR AĞLARI VE TARIMDA KULLANIM POTANSİYELLERİ

Metin YAĞMUR

İl Tarım ve Orman Müdürlüğü, Bayburt

Atatürk Üniversitesi, Ziraat Fakültesi, Tarımsal Biyoteknoloji Anabilim Dalı, Erzurum

Email: metin.yagmur@tarimorman.gov.tr

ORCID: 0009-0002-0290-7477

Doç. Dr. Semra ÇİÇEK*

Atatürk Üniversitesi, Ziraat Fakültesi, Tarımsal Biyoteknoloji Anabilim Dalı, Erzurum

Email: semra.cicek@atauni.edu.tr,

ORCID: 0000-0002-2927-2793

ÖZET

Konvolüsyonel Sinir Ağları (CNN), özellikle görsel verilerin işlenmesi ve analizinde öne çıkan derin öğrenme modelleridir. CNN'ler, katmanlı yapıları sayesinde görüntülerden kenar, köşe veya renk yoğunluğu gibi öznitelikleri otomatik olarak çıkarabilmekte ve bu öznitelikleri sınıflandırma ya da tahmin süreçlerinde kullanabilmektedir. Bu yönüyle, insan gözüyle fark edilmesi zor ayrıntıları yakalama kapasitesi, CNN'leri tarımsal uygulamalarda öne çıkarmaktadır.

Tarım sektöründe son yıllarda giderek artan şekilde kullanılan CNN tabanlı yaklaşımlar; bitki hastalıklarının erken tespiti, ürün sınıflandırma ve kalite kontrol, yabancı ot ve zararlıların belirlenmesi, hasat zamanının tahmini, toprak ve arazi analizleri ile otonom tarım araçlarının geliştirilmesi gibi birçok alanda önemli katkılar sağlamaktadır. Bitkisel üretimde kullanılan bu yöntemler, verim kayıplarını azaltırken aynı zamanda hassas tarım uygulamalarının yaygınlaşmasına olanak tanımaktadır. Hayvancılıkta ise CNN'ler, hayvan davranışlarının ve refahının izlenmesi, sürü yönetimi, sağlık durumlarının erken teşhisi (örneğin mastitis, solunum hastalıkları veya topallık), otomatik gözetim sistemleri ve yemleme süreçlerinin optimize edilmesi gibi alanlarda değerli çözümler sunmaktadır. Bu sayede, hem üretim verimliliği hem de hayvan sağlığı iyileştirilebilmektedir.

CNN'lerin tarım ve hayvancılıkta kullanımı, verimlilik ve doğruluğun artırılmasına, iş gücü maliyetlerinin azaltılmasına ve çevresel etkilerin en aza indirilmesine katkı sağlamaktadır. Bununla birlikte, yüksek kaliteli veri gereksinimi, modelin saha koşullarına uyarlanması ve yüksek hesaplama maliyetleri, başarı için göz önünde bulundurulması gereken temel zorluklardır.

Bu çalışma, CNN tabanlı yaklaşımların tarım ve hayvancılıktaki potansiyel kullanım alanlarını özetleyerek, gelecekteki araştırmalar için yol gösterici olmayı amaçlamaktadır. Genel olarak, CNN'ler karar destek sistemlerinden otonom makinelere kadar geniş bir yelpazede uygulanabilir çözümler sunmakta ve Tarım 4.0 sürecinde hem akademik hem de endüstriyel düzeyde güçlü bir araştırma alanı oluşturmaktadır.

Anahtar Kelimeler: Konvolüsyonel Sinir Ağları, Görüntü İşleme, Bitki Hastalıkları, Hayvan Refahı, Hassas Tarım, Yapay Zekâ

CONVOLUTIONAL NEURAL NETWORKS AND THEIR POTENTIAL APPLICATIONS IN AGRICULTURE

ABSTRACT

Convolutional Neural Networks (CNNs) are deep learning models that are particularly prominent in the processing and analysis of visual data. Due to their layered structure, CNNs can automatically extract features such as edges, corners, or colour intensity from images and use these features in classification or prediction processes. This ability to capture details that are difficult to detect with the human eye makes CNNs a prominent choice for agricultural applications.

CNN-based approaches, increasingly used in the agricultural sector in recent years, offer significant contributions in many areas, including early detection of plant diseases, product classification and quality control, identification of weeds and pests, harvest estimation, soil and land analysis, and the development of autonomous agricultural vehicles. These methods, used in crop production, reduce yield losses and enable the widespread adoption of precision agriculture practices. In animal husbandry, CNNs offer valuable solutions for monitoring animal behavior and welfare, herd management, early diagnosis of health conditions (e.g., mastitis, respiratory diseases, or lameness), automated surveillance systems, and optimizing feeding processes. This can improve both production efficiency and animal health.

The use of CNNs in agriculture and animal husbandry contributes to increased efficiency and accuracy, reduced labor costs, and minimized environmental impacts. However, the need for high-quality data, model adaptation to field conditions, and high computational costs are key challenges for success.

This study aims to provide guidance for future research by outlining the potential applications of CNN-based approaches in agriculture and animal husbandry. Overall, CNNs offer a wide range of applicable solutions, from decision support systems to autonomous machines, and constitute a strong area of research at both academic and industrial levels in the Agriculture 4.0 era.

Keywords: Convolutional Neural Networks, Image Processing, Plant Diseases, Animal Welfare, Precision Agriculture, Artificial Intelligence

1. INTRODUCTION

With the digital transformation process, the use of artificial intelligence (AI) and deep learning (DL) technologies is becoming increasingly widespread in the agriculture and livestock sectors. These technologies significantly facilitate the processing, classification, and interpretation of visual data, in particular. Making sense of the large volumes of data obtained through sensors, drones, satellite systems, and automatic cameras used in agricultural activities has become difficult with traditional methods. At this point, Convolutional Neural Networks (CNN), which can automatically extract features from visual data, stand out as a powerful tool in agricultural analysis (Gülmez, 2025).

Due to their layered structure, CNN models can automatically recognize features such as edges, corners, color intensity, or texture in images. This ability allows for the detection of even small details invisible to the human eye, enabling highly accurate results in areas such as agricultural disease diagnosis, product quality assessment, and yield estimation. In agricultural production, these models contribute to the development of decision support systems by saving both time and reducing labor costs (Ma'arif et al., 2022).

CNNs have numerous innovative applications, particularly in crop production. CNN-based models offer high success rates in areas such as early disease detection based on the analysis of plant leaf images, automatic identification of pests and weeds, classification of fruit maturity, and harvest time prediction. For example, CNN models trained on large datasets like PlantVillage can detect diseases in various plant species with over 95% accuracy. Such applications contribute to both reducing pesticide use and preventing yield losses (Rastogi et al., 2024; Shafik et al., 2025).

Recent research has shown that CNN-based approaches are not limited to crop production but also have significant applications in animal husbandry. CNN models are particularly effective in monitoring animal behavior and welfare, herd management, early diagnosis of diseases (such as mastitis or lameness), and optimization of automated feeding systems. These systems have positive effects on both production efficiency and animal health. (Bello et al., 2025; Umurungi et al., 2025).

However, several technical challenges must be overcome for CNNs to be effectively applied in agriculture and animal husbandry. The main limitations researchers face are the need for high-quality data, the need to adapt the model to field conditions, the high computational costs of training, and its ability to generalize. In this context, improving existing studies and creating local datasets will directly impact the success of CNN-based systems (Tugrul et al., 2022).

In general, CNNs offer a wide range of applicable solutions, including early detection of plant diseases, product quality classification, weed detection, soil and terrain analysis, animal welfare monitoring, and the development of autonomous agricultural systems. This review aims to present the current applications of CNN-based approaches in agriculture and animal husbandry, their advantages, and challenges, and to provide a fundamental assessment that will guide future research.

1.1. Basic Principles of Convolutional Neural Networks

Convolutional Neural Networks (CNNs) are deep learning models inspired by the human visual system. These networks are specifically designed to identify patterns, shapes, and structural relationships in image-based data. The fundamental principle of CNNs is to extract local features from the input image and transform them into more abstract representations in higher layers. This allows the network to identify, classify, and predict complex objects or events in the image.

A CNN model typically consists of several main components: convolution layers, activation functions, pooling layers, fully connected layers, and an output layer. Each of these layers serves a specific function in the network's process of extracting meaningful information from data (Ma'arif et al., 2022).

Convolutional layers form the fundamental building blocks of a CNN. In these layers, small-sized filters (kernels) are slid over the input image (sliding windows) to capture specific features. The filter multiplies different regions of the image to produce feature maps. For example, one filter can detect edges, while another can recognize color intensity or textural differences. With this multilayered approach, the CNN hierarchically learns low-level (edge, line) and high-level (leaf shape, fruit shape) features in the image (Jogin et al., 2018).

Features obtained from convolutional layers need to be transformed nonlinearly. The most commonly used activation function for this is ReLU (Rectified Linear Unit). ReLU reduces negative values to zero while preserving positive values, increasing the network's learning speed. This allows CNN models to generalize with high accuracy even on complex agricultural image data (Alsajri and Hacimahmud, 2023).

Pooling layers in CNNs reduce the size of feature maps, reducing both computational overhead and the risk of overfitting. Max-pooling is the most commonly used technique; it represents the most significant feature by taking the highest value in a given region. For example, this method is quite effective in detecting a prominent spot on a leaf surface (Zafar et al., 2022).

The fully connected layers at the end of the network perform the classification process by combining the features extracted in previous layers. This part operates similarly to classical artificial neural networks. The final layer typically uses a softmax function and generates the probability value for each class. In plant disease classification, this layer calculates the probability of each disease type and presents the highest value as the "prediction result." (Yadav et al., 2022).

One of the key advantages of CNN over other types of neural networks is the principle of weight sharing. This principle allows the same filter to be used repeatedly across the entire image, making the network both computationally efficient and reducing the number of parameters during the learning process. The learning process is based on minimizing the error function using a backpropagation algorithm. At each iteration, the network's parameters are updated, reducing errors (Taye, 2023).

CNNs are particularly robust against challenges such as high noise, light variability, and complex backgrounds in the analysis of agricultural images. This feature allows them to reduce errors caused by wind, shadow, or soil texture in plant images taken in open fields. Furthermore, transfer learning approaches allow pre-trained CNN models (e.g., VGGNet, ResNet, AlexNet) to be easily adapted to new agricultural datasets, achieving high accuracy even in studies with limited data. Therefore, CNNs are considered a fundamental deep learning approach for applications such as plant disease diagnosis, crop classification, quality control, and autonomous agricultural systems (El Sakka et al., 2025).

1.2. Use of CNNs in Agriculture

CNNs have the potential to be used in the high-accuracy detection of plant diseases, automatic classification of agricultural products according to their types, maturity status or quality standards, detection of weeds and pests, determination of harvest time of products, soil and land analysis, animal welfare and development of visual detection systems in autonomous agricultural vehicles.

1.2.1. Diagnosis of Plant Diseases

Fast and accurate plant disease detection is critical for reducing yield losses by preventing pest spread and optimizing pesticide use. Over the past decade, CNN learning on image-based data has made significant progress in this area. Two main approaches can be identified in the research literature: (i) classification-based methods (determining which disease/class an image belongs to), and (ii) detection/segmentation-based methods (localizing disease lesions within the image and separating them at the pixel level). While classification studies are typically performed on single leaf images, detection and segmentation networks (e.g., Faster R-CNN, YOLO, U-Net, and their derivatives) are preferred for detecting multiple lesions or plant samples in field images. Extensive comparisons and example applications of these two approaches have been reported. (Ferentinos, 2018; Liu and Wang, 2021).

Transfer learning and adapting pre-trained networks (AlexNet, VGG, ResNet, etc.) to agricultural imagery has been a practical and effective strategy for studies with limited data. Early studies, such as Sladojevic et al. (2016), demonstrated that high performance can be achieved even with fine-tuning small datasets from the internet; later applications of transfer learning with larger datasets have further improved performance (Frentinos, 2018).

However, high accuracies achieved in laboratory or controlled conditions do not always translate to the same success in real-world applications. Factors such as variable outdoor light conditions, background complexity, different plant varieties/races, and disease stage can reduce model generalization. Picon et al. (2019) highlighted the challenges of early detection studies conducted in the field and the need for real-time application.

Jiang et al. (2019) developed a deep CNN model combined with the Inception module to detect five different apple leaf diseases. Similarly, Bukumira et al. (2022) introduced a carrot grading system that employed computer vision and a cascaded graph CNN, effectively classifying and grading carrots with high accuracy. Hosny et al. (2023) proposed a hybrid technique that integrated lightweight deep learning features with Local Binary Pattern (LBP) features to identify leaf diseases in apples, grapes, and tomatoes, achieving accuracy rates of 97.8%, 97%, and 96%, respectively. Ahila Priyadharshini et al. (2019) adapted the LeNet architecture to design a CNN for classifying corn leaf diseases using the PlantVillage dataset, reaching an accuracy of 97.89%. Waheed et al. (2020) optimized a DenseNet-based structure to detect and classify various corn leaf diseases, including northern leaf blight, common rust, and gray leaf spot, with an accuracy of 98.06%. In another study, Wu et al. (2019) used UAV images and a pre-trained ResNet for feature extraction to identify northern leaf blight in corn leaves, achieving an overall accuracy of 95.1%.

Furthermore, hybrid approaches that combine CNNs with attention mechanisms have been explored to enhance plant disease prediction and classification. Zeng and Li (2020) developed a residual CNN enhanced with self-attention, which achieved 98% accuracy on the MK-D2 dataset and 95.33% on the AES-CD9214 dataset. Likewise, Chen et al. (2021) utilized a pre-trained MobileNet-V2 with an integrated attention mechanism to detect rice leaf diseases, attaining 98.48% accuracy. Most recently, Aboelenin et al. (2025) presented a hybrid model that merged VGG16, Inception-V3, and DenseNet20 architectures, successfully identifying and classifying multi-class plant leaf diseases, and outperforming comparable methods with accuracy rates of 99.24% for apple and 98% for corn datasets.

1.2.2. Product Classification and Quality Control

The grading and quality control of agricultural products is a critical stage in the production chain, both for consumer satisfaction and economic value. Traditional methods for classifying products often rely on human observation or simple color/shape analysis, leading to subjective

errors and low accuracy. CNN-based image processing methods have revolutionized this field by providing an objective, rapid, and repeatable solution for product quality assessment. (Kamilaris and Prenafeta-Boldú, 2018).

CNN models can automatically identify characteristics of products such as color, shape, surface texture, and defect status, thus enabling the determination of ripeness level, class, and defect rate of fruits and vegetables. For example, a deep learning model developed by Xiao et al. (2021) classified apple ripeness degrees with 96% accuracy. CNN approaches combined with hyperspectral data have demonstrated superior performance, particularly in cases such as internal quality (internal spoilage, chemical content) or early ripeness detection. For example, a CNN trained on Vis/NIR spectroscopy data applied to Fuji apples was able to accurately classify different ripeness classes with over 96% accuracy; this study demonstrates that the combination of hyperspectral/spectral data with CNN is robust in classifying internal quality regardless of the external surface (Benmouna et al., 2022).

RGB images and lightweight (mobile/edge) CNN architectures are also important for field and business-line applications. Fine-tuned lightweight networks such as MobileNet have reported high accuracies in classification and ripeness estimation on multi-class fruit/vegetable datasets, demonstrating the feasibility of real-time quality control with low-cost cameras. However, issues such as data diversity, illumination variability, and image occlusion can impact application success (Tapia-Mendez et al., 2023).

Sample applications and performance reports provide practical validation: an optimized CNN-based classification/grading system developed for mango reported classification accuracy around 97–98% (Zheng and Huang, 2021). Similarly, pre-trained models (Faster R-CNN, RFCN, SSD) used with fine-tuning for potato surface defect detection achieved detection/accuracies ranging from 92.5–98.7% (Wang and Xiao, 2021). These results demonstrate the suitability of CNN-based approaches for industrial applications in both fruit-vegetable discrimination and product surface defect detection.

CNN-based approaches are also successful in grain and seed quality control: CNN models have been reported with high accuracy in distinguishing wheat grains from intact/broken, detecting foreign matter, or classifying grain purity; such applications enable the implementation of automated sorting systems, particularly in packaging and quality assurance lines. Furthermore, high reliability regarding internal quality (moisture, starch, internal spoilage) can be achieved when multi-channel data such as hyperspectral/terahertz/NIR is used periodically (Polder et al., 2019; Zhu et al., 2023).

CNN-based product classification and quality control approaches are important technological tools that reduce human error, automate processes, and strengthen standardization. With the proliferation of low-cost cameras and AI-powered systems in the coming years, agricultural product quality control processes are expected to become fully automated.

1.2.3. Weed and Pest Detection

Weeds and pests are major drivers of yield losses and increased pesticide use in agricultural production. Traditional detection methods typically rely on manual observation or simple image thresholding techniques, resulting in both time-consuming and low accuracy in large areas. In this context, CNN-based image analysis systems offer fast, automated, and highly accurate solutions for weed and pest detection.

Dos Santos Ferreira et al. (2017) used CNN-based classification to distinguish weeds from RGB drone images taken in soybean fields with 97% accuracy. This work provides a pioneering example for autonomous spraying and targeted mechanical intervention systems. Subeesh et al. (2022) evaluated the applicability of deep learning-based techniques (Alexnet, GoogLeNet,

InceptionV3, Xception) in weed identification from RGB images of a bell pepper field. Models were trained with different epoch values (10, 20, 30) and batch sizes (16, 32), and hyperparameters were tuned to achieve optimal performance. The overall accuracy of the selected models ranged from 94.5% to 97.7%. Among the models, InceptionV3 showed superior performance with 97.7% accuracy, 98.5% precision, and 97.8% recall at 30 epochs and a batch size of 16. Type 1 error was 1.4% and Type II error was 0.9% for this Inception3 model.

Faisal et al. (2025) compared the effective identification and classification of cotton weeds with other existing CNN models, such as VGG-16, ResNet, DenseNet, and Xception Model. Experimental results show that VGG-16, ResNet-101, DenseNet-121, and XceptionNet models have an accuracy rate of 95.4%, 97.1%, 96.9%, and 96.1%, respectively. The proposed model outperformed other models, achieving an accuracy rate of 98.3%.

UAV-based system research using drone imagery is also attracting attention. The CNN LVQ model developed by Haq (2022) and trained using 4400 UAV images showed 99.44% overall accuracy for weed detection after rigorous hyperparameter tuning.

Visual detection of pests and larvae is often challenging due to their small size, rapid motion, and background complexity. CNN-based approaches have provided effective results by extracting multi-layered features from high-resolution images to solve this problem. Wang et al. (2021) proposed an effective CNN-based automatic handheld pest monitoring system to detect and count rice pests. Experimental results using the proposed approaches evaluating three types of density pest images show that our system performs well in detecting rice pests in non-specific wild environments, with recognition recovery up to 91% under industrial conditions. Wang et al. (2023) proposed a three-scale CNN model with added channel and spatial attention mechanisms for pest detection of different sizes under complex backgrounds, and reported an accuracy of 93.16% in field images. Yulita et al. (2023) used a GoogleNet-based CNN for pest detection in mobile applications for farmers in Indonesia, and reported an accuracy of 93.78%.

These developments directly contribute to agricultural management processes, supporting the reduction of chemical inputs, environmental sustainability and production efficiency.

1.2.4. Determining Harvest Time

Accurately determining harvest timing is crucial for agricultural production efficiency, quality control, and logistics planning. Premature or delayed harvesting can reduce product quality and increase storage and marketing costs. Therefore, predicting harvest timing using image analysis, sensor data, and time-series models is a prominent research area in modern agriculture.

Minagawa and Kim (2022) used Mask R-CNN to detect tomato clusters and estimate harvest time based on these images. A harvest time prediction model was developed using images of fruit remaining after removing the fruit covering (leaves, stems, etc.), and the "harvestable" status of the fruit was determined based on its maturity stage. This study presents a new approach to harvest time prediction, specifically by directly using visual data (RGB images).

Han et al. (2022), used the InceptionV3-LSTM model to predict harvest time for canola (rapeseed). This model demonstrated better performance in harvest time prediction by combining InceptionV3's image-based feature extraction with LSTM's time-series dependencies. The technology aims to more accurately predict harvest time by processing features from multispectral data (spectral + image) in the time domain.

Zhang et al. (2020) used a Faster R-CNN-based system to detect fruit, branches, and stems in apple trees. Harvest time and shaking points were then determined based on the detected fruit locations, and recommendations were presented for an automated apple harvesting system. This

approach not only determines harvest timing but also contributes to harvest strategy planning (e.g., where to shake trees).

Some studies use hybrid deep learning models not only with image (or spectral) data but also with time-series features such as meteorological and satellite data. For example, Wang et al. (2023) studied crop (e.g., wheat) yield and development predictions by modeling time-series dependencies with GRU (Gated Recurrent Unit) and spatial features extracted with CNN.

1.2.5. Soil and Land Analysis

Soil and terrain analysis includes elements such as soil texture, moisture content, salinity, organic matter distribution, and land cover mapping. This information forms the basis for agricultural planning, irrigation management, erosion control, and environmental monitoring. In recent years, the combination of high-resolution satellite imagery with sensor data, coupled with deep learning techniques, particularly CNN, has demonstrated effective results in quickly and accurately extracting soil spatial patterns (Ahmed et al., 2021; Zhao et al., 2022).

Combining surface soil moisture with remote sensing data and climate indices is critical for irrigation planning and drought management. Hybrid deep learning models (e.g., CEEMDAN-CNN-GRU) have produced reliable soil moisture estimates at daily scales using satellite-derived time-series data such as MODIS and ground observations; these approaches statistically significantly outperform traditional single models (such as GRU or LSTM alone). Such studies demonstrate the practical application of soil moisture predictions in agricultural water management. (Ahmed et al., 2021).

Image-based approaches (e.g., hybrid models such as DLAC-CNN-RF using features extracted from laboratory/smartphone images) for rapid estimation of properties such as soil texture (sand, silt, clay ratios) have reported high accuracy and R^2 values (0.99 for sand, 0.98 for clay, 0.98 for silt). These methods have the potential to reduce field sampling costs and contribute to the creation of digital soil maps. (Zhao et al., 2022).

Salinity (soil salinity) monitoring studies have yielded successful results by combining CNN-based models with multispectral/hyperspectral satellite data. Deep learning approaches have been used, particularly for identifying sources of saline runoff due to drought and lake retreat, and for mapping the spatial distribution of saline areas; in one example study (Lake Urmia basin), high classification and mapping accuracies were reported with a DL-CNN-based model. Such remote sensing-CNN combinations, calibrated with field samples, are suitable for monitoring salinity changes over large areas (Garajeh et al., 2021).

For land use/cover (LULC) classification, CNN and CNN+RNN hybrid models (e.g., HCRNN) provide high pixel-level accuracies on multispectral Sentinel-2 data; these maps are directly used for both agricultural land update and land change analysis. CNN-based approaches have demonstrated superior performance compared to classical machine learning methods, particularly because they efficiently extract multispectral spectral information. Experimental results show that the overall accuracy of the HCRNN model reaches 97.62% on the Sentinel-2 dataset, which improves performance by 1.78% compared to the RNN model (Fan et al., 2023).

1.2.6. Animal Welfare

Animal welfare is a multidimensional concept encompassing not only the physical health of production animals but also their behavioral and psychological states. Accurately monitoring welfare in modern animal husbandry not only increases production efficiency but also contributes to the achievement of ethical production standards. Because traditional observation-based assessment methods are prone to human error and subjective judgments, automated

monitoring of animal behavior, facial expressions, and health indicators using CNN-based computer vision systems has become an important area of research in recent years.

Lencioni et al. (2021) developed a machine vision algorithm to assess pain levels in horses using an automatic computational classifier based on the Equine Grimace Scale (HGS) and trained using machine learning. The study evaluated the facial expressions of seven castrated horses, collected via a video system placed above the feeding station and capturing images at four different time points per day: two days before and four days after surgical castration. The machine vision algorithm was developed using a CNN training system, which achieved an overall accuracy of 75.8% when classifying pain into three levels: absent, moderately present, and clearly present. When classifying between two categories (no pain and present pain), the overall accuracy reached 88.3%.

Video-based deep learning applications for gait analysis and lameness detection in cattle have reported high accuracy; for example, the method developed by Kang et al. (2020) reported 96% correct classification using support phase analysis and has demonstrated practical use in deep sensing and lameness detection in cows. Such automated systems are effective for early intervention and improved animal welfare.

CNN-based tracking and recognition algorithms have been used in farm settings for individual animal identification and tracking, automated measurement of feeding/grazing behavior, and social interactions. For example, the "Now You See Me" study developed a CNN-based tracker for continuous monitoring and individual tracking of cows on farms. Experiments show that a cow can be monitored approximately 4 minutes before incidents of malfunction occur and that cows can be successfully monitored for over 20 minutes in lightly crowded scenes (<10 cows). Such tracking systems are used to detect behavioral anomalies and social changes related to welfare (Guzhva et al., 2018).

Production-oriented welfare indicators such as body condition score (BCS) and weight estimation can be automatically estimated using combinations of 2D/3D imagery and deep learning; in recent examples, multiple 3D camera + CNN-based approaches have demonstrated successful and practical results (e.g., BCS estimation using ensemble 3D-CNN models). This automation contributes to both health management and feed/production optimization through frequent and objective BCS monitoring (Summerfield et al., 2023). A reliable body condition estimation model using 3D images in Jersey cows has been reported to achieve 93.5% accuracy with an average accuracy of 48.1% and a deviation of 0.5 units for the exact phenotype (Stephansen et al., 2023).

The combination of infrared (thermal) imaging and deep learning has yielded successful results in the non-invasive early detection of mastitis and heat stress. Because thermal methods are sensitive to field conditions, they are generally used by combining image segmentation and multiple measurements (eye + udder + environmental conditions). A total of 105 dairy cows passing through a passage were randomly selected from thermal infrared videos and identified using a new and comprehensive detection method. The results of bovine mastitis detection were compared with somatic cell counts. The YOLOv5 deep learning network model used to identify critical regions of the cow demonstrated that the accuracy, specificity, and sensitivity of mastitis detection were 87.62%, 84.62%, and 96.30%, respectively, with an average accuracy of 96.1% and a mean frame rate of 116.3 f/s (Wang et al., 2022). Compared with somatic cell count (SCC), the accuracy, sensitivity and F1 value of 86.67%, 82.35% and 87.5% were obtained for mastitis detection in dairy cows by the CLE-UNet algorithm, respectively (Zhang et al., 2023).

1.2.7. Autonomous Agricultural Vehicles

Autonomous agricultural vehicles (autonomous tractors, ground-based robots, autonomous spraying/spot-spraying systems, and agricultural drones) are a rapidly developing technological field with the aim of reducing labor requirements in agricultural production, utilizing inputs in a targeted manner, and reducing environmental impact. The design of these vehicles requires integrating high-accuracy positioning (GNSS/RTK), environmental sensing (RGB, multispectral, LiDAR), real-time path planning and control, and decision-making software. Image processing and deep learning (especially CNN-based object detection/classification and real-time detection networks) play a critical role in the perception layer of autonomous agricultural vehicles: models have been developed that can be integrated with both ground-based robots and drones for tasks such as weed/crop discrimination, pest detection, and crop occupancy/maturity detection.

Qin et al. (2023) performed 3D obstacle detection in a field environment using LiDAR data with a model called Focal Voxel R-CNN and achieved mAP = 91.43%. This system operates at a detection rate of approximately 28.57 frames per second. Such LiDAR-based methods provide environmental detection mechanisms that are not dependent on constant light conditions.

Muvva et al. (2024) reported that they detected weedy and weed-free images in potato farms with 95.96% accuracy using an autonomous robot equipped with a motorized ESP32 microcontroller and integrated with a CNN model. The AGRIBOT prototype, designed by Patel et al. (2022), can detect weeds using RGB images and provides a CNN model optimized for real-time operation.

Kim et al. (2020) proposed a CNN-based method for autonomous vehicles to track in orchards. The path detection performance of this method was evaluated in terms of patch size, and a 96 × 96 patch showed the best performance with a classification accuracy of 0.93, an IoU of 0.75, and a processing time of 0.111 seconds.

1.3. Potential Challenges and Future Perspective of Convolutional Neural Networks

Despite their high performance in tasks such as image processing, classification, and object detection in agriculture, CNNs face several fundamental challenges in terms of field applicability. These challenges can be examined at both technical and operational levels.

CNNs, due to their complex structure containing millions of parameters, require large and balanced datasets. Networks trained with limited data often exhibit overfitting, leading to a significant decrease in performance on test data. This problem is particularly pronounced in agricultural fields under agroclimatic conditions or in remote sensing applications where data collection is challenging. Kamilaris and Prenafeta-Boldú (2018) stated that a lack of data diversity is a major bottleneck in agricultural deep learning applications.

Another significant challenge is the high computational power and hardware requirements of CNN models. Training deep architectures is costly in terms of both time and energy because they require large-scale GPU or TPU infrastructure. This reduces the accessibility of deep learning applications, especially in resource-constrained research environments. Furthermore, high energy consumption has been criticized for its environmental impact, with training deep networks being highlighted as a significant contributor to carbon emissions (Shruthi and Naveen, 2024).

The interpretability of CNNs is another significant issue. These models are often considered "black box" systems because it is often impossible to understand the characteristics underlying a decision. Especially in applications critical to security and accuracy, such as agricultural

decision support systems, a lack of model explainability can reduce user confidence (Nieradzik et al., 2024). In recent years, advances have been made in visualizing the internal dynamics of models through methods such as Grad-CAM and Layer-wise Relevance Propagation, but these methods still fail to provide complete transparency into decision-making processes.

The success of future CNN-based agricultural AI systems will depend on advances in areas such as data quality, explainability, energy efficiency, and integration capacity. Multimodal CNN models created by combining RGB, hyperspectral, thermal, and LiDAR data can improve decision accuracy by simultaneously analyzing both intrinsic quality and extrinsic appearance parameters. Garajeh et al. (2021) demonstrated that such data fusion provides accuracy gains in soil salinity estimation in the Urmia Lake basin. Lightweight CNN architectures such as MobilNet, EfficientNet-Lite, or Tiny-YOLO enable real-time operation in field robotic or drone-based systems. Muvva et al. (2024) achieved low-latency field detection using a lightweight CNN for autonomous weed detection. Integrating CNN models with autonomous agricultural vehicles will expand the capacity for visual decision-making in the field. Patel et al. (2022) demonstrated the effectiveness of the CNN-based AGRIBOT prototype for real-time weed detection. The proliferation of open data platforms internationally will facilitate model retraining and comparability. Such initiatives can mitigate the generalization and reliability issues of AI models in agriculture.

2. CONCLUSION

Over the past fifteen years, CNNs have revolutionized agricultural production systems, demonstrating unparalleled accuracy and automation capabilities, particularly in image-based decision support applications. CNN models have digitized and objectified production processes across a wide range of applications, from plant disease diagnosis and crop classification to weed and pest detection, harvest timing, soil and field analysis, and animal welfare monitoring.

This review clearly demonstrates that CNN-based approaches have initiated a multifaceted transformation in agriculture. Deep learning models used in early plant disease detection, crop quality control, and weed detection provide high levels of accuracy, effectively replacing traditional methods based on human observation. Similarly, CNN-enabled imaging systems have ushered in a new era in welfare management by enabling objective measurement of animal behavior and health indicators. Integrating CNN with hyperspectral and LiDAR data in soil and terrain analysis has enabled the estimation of soil moisture, texture, salinity, and land cover changes at high spatial resolution. Recent studies in the field of autonomous agricultural vehicles demonstrate that CNN can be effectively used not only for perception but also for decision-making and action. Thus, CNN has become not only an analysis tool but also the cognitive backbone of autonomous agriculture.

However, several challenges limit the widespread application of CNN-based systems. These include data insufficiency and instability, model generalization problems (domain shift), high processing power requirements, and a lack of explainability. Overcoming these challenges is critical for the sustainable scalability of deep learning applications in agriculture.

Future research is expected to focus on (i) multimodal data fusion (RGB, hyperspectral, thermal, LiDAR), (ii) lightweight and energy-efficient CNN architectures (MobileNet, EfficientNet-Lite, Tiny-YOLO), (iii) explainable artificial intelligence (XAI) approaches, and (iv) autonomous system integration. Developing explainable, environmentally friendly, and cost-effective CNN models in this direction will increase both efficiency and ethical standards in agricultural production.

Ultimately, CNN architectures are at the forefront of a data-driven, intelligent, and autonomous transformation across all levels of agriculture. Sustainable adoption of this technology will

strengthen not only production efficiency but also environmental protection, food security, and animal welfare on a global scale.

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TARIMDA TEK ÜRÜN ÜZERİNE GERÇEKLEŞTİRİLEN AÇIK ALAN UYGULAMALI FUARCILIK: POTATO DAYS TÜRKİYE FUARI ÖRNEĞİ

Dr. Osman İNAN

Bağımsız Araştırmacı

Email: osmaninan.2025@gmail.com

ORCID: 0000-0001-7306-5516

ÖZET

Potato Days Türkiye Fuarı, 2019 ve 2021 yıllarında Konya-Selçuklu-Karaömerler'de, 2023 ve 2025 yıllarında Nevşehir-Gülşehir'de olmak üzere 4 kez organize edilmiştir. Türkiye'de tarımda açık alan uygulamalı tek bir tarım ürününe (patates) yönelik profesyonelleşmiş öncü ve tek fuar olması ile düzenlendiği her iki yılda bir üreticilerden yoğun ilgi görmektedir. Katılımcı firmaların ürün / yenilik tanıtım ve gösterilerinden; fuar organizatörlerinin sektör liderlerinin katılımlarıyla düzenledikleri söyleşilerden; kamu kurumlarının ve meslek örgütlerinin uzman bilgilendirmelerinden yerinde uygulamalı olarak istifade edilmektedir. Sonuncusu 19-21 Ağustos 2025 tarihleri arasında 4. kez gerçekleştirilen fuar, sektörün önemli bir kısmını temsil eden 78 katılımcı firma ve %10'dan fazlası yabancı ve çok çeşitli ülkelerden gelen 5.113 ziyaretçi tarafından yerinde ilgi görmüştür. Bu bildiride, tarım fuarcılığı, tarımda açık alan uygulamalı fuarcılık, tarımda açık alan uygulamalı tek ürün fuarcılığı ve 'Potato Days Türkiye Fuarı' hakkında bilgiler verilmiştir. Potato Days Türkiye Fuarının tanıtılarak kayıt altına alınması, fuarın tarımsal yayım ve yerel kalkınma için öneminin anlaşılması ve fuarın geliştirilmesi için öneriler sunulması da amaçlanmıştır. Sonuçta, fuar patates sektörüne katkısı üretici, firma ve tüketiciye sağladığı faydalar açısından geliştirilebilir bulunmuştur. Reklam, duyuru ve ulaşım olanakları artırılmalıdır. Doğrudan patates ürünün katma değerini artırması ve diğer ekonomik katkıları dikkate alınarak yerel yönetimler tarafından daha fazla desteklemelidir. Üreticiler ve katılımcılar fuardan daha fazla yararlanmalı, üreticiler sözleşmeli üretim hakkında bilgilendirilmeli ve sözleşmeli üretim yapan kuruluşlarının işbirliği olanaklarını araştırabilmelidirler. Fuarın tarımsal yayım faaliyetlerini destekleyen katkıları ile fuar süresince ve fuar sonrasında yöreye sosyo-ekonomik katkılarına dikkat çekilmelidir. Türkiye'de alanında tek örnek olan bu fuarın sürekliliği ve başarısı görülerek, birbirinden farklı tarım ürünleri ile bilinen Türkiye'nin farklı coğrafyalarında bu yaklaşımda fuarların yapılma olanakları araştırılmalıdır.

Anahtar Kelimeler: Tarım Fuarları, Tarımda Açık Alan Fuarcılığı, Tarımda Açık Alan Uygulamalı Fuarcılığı, Üretici, Potato Days Türkiye Fuarı

OPEN-FIELD APPLIED EXHIBITION PRACTICES FOCUSED ON A SINGLE CROP IN AGRICULTURE: THE CASE OF POTATO DAYS TÜRKİYE EXHIBITION

ABSTRACT

The Potato Days Türkiye Fair has been organized four times: in 2019 and 2021 in Konya-Selçuklu-Karaömerler, and in 2023 and 2025 in Nevşehir-Gülşehir. As the only specialized and pioneering trade fair in Turkey focused on a single agricultural product (potatoes) in open field applications, it attracts significant interest from producers every two years it is held. Participants benefit from the product/innovation presentations and demonstrations of participating companies; from the discussions organized by the fair organizers with the participation of industry leaders; and from the expert briefings provided by public institutions and professional organizations. The most recent fair, held for the fourth time between August 19-21, 2025, attracted 78 participating companies representing a significant portion of the sector and 5,113 visitors, more than 10% of whom were foreign and came from a wide variety of countries. This paper provides information on agricultural fairs, open-field applied fairs in agriculture, open-field applied single-product fairs in agriculture, and the 'Potato Days Türkiye Fair'. It also aims to introduce and document the Potato Days Türkiye Fair, highlight its importance for agricultural dissemination and local development, and offer suggestions for its improvement. Ultimately, the fair was found to be developable in terms of its contribution to the potato sector and the benefits it provides to producers, companies, and consumers. Advertising, publicity, and transportation opportunities should be increased. Local governments should provide more support, considering the direct increase in the added value of potato products and other economic contributions. Producers and participants should benefit more from the fair; producers should be informed about contract farming and should be able to explore opportunities for cooperation with organizations engaged in contract farming. Attention should be drawn to the fair's contributions to agricultural extension activities and its socio-economic contributions to the region during and after the fair. Seeing the continuity and success of this fair, which is the only one example of its kind in Turkey, the possibilities of organizing fairs with this approach in different regions of Türkiye, known for its diverse agricultural products, should be investigated.

Keywords: Agricultural Fair, Open-Air Exhibition in Agriculture, Open-Air Practical Exhibition in Agriculture, Producer, Potato Days Türkiye Fair

1. GİRİŞ

Fuar, ticarete konu ürünlerin veya hizmetlerin, teknolojik ilerlemelerin, bilgi ve yeniliklerin tanıtılması, pazarlanması, geleceğe yönelik ticari ilişki ve teknik iş birliğinin kurulması ve geliştirilmesi için belirli bir takvime bağlı olarak, düzenli aralıklarla ve genelde aynı yerde gerçekleştirilen bir tanıtım etkinliğidir (Tütüncüoğlu, 2009). Fuarların, temel bileşenleri olan katılımcılarına, ziyaretçilerine, fuar düzenleyicilerine, katılımcılara yan hizmetler sunan teşebbüslere (Rekabet Kurumu, 2019) ve yöreye sosyo-ekonomik yönleriyle pek çok açıdan katkıları bulunmaktadır.

Fuarlar, düzenlendikleri yerlere başka şehir ve ülkelerden gelen katılımcı ve ziyaretçileri sayesinde fuar süresi boyunca ticari bir hareketlilik de yaşatmaktadır. Katılımcı ve ziyaretçilerin konaklama, yeme, içme gibi temel ihtiyaçlarının karşılanması zorunluluğu bölgede faaliyet gösteren birçok işletmenin gelirine katkı sağlamaktadır. Ayrıca, bölge halkı fuar dönemi boyunca gerçekleştirilen aktivitelere katılarak sosyal ve kültürel faaliyetlerde bulunabilmektedir (Göksel, 2005).

Fuarlardan, tarım sektörünün geliştirilmesinde de yararlanılmakta, tarımsal amaçlı olarak yapılan fuarların sayıları her yıl artmaktadır. Tarımda üreticiler; yenilikleri görebilmek, iş çevrelerini genişletmek ve sektörle etkileşim kurmak, üretimlerini artırabilecek kişilerden bilgilendirmeler almak, yeni teknolojiler görebilmek, sektördeki yeni ve öncü firmaları görebilmek, yenilikleri deneyimleyebilmek vb. beklentilerle tarım fuarlarını ziyaret etmektedir. Katılımcı firmalar ise, daha fazla kişiye ulaşabilmek, firma bilinirliğini artırmak, sektörle etkileşim sağlamak, firmanın yeni ürünlerinin ve başarılı çalışmalarını tanıtmak vb. amaçlarla tarım fuarlarına katılım sağlamaktadır.

Tarım fuarları düzenlendikleri yörede kırsal kesim ve yerel yönetimler de fuardan beklentiler içerisindedir. Bu beklentiler şu gibi sayılabilmektedir (İnan ve Konyalı, 2024);

- Konaklama, yeme-içme, gezme, turizm vb. (Çıldır, 1991).
- Tekrar gelme isteği ile yörenin kırsal turizm gelirlerinin artırılması,
- Kırsal altyapının, fuar vesilesiyle iyileştirilmesi,
- Merkezden yöreye katkının artırılması,
- Yerelde yönetiminin deneyimlenmesi ve güçlenmesi,
- Kırsalda yatırımların artması ve kalkınmaya katkı, vb.

Fuarların katılımcı, ziyaretçi, organizasyon ve yöreye katkılarını artırabilecek çalışmalar karar vericilere destek olunması bakımından artırılmalıdır. Böylece, etkinlik yöneticileri, daha iyi bir fuar düzenlemek ve yerel halkın bu etkinliklere katılımını sağlamak için, vatandaşlara düzenlenen fuarlardan özellikle toplumsal, bireysel ve kültürel anlamda nasıl fayda sağlayacağını daha kapsamlı bir şekilde anlatmaya çalışabilirler (Binbaşıoğlu ve Gültekin, 2017).

Türkiye'de tarım fuarlarına bir yenilik ilki 2011 yılında gerçekleştirilen ve her yıl düzenlenmeye devam eden ''Tarım ve Teknoloji Günleri Fuarı''nın tarımda açık alan uygulamalı özellikleri ile tarım ve teknoloji temasının bir arada gerçekleştirilmesi ile olmuştur. Bu fuarda makine-ekipman, teknoloji, zirai ilaç, tohum, gübre üreticileri en yeni ve güncel ürünlerini tarlada uygulanmış olarak ziyaretçilere tanıtabilmekte; ziyaretçiler ise tarım profesyonelleri ve uzmanlarından kendi işletmeleri için ihtiyaç duyabilecekleri ürünler ile ilgili bilgileri ürünleri uygulamalı olarak yerinde görerek alabilmektedir. Tarımda açık alan uygulamalı, tarım ve teknoloji temalı olan bu fuar oldukça ilgi gördüğünden organizasyon

firması bu kez ilki 2019 yılında ve 2 yılda bir tarımda açık alan uygulamalı tek bir üründe fuar düzenlemeye devam etmiştir.

2. Materyal ve Metot

Bu bildiri, tarımda tek ürün üzerine (patates) 2025 yılında 4. kez gerçekleştirilen ‘‘Potato Days Türkiye Fuarı’’nda yapılan gözlemler ve literatürün incelemesi ile gerçekleştirilmiştir. Bildiri ile, organizasyonu her yıl ilerleme gösteren, çokça ilgi gören ve tarımda tek ürün teması ile diğerlerinden ayrışan ‘‘Potato Days Türkiye Fuarı’’nın gelişimine katkı sağlanabilecektir. Bildiride, Türkiye’de tarım fuarcılığı, tarımda açık alan uygulamalı fuarcılığı ve tarımda tek ürün temalı fuarcılık konularında bilgiler verilmiş, geliştirilmesi için öneriler sunulmuştur.

3. Bulgular

Tarım fuarları planlanırken üreticilerin, katılımcı firmaların, ziyaretçilerin ve fuarların diğer unsurlarının fuardan en iyi şekilde yararlanması sağlanmalıdır. En başında, fuar sahası etkinliği ve önemi dikkate alınarak tespit edilir. Çok çeşitli kriterler dikkate alınsa da temel olan coğrafya ve coğrafyanın sunduğu olanaklardır. Bir sahanın fuar alanı veya fuarcılık merkezi olmasında hiç kuşkusuz ki o sahanın coğrafi avantaj ve dezavantajları dikkate alınmaktadır (Acartürk, 2013). Fuar planlamasında, ürün ve yer seçimi ile bunların ilişkisi çok dikkatli planlanmalıdır.

Tarım ürünlerine düzenlenen fuarlara bir örnek olarak patates bitkisinin öneminin görülmesi, üretim alanı ve miktarı, pazarlama ve teknolojiyle geliştirilmesi imkanlarının fuar gibi organizasyonlarla artırılmaya çalışılması kıymetlidir. Patates, bitkisel kaynaklı beslenmede tahıllardan sonra en fazla tüketilen besin maddesidir. Ucuzluğu, birim alandan fazla verim alınması, besin değerinin yüksek oluşu, sindiriminin kolaylığı, kullanım alanının geniş olması ve her çeşit iklimde yetişmesi açısından, hemen hemen bütün dünya ülkeleri tarafından üretilmekte ve tüketilmektedir (Elçi vd., 1994). Temel gıda ürünü olan patatesin kullanım alanlarının yaygınlaşması ve dünya nüfusunun artması patatese olan talebi ve tüketimi hızlı bir şekilde arttırmaktadır (TEPGE, 2024). Türkiye’de patates üretici ve tüketici fiyatı en fazla dalgalanma gösteren ürünlerin başında gelmektedir (Kadakoğlu ve Karlı, 2021).

Patates bitkisine özel ‘‘Potato Europe’’ adlı bir fuar organizasyonu, ilk kez düzenlendiği 2006 yılından bu yana Avrupa’da her yıl Almanya, Hollanda, Fransa ve Belçika olmak üzere dört ayrı ülkede gerçekleştirilmektedir (Potato Europe, 2025). Açık alan uygulamalı alanının fazlalığı, kapalı alanları, söyleşi, sunum ve diğer bilgilendirmelerinin çokça olması, gezme kolaylığı ve diğer organizasyon başarılarıyla her yıl gelişerek dünyanın her yerinden gelen ziyaretçileri tarafından yerinde oldukça ilgi görmektedir. Fuarın, böylesine ilgi görmesi, sürekliliği ve yıllardır geliştirilebilmesi dikkat çekmektedir.



Fotoğraf 1. Potato Europe 2025 Hollanda (**Kaynak:** https://potatoeurope.nl/)

Fuarın, Türkiye’de de patates sektörü açısından bilinen bir organizasyondur. Türkiye’deki patates sektörünün paydaşları olan tohum üreticileri, zirai ilaç imalatçıları, tarım ekipmanı üretenler, büyük çiftçiler ve patates ticareti yapanların çok yakından takip ettikleri ve yerinde ziyaret ettikleri bilinmektedir. Avrupa’da fuarın organizasyonun yapan firmanın Türkiye’deki

şirketi, Avrupa'daki organizasyonun bir benzerini Türkiye'de gerçekleştirmek üzere 2017 yılında hazırlıklara başlamış, 2 yıla yakın bir süreçte patates sektörünün analizini yaparak ve fuardan yararlandırılma araştırmasını yaparak Türkiye'de ilk kez 2019 yılında benzer bir fuarı getirmişlerdir.

Türkiye'de sofralık, sanayi tipi ve tohum dahil olmak üzere 1,5 milyon dekar civarı alanda patates ekimi yapılmaktadır. Ekili arazilerin yüzde 47'si Konya, Nevşehir ve Niğde üçgeninde yer almaktadır. Bölge, patates arzı ve gıda güvencesi açısından tedarik zincirinin sağlanmasında kritik bir rol üstlenmektedir. Kapadokya bölgesinde, bin 320 civarı doğal depoda 2 milyon ton civarında patates depolanmaktadır. 2024 yılı verilerine göre 30 bin ton yemeklik, 14 bin ton işlenmiş ve 1.295 ton tohumluk patates olmak üzere toplamda 1.4 milyar TL'lik ihracat gerçekleştirilmiştir (TÜİK, 2025). Patates, bölge için son derece önemli bir üründür. Hem üreticilere yakın olmak hem de yurtiçi ve yurtdışından gelecek ziyaretçiler için ulaşım ve konaklama kolaylığı açısından bu bölge fuar organizatörleri tarafından fuar yeri olarak bilinçli bir şekilde seçilmiştir (Anonim, 2019).

Türkiye'de ''Potato Days Türkiye Fuarı'' ismiyle gerçekleştirilen organizasyon Türkiye'de ilk ve tek patatese özel ve tek bir tarım ürününe gerçekleştirilen açık alan uygulamalı fuardır. Fuarın, Konya-Selçuklu-Karaömerler'de 80 bin metre kare alanda açık alan uygulamalı Tarım fuarı konseptiyle 22 – 24 Ağustos tarihleri arasında 61 katılımcı firma, 387 yurt dışından olmak üzere toplam 4578 ziyaretçi ile gerçekleştirilmiştir. Fuar için nisan ayında sofralık ve sanayilik olmak üzere fuar sahasına 50'nin üzerinde farklı çeşit patates tohumunun dikimi yapıldı. İlk kez düzenlendiğinde bu fuar Türki Cumhuriyetler, Ortadoğu ve Avrupa'daki patates sektörünün liderleri, yerli ve diğer yabancı patates üreticileri ve sektör profesyoneli ziyaretçiler tarafından oldukça yoğun ilgi görmüştür (Anonim, 2019).

Fuar, 18-20 Ağustos 2021 tarihleri arasında tekrar Konya-Selçuklu-Karaömerler'de bu kez Covid-19 pandemisi tedbirleri altında düzenlenmesine rağmen 50 adet katılımcı firma, 3451 adet üretici ve/veya profesyonel ziyaretçilerden tekrar büyük ilgi görmüştür. Patates konusunda zirai ilaç ve gübre üreten yerli ve uluslararası firmalar minimum 400 metrekarelik kendi alanlarında patates üretimi gerçekleştirdi ve üretmiş oldukları ilaç ve gübreleri uygulayarak göstermişlerdir. Kök hücreden patates tohumu üreten yerli firmalardan, patates tohumu konusunda faaliyet gösteren uluslararası firmalara kadar patates tohumu üreten yurtiçi ve yurtdışına satışını gerçekleştiren tüm firmalar fuarda bulunmuştur. Bununla birlikte sözleşmeli üretim yaptıran sanayilik patates üretimi konusunda faaliyet gösteren kuruluşlarda fuara büyük ilgi göstermiştir. Tarla hazırlığından patates hasadına kadar çiftçinin ihtiyaç duyduğu bütün tarım ekipmanları bu alanda görerek değerlendirme fırsatı olmuştur (Anonim, 2021).

Fuar, 23-25 Ağustos 2023 tarihleri arasında 3. kez ve yeni yerinde Nevşehir-Gülşehir'de düzenlenmiştir. 65.000 metrekarelik açık alan uygulamalı tarım fuarı, 70'den fazla katılımcıya ev sahipliği yaparak patates endüstrisindeki tohumlar, gübreler, bitki koruma ürünleri, makineler ve ekipmanlarda dahil olmak üzere yenilikçi ürün ve hizmetleri 572'si yabancı ziyaretçi olmak üzere toplam 5760 ziyaretçiye sergiledi. Ziyaretçiler, makine demonstrasyonlarına tanık olmuş ve kampus alanların yanı sıra, 90'dan fazla patates çeşidinin yer aldığı 25 patates deneme alanını yerinde incelemişlerdir. Fuar, sektördeki en son teknik gelişmeleri takip etmek isteyen patates çiftçileri için önemli bir platformdur ve bu gelişmeler uygulamalı bir şekilde değerlendirilmiştir. Yeni patates türlerinin sergilendiği 500 m2'lik deneme parsellerinden oluşan, sergi alanı, ziyaretçiler, farklı herbisit ve gübrelerin patates mahsulü üzerindeki etkilerini ilk elden gözlemleme ve çeşitli yöntemleri karşılaştırma fırsatı bulmuştur. Makine parkurunda toprak hazırlığından hasada kadar en son teknolojiye sahip makineler çalışır durumda sergilenmiştir (Anonim, 2023).

Fuarın 4.'sünün 19-21 Ağustos 2025 tarihleri arasında tekrar gerçekleştirildiği Nevşehir-Gülşehir'de gerçekleştirilmiştir. Fuar, 8 hektar civarı alanda yapılmış, 78 katılımcı firma ve 5.113 ziyaretçi tarafından yerinde ilgi görmüştür. Türkiye ve çevre bölgelerden gelen uzman patates ziyaretçilerine, tohum, gübre, bitki koruma ve 10 makine ve ekipman alanındaki yeniliklerin yanı sıra makine gösterileri ve saha stantlarının sunulduğu 25 patates deneme alanını yakından inceleme fırsatı sunulmuştur. Fuar ziyaretçilerinin 521'i yabancı VIP sektör temsilcilerindendir. Bu ziyaretçiler, Kazakistan, Özbekistan, Rusya, Hindistan, Irak, Sudan, Lübnan, Fransa, Hollanda ve Avusturya gibi ülkelerden gelerek etkinliğe uluslararası bir boyut kazandırmıştır. Katılımcı firmalar, Türkiye'de üretimi yapılan 1 milyon dekarın üzerindeki patates ekim alanına sahip büyük ve orta ölçekli üreticilerle doğrudan buluşma imkânı yakalamış, böylece yeni iş birliklerinin önü açılmış ve sektör için stratejik bağlantılar kurulmuştur (Anonim, 2025a).



Fotoğraf 2. Potato Days Türkiye Fuarı

Ziyaretçiler, fuar sırasında çok sayıda ülkelerden ve Türkiye'den sektörün önde gelen üreticileri ile bir araya gelme fırsatı yakalamaktadır. Fuar ile, sözleşmeli üretim yapan firmalar ve karar vericiler ile bir araya gelme imkanı, da bulunabilmektedir. Fuarda, patates üretimiyle ilgili en yeni makineler, ekipmanlar, sulama sistemleri ve tarımsal yenilikler uygulamalı olarak yerinde gösterilebilmektedir. Tarla ortamında yapılan demonstrasyonlarla yeni teknolojilerin sahada nasıl çalıştığı görülebilir, makineler ve ekipmanlar test edebilir. Fuara özel satış kampanyalarından yararlanma imkanına sahip olunabilir. Fuar, patates ürününün toprak hazırlığından nihai ürüne kadar her aşamasının firma ve ürün düzeyinde yer aldığı Türkiye'deki tek organizasyon olma özelliği taşımaktadır (Anonim, 2025b).

Fuarda katılımcı firmalar tarafından ürün, firma ve yeniliklerini tanıtma, fuar organizatörleri tarafından fuara ilginin artırılması bağlamında çeşitli yarışmalar ve söyleşiler ile sektör öncü ve liderlerinin, kamu kurumlarının ve meslek örgütlerinin çok çeşitli gösterileri görülebilmektedir.

Üreticiler, Türkiye ve dünyadan farklı patates çeşitlerini, tohumları ve yetiştiricilik tekniklerini inceleyerek verimi artıracak yeni çözümler keşfedebilir. Patates sektöründe tohum ıslahçısı, üretici ve dağıtımcı firmalar yeni ve halihazırdaki çeşitlerini, toprak düzenleyiciler/ üst gübreler ve bitki besleme/ bitki koruma ürünleri imalatçıları ve dağıtımcıları en son ürünlerini, sulama sistemi tasarımcıları yeni sulama teknikleri ve ürünlerini, anında ve yerinde gösterebilme, performansını deneyimletme, ürünü ispatlayabilme gibi tarımda açık alan uygulama fuarcılığının imkânlarını kullanabilmektedir. Bunun, üreticiler üzerinde şüphe bırakmama, kullandırma, performansın ölçülebilmesi gibi olumlu özellikleri, fuar sırasında ve sonralarında firmaları öne çıkarabilmektedir.

Patates ekim ve hasat makinaları ve teknolojileri, mekanik ot kontrolü teknolojileri, depolama çözümleri konusunda faaliyet gösteren ve fuarın katılımcıları olan firmalar, açık alanda ve ürünün özelliklerinin sunarak fuar sırasında ziyaretçilerin ilgisini çekebilmektedir. Bu firmaların ürün tanıtımı ve pazarlamasının etkin, üreticiler için anlaşılabilir ve kanıtlanabilir olması, uygulamasının anında gösterilebilmesi ile firmalar, üreticilere ve fuara katkıları bulunmaktadır.

Başta çiftçi örgütlenmeleri olmak üzere tarımsal alanda faaliyeti olan yerli ve yabancı meslek örgütlerinin fuarda standlarının olması, sunumlara katılmaları ve söyleşi düzenlemeleri, meslektaşlar arasında etkileşim oluşturarak bilgi aktarımına katkı sağlamaktadır. Ziraat Odaları, Ziraat Mühendisler Odası gibi meslek ve sivil toplumun fuarda tarımsal üretimin beklenti, güçlük ve fırsatlarının yayılmasında katkısının olması beklenmektedir. Üreticiler, patates sektör uzmanlarıyla bir araya gelerek yeni iş bağlantıları kurabilir ve bilgi paylaşımında bulunabilir. Üreticilerin, topladıkları broşür ve kitapçıkların tarımsal üretim süreçlerinde kaynak olduğu bilinmektedir (Çukur, 2013).

Üniversite, enstitü gibi kurumlar ile bilginin ışığından gitmeyi benimsemiş akademisyenlerin hizmet sundukları üreticilerin oldukları yerlerde üzerlerine düşen sorumlulukla hareket etmeleri beklenmektedir. Bu bağlamda, tarımda açık alan fuarında bunlardan bulunma ve bilgi aktarmaları aranmaktadır. Tarım uzmanları ve akademisyenler tarafından verilen eğitimler ve paneller katılım patates yetiştiriciliği, hastalıklarla mücadele, gübreleme ve sürdürülebilir tarım konularında bilgi edinmeyi sağlar. Üreticiler, bu şekilde araştırma kuruluşları, yayım kuruluşları ve üniversitelerin personelleriyle bir araya gelebilir (Çukur ve Çukur, 2017).

Üreticiler, üretimlerine katkı sağlayacak, sorunlarıyla ilgilenecek ve politikaların yapılmasında karşılık bulabilecekleri kimseleri tarımda açık alan uygulamalı tek ürün fuarında görmek istemektedir. Bu kapsamda, kredi imkanlarını açıklamak üzere tarımda kredi veren kuruluşlar ile sektör öncüleri ve liderlerinin söyleşiler için fuara davet edilmeleri önemlidir.

Fuar organizasyonunun başarısı için fuar organizatörleri ve sponsorlarının firmaların ve ziyaretçilerin fuara katılım hedef ve amaçlarını tam olarak karşılaması, fuarın plan ve programa uygun gerçekleştirilmesi, sonraki yıllarda geliştirilebilir olması gerekmektedir. Bu anlamda, fuar alanı sahası, temel ihtiyaçlar, güvenlik-sağlık-ulaşım koordinasyonunun başarılı olması gerekmektedir.

Valilik, Kaymakamlık, Belediyeler, il/ilçe tarım ve orman müdürlükleri tarım alanında faaliyetlerini ve desteklemelerini anlatarak üreticilere ulaşabilmektedir. Bunun yanında, fuarın geniş ve ilgili kesimlere duyurulması, fuar sırasında ulaşım, sağlık, güvenlik, temizlik vb. ile fuarın etkin ve başarılı olabilmesi için merkez ve yerel yönetimlerden desteklenmesi sağlanmalıdır.



Fotoğraf 3. Potato Days Türkiye Fuarı

4. Sonuç

Fuarlara, tarım sektöründe tek bir ürüne odaklanmasına göre bakıldığında, fuarın kurulduğu alanda sektörün paydaşlarının bir arada bulunması ve etkileşim sağlanması önemlidir. Bildiride, Potato Days Türkiye Fuarı'nın ve tarımda açık alan uygulamalı tek ürün fuarcılığın geliştirilmesine katkı sağlaması hedeflenerek kırsal kesime katkıları da detaylıca açıklanmıştır. Bu araştırmanın, tarımda açık alan uygulamalı tek ürün fuarcılığı hususundaki sınırlı literatüre katkı sağlanması hedeflenmiştir.

Avrupa'da ilki 2006 yılından başlayarak her yıl 4 farklı ülkede gerçekleştirilen ''Potato Europe'' fuarının bir benzeri olarak, Türkiye'de ''Potato Days Türkiye Fuarı'' ismiyle gerçekleştirilen organizasyon, 2019 ve 2021 yıllarında Konya-Selçuklu-Karaömerler'de, 2023 ve 2025 yıllarında Nevşehir-Gülşehir'de olmak üzere 4 kez organize edilmiştir. Avrupa'daki benzerinin fuar saha büyüklüğü, açık ve kapalı alan aktivite çeşitliliği, katılımcı ve ziyaretçi sayıları, devamlılığı ve diğer başarılarına dikkat edilmelidir. Türkiye'deki fuarın halihazırdaki başarısı ve fuar organizatörlerinin deneyimi, Türkiye'nin patates sektörü ve alandaki potansiyeli varlığı birlikte değerlendirildiğinde fuarın geliştirilebilir olduğu açıkça görülmektedir.

'Potato Days Türkiye Fuarı', kırsalda tarımsal üreticilerin patates ürünü ile ilgili teknoloji ve yenilikleri görebilmeleri, sektörle etkileşim kurabilmeleri ve üretimlerine katkı sağlayabilmeleri bakımından önemlidir. Tarım sektöründeki firmalar da, çiftçilere ulaşabilmek, ürünlerini pazarlamak ve firma bilinirliğini artırmak amacıyla yerinde göreme imkanı sunan tarımda açık alan uygulamalı tek bir tarım ürününde (patates) uzmanlaşmış bu fuarı tercih etmektedir. Kırsal kesim ve yerel halk ise, fuarın doğrudan ve dolaylı etkileri ile yörenin ekonomik kalkınmasından çok çeşitli şekillerde faydalanmaktadır.

Bu fuarın konusu olan patates gibi bazı tarım ürünlerinde dalgalanmaya neden olan pek çok problem bulunabilmektedir. Buna karşın, pek çoğu tarımsal yayım ve haberleşme eksikliklerinden de kaynaklanabilen üreticilerin ekip ekmeme nedenlerinin araştırılmasının, fuarın tarımsal yayım ve haberleşme olanaklarını artıran yönünden daha fazla faydalanılmasıyla üretici iletişiminin güçlendirilmesinin üretim ve tüketimdeki dalgalanmaları azaltabileceği dikkate alınmalıdır. Bu açıdan bakıldığında, patates gibi tarımsal ürünlerle ilgili düzenlenen fuar gibi organizasyonların tarımsal yayım ve haberleşmeyi geliştirdiği üretici, firma ve diğer sektör paydaşları arasında iletişimi ve birlik kurmayı güçlendirdiği görülmelidir.

Patates ürününün tarladan sofraya bütün süreçlerinin yer aldığı, sektörün önemli bir kısım üretici ve profesyonellerinin bir arada olduğu fuara her yıl daha geniş bir ilgi olmaktadır. Fuarda, gerek katılımcıların profesyonelleri gerek yabancı ziyaretçilerle olan gerek organizatörlerin söyleşileri uluslararası tarımsal bilgi ve en iyi uygulamaların paylaşılmasına imkan vermektedir. Örneğin; 2023 yılında Özbekistan Patates Birliğinin, Kazakistan ve Rusya Patates Yetiştiricileri Birliğinin katılımları, 2025 yılındaki Türki Cumhuriyetlerden ve Uzak Doğu'dan uzmanların fuardaki söyleşileri, her yıl Azerbaycan, Ermenistan, Irak, Lübnan, İran, Hollanda, Almanya, Yunanistan, İngiltere, Sudan, Kırgızistan ve diğer pek çok ülkeden gelen uluslararası ziyaretçilerin etkileşimleri bilginin aktarılması için kıymetlidir.

Fuarın hem üreticilere hem firma katılımcılarına faydalarının doğru kurulan karşılıklı etkileşimlerle artırılması olanakları bulunmaktadır. Örneğin; patates bitkisindeki arz talep dengesizliğine ve fiyat belirsizliklerine karşın, fuarın üretici ve firmalar arasında işbirliği imkanlarının geliştirilmesi, sözleşmeli üretimin anlatılması, desteklerin duyurulması ve bilgilendirilmeler için avantajlarından yararlanılmalıdır. Doğrudan patates ürünün katma değerini artırması ile yöredeki üreticilere ve yöreye diğer ekonomik katkıları düşünülerek fuarın yerel yönetimler tarafından reklam, duyuru, ulaşımın kolaylaştırılması ve diğer yöntemlerle daha fazla desteklemesi sağlanmalıdır.

Türkiye'nin sahip olduğu olanaklar, pek çok farklı tarım ürünü için ve birbirinden farklı illerinde açık alan uygulamalı özellikli fuar geliştirilmesine imkan sağlayabilir. Örneğin; pek çok ilin kendisine özgü ürünleri bulunmaktadır. Bir yörede açık alan uygulamalı tek bir tarım ürününe özel fuar düzenlenebileceği gibi yörenin birden fazla ürünü için aynı anda tek bir açık alan uygulamalı fuar da düzenlenebilir. Bu şekilde planlanacak fuarların yerel üretime ve coğrafi işaretlemeye olası katkıları da araştırılmalıdır. Ancak, bu alanda yeterince araştırma bulunmadığı tespit edilmiştir. Bu bakımdan, Türkiye'nin var olan potansiyelinin derinlemesine saha araştırmalarıyla ortaya çıkarılması önerilmektedir.

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YAPAY ZEKANIN TARIM ALANINDA UYGULAMALARI

Zeynep KARAKAYA

Veteriner Hekim, Burdur Mehmet Akif Ersoy Üniversitesi, Sağlık Bilimleri Enstitüsü Hayvansal Ürünler Hijyen ve Teknolojisi

Email: zynpkarakaya20@gmail.com

Seval Sevgi KIRDAR

Prof. Dr. Burdur Mehmet Akif Ersoy Üniversitesi, Burdur Gıda Tarım ve Hayvancılık MYO Gıda İşleme Bölümü

Email: skirdar@mehmetakif.edu.tr

ÖZET

Son yıllarda teknolojide yaşanan hızlı gelişmeler, tarım sektöründe de yenilikçi uygulamaların hayata geçirilmesine zemin hazırlamıştır. Yapay zekâ teknolojileri, yalnızca endüstriyel üretim süreçlerinde değil, aynı zamanda karar verme, veri yönetimi ve veri analizi gibi çok boyutlu alanlarda da giderek artan bir kullanım alanı bulmaktadır. Günümüzde tarım alanında yapay zekâ tabanlı sistemlerin bilgi toplama, işleme, depolama ve analiz süreçlerinde etkin şekilde kullanılması kaçınılmaz bir gereklilik hâline gelmiştir. Özellikle karmaşık problemlerin çözümünde Yapay Sinir Ağları, Bulanık Mantık ve Genetik Algoritmalar gibi yapay zekâ temelli yöntemler sıklıkla başvurulan yaklaşımlar arasında yer almaktadır.

Yapay zekâ, tarım makinelerinin otomasyonu ve robotik sistemlerin entegrasyonu yoluyla tarımsal verimliliği artırmakta ve insan müdahalesine ihtiyaç duyulmaksızın birçok tarımsal faaliyetin gerçekleştirilmesine olanak sağlamaktadır. Bu sayede hem iş gücü tasarrufu sağlanmakta hem de tarımsal faaliyetler daha hassas ve etkin bir şekilde sürdürülebilmektedir. Ayrıca yapay zekâ, gübre, su ve diğer tarımsal girdilerin daha verimli kullanılmasına katkı sunmaktadır. Bu girdilerin doğru miktarlarda ve doğru zamanlarda uygulanması, gereksiz maliyetlerin azaltılmasına ve çevresel etkilerin en aza indirilmesine imkân tanımaktadır. Bununla birlikte, pazar ve fiyat analizlerinde yapay zekânın kullanımı da çiftçiler açısından önemli avantajlar sağlamaktadır. Yapay zekâ tabanlı veri analitiği araçları, piyasa trendleri ile fiyat dalgalanmalarını analiz ederek üreticilerin ürünlerini en uygun fiyatlardan pazarlamalarına rehberlik edebilmekte ve karar alma süreçlerinde stratejik katkılar sunmaktadır. Yapay zekâ, tarımsal üretimde verimliliğin artırılması ve kayıpların en aza indirilmesi amacıyla da etkin bir biçimde kullanılmaktadır. Özellikle bitki hastalıklarının erken ve doğru teşhisi, tarımsal kayıpların önlenmesinde kritik bir rol oynamakta olup, bu durum gelişen teknolojilerin entegrasyonu sayesinde mümkün hâle gelmektedir.

Tarım ürünlerinin işlenmesi, sınıflandırılması ve kalite değerlendirilmesinde farklı yapay zekâ tabanlı yöntemlerin kullanıldığı çeşitli çalışmalar mevcuttur. Bu kapsamda, muz hastalıklarının tespiti ve bu hastalıklarla mücadele yöntemlerinin belirlenmesi, arpa tanelerinin sınıflandırılması ve kahve çekirdeklerinin kalite derecelendirilmesi amacıyla uzman sistem uygulamalarından yararlanılmıştır. Öte yandan, tohumların hazırlanmasında farklı çıkarma yöntemlerinin sıralanması, çeşitli nem içeriklerine sahip fasulyelerin fiziksel parametrelerinin tahmin edilmesi, soğanların kuruma kinetiğinin belirlenmesi ve kurutma sürecinde dutun nem oranının tahmin edilmesi gibi çalışmalarda bulanık mantık yaklaşımı tercih edilmiştir. Ayrıca, kurutulmuş havuçların kalite değerlendirmesi ve sınıflandırılması, sarımsağın duyusal kalitesinin tahmini, mangonun ağırlık tahmini, pirinç üretim veriminin öngörülmesi ve pirinç

mahsul verimini etkileyen faktörlerin incelenmesi süreçlerinde ise yapay sinir ağları (YSA) kullanılmıştır.

Bu çalışmada tarım alanında kullanılan yapay zekayla ilgili çalışmalardan ve uygulamalardan bahsedilecektir.

Anahtar Kelimeler: Yapay Zekâ, Tarım, Yapay Sinir Ağları, Bulanık Mantık, Genetik Algoritmalar, tarında uygulamalar

APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN AGRICULTURE

ABSTRACT

Rapid developments in technology in recent years have paved the way for innovative applications in the agricultural sector. Artificial intelligence technologies are finding increasing use not only in industrial production processes but also in multidimensional areas such as decision-making, data management, and data analysis. Today, the effective use of artificial intelligence-based systems in information gathering, processing, storage, and analysis processes has become an inevitable necessity in the field of agriculture. Artificial intelligence-based methods such as Artificial Neural Networks, Fuzzy Logic, and Genetic Algorithms are frequently used approaches, especially in solving complex problems.

Artificial intelligence increases agricultural productivity through the automation of agricultural machinery and the integration of robotic systems, enabling many agricultural activities to be carried out without the need for human intervention. This saves labor and allows agricultural activities to be carried out more accurately and efficiently. In addition, artificial intelligence contributes to the more efficient use of fertilizers, water, and other agricultural inputs. Applying these inputs in the right amounts and at the right times reduces unnecessary costs and minimizes environmental impacts. Furthermore, the use of artificial intelligence in market and price analysis provides significant advantages for farmers. Artificial intelligence-based data analytics tools can guide producers in marketing their products at the most appropriate prices by analyzing market trends and price fluctuations, and provide strategic contributions to decision-making processes. Artificial intelligence is also effectively used to increase productivity and minimize losses in agricultural production. In particular, the early and accurate diagnosis of plant diseases plays a critical role in preventing agricultural losses, which is made possible through the integration of developing technologies.

There are various studies in which different artificial intelligence-based methods are used in the processing, classification, and quality assessment of agricultural products. In this context, expert system applications have been used to detect banana diseases and determine methods to combat these diseases, classify barley grains, and grade the quality of coffee beans. On the other hand, the fuzzy logic approach has been preferred in studies such as ranking different extraction methods in seed preparation, estimating the physical parameters of beans with various moisture contents, determining the drying kinetics of onions, and estimating the moisture content of mulberries during the drying process. Additionally, artificial neural networks (ANNs) were used in processes such as the quality assessment and classification of dried carrots, the estimation of garlic's sensory quality, the weight estimation of mangoes, the prediction of rice production yield, and the examination of factors affecting rice crop yield.

This paper will discuss studies and applications related to artificial intelligence used in agriculture.

Keywords: Artificial Intelligence, Agriculture, Artificial Neural Networks, Fuzzy Logic, Genetic Algorithms, Applications in Agriculture

GİRİŞ

Yapay zekâ, insan gibi düşünebilen, yorum yapabilen ve karar alabilen bilgisayar programlarının geliştirilmesine olanak tanımaktadır. Bu teknolojinin giderek daha yaygın kullanılması ve bilimsel ilerlemelerle desteklenmesi, mesleklerin niteliğini ve iş gücüne duyulan gereksinimleri de değiştirmektedir. Buna bağlı olarak bazı mesleklerde ihtiyaç azalırken, bazı alanlarda ise yeni gereksinimler ortaya çıkmakta ve artış göstermektedir (Karakaya, 2025).

Yapay zekâ, tarım sektöründe verimliliğin artırılmasına ve sürdürülebilirlik hedeflerine ulaşılmasına önemli katkılar sağlayan kritik bir teknolojik araçtır. Tarımsal süreçlerin optimize edilmesi ve kaynak kullanımının azaltılması amacıyla yapay zekâyla birlikte çeşitli dijital teknolojilerden yararlanılmaktadır (Nabatov, 2024).

Yapay zekâ, tarım makinelerinin otomasyonu ve robotik sistemlerin entegrasyonu yoluyla tarımsal verimliliği yükseltmekte, insan gücüne ihtiyaç duymaksızın tarımsal faaliyetlerin yürütülmesine imkân tanımaktadır. Bu durum hem iş gücünde tasarrufu sağlamakta hem de tarımsal faaliyetlerin daha hassas ve etkin biçimde sürdürülmesini sağlamaktadır (Sui, Thomasson ve Huang, 2018). Ayrıca yapay zekâ, gübre, su ve diğer tarımsal girdilerin doğru miktar ve zamanda uygulanmasını sağlayarak hem maliyetleri azaltmakta hem de çevresel etkilerin en aza indirilmesine katkı sunmaktadır (Zhang, Wang ve Wang, 2002).

Bunun yanı sıra, yapay zekânın pazar ve fiyat analizlerinde kullanımı çiftçilere stratejik avantajlar sağlamaktadır. Yapay zekâ tabanlı veri analitiği araçları, piyasa eğilimlerini ve fiyat dalgalanmalarını inceleyerek üreticilerin ürünlerini en uygun koşullarda pazarlamalarına rehberlik etmektedir (Kamilaris, Kartakoullis ve Prenafeta-Boldú, 2017).

YAPAY ZEKÂ

Yapay zekâ, bilgisayar biliminin bir alt alanı olarak, insan düşünce ve davranışlarını taklit etmeyi ve aynı zamanda bunları geliştirmeyi amaçlayan, gelişmekte olan bir bilim dalı ve teknolojidir (Atilla, 2022).

Yapay zekâ, işlevsel açıdan çevresini algılayabilen ve belirlenen hedeflere ulaşma olasılığını en üst düzeye çıkaracak eylemleri gerçekleştirebilen bir uygulamalı zekâ biçimi olarak tanımlanabilir. Buna karşılık doğal zekâ, insan düşünme süreçleri ve hayvan bilişi tarafından sergilenen bilinç ve duygusal unsurları içermektedir (Atilla, 2022).

Yapay zekânın temelinde yer alan teknoloji, dört ana süreç kapsamında değerlendirilmektedir (Atilla, 2022).

- **Veri toplama:** Yapay zekâ uygulamalarında kullanılacak verilerin elde edilmesi için uygun teknolojiler belirlenir.
- **Veri depolama:** Yapay zekâ verileri çoğunlukla büyük veri niteliğinde olduğundan, geniş kapasiteli depolama alanlarına ihtiyaç duyulmaktadır. Bu bağlamda, bazı işletmeler bulut depolama çözümlerinden yararlanırken, bazıları kendi veri merkezlerini inşa etmektedir.
- **Veri işleme ve analitiği:** Verilerden anlam çıkarabilmek için algoritmalar kullanılmakta; derin öğrenme, makine öğrenmesi ve görüntü tanıma gibi teknolojiler bu sürece dâhil edilmektedir.
- **Veri çıktısı ve raporlama:** İşletmenin hedeflerine uygun şekilde, analiz edilen verilerin çıktı ve raporlaması için gerekli teknolojiler kullanılmaktadır.

Yapay zekânın temel bileşenleri altı ana alan kapsamında ele alınmaktadır (Atilla, 2022):

- **Doğal dil işleme (NLP):** Bilgisayarların insanlarla etkili bir iletişim kurabilmesi, dilin doğru bir şekilde anlaşılması ve kullanılabilmesi.
- **Bilgi temsili:** Bilgisayarın edindiği veya algıladığı verileri sistematik biçimde saklayabilmesi.
- **Otomatik akıl yürütme:** Depolanan bilgilerin kullanılarak sorulara yanıt verilmesi ve yeni çıkarımlar yapılması.
- **Makine öğrenmesi:** Yeni modellerin algılanması, çıkarımların yapılması ve değişen koşullara uyum sağlanabilmesi.
- **Bilgisayarlı görü:** Nesnelerin tanınması, algılanması ve görsel verilerin yorumlanabilmesi.
- **Robot teknolojisi:** Fiziksel nesnelerin hareket ettirilmesi ve manipüle edilebilmesi.

Bu uygulamalar sayesinde çok sayıda değişkenin eşzamanlı olarak analiz edilmesi mümkün hâle gelmekte, bu durumda daha hızlı ve isabetli karar süreçlerinin geliştirilmesine olanak tanımaktadır. Son yıllarda gerçekleştirilen çalışmalar, yapay zekâ destekli modelleme tekniklerinin; araştırma ve geliştirme süreçlerini hızlandırma, analiz süresini kısaltma ve daha nitelikli ürünlerin ortaya konmasını sağlama açısından önemli avantajlar sunduğunu ortaya koymaktadır. Ayrıca bu tür sistemler, alternatif çözümlerin hızlı biçimde test edilmesine ve en uygun sonucun etkin şekilde seçilmesine imkân tanıyarak sektördeki inovasyon kapasitesini güçlendirmektedir (Sofu ve ark., 2007).

TARIM ALANINDA YAPAY ZEKÂ UYGULAMALARI

Gelişen teknoloji ile nesnelerin interneti (IoT) ve kablosuz sensör ağları kullanılan sera sistemleri; zaman, enerji, su ve ışık açısından yüksek verimlilik sağlayarak ürün kalitesi ve üretim miktarı açısından önemli avantajlar sunmaktadır. Bu kapsamda geliştirilen akıllı sera sistemleri sayesinde, ısıtma, soğutma, aydınlatma, gölgelendirme ve sulama işlemleri uzaktan erişim yoluyla kontrol edilebilmektedir (Alpay, 2018). Sistemde kullanılan kablosuz sensör ağı, **bulanık mantık yöntemi** ile yönetilmiş; sera için gerekli optimum değerler bu yöntem aracılığıyla hesaplanmıştır. Giriş verilerinden elde edilen çıkış değerleri, android tabanlı bir uygulama üzerinden kullanıcıya aktarılmış ve uzaktan erişim imkânı sağlanmıştır. Ayrıca, bulanık mantık sisteminin ara durumları da düzenli olarak hesaplayabilmesi sayesinde etkin ve sürekli bir kontrol mekanizması oluşturulmuştur (Alpay, 2018).

Cantürk (2018) tarafından gerçekleştirilen bir çalışmada, patlıcan tarlasına ait toprak ve iklim verileri kullanılarak bulanık mantık temelli modellemeler yapılmıştır. Elde edilen bulgular, bulanık mantık yöntemi ile bitki su tüketimi, bitki katsayısı, bitki su stres indeksi ve verim değerlerinin başarıyla modellenebildiğini ortaya koymuştur. Bu modelleme sistemlerinin, bitki verimliliğinin artırılması ve besin maddelerinin daha etkin kullanılmasına önemli katkılar sağlayabileceği belirlenmiştir (Cantürk, 2018).

Daha verimli tarım uygulamaları için ürün çeşitliliğinin doğru şekilde belirlenmesi de kritik öneme sahiptir. Ancak benzer çeşitlerin beşerî imkânlarla tanımlanması hem güç hem de tutarsız sonuçlar doğurabilmektedir. Bu sürecin en etkin biçimde yürütülmesi için yapay zekâ yöntemleri kullanılmaktadır (Mengstu, 2024). Nitekim Mengstu (2024) tarafından yapılan bir çalışmada, 124 buğday çeşidine ait görüntüler farklı açılardan toplanmış ve toplamda 465.000 görüntüden yararlanılarak yapay zekâ yöntemleriyle buğday çeşitlerinin sınıflandırılması gerçekleştirilmiştir.

Bir çalışmada, morfolojik, şekil ve renk özelliklerinden yararlanılarak sınıflandırma işlemlerinin gerçekleştirilmesi amacıyla aynı markaya ait beş farklı pirinç çeşidi seçilmiştir.

Her bir çeşitten yaklaşık 75.000 pirinç tanesi görüntüsü elde edilmiş; bu görüntüler MATLAB yazılımı kullanılarak ön işleme tabi tutulmuş ve özellik çıkarımı için hazırlanmıştır. Sonuçlar incelendiğinde, sınıflandırma sürecine eklenen her yeni özelliğin doğruluk oranını artırdığı görülmüştür. Bu bulgular, pirinç çeşitlerinin sınıflandırılmasında yüksek başarı sağlandığını ve yöntemin etkinliğini ortaya koymaktadır (Çınar, 2019).

Ölmezoğlu (2022) tarafından gerçekleştirilen çalışmada, Türkiye İstatistik Kurumu'ndan (TÜİK) 2002-2020 dönemine ait aylık **Genel Ticaret Sistemi (GTS) Dış Ticaret verileri** elde edilmiştir. Bu kapsamda, 2020 yılına ait kayısı verileri **Yapay Sinir Ağları (YSA), Mevsimsel Otoregresif Entegre Hareketli Ortalama (SARIMA)** ve **Gradyan Artırılmış Ağaçlar (XGBoost)** yöntemleri kullanılarak tahmin edilmiştir. Analiz sonuçları mevcut verilerle karşılaştırıldığında, en uygun tahmin yönteminin **XGBoost** olduğu belirlenmiştir.

Yapay zekâ, tarımsal verimliliğin artırılması ve kayıpların en aza indirilmesi amacıyla da etkin biçimde kullanılmaktadır. Özellikle bitki hastalıklarının erken ve doğru teşhisi, tarımsal kayıpların önlenmesinde kritik bir rol oynamakta olup, bu süreç teknolojik yöntemlerin entegrasyonu sayesinde mümkün hâle gelmektedir (Güzel, 2024). Nitekim Güzel (2024) tarafından yürütülen bir çalışmada, Antalya bölgesinden elde edilen domates yaprağına ait 1100 adet **ToBRFV** (Tomato Brown Rugose Fruit Virus / Domates Kahverengi Buruşukluk Meyve Virüsü) içeren görüntü, veri artırma teknikleri kullanılarak genişletilmiş ve 3070 görüntüden oluşan kapsamlı bir veri kümesi oluşturulmuştur. Bu veri kümesinde yer alan, "hastalıklı" ve "sağlıklı" olmak üzere etiketlenmiş 12 farklı sınıf, çeşitli **Evrişimsel Sinir Ağı (ESA)**mimarileri kullanılarak sınıflandırılmıştır.

3.1. TARIMDA BİLGİ TABANLI UZMAN SİSTEMLERİN KULLANIMI

Bilgi tabanlı sistemler, farklı kaynaklardan ve verilerden elde edilen bilgileri bütünleştirerek karmaşık problemlerin çözümünü amaçlayan bilgisayar programlarıdır. Bu sistemler genel olarak üç ana kategori altında incelenmektedir: uzman sistemler, bilgi tabanlı yapay zekâ uygulamaları ve bilgi tabanlı mühendislik yaklaşımları (Karakaya, 2025).

Uzman sistemler (Expert Systems – ES), karar verme süreçlerinde insan uzmanlarının bilişsel yeteneklerini taklit edebilen, tutarlı ve kolektif yapay zekâ tabanlı bilgisayar sistemleridir (Szturo ve Szczypinski, 2017). Yapay zekâ alanındaki ilk başarılı uygulamalardan biri olarak kabul edilen bu sistemler, belirli bir uzmanlık alanındaki karmaşık sorunların çözümünde, uzman bilgisinin sistematik bir şekilde modellenmesine dayanmaktadır. Uzman sistemler, genel olarak **bilgi tabanı** ve **çıkarım motoru** olmak üzere iki temel bileşenden oluşmaktadır. **Bilgi tabanı**, alanla ilgili gerçekler, kurallar ve uzman görüşlerini depolarken; **çıkarım motoru** ise bu bilgileri işleyerek mantıksal çıkarımlar yapmakta ve çoğunlukla "EĞER–O HALDE (IF–THEN)" kuralları biçiminde ifade edilen yapılar aracılığıyla sonuçlar üretmektedir (Leo Kumar, 2019).

Bu sistemler, uzmanlardan elde edilen bilgilerin bilgi mühendisleri tarafından işlenmesiyle geliştirilmekte olup, karmaşık problemlerin çözümünde doğrudan uzman insana duyulan ihtiyacı azaltmayı hedeflemektedir. Tipik bir uzman sistem; **uzman insan**, **bilgi mühendisi**, **bilgi tabanı**, **çıkarım motoru**, **kullanıcı arayüzü** ve **nihai kullanıcı** gibi bileşenlerden oluşmaktadır. Tarımda özellikle karar destek sistemlerine olan gereksinim doğrultusunda, bilgi tabanlı uzman sistemleri çeşitli alanlarda etkin biçimde kullanmaktadır (Sipos, 2020). Tablo 1a'da, tarımda çeşitli uygulamalarda ES teknolojilerinin son dönem örneklerine yer verilmektedir.

Tablo 1a. Tarımda uzman sistem uygulanması (Karakaya, 2025).

Ürün	**Amaç**	**Sektördeki kategori**	**Önemli sonuçlar**
Muz	Muz hastalığını ve bunların üstesinden gelme yöntemlerini belirlemek	Hammadde/Tarım	Sistem, bitkilerdeki hastalıkları gövde, yaprak ve köklere göre teşhis edebildi ve bu da hastalıkların oluşmasını önlemeye yardımcı oldu.
Kahve çekirdekleri	Kahve çekirdeklerinin kalite derecelendirmesini belirlemek için	Duyusal değerlendirme	Geliştirilen bulanık ES, kahveyi %95 doğrulukla derecelendirebildi
Mısır	Mısır zararlılarını ve hastalıklarını tespit etmek	Tarım/hammadde	Sistem zararlıları ve hastalıkları %76,6 doğrulukla tespit edebildi ve ayrıca bunları kontrol altına almanın yollarını da sağladı Geliştirilen sistem, tanı sonuçlarına ilişkin tesis açıklaması sağlayabilmiştir.
Pirinç mahsulleri	Çiftçilerin pirinç mahsulleri için karar almalarına yardımcı olmak	Tarım/üretme	Çiftçilere, pirinç mahsulleri için tohumların seçilmesi ve zararlılar ve hastalıklarla mücadele edilmesi konusunda ES tarafından yardım edilir ve bu da nihayetinde pirinç mahsullerinin üretimini artacaktır.
Soya fasülyesi	Soya fasulyesindeki hastalıkları tespit etmek	Tarım	Çalışma çerçeve tabanlı gösterim ve kural tabanlı gösterim yöntemini kullanarak doğruluğu karşılaştırarak soya fasulyesi hastalıklarını tanımlamak için başarılı bir şekilde ES tasarladı.
Arpa	Arpa taneleri sınıflandırmak için	Kalite kontrolü	ES yöntemi kullanılarak yapılan sınıflandırma doğruluğu %72'nin üzerindeydi ve bu tatmin edici olarak kabul edildi

3.2. TARIMDA BULANIK MANTIK UYGULAMALARI

Bulanık mantık (Fuzzy Logic – FL), sahip olduğu basitlik, karar verme süreçlerinde sağladığı yüksek hız ve doğruluk nedeniyle uzun süredir endüstriyel uygulamalarda tercih edilen bir yöntemdir. Özellikle gıda endüstrisinde; **modelleme, kontrol, sınıflandırma** ve **duyusal değerlendirme** gibi alanlarda yaygın biçimde kullanılmaktadır (Al-Mahasneh ve ark., 2016).

Bulanık mantığın, geleneksel kontrol sistemlerine kıyasla daha düşük enerji tüketimi sağladığı ve bu sayede üretim süreçlerini daha verimli hâle getirdiği çeşitli araştırmalarla ortaya konmuştur. Nitekim Baliuta ve ark. (2020) tarafından yürütülen bir çalışmada, gıda üretim sistemlerinde FL uygulamasıyla yaklaşık %7 oranında elektrik kaybının önlenebildiği gösterilmiştir. Ayrıca, duyusal değerlendirme gibi öznel unsurların analizinde de bulanık mantığın önemli katkılar sunduğu görülmektedir. Bu tür uygulamalarda, **bulanık kurallar** aracılığıyla problemler daha hızlı ve etkin biçimde çözülebilmekte; böylece karar verme süreçleri daha güvenilir sonuçlar üretmektedir (Cebi ve ark., 2019). Tablo 2a'da, FL'nin tarımda önceki uygulamaları ve bu uygulamaların temel nitelikleri ayrıntılı olarak sunulmaktadır.

Tablo 2a. Bulanık mantığın tarımda uygulanması (Karakaya, 2025).

Ürün	**Amaç**	**Bulanık çıkarım sistemi**	**Önemli sonuçlar**
Karahindibağ tohumu	Tohumların hazırlanmasında farklı çıkarma yöntemlerini sıralamak	Mamdani Üçgen	Özelliklere ekstraksiyon çıktısına ve süreye dayalı sıralama, tohumların hazırlanması için en iyi yöntemi belirlemeyi mümkün kılmıştır
Ananaslı rasgulla	Rasgulla ananasını parametrelere göre sıralamak için	TSK Üçgen	Rasgulla ananasının farklı konsantrasyonları için duyusal değerlendirme ve örneklerin sıralanması FL modeli kullanılarak başarıyla gerçekleştirildi.
Beyaz dut	Kurutma işlemi sırasında dutun nem oranını tahmin etmek	Mamdani Üçgen	Model, R2 değerinin 0,9996 ve RMSE değerinin 0,01095 olduğu değişen koşullar altında dut ağacının nem oranını yüksek doğrulukla tahmin edebilir.
Pancar şekeri	Çeşitli içerik oranlarına sahip şekerlemeleri sıralamak için	Mamdani Üçgen	Geliştirilen model, farklı bileşen oranlarını içeren şekerlemelerin sıralamasını optimize etmeyi ve gerçekleştirmeyi başardı.
Soğanlar	Soğanların kuruma kinetiğini tahmin etmek	Mamdani Üçgen	Model, R değerinin 0,9999 ve düşük ortalama karekök hatasının (RMSE) 0,004157 olduğu yüksek performansla değişen koşullarda nem oranını tahmin edebildi.
Bakla fasülyesi	Çeşitli nem içeriklerine sahip fasulyelerin fiziksel parametrelerini tahmin etmek	Mamdani Üçgen	Model, girdideki nem içeriği %9,3 ile %31,3 arasında değişen fasulyelerin on üç parametresini tahmin edebildi. FL sonuçları ile deneysel değer arasında karşılaştırma yapıldı: burada 0,999 olan yüksek bir korelasyon değeri ve %1,23-

			12,56 aralığında ortalama, standart sapma elde edildi ve bu, işleme sırasında çeşitli aşamaları kontrol etmek ve yönetmek için bir model geliştirmek amacıyla kullanılabilir.

3.3. TARIMDA YAPAY SİNİR AĞLARI UYGULAMALARI

Yapay Sinir Ağları (YSA), insan beyninin işleyişini taklit etmek amacıyla geliştirilen, öğrenme süreçlerini nöronlar arasındaki bağlantılar üzerinden ve sinaptik ağırlıklar temelinde gerçekleştiren bir yapay zekâ teknolojisidir (Kumar, 2016; Al-Waeli ve ark., 2019). YSA'larda kullanılan veri setleri, ağı eğitmek amacıyla uygulanan çeşitli öğrenme algoritmalarıyla ilişkilendirilmekte olup, bu algoritmalar genel olarak üç temel grupta incelenmektedir: **denetimli öğrenme**, **denetimsiz öğrenme** ve **pekiştirmeli öğrenme**. Eğitim sürecinin tamamlanmasının ardından, model test verileri üzerinde denenmekte ve elde edilen çıktılar analiz edilerek sistemin performansı değerlendirilmektedir (Shanmuganathan, 2016).

Önceki araştırmalar, **yapay sinir ağlarının (YSA)** tarımda farklı görevlerde başarıyla uygulandığını ortaya koymuştur. Bu uygulama alanları; **numune sınıflandırması, ısı ve kütle transferi gibi karmaşık mühendislik hesaplamaları, kontrol sistemleri** ve **öngörüsel analizler** şeklinde çeşitlilik göstermektedir (Karakaya,2025). Tablo 3a'da sunulan örneklerde de görüldüğü üzere, söz konusu uygulamaların büyük çoğunluğu yüksek **R^2 (belirleme katsayısı)** değerleri elde etmiştir. Bu bulgular, yapay sinir ağlarının tarımda doğru, güvenilir ve etkin sonuçlar sağlayabilme potansiyelini açıkça ortaya koymaktadır.

Tablo 3a. Tarımda yapay sinir ağlarının uygulanması (Karakaya, 2025).

Ürün	**Amaç**	**YSA Türleri**	**Önemli sonuçlar**
Pirinç mahsulü	Pirinç üretim verimini tahmin etmek ve pirinç mahsul verimini etkileyen faktörleri araştırmak	Çok kanallı	Geleneksel doğrusal regresyon yöntemlerine kıyasla pirinç üretim verimini tahmin etmek için iyi bir alternatif Geliştirilen algoritma ile elde edilen doğruluk %97,54, duyarlılık %96,33 ve özgüllük %98,12 idi.
Patlıcan	Patlıcanların ozmotik dehidrasyondaki (OD) kütle transfer kinetiğini tanımlamak	Çok kanallı	Yüksek hacimli karmaşık problemler YSA kullanılarak modellenebilir ve analiz edilebilir ve hesaplama problemleri için en uygun yazılımdır. Geliştirilen model yüksek 0,9825'lik en R2 değerine ulaştı
Sarımsak	Sarımsağın duyusal kalitesini tahmin etmek	Çok kanallı	Sarımsak ve sarımsak ürünlerinin duyusal kalitesinin en iyi tahminini sağlayan bir model. 0.9866 R2 değeriyle geliştirildi

Mango	Mangonun ağırlığını tahmin etmek için	Çok kanallı	Mangoların ağırlığının tahmini, modele on üç farklı parametrenin uygulanmasıyla yapılabilmiştir.
Mantarlar	Kurutma işlemi sırasında mantarların nem içeriğini tahmin edebilen bir YSA modeli geliştirmek	Çok kanallı	ANN modeli, kurutma işlemi sırasında mantarların nem içeriğini 0,9817 R değeriyle tahmin edebildi.
Mantarlar	Oda sıcaklığını etkileyen parametrelere dayanarak mantar yetiştirme salonunun sıcaklık çeşitliliğini tahmin etmek	MLP, RBF	RBF yöntemi kullanılarak yapılan tahmin, korelasyon değerinin sırasıyla 0.996 ve 0,9612 olduğu MLP'ye kıyasla daha yüksek bir doğruluğa sahiptir.
Soğanlar	Soğanın kuruma davranışını tahmin etmek için	Çok kanallı	Geliştirilen model, R değerinin 0.99956 değerine ulaştığı yüksek bir performansla soğanların farklı sıcaklık ve zamanlardaki kuruma kinetiğini tahmin edebildi.
Ayva meyvesi	Kurutma işlemi sırasında meyvenin nem oranını belirlemek ve geliştirilen modelin performansını test etmek	Çok kanallı	Farklı YSA yapıları uygulanarak, ayva meyveleri için kurutma işlemi sırasında nem oranı başarılı bir şekilde modellenmiştir. Geliştirilen model, elde edilen R2'nin %99'dan büyük olduğu yüksek korelasyon değerine sahip nem oranını tahmin edebildi.
Kurutulmuş sebzeler	Kurutulmuş havuçların kalitesini belirlemek ve bu tür kurutulmuş ürünlerin sınıflandırılması	Çok kanallı	Kuru havuçların değerlendirilmesi ve sınıflandırılması için kullanılmaya uygundur. Kalite değerlendirmesi için önemli temsili özelliklerin seçilmesini sağlayın. Algoritmalar arasında karşılaştırma yapıldı ve geri yayılım, diğer algoritmalarla karşılaştırıldığında en başarılı algoritmadır

3.4. TARIMDA MAKİNE ÖĞRENMESİ UYGULAMALARI

Makine öğrenimi (Machine Learning – ML), yapay zekânın bir alt dalı olarak kabul edilmekte olup, bilgisayar algoritmalarının deneyimlerden yola çıkarak otomatik olarak gelişmesini sağlayan bir yöntemdir (Butler ve ark., 2018; Sharp ve ark., 2018). ML algoritmaları genel olarak üç ana kategoriye ayrılmaktadır: **denetimli öğrenme, denetimsiz öğrenme** ve **pekiştirmeli öğrenme** (Erickson, Korfiatis ve ark., 2017; Mullainathan ve Spiess, 2017).

- **Denetimli öğrenme**, belirli bir girdi kümesine dayalı olarak hedeflenen çıktının tahmin edilmesini sağlayan, yapılandırılmış bir öğrenme sürecidir (Mullainathan ve Spiess, 2017).
- **Denetimsiz öğrenme**, önceden tanımlanmış bir çıktı bulunmaksızın, verilerin iç yapısını analiz ederek doğal örüntüleri ve gizli ilişkileri keşfetmeyi amaçlamaktadır (Deo, 2015).
- **Pekiştirmeli öğrenme** ise sistem ile çevresi arasındaki etkileşimler aracılığıyla, ödül temelli karar alma süreçlerinin optimize edilmesine odaklanmaktadır (Carleo ve ark., 2019).

Tarımda yaygın olarak kullanılan başlıca **makine öğrenimi (ML) yöntemleri** arasında**; sıradan en küçük kareler regresyonu (OLS-R), kademeli doğrusal regresyon (SL-R), temel bileşen regresyonu (PCR), kısmi en küçük kareler regresyonu (PLSR), destek vektör regresyonu (SVM-R), güçlendirilmiş lojistik regresyon (BLR), rastgele orman regresyonu (RF-R) ve k-en yakın komşular regresyonu (kNN-R)** yer almaktadır (Estelles-Lopez ve ark., 2017). Literatürdeki araştırmalar, ML tabanlı yaklaşımların özellikle **duyusal analiz maliyetlerinin azaltılması, karar verme süreçlerinin iyileştirilmesi ve kullanıcı odaklı iş stratejilerinin geliştirilmesi** konularında etkin bir rol üstlendiğini göstermektedir (Lu ve ark., 2020). Makine öğreniminin tarımdaki başlıca kullanım alanları ve sağladığı avantajlar, Tablo 4a'da özetlenmiştir.

Tablo 4a. Tarımda makine öğrenmesi uygulanması (Karakaya, 2025).

Ürün	**ML yöntemleri**	**Önemli sonuçlar**
Elma	Doğrusal ayırıcı analiz, adaptin güçlendirme	ML, toplanan akustik emisyon sinyallerini kullanarak elmaları %100 oranında doğru bir şekilde sınıflandırabildi
Enginar	MLP, RF, BLR	İyon desenlerinin özellikleri, her enzim için %95'in üzerinde yüksek bir tahmin oranına sahip ML modelleri kurularak yapıldı.
Mangolar	Naif Bayes, SVM	Sistem, mangoların olgunluğunu kalite özelliklerine göre tespit edebilmektedir
Narenciye limetta (Mosambi kabuğu)	SVM-ANN, SVM-Gaussian süreç regresyonu (SVM-GPR)	SVM modeli, tuzla muamele edilmiş kireç tozunun tadına ilişkin tüm sonuçları 1,0 doğrulukla tahmin edip sınıflandırabilmiştir. ML aracının kullanımıyla yapılan optimizasyon, limondaki tadın korunmasını ve polifenol içeriğinin muhafaza edilmesini sağlar
Meyveler	RF, SVM, YSA	Arbutus unedo L. Meyvelerindeki ekstraktların sulu ve toz sistemler açısından stabilitesi, seçilen en iyi modeller için 0,9128 ile 0,9912 aralığında genel katsayı ile ML yöntemleri ile yapılabilmiştir.

3.5. TARIMDA ANFIS (UYARLANABİLİR AĞ TABANLI BULANIK ÇIKARIM SİSTEMİ) UYGULAMALARI

Uyarlanabilir Ağ Tabanlı Bulanık Çıkarım Sistemi (ANFIS), bulanık mantık (FL) ile yapay sinir ağlarının (YSA) avantajlarını bir araya getiren hibrit bir yapay zekâ yaklaşımıdır. Bu sistem, FL'nin insan benzeri muhakeme yeteneğini YSA'nın öğrenme kapasitesi ve hesaplama gücüyle bütünleştirerek daha etkili ve güvenilir sonuçlar üretmeyi amaçlamaktadır (Al-Mahasneh ve ark., 2016). ANFIS'te öğrenme süreci, yapay sinir ağı mekanizmaları aracılığıyla yürütülmekte; bu öğrenme çıktıları, uygun üyelik fonksiyonlarına sahip bulanık kurallar oluşturmak üzere bulanık mantık sistemine aktarılmaktadır (Melin ve ark., 2018). Bu sayede, hem bulanık mantığın esnek ve insan benzeri yorumlama kabiliyeti hem de yapay sinir ağlarının güçlü öğrenme kapasitesi aynı çatı altında birleştirilmiş olmaktadır. Bu kapsamlı uygulamaların tarımdaki gelişimi ve ayrıntıları Tablo 5a'da özetlenmiştir.

Tablo 5a. Tarımda ANFIS'in uygulanması (Karakaya, 2025).

Ürün	**Önemli sonuçlar**
Turunç	Geliştirilen ANFIS modeli portakal tadını tahmin edebildi ve çoklu regresyon modeliyle karşılaştırıldığında daha yüksek performansa sahip oldu.
Ayva meyveleri	ANFIS modeli, kurutma işlemi sırasında ayva meyvesinin nem oranını, enerji kullanımını, enerji kullanım oranını, ekserji kaybını ve ekserji verimliliğini sırasıyla 0,9997, 0,9989, 0,9988, 0,9986 ve 0,9978 R2 değeriyle yüksek doğrulukla tahmin edebildi. ANFIS modeli ANN modeliyle karşılaştırıldı ve elde edilen sonuçlar ANFIS modelinin ANN modeline kıyasla daha yüksek doğruluğa sahip olduğunu gösterdi; burada R2 değeri daha yüksek ve ANFIS modelinde daha düşük bir hata değeri vardı
Sebzeler (kavun, sarımsak, patates)	ANFIS sistemini kullanarak geliştirilen model, sebzelerin etkili nem yayılma hızını, özgül enerji tüketimini, nem oranını ve kurutma hızını sırasıyla 0,9990, 0,9917, 0,9974 ve 0,9901'lik yüksek bir regresyon katsayısıyla, minimum hata değerivle tahmin edebildi. ANFIS modeli ile ANN modeli arasında karşılaştırma yapıldı ve sonuçlar ANFIS modelinin ANN modelinden daha yüksek bir verimliliğe sahip olduğunu gösterdi.

3.6. TARIMDA GERÇEK ZAMANLI ALGILAMA İÇİN YAPAY ZEKÂNIN HARİCİ SENSÖRLERLE ENTEGRASYONU

Gerçek zamanlı algılamaya yönelik sistemlerde, yapay zekâ yöntemleri özellikle **bulanık mantık (FL)** ve **yapay sinir ağları (YSA)** gelişmiş sensör teknolojileriyle entegre edilerek daha kısa sürede ve daha yüksek doğrulukla sonuç elde edilmesine olanak tanımaktadır. Bu çerçevede, **elektronik burun (e-burun), elektronik dil (e-dil), makine öğrenimi (ML), bilgisayarlı görme sistemleri (CVS)** ve **yakın kızılötesi spektroskopisi (NIRS)** gibi harici sensörler; FL ve YSA tabanlı algoritmalarla birlikte kullanılarak gıda endüstrisinde geniş bir uygulama alanı bulmuştur. Sensör teknolojileri ile yapay zekâ algoritmalarının bu

entegrasyonu, sistem performansının iyileştirilmesine ve hedef odaklı doğruluğun artırılmasına önemli katkılar sağlamaktadır. Nitekim son yıllarda bu teknolojik birliktelik, gıda endüstrisinde giderek daha yaygın şekilde benimsenmiştir (Karakaya, 2025).

Elektronik burun (e-burun), insan burnunun koku alma işlevini taklit edecek şekilde tasarlanmış ve kokular ile uçucu bileşiklerin analiz edilmesine imkân tanıyan yapay bir algılayıcı sistemdir (Yan ve ark., 2015). Bu sistem hem basit hem de karmaşık kokuların tanımlanmasında kullanılabilen çeşitli elektronik kimyasal sensör dizilerinden oluşmaktadır. E-burun sistemleri, gazların veya gaz-buhar karışımlarının bileşenlerini ayırt etmek ve analiz etmek amacıyla yaygın olarak kullanılmakta olup, özellikle gıda ürünlerinin **kalite kontrol süreçlerinde** kritik bir rol üstlenmektedir. Ayrıca, karmaşık aromatik profilleri algılama kabiliyeti sayesinde yalnızca gıda sektöründe değil, aynı zamanda **çevresel izleme**de **patlayıcı madde tespiti** gibi alanlarda da önemli uygulamalara sahiptir (Deshmukh ve ark., 2015). Yapay zekâ destekli hesaplama yöntemleriyle geliştirilen e-burun sistemlerinin tarımdaki son uygulamaları Tablo 6a'da özetlenmektedir.

Tablo 6a. Tarımda yapay zekâ ile E-burun uygulaması (Karakaya, 2025).

Ürün	**Amaç**	**Yapay zekâ tekniği**	**Önemli sonuçlar**
Kakao	Kakao çekirdeklerinin fermantasyon süresini anlamak ve sınıflandırmak	DT, Güçlendirilmiş ağaç RF, ANN, KNN, saf Baiyes (NB)	ANN ve Boosted Tree algoritması kabul edilebilir bir sınıflandırma oranı elde etmeyi başarırken, fermantasyon süresi KNN ve NB algoritması tarafından belirlenemedi.
Safran	Safran numunelerinin sahteliğini tespit etmek için	YİNE	Orijinal ve sahte safranın sınıflandırılması, desen tanıma yöntemi kullanılarak e-burun kullanılarak sırasıyla %100 ve %86,87 doğrulukla başarıyla gerçekleştirildi.
Meyveler	Elektronik burundan gelen verileri sınıflandırmak ve performansını değerlendirmek için Yapay Arı Kolonisi (ABC) algoritmasını YSAda uygulamak	ANN ve yapay arı kolonisi	ABC-ANN, e-burun verilerinin koku sınıflandırmasında daha başarılıdır ve kullanılan geri yayılım algoritmasına kıyasla daha yüksek performansa sahiptir. Sistem, limon, kiraz, çilek ve kavun aroması olmak üzere dört farklı aromayı sınıflandırabildi.
Safran	İran safranının farklı aromalarını tanımlamak	ES, LÜTFEN, YAYIN	E-burun, ANN ile birleştirildiğinde safran örneklerinin sınıflandırılması için %100'e başarıyla ulaşıldı

Meyveler	Meyve kokularının tanınması ve algılanması için E-burun' da Kernel aşırı öğrenme makinelerinin uygulanması	Çekirdek aşırı makine öğrenimi	Önerilen sistem koku i tanımada önemli ölçüde iyi performans gösterdi Meyve kokularını tanımada kullanılan diğer sistemlerle karşılaştırıldığında daha yüksek test doğruluğu ve en düşük eğitim süresi ve test süresi değeri elde edildi.
Limon	Çeşitli limon dilimlerinin kalitesini karakterize etmek ve tahmin etmek	ELM, RF, SVM	ELM yöntemi kullanılarak yapılan tahmin, 0,959'luk en yüksek doğruluğu elde etti, bunu sırasıyla 0,935 ve 0,922 ile RF ve SVM izledi, bu da E-burun ile entegre ELM'nin en iyi sınıflandırma modeli olduğunu gösteriyor.
Armut	Balsam armutunun kurutma sürecini optimize ederek gıda kalitesini artırmak	Florida	Aromayı korumak ve ürün kalitesini artırmak için kurutma süresi kısaltılabildi Endüstriyel kontrol yönteminin tanımı, kontrolü basitleştirmek ve iyi kurutma etkilerine sahip olmak için oluşturulmuştur
Pirinç taneleri	Depolanmış pirinç tanelerinde Sitophilus oryzae istilasını tespit etmek	FL SANAT Haritası PCA, MLR	FL ARTMAP uygulamasıyla e-burun, veriler kapsamlı olduğunda ve analiz hakkında çıkarımlar yapılması gerektiğinde yararlıdır. Model, tahılları istila edilmiş, istila edilmemiş, gerekli işlem görmüş ve diğerlerini sınıflandırabilmiştir. Hibrit sistem, tahıldaki istilaların erken tespitinin yapılabilmesi ve hasat sonrası kayıpların en aza indirilebilmesi sayesinde gıda ve tahıl endüstrisinde faydalıdır.
Pirinç taneleri	Rhyzopertha'yı sınıflandırmak için Dominika'nın istila ettiği pirinç tanelerini tanımak	YİNE	E-burun sistemiyle BPANN, sınıflandırma işlemi için e-burunla kullanılan diğer yöntemlerle karşılaştırıldığında 0,98 olan en yüksek R2 değerini verdi ve geri kalanına kıyasla en yüksek doğruluğa sahiptir Sistem, farklı günler için istila edilmiş pirinç tanelerini tahmin edebildi

Kabuklu fıstık	Kabuklu fıstıkların depolama kalitesini değerlendirmek	Florida	FL analizi, e-burun sensörlerini tarayıp sıralayabildi ve kabuklu fıstıklar için atık süresi belirlenebildi Geleneksel yöntemlerle yakından eşleşen sensörler kullanılarak kabuklu fıstıkların depolama süresinin tahmini Hızlı ve yıkıcı olmadığı için çevre dostu bir alternatif olabilir.
Ispanak	Ispanağın hasat sonrası tazeliğini tespit etmek için	YİNE	E-burun ile BPNN yönteminin birleştirilmesi, sınıflandırma doğruluğu açısından %93,75 doğrulukla ıspanak tazeliğini hızlı ve tahribatsız bir şekilde tespit etmenin etkili bir yolu olduğunu kanıtlamıştır.
Buğday tanesi	Depolanmış buğday tanelerindeki ambar böceği istilasını belirlemek için	Florida	Böcek bulaşmış buğday tanelerinin ürettiği en duyarlı sensörler ve belirli VOC'ler, bulanık mantık analiziyle ilişkili e-burun sensörü tarafından taranabildi. E-burun, depolanan buğday tanesindeki istilaları doğru ve hızlı bir şekilde izlemek için potansiyel bir yöntem olduğu kanıtlanmıştır. Ayrıca, endüstrilerin depolama süresi boyunca ürünün kalitesini belirlemesi için güvenilir bir yöntemdir.

Elektronik dil (E-dil), farklı tatları algılayabilen ve analiz edebilen, insanın duyusal sistemini taklit eden bir teknolojik cihazdır. Literatürde "çok duyulu sistem" olarak da tanımlanan E-dil, düşük seçiciliğe sahip çok sayıda sensörün, **desen tanıma (Pattern Recognition – PARC)** teknikleri ve çok değişkenli veri analizine dayalı gelişmiş matematiksel algoritmalarla entegrasyonu sonucunda çalışmaktadır (Ha ve ark., 2015). Bu sistem, özellikle sıvı fazdaki numunelerde bulunan çeşitli kimyasal bileşenlerin ayrıştırılması ve tanımlanmasında yüksek etkinlik göstermekte olup, gıda endüstrisi başta olmak üzere farklı araştırma ve endüstriyel uygulama alanlarında kullanılmaktadır.

Artan tüketici bilinci ve daha güvenli, yüksek kaliteli gıda ürünlerine yönelik talepler doğrultusunda, **elektronik dil (E-dil)** teknolojisine olan ilgi ve kullanım oranı gıda endüstrisinde giderek artış göstermektedir. Bu bağlamda, elektronik dil sistemlerinin tarımdaki güncel uygulamalarına ilişkin ayrıntılar **Tablo 6b'**de özetlenmektedir.

Tablo 6b. Tarımda yapay zekâ ile E-dil'in uygulaması (Karakaya, 2025).

Ürün	**Amaçlar**	**Yapay zekâ tekniği**	**Sonuçlar/etkiler**
Ananas	Ananasları tatlılık seviyelerine göre sınıflandırmak ve en iyi algoritmayı belirlemek	SVM, KNN, YSA, RF	Ananasın tatlılığını belirlemede farklı makine öğrenimi algoritmaları kullanıldı ve elde edilen en iyi algoritma, %0,820 doğruluk elde edilen KNN yöntemi oldu. Geliştirilen model, büyük miktarlarda ananas seçiminin gerekli olduğu endüstride faydalı olacaktır.
Pirinç	Katı gıdaları ayırt etmek ve tahmin etmek ve gıda endüstrileri için bir değerlendirme aracı sağlamak	YİNE	RBFNN, sınıflandırmada %95 doğrulukla farklı pirinç türlerini ayırt edebildi Voltametrik E-dil, pirinç için nitel analizde kullanılışlıdır
Pirinç	E-dilde pirinç duyusal kalitesinin tahmini için yapay sinir ağları (SA-ANN) ile birleştirilmiş benzerlik analizini geliştirmek	YİNE	E-dilindeki SA-ANN, pirinç duyusal kalitesini tahmin edebildi ve sistematik analizler yürütebildi PCA-ANN ile SA-ANN arasında karşılaştırma yapıldı ve SA-ANN'nin PCA-ANN'ye kıyasla daha iyi hassasiyet ve doğruluğa sahip olduğu bulundu. SA-ANN daha az emek gerektiren, daha hızlı bir yöntemdir ve pirinç duyusal özelliklerinin hızlı ve büyük ölçekli tahmini için potansiyele sahiptir
Şeker kamışı	Şeker kamışından elde edilen glikozun analizi için voltametrik e-dilin karakterize edilmesi ve uygulanması	YİNE	Dalgacık bilgisine sahip çok katmanlı YSA, E-dilinden gelen karmaşık yanıtları işleyebildi Önerilen model, şeker kamışı bazlarından hidrolize edilmiş numuneler için kullanılmaya uygundur
Çaylar	Farklı çay türlerini ayırt etmek	YNS, SVM	Geliştirilen sistem kullanılarak farklı çay türleri ayırt edilebildi ve çayın bileşenleri de tanımlanabildi.

Mandalina kabuğu	Farklı yaşlardaki mandalina kabuklarını sınıflandırmak	BPNN, ELM	Model, farklı yaşlardaki mandalina kabuğu örneklerini sınıflandırabilmiştir. Birkaç doğrusal model ve doğrusal olmayan modeller için karşılaştırma yapıldı ve doğrusal olmayan modellerin doğrusal modellerden daha iyi performans gösterdiği elde edildi. ELM, BPNN'i takip eden yüksek doğrulukla numunelerin sınıflandırılması için en iyisiydi.

3.7. TARIMDA BİLGİSAYARLI GÖRÜŞ SİSTEMİ (CVS) UYGULAMALARI

Bilgisayarlı Görüş Sistemi (Computer Vision System – CVS), görüntü işleme ve desen tanıma tekniklerinin entegrasyonuna dayanan yapay zekâ temelli bir teknolojidir. Tahribatsız bir analiz yöntemi olan CVS, görsel veriler üzerinden sınıflandırma süreçlerini kolaylaştırmak amacıyla görüntülerin boyut, şekil, renk ve yüzey kusurları gibi dışsal özelliklerinin nicel olarak incelenmesini ve çıkarılmasını mümkün kılmaktadır (Cardenas-Perez ve ark., 2017). Özellikle **CVS** teknolojisinin, **yumuşak hesaplama (soft computing)** teknikleriyle bütünleştirilmesi; gıda endüstrisinde güçlü, hızlı ve güvenilir karar verme süreçlerinin geliştirilmesine olanak sağlamaktadır. Tarımda CVS teknolojisinin yumuşak hesaplama yöntemleriyle entegrasyonuna yönelik güncel uygulamalar ve örnekler Tablo 7a'da detaylı şekilde sunulmaktadır.

Tablo 7a. Tarımda yapay zekâ ile CVS'nin uygulanması (Karakaya, 2025).

Ürün	**Amaçlar**	**Yapay zekâ tekniği**	**Önemli sonuçlar**
Elma	Arızalı ve normal elmaları ayırmak için	CNN, SVM	CVS modeli ile geliştirilen CNN, elmaları %96,5'lik yüksek bir doğruluk oranıyla sınıflandırabilmiş ve doğruluk oranının %87,1 olduğu SVM sınıflandırıcısı ile birleştirilen geleneksel görüntü işleme yönteminden daha etkili olduğu kanıtlanmıştır.
Elma dilimleri	Elma dilimlerinin renginin değişmesi üzerine kurutmanın etkilerini incelemek	YİNE	CVS, kurutma işlemi sırasında renk değişimlerini izleyebildi ve ANN ile kombinasyon, kurutma işlemi sırasında elmanın kalitesini tahmin edebildi. Geliştirilen model tüm analizler için 0,92'den büyük R2 değerlerine ulaştı

Muz	Muzları olgunluklarına göre sınıflandırmak	YSA, SVM, KSA, DT	ANN tabanlı model sistemi, %97,75'lik en yüksek genel tanıma oranına sahip diğer algoritmalara kıyasla daha yüksek bir sınıflandırma oranına sahiptir.
Maracuya meyveleri	Tutku meyvelerini olgunluk seviyelerine göre sınıflandırmak	Çok Sınıflı SVM (MCSVM)	Geliştirilen sistem, passion meyvelerinin olgunluk seviyesini 0,94128 saniye içinde %93,3 doğrulukla sınıflandırabilmiştir.
Kuru fasulye	Üretimden itibaren farklı tohum tiplerini sınıflandırmak	YAS, KAŞ, DT, SVM	Fasulyelerin sınıflandırılması, %93,13'lük en yüksek genel sınıflandırma oranlarına ulaşan SVM ile tüm ML algoritmaları tarafından yapılabildi; bunu sırasıyla %92,52, %91,73 ve %87,92'lik sınıflandırma oranlarına sahip DT, ANN ve KNN izledi.
Dolmalık biber	Biberin olgunluk seviyesini otomatik olarak tanımlamak için	ANN, FL	CVS ve ANN/FL kullanılarak dolmalık biberin olgunluğunu tahmin etmede yapay bir görme sistemi geliştirilebildi RBF-ANN kullanan model, her iki modelin de elde ettiği maksimum doğruluğun sırasıyla %100 ve %88 olduğu FL ile karşılaştırıldığında daha yüksek bir sınıflandırma doğruluğuna sahiptir.
Cape bektaşi üzümü	Bektaşi üzümünün olgunluğunu sınıflandırmak için	YSA, SVM, DT, KNN	Tüm modeller, farklı renk uzayları kullanılarak tüm modellerin elde ettiği doğruluk %86'dan fazla olduğu için, pelerin bektaşi üzümünün olgunluğunu yüksek bir doğrulukla sınıflandırabilmiştir; bu da bunun iyi bir sınıflandırıcı sistem olduğunu gösterdi.
Kahve çekirdekleri	Kahve çekirdeklerini sınıflandırılabilecek bir sistem geliştirmek	YİNE	Yeşil kahve çekirdekleri geliştirilen sistem kullanılarak analiz edilebildi ve sınıflandırılabildi Bu sistemde, dönüştürülen değerin daha sonra sınıflandırma amaçları için kullanıldığı bir renk alanı dönüştürme modeli olarak ANN kullanıldı

İncirler	İncir meyvelerini görsel özelliklerine göre sınıflandırmak	Karar ağacı-FL	CVS'den elde edilen veriler için üç farklı karar ağacı türü arasında karşılaştırma yapıldı ve REP karar ağacının en yüksek R değerine ve daha düşük RMSE değerlerine sahip olduğu gösterildi ve bu nedenle bulanık sistemde uygulanmak üzere seçildi. Geliştirilen sistem, incir meyvelerini yüksek doğrulukla beş nitel sınıfa ayırabilmiştir.
Mango	Mangonun meyve kütlesini tahmin etmek için	YİNE	CVS'den elde edilen veriler geliştirilen ANN modelinde girdi parametreleri olarak kullanıldı ve model meyve kütlesini başarılı bir şekilde tahmin edebildi. Geliştirilen sistem, iki girdi parametresi veya üç girdi parametresi uygulanarak %97'lik en yüksek başarı oranına ve 0,99'luk verimlilik katsayısına sahiptir.
Mantarlar	Mantarların görünüm kalitesini belirlemek için	ANN, FL	Görüntü işleme sistemi tarafından elde edilen doğruluk %95,6'dır YSA mantarların ağırlığını belirleyebildi ve bulanık mantık CVS'den gelen verileri kullanarak mantarın kalitesini belirleyebildi.
Patatesler	Patatesler için bir derecelendirme sistemi geliştirmek	Florida	CVS ve bulanık mantığın birleşimi, pateslerin daha hızlı sınıflandırmasını sağlar ve manuel sınıflandırma için gereken maliyeti azaltır.
Pirinç	Öğütülmüş pirincin nitel sınıflandırmasın ı gerçekleştirmek	Florida	Çalışma, geliştirilen hibrit sistemin öğütülmüş pirincin otomatik olarak sınıflandırılması için işleme endüstrisinde kullanılabileceği sonucuna varmıştır. Geliştirilen sistem ile uzmanların yargıları arasında karşılaştırma yapıldı ve genel olarak yaklaşık %89,80 güven elde edildi. Bulanık sistem, öğütülmüş pirincin kalite derecelendirmesi için %89,83 toplam duyarlılık ve %97,45 özgüllük elde etti.

Pirinç	Pirinç beyazlatma makinelerinin performansını kontrol etmek için	Florida	Geliştirilen otomatik kontrol sistemi, normal bir insan operatöründen ortalama %31,3 daha yüksek performans hızına sahipti ve sistem tarafından alınan karara dayalı olarak çıktı kalitesinde bir iyileşme vardı.

3.8. TARIMDA YAKIN KIZILÖTESİ SPEKTROSKOPİSİ (NIRS) VE YAPAY ZEKÂ ENTEGRASYONU

Yakın kızılötesi spektroskopisi (Near-Infrared Spectroscopy – NIRS), kimyasal reaktif kullanımına ihtiyaç duymaması, tahribatsız analiz imkânı sunması ve kısa sürede yüksek doğrulukta sonuçlar üretebilmesi nedeniyle gıda endüstrisinde yaygın olarak kullanılan önemli analitik tekniklerden biridir (Qu ve ark., 2015). Geleneksel analiz yöntemleriyle karşılaştırıldığında, **daha basit, daha hızlı, düşük maliyetli ve çevre dostu** bir yaklaşım sunması, NIRS'i sürdürülebilir üretim süreçleri açısından dikkat çekici bir alternatif hâline getirmektedir. Ayrıca NIRS'in kimyasal madde kullanmayan çalışma prensibi hem insan sağlığı hem de çevre güvenliği açısından önemli avantajlar sağlamaktadır (Porep ve ark., 2015).

NIRS sisteminin, gıda ürünlerinin fiziksel ve kimyasal özelliklerini yüksek doğrulukla tespit edebilme kapasitesi, yapay zekâ yöntemleriyle özellikle **yapay sinir ağları (ANN), bulanık mantık (FL)** ve **makine öğrenimi (ML)** entegrasyonu sayesinde önemli ölçüde artmaktadır. Bu entegrasyon, gıda ürünlerinin **sınıflandırılması** ve **özelliklerinin tahmin edilmesi** süreçlerinde güçlü ve etkin bir analiz aracı sunmaktadır. **Tablo 8a**'da tarımda yapay zekâ teknikleriyle bütünleştirilmiş NIRS uygulamalarına ilişkin güncel örnekler özetlenmektedir.

Tablo 8a. Tarımda yapay zekâ ile NIRS'nin uygulanması (Karakaya, 2025).

Ürün	**Amaçlar**	**Teknik Yapay Zekâ**	**Önemli sonuçlar**
Keemun siyah çay	Çin'de farklı keemun siyah çay kalitelerinin ayrımı için bir model geliştirmek	ANN, en küçük kare SVM (LSSVM), Rastgele Orman	Modeli geliştirmek için ANN ve LSSVM olmak üzere üç farklı yöntem kullanıldı ve tüm yöntemler keemun çayının farklı derecelerini ayırt edebildi. LSSVM yönteminin diğerlerine kıyasla daha yüksek bir performansa ve öngörüye sahip olduğu tespit edildi.
Armutlar	Armutta çözünen katı madde içeriğini belirlemek için	KARA AĞAÇ	Önerilen ardışık projeksiyon algoritması ve aşırı öğrenme makinesi (SPA-ELM), içerikleri geleneksel PCA-ELM yönteminden daha iyi tahmin edebildi
Beyaz kuşkonmaz	Kuşkonmazın kökenini tahmin etmek ve Alman ürünlerini ithal ürünlerden ayırt etmek	SVM	Doğrusal SVM, beyaz kuşkonmazın menşe ülkesini %89 doğrulukla tahmin edebildi ve ayrıca Alman ve Alman olmayan ürünleri ayırt edebildi.

4. SONUÇ

Yapay zekâ, tarım sektöründe üretim süreçlerini köklü biçimde dönüştürerek verimliliği artıran, kaynak kullanımını optimize eden ve sürdürülebilir üretim hedeflerini destekleyen stratejik bir teknoloji hâline gelmiştir. Bitki hastalıklarının erken teşhisi, ürün verimliliğinin öngörülmesi, sulama ve gübreleme süreçlerinin hassas biçimde yönetilmesi, otomasyon ve robotik uygulamalar aracılığıyla iş gücü tasarrufu sağlanması, bu teknolojinin tarımdaki başlıca katkıları arasında yer almaktadır.

Ayrıca yapay zekânın, nesnelerin interneti (IoT), sensör ağları, bilgisayarlı görme ve elektronik algılayıcı sistemlerle entegre edilmesi; daha doğru, hızlı ve güvenilir karar mekanizmalarının oluşturulmasına imkân tanımaktadır. Bu durum yalnızca üretim maliyetlerini azaltmakla kalmamakta, aynı zamanda çevresel etkilerin en aza indirilmesine ve gıda güvenliğinin güçlendirilmesine de katkı sağlamaktadır.

Genel olarak değerlendirildiğinde, yapay zekâ destekli tarımsal uygulamalar; **verimlilik, kalite ve sürdürülebilirlik** açısından sağladığı avantajlarla geleceğin tarım sektöründe vazgeçilmez bir unsur olarak öne çıkmaktadır.

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HAYVANCILIKTA YAPAY ZEKÂ UYGULAMALARI

Zeynep KARAKAYA

Veteriner Hekim, Burdur Mehmet Akif Ersoy Üniversitesi, Sağlık Bilimleri Enstitüsü Hayvansal Ürünler Hijyen ve Teknolojisi

Email: zynpkarakaya20@gmail.com

Seval Sevgi KIRDAR

Prof. Dr. Burdur Mehmet Akif Ersoy Üniversitesi, Burdur Gıda Tarım ve Hayvancılık MYO, Gıda işleme Bölümü

Email: skirdar@mehmetakif.edu.tr

ÖZET

Yapay zekâ, genel olarak makinelerin karmaşık problemlere insan benzeri yöntemlerle çözüm üretebilmesine imkân tanıyan bir bilim dalı olarak tanımlanmaktadır. Yapay zekâ ve sensör teknolojilerindeki hızlı ilerlemeler, farklı sektörlerde yeni ufuklar açmış; bu dönüşümden genellikle göz ardı edilen hayvancılık sektörü de önemli ölçüde etkilenmeye başlamıştır.

Özellikle karmaşık problemlerin çözümünde; Yapay Sinir Ağları, Bulanık Mantık, Genetik Algoritmar, Derin Öğrenme ve Makine Öğrenmesi gibi yapay zekâ tabanlı yöntemler sıklıkla tercih edilmektedir. Bu yaklaşımlar sayesinde çok sayıda değişkenin eşzamanlı olarak analiz edilmesi mümkün olmakta; böylece daha hızlı, doğru ve etkin karar süreçlerinin gerçekleştirilmesine olanak sağlanmaktadır.

Yapay zekâ teknikleri, hayvancılık sektöründe çeşitli uygulamalarda başarıyla kullanılmaktadır. Bu uygulamalar arasında hayvan ıslahı; kızgınlık periyodunun tespiti, mastitis gibi hastalıkların erken teşhisi; süt, yumurta ve benzeri hayvansal ürünlerin verim özelliklerinin tahmini gibi alanlar sayılabilir.

Yapay zekâ ile yapılan hayvancılık çalışmalarında sağmal ineklerde bulanık mantık yöntemlerinin yemleme ve hastalık yönetiminde kullanımı incelenmiştir. Ayrıca otomatik sağım sistemlerinde mastitisin kontrolü ve sınıflandırılması amacıyla bir bulanık model geliştirilmiştir. Derin öğrenme, yapay sinir ağları ve makine öğrenmesi gibi teknolojilerin gelişmesiyle birlikte çiftlik hayvanlarında ısı stres yönetiminde de yapay zekâdan yararlanılmaktadır. Taşınamaz sensörler de hayvanların üzerine yerleştirilemeyen ve çiftlikte belirli noktalara sabitlenerek kullanılan sistemlerdir. Özellikle **yoğun üretim yapılan işletmelerde ve süt çiftliklerinde,** hayvanların düzenli olarak sağım alanına yönlendirilmesi sayesinde bu cihazlar önemli avantaj sağlamaktadır.

Kümes hayvancılığında yapay zekâ ve makine öğrenmesi kullanılarak refah çalışmaları yapılmıştır. Başka bir çalışmasında Arduino ve bulanık mantık kullanılarak arı kovanlarının uzaktan izlenip kontrol edilebileceği bir sistem geliştirilmiştir.

Bu çalışmada hayvancılık alanında kullanılan yapay zekâ ile ilgili çalışmalardan ve uygulamalardan bahsedilecek ve yapay zekânın hayvancılık sektöründeki dönüştürücü etkisi ele alınacaktır.

Anahtar Kelimeler: Hayvancılık, Yapay Zekâ, Sensör Teknolojileri

ARTIFICIAL INTELLIGENCE APPLICATIONS IN LIVESTOCK

ABSTRACT

Artificial intelligence is generally defined as a field of science that enables machines to produce solutions to complex problems using human-like methods. Rapid advances in artificial intelligence and sensor technologies have opened new horizons in various sectors; the livestock sector, which is often overlooked in this transformation, has also begun to be significantly affected.

Artificial intelligence-based methods such as Artificial Neural Networks, Fuzzy Logic, Genetic Algorithms, Deep Learning, and Machine Learning are frequently preferred, especially in solving complex problems. These approaches enable the simultaneous analysis of numerous variables, thus facilitating faster, more accurate, and more effective decision-making processes.

Artificial intelligence techniques are successfully used in various applications in the livestock sector. These applications include animal breeding; detection of the estrus period; early diagnosis of diseases such as mastitis; and estimation of the yield characteristics of milk, eggs, and similar animal products.

In livestock studies conducted with artificial intelligence, the use of fuzzy logic methods in feeding and disease management in dairy cows has been investigated. In addition, a fuzzy model has been developed for the control and classification of mastitis in automatic milking systems. With the development of technologies such as deep learning, artificial neural networks, and machine learning, artificial intelligence is also being used in heat stress management in farm animals. Non-wearable sensors are systems that cannot be placed on animals and are fixed at specific points on the farm. These devices offer significant advantages, especially in intensive production facilities and dairy farms, by regularly directing animals to the milking area.

Welfare studies have been conducted in poultry farming using artificial intelligence and machine learning. In another study, a system was developed using Arduino and fuzzy logic to remotely monitor and control beehives.

This study will discuss artificial intelligence-related studies and applications used in animal husbandry and address the transformative impact of artificial intelligence on the animal husbandry sector.

Keywords: Livestock Farming, Artificial Intelligence, Sensor Technologies

1. GİRİŞ

Yapay zekâ, günümüzde farklı sektörlerde karar verme süreçlerinin merkezinde yer almaktadır. 2010-2018 yılları arasında yapay zekâ ile ilgili araştırma projelerinin sayısı, bir önceki on yıla göre 2,5 kat artış göstermiştir. Yapay zekâya yatırım yapan şirketlerin satış, istihdam ve piyasa değerlerinde kayda değer artışlar elde edildiği bildirilmiştir. Bu gelişmeler 2007-2018 döneminde yapay zekâ odaklı iş alanlarının belirgin bir biçimde artmasını da açıklamaktadır (Menezes ve ark., 2024).

Tarım ve hayvancılık alanında ise Babina ve ark. (2024), 2014-2018 yılları arasında yapay zekâ ile ilişkili pozisyonların, önceki yedi yıla kıyasla iki katına çıktığını ortaya koymuştur. Bu büyüme, devlet destekli girişimlerle de teşvik edilmektedir. Örneğin, USDA-NIFA ve NSF, 2021 yılında NSF öncülüğünde kurulan 11 yeni Yapay Zekâ Araştırma Enstitüsü'ne toplam 220 milyon ABD doları yatırım yapmıştır (Menezes ve ark., 2024).

Aynı zamanda, toplumun hayvan sağlığı ve refahına dair artan duyarlılığı ile tüketilen ürünlerin kalitesine yönelik beklentileri, hayvancılık işletmelerinde bireysel ve sürü düzeyinde izleme ve kontrol sağlayan sistemlerin önemini artırmıştır. Bu bağlamda, yeni sensörlerin ve teknolojilerin geliştirilmesi ile yapay zekânın ilerlemesi, **hassas hayvancılık** uygulamalarını sektörde temel bir gereklilik haline getirmiştir (Michelena ve ark., 2024).

2. YAPAY ZEKÂ VE UYGULAMA ALANLARI

Yapay zekâ teknolojileri, sayısal analiz yöntemlerine dayalı sezgi ve beceriler aracılığıyla belirsizlik koşullarında çözüm üretme yeteneği kazandırmaktadır. İnsan zekâsı, dış dünyadaki olaylara uyum sağlama kapasitesi ile tanımlanırken; benzer şekilde yapay zekâ sistemlerinin de karşılaştıkları yeni durumlarda anlamlı bilgiyi yorumlaması, bu bilgiyi yeni koşullara uygulaması ve anlamlı ilişkiler kurması beklenmektedir. Bu bağlamda, yapay zekâ üzerine çalışan araştırmacılar örüntü tanıma, öğrenme, problem çözme, teorem geliştirme, oyun oynama, tümevarım ve genelleme ile dil kullanımı gibi çeşitli uygulama alanlarında önemli yöntemler geliştirmiştir (Baykal ve Beyan, 2004b).

Yapay zekâ ve ilgili konularda yaşanan gelişmeler, sekiz temel alt dal kapsamında sınıflandırılabilmektedir (Krishnamoorthy ve Rajeev, 1996: 2-5):

- **Problem Çözme ve Planlama:** Hedef hiyerarşisinin sistematik olarak geliştirilmesi, revizyon mekanizmalarının planlanması ve önemli hedeflere odaklanan araştırmaların organize edilmesiyle ilgilenmektedir.
- **Uzman Sistemler:** Bilgi işleme süreçleri ve karmaşık karar verme problemlerine yönelik çözümler üretmektedir.
- **Doğal Dil İşleme:** Otomatik metin oluşturma, metin işleme, çeviri, konuşma sentezi ve analizi, dilbilgisi ve üslup analizleri gibi alanları kapsamaktadır.
- **Robotik:** Nesneleri kavrama ve manipüle etme süreçlerinde robotların kontrolünü, ayrıca eylemleri yönlendirmek için sensörlerden elde edilen bilgilerin kullanılmasını içermektedir.
- **Bilgisayarla Görme:** Akıllı görselleştirme, sahne analizi, görüntü işleme, görüntü anlama ve hareket çıkarımı üzerine odaklanmaktadır.
- **Öğrenme:** Farklı makine öğrenmesi yöntemlerine ilişkin araştırma ve geliştirme faaliyetlerini kapsamaktadır.
- **Genetik Algoritmalar:** İçsel öğrenme yeteneğine sahip, uyarlanabilir algoritmalardır. Arama, makine öğrenimi ve optimizasyon süreçlerinde kullanılmaktadır.

- **Sinir Ağları:** Örüntü tanıma görevleri, tümdengelimli akıl yürütme ve sayısal hesaplamaları birleştirerek insan beyninin öğrenme sürecini simüle etmeye yönelik çalışmaları kapsamaktadır.

Yapay zekânın kavramsal olarak anlaşılabilmesinde iki temel unsur ön plana çıkmaktadır: algoritma ve zekâ. Algoritmalar, karmaşık problemlerin sistematik bir biçimde incelenmesine olanak tanıyan yapılardır. Bu yapılar, problemleri daha küçük ve işlenebilir birimlere ayırarak analiz edilmesini sağlar. Birbirini takip eden bu küçük birimler üzerinden yürütülen işlemler sonucunda, karmaşık problemler hızlı ve etkin bir şekilde çözüme kavuşturulabilmektedir Zekâ, yaşam içerisinde karşılaşılan karmaşık problemlere eksiksiz, verimli ve etkin çözümler üretebilme yetisi olarak tanımlanabilir. Diğer bir ifadeyle, zekâ algoritma üretebilme melekesiyle de ilişkilendirilmektedir. Yapay zekânın ise üç temel bileşeni bulunmaktadır. Bu bileşenler ve insandaki karşılıkları şu şekilde sıralanabilir (Köroğlu, 2017: 2):

- **Sembolik Çıkarımsama:** Neden-sonuç ilişkilerini kurma yeteneği.
- **Yapay Öğrenme:** Veriler üzerinden genellemeler elde etme, yani öğrenme süreci.
- **Genetik Algoritmalar:** Daha önce bilgi sahibi olunmayan yeni unsurlar üretme, yani icat etme kapasitesi.

Yapay zekâ net, kesin ve doğru bir biçimde tarif edilmiş alanlarda çok iyi sonuçlar alabilmektedir.

3. YAPAY ZEKÂNIN HAYVANCILIKTAKİ ROLÜ VE İLKELERİ

Artan verimlilik ve üretkenlik: Yapay zekâ, çiftlik yönetiminin birçok alanında yemleme, hayvan sağlığı takibi ve çevresel kontrol dâhil karar verme süreçlerini ileri düzeyde geliştirme potansiyeline sahiptir. Gerçek zamanlı veri analizi sayesinde kaynak kullanımı optimize edilerek israf azaltılmakta ve genel verimlilik artırılmaktadır (Rosati, 2024).

Hayvan refahının iyileştirilmesi: Yapay zekâ tabanlı araçlar, hayvanların sağlık ve refahını anlık olarak izleyerek, olası sorunları ortaya çıkmadan öngörebilmekte ve erken müdahalelerle daha etkin bakım imkânı sunmaktadır. Bu yaklaşım hem üretim verimliliğini hem de hayvanların yaşam kalitesini artırmaktadır (Rosati, 2024).

Sürdürülebilirlik: Yapay zekâ teknolojileri, su, yem ve enerji gibi kaynakların etkin kullanımını sağlayarak çevresel etkilerin azaltılmasına katkıda bulunmakta, böylece daha sürdürülebilir tarım uygulamalarının hayata geçirilmesini desteklemektedir (Rosati, 2024).

Değişen yetkinlik gereklilikleri: Yapay zekânın etkin yönetimi, ileri düzey teknik bilgi ve beceriler gerektirmektedir. Bu durum, tarım sektöründe iş gücü profillerinin değişmesine yol açmakta; çiftçilerin ve tarım çalışanlarının yapay zekâ teknolojilerini kullanabilmek için yeni beceriler edinmesini zorunlu kılmaktadır (Rosati, 2024).

Veri erişilebilirliği sorunları: Yapay zekâ modellerinin başarısı, kapsamlı ve çeşitli veri setlerinin mevcudiyetine bağlıdır. Ancak, özellikle farklı türler, çevresel koşullar ve çiftlik ölçeklerini kapsayan yüksek kaliteli veri eksikliği, bu teknolojilerin potansiyelini sınırlayan temel engellerden biridir (Rosati, 2024).

Etik ve gizlilik kaygıları: Yapay zekânın tarım uygulamalarına entegrasyonu, veri güvenliği ve mahremiyetle ilgili önemli tartışmaları gündeme getirmektedir. Ayrıntılı çiftlik verilerinin üçüncü taraflarla paylaşılması, hassas ticari bilgilerin açığa çıkmasına ve güvenlik risklerine yol açabilmektedir (Rosati, 2024).

Karar verme süreçlerine etkiler: Uzun vadeli tahminlerde insan sezgisini aşma potansiyeline sahip olan yapay zekâ, operasyonel kararların giderek daha fazla yapay sistemler tarafından

yönlendirilmesine neden olabilir. Bu durum, çiftlik yönetiminde insan kontrolünün azalmasına dair endişeleri artırmaktadır (Rosati, 2024).

Küresel benimsemedeki eşitsizlikler: Ekonomik ve teknolojik kapasitedeki farklılıklar nedeniyle yapay zekânın tarıma entegrasyonu bölgeler arasında eşitsiz biçimde ilerleyecek; bu da gelişmiş ve gelişmekte olan tarım sektörleri arasındaki uçurumu derinleştirebilecektir (Rosati, 2024).

Yapay zekânın yönetişimi ve kontrolü: Yapay zekânın geliştirilmesi ve uygulanmasının büyük ölçüde az sayıda çok uluslu şirketin elinde toplanması, bu şirketlere olan bağımlılığı artırmakta ve hayvancılık gibi kritik sektörler üzerinde jeopolitik etkilere dair kaygıları gündeme getirmektedir (Rosati, 2024).

Yapay zekâya duyulan güven: Özellikle sonuçların sezgilere aykırı göründüğü durumlarda, kritik kararların yapay zekâya bırakılması çiftçilerin bu teknolojilere olan güvenini zorlamaktadır. Yapay zekânın tarımsal karar alma süreçlerindeki rolü büyüdükçe, güven sorunu daha da önemli bir tartışma alanı hâline gelecektir (Rosati, 2024).

4. HAYVANCILIKTA YAPAY ZEKÂ UYGULAMALARI

Bulanık mantık; tıp, mühendislik ve biyoloji alanlarında olduğu gibi, hayvancılıkta da başarılı bir şekilde uygulanabilmektedir (Akkaptan, 2012). Yapay zekâ teknikleri; hayvan ıslahı, kızgınlık tespiti, mastitis gibi hastalıkların teşhisi, süt ve yumurta gibi hayvansal ürünlerde verim özelliklerinin tahmini gibi birçok alanda kullanılmaktadır (Karakaya, 2025).

Özellikle süt sığırcılığında yapay zekâ, veri odaklı karar alma süreçlerini destekleyerek üretim verimliliğini ve hayvan refahını artırma potansiyeli taşımaktadır. Bilgisayarlı görme sistemleri (CVS), hayvanların kimliklendirilmesi, davranışlarının izlenmesi, yem tüketiminin takibi, vücut ağırlığı tahmini ve hastalık tespiti gibi kritik alanlarda başarıyla uygulanmaktadır (Menezes ver ark., 2024).

Grinspan ve ark. (1994) tarafından yürütülen bir çalışmada, sağmal ineklerin beslenme yöntemi seçiminde bulanık mantık, karar verme aracı olarak kullanılmış ve alınan kararların süt üretimi, vücut değişimleri ve bunlar arasındaki etkileşime dayandığı belirtilmiştir. Bir başka çalışmada ise, sağmal ineklerde aylık üretim verilerini kullanarak ayıklanacak hayvanların belirlenmesinde bulanık mantıktan yararlanmış; bu yöntemin gelecekte oluşturulacak sistemler için örnek teşkil edebileceği ifade edilmiştir (Strasser ve ark., 1997).

İneklerin canlı ağırlık verilerini kullanarak bulanık mantık ve uzman sistemler aracılığıyla pratik yönetim uygulamalarının etkinliğini araştırılmıştır (Malttz, 1997). Harris (1998), farklı kaynaklardan elde edilen çiğ süt örneklerinin hijyenik ve bileşimsel kalite değerlendirmelerini karşılaştırmış; tereyağı, yağsız kuru madde ve toplam kuru madde miktarını bileşimsel kalite değişkenleri olarak, somatik hücre sayısı ile toplam bakteri sayısını ise hijyenik değişkenler olarak kullanmıştır.

Salehi ve ark. (2000), süt veriminin kalitatif analizleri için bir yapay sinir ağı bulanıklaştırıcısı geliştirmiş ve bu modeli Lacroix'in (1998) tek değişkenli bulanıklaştırıcısı ile karşılaştırmıştır. 305 günlük süt verimi, laktasyon sırası, laktasyon günü, test günü süt verimi, standart süt verimi ve sapma parametreleri kullanılarak oluşturulan bulanık kümeler sonucunda, yapay sinir ağlarının süt verimini uzmanlar kadar başarılı şekilde bulanıklaştırabildiği ve tek değişkenli modele kıyasla daha üstün performans sergilediği belirlenmiştir. Bu yöntemin, hayvanların düşük veya yüksek verimli olarak sınıflandırılmasında, ayrıca ayıklama ve beslenme kararlarının alınmasında yararlı olabileceği ifade edilmiştir.

Morag ve ark. (2001), süt verimi ve vücut ağırlığı verilerine dayanarak, rasyonlara katılması gereken kesif yem miktarını bulanık mantık ile belirleyen bir karar destek sistemi geliştirmiştir.

Bu modelin sürü yönetim programlarıyla entegre olabildiği ve çiftçilere optimum rasyon hazırlama sürecinde faydalı bir araç sunduğu rapor edilmiştir. Firk ve ark. (2002b) ise aktivite, süt verimi, süt akış hızı ve elektrik iletkenliği özelliklerini birlikte değerlendirerek bir bulanık mantık modeli kurmuş; modelin hassasiyet ve hata oranlarının, son kızgınlıktan sonra geçen süre dikkate alındığında azaldığını ortaya koymuştur.

Cavero ve ark. (2006), otomatik sağım sistemlerinde mastitis kontrol ve sınıflandırması amacıyla bir bulanık model geliştirmiştir. Elektrik iletkenliği, süt üretim oranı ve süt akım oranı parametreleri kullanılarak mastitis uyarıları üretilmiş ve model, duyarlılık ve hata oranları açısından değerlendirilmiştir. Bulgular, modelin hata oranının yüksek olmasına rağmen, tek değişkenli modellere kıyasla daha başarılı olduğunu göstermiştir.

Dökme tank sütlerinin mikrobiyolojik test sonuçlarına dayalı olarak sürülerin sağım uygulamalarını ve süt kalitesini değerlendirmek amacıyla bulanık tanımlayıcı kümeler geliştirmiştir (Cha ve ark., 2008).

Kramer ve ark. (2009), mastitis ve topallığın kontrol ve sınıflandırılmasına yönelik bulanık mantık tabanlı bir model geliştirmiştir. Süt verimi, tüketilen kuru madde, yem kabı ziyareti sayısı ve süresi, su tüketimi, geçici hastalık bilgileri ve hayvanların hareketliliği gibi parametreler girdi değişkenleri olarak kullanılmıştır. Ancak model, uygulama açısından beklenen performansı sağlayamamıştır.

Yapay zekâ destekli çözümler; otomatik veri toplama, ön işleme, veri düzenleme, algoritma geliştirme ve model uygulama aşamalarını kapsayarak üreticilerin gerçek zamanlı karar alma süreçlerini desteklemektedir. Ayrıca, tahmine dayalı modeller aracılığıyla hastalık dinamiklerini öngören erken uyarı sistemleri olarak işlev görmektedir. Yapay zekâ modellerinin yüksek doğruluk, hassasiyet ve güvenilirlik düzeyi, iklim dostu hayvancılık üretiminde ölçeklenebilir kullanımına olanak tanımakta; böylece ısı stresinin etkilerini azaltarak sürdürülebilir üretimi güvence altına almakta ve küresel ekonominin korunmasına katkı sağlamaktadır (Rebez ve ark. 2024).

Sığır yetiştiriciliğinde kullanılan sensör ve donanım cihazları, hassas hayvancılık uygulamalarının gelişmesiyle birlikte önemli bir dönüşüm sürecine girmiştir. Günümüzde farklı fizyolojik, morfolojik ve davranışsal parametreleri ölçebilen çok çeşitli sensörler mevcuttur. Bu sistemler, hastalıkların erken tespiti, hayvan refahının artırılması ve daha sürdürülebilir üretim süreçlerinin desteklenmesinde kritik bir rol oynamaktadır (Michelena ve ark., 2024).

Sensörlerin stratejik konumlandırılması (çiftlik altyapısı, mera veya doğrudan hayvan üzerinde) etkinlikleri açısından büyük önem taşımaktadır. Kullanım amaçları, çiftlik tipi, çevresel koşullar ve hayvan özellikleri bu seçimde belirleyici faktörlerdir.

Genel olarak sensörler iki ana grupta sınıflandırılmaktadır (Michelena ve ark., 2024):

- **Taşınabilir cihazlar:** Hayvan üzerine takılan hızölçerler, jiroskoplar vb.
- **Taşınamaz cihazlar:** Çiftlikte sabit noktaya yerleştirilen kameralar veya yük hücreleri vb.

Bununla birlikte, sensörler invaziv/invaziv olmayan yapıları ya da veri toplama yöntemleri gibi farklı kriterlere göre de sınıflandırılabilmektedir. Sonuç olarak, bu teknolojiler hem bireysel hayvan hem de sürü düzeyinde yönetimi kolaylaştırarak daha etik, verimli ve çevre dostu hayvancılığa katkı sağlamaktadır (Michelena ve ark., 2024).

Yapay zekâ hayvan refahının arttırılmasına yönelik çalışmalarda da kullanılmaktadır. Essien ve Neethirajan (2025), tarafından hazırlanan makalede, yumurtacı tavuk refahının izlenmesinde geleneksel yöntemlerin yetersizliklerini ortaya koyarak, çok modlu yapay zekâ tabanlı

yaklaşımların devrimsel potansiyelini vurgulamaktadır. İnsan gözlemine ve tek tip sensörlere dayalı geleneksel sistemler, modern ticari ortamların karmaşık refah dinamiklerini yakalayamamaktadır. Görsel, işitsel, çevresel ve fizyolojik verilerin entegrasyonunu mümkün kılan çok modlu yapay zekâ ise bu alanda kritik bir dönüm noktası oluşturmaktadır. Çok modlu yapay zekânın asıl gücü, teknik kapasitesinden öte, hayvanlarla bakıcıları arasındaki iletişim boşluğunu kapatabilmesidir. Stresin akustik ve termal işaretleri, konforun davranışsal göstergeleri ve sağlığın fizyolojik parametrelerini bir araya getirerek kapsamlı bir refah anlatısı oluşturur. Araştırmalar, bu yaklaşımın refah değerlendirmelerinde **%90'ın üzerinde doğruluk** sağladığını; tek modlu sistemlerin ise genellikle **%60–75** aralığında kaldığını ortaya koymaktadır. Sonuç olarak, çok modlu yapay zekâ yalnızca bir teknoloji değil, aynı zamanda **etik, bilimsel ve bütüncül bir refah yönetimi paradigmasının temel taşı** olarak öne çıkmaktadır.

Kanatlı üretiminde de yapay zekâ, makine öğrenimi ve **IoT tabanlı sensör teknolojilerinin entegrasyonunun** nasıl dönüştürücü bir rol üstlenebileceği üzerine çalışma yapılmıştır. Çalışma, hastalık tespiti, davranış analizi, çevresel kontrol, otomasyon ve verimlilik optimizasyonu olmak üzere beş temel alanda mevcut uygulamaları sınıflandırmaktadır. Bulgular, özellikle **YOLOv8 tabanlı CNN modellerinin** görsel hastalık tespitinde %90'ın üzerinde doğruluk sağladığını; IoT sensörlerinin ise sıcaklık, nem ve sürü davranışını sürekli izleyerek otomatik iklimlendirme ve yemleme gibi süreçleri optimize ettiğini ortaya koymaktadır. Buna karşın, yüksek kurulum maliyetleri, sınırlı altyapı ve küçük ölçekli yetiştiricilerin dijital okuryazarlık eksikliği, yaygın benimsemenin önünde önemli engeller oluşturmaktadır. Araştırma boşlukları arasında veri setlerinin genellenebilirliği, çok modlu sensör füzyonu ve ölçeklenebilir saha uygulamaları öne çıkmaktadır (Natsir ve ark., 2025).

Yapay zekâ ve IoT; kanatlı yetiştiriciliğinde **hayvan refahını artıran, operasyonel verimliliği geliştiren ve sürdürülebilirliği güçlendiren** veri odaklı karar mekanizmalarının temelini oluşturma potansiyeline sahiptir. Ancak bu dönüşümün başarısı, teknik yeniliklerin yanı sıra **sağlam metodolojiler** ve **kapsayıcı uygulama stratejileri** ile mümkündür.

Son yıllarda geliştirilen yapay zekâ algoritmaları, hayvan performansının değerlendirilmesinde de kayda değer iyileşmeler sağlamıştır. Yapay zekâ tabanlı araçlar; sağlam, güvenilir ve kapsamlı performans ölçümleri sunarak ısı stresine bağlı üretim kayıplarını en aza indirme kapasitesine sahiptir. Davranışsal, fizyolojik ve sağlık göstergelerine dayalı otomatik izleme yöntemleri, makine öğrenmesi, sinir ağları ve derin öğrenme gibi teknolojilerin gelişimiyle birlikte ısı stresi yönetiminde yaygın kabul görmektedir (Rebez ve ark. 2024).

Koçak (2018), tarafından yapılan çalışmada ise **Arduino ve bulanık mantık kullanılarak arı kovanlarının uzaktan takip ve kontrolünü sağlayan bir sistem** tasarlanmıştır. Sistem; kovan içi sıcaklık ve nemin izlenmesi ve kontrolünü gerçekleştirerek bal verimini artırmayı ve iklim koşullarının arılar üzerindeki olumsuz etkilerini azaltmayı amaçlamaktadır. Çalışmanın literatüre katkıları; arı kovanlarının web/mobil arayüz üzerinden kontrol edilebilmesi, manuel ve bulanık mantık tabanlı iki farklı yöntemle yönetilebilmesi ve adaptif yapısıyla farklı çevre koşullarına uyum sağlayabilmesidir. Ayrıca, sisteme yeni sensörler eklenerek kullanılabilirliğinin daha da artırılabileceği öngörülmektedir.

5. SONUÇ

Yapay zekâ destekli sistemler, otomatik veri toplama, analiz ve modelleme yetenekleri sayesinde hastalıkların erken tespiti ve tahmine dayalı yönetim uygulamalarının geliştirilmesine olanak tanımakta; böylece hayvan sağlığı ve refahı üzerinde doğrudan olumlu etkiler yaratmaktadır. Ayrıca iklim değişikliğine bağlı ısı stresi gibi çevresel faktörlerin etkilerini azaltma potansiyeli, sürdürülebilir üretim hedefleri açısından yapay zekâyı stratejik bir araç haline getirmektedir. Sensör teknolojilerinin gelişimi ve doğru konumlandırılmasıyla birlikte,

bireysel hayvan düzeyinde bile davranışsal ve fizyolojik verilerin toplanması mümkün hâle gelmiş; bu da daha etik, çevre dostu ve verimli üretim sistemlerinin tasarlanmasını sağlamıştır.

Çok modlu yapay zekâ yaklaşımları, hayvan refahı izleme ve değerlendirme süreçlerinde devrimsel bir potansiyel ortaya koymakta ve insan gözlemine dayalı geleneksel yöntemlerin ötesine geçmektedir. Kanatlı yetiştiriciliğinde de makine öğrenimi ve IoT entegrasyonu, çevresel koşulların optimize edilmesi, davranış analizi ve otomasyonun sağlanması gibi alanlarda önemli kazanımlar sunmaktadır. Ancak yüksek kurulum maliyetleri, altyapı eksiklikleri ve dijital okuryazarlık düzeyinin yetersizliği, bu teknolojilerin yaygınlaşmasının önünde halen önemli engeller olarak durmaktadır.

Sonuç olarak, yapay zekâ ve ilgili teknolojilerin hayvancılık sektöründe sunduğu olanaklar, yalnızca verimlilik ve üretim artışıyla sınırlı kalmayıp; hayvan refahının iyileştirilmesi, çevresel etkilerin azaltılması ve sürdürülebilir üretim sistemlerinin geliştirilmesi açısından da büyük önem taşımaktadır. Gelecekte bu teknolojilerin daha yaygın bir şekilde kullanımı, hayvancılığın küresel ölçekte daha rekabetçi, çevre dostu ve etik bir yapıya kavuşmasına katkı sağlayacaktır.

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CLIMATIC FACTORS AFFECTING PRODUCTIVITY IN SILKWORM (*Bombyx mori* l.)

Şeniz Öziş Altınçekiç

Doç. Dr., Bursa Uludağ Üniversitesi, Ziraat Fakültesi, Zootekni Bölümü, Bursa, Türkiye.

ORCID: 0000-0001-9044-8092

Email: seniz@uludag.edu.tr

Arda Sözcü

Doç. Dr., Bursa Uludağ Üniversitesi, Ziraat Fakültesi, Zootekni Bölümü, Bursa, Türkiye.

ORCID: 0000-0002-0955-4371

Email: ardasozcu@uludag.edu.tr

Ezgi Şenses

Arş. Gör., Bursa Uludağ Üniversitesi, Ziraat Fakültesi, Zootekni Bölümü, Bursa, Türkiye

ORCID: 0000-0003-3707-6415

Email: ezgisenses@uludag.edu.tr

ABSTRACT

The silkworm (*Bombyx mori L.*) is a holometabolous species with distinct morphological and physiological characteristics in its egg, larva, pupa, and adult stages, and is of great economic importance in sericulture. Larvae undergo a larval stage lasting 25-30 days from hatching to cocoon spinning; this period consists of five instars. The first, second, and third instars represent the juvenile stage, while the fourth and fifth instars represent the adult stage. All developmental stages of the silkworm are extremely sensitive to environmental conditions. The most critical abiotic factors are temperature, humidity, and air. Temperature directly affects the larvae's metabolic rate, feeding behavior, growth period, and energy use. The optimal temperature range is 23-28°C, and 20-26°C is recommended for the healthy development of eggs. Low temperatures slow feeding, while high temperatures are associated with early pupation, fiber thinning, and increased mortality. Relative humidity has both direct and indirect effects on the growth and development of silkworms. Directly, it accelerates the physiological activities of the larvae; indirectly, it affects the quality of the mulberry leaves, which are their food source. Low humidity leads to drying and growth delays, increasing the larvae's susceptibility to disease. Ventilation and air quality are critical for respiration and metabolic processes. Larvae breathe through air holes in their bodies; low oxygen or high CO_2, NH_3, and SO_2 levels slow growth, reduce feeding, and decrease cocoon quality. Oxygen requirements are particularly high in the fourth and fifth instars. Therefore, adequate air circulation and removal of toxic gases are essential for healthy development and high-quality silk production. This study aims to comprehensively examine the climatic requirements of silkworms at different developmental stages and the effects of changes in environmental conditions on larval growth, health, and cocoon yield.

Keywords: Bombyx mori, silkworm, rearing, climatic factors

İPEK BÖCEĞİNDE *(Bombyx mori* l.*)* VERİMLİLİĞİ ETKİLEYEN İKLİMSEL FAKTÖRLER

ÖZET

İpek böceği (*Bombyx mori L.*), yumurta, larva, pupa ve ergin evreleri morfolojik ve fizyolojik özellikleri bakımından farklı olan holometabol bir türdür ve kültür ipekçiliğinde ekonomik açıdan büyük öneme sahiptir. Larvalar, yumurtadan çıkışlarından koza örmeye kadar geçen 25-30 günlük süreyi kapsayan larva devresinden geçer; bu dönem beş yaştan oluşur. I., II. ve III. yaşlar genç dönemi, IV. ve V. yaşlar ise yetişkin dönemi temsil eder. İpek böceğinin tüm gelişim evreleri çevresel koşullara son derece duyarlıdır. En kritik abiyotik faktörler sıcaklık, nem ve havadır. Sıcaklık, larvaların metabolizma hızını, beslenme davranışlarını, büyüme süresini ve enerji kullanımını doğrudan etkiler. Optimal sıcaklık aralığı 23-28°C olup, yumurtaların sağlıklı gelişimi için 20-26°C önerilmektedir. Düşük sıcaklık beslenmeyi yavaşlatırken, yüksek sıcaklık erken pupasyon, lif incelmesi ve mortalite artışı ile ilişkilidir. Nem, ipek böceklerinin büyüme ve gelişmesi üzerinde hem doğrudan hem dolaylı etkilere sahiptir. Doğrudan olarak larvaların fizyolojik aktivitelerini hızlandırır; dolaylı olarak ise besin kaynağı olan dut yapraklarının kalitesini etkiler. Düşük nem kuruma ve büyüme gecikmesine yol açarak larvaların hastalıklara karşı duyarlılığını artırır. Havalandırma ve hava kalitesi, solunum ve metabolik süreçler açısından kritik öneme sahiptir. Larvalar vücutlarındaki hava delikleri aracılığıyla solunum yapar; düşük oksijen veya yüksek CO_2, NH_3 ve SO_2 seviyeleri büyümeyi yavaşlatır, beslenmeyi azaltır ve koza kalitesini düşürür. Dördüncü ve beşinci instarlarda oksijen gereksinimi özellikle yüksektir. Bu nedenle yeterli hava sirkülasyonu ve zehirli gazların uzaklaştırılması, sağlıklı gelişim ve yüksek kaliteli ipek üretimi için zorunludur. Bu çalışma, ipek böceğinin farklı gelişim evrelerindeki iklimsel gereksinimlerini ve çevresel koşullardaki değişimlerin larvaların büyümesi, sağlığı ve koza verimliliği üzerindeki etkilerini kapsamlı bir biçimde incelemeyi amaçlamaktadır.

Anahtar Sözcükler: Bombyx mori, ipek böceği, yetiştirme, iklimsel faktörler

INTRODUCTION

The mulberry silkworm (*Bombyx mori L.*) is a fully domesticated insect belonging to the order of Lepidoptera, widely cultivated worldwide for silk production, and produces approximately 95% of commercial silk (Bajwa et al. 2017). *Bombyx mori* (B. mori), essentially a monophagous insect that feeds exclusively on mulberry leaves (Morus spp.), and its growth, development, cocoon, and silk production are entirely dependent on the quantity and quality of mulberry leaves (Hailu 2016). B. mori is an economically important holometabolous species, meaning it undergoes metamorphosis, with distinct physiological and morphological characteristics in its egg, larva, pupa, and adult stages (Figure 1) (Agustarini et al. 2020). The 25-30-day period from the hatching of silkworm larvae to the spinning of cocoons is called the larval stage, and this period consists of five instars. The first, second, and third instars are called the young stage, while the fourth and fifth instars are referred to as the adult stage (Şahan 2011).

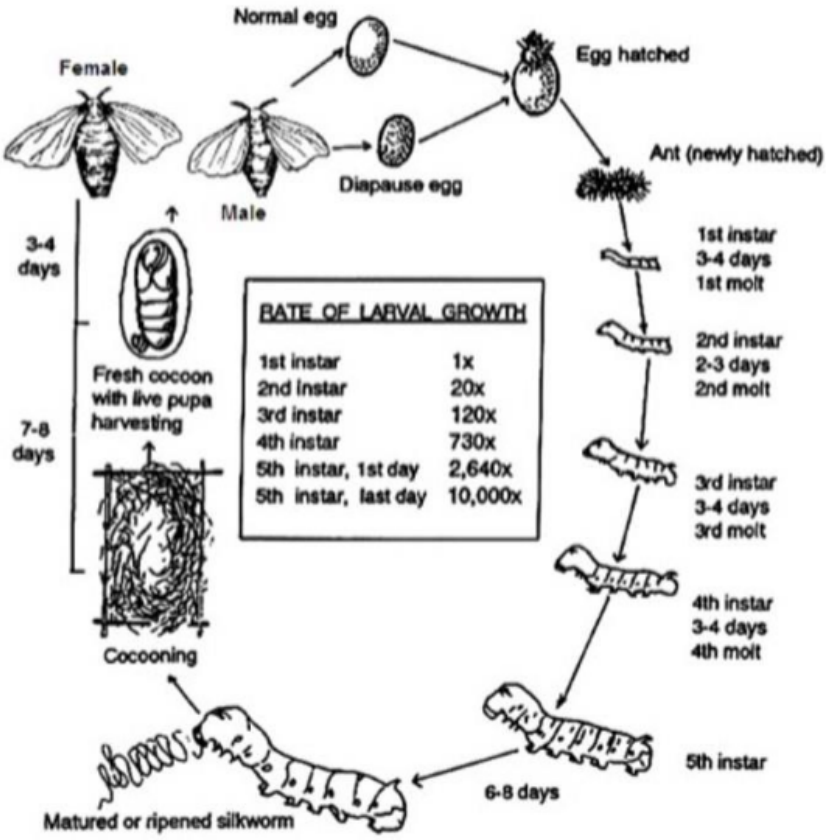


Figure 1. Silkworm breeding process (Agustarini et al. 2020)

In the young stage, larvae have higher temperature and humidity requirements compared to the adult stage. Because during this period, larvae actively feed and grow very quickly. If they pass through this young stage healthily and mature, they become more resilient to adverse conditions in the adult stage and can successfully spin cocoons (Malik and Reddy 2007). The aim of silkworm farming is to produce high-quality cocoons with a high silk content by utilizing the existing optimal environmental conditions. The silkworm is inherently very delicate and sensitive to environmental conditions. During cultivation, ecological factors such as temperature, humidity, light, and air primarily have a significant impact on the growth of larvae and ultimately on the quality of the cocoon product. However, other factors such as the quality and quantity of leaf supply, feeding regimen, and bed cleanliness, which are part of the rearing techniques, also affect the quality of the obtained cocoons (Gupta and Dubey 2021). Jumagulov et al. (2021) reported that the larger the size of the silkworm rearing rooms, the more difficult

it is to maintain a comfortable temperature, relative humidity, and other environmental factors, resulting in changes in the development of silkworms and the cocoon spinning processes.

Silkworms are poikilothermic organisms, meaning their body temperature is roughly the same as the temperature of the surrounding microenvironment, and since it is controlled by this environment, their body temperature is also quite variable, making them cold-blooded animals. Therefore, since biotic and abiotic factors significantly influence the physiological activities of silkworms, they generally determine their productivity and fate (Bora and Saikia 2022). In this case, the organism's ability to adapt to an unstable or extreme environment, that is, its ability to survive in various environments, is important. Some organisms have the ability to cope with environmental stress by specifically altering their physiology, morphology, and behavioral strategies (Lemoine et al. 2014). If environmental stress originates from biotic factors, the organism makes behavioral changes particularly according to its interactions with biotic factors (Badyaev 2005). On the contrary, if environmental stress originates from abiotic factors, the organism's response typically manifests as physiological changes that result in phenotypic alterations, such as shortening or lengthening the instar stage period in the life cycle and continuing to the next life stage (Whitman and Agrawal 2009). Resistance to abiotic factors varies among different silkworm strains from the embryonic stage (Manjunatha et al. 2010). Among the four commercially used silkworm species, the fully domesticated B. mori is much more sensitive to sudden fluctuations in temperature, humidity, and other abiotic factors. Therefore, the ability of B. mori to adapt to environmental conditions is quite different from that of wild silkworms (Rahmathulla 2012).

In this study, environmental factors such as temperature, humidity, air circulation, gases, and light that affect the growth, development, productivity, and silk quality of B. mori have been addressed.

Temperature

Among abiotic factors, temperature is the most important environmental factor affecting insect behavior, development, survival, and reproduction. All insect species have specific temperature preferences for normal growth, and very high temperatures can cause various developmental disorders in both larval and adult stages, slowing growth (Çelik Biçer et al. 2023). Silkworm physiology—metabolism, enzyme activity, nutrient conversion, digestion, assimilation, excretion, neural stimulation, and hormonal activity—is affected by environmental temperature. In other words, because silkworms are cold-blooded animals, temperature has a direct impact on physiological activities that play a significant role in their growth and development (Ibragimov and Tokhirjonova 2023). Consequently, it also affects hatching, larval growth, the quality of cocoons produced, and adult fertility.

The recommended temperature for healthy development of silkworm eggs ranges from +20°C to +26°C, while the temperature range required for optimal productivity is 23°C to 28°C (Şahan 2011). According to Mărghitaş et al. (2009), the egg stage is the most time-consuming stage, as it takes more than nine months in monovoltines. To maintain egg viability, embryogenesis is reduced using temperature. After the B. mori female lays the eggs, the temperature is gradually lowered to 8°C and then to 2.5°C. If an incubation temperature of 24-26˚C, a relative humidity of 75-85%, and a lighting period of 18 hours are applied during incubation period, hatchability could be achieved at higher percentage betweem 70% to 100% (Anton et al. 2015). Kumar and Ravishankar (2024) reported that the egg-laying ability of B. mori tended to increase as the temperature increased from 14˚C to 18˚C and remained constant until the temperature reached 26˚C, where it started to decrease as the temperature increased to 34˚C. The minimum number of eggs laid by a female butterfly at 14˚C was reported as 249, while the maximum number of eggs laid by a female at 26˚C was reported as 386 (Kumar and Ravishankar (2024).

Krishnaswami (1978) stated that the ideal temperature and humidity conditions for egg incubation should be 25°C and 80%, respectively. In addition, it was emphasized that the importance of maintaining the relative humidity of the incubation around 80% has crucial importance to prevent the eggs from drying out and that only under optimum conditions of temperature and humidity during incubation period could provide the development of the embryo stably and properly. Kumar and Ravishankar (2024) reported that as the temperature increased from 10˚C to 14˚C, the incubation period of the eggs decreased from 21.66 days to 15.16 days, and it lasted 9.46 days at 26˚C, and as the temperature increased to 38˚C, the incubation period significantly decreased to 6.56 days. Furthermore, low (50%) or high (90%) relative humidity levels have negative effects on female butterfly fecundity, egg hatchability, and pupal and larval mortality. Relative humidity levels below 70% lead to lower hatchability due to unfertilized eggs and poor egg formation, while relative humidity above 80% facilitates disease transmission and leads to larval mortality (Hussain et al. 2011a).

In the juvenile stage, larvae are tolerant to high temperatures, which contributes to their survival and cocoon characteristics. Furthermore, temperature is directly related to larval growth, so wide fluctuations in temperature are detrimental to larval development (Haisley 2021). Sinha and Sanyal (2013) reported that temperature fluctuations during rearing lead to the death of silkworm larvae. During silkworm rearing, an increase in temperature increases various functions, while a decrease in temperature decreases their activity. Especially in the adult stage, increasing temperature accelerates larval growth and development, shortening the larval period, resulting in the formation of cocoons of lower weight and quality. Low temperatures, on the other hand, slow growth and development and prolong the larval period, resulting in a retardation of larval growth (Singh et al. 2009). Similarly, Shirota (1992), and Tazima and Ohuma (1995) reported that silkworms are more sensitive to high temperatures in the fourth and fifth instars. This is because, particularly in the first two instars, silkworm larvae consume only 1% of the mulberry leaves of total consumed leaves. Due to the lower consumption of mulberry leaves, enzyme activity in digestive process decreases, resulting in lower heat production. This is the main reason for maintaining a relatively higher temperature in the rearing chamber during the juvenile stage. However, the opposite trend is observed in the fourth and fifth instars, as larvae consume almost 94% of the total mulberry leaves. This leads to increased enzyme activity in digestion, resulting in an increment of heat production in the silkworm body. Therefore, maintaining a relatively lower temperature in the rearing chamber is important (Jumagulov et al. 2021). B. mori reaches maximum oviposition and fecundity at 25-36°C, and any fluctuation in this level reduces oviposition and fecundity (Mathur et al. 1988). Sarkar et al. (2008) suggested that 24-28°C is ideal for larval growth. The optimum temperature for normal growth of silkworms is between 20°C and 28°C, and the desired temperature for maximum productivity is between 23°C and 28°C (Rahmathulla 2012). It has been reported that good quality cocoons are produced in the temperature range between 22 and 27°C, and cocoon quality is lower above these levels (Krishanswami et al. 1973). Rahmatulla (2012) also pointed out that environmental conditions such as temperature and relative humidity, which vary from season to season, must be constantly controlled for consistent cocoon production. When the temperature rises above 30°C, the health of the larva is directly affected, while if the temperature is below 20°C, all physiological activities in the larvae, especially in the early stages, decline, the larvae remain very weak and become susceptible to various diseases (Gupta and Dubey 2021). Furthermore, high temperatures negatively affect almost all biological processes, including the rates of biochemical and physiological reactions, and can ultimately affect the silkworm's cocoon quality, quantity, and subsequent silk production (Willmer et al. 2004). Exposure of larvae and cocoons to temperatures of 35°C or above results in poor performance in terms of egg number and egg fertility, as well as the laying of unfertilized eggs due to the high temperatures during rearing, cocooning, mating, and

oviposition (Datta et al. 2001). Ramachandra et al. (2001) also reported that the cocoon formation process is significantly affected by fluctuations in temperature and humidity. Pezhman and Jagadeesh Kumar (2010) reported that good-quality cocoons are produced at temperatures between 22 and 27°C, with cocoon quality deteriorating at temperatures above these levels. Khan (2014) stated that temperature and humidity play a vital role in silkworm growth and development and cocoon quality, and reported that the optimal environmental conditions are 25±1°C and 80% relative humidity. Pal et al. (2014) observed a lower mortality rate and higher pupal and shell weights at 24°C. Sarkhel et al. (2017) observed that larval development was better at 22-26°C and 75-85% relative humidity, and that pupal and shell weights were higher at an average temperature of 22-24°C and 80-85% relative humidity. However, the researchers noted that larval weight decreased as temperature increased. They also reported that high temperatures did not support productivity, leading to decreased cocoon quality due to accelerated growth rates, and also mulberry leaves fed to the silkworms wilted, reducing their nutritional intake. Verma et al. (2016) also reported that mortality was lowest in B. mori larvae reared at 22-26°C and 80-85% relative humidity, and that pupal and shell weights were higher. Sisodia and Gaherwal (2017) reported that the suitable temperature for the development of B. mori is 25ºC and humidity is 75-80% and that in this environmental condition, cocoon weight (1.701 g), pupal weight (1.532 g) and silk filament length (800 m) were the highest and the mortality rate in larvae was the lowest (12%). Ramachandra et al. (2001) reported that the cocoon spinning speed of B. mori larvae was slow at 22°C and fast at 38°C and the duration for cocoon completion was longest at 98±2% relative humidity and the shortest at 40±2% relative humidity. However, they stated that since quality cocoons are obtained at 22°C and 65±5% relative humidity, care should be taken to maintain these temperature and relative humidity during cocoon spinning. Sharma et al. (2023) reported that when the temperature was kept at 25±1ºC, the maximum values of cocoon weight (1.80 g), shell weight (0.38 g) and shell ratio (21.10%) were observed, and when the temperature was increased to 35±1ºC, the lowest average values of cocoon weight (0.83 g), shell weight (0.06 g) and shell ratio (7.21%) were obtained. Mishra (2018) reported that cocoon shell weight increased as temperature increased between 15°C and 25°C, from 0.124 g to 0.192 g, while temperatures above 25°C caused a gradual decrease in cocoon shell weight. Umarov and Nasirillaev (2023) reported that when these environmental conditions were extreme, the cocoon lost 1.11–1.39 g in weight, depending on the characteristics of the silkworm race. Dahi et al. (2016) found that 20°C significantly increased cocoon weight (1.57 g) compared to 23°C and 26°C, but the increase in both cocoon shell weight (0.29 g) and cocoon shell ratio (19.03%) was not significant compared to the other two temperatures. For cocoon spinning parameters, they reported that both the longest silk filament length (993.8 m) and silk ratio (49.19%) were achieved at 20°C. Similarly, they reported that pupal rate, pupal weight and egg production (number of eggs per female) were significantly higher at 20°C and 23°C than at 26°C. The researchers reported that while 20°C was slightly lower than generally recommended, it did not significantly affect the reproductive behavior and fertility of the silkworm, perhaps resulting in fewer eggs laid, but the female could mate with more than one male, resulting in more eggs laid and therefore fertilized eggs. Wanule and Balkhande (2013) reported that adult B. mori larvae died and could not lay eggs when kept at 40±5°C, while reproductive behavior and fertility were affected at 30±1°C, and therefore laid the least number of eggs and died within 72 hours. Datta et al. (2001) and Pandey and Tripathi (2008) reported that lower temperatures are always better than higher temperatures in terms of silkworm productivity and larval duration for different stages.

The weight of the silk gland is a very important parameter for cocoon production. Temperature fluctuation causes a decrease in silk production and silk gland weight (Hsich et al. 1995). Mishra (2018) reported that the silk gland weight of V. instar larvae increased with temperature

change between 15 and 25°C, from 0.132 g to 0.267 g, and gradually decreased above 25°C. Jeena and Quraiza (2022) reported that at 25°C, B. mori larval weight (2248 mg), silk gland ratio (41.37%), cocoon weight (1240 mg), pupa weight (950 mg), shell weight (290 mg), shell ratio (23.38%) and silk index (1.26) increased significantly and reached the highest level, which helped to increase the productivity of silkworm.

Because silkworms cannot regulate their body temperature according to the ambient temperature, the rearing room temperature must be adjusted using stoves or electric heaters during the first days of rearing (Gülseren and Sipahioğlu 1992). The room temperature should be kept as constant as possible throughout all stages of the silkworm's life, and sudden changes should be avoided to avoid negatively affecting their productivity. When the temperature in the rearing room is too high, practices such as periodically moistening the floor with water, placing wet clothes on windows and doors and constantly wetting them, and using paraffin paper on feeding tables until adulthood are reached are employed. These methods used to lower the ambient temperature generally increase the humidity in the rearing room. It is generally estimated that a 4% increase in relative humidity can lower the temperature by 1°C (Sarkar et al. 2016). Furthermore, doors and windows should be kept closed, especially at night. Later in the day, as the outside temperature rises, doors and windows should be opened (Şahan 2011).

Humidity

Humidity is the most important and strongest abiotic factor for silkworm growth and development after temperature. However, the combined effects of temperature and relative humidity largely determine silkworm growth and the production of high-quality cocoons (Tanjung et al. 2017). Humidity has both direct and indirect effects on silkworm growth and development. It directly accelerates the larval physiological functions, helping to reduce the length of the silkworm's growth period. It indirectly affects the rate of wilting of leaves in larval beds, making them unsuitable for silkworm consumption, which in turn delays larval growth. As a result, the larvae remain weak and susceptible to disease (Haisley 2021).

During incubation, maintaining an average humidity of 80% is crucial for normal embryonic growth. If humidity reduces below 70% during incubation, it affects hatching (Singh et al. 2009). Larval water content varies according to instar stage, particularly increasing after molting until the first molt. Newly hatched larvae have the lowest water content, remaining almost constant at the end of the fourth instar. Fifth-instar water content is highest in newly molted larvae and lowest in mature larvae at the end of the fifth instar. Therefore, first-instar larvae have a physiological need for more water, and therefore, the ambient humidity is higher. They accumulate high levels of water in their bodies by feeding on mulberry leaves, which have high water content (Sarkar 2018). Humidity varies not only seasonally but also, like temperatures, throughout the day.

For successful silkworm rearing, the humidity in the rearing chambers must be constantly monitored throughout the day. During the early stages of feeding, feeding tables are covered with paraffin paper to maintain humidity and prevent the leaves from drying out (Haisley 2021). In contrast, fifth-instar larvae require water at a lower level than the water content of mulberry leaves, so the humidity is kept lower (Sarkar 2018). The heat required by silkworms in the rearing chamber is the difference between the heat loss from structural elements and ventilation and the heat radiated by the larvae. However, it is assumed that silkworms do not release heat or moisture to their environment outside of the fifth instar. Therefore, the heat required by silkworms is equal to the heat loss from structural elements and ventilation. During the fifth instar (just before cocoon spinning), 100 larvae release approximately 40 ml of urine, and this value is approximately 6,400 g for 16,000 larvae (the

specific gravity of urine is taken as 1 g/cm^3). Therefore, the relative humidity in the feeding rooms is accepted as 70% for V. instar in the growing room (Gençoğlan and Başpınar 2016).

Gençoğlan and Başpınar (2016) reported that the heat requirement of the silkworm decreases from the 1st to the 4th instar stage, but increases again in the 5th instar stage. Hussain et al. (2011) reported that silkworm performance differs significantly from each other under various temperature and humidity exposures during the 4th and 5th instars, that silkworm performance generally remains constant at 25°C and 75% relative humidity, that hatching and pupal rates decrease when exposed to an environment above 25±1°C and below 70% relative humidity, and that even at 25°C, lower relative humidity (55 and 65%) causes higher larval mortality. However, they stated that the highest larval mortality rate (11,92%) was observed at 35°C and 55% relative humidity. Kaleem et al. (2011) reported that changing temperature and humidity levels affect both the quantity and quality of silkworms, and that while the mortality rate in larvae was 40% at 25°C and 70% relative humidity, development was good at 20°C and 80% relative humidity.

Lakshminarayana et al. (2003) reported that under natural day photoperiodic (12:12 h) conditions in B. mori, extreme temperature (35%) and humidity (80%) reduced both molting and larval viability. They stated that temperature and humidity, especially during molting, created a synergistic effect and significantly affected silkworm viability. Gowda and Reddy (2007) reported that the detrimental effects of high temperature (30°C±1) and high relative humidity (80±5%) on the rearing and cocoon spinning of silkworm larvae were more pronounced than other temperature and relative humidity treatments. They also showed that cocoon characters of larvae affected by high temperature and relative humidity could be improved by providing ideal environmental conditions even during the cocoon spinning stage and that high temperature and low humidity had a greater effect on the rearing stage than on the cocoon spinning stage. Rahmathulla et al. (2004) reported that in order to obtain high quality cocoons, the water content of the cocoon layer must be below 20%, and if the ambient humidity is high during cocoon weaving, the water in the cocoon and the body of the silkworm gradually evaporates, affecting the structure of the sericin.

Ventilation and Lighting

Air quality in the rearing environment plays a crucial role in silkworm health and cocoon production. Silkworms breathe through blowholes located on the sides of their bodies, and the air they breathe directly affects their physiological functions. Poor air quality, characterized by low oxygen levels or the presence of harmful gases, leads to a decline in silkworm health and a decrease in silk quality (Amit Kumar et al. 2021). Therefore, silkworms, like other living creatures, need clean air. Larvae, especially in the fourth and fifth instars, have high oxygen requirements. Oxygen is vital for silkworm respiration and general metabolic processes. Inadequate oxygen levels can cause hypoxia, leading to lethargy, decreased feeding, and stunted growth (Subhan et al. 2013). When stoves are used to heat the rearing chamber during rearing, gases are produced that alter the air composition within the facility.

Carbon dioxide (CO_2), ammonia (NH_3), and sulfur dioxide (SO_2) are some of the gases released in rearing facilities due to the fermentation of animal and plant wastes and human activity (Rahmathulla 2012). Because these gases are harmful to silkworms, the ambient air must be kept clean with adequate ventilation to keep these toxic gases at low levels. The freshness of the air in rearing rooms can be assessed by the CO_2 concentration. The amount of CO_2 exhaled by silkworms through respiration increases with increasing body temperature during the adult period (Sarkar 2018). Concentrations of 1% CO_2, 0.02% SO_2, and 0.1% NH_3 in the air are acceptable limits for B. mori rearing (Singh et al. 2009). If the CO_2 concentration in the rearing room air exceeds 2%, larval development slows down (Haisley 2021). Lee (1999)

reported that high CO_2 levels make silkworms lethargic, reducing feeding efficiency and causing slower growth, leading to smaller cocoons (Amit Kumar et al. 2021).

Young larvae are more sensitive to toxic gases, so ventilation is beneficial in reducing polluted air levels (Grekov et al. 2005). Ventilation helps ensure a constant supply of fresh air, removes excess CO_2, and prevents the accumulation of harmful gases. While traditional rearing typically utilizes natural ventilation through windows and doors, modern silkworm rearing utilizes mechanical ventilation systems that provide better air quality control. These systems not only improve the health and productivity of silkworms but also contribute to more consistent cocoon quality (Amit Kumar et al. 2021). In silkworms, a 1.0 m/s airflow in rearing chambers during the fifth instar, compared to zero ventilation, has been reported to reduce larval mortality and increase leaf consumption and digestibility, leading to increased larval weight, cocoon weight, and pupal rate (Awasthi 2022).

Silkworm larvae are sensitive to light and tend to move toward dim light. They dislike both intense light and complete darkness, generally preferring low light of 15 to 20 lux (Grekov et al. 2005). Silkworms' light requirements change as their life stages progress. In early larval stages, silkworms are more tolerant of light and require a balanced light-dark cycle to regulate their feeding and growth (Oripovich and Ramazonovich 2020). Juvenile larvae generally exhibit positive phototropism, while adults exhibit negative phototropism (Grekov et al. 2005). Adult larvae perform better under cycles of 16 h light and 8 h dark, while juvenile larvae prefer a 16-h dark phase and an 8-h photoperiod. If larvae are kept in constant darkness or intense light, growth and metamorphosis are disrupted. Furthermore, excessive light exposure can cause stress in larvae, leading to erratic movements and poor feeding. Consequently, both larvae and cocoons lose weight (Awasthi 2022). However, light exposure influences silkworms' circadian rhythms, affecting activities such as feeding and resting. Therefore, appropriate light management plays a crucial role in ensuring silkworms have a consistent and stable growth cycle (Amit Kumar et al. 2021).

Light stimuli (light color, wavelength, and ambient light intensity) are also crucial for larval hatching behavior in the rearing of B. mori for silk production. Hatching rhythms are a fundamental part of the survival mechanisms of newly hatched larvae, which are vulnerable to attack, and are determined by the organism's interactions with its environment. In silkworm rearing, hatching behavior is controlled by light stimuli, in addition to photoperiod, like a biological clock (Tao et al. 2017). Tanaka (1966) reported that light and constant darkness conditions caused a loss of the hatching rhythm in larvae. Tao et al. (2017) stated that 12-h light: 12-h dark photoperiod conditions regulate the hatching rhythm of B. mori through a circadian negative feedback loop. Faruki et al. (2007) reported a gradual decrease in hatching percentages for Lepidoptera when exposed to short-wavelength ultraviolet light (254 nm) for different durations. Iqbal et al. (2008) found that the average life cycle of B. mori under conditions of 25±2 ºC temperature and 70±10% relative humidity, complete darkness (24 hours) and complete light (24 hours) was 62 days in the dark and 68 days in the light, the average cocoon weight was 1.06 g in the dark and 0.9 g in the light, the average shell weight was 0.2 g in the dark and 0.16 g in the light, the shell ratio was 19.40 g in the dark and 18.35 g in the light, the mortality rate of the larvae was 13.3% in the dark and 24.4% in the light, and they reported that in general, the larvae reared in the dark were found to be significantly better than the larvae kept in the light conditions in terms of the examined parameters. Abdelaal et al. (2018) compared the effects of light color (green, blue, and red light) and exposure time (12 and 24 hours) on the length (m), weight (g), and dimensions (denier) of silk fiber obtained from the cocoons of B. mori larvae and reported that the longest silk (1119.2 m) and the highest average silk filament weight (0.228 g) were obtained in larvae exposed to green light for 24 hours. According to Sarkar (2018), the larval instar period was prolonged, and body weight and cocoon

shell weight increased in silkworms reared under purple light. Rani and James (2024) found that the larval life cycle of B. mori was 18 and 16 days under conditions of 25±2ºC, 70±5% relative humidity, continuous artificial light (7 watts) and daylight, respectively, and the larval weight of V. instar was 2.40 and 2.80 g, respectively. They concluded that because silkworms are naturally active during the day, exposure to artificial light has a positive effect on the life cycle by stimulating their feeding and growth rate, and that artificial light applications can be successfully used in rearing. Similarly, Taha (2017) suggested the use of LED light as a non-heat-emitting light source to increase hatchability and shorten the incubation period in B. mori embryos during the final stage of diapause. Bharathi and Yungen (2008) studied the effects of 20-watt ultraviolet light applied for 30, 60, or 120 minutes at a height of 40 cm above the first-day V. instar larvae on the biosynthetic activities of silk glands. They reported that 60 and 120 minutes of ultraviolet light application caused a significant decrease in silk gland weight, total protein, free amino acids, RNA, and carbohydrate levels, but 30 minutes of application had no effect. Suji et al. (2022) reported that light has the potential to stimulate protein and carbohydrate synthesis in B. mori, that 3-watt light exposure caused significant changes in economic parameters such as cocoon weight, shell weight, shell ratio and sericin in B. mori larvae, providing a better performance, that 5-watt light exposure led to the highest protein (10.71 mg/g) and the highest fibroin amount (65.50%) in the silk gland, while all of these economic parameters decreased in larvae exposed to 8 watts. Devi et al. (2024) studied the effects of different exposure times (2, 5 and 10 min) to ultraviolet light on various morphological and economic traits of silkworm larvae and emphasized the detrimental effects of long-term ultraviolet exposure on silkworm productivity, causing decreases in hatching percentage, larval weight, cocoon weight, fecundity and survival percentage. Furthermore, light exposure interacts with other environmental factors, such as temperature and humidity, which can increase the temperature in the rearing chamber and, if not managed properly, lead to heat stress in larvae. Similarly, light affects humidity levels by affecting the evaporation rate of moisture from the air. Therefore, successful light management in silkworm rearing requires an integrated approach that considers the interaction between light, temperature, and humidity (Amit Kumar et al. 2021).

CONCLUSION

For successful cocoon production, larvae must be reared in rooms with optimal temperature and humidity conditions, good ventilation, and sufficient light. They should also be fed a suitable quantity and quality of mulberry leaves with sufficient moisture. When larvae are reared at optimal temperature and humidity, their growth, development, and the quality of the resulting cocoons are significantly higher. Seasonal variations in environmental factors significantly affect phenotypic traits such as cocoon weight, shell weight, and cocoon-to-shell ratio. Climatic changes, particularly occurring in the last decade, highlight the importance of optimizing environmental conditions for sustainable cocoon production and emphasize the necessity of temperature and relative humidity management.

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AI-DRIVEN PRECISION AGRICULTURE FOR CLIMATE-RESILIENT CROP PRODUCTION

[1]Amadi Oko Amadi, [2]Eziechina Malachy Amaechi, [3]Ifeanyi Moses Iwueze,[4]Osita Ngozika Ann, [5]Okwa Eyare Nola, and [6]Ahmed Enesi Abdulrahman

[1]Department of Computer Engineering Technology Akanu Ibiam Federal Polytechnic Unwana-Ebonyi state.

Email: aaoko@akanuibiampoly.edu.ng

ORCID: 0000-0002-7329-4746

[2]Department of Computer Science, Akanu Ibiam Federal Polytechnic Unwana, Ebonyi state.

maezichina@akanuibiampoly.edu.ng

ORCID: 0009-0008-9760-9774

[3]Mechatronic Engineering Department Federal Polytechnic Nekede, Owerri, Imo State

Email: engriwuez@gmail.com

ORCID: 0009-0002-0731-1023

[4&6]Department of Electrical / Electronic Engineering Technology Akanu Ibiam Federal Polytechnic Unwana-Ebonyi state.

Email: infomahmed@yahoo.co.uk &,ngozikaann@yahoo.com

ORCID: 0009-0008-8879-5800 , ORCID: 0009-0007-5192-4616

[5]Department of Computer Engineering Technology, Federal Polytechnic Ugep

Email: eyareokwa@fedpolyugep.edu.ng

ORCID: 0009-0007-2939-7792

ABSTRACT

Rapid climate variability poses serious challenges to global agricultural productivity. Artificial Intelligence (AI)-driven precision agriculture provides a promising pathway for enhancing crop resilience through data-driven resource optimization and adaptive management. This empirical study investigates how AI models integrated with Internet of Things (IoT) sensors and satellite data improve decision-making in climate-resilient farming. Data were collected from 120 smart farms across Kaduna, Oyo, and Benue States, Nigeria, over two planting seasons (2023–2024). A Random Forest algorithm was implemented for yield prediction and resource optimization using soil moisture, temperature, and rainfall datasets. The AI-based model improved yield forecasting accuracy by 28.5% and reduced water and fertilizer waste by 17.3% compared to traditional methods. Results demonstrate that AI-driven precision agriculture significantly enhances climate adaptability, resource use efficiency, and productivity. The study contributes empirical evidence supporting AI integration in sustainable agricultural policy and technology adoption strategies.

Keywords: precision agriculture, artificial intelligence, machine learning, climate resilience, IoT, yield prediction.

1. INTRODUCTION

Agriculture remains the cornerstone of global food security, economic growth, and rural livelihood sustainability, yet it faces unprecedented challenges in the 21st century. Across the globe, climate variability has emerged as one of the most pressing threats to agricultural productivity, particularly in developing regions dependent on rain-fed farming systems. The Food and Agriculture Organization (FAO, 2023) warns that climate change is expected to reduce agricultural yields by up to 30% in sub-Saharan Africa by 2050 if adaptive innovations are not adopted. Irregular rainfall patterns, increasing frequency of droughts, soil degradation, and the emergence of new pest and disease vectors have collectively intensified production uncertainty. These climatic stressors directly threaten smallholder farmers who constitute the majority of the agricultural workforce and contribute significantly to regional food supply.

In Nigeria and other African nations, agricultural output continues to decline despite policy interventions and technological initiatives. Empirical evidence from Adeyemi et al. (2022) shows that rainfall variability and soil fertility depletion have contributed to yield losses of between 15–25% in staple crops such as maize, rice, and sorghum over the past decade. This production gap widens the risk of food insecurity, increases rural poverty, and exacerbates vulnerability to climate shocks. Furthermore, the expansion of agricultural land into marginal environments as a coping mechanism accelerates environmental degradation, creating a vicious cycle of unsustainable production. Addressing these challenges requires a fundamental transformation of traditional farming systems toward adaptive, data-driven precision agriculture models. Traditional agricultural practices, often reliant on farmers' intuition and manual observation, are increasingly inadequate for coping with dynamic climate variables and complex ecosystems. Precision agriculture (PA) represents a paradigm shift that leverages digital technologies to manage spatial and temporal variability in crop and soil conditions. According to Mekonnen and Tadesse (2021), precision agriculture integrates sensors, satellite imagery, drones, and data analytics to deliver targeted interventions—ensuring that each segment of a farm receives the precise amount of water, fertilizer, and pesticide required. This approach minimizes waste, enhances resource efficiency, and maximizes yield potential, aligning with global sustainability objectives. The incorporation of **Artificial Intelligence (AI)** into precision agriculture further elevates its capability by enabling predictive analytics and autonomous decision-making. Machine learning (ML) and deep learning (DL) algorithms can process vast datasets from IoT devices, weather stations, and remote sensing imagery to uncover complex relationships between climatic, soil, and crop growth factors (Zhou et al., 2023). Through such pattern recognition, AI systems can forecast crop diseases, predict yield outcomes, optimize irrigation schedules, and recommend nutrient applications in real time. This data-driven adaptability makes AI-driven precision agriculture a cornerstone of climate resilience and sustainable productivity.

Artificial Intelligence enhances the precision agriculture ecosystem through its capacity to model uncertainty and generate actionable intelligence from unstructured environmental data. For instance, convolutional neural networks (CNNs) and random forest algorithms have been successfully applied in detecting crop stress, classifying pest species, and predicting harvest times with high accuracy (Bai et al., 2022). Reinforcement learning systems are now capable of autonomously controlling irrigation valves, balancing soil moisture, and reducing energy costs in smart greenhouses. These intelligent applications bridge the gap between technology and practical on-field decision-making. In the context of climate-smart agriculture (CSA), AI acts as a catalyst for adaptation and mitigation. It supports early warning systems for droughts and floods, enhances carbon monitoring, and facilitates dynamic crop insurance schemes based on predictive modeling. According to the United Nations Development Programme (UNDP, 2024), integrating AI into CSA frameworks aligns with the broader goals of **Sustainable**

Development Goal (SDG) 2 – Zero Hunger, by promoting resilient food systems that can withstand climate variability while ensuring equitable resource distribution. Importantly, AI applications can help optimize resource use efficiency—achieving higher yields with less water, energy, and fertilizer—thus reducing agriculture's ecological footprint.

In tropical and semi-arid regions such as Nigeria, agricultural productivity is highly climate-sensitive. The country experiences pronounced rainfall variability, with alternating periods of drought and flooding that disrupt planting calendars. Despite efforts through the Agricultural Transformation Agenda (ATA) and other policies, technology adoption among smallholder farmers remains low (Nwosu et al., 2021). Most farms still rely on manual methods of pest control, non-digital irrigation, and generalized fertilizer application, which lead to inefficiencies and resource wastage.

Recent pilot initiatives on smart farming have demonstrated potential benefits. Studies conducted by Ogunleye and Yakubu (2022) revealed that farms equipped with IoT-based soil moisture sensors in Oyo State achieved a 20% reduction in water consumption and a 15% increase in maize yield compared to control farms. However, these initiatives remain fragmented and localized, lacking large-scale empirical validation across different agro-ecological zones. Furthermore, infrastructural constraints—such as limited internet connectivity, high cost of IoT devices, and insufficient digital literacy—pose significant barriers to scaling AI-driven agriculture across rural Nigeria. The theoretical underpinning of this study draws from **the Adaptive Systems Theory** and **Sustainable Livelihoods Framework (SLF)**. The Adaptive Systems Theory explains how complex agricultural systems can self-regulate and adjust to environmental feedback through information-driven mechanisms (Holling, 2001). AI models serve as adaptive agents within this framework, capable of learning from climatic variability and improving predictive accuracy over time. The SLF complements this by emphasizing the need for sustainable resource utilization that strengthens farmers' livelihood assets—natural, human, social, and technological capital. Hence, AI-driven precision agriculture operationalizes both frameworks by enabling real-time adaptation, efficient resource use, and long-term sustainability. Despite the growing global literature on smart agriculture, there remains a paucity of **empirical evidence from tropical contexts**, particularly in Nigeria and similar developing economies. Much of the existing research focuses on simulations, pilot projects, or case studies conducted in temperate climates with robust technological infrastructures (Zhou et al., 2023; Bai et al., 2022). Consequently, there is a limited understanding of how AI-based precision systems perform in environments characterized by irregular data availability, low mechanization, and variable climatic conditions. Moreover, while international organizations such as FAO and UNDP advocate for digital transformation in agriculture, evidence-based metrics quantifying the real-world benefits of AI interventions in yield stability, input efficiency, and climate resilience are still scarce.

This gap underscores the necessity of conducting **contextualized empirical investigations** to evaluate the effectiveness of AI-driven models under actual field conditions in Nigeria. Such studies are vital for informing data-driven agricultural policy, guiding investment in smart technologies, and building localized models tailored to the socio-ecological realities of African farmers. The overarching problem driving this research is the persistent vulnerability of agricultural production systems to climate variability, compounded by inefficient resource utilization and limited access to adaptive technologies. The inability of traditional farming methods to cope with unpredictable rainfall patterns, pest invasions, and soil nutrient imbalances results in substantial yield losses and increased production costs. Although AI offers transformative solutions, its adoption in rural agricultural systems is constrained by infrastructural and knowledge barriers. The **aim** of this study is to empirically examine how AI-driven precision agriculture contributes to climate-resilient crop production through

improved predictive analytics and optimized resource management. The **objectives** are threefold, to evaluate the predictive performance of AI-based models in forecasting crop yields under variable climatic conditions, to assess the efficiency of AI systems in optimizing the use of water and fertilizers in farming operations, to analyze farmers' adaptability, perception, and satisfaction with AI-enabled precision agriculture tools. This study is significant for several reasons. Academically, it extends the empirical frontier of AI and precision agriculture research in tropical agro-ecological systems, providing a robust model for future studies. Practically, it offers evidence-based insights that can guide policymakers, agritech developers, and agricultural extension services in scaling digital innovation among smallholder farmers. Socioeconomically, it contributes to enhancing productivity, improving food security, and strengthening resilience against climate-induced shocks in rural communities. By validating the tangible benefits of AI integration in agriculture, this research aligns with the broader agenda of digital transformation for sustainable rural development. In essence, the introduction situates AI-driven precision agriculture as a transformative response to climate threats facing agricultural productivity in sub-Saharan Africa. It establishes a clear research gap, theoretical foundation, and empirical motivation to evaluate AI's practical contribution to climate-resilient crop production in Nigeria.

2. Methodology

2.1 Study Area

The study was conducted in three major agricultural zones in Nigeria Kaduna (North), Oyo (West), and Benue (Central) representing different agro-ecological conditions.

2.2 Data Collection

A mixed-method approach was adopted:

Quantitative Data: 120 farms equipped with IoT sensors collected data on soil moisture, temperature, humidity, and rainfall during two planting seasons (2023-2024).

Qualitative Data: Farmer feedback was collected via structured interviews to assess adaptability and satisfaction with AI tools.

2.3 Experimental Setup

AI models were developed using Python (TensorFlow and Scikit-learn libraries). A **Random Forest Regressor (RFR)** and **Artificial Neural Network (ANN)** were trained using 80% of the dataset, with 20% used for validation. Data preprocessing included normalization and missing-value imputation.

2.4 Evaluation Metrics

Performance was evaluated using:

a. Root Mean Square Error (RMSE)

b. Mean Absolute Error (MAE)

c. Coefficient of Determination (R^2)

d. Resource optimization ratio (water/fertilizer savings)

2.5 Statistical Analysis

Descriptive and inferential analyses were performed using SPSS 28.0. One-way ANOVA tested yield variation across farms using AI tools versus control farms.

3. Results and Discussion

Table 1. Comparison of Yield Prediction Accuracy Between AI and Traditional Models

Model Type	RMSE (t/ha)	MAE (t/ha)	R^2	Accuracy Improvement (%)
Traditional Regression	0.98	0.72	0.68	–
Random Forest (AI)	0.71	0.49	0.83	22.4
ANN (AI)	0.65	0.42	0.86	28.5

Table 1 shows that AI models outperformed traditional regression methods by a significant margin. The ANN model achieved the highest predictive accuracy ($R^2 = 0.86$), indicating its robustness in capturing nonlinear climatic interactions influencing yield.

Table 2. Resource Optimization Using AI-Based Decision Support

Resource Type	Traditional Use (L/ha or kg/ha)	AI-Optimized Use	Reduction (%)
Water	11,500 L/ha	9,400 L/ha	18.3
Fertilizer	92 kg/ha	76 kg/ha	17.4

Table 2 shows that AI-driven scheduling algorithms reduced water and fertilizer waste by over 17%, demonstrating efficiency gains through adaptive irrigation and nutrient management systems.

Table 3. Farmers' Adoption and Perception Scores (n = 120)

Parameter	Mean Score (1–5 scale)	Std. Dev.
Ease of Use	4.3	0.8
Perceived Reliability	4.1	0.9
Cost-Benefit Value	4.0	1.0
Training Adequacy	3.7	0.7

Table 3 shows that high adoption rates were recorded, with farmers appreciating the reliability of AI systems. However, training gaps remain, indicating the need for capacity-building programs to fully leverage AI technologies.

Table 4. ANOVA of Yield Variation Across Study Regions

Source	SS	df	MS	F	Sig.
Between Regions	15.42	2	7.71	4.83	0.012*
Within Regions	183.55	117	1.57		
Total	198.97	119			

Table shows that yield improvements were statistically significant across regions ($p < 0.05$). The Northern farms benefited most, likely due to better AI integration with irrigation systems.

Table 5. Correlation Between Climatic Factors and AI Model Performance

Climatic Variable	Pearson's r	p-Value	Interpretation
Temperature	0.67	0.001	Strong positive correlation
Rainfall Variability	-0.59	0.004	Negative correlation
Soil Moisture	0.73	0.000	Strong positive correlation

Table 5 shows that AI model performance strongly correlated with soil moisture and temperature stability, confirming the sensitivity of machine learning algorithms to high-quality climatic data inputs.

4. Research Findings and Implications

4.1 Findings

The integration of Artificial Intelligence (AI) into precision agriculture demonstrated substantial benefits across the three agro-ecological zones—Kaduna (North), Oyo (West), and Benue (Central)—examined in this study. The experimental results and farmer responses indicated that AI-enhanced systems significantly improved climate resilience and production efficiency. The AI-based models—Random Forest Regressor (RFR) and Artificial Neural Network (ANN)—successfully identified early signs of drought stress and excessive rainfall, allowing for timely intervention. On-farm adaptive decisions, such as adjusted irrigation schedules and fertilizer management, were made possible through real-time predictive alerts. This early adaptation led to a measurable reduction in crop losses and an improvement in average yield stability across planting seasons. The models achieved a **28.5% increase in yield prediction accuracy** compared to traditional manual estimation methods. This improvement provided farmers with precise forecasts for production planning, market supply estimation, and post-harvest storage requirements. The ANN model outperformed the RFR by a margin of 6.3% in predictive accuracy, indicating its superior capacity to model nonlinear relationships between soil, weather, and crop parameters. Through AI-driven irrigation and fertilizer recommendations, water and nutrient use were reduced by **17%** across the study areas. This not only decreased production costs but also mitigated nitrate leaching and greenhouse gas emissions, aligning with the objectives of climate-smart agriculture (CSA). The reduction in resource wastage reinforces the environmental sustainability potential of AI-enabled decision support systems. The qualitative feedback revealed a high level of **farmer acceptance (mean = 4.12, SD = 0.46)** toward AI-based precision systems. Participants acknowledged improvements in decision-making, yield predictability, and profitability. However, digital literacy and access to stable internet connectivity remain notable barriers, particularly in rural zones of Kaduna and Benue. Some respondents expressed the need for local-language interfaces and mobile-based applications for easier use.

4.2 Comparative Analysis with Previous Studies

The empirical results of this study corroborate findings from earlier works emphasizing the potential of AI in agricultural resilience. Zhou et al. (2023) reported a 25% enhancement in yield prediction accuracy using deep learning models in East Asian rice fields, while Bai et al. (2022) demonstrated a 15–20% improvement in water use efficiency under variable climatic conditions. Similarly, Mekonnen and Tadesse (2021) observed that AI-enabled irrigation reduced wastage by 18% in Ethiopian maize farms. The 28.5% accuracy gain and 17% reduction in water and fertilizer use recorded in this Nigerian context suggest that AI systems can perform even more effectively under tropical agricultural conditions, provided that adequate data infrastructure is in place.

Furthermore, the results highlight that **AI-based tools not only improve agronomic outcomes but also strengthen adaptive capacity**—a key component of resilience as defined by the FAO (2023). Unlike conventional practices that rely on historical knowledge and manual estimation, the AI-driven framework continuously learns from environmental and crop data, enabling dynamic and context-specific responses. This confirms the theoretical proposition that **machine learning can operationalize the adaptive management principle** of CSA, bridging the gap between reactive and proactive farming strategies.

4.3 Implications for Policy and Practice

The findings have several critical implications for agricultural policy, technology diffusion, and rural capacity building:

Governments and agricultural agencies should embed AI-based precision agriculture technologies into **national climate adaptation frameworks**. Subsidies for IoT sensors, drones, and AI analytics platforms can accelerate adoption among smallholder farmers. The study underscores the urgent need for **digital literacy training** among rural farmers. Building AI-awareness programs and farmer–technologist collaborations will bridge knowledge gaps and enhance usability. Extension agents can be trained as intermediaries to translate AI insights into practical field operations. Reliable broadband access and rural electrification are prerequisites for real-time data transmission and model updates. Public–private partnerships can enhance digital infrastructure to ensure that AI systems remain functional and scalable in rural contexts. The 17% reduction in resource use validates AI's contribution toward achieving **Sustainable Development Goal (SDG) 13 – Climate Action** and **SDG 2 – Zero Hunger**. The deployment of AI in precision agriculture supports not only productivity but also long-term ecological balance through reduced input waste and emissions.

4.4 Research Contributions and Future Directions

This study provides empirical validation for the effectiveness of AI-driven precision agriculture within the tropical context of Sub-Saharan Africa, specifically Nigeria. By employing machine learning models (RFR and ANN) trained on multi-season, multi-location datasets, the research demonstrates that localized AI frameworks can substantially enhance agricultural resilience and efficiency. However, the study also identifies **key gaps for future research**. These include:Development of lightweight AI models optimized for **low-power mobile devices** to enhance accessibility. Exploration of **federated learning architectures** that allow decentralized data sharing among farmers while preserving privacy. Integration of **blockchain systems** for traceability and trust in AI-generated recommendations. Expansion of longitudinal studies to monitor long-term environmental and economic impacts of AI-enabled precision farming. Overall, the empirical findings confirm that AI-driven precision agriculture provides measurable benefits in **climate adaptation, resource optimization, and yield forecasting**. The integration of machine learning into farm management represents a paradigm shift from reactive to predictive and sustainable agricultural systems. When coupled with improved rural digital infrastructure and farmer education, AI technologies have the potential to revolutionize tropical agriculture, enhancing food security and resilience against the growing threat of climate variability. These outcomes position AI not merely as a technological innovation but as a **transformative enabler of sustainable development**, reinforcing the strategic role of digital agriculture in addressing both current and future food system challenges in Nigeria and beyond.

5. Conclusion

This study provides empirical validation that **AI-driven precision agriculture** significantly enhances **climate-resilient crop production** across diverse agro-ecological zones in Nigeria. By integrating **machine learning algorithms** with **IoT-based environmental sensors** and

remote sensing technologies, farmers achieved measurable improvements in yield prediction accuracy, irrigation efficiency, and input utilization. The application of Random Forest and Artificial Neural Network models demonstrated superior predictive capabilities, resulting in a **28.5% improvement in yield forecasting** and a **17% reduction in water and fertilizer consumption**. These outcomes affirm that AI-driven decision support systems not only increase productivity but also strengthen adaptive capacity against climatic variability. The study further underscores that **AI-enabled analytics can serve as a cornerstone for climate-smart agriculture (CSA)** by providing data-driven insights into crop performance, soil health, and weather dynamics. The integration of digital intelligence into agricultural practices fosters sustainability through optimized resource allocation and reduced greenhouse gas emissions. Moreover, the positive response from farmers (mean satisfaction > 4.0) reflects a growing openness to digital transformation in agriculture, although challenges related to **digital literacy, infrastructure, and affordability** remain evident. From a broader development perspective, the findings emphasize the strategic importance of embedding AI and data analytics into **national agricultural and climate policies**. Empowering smallholder farmers with accessible AI tools can substantially contribute to achieving **Sustainable Development Goals (SDG 2: Zero Hunger)** and **SDG 13: Climate Action** by enhancing productivity, resilience, and environmental stewardship.

Future research should focus on :

Localization of AI models to reflect region-specific climatic, soil, and crop dynamics, ensuring adaptability for smallholder conditions. **Capacity building and farmer training**, enabling rural communities to interpret and apply AI insights effectively. **Integration of renewable energy solutions**, such as solar-powered IoT networks, to ensure sustainable operation of digital agricultural systems in off-grid areas. By addressing these dimensions, AI-driven precision agriculture can evolve from pilot applications to a **mainstream, scalable framework for sustainable rural transformation** in Nigeria and the broader Sub-Saharan region. Ultimately, the empirical evidence confirms that AI technologies, when inclusively implemented, hold the potential to revolutionize agricultural resilience, empower farmers, and secure global food systems against the growing threat of climate change

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POTENTIALS OF *Kigelia africana* AS A NATURAL APHRODISIAC AND FERTILITY BOOSTER IN RABBITS

Dr. Karimat I. ALIYU

Department of Animal Science, University of Abuja, Abuja, Nigeria

Email: karimat.aliyu@uniabuja.edu.ng; tanwaaliyu@gmail.com

ORCID: 0009-0001-5117-2035

Prof. Mashood A. Belewu

Department of Animal Production, University of Ilorin, Ilorin, Nigeria

Email: moshood.belewu@uniabuja.edu.ng; mabel@unilorin.edu.ng; milkyinka@yahoo.com

ORCID: 0000-0003-3553-7652

ABSTRACT

In response to growing problems of protein shortage in human diets, rabbit production is advocated due to their high prolificacy and ability to convert low quality feed to high quality meat. However, inadequate libido is sometimes a problem in rabbit production. Therefore, this study was conducted to investigate the effects of *Kigelia africana* (KA) leaf and fruit meals on libido and fertility performance of rabbits. The experiment which lasted for 12 weeks was done at the University of Ilorin Teaching and Research Farm with a total of 108 ten weeks old female and male rabbits in a ratio of 2:1. They were randomly allotted to nine (9) treatment groups of eight does and four bucks per treatment, in a 2×4+1 factorial arrangement. The first factor was plant parts (fruit or leaf) while the second factor was inclusion levels comprising of 5%, 10%, 15%, and 20% plus 0% which served as the control for both. This arrangement was setup independently for fruit and leaf. Rabbits were housed individually and had access to feed and water *ad libitum*. All procedures were approved by the University Ethical Review Committee (protocol identification code: UERC/ AGR 084). The mounting reaction of rabbit bucks and receptivity of the does fed KA parts were significantly influenced ($p<0.05$). The reaction times were shorter in bucks fed KA fruit meals (15.65 s) at 18 weeks of age. However, data collected at a later age (22 weeks) showed no effect of KA parts but the inclusion levels still played a significant role. The inclusion levels as a factor significantly affected the reaction as well as the receptivity time by the buck and doe respectively. The times reduced with increasing levels of KA meals. The control groups had the longest (37.25 s) while those on 20% inclusion had the shortest (17.50 s) reaction time. The libido was significantly ($p<0.05$) improved in the treated groups (4.50-4.75 s). Similarly, the percentage conception by the does were significantly ($p<0.05$) influenced by the inclusion level of KA meals, with 15% and 20% inclusions having the highest (100%). Overall, KA fruit meal as well as higher inclusion showed a better improvement in libido and fertility of rabbit.

Keywords: Libido, aphrodisiac, *Kigelia africana*, fertility, rabbits

1. INTRODUCTION

Kigelia africana is commonly called Sausage tree or Cucumber tree due to its long sausage-like fruit, and belongs to the family *Bignoniaceae*. It grows commonly in tropical west, east and central African regions particularly in low plains in Nigeria and can also be found in open woodland (Ogbeche *et al*., 2002; Owolabi and Omogbai, 2007). The tree is usually planted for ornamental purposes due to its decorative flowers which has a bell shape with colours ranging from orange, maroon to purplish green and its unusual fruit (Roodt, 1992). The fruit is a woody and fibrous berry that hangs from a long fibrous stalk. It weighs between 5 to 12 kg. It contains numerous hard seeds that resembles that of cucumber. In the wild, the fruits are eaten by mammals such as hippopotamus, monkeys, giraffes, baboons, bush pigs, savannah elephant and so on (de Hoyo *et al*., 1997; Joffe, 2003). In folklore, the fruit of *Kigelia africana* represents a symbol of fertility (Burkill, 1985), the native doctors use various parts of the plant soaked in alcohol or water for treatment of various fertility related problems in women and men of child bearing age (Ogbeche *et al*., 2002). It is abundant in the tropics and is widely used in Southern and Eastern Nigeria as an herbal remedy for various ailments like retained placenta, postpartum hemorrhage, dizziness as well as anti-cancer agent (Gill 1992). In South western Nigeria, the bark extract is said to have an aphrodisiac effect as it enhances sexual libido and erection in males (Oliver-Bever, 1986; Abioye *et al*., 2003). Over the years, ethnobotanical plants such as *Kigelia africana* have been used for the management and treatment of many ailments in folklore medicine. Its application is however gradually gaining grounds due to its availability and affordability in areas where the trees are predominant, helping in mitigating the problems of high cost of animal feed. In animal production, the role of these ethnobotanical plants cannot be over emphasized, they serve as possible sources of food/nutrients (Aliyu & Adeyina, 2022) as they supply some of the essential nutrient requirements of farm animals at a low price due to their minimal competition with man. Additionally, they serve as therapeutic agents boosting reproductive performance as well the overall health of the animals. This strategy could help reduce the cost of production, and ensure cheaper meat production thereby making available the major crops for human consumption (Bhatt and Sharma, 2001; Muriu *et al*., 2002).

The use of *Kigelia africana* in rabbit feed is not limited to reduction in the cost of feeding but also can solve some of the problems associated with rabbit farming, one of which is inconsistent libido (shy rabbit). KA if well incorporated in rabbit diet may solve the problem as well as improving their general well-being since its high in antioxidant levels (Aliyu and Adeyina, 2022).

2. Materials and methods

Animal managements and experimental layout

The experimental trial was conducted at the University of Ilorin Teaching and Research Farm.

A total of one hundred and eight 10-weeks old rabbits were used for this experiment. Seventy-two (72) rabbit does and thirty-six (36) bucks in ratio 2:1 were randomly allotted to nine (9) treatment groups of eight does and four bucks per treatment, in a factorial 2×4+1 factorial arrangement. The first factor was plant parts consisting of two levels of fruit or leaf while the second factor was inclusion levels comprising of 5%, 10%, 15%, and 20% plus 0% which served as the control common to both fruit and leaf. The nine (9) treatment groups A, B, C, D, E, F, G, H, and I consisted levels of fruit and leaf meals of *Kigelia africana* plant independently fed at 0%, 5%, 10%, 15% and 20% inclusion as shown in Table 1. Rabbits were housed individually and had access to feed and water *ad libitum*. The experiment lasted for twelve (12) weeks and these experiments were conducted with approval of ethical review committee of University of Ilorin with the protocol identification code: UERC/ AGR 084.

Reproductive performance of rabbit fed *Kigelia africana* fruit and leaf meals

Libido, intromission (thrusting), and fertility performances were used to measure reproductive responses of rabbits in this study.

At six weeks after the commencement of the experiment (16-weeks of age), libido of bucks and does were observed. The rabbit bucks were closely observed for pubertal signs and reproductive alertness by introducing does to bucks. Does from each treatment were introduced to the bucks of corresponding treatments to observe any mounting/receptivity attempts. Receptivity of rabbit does and reaction/activity of the bucks were observed from the time of introduction and noted in seconds as described by Gado *et al*., (2015). This process was repeated twice, first at 18 weeks and at 22 weeks of age when larger percentage of non-receptive does and active bucks were obtained. This was achieved at twenty-two weeks of age (twelve weeks into the experiment). Age at which each rabbit attained puberty/sexual maturity was recorded based on their responses, this was at 22-weeks of age.

Fertility performance of rabbits fed *Kigelia africana* fruit and leaf meals

At twenty-six weeks of age, bucks and does of same treatment were crossed using natural mating in a ratio 1:2. The dates of mating were recorded for each does for determination of gestation periods. Conception was observed in does after ten days and up to fourteen days after mating through palpation. Parturition date, litter size, birth weight of kids, abnormalities in kids, mortality rate and gestation period were recorded for each doe. The kid birth weights were taken using a sensitive digital scale (Electronic scale, Model EHA251) and were recorded in grams.

Statistical analysis

All data obtained from buck mounting reaction time, doe receptivity, semen characteristics and fertility performance were subjected to a two-way analysis of variance procedure following a model for 2×4 factorial design (Steel and Torrie, 1980) to evaluate the effect of KA parts and dietary inclusion when compared with the control, all data from each group were analyzed using General Linear Model procedure SAS Institute (2002), and significant differences between treatments means were separated using the Duncan's Multiple Range Test.

Table 1. Composition of Experimental Diets Supplemented with *Kigelia africana* Fruit/Leaf Meals

Ingredients	Control	5% Fruit	10% fruit	15% Fruit	20% fruit	5% Leaf	10% Leaf	15% Leaf	20% leaf
Maize	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
Soybean Meal	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Wheat Offal	12.00	14.00	10.00	10.00	5.00	14.00	12.00	9.00	11.00
Maize offal	7.00	5.00	5.00	7.00	11.00	10.00	5.00	10.00	5.00
Rice husk	27.00	22.00	21.00	14.00	10.00	21.00	19.00	12.00	10.00
Fish Meal	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KAM	0.00	5.00	10.00	15.00	20.00	5.00	10.00	15.00	20.00
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50

Dicalcium phosphate	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Lysine	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Premix	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Analyzed Nutrients									
Crude protein (%)	15.94	16.06	16.36	16.10	16.12	15.80	15.62	15.59	16.23
Crude Fibre (%)	11.62	11.71	11.88	11.80	11.50	10.80	10.72	10.85	10.92
Ether Extract (%)	4.50	4.0	3.89	5.0	4.56	5.0	4.54	4.90	4.98
Calculated Energy (Kcal/kg)	2,417.10	2,366.83	2,286.66	2,247.39	2,212.82	2,349.67	2,308.83	2,200.50	2,200.16

*KAM= *Kigelia africana* meals

3. RESULTS

Table 2 shows the results of mounting reactions time exhibited by rabbit bucks fed *Kigelia africana* fruit and leaf meals. The rabbit bucks on the leaf exhibited a significantly ($p<0.05$) longer reaction time than those fed fruit at both 18 and 22 weeks of age. At graded levels, the longest reaction time was recorded in the control groups while the shortest time was recorded in the groups fed 20% inclusion. This was a case of reduction of reaction time with increasing levels of KA meals. The period between mounting and fall-off (thrusting) was longest in control and 20% ($p<0.05$) compared with other groups. The detail of interaction for the significant parameters are presented in the interaction table.

Table 2. Effects of *Kigelia africana* Fruit and Leaf Meals on Mounting Reaction Time of Rabbit Bucks

KA parts	BRT at 18weeks (seconds)	BRT at 22weeks (seconds)	Thrusting period (seconds)
Fruit	21.65^{b}	14.60^{b}	4.95
Leaf	25.65^{a}	16.10^{a}	5.10
P value	0.002	0.05	0.46
Inclusion levels (%)			
0	37.25^{a}	33.25^{a}	5.50^{a}
5	23.00^{b}	13.25^{b}	4.50^{b}
10	19.88^{bc}	10.63^{c}	4.63^{b}
15	20.63^{bc}	10.25^{c}	4.75^{b}

20	17.50[c]	9.38[c]	4.98[ab]
P value	<.0001	<.0001	<.0001
Parts*Inclusion Levels	*	NS	NS
P value	0.02	0.79	0.91
SEM	0.83	0.52	0.14

KA= *Kigelia africana*, a, b, c – means with different superscript are significant along the column, BRT- Buck Reaction Time, *- significant, NS – Not-significant, SEM=Standard Error of Mean

Table 2a presents the details of interaction between *Kigelia africana* parts (fruit or leaf) and inclusion levels for bucks' reaction time at 18 weeks of age. The control group was significantly different ($p<0.05$) from all other groups presenting the highest reaction time to does presence. The shortest reaction time was noted in bucks fed 20% *Kigelia africana* fruit meal.

Table 2a. Interactions between KA Parts and Inclusion Levels of *Kigelia africana* Fruit and Leaf Meals on Rabbit Buck Reaction Time

Inclusion Level (%)						
KA Parts	**0%**	**5%**	**10%**	**15%**	**20%**	**SEM**
Fruit	37.25[a]	23.25[b]	18.50[b]	17.50[bc]	11.75[c]	1.86
Leaf	37.25[a]	22.75[b]	21.25[b]	23.75[b]	23.25[b]	1.86

KA= *Kigelia africana*, a, b, c – means with different superscript are significant along the row, SEM=Standard Error of Mean

Table 3 shows the result of receptivity of rabbit does to bucks. There was a significant difference ($p<0.05$) in the acceptability of bucks by the does. Comparing the interval of examination, KA leaf meal inclusion significantly increased ($p<0.05$) receptivity of rabbit does. However, does on fruit meal had the shortest time of reaction/receptiveness to bucks. Acceptance of rabbit does at 24 weeks of age was significantly the same irrespective of either fruit or leaf inclusion. More so, there was no significant difference in their receptivity time. At treatment levels however, the receptiveness of rabbit does significantly increase ($p<0.05$) as level of KA inclusion increased with 20% inclusion presenting the highest percentage of receptive does. No significant difference was observed in the receptivity time at 22 weeks of age. Conception of the does was significantly ($p<0.05$) increased with fruit meal inclusion. Similarly, the level of inclusion of the treatments significantly ($p<0.05$) influenced the conception percentage. It increased with an increase in treatment levels.

Table 3. Receptivity of Rabbit Does Fed *Kigelia africana* Fruit and Leaf meals

KA Parts	**Receptivity at 18 weeks (second)**	**% Receptivity at 18 weeks**	**Receptivity at 22 weeks (second)**	**% Receptivity at 22 weeks**	**Conception (%)**
Fruit	5.58[b]	65.00[b]	8.93	95.00	92.50[a]
Leaf	9.25[a]	72.50[a]	10.68	95.00	90.00[b]
P value	0.01	0.01	0.12	-	0.0001

Treatment levels (%)					
0	8.25	50.00^{d}	10.88	87.50^{b}	75.00^{c}
5	7.56	62.50^{c}	9.69	87.50^{b}	81.30^{b}
10	6.63	62.50^{c}	9.19	100^{a}	100^{a}
15	8.25	75.00^{b}	10.56	100^{a}	100^{a}
20	8.38	93.75^{a}	8.69	100^{a}	100^{a}
P value	0.84	0.01	0.71	0.01	0.001
Type*Levels	NS	NS	NS	-	*
P value	0.74	0.77	0.77	-	0.0001
SEM	1.01	0.00	0.79	0.00	0.00

a, b, c – means with different superscript are significant along the column, * – significant, NS – Not-significant

The results of reproductive responses of rabbit does fed *Kigelia africana* fruit and leaf meal are presented in table 4.14. The inclusion of the treatment had no significantly (P>0.05) influence on the gestation periods, birth weights of the kids, mortality and kits' abnormality. However, litter size showed a significant (P<0.05) difference among the varied levels of the treatments with means ranging from 4.88 to 7.94. The mean of litter size increase with increase in the treatment inclusion levels and was significantly highest at 20% inclusion while the lowest was recorded in the control group.

Table 4. Fertility Performance of Rabbit Does Fed *Kigelia africana* Fruit and Leaf Meals

KA Parts	**Gestation period(days)**	**Litter size (no)**	**Birth weight(g)**	**Mortality (%)**	**Abnormality (%)**
Fruit	30.63	6.68^{a}	41.59	0.73	0.00
Leaf	30.78	6.10^{b}	42.22	0.53	0.00
P value	0.51	0.03	0.45	0.18	0.00
Inclusion Levels (%)					
0	30.88	4.25^{d}	36.58^{b}	0.75	0.00
5	30.38	6.13^{c}	43.00^{a}	0.63	0.00
10	31.19	6.63^{b}	43.23^{a}	0.50	0.00
15	30.63	7.13^{ab}	43.40^{a}	0.56	0.00
20	30.44	7.81^{a}	42.47^{a}	0.68	0.00
P value	0.16	0.01	0.05	0.84	-
Parts*Levels	NS	NS	NS	NS	-
P value	0.45	0.46	0.81	0.65	0.00
SEM	0.16	0.11	1.37	0.10	0.00

a, b, c, d – means with different superscript are significant along the column, no- number, *- significant, NS- Not significant

4. DISCUSSION

Onset of puberty and the level of sexual drive (libido) are vital physiological trait in a successful rabbit production. Fighting, mounting of objects, spraying of urine, growling, circling, territorial biting, destructive chewing and digging (in females) are major characteristic signs of puberty attainment in rabbit. In this present study, mounting and thrusting were used for the evaluation. Rabbit bucks on *Kigelia africana* (KA) fruit and leaf presented higher sex drive compared with the control group. The reaction time of rabbit bucks fed KA meals were significantly reduced at earlier age and with minimum time duration compared with the control. However, the reaction times at various weeks of evaluation were lowest at 15% and 20% fruit inclusion, suggesting that KA part was a significant factor for libido performance. Various factors have been identified as key responsible for libido, fertility and overall reproductive performance, among which is testosterone concentration. Coincidentally, serum testosterone levels of rabbits in these groups were also higher (Aliyu *et al*., 2024). The reaction time reported from this study was longer but close to 4.2s reported by Ogbuewu *et al*. (2009) and shorter than 14 – 21s reported by Saafa *et al*. (2008), and 22.31s reported by Gado, (2015). This could be due to the high concentration of testosterone which has been associated with male maturity and pubertal characteristics. This increased concentration could be linked to presence of bioactive compounds and phytochemicals in KA which possesses antioxidant properties. Antioxidants have been reportedly influencing sexual drive and overall reproductive health (Ranjith *et al.* 2025).

Good sex drive (libido) of rabbit bucks is essential to achieve maximum productivity in breeding especially through natural mating (Saleh *et al*., 2010).

The reproductive performance of rabbit does in this study showed that the inclusion of *Kigelia africana* fruit and leaf meals had a significant positive influence on the litter size. This was observed with a correspondent increased level of KA meals. Physiologically, higher number in litter size implies that multiple eggs have been released by the does, this suggest that KA might have some super ovulatory effects on the rabbit does and this may be corroborated with their usage by the traditional healers to treat infertility in man and woman of child bearing age, (Ogbeche *et al*., 2002, Oyeku *et al*., 2011). It could also be associated with antioxidant potential possessed by plant. According to Shan Wang *et al*. (2017), the reactive oxygen species (ROS) produced during ovarian physiological metabolism is maintained with the help of antioxidant thereby ensuring oocyte maturation, ovulation, fertilization, implantation and embryo development without damage by these free radicals.

5. CONCLUSION AND RECOMMENDATION

Kigelia africana fruit and leaf meals inclusions up to 20% improved the libido and reproductive performance of rabbit. KA meals can be included in rabbit diets up to 20% for a improved reproductive performance.

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FOOD INSECURITY IN NIGERIA: AN ANALYSIS OF THE IMPACT OF CLIMATE CHANGE, ECONOMIC DEVELOPMENT AND CONFLICT ON FOOD SECURITY

Dr. Chukwuemeka G. Eme

Lecturer, Department of Business Administration, Faculty of Management Sciences,

National Open University of Nigeria (NOUN), Jabi – Abuja, Nigeria

E-Mail: kaluchukwuemeka26@yahoo.co.uk

Mr. Lugard Mumen

Lecturer, Department of Public Administration, Faculty of Management Sciences,

National Open University of Nigeria (NOUN), Jabi – Abuja;

E-Mail: lmumen@noun.edu.ng

ABSTRACT

Food insecurity is a major problem in Nigeria. The Food and Agriculture Organization (FAO) estimates that Nigeria's food security has worsened in the past 15 years. This paper examines the impacts of different factors that jeopardize the Nigerian food security situation. According to previous literature, there are mostly three factors that affect food security; climate change, economic development and violent conflict. Nigeria is the chosen case study because all the above mentioned factors play a key role in the country; it is affected by climate change, the economy is fluctuating and there has been the Boko Haram insurgency going on since 2009. This paper aims, with the help of the concept of food security, to analyze these factors to see whether and to what extent they influence food insecurity in Nigeria. This paper uses a mixed-methods approach. Quantitative data are retrieved from several data-bases that give measurements on food security, climate change, economy, and conflict. Qualitative data are reports and interviews that were conducted with Nigerian NGOs. Cautious findings show that all three factors can lead to food insecurity and, therefore, can explain why there is food insecurity in Nigeria. Finally, this paper concludes and confirms the results of existing research in the case of Nigeria.

Key Words: Food Security and Insecurity, Climate change, Economic development, Violent conflict, Nigeria

1. INTRODUCTION

When food security issues were first highlighted in the 1970s, the question was whether a nation or a region could command enough food to meet the aggregate requirements of its people. Special attention was paid to fluctuations in aggregate food supply and food security interventions were primarily concerned with providing effective buffer mechanisms against such fluctuations. In this context, food security measures came to be identified with macro-level instruments such as national and international storage of food and balance-of-payments support for countries facing temporary food shortages (see Waldes, 2011).

Food security is a basic human need and fighting hunger is one of the greatest challenges of this country (Ojo and Adebayo, 2012: 204). Although the number of people living in hunger has declined for many years, in 2015 it has started to increase again (FAO et al. 2019). Today, two billion people in the world are still living in moderate or severe food insecurity, because they do not have regular access to food, not a necessary variety of nutritional value, or there is not enough food for the whole population available. 820 million of these two billion facing insecurity are living in hunger (FAO et al., 2019: 22). Particularly in developing countries, people cannot meet their nutritional needs (Oyinloye et al., 2018: 69).

It is an immensely discussed issue in our society and many scholars have studied the factors leading to food security with their direct and indirect impacts on food security (e.g. Berhanu and Wolde, 2019; Martin-Shields and Stojetz, 2019; Musenwa et al., 2015). Amongst others, Misselhorn (2005) has compared different drivers and three key factors causing food insecurity: conflict, climate change, and economic development. As many scholars analyzed, these drivers often co-exist and influence each other. Only assessing a single factor influencing food insecurity is almost impossible and it is important to take confounding drivers into account.

The decline in the production of some of Nigeria's leading agricultural export commodities was most worrisome. For instance, Nigeria that was ranked as the world's leading producer and exporter of palm oil in the 1960s had become a net importer of this commodity in the mid-1970s. Similarly, Nigeria's cocoa production which ranked a peak of 305,000 tons in 1970 fell drastically to 160,000 tons in 1985 (CBN, 2004). The sharp down-turn in the gross value terms of trade in agriculture was equally serious. The ratio of agricultural exports to food imports which stood at 147 per cent in 1970-1975 suffered significant deterioration and reached the lowest trough at 38 per cent by 1976-1982.

Today, Food security ranks the top most among the development problem facing Nigeria. The level of food insecurity has continued to rise steadily since 1986 to about 41% in 2004 (Sanusi, et al 2006). According to Barrett (2002), the lack of food excludes people to practice what other people are doing every time. However, large amount of food production in the world does not ensure any country's food security. Moreover, huge production in food at national level does not guarantee for the household food security. This may be due to unfair distribution of resources, variation in production functions, and motives for productivity. That is why even if the production increases through time, food insecurity, malnutrition and hunger remain the main agenda and much more serious problems in the world (Akume and Bakporhe, 2013).

1.1 Research Problem

A strong argument that encourages analyzing food security issues is the importance of food in our lives. There is evidence that climate change, economic development, and conflict affect food security negatively. For example, the Food and Agriculture Organization (FAO), International Fund for Agricultural Development, United Nations Children's Emergency Fund (UNICEF), World Food Program, and the World Health Organization have for the last three

years published the report 'The State of Food Security and Nutrition in the World' that focused on conflict (FAO et al., 2017), climate change (FAO et al., 2018), and the economy as a driver of food insecurity (FAO et al., 2019). This shows that these factors are a global concern in today's world.

Nigeria is one of the most food insecure countries and highly affected by all three drivers. For one, the country is vulnerable to climate change and successively hit by environmental disasters, that impact people's livelihoods (Nkechi et al., 2017: 301). Furthermore, its economy is thriving, but around 48% of its population lives below the poverty line (World Bank, 2020; World Poverty Clock, 2020). In addition to that, since 2009 north-eastern Nigeria is struck by conflict, with the terrorist group Boko Haram involved. Due to that, Nigeria is suitable to use as a case study.

1.2 Aim and Research Question

Research that has been done on food security, has mostly focused on one driver, acknowledging others as compounding variables. Furthermore, many scholars have done a quantitative analysis. This paper analyzes different drivers for food insecurity in a single country analysis. It focuses on Nigeria, because as mentioned above, it is a food-deficit country and all three key drivers exists in the said country and can be analyzed. This leads to the following research questions:

- What factors impact food insecurity and jeopardize the food security situation in Nigeria?

The impact these drivers have on the food security situation in Nigeria is assessed in the paper. The analysis can be examined with the help of deductive research and a case study research design. To answer the research question, there are three sub-questions to be answered:

- What impact does climate change have on food security in Nigeria?
- What impact does Nigeria's economy have on its food security situation?
- What impact does the Boko Haram Insurgency have on food security in Nigeria?

1.3 Organization of the Study

After this introductory section, the next section elaborates on the literature review comprising of background information on climate change in Nigeria, Nigeria's economy, and Boko Haram terrorist group ant a review of previous literature which shows what scholars found on the different drivers impacting food security. This section also illustrates the concept of food security as used in this paper. The next section describes the research design and also analyzed the data collected from the field. Finally, a conclusion, recommendations and a roadmap for further research in related area were highlighted.

2.0 LITERATURE REVIEW

2.1 Background

The Federal Government of Nigeria is a culturally and religiously multifaceted country located in West Africa. It consists of 36 states and a capital territory. With approximately 201 Million, it is the most populated country in Africa, and its population is growing rapidly (World Poverty Clock, 2019). Nigeria declared its independence from Great Britain in 1960. After going through years of military junta, the country held its first democratic elections in 1999. Since then it has been on stable democracy with a lot of corruption and struggles to fight terrorism (Kah, 2017; World Bank, 2016). This section gives a background on Nigeria's economic sector, climate change in Nigeria, and the Boko Haram insurgency.

2.1.1 Economic Development

Today, Nigeria has a key role in Africa's economy with a large natural resource reservoir. It is a founding member of the African Union and an important, influential member of the Economic Community of West African States (ECOWAS).

Nigeria's biggest economic sector is the oil industry. With exporting, these natural resources, its economic growth depends largely on the world market and world oil prices (World Bank, 2020). Another important, but smaller sector, that has been contributing to Nigeria's economic growth is agriculture. Agriculture is the income for many Nigerians. The Nigerian Government operates on an agriculture strategy to achieve the first two goals of the sustainable development goals, reducing hunger and poverty, by for example bringing private sectors to invest in agriculture, building institutions in rural areas and developing the infrastructure all over the country (Obi et al., 2020: 208; World Bank, 2020). The Nigerian government has started with its intense oil trade under British rule and as a result, neglected agriculture as an important economic sector when the oil industry got bigger and they invested more in oil exploration, however at the moment they are working on reinvesting in this sector (Ojo & Adebayo, 2012: 205; Babu, 2018: 113-114).

Despite being an overall rich country with oil assets, Nigeria's economy has not created many more job opportunities and only a few people benefit from the GDP growth (World Bank, 2019: 20). About 96 million people, 48% of the population suffered from extreme poverty (Otekunrin et al., 2019: 4-5; World Poverty Clock, 2020). Since the population is growing rapidly and the percentage of people living in poverty is only slightly changing, the absolute number of people living in poverty is increasing as well, which causes even more people to suffer from food insecurity (Ugwoke et al., 2020: 1).

While poverty in the South has been decreasing over the years, it has been increasing in the North, especially the North East, because the region is developing less than the South (Ugwoke et al., 2020: 1). The poverty level is more than 50% higher in the North than in the South. Oil reserves are in the South and the economy in the Northeast and the cultivation of land is mostly done in rural areas in the North (Otekunrin et al., 2019: 6).

2.1.2 Climate Change in Nigeria

Climate change is a global issue that affects every country. Nigeria is amongst most sub-Saharan states vulnerable to the impacts of environmental problems. Throughout the years, environmental disasters have become more frequent. In 2012, for example, there was one of the worst floods in Nigeria in 40 years. This led to the loss of many lives, displacement of people, and farmlands being washed away (Nkechi et al., 2017: 301). Nevertheless, climate change does not affect all states the same. Nigeria has four semi-arid savannah climate in the middle belt and parts of the southwest' (Akande et al., 2017).

Desertification as well as too much rainfall can lead to changes in cultivation and displacement of people. Therefore, the whole country is hit by climatic change. All in all, there is evidence that climate change will worsen Nigeria's environment in the future (World Bank, 2016: 49; Abdulkadir, 2017; FAO, 2017).

2.1.3 Development of the Boko Haram terrorist organization

Jama' atu Ahlis Suma Lidda 'awati Wal,Jihad, commonly known as Boko Haram and in this study referred to as Boko Haram is an Islamic territorial terrorist organization in Nigeria. They do not only aim for territories but also want to destroy the current Nigerian political system in said area to establish their political and religious ideology. They do this through attacks on

humans and public facilities as well as the destruction of infrastructure and economic development (ICC, 2014: 4; Adelaja and George, 2019: 185-186).

The group was established between 2002 and 2003 in northeastern Nigeria, where contrary to the south, most of the population is Muslim. Boko Haram has surfaced in 2003 when they attacked police stations and public buildings in the northeastern Yobe State. The buildings were occupied for some days and the group demonstrated its sympathy with Afghanistan's Taliban (Pham, 2016: 3).

Until Nigerian authorities captured and killed their leader Mohammed Yusuf in 2009 they were quite unknown, their attacks were small and simple. Yusuf wanted an Islamic government but achieving that politically in a nonviolent way (ICC, 2014: 9). They turned to the Al-Qaeda in the Islamic Maghreb (AQUIM) terrorist group, got support mainly with financial aid, by AQUIM'S leader and became a jihadist terrorist group. One attack, that gave Boko Haram international attention, was suicide attack on a United Nations (UN) compound in Abuja in 2011 (Pham, 2016: 6).

Since the summer of 2009, northeastern Nigeria has struggled with numerous terrorist attacks, many of them suicide attacks, regularly, aiming against the Nigerian government and its democracy. The three northeastern states, Adamawa, Borno, and Yobe have a majority of Muslims and were targeted most. Other states were also hit, but they also dealt with people fleeing from the conflict, that they took local government resources and budgets away (Adelaja and George, 2019: 3).

Boko Haram aims to destruct selectively. They destroy assets, infrastructure, and agriculture. At the same time, they attack government storage facilities, fertilizer factories, agricultural input, transport systems and farms' (Adelaja and George, 2019: 185), which they attack for their use and survival.

In 2012 the group got more power and became internationally recognized as a militant group that can build and use bombs. Boko Haram built an international network with other African Islamic groups and was able to expand to the neighboring countries, Niger and Cameroon. The militants attacked prisons to release the prisoners, destroyed government buildings, hospitals, and burned down schools, forcing students out of education. By mid-2013 Boko Haram has controlled several local governments, having de facto authorities in these regions. In 2014 the Boko Haram insurgency hit its height. In the first half of the year, they killed at least 2053 civilians in numerous locations, almost daily attacks on marketplaces, churches, and residential areas. One of the most infamous attack was the kidnapping of 2776 girls (Chibok girls) in a school in Borno state (Human Rights Watch, 2014). In mid-2014, the fighters had enough money and resources to go into offense, executing people in public and expand successively. By then they were able to occupy approximately 26-27 local governments. Most of the occupied regions were in a rural area, where agriculture is the livelihood of the population, hereby agricultural land was destroyed (Pham, 2016: 9-10; Adelaja and George, 2019: 186).

In 2015 Boko Haram showed weakness and the Nigerian army and government reclaimed the zones that were taken over. Nigeria declared victory over Boko Haram quickly. The group has had internal struggles and spilt into two factions. One faction pledged allegiance to the Islamic State (IS), turning into the Islamic West Africa Province (BBC, 2015; Anao, 2020). The number of attacks and fatalities has dropped, but in 2017, now being two groups, attacks have gone up again and the Nigerian government is continuously challenged (ACLED, 2019a; Anao, 2020: 7).

2.2 Conceptual and Empirical Framework

2.2.1 Climate change as a driver of food insecurity

Climate change is defined as any change in climate over time, whether due to natural variability or as a result of human activity' (IPCC 2001: 2). Climate change has turned into a global issue and has worsened in recent times. It is now considered a climate crisis and threatens the agricultural production due to higher and more inconsistent temperatures as well as the variation in rainfall patterns and extreme events, such as droughts and floods, occurring more often (Ojo and Adebayo, 2012: 211; Ogbo et al., 2013: 221). With this change, researchers decided to study the relationship between climate change and food security. Studies were done concerning one single country, several countries, or simply regions. Most of the research has been conducted through surveys, direct observation, and weather data. They often use a modeling approach, because they often predicted future scenarios (Zewdie, 2014; Berhanu and Wolde, 2019; Wossen et al., 2018; Fadjumdjum et al. 2019). Researchers agree upon several impacts that climate change already has or will have on food security: on the cultivation and crop yields, as well as on biodiversity.

Climate change affects the first aspect of the food supply chain most. Food production starts with crop growth and cultivation. These are strongly affected by climate variability and therefore especially the agricultural sector is hit by climate change (Jung and Kunstmann, 2007; Wossen and Berger, 2015). In Iran for example impacts, the decline of water resources and precipitation, warmer temperature, and higher CO2 emissions will have on crop growth and food production. Their findings were similar to the majority of research on food security that: food production depends on a steady climate and enough clean water resources.

Aside from food production, climate change also restrains people from having food available and access to it. Extreme weather events can damage food storage. When it gets warmer, air conditioning and refrigeration is needed, which can get expensive, and sometimes there are problems with electricity. If it does not work, the harvested food get expensive, and sometimes there get ruined or no longer be healthy to eat (FAO, 2008; James, 2010). Even though most researchers argue that climate change negatively affects agriculture, some studies have found a positive correlation between global warming and agriculture. This research focused on industrial countries and less on developing countries.

Climate change also forces people to leave their homes, which makes them vulnerable to food insecurity. Internally displaced persons (IDPs) are often forced to leave because of climate change and conflict, two of the three drivers reviewed here. McGregor (1994) addressed the nexus of climate change, forced migration, and food insecurity because already in 1994 there have been many involuntary population displacements due to climate change. Food is one of the most vital needs in displacement camps, where a lot of the IDPs have to live in for many years. They have limited access to it and because they mostly depend on aid that is not always given and most likely they are not able to consume the amount and diversity needed. Thus, they increase food insecurity in a country (McGregor, 1994; Mooney, 2015).

As this section shows, climate change affects food security in various ways. It mostly affects people's livelihoods through food production, people live food insecure because there is less food available or the available food does not have enough nutrients. This leads to people not being able to access food. Most researchers asserted that climate change led to food insecurity. Therefore, it is worth it to explore how climate change has led to food insecurity in Nigeria.

2.2.2 Economic development as a driver of food insecurity

Previous literature suggests that the economy influences food security. Economic growth is one of the highest variables to measure the economy and can be closely connected to food security. Studies by several scholars provide proof that the better the economic growth is, the more people are likely to be food secure (Warr, 2014). Hence a weak economy or an economic crisis can lead to food insecurity in a country (Tawodzera, 2011; Musenwa, 2015; FAO et al., 2019). Most research has been conducted in developing countries in Africa because especially developing countries might have thriving economic growth, but at the same time are vulnerable to an economic crisis, because they are often low-income countries, countries in conflict and the countries that are hit most by climate change. All this increases the vulnerability of a population (FAO, 2019: 59).

For the food security status of a household, the economic situation of the individual is significant as well. Many researchers analyzed factors in the field of economic development and food security. Being unemployed puts people into poverty and poor people usually depend on the market to obtain food. They spend a higher percentage of their income on food and consequently suffer more likely from food insecurity (Etana and Tolossa, 2017: 64). A lot of other literature argues that unemployment, in particular long-term unemployment, does not only result in people spending less money on food but also causes people to change their diet. Evidence showed that they bought cheaper and less healthy food, which in turn impacted the quality of the daily calorie intake. Other studies also found that consumption pattern change when one gets unemployed (Leichchenko and Silva, 2014: 540). Therefore, unemployment can lead to food insecurity on the individual level.

Food prices are another indicator leading to insecurity (Herte et al., 2010; Smith et al, 2017). Global food price drops or rises hit especially countries with an uneven trade balance. When a country depends on exporting agricultural goods or minerals, they are more vulnerable to global price volatility (FAO, 2019: 66).

As mentioned above, most scholars argue that often developing countries are affected by economic crisis. However, all countries can be affected by a sudden global economic shock. Especially the 2008 financial crisis and the recession that followed negatively impacted several countries in the Global North. Davis and Geiger (2017) analyzed the demand for food aid in Europe after 2008. They argue that the need for more food aid represents higher food insecurity. They found that a rise in food aid and led to a more food insecurity after 2008. Griffith et al. (2013) have, on the other hand, examined the food expenditure of people in the UK and concluded that after 2008 there was a significant change in what people bought. Further studies have also shown identical results in studies covering developing countries (Browning and Crossley, 2009; Huang et al. 2016). The economic situation of people affects their state of food security. Hence it does not matter whether a country is in the Global North or Global South, an economic crisis can hit every country.

2.2.3 Violent conflict as a driver of food insecurity

The FAO (2017) has asserted that conflict-affected countries have on average higher rates of food insecure people than countries not affected by conflicts. Violent conflicts can have short-livelihoods. There are several ways where violent conflicts affects food security. However at first, it has to be mentioned that the effect conflict has on food security depends on what kind of conflict it is, considering that ‘measuring and categorizing conflict is not straightforward’ (Martin-Shields and Stojetz, 2019: 151). Studies showed that the outcome depends on the type of conflict.

Literature shows that conflict often occurs in rural areas, areas that have a lot of agriculture (FAO, 2017: 44). Consequently, violent conflict can especially impact agricultural production. On the other hand, food production can decrease. Cultivation is interrupted, where people depend on agriculture. Often fields were ruined by bombs, or it was simply unsafe to work on them (Baumann and Kuemmerle, 2016). Other times farmers abandoned their lands because farmers or workers were killed, people were forced to leave, fled voluntarily, or were involved in the fighting. This can lead to a labor shortage and therefore fewer people harvesting which then can lead to crop yield loss and food insecurity (Suthakar and Bur, 2008; Eklund, et al., 2016; Adelaja et al., 2019: 184). On the other hand, agricultural productivity can increase and have a positive impact on the food security situation in conflict areas. Agriculture can be an important income source for the militants. Jaafar and Woerz (2016) analyzed the agricultural productivity of the Islamic State in their controlled area until 2016. Their findings were that it is an important source of domestic food security.

Whereas the scholars above agreed that conflict impacts food security, Adelaja and George (2019) came to different findings. Their focus was also not on food security at all. They collected data from household surveys and the Armed Conflict Location & Event Data Project (ACLED). When analyzing the data, they found that the amount of land that can be harvested does not decrease when the number of attacks goes up. Although at the same time they did find that a higher intensity of the conflict harms the output of agriculture (Adelaja and George, 2019).

Food access to households and individual food consumption has also been researched by people. A reduced production can lead to a decline in food availability which can cause a reduction in market access to buyers. An example of long-term impacts of food insecurity due to a conflict are studies that focused on the long-term effect of children that were exposed to conflict at an early age (Martin-Shields and Stojetz, 2019; George et al., 2020). The researchers often used the differences-in-differences approach. They analyzed one region where conflict occurred and one where there was no conflict and compared the results. Bundervoet et al. (2007), for example, studied the impact of the civil war in Burundi on children's nutritional status over time. They used data from household surveys in civil war affected and non-affected areas. According to their study, children that were born in regions that at the time of birth experienced violence and had no access to food, due to the disruption of the agricultural production, had lower height-for-age z-score (HAZ) and were therefore not developing the same way as other children. Minoiu and Shemyakina (2014), as well as Arcand et al. (2015), based their research on Bundervoet et al. and did similar studies in Cote d' Ivoire and Angola. With the same approach, their findings are similar: Children who were exposed to these conflicts while born or in their early childhood had a lower HAZ than others.

Lastly, other scholars focused on the impact on IDPs. As above mentioned, conflict can lead to people fleeing and as noted, they are especially vulnerable to food insecurity. The outcomes are the same as when there are IDPs due to climate change. However, these scholars show that not only climate change can lead to internal displacements, also conflict can be a reaon (Tasime et al., 2013).

As this section demonstrates, violent conflict can impact food security directly and indirectly. Direct impacts are mostly on the national level and indirect impacts mainly on the individual level. For example, as the prior section of economic development on food security shows, unemployment, and reduced household expenditure can impact the household at individual level, although not every scholar supports this, it can be said that conflict can have an impact on all different levels of food security.

The literature review shows that these different drivers can lead to food insecurity but are also intertwined. Despite the wealth of literature and the diversity of studies, there is rarely literature disagreeing with the fact that these drivers impact food security in some way. Most scholars argue that the drivers they analyzed lead to food insecurity, but they also state that other drivers have to be acknowledged as interfering variables. They overall agree that each of the drivers can lead to food insecurity, in different parts more than in others. Therefore, when all the drivers are occurring in one country, this country's population is more likely to be severely food insecure.

3. Methodology

This study adopted a mixed-methods approach, that is qualitative and quantitative methods approach. Quantitative data were retrieved from several data-bases that give measurements on food security, climate change, economy and conflict. Qualitative data were drawn from reports and interviews that were conducted with Nigerian NGOs.

The statistical data on the climate is retrieved from the Climate Change Knowledge Portal, which is part of the World Bank Group. Even though they do offer metadata information, it is not exactly clear where data come from. As per economic development, the secondary data is taken from two different sources: The World Bank and UN Contrade Database. The World Bank shows a pool of statistics covering several areas from many different sources. This database is publicly accessible and is updated regularly. The indicators itself do not only come from the World Bank. The metadata with its source for every single indicator can be downloaded on their website. Concerning violent conflict, the primary data utilized is interview method. Other methods of data analysis include the ACLED database, and IDMC sources.

4. Analysis

The following chapter shows the analysis of the study. With the help of all the data described in the previous sections, this section analyzes the said data. Previous scholars mostly approached their articles by first conceptualizing and analyzing food security (e.g. Martin-Shields and Stojetz, 2019). Here it also seems appropriate to analyze the food security situation using the three drivers as already stated.

4.1 Food security situation in Nigeria

As shown and explained in previous sections, food security in Nigeria is analyzed through data from FAO database, the Nigerian GHS as well as interviews. This section shows evidence that there is a significant amount of people facing food insecurity in Nigeria. All conducted interviews with the NGOs have agreed that food insecurity is visible all over the country. According to all of them, the food security situation worsened over the past years. They mentioned that since the Covid-19 outbreak it has gotten even worse and it will not get better in the next few years, but there are no evidential facts about it yet.

Using both figure 1.1 1.2 and a graph, figure 1.1 shows how food security has changed over time. Each measuring period has been conducting its data in the same way and can therefore, be compared. It indicates that there has been quite a change since around 2008. As shown in the figure from 2008-2010 the percentage of undernourishment has been constantly on the rise. At first, it is slowly rising, but looking at the years from 2014-2016 and 2015-2017, there was a drastic rise, with an increase of almost two percent from 9.6% in 2014-2016 to 11.5% in 2015-2017 and after this again another two percent to 13.4% in 2016-2018. Due to the fact that these numbers are always only a three-year average, it can be said that 2014-2016 was another significant turning point in the Nigerian food security situation.

4.1.1 Climate Change data

As much of the literature shows, climate change is one of the causes of food insecurity, and is therefore an independent variable to analyze. To answer the sub-question on what impact climate change has on food security in Nigeria, data that shows the trend in climate variability seems appropriate. This can be the trend of rainfall, the occurrence of rain and drought days, or mean temperatures. Descriptive data that is available on trends in climate variability is the trend of yearly mean temperature and rainfall pattern. Further data that can help get to the connection to food insecurity is data on internal displacement which shows how many people fled due to climate change. Further indicators used in the analysis are the interviews. Interviewees were asked about the experience of monthly rainfall change and droughts affecting cultivation. Secondly, the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) publishes situation reports that give information about certain strong floods and its impact on people's livelihoods in the areas hit.

4.1.2 Economic Development Data

Previous literature argues that whether somebody lives in food security is often also influenced by the countries' current economic performance. Thus, economic development can be a catalyzer for food insecurity and is one of the three independent variables in this study. To analyze the economic development as a cause for food security situation, data has to provide information about the economy in Nigeria and must be compatible with the given food security data.

The economy can be measured through multiple indicators. In general, the GDP can be a relevant summary of the overall economic performance (FAO, 2019). Therefore, GDP and economic growth are the first indicators to use in the analysis . Further indicators to understand the economic situation in Nigeria and how it has evolved across time are the trade balance and products that are predominantly exported. Moreover, food inflation and the unemployment rate are used as secondary data, qualitative data and primary source, that contributes to the analysis are the interviews.

4.1.3 Violent Conflict Data

According to existing literature, the presence of conflict plays an important role in how food insecure somebody is. Thus, a third independent variable chosen to analyze in this study is the Boko Haram conflict in Northeast Nigeria. To measure the food security situation in Nigeria and its relation to the northeastern conflict, especially interviews are good as a primary source. To get statistical data that can be compared to the FAO and Nigerian GHS data is data about the number of conflict and the fatalities that happened over the years since the Boko Haram insurgency began. As Adelaja and George (2019) state in their study that longitudinal data for comparison is limited. I found that this is true and it was difficult to get the right data for this analysis.

However, there are several databases available that measure conflicts. Previous literature that used quantitative data usually either worked with the UCDP or ACLED. After consideration of what database is best to the Boko Haram Insurgency, ACLED was chosen. This database offers information on different kinds of violence in real time, broken down into the date and place of the event, the type of violence and the actors involved (ACLED, 2019). Including the exact source for each for each event and even quotes the source to show that it was precisely taken from there.

According to ACLED, their data is collected by experienced researchers. However, it is primarily taken from secondary sources, but to make sure that the data is accurate and not biased, ACLED uses a variety of sources and does not only trust one source.

5. Conclusion

The study aimed to answer the question: What factors impact food insecurity and jeopardize the food security situation in Nigeria? To answer this, the whole study was focusing on the three factors that, according to previous literature, seemed to influence food security the most: climate change, economic development, and violent conflict. The concept of food security with its four dimensions was the concept often used in the existing literature and previous research showed that each of the drivers influences the different dimensions in some way. The findings demonstrated that these factors can in fact, lead to food insecurity.

The analysis of this study examined these determinants to see how they influence food security and whether they lead to food insecurity in Nigeria. Data was taken from several sources, statistical databases as secondary sources and interviews with NGOs as primary sources. Since the data was rare, the conclusions had to be drawn cautiously. The results of this analysis, however, do confirm the findings in previous research.

According to previous literature, the drivers are intertwined and do not only affect food security, but also impact each other. This study has also found that it cannot be said that either of the drivers alone could have led to food insecurity in Nigeria. In this case It is also more likely that they all influence each other. Climate change and the Boko Haram conflict for example can lead to a lack of food production, which can lead to fewer labor needs, that on the one hand leads to unemployment, then again makes it hard for people to buy food, then facing a food shortage. On the other hand, less food production can lead to more dependence on food imports. A bad economy again can lead to more conflict and so on. It can be said that Nigeria is currently in a vicious circle and it is hard to achieve stable food security. Because Nigeria is affected by all three drivers, it is likely that food insecurity occurs, with what the literature review agrees.

Therefore, the research question can be answered by saying that all three different determinants can jeopardize the food security situation in Nigeria. Furthermore, they all impact people's livelihoods in different years, keeping some people continuously in a state of food insecurity. Moreover, the study found that even though all drivers impact all dimensions of the food security concept, they do influence each of them in other ways. While, according to this study's findings, climate change and the Boko Haram insurgency primarily impact food availability, the economy affects the food access dimension foremost. Especially the interviews have brought the focus on food production in general, meaning that the food availability dimension is often the first dimension that is hit. When there is less food available, and a country depends on food imports, it can lead to a lack of the other dimensions, meaning to many people not having access to food or not having enough food diversity. Because all drivers impact the different dimensions, the last dimension of food security is not met. There is no food stability, and it takes time to achieve the dimensions.

This study also shows that food security depends not only on how a country, specifically Nigeria performs, but also how other countries deal with issues that can reflect back to a country like Nigeria. Globalization has made it hard for such a country to achieve food security by itself.

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CLIMATE CHANGE AND ITS EFFECTS ON THE SOCIO-ECONOMIC DEVELOPMENT OF NIGERIA

Dr. Chukwuemeka Godson Eme (Ph. D)

Lecturer, Department of Business Administration, Faculty of Management Sciences,

National Open University of Nigeria, Jabi- Abuja, Nigeria

E-Mail: kaluchukwuemeka26@yahoo.co.uk; ceme@noun.edu.ng

ABSTRACT

Climate change has become a great challenge to our generation and its impact is felt in almost every society in the world. Nigeria is likely to be the one of the most negatively impacted countries in the world as a result of climate change. Nigeria is plagued with many ecological problems of various dimensions. Whilst the people living in the southern part of the country are being ravaged by flood and gully erosion, their counterparts in the north are contending with the menace of desertification, deforestation and drought, among others. These environmental challenges have direct and indirect effects on the social and economic activities of the societies. The paper reviews the potential impact of climate change on Nigeria's economic and socio-cultural developments. Secondary data were used and descriptive research design was adopted. The findings indicates that many sectors of the Nigerian economy appears to be directly vulnerable to the impacts of climate change such as manufacturing, insurance, transportation, offshore oil and gas exploration and thermal and hydro-power generation and transmission. Other vulnerable sectors are those dependent on climate-sensitive resources like agriculture, fishing, forestry, renewable energy and eco-tourism. These cumulative effects will impact the GDP negatively. On the basis of the findings, the following were recommended; there should be policies toward mitigation and toward developing technology that can improve productivity and are environmentally friendly, irrigation should be encouraged, NIMET should be well equip to enable it function effectively, government agencies and NGO should sensitize the people about the danger and had to work towards a sustainable environment.

Key Words: Climate change, Global warming, Economic development, Sustainable development, Nigeria

1. Introduction

Climate change has become a great challenge to our generation and its impact is felt in almost every society in the world. Nigeria as a developing country with a population of about 160 million is likely to be adversely impacted by climate change due to the vulnerability and low coping capability. Evidences have shown that climate change impacts on Nigeria arises from various climate change related causes experienced due to the increase in temperature, rainfall, sea level rise, impact on fresh water resources, extreme weather events, flooding, drought in the north and increased health risk.

Climate change is an interminable environmental threat of the 21st century which the world is currently experiencing and seeking measures to adopt and mitigate its impact. The United Nations Framework Convention on Climate Change (UNFCC) defines climate change as a change which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere over comparable time periods. Climate change is wreaking havoc on the economies of several individuals, societies, and countries, including Nigeria. This has detrimental effect on a huge number of farmlands and the means of sustenance of persons, increasing poverty and leading to food insecurity, migration, conflicts and public health concerns. As poverty becomes severe, the poor become more reliant on unsustainable development strategies. Thus, unsustainable development strategies such as fossil fuels add to global warming. Global warming therefore exacerbates problems in underdeveloped countries, particularly in sub-Saharan Africa, which lacks the capacity to adapt to climate change. As greenhouse gas emissions cover the Earth, they trap the sun's heat, causing it to warm at an unprecedented rate; hence, global warming and climate change occur.

As one of the most pressing environmental challenges and global crisis affecting civilization today, climate change is becoming a significant global concern, particularly in Africa and Nigeria, where rain-fed agriculture is used. One fossil-fuel-based economic system has been altering the world for many years. Sub-Saharan Africa, in general, and Nigeria, in particular, have been recognized as the region most likely to be affected by climate change, including increasing heat, erratic rainfall and natural catastrophes, as a result of global warming. The failure of the international leaders' meeting in Copenhagen to enhance aspirations for a healthy climate saddened the region. The gathering, a worldwide meeting held in December 2009 to assess progress toward the 1997 Kyoto Protocol's aim and design a new direction for addressing climate change challenges, did not yield a satisfactory result (Muller, 2010). Co2 emissions and the building of greenhouse gases in the atmosphere have changed weather and climate patterns; sadly, those responsible for climate change are rarely held accountable. Climate change has been exacerbated by traditional agriculture practices such as deforestation (tree felling for firewood and cooking energy) and bush burning as a farming practice.

Despite the fact that man and nature are closely linked, growing industrialization has accelerated the carbonization of the biosphere, leaving mother Earth with a negative carbon imprint that is redefining our symbolic relationship with nature. The issue of slow accumulation of dangerous gases in the atmosphere is central to the issue of anthropogenic carbonization of the biosphere and the bio-geophysical interests of world powers, which influence the nature and extent of all socioeconomic and political interactions on climate change (Sadiq, 2013).

Nigeria is vulnerable to climate change. Under the A2 Scenario of the Intergovernmental Panel on Climate Change's (IPCC's) Emissions Report (National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN, 2011), it is projected that Nigeria will experience a temperature increase of 0.04 Oc per year from 1981/2000 until the 2046/2065 period, rising to 0.08 0c per year after 2060. The scenario also projects wetter conditions in the southern part. The drier conditions are expected to be most severe in the north-eastern part of

the country. For the 2046/2065 period, rainfall is projected to increase by an average of 15 on annually rate of 7.5 cm annually in the north (NASPA-CCN 2011: 10). Increased climatic risks, notably floods and droughts, are typically the result, wreaking havoc on food supplies and the economy. Climate change and global warming would wreak havoc on Nigerian livelihoods, including crop production, livestock production, fisheries, forests, and post-harvest activities, if they go uncontrolled.

The impact of these changes, therefore without adaptation could cost between 6% of Nigeria's GDP by 2050, amounting to between USD 100 billion and USD 200 billion. The government has put in place N460 billion to enable them fight the menace of climate change and global warming (Department for International Development (DFID, 2009: 10).

1.1 Objective of the Study

The main objective of this study is to examine climate change in Nigeria, looking at its impact on the socio-economic and cultural sustainable developments of Nigeria. Others include, examining climate governance and policies as response to climate change in Nigeria.

1.2 Methodology

The research adopted a descriptive research design. It dealt exhaustively on the impact of climate change on Nigeria's socio-economic and cultural development. The research made extensive use of secondary sources of data from textbooks, internets sources and newspapers.

2.0 Conceptual Clarifications

2.1.1 Concept of Climate Change

There are many different ways to measure climate change. The International Panel on Climate Change says that it's a 'change in the state of the climate' that can be found by looking at how its properties change over time, usually for decades or more. Any change in temperature over time, whether caused by natural variability or human activity, is called climate change. ''Climate change is defined as ''a change in the climate that is caused by human activity and that is in addition to natural climate variability that has occurred over the same time periods'' (United Nations Framework Convention on Climate Change UNFCCC, in IPCC, 2007). ''A change in the statistical distribution of weather over long periods of time is called ''climate change''. Wikipedia says that ''climate change'' is a change in the weather over a long period of time (Wikipedia, 2009). Wikipedia (2009) says that global warming is ''the rise in the average temperature of the Earth's surface, air, and oceans since the mid-20th century and its expected continuation''. This makes it clear that what is called climate change is actually the result of global warming. Climate change is a problem or phenomenon that has come about because there has been a high rise in the concentration of greenhouse gases (GHGs) made by humans (Spore, 2008). Natural resource depletion, ozone layer depletion, and global warming are some of the most important things about climate change. These traits are more self-reinforcing than other traits. A big problem in Africa when it comes to climate change is how many different stressors, like HIV/AIDS spreading and the effects of economic globalization and resource privatization, work together with climate change to make things worse.

Climate change has arisen as a new component, contributing to increased underdevelopment. There's a danger that Nigeria's climate change crisis may be exacerbated by the lack of a robust emergency and development policy, further complicating problems and increasing dependency and underdevelopment. Thus, the subject of climate change in Nigeria must be viewed in conjunction with developmental challenges, poverty, and unemployment. Nigeria has been seen as a weak, fragile state that has failed to put in place strong systems to help its citizens who have been affected by global economic woes. Every aspect of development in Nigeria is

vulnerable to climate-related stressors. Nigeria's natural capital, including land, forests, landscapes, water and fisheries) and physical capital, including cities, infrastructure, and other kinds of capital are highly susceptible to the impact of climate change. Climate change affects the ability of natural capital, which is the main source of income and livelihoods for majority of Nigerians, to deliver its wide range of products and services including food, timber, and the regulation of water cycle. It's worth highlighting for instance, that economic fights are inextricably linked to social and environmental aspects of man's interaction with the climate system (Edeh, Eme and Nnoli, 2014).

2.1.2 Concept of Global Warming

The continuous rise in temperature of the planet is really upsetting. The root cause for this is global warming. Global warming begins when sunlight reaches the Earth. The clouds, atmospheric particles, reflective ground surfaces, and surface of oceans then sends back about 30% of sunlight back into the space, whilst the remaining is absorbed by oceans, air and land. This consequently heats up the surface of the planet and atmosphere, making life feasible. As the Earth warms up, this solar energy is radiated by thermal radiation and infrared rays, propagating directly out to space, thereby cooling the Earth. However, some of the outgoing radiation is re-absorbed by carbon dioxide, water vapour, ozone, methane and other gases in the atmosphere and is radiated back to the surface of the Earth. These gases are commonly known as greenhouse gases due to their heat-tripping capacity. It must be noted that re-absorption process is actually good as the Earth's average surface temperature would be very cold if there was no resistance of greenhouse gases. The dilemma began when the concentration of greenhouse gases in the atmosphere was artificially increased by humankind at an alarming rate since the past two centuries. As of 2004, over 8 billion tons of carbon dioxide was pumped, thermal radiation is further hindered by increased levels of greenhouse gases resulting in a phenomenon known as human enhanced global warming effect. Recent observations regarding global warming have sustained the theory that it is indeed a human enhanced greenhouse effect that is causing the planet to heat up. The planet has experienced the largest increase in surface temperature over the last 100 years. Between 1906 and 2006, the Earth's average surface temperature augmented between 0.6 to 0.9 degrees Celsius. Millions of pounds of methane gas are generated in landfills and agricultural decomposition of biomass and animal manure. Nitrous oxide is released into the atmosphere by various nitrogen-based fertilizers including area and diammonium phosphate and other soil management utilizations. Once released, these greenhouse gases stay in the atmosphere for decades or even longer. According to Intergovernmental Panel on Climate Change (ICCC), carbon dioxide and methane levels increased by 35% and 148% since the industrial revolution of 1750.

2.1.3 Impact of Climate Change on the socio-economic development of Nigeria

Climate change has been described as a statistical variation that persists for an extended period, typically for a decade or longer. I includes shift in the frequency and magnitude sporadic weather events as well as the slow but continuous rise in global average surface temperature (Intergovernmental Panel on Climate Change (IPCC, 2001). The German advisory council on climate change noted that climate is a threat already having substantial impact on human beings and the natural eco-system both in developed and developing countries but at varying degrees (German Advisory Council on Global Change (WBGU, 2003). For the developed countries, the impact of climate change has been perceived to be less severe due to natural advantage, high adaptation techniques, high technology, mechanical agricultural system and wealth status. These factors have enabled the developed economies to curtail the adverse effects of climate change. For developing countries like Nigeria, the impact of climate change is of great importance given the high temperature level, poor adaptation capacity and lack of early warning

system. Apart from the above, climate change affects economies whose economic activities are natural resource sensitive such as agricultural activities. Unfortunately, some aspects of the existing literature shows that climate change may lead to significant reductions in agricultural productivity in developing countries (McGungan et al., 2002). Indeed, the effect of climate change on agricultural activities can be viewed from various aspects. Climate change affects the distribution of rainfall and temperature during a year and this determines crop yields especially those crops cultivated under rain-fed conditions (Thurlow et al., 2009). Excessive rainfall leads to destruction of arable land, impairment of cultivated crops, increased growth of weeds and greater post-harvest loss while a significant reduction in rainfall may culminate in drier land, reduction in water level in streams and rivers, increase in famers' search for water for irrigation and consequently resulting in invaluable man hour losses and reductions in crop yield (Ozor, 2009). Climate change also affects livestock production due to reduction in the available pasture land, reduction in surface water resources for animals, increase in salinity of water resources for animals, increase in salinity at watering points due to increased temperature and evaporation in the face of reduced rainfall. This implies that there would be a decline in the production of livestock, resulting in a reduction in the supply and availability of annual protein including meat, egg, milk and other animal produce such as hides and skins (Ozor, 2009).

In Nigeria, climate change also affects forestry due to erosion and excessive wind thereby resulting in decline I forest produce such as wood and cane. Consequently, it leads to reduction in forestry produce and low income, as well as an increase in the costs of building and furniture materials. Onuoha (2009) estimated the cost of deforestation and losses in non-timber forest products in the last 5 years in Nigeria at N120 billion per year which is equivalent of 1.7% of gross domestic product (GDP) in 2003. Obviously, climate change portrays a potential threat to the composition of agricultural output on agricultural output in particular and to aggregate national output in general.

In 2012, Nigeria adopted its Climate Change Policy Response and Strategy (CCPRS) to ensure an effective national response to the multi-faceted impacts of climate change. The main goals of the CCPRS include: Implementation of mitigation measures that will promote low carbon as well as sustainable and high economic growth, enhancement of national capacity to adapt to climate change, raising climate change related science, technology and research and development to a new level that will enable the country to better participate in international scientific and technological cooperation on climate change; significantly increase public awareness and involve private sector participation in addressing the challenges of climate change; strengthen national institutions and mechanisms (policy, legislative and economic) to establish a suitable and functional framework for climate change governance. The National Adaptation Strategy and Plan of Action for Climate Change Nigeria (NASPA-CCN) describes the adaptation priorities for future action. The NASPA-CCN vision is a Nigerian approach in which climate change adaptation is an integrated component of sustainable development, reducing the vulnerability and enhancing the resilience and adaptive capacity of all economic sectors and of all people to the adverse impacts of climate change, while also capturing the opportunities that arise as a result of climate change.

The impact of climate change is numerous. The variations in rainfall, temperature, drought, and humidity associated with the science of climate change in Nigeria affect climate dependent sectors. It affects the socioeconomic and political landscapes of countries as well as the relationship across nations as a trans-boundary phenomenon. As a result of its features which are life threatening; the rising sea levels, flooding, starvation, desertification, it is recognized as a threat to human existence. Certain factors such as HIV/AIDS, failing commodity prices, and in some areas have significantly weakened the ability of poor Nigerians to withstand shocks from extreme climate events.

Climate change puts our food and waste supplies at risk, as well as our health, security, stability, and property. Different countries' economic conditions and institutional infrastructure have an effect on their vulnerability to climate change. Certain countries particularly those with affluent economies, exhibit a high degree of resilience, while others, particularly those in sub-Saharan Africa with less favourable economic and institutional conditions, are more fragile. Indeed, because developing countries are frequently exposed to a variety of climatic and non-climatic stresses, their failure to collect reliable data on the resulting consequences exacerbates the consequences.

With climate change affecting highly populated locations in Nigeria like Lagos state, the number of environmental refugees displaced by natural disaster will increase. Forced migration therefore becomes one of the effects of climate change in human settlements, industries and businesses. Flood catastrophes in 2010 affected almost 250,000 people in Nigeria (BRNCCC 2011). In 2012, the situation became worse as the country was hit by high incidence of flooding; 1.3 million people were affected and over 400 people killed and in Makurdi, the flood was much that crocodiles were found in the streets of the town. These incidence were blamed on climate change thus making the Director General of the National Emergency Management Agency (NEMA), Muhammad Sani-Sidi, to say that, 'We are now living witnesses to the reality of climate change and global warming where areas considered dry land in the Northern part of the country witnessed excessive and torrential rainfall while some communities in the South were also submerged'' (Ezigbo, 2012). Rainfall patterns across the country have changed dramatically over the years, with most regions now seeing late onset rainfall as opposed to only a few areas in the northeast, northwest, and southeast (BNRCC, 2001).

Climate change affects human health and survival creating a major concern as well as the health and survival of other species of flora and fauna, and the environment. The World Health Organization (WHO) estimated that at least 150,000 deaths each year could be traced to the outcome of climate change. Moreover, the figure is expected to double by 2030 with connections to flooding and water-related diseases (WHO, 2021). Studies have claimed that climate change-related torrential flooding has led to disease outbreaks in various regions of the globe (Lislie, 1995; Rose et al., 2000). Consequently, the Nigerian population could be exposed to such threats.

Another area affected by climate change is source of livelihood. Livelihood is a means of securing the necessities of life. The effect of climate change threatens the means of sustenance of people. With the increased threats to productivity, farmers' income will diminish and their ability to meet household needs (food, income, etc) will be difficult (Ozor, 2009). Oceanic acidification and increase in surface water temperature especially around the coast affects fish stocks and as a result threaten the livelihood of small-scale fishing communities in the area (IPCC 2007). This eventually will further deepen the vulnerability of the poor.

Climate change could also engender resource conflicts. In Nigeria, resource conflicts worsen given climate change as a result of the scarcity of resources. Population growth and the resulting increases in supply and demand for resources increase competition for scarce food, water, oil, and other resources. For instance, the Fulani herdsmen and farmers in Nigeria compete for grassland and water resources thereby engaging in violent conflicts.

Aside from the effects of climate change visible in the nature of glaciers, vegetation, the core, and other exotic indicators, sea level variations are especially important in our assessments of Nigeria's socio-economic development. Some Nigerian observers have pointed out with some justifications that Nigeria is doubly vulnerable to climate change: heavy rainfall, flooding, soil erosion, and submergence of land in coastal areas as well as loss of wetlands (Ekott, 2009). Climate change in the South-South zone of Nigeria manifests primarily in increased

precipitation, widespread flooding risk, ocean encroachment, increased deforestation, psychosomatic illnesses caused by the excessive heat of gas flaring and sea-level rise. However, it should be pointed out that while developing countries are concerned about the effects of climate change on their population, developed countries are concerned that climate change will limit their unique habits and lifestyle. This is the irony of life.

Climate change impacts are moderated by the level of socioeconomic development of a given community and Nigeria's rather weak socioeconomic development is heightening the severity of the impact; further limiting the country's capacity to respond to emerging challenges (Adesina & Odekunle, 2011). Without serous interventions, including, adaptation, the impact of climate change could be greater as the century progresses. This makes it crucial for Nigeria to focus on those activities and programs that would strengthen its resilience and adaptive capacity in terms of socioeconomic development and effective management of ecosystems (Raffaello et al., 2013; United States Agency for International Development (USAID, 2018).

2.1.4 Climate Governance and Policies as Response to Climate Change in Nigeria

Awareness creation on the impact of climate change involves the effort of everyone; thus, climate change governance involves broad public participation in decision-making which is a critical condition for achieving climate-resilient development. In Nigeria, various stakeholders, (government, non-governmental organizations, the academia and private organizations) collaborate to achieve positive results in climate change management and governance, disseminating information to every local community, stating the impact of climate change on the people especially those into agriculture. With the recognition of the impact of climate change on the socio-economic development of the country and the well-being of the populace by the federal government and other non-governmental organizations, efforts are made to manage climate-related development challenges with appropriate policy and institutional arrangements that will encourage the implementation of mitigation and adaptation actions at all levels of governance for climate compatible sustainable development. Such efforts include in 2012, the Federal Executive Council approved a comprehensive strategy policy on climate change: the Nigeria Climate Change Policy Response and Strategy (NCCPRS), a document which is an output of a national participatory and stakeholders consultative approach to put in place a well-defined national climate change response framework and implementation plan that incorporates critical elements of mitigation and adaptation, contains policy elements and short, medium and long-term national strategies that will enable the country to mainstream mitigation and adaptation into its national development efforts. This is to enable Nigeria respond effectively to the impact of climate change to reduce its vulnerability and enhance its resilience so that the national priorities of rapid economic growth, energy sufficiency, job creation, food security, transparent and accountable climate change governance will be properly addressed.

The Policy has been guiding policy decisions and led to actions in responding to climate change in the country. With the development of the NCCPRS, the global discourse on climate change has led to the adoption of new initiatives that have been domesticated to guide national response to reducing the impact and adapting to the challenge. In particular, a major basis for Nigeria's effective response to the challenge of climate change is the implementation of the 2015 Paris Agreement constitutes an important milestone in promoting the transition to a low carbon economy. Thus, the purpose of this National Policy on Climate Change is to define a new holistic framework to guide the country's response to the development challenge of climate change. As a framework document, it prescribes sector and cross-sectoral strategic policy statements and actions for the management of climate change within the country's pursuit for climate resilient sustainable development (Federal Ministry of Environment, 2021).

Also, the government of Nigeria mapped out other steps to address the challenges of climate change and they include the establishment of the Department of Climate Change (DCC) in the Federal Ministry of Environment which is the focal point to the United Nations Framework Convention on Climate Change (UNFCCC) and also the Designated National Authority (DNA) for the Clean Development Mechanism. The DCC works with other Ministries through the Inter-Ministerial Committee on Climate Change. Also taken as a measure are some development policies with clear implications for climate change adaptation: (i) Vision 20:2020; (ii) the Transformation Agenda (2011 – 2015); and (iii) Economic Recovery and Growth Programme (ERGP) (2017 – 2020). There is also the Nationally Determined Contribution (NDC) which was developed in 2015 towards the ratification of the Paris Agreement on Climate Change. Its aim is to reduce greenhouse gas (GHG) emissions intensity of GDP by 20% by 2030 relative to the emissions intensity of GDP in the base period 2010 to 2014 on an unconditional basis as well as a further 45% on a conditional basis consequent upon receiving climate finance, technology transfer and capacity building from the developed countries.

2.2 Theoretical Review

Two theoretical perspectives are particularly relevant towards our understanding of the phenomenon of climate change; namely the Anthropogenic Global Warming (AGW) hypothesis and the standard theory of externalities. The UK Met Office (1998) describes the AGW hypothesis as the first theory of climate change, which contends that human emissions of greenhouse gases principally carbon dioxide (CO2), methane, and nitrous oxide, are causing a catastrophic rise in global temperatures. The mechanism whereby this happens is called the enhanced greenhouse effect. Energy from the sun travels through space and reaches the earth. The earth's atmosphere is mostly transparent to the incoming sunlight, allowing it to reach the planet's surface where some of it is absorbed and some is reflected back as heat into the atmosphere. Certain gases in the atmosphere, called ''green-house gases'' absorb the outgoing reflected or internal thermal radiation, resulting in earth's atmosphere becoming warmer than it otherwise might be. Water vapour is the major greenhouse gas, responsible for about 36-90% of the greenhouse effect, followed by CO2, methane, and ozone. During the past century, human activities such as burning of wood and fossil-fuel as well as burning of forests are thought to have increased the concentration of CO2 in the atmosphere by approximately 50%. Proponents of the AGW theory believe that man-made crop failures, species extractions, spread of diseases, ocean coral bleaching, famines and literally hundreds of other catastrophes are fall-outs of climate change. According to them, all these disasters will become more frequent and more severe as temperatures continue to rise so that only large and rapid reductions in human emissions will save the planet from these catastrophic events.

Like other environmental problems, climate change involves externality, for instance, the emission of greenhouse gases causes damages to other economic agents for which they are not compensated by the agent responsible for the emission. The standard theory of externalities points to one of taxation of the emitter equivalent to marginal social cost of the externalities generated by it. But where there is weak representation of those most affected, coupled with long-term horizons, a global scale major externalities, and important interactions with other market failures, then resolving the externality problem can be quite complex. Hence, while the standard theory can provide useful initial insights, there is a much deeper and more complex economic policy problem. There is a problem of intertemporal international collective action with major uncertainty and linked market failures.

2.3 Empirical Review

Empirical studies have also confirmed that climate change can have substantial impacts on the overall economy. In Ethiopia, Gebreegziabher et al. (2011) examined the economic effect of

climate on agriculture productivity (GGE) model. The study observed that the impact of overall climate change will be relatively benign until approximately 2050, and thereafter worsen considerably. Further, the simulation results showed that, over a 50-year period, the projected reduction in agricultural productivity may lead to about 30% less average of climate change. Using descriptive analysis, Ozor (2009) demonstrated the processes that lead to climate change so as to enable a better understanding of the concept. The study described in details the impacts of climate change on various issues of national development such as low agricultural productivity, food insecurity, resource conflicts, unemployment, environmentally-induced migration, livelihood problems and health issues. The study also noted that these impacts are as a result of devastating effects of flooding, drought, erosion, desertification, sea level rise, heat stress, pests and diseases, and erratic rainfall patterns, arising from climate change. The study further suggested the need for climate policy in Nigeria, the establishment of NCCC, the development of a national framework for climate change adaptation, and the embracing of emerging technologies.

Onuoha (2009) examined the threats posed by climate change across the globe with particular reference to developing countries, where agriculture is a dominant sector and in turn depends on weather and climate. The study utilized the sustainable development model in the form of the Green Wall Sahara Nigeria Program as a strategy for greening the drought-prone and desert infested areas of Northern Nigeria. The study concluded that the challenges of climate change to economic growth and sustainable development in Nigeria require creative thinking, holistic ideas, innovative solutions and the involvement of all stakeholders. Agwu and Okhimamhe (2009) conducted two studies on the gender dimensions of climate change in North-Central and South-Eastern Nigeria. The North-Central study assessed the impact of climate change on the Zumba and Augie Communities in Niger and Kebbi states respectively. It highlighted the challenges and adaptation strategies of the selected communities. The study observed that communities had noticed climate change but failed to identify its causes. Some of the women in these communities attributed the climate change such as environmental degradation to the construction of the Shiroro dam and the resulting massive deforestation. Less scientifically, Augie women believed that the flood waters from Bakoleri and Goronyo dams which destroyed their farms and affected the health of their people were calamities inflicted by the gods. Again, the women accepted that they had contributed to deforestation in their search of the wood which led to the disappearance of many plant and animal species. Although these resilient communities have put various adaptation measures in place, they were not primarily targeted at reducing the impact of climate change. The study finds that Augie community is already practising a number of coping strategies and requesting for assistance to strengthen them. Specifically, the stakeholders of the community requested for funding, awareness campaigns and capacity building. In Zumba, awareness campaigns are also needed to address traditional beliefs. The second aspect of the study focused on two South-eastern communities, namely Enugwu Nanka in Anambra State and Akama Amankwo Ngwo in Enugu State. The study revealed that the impacts of climate change in South-Eastern Nigeria include the destruction of roads and economic trees by landslides and tornadoes. Climate change is also responsible for excessive heat, heightened insect activity and the drying up of streams. The study concluded that while ingenious adaptive and mitigation strategies developed by women were found in the sample states, better policy making to combat climate change is urgently needed.

Nwafor (2007) notes that a common theme in the climate change vulnerability literature is the idea that countries, regions, economic actors and social groups differ in their degree of vulnerability to climate change. This is partly due to the fact that changes in temperature and precipitation occur unevenly and that climate change effects on resources and wealth are distributed unevenly across the globe. Onuoha (2008) examined these observations by adding

that unless appropriate mitigation measures are adopted to reduce vulnerability in Nigerian and other developing countries of sub-Saharan Africa, climate change portends grave danger not only to the people but also to the biotic and abiotic environments. The study expressed concern that all the developmental advances witnessed in sub-Saharan Africa may be destroyed or reversed over a short period of time unless the effects of climate change are urgently tackled.

3.0 Results and Discussion

The empirical analysis began with the examination of the data for its time series properties. The results of the unit root tests are shown in Table 1. The results indicate that all the series are i/1 except annual rainfall. This suggests that the variables may be co-integrated, since the dependent variable (GDP) has the same order of integration with majority of the regressors. Indeed, we conducted the co-integration test using the residual approach. The result which is shown in Table 2, indicates that the residual is stationary at all level, thereby confirming the existence of an equilibrium relationship between the variables.

Table 1: Unit root test results

Variable	ADF	Phillips-Perron	Result
GDP	1(1)	1(1)	1(1)
ARF	1(0)	1(0)	1(0)
GEM	1(1)	1(1)	1(1)
FDI	1(1)	1(1)	1(1)
GEXP	1(1)	1(1)	1(1)
PINV	1(1)	1(1)	1(1)
REXR	1(1)	1(1)	1(1)

1(0) and 1(1) denote stationary at level and after first difference, respectively. The unit root tests were performed at 5% level controlling for trend and intercept for GDP, GEXP and REXR and controlling for only intercept in other cases. All variables are in their natural log transformation, GDP (Gross Domestic Product); ADF, Augmented Dickey Fuller

As a robustness check, we also conducted the Johansen co-integration test and the results are shown in Table 3. While the Trace test indicates the existence of at least 4 co-integrating equations.

Table 2: Testing the residual for unit root

Variable	Augmented Dickey Fuller Test Statistics	1% Critical Value	5% Critical Value	Probability Value
Residual	-6.339649	-3.646342	-2.954021	0.0000

The residual is stationary at 1% level of significance

Table 3: Johansen co-integration test results

Hypothesized number of CE (s)	Trace Statistics	5% critical value	P value	Hypothesized number of CE (s)	Max-Eigen statistics	5% critical value	P value

None (x)	218.0508	150.5585	0.0000	None	56.8722	50.5999	0.0099
At most 1 (x)	161.1786	117.7082	0.0000	At most 1	51.3355	44.4972	0.0078
At most 2 (x)	109.8431	88.8038	0.0007	At most 2	43.1871	38.3310	0.0128
At most 3 (x)	66.6560	63.8761	0.0286	At most 3	30.1416	32.1183	0.0855
At most 4	36.5144	42.9153	0.1881	At most 4	18.4746	25.8232	0.3418
At most 5	18.0380	25.8721	0.3414	At most 5	11.7789	19.3870	0.4360
At most 6	6.2592	12.5180	0.4281	At most 6	6.2592	12.5180	0.4281

Note: The xx indicates that the Trace statistics or the Max-Eigen statistics is greater than the corresponding 5% critical value

Table 4: Robust long-run estimation results (dependent variable = GDP)

Variable	Coefficient	Diagnostic checks	Remarks
Constant	3.71 (xxx)	Adjusted R	Good
ARF	0.17 (xx)	P-statistic	‘’
CEM	0.22 (xxxx)	Valid F-statistic	‘’
FDL	0.01	Durbin-Watson Statistic	
GEXP	0.84 (xxxx)	Breusch-Godfrey Test (observed Chi-square)	
PINV	-0.35 (xxxx)	Breusch-Pagan-Godfrey Test (observed Chi-square)	
REXR	-0.14 (xx)	Jarque-Bera statistic	

Table 5: ECM estimation results (dependent variable = D(GDP)

Variable	Coefficient	Diagnostic checks	
Constant	0.05	R Square	0.59
D(ARF)	0.10 (x)	Adjusted R square	0.48
D(CEM)	-0.21 (x)	F-statistic	Remarks

D(FDL)	-0.05	Durbin-Watson statistic	
D(GEXP)	0.76 (xxx)	Breusch-Godfrey test (observed Chi-square)	
D(PENV)	-0.30 (xxxx)	Breusch-Pagan-Godfrey test (observed Chi-square)	
D(REXR)	-0.29 (xxx)	Breusch-Pagan-Godfrey (observed Chi-square)	
BCM(-1)	-1.09 (xxx)	Jarque-Bera statistic	

Following the establishment of an equilibrium relationship between the variables, we estimated the long-run relationship of equation 1. The results are shown in Table 4. We summarize the main findings as follows. First, out of the three climate change variables in this study, only carbon emission impacts negatively on the overall output growth of the Nigerian economy. This suggests that Nigerian government must resolve and implement policies that will reduce the amount of carbon emission in the country, especially those coming from the consumption of fossil fuel and gas flaring. Second, the impacts of rainfall and carbon emission are statistically significant at the 5% level. This shows that these climate change variables are important in Nigeria. Third, contrary to expectation, the impact of forest depletion is positive, though it is not statistically significant. This may be due to inadequacies in documenting forest depletion activities in Nigeria. Consequently, the study will favour the continuation of efforts towards forest conservation in Nigeria. Fourth, all the control variables conformed to theoretical expectations, except for domestic private investment. While government expenditures impacts positively and significantly on output at the 1% level, both private investment and exchange rate impact negatively.

The diagnostic checks indicate that the underlying assumptions of the model have been substantially satisfied. The adjusted R square shows that the regressors have adequately accounted for the variations in the dependent variable. The F-statistics, which is strongly significant at the 1% level, shows that the model as a whole is meaningful. The Durbin-Watson Statistic which is approximately 2 is in line with theoretical expectation. Even though the Breusch-Godfrey Test indicates the presence of residual serial correlation problem at the 5% level, we corrected the problem using the Newey-West FAC method. The Breusch-Pagan-Godfrey test shows that there is no problem of Heteroscedasticity in the results. The Jarque-Bera statistic shows that the residual is normally distributed in line with theoretical expectations. Overall, the model assumptions are adequately fulfilled.

5. Conclusion and Recommendations

This paper examined the impact of climate change on socio-economic growth and development in Nigeria. The paper used OLS estimation technique and data for the period 1981-2014. Changes in annual rainfall, carbon emission and forest depletion were used to capture climate change, while government expenditure, domestic private investment and exchange rate were used as control variables in order to obtain robust estimates. The paper estimated an error correlation model in order to account for both long-run and short-run relationships. The results indicate that both in the long-run and short-run, carbon emission affect output growth in Nigeria adversely. In addition, forest depletion impacts negatively on national output growth in Nigeria

in the short-run. These results imply that Nigerian government should evolve and implement policies to curb carbon emissions and forest depletion. In other words, government intervention is required to reduce carbon burning, deforestation and fossil fuel consumption. Government should evolve policies to encourage the use of environmental-friendly equipment, machines, infrastructure, and technologies that generate minimal greenhouse gases, such as improved road and rail transport as well as use of bio-fuels and energy saving devices. A NCCC is obviously required in Nigeria to deal with all climate change issues. Furthermore, the finding that domestic private investment and naira-to-dollar exchange rate impede output growth in Nigeria implies that policymakers and governments at all levels in Nigeria should evolve and implement policies to reverse these undesirable outcomes.

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AKILLI TARIM UYGULAMALARI İÇİN YOLO11 MİMARİSİ KULLANILARAK BUĞDAY TANELERİNİN OTOMATİK SINIFLANDIRILMASI

Nour BAROUDI

Fırat University, Faculty of Technology, Department of Software Engineering, Elazig, Turkey

Email: 241137104@firat.edu.tr

ORCID: 0009-0001-2208-9320

Arş. Gör. Esra YÜZGEÇ ÖZDEMİR

Fırat University, Faculty of Technology, Department of Software Engineering, Elazig, Turkey

Email: eyuzgec@firat.edu.tr

ORCID: 0000-0003-2914-2603

Doç. Dr. Fatih ÖZYURT

Fırat University, Faculty of Technology, Department of Software Engineering, Elazig, Turkey

Email: fatihozyurt@firat.edu.tr

ORCID: 0000-0002-8154-6691

Vedat KARACA

Diyarbakır Plant Protection Research Institute, Diyarbakır, Turkey

Email: vedatkaraca@hotmail.com

ORCID: 0000-0002-1144-047X

ÖZET

Bu çalışma, YOLOv11s nesne algılama modeli tabanlı otomatik bir buğday tanesi kalite değerlendirme çerçevesi sunmaktadır. Gerçekçi denetim senaryolarını simüle etmek amacıyla, yazarlar tarafından 219 görüntü ve 46.689 elle etiketlenmiş buğday tanesinden oluşan özel bir veri kümesi oluşturulmuştur. Veri kümesinde, farklı aydınlatma ve arka plan koşulları altında çekilmiş üç buğday türü (açık, tam ve makarna buğdayı) yer almaktadır. Model, yoğun ve görsel olarak karmaşık sahnelerde sağlamlığı artırmak için hiperparametre optimizasyonu ve veri artırma teknikleri (Mosaic karıştırma, bounding box kayıp ağırlıklarının artırılması vb.) kullanılarak ince ayar yapılmıştır. Deneysel sonuçlar, önerilen YOLOv11s modelinin ortalama doğruluk (mAP@50) değerinin 0.90 olduğunu ve tüm sınıflarda (Sağlıklı, Sağlıksız ve Yabancı Madde) yüksek doğruluk ve geri çağırma oranlarına ulaştığını göstermektedir. Bu sonuçlar, YOLOv11s mimarisinin hem yüksek tespit doğruluğu hem de gerçek zamanlı işleme hızını koruyarak, tarım endüstrisinde pratik kalite kontrol uygulamaları için uygun bir çözüm sunduğunu ortaya koymaktadır. Ayrıca, çalışmada oluşturulan özel veri kümesi, gelecekteki araştırmalar için buğday tanesi kalite sınıflandırmasında değerli bir referans niteliği taşımaktadır.

Anahtar Kelimeler: Buğday Kalitesi, YOLOv11, Nesne Tespiti, Derin Öğrenme, Tarımsal Otomasyon, Veri Kümesi Etiketleme

AUTOMATIC CLASSIFICATION OF WHEAT GRAINS USING YOLO11 ARCHITECTURE FOR SMART AGRICULTURE APPLICATIONS

ABSTRACT

This study presents an automated wheat-grain quality assessment framework based on the YOLOv11s object detection model. A custom dataset comprising 219 images and 46,689 manually annotated grains was constructed by the authors to simulate realistic inspection scenarios, including three wheat types (light, whole, and durum) under diverse lighting and background conditions. The model was fine-tuned using hyperparameter optimization and data augmentation techniques such as Mosaic blending and increased bounding-box loss weighting to improve robustness in dense and visually complex scenes. Experimental results demonstrate that the proposed YOLOv11s model achieves a mean Average Precision (mAP@50) of 0.90, with high precision and recall across all classes (Healthy, Unhealthy, and Foreign-material). These results highlight that the YOLOv11s architecture maintains both high detection accuracy and real-time processing speed, making it suitable for practical agricultural quality control applications. Moreover, the constructed dataset provides a valuable benchmark for future research in wheat-grain quality classification.

Keywords: Wheat Quality Detection, YOLOv11, Object Detection, Deep Learning, Agricultural Automation, Dataset Annotation

1. INTRODUCTION

Wheat stands as a cornerstone of global agriculture, making the assessment of its grain quality and yield paramount for maintaining food security and economic stability. According to the U.S. Department of Agriculture (USDA, 2024), global wheat production in the 2024–2025 marketing year is estimated to exceed 790 million metric tons (MT), reaffirming its position among the top three staple cereal crops worldwide, alongside rice and maize [1].

Traditional human inspection for grain quality remains labor-intensive, costly, and fundamentally unscalable for the vast quantities processed in modern industry. Moreover, such manual evaluations are subjective and prone to inconsistency and human error. Earlier computer-vision systems, while partially automating the process, were constrained by handcrafted, non-adaptive features, which limited their robustness and generalization under diverse real-world lighting and background conditions [2].

Consequently, reliance on human judgment and outdated vision pipelines creates a critical bottleneck in large-scale agricultural quality control. This challenge underscores the need for automated, objective, and data-driven solutions leveraging modern deep-learning architectures.

Deep-learning-based object-detection models are generally categorized into two main paradigms: two-stage detectors (e.g., Faster R-CNN) and one-stage detectors (e.g., SSD, YOLO). While the former achieve high accuracy, they suffer from slower inference speeds that limit real-time deployment. In contrast, YOLO is widely used because it prioritizes processing speed over detection accuracy, offering the efficiency required for industrial automation [3].

Recent studies have investigated YOLO-based and deep learning approaches for wheat grain inspection.

For example, Zhao et al. (2022) proposed an improved YOLOv5 model for wheat grain quality detection [4], while Ma et al. (2024) introduced YOLOv8-HD for seed detection and counting under challenging conditions of adhesion and impurity [5].

Similarly, Qiu et al. (2024) developed YOLO-SDL, a lightweight YOLOv8n variant for classifying perfect, germinated, diseased, and damaged grains [6].

In addition, Liu et al. (2022) employed terahertz spectral imaging with deep learning techniques to identify unsound wheat grains [7].

However, these studies primarily relied on earlier YOLO versions (v5–v8) or non-RGB modalities, and most focused on detection or counting tasks in controlled laboratory environments.

In contrast, the present study introduces a manually annotated dataset containing over 46 000 labeled objects captured under realistic conditions involving multiple wheat varieties and imaging angles. A fine-tuned YOLOv11 model is proposed to balance accuracy and speed, achieving efficient multi-class wheat grain quality detection suitable for practical, real-world deployment in industrial processing environments.

2. MATERIALS AND METHODS

A.DATASET CONSTRUCTİON AND ANNOTATİON

The dataset was originally created and annotated by the authors to support the development of a realistic wheat-grain quality detection model. Wheat grains were manually arranged on A4 sheets and photographed using a mobile-phone camera at multiple viewing angles. To better mimic real inspection conditions, three different wheat types were included light wheat, whole wheat, and durum (pasta) wheat representing the common varieties encountered in food-processing and grain-storage environments. The grains were distributed with varying densities,

from sparse to closely packed, and imaged under different lighting conditions and perspectives. This setup, though simple, effectively reproduced the visual diversity found in real inspection scenarios.

Figure 1 shows representative sample images from the constructed dataset, illustrating the diversity in lighting, angle, and grain arrangement across the three wheat varieties.

All annotations were performed manually using the Roboflow Annotate platform. The dataset consists of 219 images with a total of 46,689 manually labeled bounding boxes, distributed as follows: Healthy-wheat (14,750), Unhealthy-wheat (21,100), and Foreign-material (10,839). Images were exported in YOLO v11 format, each resized to 1024 × 1024 pixels to ensure uniform input dimensions prior to training.

The dataset was divided into 75 % for training and 25 % for testing. Although the total image count was moderate, the high number of labeled instances per image provided sufficient diversity and effectively compensated for the limited number of source images. All annotations were converted to YOLO format to ensure compatibility with the YOLOv11 fine-tuning pipeline, allowing the model to achieve an optimal balance between speed and detection accuracy for multi-class wheat-grain quality assessment.



Figure 1. Sample Images

To illustrate the visual diversity and labeling quality, Figure 1 presents sample images from the constructed dataset, each representing different classes and acquisition conditions. Figure 1. Sample images from the constructed wheat grain dataset, showing examples of healthy, unhealthy, and foreign-material grains.

B. MODEL SELECTİON AND ARCHİTECTURE

In The YOLOv11s model was adopted in this study due to its efficient architectural design and balanced trade-off between speed and detection accuracy [8].

1) YOLOv11 Architecture

The model architecture is organized into three main components [9]:

- Backbone: The backbone employs the R-ELAN (Residual-Enhanced Efficient Layer Aggregation Network) structure, which facilitates better feature reuse and gradient flow through residual aggregation. It also integrates C2f-PSA (Cross-Stage Partial with Parallel Spatial Attention) and SPPF (Spatial Pyramid Pooling – Fast) modules to capture multi-scale spatial information while maintaining computational efficiency.
- Neck: The neck combines Feature Pyramid Network (FPN) and Path Aggregation Network (PAN) layers, enabling multi-level fusion of low- and high-level semantic features. This design improves the model's capability to detect targets of varying scales and aspect ratios.
- Head: The decoupled detection head separates the classification and regression branches, allowing independent optimization of localization and confidence prediction. This modification stabilizes training and increases detection precision in cluttered scenes.

Overall, YOLOv11 achieves enhanced inference stability and accuracy across multiple benchmark datasets while preserving lightweight efficiency, making it suitable for deployment in real-time detection pipelines.

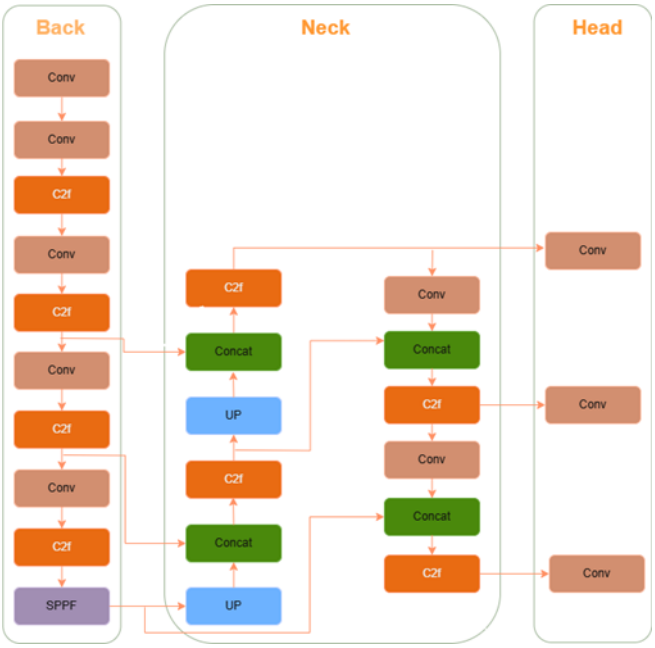


Figure 2. YOLOv11 Architecture

C. MODEL FİNE-TUNİNG AND OPTİMİZATİON

To tailor the model for the wheat-grain quality detection task, a fine-tuning strategy was applied using the custom dataset described earlier. Several hyperparameters and data-augmentation techniques were carefully configured to enhance robustness and generalization:

• Input Resolution: All images were resized to 1024 × 1024 pixels prior to training to preserve the fine-grained details required for accurate detection. Studies have shown that higher input resolution improves localization accuracy, especially for small or densely packed objects [10].

• Data Augmentation: The Mosaic augmentation technique was adopted to enrich the dataset by blending four images into one, effectively increasing diversity in object positions, scales, and backgrounds. Mosaic has been proven effective in agricultural and dense-scene applications by improving contextual learning [11].

• Loss-Weight Adjustment: The bounding-box loss weight (box = 7.5) was increased to encourage the model to prioritize spatial localization over classification probability. This hyperparameter tuning improves the detection of overlapping and adjacent objects by reducing false negatives [12]. Training Environment: All experiments were conducted on Google Colab using an NVIDIA T4 GPU (16 GB VRAM), batch size = 8, and 155 epochs. The default Stochastic Gradient Descent (SGD) optimizer and a cosine-annealing learning-rate scheduler (cos_lr = True) were employed, with early stopping (patience = 40) to prevent overfitting. This fine-tuned configuration allowed the YOLOv11s model to achieve a stable balance between accuracy and real-time inference, ensuring its suitability for practical agricultural inspection tasks. The overall workflow of the proposed wheat grain quality detection system is illustrated in Figure 3.

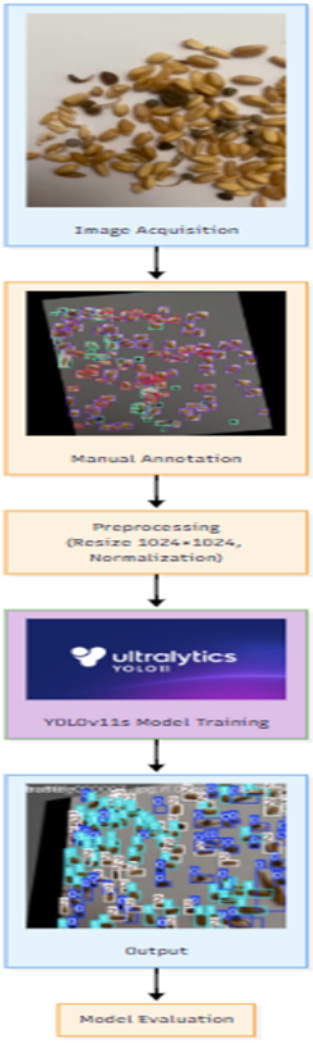


Figure 3. Overall workflow of the proposed system

D. EVALUATİON METRİCS

To evaluate the performance of the object detection models on the wheat classification task, this study employed several well-established evaluation metrics, including Precision (P), Recall (R), F1-score, mean Average Precision at IoU threshold 0.5 (mAP@50), mean Average Precision over multiple IoU thresholds (mAP@50–95), Giga Floating Point Operations per Second (GFLOPs), and Frames Per Second (FPS).

These metrics are widely adopted in modern object detection benchmarks and follow the COCO evaluation standards [13].

Precision (P): Quantifies the percentage of predicted positive instances that are actually correct, measuring the model's ability to avoid false positives:

$$P = \frac{TP}{TP+FP} \qquad (1)$$

Recall (R): Measures the proportion of actual positive instances that are correctly predicted, reflecting the model's ability to detect all relevant objects:

$$R = \frac{TP}{TP+FN} \qquad (2)$$

F1-score: The harmonic mean of precision and recall, offering a balanced metric especially

valuable in imbalanced datasets:

$$F1 = 2 * \frac{P*R}{P+R} \quad (3)$$

mAP@50: Mean Average Precision calculated when the Intersection over Union (IoU) threshold is set at 0.5. This metric provides an overall view of the model's ability to correctly detect and localize objects:

$$mAP_{50} = \frac{1}{m}\sum_{i=1}^{m} AP_i \quad (4)$$

mAP@50–95: As introduced in the COCO evaluation protocol (Lin et al., 2014), this metric averages AP across 10 different IoU thresholds (from 0.50 to 0.95 in steps of 0.05), providing a more comprehensive assessment of detection performance:

$$mAP_{50-95} = \frac{1}{m}\sum_{i=1}^{m}\left(\frac{1}{10}\sum_{j=1}^{10} AP_{i,j}\right) \quad (5)$$

3. RESULTS

A. Quantitative Performance

The model achieved strong detection performance, with Precision = 0.91, Recall = 0.88, F1-score = 0.895, mAP@50 = 93.8 %, and mAP@50-95 = 80.5 %. The high mAP@50–95$ value validates the success of the customized Bounding Box Loss Weight tuning in achieving precise localization, which is vital for distinguishing small, clustered grains.

B. Performance Evaluation Based on Precision–Recall Curves

As illustrated in Figure 4, the Precision–Recall (PR) curve demonstrates strong overall detection performance across all three classes, achieving a mean Average Precision (mAP@50) of 0.90.

The Healthy-wheat class exhibits the highest precision and recall values, reflecting the model's strong ability to both correctly identify and avoid false detections for regular grains.

The Unhealthy-wheat class shows slightly lower recall, suggesting that a small proportion of damaged kernels were missed likely due to partial or subtle discolorations blending with normal grains.

The Foreign-material class displays the lowest precision among the three, indicating occasional false positives where background artifacts or light reflections were misinterpreted as foreign objects.

Nonetheless, all curves remain consistently above 0.85, confirming the YOLOv11s model's robust discrimination capacity and balanced trade-off between sensitivity (recall) and precision under real-world imaging conditions.

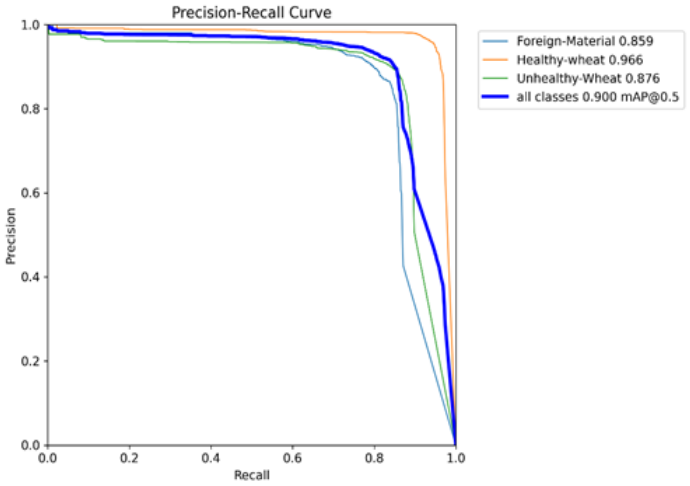


Figure 4. Precision–Recall (PR) curve

C. Confusion Matrix Analysis

As shown in Figure 5, the confusion matrix demonstrates that the YOLOv11s model achieved consistently high per-class accuracy, with most predictions correctly located along the diagonal.

Minor misclassifications were mainly observed between the Foreign-material and Unhealthy-wheat classes. This confusion likely arises from visual overlap in texture and tone, as certain foreign particles such as straw fragments or pasta residues share surface characteristics with damaged grains.

Additionally, a small portion of Foreign-material instances were misinterpreted as background, reflecting the difficulty of detecting low-contrast or partially occluded objects under complex lighting.

Nevertheless, the overall confusion remained limited, confirming the model's strong discriminative capacity and robustness in multi-class wheat-grain quality detection.ecision under real-world imaging conditions.

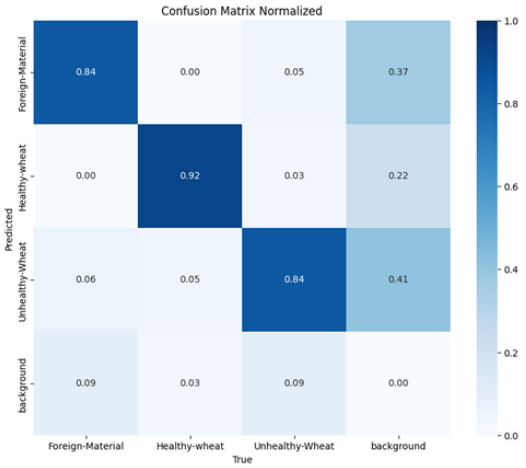


Figure 5. Confusion Matrix

4. CONCLUSION

This study presented a deep learning–based framework for automated multi-class wheat grain quality assessment using the YOLOv11s model. The model achieved a strong overall performance, with a mean Average Precision (mAP@50) of 0.90 and high per-class accuracy

across Healthy-wheat, Unhealthy-wheat, and Foreign-material categories. These results demonstrate the potential of modern one-stage detectors, such as YOLOv11, to provide reliable, real-time quality inspection suitable for industrial deployment.

Despite its promising accuracy, the analysis revealed that foreign-material detection remains the most challenging task due to the high visual similarity between impurities and damaged kernels, as well as background interference.

Future work will therefore focus on expanding and refining the dataset, particularly by increasing the representation and diversity of foreign-material samples under varying lighting and background conditions.

Additionally, future experiments will investigate the integration of attention-based modules and data-driven fine-tuning strategies to enhance small-object discrimination.

Finally, real-time deployment tests will be conducted to evaluate hardware feasibility, ensuring that the system can operate efficiently on embedded devices or industrial inspection units, bridging the gap between research and practical application.

ACKNOWLEDGMENT

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KEDİLERDE MEME HİPERPLAZİSİ

Doç. Dr. Sakine Ülküm ÇİZMECİ

Selçuk Üniversitesi, Veteriner Fakültesi, Doğum ve Jinekoloji Anabilim Dalı, Konya

Email: ulkum@selcuk.edu.tr

ORCID: 0000-0003-2939-8019

Doç. Dr. Ayşe Merve KÖSE

Hatay Mustafa Kemal Üniversitesi, Veteriner Fakültesi, Doğum ve Jinekoloji Anabilim Dalı, Hatay

Email: aysemervekose@gmail.com

ORCID: 0000-0003-1863-5955

ÖZET

Bu çalışma, dişi kedilerde siklik dönemlerde sıkça karşılaşılan, neoplastik olmayan ve memelerde büyümeyle karakterize olan meme hiperplazisi hakkında bilgi vermek amacıyla hazırlanmıştır. Meme hiperplazisi; fibroadenoma kompleks, meme displazisi, fibroglandular meme hipertrofisi, meme fibroadenomatozisi gibi isimlerle anılmakta olup meme stroması ile meme kanal epitelinin proliferesyonuyla karakterizedir. Meme hiperplazisi genellikle birden fazla meme lobunu etkiler ve genç siklik kedilerde daha çok rastlanılmaktadır. Meme hiperplazisi bening karakterdedir ve uzun süre progesteron kullanımı hastalık insidensini arttırmaktadır. Meme bezlerinin hiperplazisi, östrus döneminden 1-2 hafta sonra veya progesteron tedavisinden 2-5 hafta sonra meme bezlerinin hızla büyümesi ile karakterizedir. Bazen kısırlaştırılmış dişi veya erkek kedilerde de görülebilir. Meme hiperplazilerinde meme bezlerinin büyümesinin geri dönüşümü mümkünkür. Etkilenen meme bezlerinde diffuz genişleme şekillenmesi ve çeşitli boyutlarda kitlelere de rastlanması sebebiyle meme tümörü ile karıştırılabilmektedir. Ancak meme neoplazileri genellikle hızlı büyür, katı ve düzensiz şekillidir ayrıca erken dönemde lenf nodüllerine metastaz yapabilir. Hiperplazi ise ısı artışı ve yangı belirtisi gibi klinik bulgular görülmeden birden çok memede şekillenen şişme olgusudur. Bu durum hiperplazinin teşhisini nispeten kolaylaştırmaktadır. Kesin teşhis biyopsi örneklerinin histopatolojik olarak değerlendirilmesiyle yapılmaktadır. Meme bezlerinin gelişimi ve büyümesi, stroma ve epitel hücrelerindeki progesteron reseptörlerinin etkisinden kaynaklanır. Progesteron, meme bezlerini proliferasyonu tetikler. Dolayısıyla progesteron salınımında yaşanan aksaklıklar yada eksternal progesteron uygulamaları meme bezi hiperplazisinin yanı sıra ilerleyen dönemlerde neoplastik aktivitenin gelişimine de neden olabilir. Hiperplazi şekillenen meme bezlerinin yumuşak ve fluktuan olduğu sınırlarının belirginleştiği, görülmektedir. Bazı hiperplazi olgularında meme derisinin gerildiği ve olgunun üzerinden geçen zamana bağlı olarak nekrotik odaklar şekillendiği de gözlemlenmektedir. Hiperplazilerde nadir olarak ateş, anemi, letarji ve anoreksi gibi sistemik belirtiler ortaya çıkabilmektedir. Tedavi amacıyla ovariohisterektomi uygulanabilir fakat hiperplazinin regrese olması için 5-6 ay süreye ihtiyaç vardır. Hiperplazinin sentetik progesteron uygulamasına bağlı olduğu durumlarda progesteron uygulaması acilen sonlandırılmalıdır. Meme bezlerinin kitle hacmi, luteoliz veya eksojen progesteron hormonu aktivitesinin sona ermesinden sonra yavaş yavaş azalabilmekte ve genellikle birkaç hafta içinde normale dönmektedir. Tedavide sekonder enfeksiyonların önüne geçebilmek için geniş spektrumlu bir antibiyotik ile yangı belirtileri mevcut ise kısa süreli antienflamatuar ilaçlar kullanılabilir. Aglepristone veya progesteron

reseptör blokerleri kullanılmaktadır. Bu ilaçlar hedef dokuda progesteron reseptörüne 9 kat afinite ile bağlanan rekabetçi bir moleküldür. Bu ilaçlar 20 mg/kg dozunda günde bir kez veya 10 mg/kg dozunda günde iki kez verildiğinde hiperplazi yaklaşık bir haftada gerileyebilmektedir. Sonuç olarak, kedilerde meme hiperplazisi siklik kedilerde hormonal değişimden etkilenen ve memelerde büyümeyle karakterize geri dönüşümlü bir hastalıktır.

Anahtar Kelimeler: Kedi, benign, hiperplazi, hipertrofi, meme

MAMMARY HYPERPLASIA IN FELINE

ABSTRACT

This study was prepared to provide information about mammary hyperplasias, which are non-neoplastic and characterized by growth in the mammary glands, frequently encountered in female cats during their estrous cycles. Mammary hypertrophy, fibroadenoma complex, mammary dysplasia, fibroglandular mammary hypertrophy, and mammary fibroadenomatosis are terms used to describe a condition characterized by rapid proliferation of the mammary stroma and mammary duct epithelium. Mammary hyperplasia is generally a disease pattern that can affect multiple mammary lobes. It is more commonly seen in young cyclic cats. Mammary hyperplasia is benign in nature, and long-term progesterone use increases the incidence of the disease. Mammary gland hyperplasia is characterized by rapid growth of the mammary glands 1-2 weeks after the estrus period or 2-5 weeks after progesterone treatment. It can sometimes be seen in spayed female or neutered male cats. In mammary hyperplasia, the enlargement of the mammary glands is a reversible disorder.

Due to the diffuse enlargement of the affected mammary glands and the presence of masses of various sizes, it can be confused with mammary tumors. However, in differential diagnosis, mammary neoplasms generally grow rapidly, are solid and irregular in shape, and can metastasize to lymph nodes in the early stages. Hyperplasia, on the other hand, is swelling that occurs in multiple breasts without clinical findings such as increased heat and inflammation. This makes the diagnosis of hyperplasia relatively easy. The definitive diagnosis is made by histopathological evaluation of biopsy samples. The development and growth of mammary glands are shaped by the effects of progesterone receptors in stromal and epithelial cells. The local action of progesterone also triggers a specific increase in progesterone that promotes mammary gland proliferation. Disruptions in progesterone stimulation or external progesterone administration can cause mammary gland hyperplasia as well as the development of neoplastic activity in later stages. Hyperplasia is characterized by clearly defined borders of the mammary glands, which are soft and fluctuant. In some cases of hyperplasia, stretching of the breast skin and the formation of necrotic foci over time have also been observed. Systemic symptoms such as fever, anemia, lethargy, and anorexia may rarely occur in hyperplasia.

Ovariohysterectomy may be performed for treatment purposes, but regression of hyperplasia requires 5-6 months. This option is not mandatory if the cat is intended for breeding. In cases where hyperplasia is associated with synthetic progesterone administration, progesterone administration should be discontinued immediately. The mass volume of the mammary glands may gradually decrease after luteolysis or the cessation of exogenous progesterone hormone activity and usually returns to normal within a few weeks. To prevent secondary infections during treatment, a broad-spectrum antibiotic may be used, and if there are signs of inflammation, short-term anti-inflammatory drugs may be used. Aglepristone or progesterone receptor blockers are used. These drugs are competitive molecules that bind to the progesterone receptor in the target tissue with 9-fold affinity. When administered at a dose of 20 mg/kg once daily or 10 mg/kg twice daily, these drugs can regress hyperplasia in about a week. In conclusion, mammary hyperplasia in cats is a reversible disease characterized by growth in the mammary glands, affected by hormonal changes in cyclic cats.

Keywords: Cat, benign, hyperplasia, hypertrophy, Mammary

1. GİRİŞ

Kedilerde meme hiperplazisi, genellikle genç, dişi ve hormonal olarak aktif kedilerde görülen, memede hızlı ve proliferatif büyüme ile karakterize benign bir hastalıktır (Görlinger et al., 2002). Kedi meme hiperplazisi, meme dokularında görülen, duktal epitel ve meme stromasının yaygın proliferasyonu ile karakterize bir değişikliktir (Uçmak et al., 2011). Dişi kedi meme bezlerindeki kitlelerin yaklaşık %80'i neoplastiktir (Görlinger et al., 2002). Meme hiperplazisi ise meme kitlelerinin %13-20'sini oluşturmaktadır (Payan-Carreira, 2013). Bu durum genellikle progesteron hormonuna bağlı olarak gelişir ve özellikle progestin içeren ilaçların kullanımıyla tetiklenebilir. Bu çalışmada, meme hiperplazisinin etyopatogenezi, klinik özellikleri, tanı yöntemleri ve tedavi yaklaşımları derlenmiştir.

Meme bezleri, embriyonun ventrolateral yüzeyindeki bilateral meme çizgileri veya sırtlarından gelişen ve torakstan inguinal bölgeye kadar uzanan bezlerdir. Kedilerde tipik olarak ventral göğüs kafesinden karına doğru uzanan iki sıra halinde simetrik olarak düzenlenmiş dört çift meme bezi bulunur. (Könıg & Liebich, 2021). İlk meme çifti kranial torasik, ikincisi kaudal torasik, üçüncüsü kranial abdominal ve dördüncüsü kaudal abdominal olarak adlandırılır. Temel olarak bağ dokusuyla kaplı loblardan oluşurlar (Dyce et al., 1997; Pantoja et al., 2017).

Doğumdan pubertasa kadarki sürede normal meme büyümesi vücudun genel büyüme hızının aksine daha yavaştır. Memelerdeki hacimsel gelişim, yağ ve bağ dokularının büyümesiyle şekillenir. İlk östrus siklusundan önce, meme bezinin parankimal dokusu vücutta dışa doğru büyümeye başlar. Her östrus siklusu sırasında meme bezleri ovaryum östrojeni, prolaktin ve hipofiz somatotropini tarafından uyarılmaktadır. Ovaryumda bulunan korpus luteum (KL), tübüloalveolar sistemdeki duktal büyüme ve farklılaşmayı uyarmak için diğer hormonlarla sinerjik olarak progesteron üretmektedir. Kedilerin meme bezinin fibroadenomatöz dokusunda hem progesteron hem de östrojen reseptörlerinin varlığı bildirilmiş, bu da her iki hormonun da patogenezde rol oynayabileceği ifade edilmektedir (Jurka & Max, 2009).

MEME HİPERPLAZİSİ

Kedilerde meme hiperplazisi, meme kanalları ile bağ dokusunun hızla büyümesi (proliferasyonu) ile ilişkili iyi huylu ve genellikle birden fazla meme lobunda şekillenen meme büyümesidir (Loretti et al., 2005; Gaviria et al., 2010). Evcil türler arasında kedilere özgü bir patolojidir. (Vasconcellos, 2003). Kedilerde Meme Hiperplazisi; Fibroadenomosis; Adenofibroma ve Fibroadenom gibi isimlerle de anılmaktadır. Etiyoloji tam olarak belirlenmemiş olsa da lezyonların oluşumuna yol açan endojen ve ekzojen progestinlerin etkisi altında ortaya çıkmaktadır. Bu hastalık, meme kanallarının ve bitişik bağ dokusunun anormal büyümesi ile karakterizedir ve bu anormal büyümesinin progesterondan kaynaklandığı veya progesterona verilen yanıt sebebiyle şekillendiği düşünülmektedir (Simas et al., 2011).

Etiyoloji

Kedilerde meme bezi hiperplazisinde ırksal bir yatkınlık saptanmamış olup, kontrolsüz üreme alanlarındaki evcil ve melez kedilerde çevresel ve iklimsel koşullar dikkate alındığında görülme sıklığının daha yüksek olduğu görülmektedir (Allen, 1973). Esas olarak progesteron veya analogları (medroksiprogesteron asetat ve megestrol asetat vb.) ile tedavi edilen tüm dişi ve erkek kedilerde yaştan bağımsız olarak ortaya çıkabilir (Hayden et al., 1981; Bethlehem & Souza et al., 2002; MacDougall, 2003; Romagnoli, 2015). Hayvanın kendi vücudu tarafından üretilen progesteron (endojen) ve kontraseptif amacıyla uygulanan progesteron (eksojen) meme hiperplazisinin şekillenmesine yol açmaktadır (Filgueira et al., 2015). Progesteron malign tümör oluşumunun yanı sıra meme hiperplazisinin oluşma riskini üç kata kadar artırabileceği ifade edilmektedir. Tek bir sentetik progestin uygulanması yapılan kedilerde dahi meme hiperplazisi gelişebileceği ifade edilmektedir (Loretti et al., 2005).

Meme bezindeki bu değişikliklerin oluşumunda rol oynayan diğer faktörler genetik yatkınlık ile hayvanın beslenme şekli ve rasyonudur (Oliveira, 2015). Obez hayvanlarda mevcut yağ dokunun dolaşımdaki östrojen seviyelerini artırabileceği bilinmektedir (De Nardi et al., 2016). Meme gelişimi üzerinde; östrojen, progesteronun yanı sıra büyüme hormonu (GH), prolaktin, adrenal kortikosteroidler ve muhtemelen tiroid hormonunun etkisi vardır. Hipofiz ve ovaryum hormonları arasındaki sinerji, maksimum meme büyümesine ulaşmak için gereklidir (Vasconcellos, 2003).

Meme hiperplazisi kısırlaştırılmamış dişi kedilerde, gebelik ve yalancı gebelik sırasında ve ekzojen veya sentetik progesteron tedavisi sonrası dişi kedilerde ve kısırlaştırılmamış erkek kedilerde görülebilmektedir (Mayayo et al., 2018; Vitasek & Dendisova, 2006; Marino et al., 2021). Meme hiperplazisi için 6 ay ila 13 yaş arasında en sık ise 13 hafta ve 2 yaş aralığında görülebilmektedir (Uçmak et al., 2011; Hayden et al., 1989; Wehrend et al., 2001; Payan-Carreira, 2013).

Klinik Bulgular

Meme hiperplazisi bir, birden fazla veya tüm meme loblarında simetrik veya rastgele şekillenebilir. Hiperplazi genellikle sağ ve sol bezlerde aynı yerde ve aynı büyüme derecesinde görülür. Genç kedilerde birden çok memede inflamasyon şekillenmesi yaygındır (Silva et al., 2002). Klinik görünüm genellikle oldukça endişe vericidir. Memelerdeki şişme ve renk değişimine bağlı olarak mastitis veya malign neoplazi ile karıştırılabilmektedir (Vasconcellos, 2003).

Klinik belirtiler, bir veya daha fazla bezde lokalize eritem, inflamasyon, kanamalar, ülserasyon ve nekroz ile birlikte meme dokusunun hızlı büyümesi ile karakterizedir. Etkilenen meme bezi, belirtilerin başlamasından birkaç hafta içinde hızlı bir şekilde büyür ve şişer (Görlinger et al., 2002; de Melo et al., 2021; Vasiu et al., 2023).

Gebe olmayan kedilerde genellikle asimetrik şişlikler bulunurken, gebe kedilerde lezyonlar daha homojendir (Payan-Carreira, 2013). İleri vakalarda lezyonlarda şekillenen ödem, iltihap ve anatomik yerleşimi nedeniyle meme dokularının rengi giderek koyulaşır. Bu bölgelerde alopesi de şekillenebilir. Travmanın artmasıyla birlikte şiddetli iltihap, kanama alanları ve nekroz görülebilir. Nekrotik alanlar en sık aksiller ve inguinal loblarda görülür. Meme hiperplazisi gebe kedilerde hangi boyutta olursa olsun meme bezlerinde süt üretimi olmaz (Görlinger et al., 2002).

Memelerin palpasyonunda lezyonlar yumuşak jelatinimsi yada sert kitlelere kadar değişebilmekte, 2,5 cm'den18 cm'e kadar ulaşabilmektedir. Kediler nodüller ülserleşmedikçe veya enfeksiyon şekillenmedikçe genelde ağrı hissetmezler (Amorim et al., 2006). Ancak olgularda ödem, hipertermi ve hiperemi gibi klinik belirtiler ile sıklıkla karşılaşılır (Filgueira et al., 2008). Lezyonların çok yaygın olması halinde kediler yürümekte isteksiz olabilir (Payan-Carreira, 2013) ayrıca travma, yalama, apse, (Vasconcellos, 2003) veya lokal perfüzyonun bozulmasına bağlı olarak ülserler şekillenebilir. İlerleyen kronik vakalarda iskemi şekillenebilir ve sekonder bakteriyel enfeksiyonlara neden olabilir (Araújo et al., 2017; Burstyn, 2010).

Kan analizlerinde hiperplaziye özgü bir değişiklik gözlenmez (Leidinger et al., 2011). Mastitis ve ülserasyon şekillenmesi halinde lökosit sayısında artış ve anemi görülebilir. Kan biyokimyasında üre, kreatinin ve karaciğer enzimleri ileri olgularda sistemik enfeksiyona bağlı olarak yükselebilir (Payan-Carreira, 2013).

Tanı

Meme hiperplazisinin klinik tanısı, hayvanın yaşı, ekzojen progesteron uygulama öyküsü veya meme bezlerinin klinik görüntüsü ve palpasyonu ile konmaktadır (Oliveira, 2015). Kedilerin

anamnezi alınırken östrusun baskılanması veya bazı deri hastalıklarının tedavisi amacıyla progesteron kullanıp kullanılmadığının (Payan-CarreİIra, 2013) yanı sıra ovariohisterektomi operasyonunun bir komplikasyonu olan ovarian remnant sendrom (ORS) şekillenip şekillenmediği bilgisi alınmalıdır. ORS teşhisi, vajinal sitoloji ve davranışsal gözlem yolu ile konulmalıdır (Giménez et al., 2010).

Hayvanın meme bezinde şekilsel bir bozukluk oluştuğunda ayırıcı tanı son derece önem kazanmaktadır. Öncelikle birden fazla meme lobunda şişlik şekillenen meme hiperplazisine benzer klinik belirtilere neden olan kistik meme displazisinden ayırt edilmelidir (Filgueira et al., 2012; Dalanezi et al., 2014). Ayrıca meme karsinomundan ayırt edilmesi, özellikle tedavi yöntemi ve prognozda belirgin bir fark olması sebebiyle çok önemlidir (Filgueira et al., 2015). Meme karsinomarından ayırmak amacıyla histopatolojik incelemeler yapılması gerekmektedir (Davidson, 2015).

Neden endojen olduğunda, meme bezi hiperplazisi ile uyumlu olarak hayvanlarda yüksek hormon seviyelerini kontrol etmek için serum progesteron ölçümleri yapılabilir (Giménez et al., 2010). Ancak, meme hiperplazisinin nedeni ekzojen hormon kullanımı sonucunda şekillendiğinde, bu tanı yönteminin sensivitesinin düşük olması nedeniyle serum progesteron seviyeleri düşük çıkabilmektedir (Payan-Carreıra, 2013). Meme dokusunun ultrasonografik muayenesinde fibroepitelyal doku normal dokuya göre daha fazla ekojenite vermektedir. Radyografik muayene meme hiperplazisinde kullanılmaz ancak ayırıcı tanıda neoplazilere bağlı şekillenebilecek metastaz olasılığını değerlendirmek için uygulanabilir (Payan-Carreıra, 2013). Meme hiperplazilerinde hayvanın öyküsünün ve klinik bulgularının tamamlamasının ardından kesin tanı koymak amacıyla biyopsi alınarak sitolojik muayene yapılabilir (Amorim et al., 2006). Histolojik muayenede normal meme bezine benzer ancak meme kanalları normal dokudan daha geniş ve stroma daha vaskülarize olarak görüntülenir (Hayden et al., 1983). Ayırıcı tanı, mastitis ve sıvı dolu büyük kistler içeren diğer meme displazisi formlarını; adenozis; erkeklerde jinekomasti; duktal ektazi ve lobüler hiperplaziyi de içermelidir (Vasconcellos, 2003).

Tedavi

Meme hiperplazisi tedavisi, altta yatan nedene bağlı olarak değişiklik göstermektedir. Dişi kedilerde siklusun tekrarlamaması ve progesteron etkisinin görülmemesi için ovariohisterektomi (OHE) yapılması gerekir. Bu operasyon median hattaki kan akışının artması nedeniyle sol lateral bölgeden yapılması önerilmektedir (Viana et al., 2012). Hasta kedi progesteron tedavisi görüyorsa ilk olarak hormon uygulamasına son verilmelidir.

Meme hiperplazisinin medikal tedavisinde, bir progesteron reseptör blokeri olan aglepristone kullanılmaktadır (Johnston et al., 2001; Nak et al., 2004; Keskin et al., 2008). Aglepristone progesteron reseptörlerine bağlanarak hormonun etkilerini bloke eden bir antiprogesteron ajanıdır. Bu ilaç aynı zamanda kedi ve köpeklerde gebeliğin sonlandırılmasının yanı sıra pyometra tedavisinde de başarılı şekilde kullanılmaktadır (Sontas et al., 2008; Enginler & Senünver, 2011; Gogny & Fieni, 2016). Çalışmalarda antiprogestinin beş ardışık gün boyunca 24 saatte aralıkla kullanıldığında herhangi bir yan etki şekillenmediği ayrıca ilk uygulamadan bir ay sonra meme bezlerinde involüsyon gözlendiği bildirilmektedir (Jurka & Max, 2009). Ayrıca, 1, 2, 7 ve 21. günlerde (10 ila 15 mg/kg/gün SC) uygulama seçeneği de mevcuttur ve bu prosedür ile altı hafta sonra tamamen gerileme görüldüğü ifade edilmektedir (Vitasek et al., 2006). Antiprogestinler oldukça pahalı ilcalar olması sebebiyle tedavi maliyetlerini yükseltmektedir.

Şiddetli eksojen progesteron kaynaklı hiperplazi vakalarında nüksün önlenmesi amacıyla memelerde tam involüsyonunu takiben OHE uygulanması sayesinde endojen progesteron kaynağı ortadan kaldırılmış olmakta ve hasta sahiplerinin östrus baskılamak amacıyla ekzojen

progesteron kullanımının da önüne geçilmiş olur (Wehrend et al., 2001; Munson, 2006). Endojen hiperplazi olgularında, birincil hormonal kaynağı ortadan kaldırmak için OHE endikedir. Hormonal uyarı kesildikten sonra bile meme involüsyonunun tam olarak gerçekleşmediği veya nüks şekillenen vakalarda mastektomi endikedir (Amorim et al., 2006).

Meme hiperplazisi tanısı konulan kedilerde, meme bezlerinin şişmesi, enfeksiyon ve nekroz şekillenmesi haline tedavi gerekebilir (Görlinger et al., 2002). Prognoz genellikle iyi olsa da kendiliğinden iyileşme görülme ihtimali düşüktür ve bu süreç haftalar hatta aylar sürebilmektedir (Loretti et al., 2004).

Tedavi protokolünün belirlenmesinin ardından, tedavinin maliyeti, iyileşme süresi ve hastalığın nüks oranları kedi sahiplerine iletilmelidir. Meme hiperplazisi şekillenen kedide mastitis, ülser, apse veya sistemik enfeksiyon şekillenmesi halinde hasta sahibi prognoz hakkında bilgilendirilmeli ve ardından tedaviye başlanmalıdır. Seçilen tedavi protokolüne ek olarak geniş spektrumlu antibiyotiler ve sıvı tedavisi uygulanabilir (Burstyn, 2010; Araújo et al., 2017). Kedilere ağrı semptomlarını hafifletmek için non-steroid antienflamatuar ilaçlar (NSAID) (meloksikam, ketoprofen veya karprofen gibi) kullanılabilir (Payan-Carreira, 2013).

Korunma

Kedilerde pubertas öncesi (ilk östrus siklusu şekillenmeden) OHE uygulanması durumunda meme hiperplazisi ve meme tümörleri gelişme riski %5 oranında azalmakta ve OHE korunmada başlıca alternatif olarak değerlendirilmektedir (De Nardı et al., 2016). Ayrıca, kedilerde östrusun baskılanması için ekzojen progestinlerin kullanımının engellenmesi korunmada önemli bir diğer adımdır (Oliveira, 2015; De Nardı et al., 2016).

Prognoz

Kedilerde meme bezi hiperplazisinin prognozu genellikle iyidir. Meme dokusunda ülserler, erozyonlar, apseler ve sistemik bulgular varsa prognoz temkinlidir. Mortalite oranları değişkendir ve sekonder komplikasyonlar ortaya çıkarsa ölüm meydana gelebilir. Ancak, sahibi hastayı ötenazi ile öldürmeyi tercih edebilir (Loretti, et al., 2004; Payan-Carrera, 2013; Pantoja et al., 2017). Ovariohisterektomiye yanıt vermeyen hastaların prognozu da temkinlidir, çünkü gerilememiş tümörleri çıkarmak için kullanılacak son protokol radikal bilateral mastektomidir (Macdougall, 2003; Loretti et al., 2005; Filgueira et al., 2008).

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DİŞİ KÖPEKLERİN MEME TÜMÖRLERİNDE KEMOTERAPÖTİK TEDAVİ

Doç. Dr. Ayşe Merve Köse
Hatay Mustafa Kemal Üniversitesi, Veteriner Fakültesi
Klinik Bilimler Bölümü, Veterinerlik Doğum ve Jinekolojisi Anabilim Dalı, Hatay
Email: aysemervekose@mku.edu.tr
ORCID: 0000-0003-1863-5955
Doç. Dr. Sakine Ülküm ÇİZMECİ
Selçuk Üniversitesi, Veteriner Fakültesi,
Klinik Bilimler Bölümü, Veterinerlik Doğum ve Jinekolojisi Anabilim Dalı, Konya
Email: ulkum@selcuk.edu.tr
ORCID: 0000-0003-2939-8019

ÖZET

Bu çalışma, dişi köpeklerin tüm neoplazilerinin yaklaşık %50'sini oluşturan meme bezi tümörlerinin tedavi seçenekleri arasında yer alan kemoterapi uygulamaları hakkında bilgi vermek amacıyla hazırlanmıştır. Meme tümörlerinin görülme sıklığı 6-7 yaşından itibaren artmakla beraber en sık 10-11 yaş arasında karşılaşılmaktadır. German Shepherds, Dachshunds, Poodles, Cocker Spaniels, Terrier, Setter gibi bazı ırklarda predispozisyon bulunur. Meme tümörlerinin gelişimi yaş, ırk, hormonal etki, kısırlaştırma zamanı, obezite ve besleme gibi çeşitli faktörlerden etkilenmektedir. Meme bezi, alveoller ve kanallardan oluşan, bağ dokusu, damarlar ve sinirlerle çevrili, modifiye bir apokrin ter bezidir. Köpeklerin meme bezi, iyi huylu ve kötü huylu tümörlerin en yaygın görüldüğü dokudur. İyi huylu tümörler genellikle küçük, iyi sınırlı, palpasyonda serttir ve yavaş büyürler; kötü huylu tümörler ise lokal olarak invaziv, üstteki deriye veya derin dokulara sabitlenmiş, ülserleşmiş veya hemorajik olabilir ve genellikle hızlı büyürler. Yaygın metastaz yerleri bölgesel lenf düğümleri ve akciğerlerdir; ancak abdominal organlar, kemikler ve beyin de etkilenebilir. Köpeklerde görülen tümörlerin yaklaşık %40-50'si kötü huyludur. Genel olarak, meme bezi tümörlü tüm köpeklerde, gerektiğinde lenfadenektomi ile birlikte tümörün ve bitişik meme bezlerinin cerrahi eksizyonu endikedir. Bu teknik, lenfatik tutulum ve uzak metastaz olmayan veya daha az agresif histolojik tiplere sahip köpeklerde küratif olabilir. Ancak bölgesel lenf nodu metastazı, agresif histopatolojik tanı ile karakterize, metastaz veya nüks riski yüksek olan invaziv meme tümörlü dişi köpekler için adjuvan tedaviler açısından kemoterapi önerilmektedir. Kemoterapide kullanılan sitotoksik ilaçlar, etki biçimlerine göre genellikle altı sınıfa ayrılmaktadırlar (Alkali ajanlar, Antimetabolitler, Antitümör antibiyotikler, Mitotik İğ İnhibitörler, Glukokortikoidler, Çeşitli ajanlar). Alkali ajanlar, antitümör antibiyotikleri ve diğer ajanların bazıları DNA replikasyonuna bir noktada engel olur. Antimetabolitler enzim inhibitörleri ya da non fonksiyonel moleküllerin sentezi sayesinde DNA ya da RNA sentezini engellerler. Vinca alkoloidler antimitotiktir, mitotik eksende metafazı durdurarak etkiler. Kemoterapötikler çoğunlukla vücut yüzey alanına göre dozlanır. Anafilaksi, kusma ve ishal, anoreksi, miyelosupresyon, alopesi, kaşıntı ve kutanöz hiperpigmentasyon, nefrotoksisite, hematüri, nötropeni, anemi, lenfositopeni, immunsupresyon en sık karşılaşılan komplikasyonlar arasında yer almaktadır. Karboplatin, doksorubisin, dosetaksel, mitoksantron ve gemsitabin içeren kemoterapi protokolleri, meme neoplazmaları olan dişi köpekler için endikedir ve tek başına

veya siklofosfamid ve COX-2 inhibitörleri ile kombinasyon halinde kullanılabilir. Köpeklerde meme tümörlerinin tedavisinde etkili olduğu bildirilen kemoterapi protokolleri vardır. Fakat bu protokoller her hayvanda ya da her meme tümörü vakasında aynı başarıyı göstermemektedir. Kemoterapötik ilaçlar ciddi toksisiteye sahiptir bu nedenle kemoterapötik ilaçları, doğru dozu ve etkili kombinasyonları belirlemek tedavide kritik öneme sahiptir. Kemoterapötiklerin ortalama yaşam süresini ve hastalığın prognozunu nasıl etkilediği hala tartışmalıdır. Sonuç olarak; meme bezi tümörlü köpeklerde kemoterapinin etkinliği hakkındaki bilgiler sınırlı olduğundan kullanımına ilişkin kılavuzlar oluşturmak için daha derinlemesine çalışmalara ihtiyaç vardır.

Anahtar Kelimeler: Meme tümörü, Kemoterapi, Dişi köpek

CHEMOTHERAPEUTIC TREATMENT OF MAMMARY TUMORS IN BITCH

ABSTRACT

This study was prepared to provide information about chemotherapy applications among the treatment options for mammary gland tumors, which constitute approximately 50% of all neoplasms in female dogs. The incidence of mammary tumors increases from age 6-7, but they are most common between ages 10-11. Some breeds, such as German Shepherds, Dachshunds, Poodles, Cocker Spaniels, Terriers, and Setters, are predisposed. The development of mammary tumors is influenced by various factors, including age, breed, hormonal influences, spaying timing, obesity, and nutrition. The mammary gland is a modified apocrine sweat gland composed of alveoli and ducts, surrounded by connective tissue, vessels, and nerves. The canine mammary gland is the most common site of benign and malignant tumors. Benign tumors are generally small, well-defined, firm on palpation, and grow slowly; malignant tumors, on the other hand, are locally invasive, fixed to the overlying skin or deep tissues, may be ulcerated or hemorrhagic, and generally grow rapidly. Common sites of metastasis are regional lymph nodes and the lungs; however, abdominal organs, bones, and the brain may also be affected. Approximately 40-50% of tumors seen in dogs are malignant. In general, surgical excision of the tumor and adjacent mammary glands, with lymphadenectomy if necessary, is indicated for all dogs with mammary gland tumors. This technique can be curative in dogs without lymphatic involvement and distant metastases, or with less aggressive histological types. However, chemotherapy is recommended as adjuvant treatment for bitches with invasive mammary tumors characterized by regional lymph node metastasis, aggressive histopathological diagnosis, and a high risk of metastasis or recurrence. Cytotoxic drugs used in chemotherapy are generally classified into six classes based on their mode of action (alkaline agents, antimetabolites, antitumor antibiotics, mitotic spindle inhibitors, glucocorticoids, and miscellaneous agents). Alkali agents, antitumor antibiotics, and some other agents inhibit DNA replication at some point. Antimetabolites inhibit DNA or RNA synthesis by inhibiting enzymes or by synthesizing nonfunctional molecules. Vinca alkaloids are antimitotic, acting by arresting metaphase in the mitotic cycle. Chemotherapy drugs are mostly dosed according to body surface area. Anaphylaxis, vomiting and diarrhea, anorexia, myelosuppression, alopecia, pruritus and cutaneous hyperpigmentation, nephrotoxicity, hematuria, neutropenia, anemia, lymphocytopenia, and immunosuppression are among the most common complications. Chemotherapy protocols containing carboplatin, doxorubicin, docetaxel, mitoxantrone, and gemcitabine are indicated for bitches with mammary neoplasms and may be used alone or in combination with cyclophosphamide and COX-2 inhibitors. There are chemotherapy protocols reported to be effective in the treatment of mammary tumors in dogs. However, these protocols do not provide the same success in every animal or every case of mammary tumor. Chemotherapy drugs have serious toxicity; therefore, determining the correct dosage and effective combinations of chemotherapy drugs is critical in treatment. How chemotherapeutics affects average life expectancy and disease prognosis is still debated. In conclusion, since information on the effectiveness of chemotherapy in dogs with mammary gland tumors is limited, more in-depth studies are needed to develop guidelines for its use.

Keywords: Mammary tumor, Chemotherapy, Bitch

1. GİRİŞ

Meme bezi, alveolar dokular ve kan damarları, bağ dokusu ve sinirlerle çevrili süt kanallarıyla karakterize, modifiye bir apokrin ter bezidir. Köpeklerdeki meme bezleri torasik bölgelerden abdominal ve inguinal bölgelere kadar uzanan beş çift halinde ve on adettir (Rath ve ark. 2024). Üreme açısından aktif dişi köpeklerin yaşamları boyunca yeniden şekillenme ve farklılaşma geçiren benzersiz bir organdır. Her östrus döngüsünde, epitel ve mezenkimal proliferasyon, duktal dallanma ve alveoligenez dalgaları yoğun regresif değişikliklerle birlikte görülür. Meme bezlerindeki bu fizyolojik ve morfolojik değişiklikler, neoplaztik değişikliklere karşı oldukça hassastır (Sewoyo ve ark. 2023). Bu nedenle köpeklerin meme bezi, iyi huylu ve kötü huylu tümörlerin gelişiminin en yaygın görüldüğü dokudur (Benavente ve ark. 2016). Tümör gelişimi ve ilerlemesi, yaş, cinsiyet, beslenme durumu, üreme durumu ve çevresel uyaranlara maruz kalma gibi çeşitli faktörlerden etkilenir (Kaszak ve ark. 2022). Meme tümörleri, seksüel yönden aktif dişi köpeklerde yaygındır. Bazı ırklar; örn. German Shepherds, Dachshunds, Poodles, Cocker Spaniels, Terrier, Setter, bu tip meme tümörüne yakalanmaya diğerlerinden daha yatkındır. Bu da meme tümörlerinde genetik nedenlerin rol oynayabileceği anlamına gelmektedir (Torres ve ark. 2021, Sewoyo ve ark. 2023). Ayrıca meme tümörleri safkan köpeklerde (%62), karma ırklara (%38) göre daha sık görülmektedir (Vascellari ve ark., 2016). Dünya genelinde meme tümörleri, dişi köpekleri etkileyen toplam tümör tiplerinin yaklaşık %25-70' ini oluşturmaktadır ve bunların da yaklaşık %50'si kötü huyludur (Torres ve ark. 2021, Sewoyo ve ark. 2023). Beş yaşından küçük köpeklerde meme tümörü gelişimi nadirdir. Meme tümörlerinin görülme sıklığı 6-7 yaşından itibaren artmakla beraber en sık 10-11 yaş arasında karşılaşılmaktadır (Benavente ve ark. 2016). Makroskopik anormallikler fark edilene veya klinikte rutin bir klinik muayene sırasında tümör tespit edilene kadar, köpek sahipleri genellikle evcil hayvanlarında tümör olduğunun farkında değildir (Sewoyo ve ark. 2023).

2. ETİYOLOJİ

Meme tümörlerinin gelişimi yaş, ırk, hormonal etki, kısırlaştırma zamanı, obezite ve besleme gibi çeşitli faktörlerden etkilenmektedir (Franco ve ark. 2024).

Meme tümörlerinin çoğu orta yaşlı ve yaşlı köpeklerde görülürken, genç köpeklerde görülme sıklığı çok düşüktür. En yüksek görülme sıklığı 7-13 yaş arasındadır (Goldschmidt ve ark. 2016). Sorenmo ve ark. (2009) iyi huylu tümörlerin genç köpeklerde (ortalama 7-9 yaşta) görülürken, kötü huylu tümörlerin yaşlı köpeklerde (ortalama 9-11 yaşta) görüldüğünü belirtmektedir. Ancak, tümörlerin gelişeceği yaş, köpeğin cinsine ve boyutuna bağlı olmaktadır; çünkü büyük ırklarda meme tümörleri küçük ırklara göre daha genç yaşta gelişir. Hem progestin hem de östrojen gibi ekzojen hormonların kullanımı da meme tümörlerinin geliştiği yaşı azaltmaktadır (Goldschmidt ve ark. 2016).

Hem normal hem de neoplazik memelerde doku büyümesi östrojen, progesteron ve prolaktin hormonları ve büyüme faktörleri tarafından uyarılır (Cassali ve ark. 2014, de Araujo ve ark. 2015). Östrojen, meme epitelinin mitotik aktivitesini uyararak bu organda neoplazma riskini artırdığı için onkogenezde önemli bir rol oynar. Progesteron, miyometriyumun aktivitesini baskılayarak, endometriyal bezlerin büyümesini uyararak ve meme alveolar dokusunun gelişimini destekler (Rueda ve ark. 2024). Östrojenle birlikte olduğunda, proliferatif faktör nedeniyle meme neoplazmlarının gelişiminde önemli bir rol oynar. Prolaktinle birlikte olduğunda, östrojen reseptörlerinin sayısını artırarak bu hormonun mitotik etkisini kolaylaştırır (Misdorp 2002, Rueda ve ark. 2024). Köpeklere veya kedilere ekzojen progesteron uygulandığında, meme bezinde büyüme hormonu sentezi uyarılır, lobulo alveolar proliferasyon ve buna bağlı olarak miyoepitelyal ve salgı elemanlarının hiperplazisi meydana gelir ve bu da genç hayvanlarda iyi huylu nodüllerin oluşumuna neden olur. Meme dokuları, sürekli olarak progesterona maruz kaldığında kötü huylu metaplaziye uğrayabilir (Misdorp 2002, Rueda ve

ark. 2024). Çok sayıda çalışma, erken yaşta yapılan ovariektominin daha sonraki meme neoplazisi gelişimini önlemede koruyucu olduğu gösterilmiştir. İlk kızgınlık döngülerinden önce ovariektomi yapılan köpeklerde, meme neoplazmı geliştirme riski %99,5 oranında azalırken, ikinci ve üçüncü kızgınlık döngülerinden önce ovariektomi yapılırsa risk sırasıyla %92 ve %74 oranında azalmıştır; üçüncü döngüden sonra ovariektomi yapılırsa istatistiksel olarak anlamlı bir fayda sağlamamıştır (McNeill ve Vienna 2015, Goldschmidt ve ark. 2016). Progestinler ve östrojenler gibi ekzojen hormonlar köpeklerde meme tümörü geliştirme riskini artırır. Düşük doz progestinler iyi huylu neoplazmların gelişimini tetiklerken, progestin ve östrojen kombinasyonunun kötü huylu neoplazmların gelişimini tetiklediği görülmektedir (Goldschmidt ve ark. 2016).

Bazı çalışmalar, dişi köpeklerde obezite ile meme neoplazmlarının gelişimi arasında olası bir ilişki olduğunu göstermektedir (Cleary vd. 2010; Lim vd. 2015; Chandler vd. 2017). Bu neoplazmların gelişimindeki obezite, leptin ve adiponektin proteinlerinin etkileriyle ilişkili olabilir (Cleary vd. 2010). Leptin apoptozu inhibe eder ve hücre çoğalmasını uyarırken, adiponektin hücre çoğalmasını azaltır ve apoptozu destekler. Yağ dokusu tarafından üretilen bu maddelerin konsantrasyonları vücut ağırlığına göre değişir, bu nedenle kilo ve vücut kitle indeksi arttığında, serum leptin konsantrasyonları artar ve adiponektin azalır (Cleary vd. 2010; Lim vd. 2015). Obezite ayrıca, globuline bağlı seks hormonlarının serum konsantrasyonunda bir azalmayla da ilişkili olabilir ve bu da serum serbest östrojen konsantrasyonlarında bir artışa neden olabilir. Ayrıca, yağ dokusu, aromataz aracılı androjen dönüşümü yoluyla artan östrojen üretiminin bir kaynağı olabilir (De Nardi ve ark. 2016).

Birkaç gözlemsel çalışma, diyet ile meme neoplazisi geliştirme riski arasında bir korelasyon bulmuştur. Kırmızı et oranı yüksek bir diyetle beslenen ve 1 yaşında obez olan köpeklerin meme neoplazmı geliştirme riski artmıştır. Başka bir çalışma, 9-12 aylıkken zayıf olan köpeklerin meme neoplazmı geliştirme riskinin azaldığını bildirmiştir. Düşük yağlı, yüksek proteinli bir diyetle beslenen köpeklerde kötü huylu meme tümörlerinin çıkarılmasından sonra daha uzun hayatta kalma süreleri ile ilgili bir ilişki olduğu öne sürülmüştür (Goldschmidt ve ark. 2016).

3. TANI

Meme tümörü olan dişi köpeklerin çoğu, tanı anında klinik olarak sağlıklıdır ve nodüller rutin klinik muayene sırasında sahipleri veya veteriner hekimler tarafından tanımlanabilir (Cassali ve ark. 2011). Oliveira ve ark. (2021), kötü huylu meme tümörlü köpeklerin yaklaşık %25 ila %50'sinde tanı anında metastazlar bulunduğunu ifade etmiştir. Lezyonun başlangıç ve ilerleme zamanı, önceki tedavi ve üreme geçmişi ile ilgili bilgileri içeren anamnez alındıktan ve genel durumu belirlemek için tam bir fizik muayene yapıldıktan sonra köpek, nodülleri veya boyut, şekil veya kıvamdaki değişiklikleri belirlemek için meme zincirlerinin ve bölgesel lenf düğümlerinin palpasyonunu içeren, lezyonları makroskopik olarak tanımlayan özel bir meme bezi fizik muayenesinden geçmelidir (Cassali ve ark. 2014, Brissot ve Edery 2017). Meme bezi ve lenf düğümlerinin palpasyonundan sonra, nodüllerin ve lenf düğümlerinin ince iğne sitopatolojik incelemesi tanıda yardımcı olarak kullanılmalıdır (De Nardi ve ark. 2016). Beş santimetreden büyük, hızlı büyüyen, yapışık, geniş ülserasyon alanları olan ve lenf düğümlerine metastaz yapan nodüller en kötü prognozla ilişkilidir. Birden fazla nodülü olan memeler hem iyi huylu hem de kötü huylu olmak üzere farklı histolojik tipler gösterebilir, bu yönler prognozu etkilediği için dikkate alınmalıdır (Rueda ve ark. 2024). Köpek meme tümörlerinde en sondaki meme bezleri en sık etkilenir ve daha kranial bezlerde hastalık görülme sıklığı azalır. Küçük neoplazmaların (<1 cm çapında) iyi huylu olma olasılığı daha yüksekken, daha büyük neoplazmaların (>3-5 cm çapında) kötü huylu olma olasılığı daha yüksektir. Ancak tüm meme nodülleri, boyutlarına bakılmaksızın, iyi huylu ve kötü huylu tümörleri ayırt etmek için histolojik olarak değerlendirilmelidir. Meme neoplazmı olan çoğu köpek, herhangi bir sistemik

hastalık belirtisi göstermez. Tümörler metastaz yaparsa, köpek son aşamada kaşeksi ve solunum güçlüğü belirtileri gösterebilir. Meme bezlerinde elle hissedilebilen bir veya daha fazla kitle dışında, çoğu köpek genellikle sağlıklıdır (Goldschmidt ve ark. 2016).

Meme neoplazmı olan dişi köpeklerin klinik derecelendirilmesi, tedavi seçenekleri konusunda planlama yapılabilmesi ve prognozun belirlenebilmesi için yapılmalıdır (Rueda ve ark. 2024). Dünya Sağlık Örgütü (WHO), birincil tümörün (T) değerlendirilmesi, bölgesel lenf düğümlerinin (N) (aksiller ve yüzeyel inguinal) tutulumu ve uzak metastazların (M) belirlenmesi gibi değişkenleri içeren TNM sistemini önermektedir (Batschinski ve Tedardi 2016; De Nardi ve ark. 2016; Cassali ve ark. 2020). Bu sınıflandırma sisteminde, tümör ilerlemesine göre beş klinik evre tanımlar: Klinik evre I: T1, N0, M0; II: T2, N0, M0; III: T3, N0, M0; IV: Herhangi T, N1, M0; V: Herhangi T ve N, M1.

4. TEDAVİ

Köpek meme tümörlerinin (CMT) tedavisi cerrahi, radyoterapi, hormonal tedavi, kemoterapi, hedefe yönelik tedavi ve viroterapiyi içerir. Cerrahi, birçok CMT türü için ilk tedavi seçeneği olmaya devam etmektedir. Cerrahi eksizyon, bölgesel tümör kontrolü için en etkili yöntemdir ve genel sağkalımı artıran histolojik değerlendirmeye olanak sağlamaktadır. Lumpektomi, bölgesel mastektomi, basit mastektomi ve tek taraflı ve iki taraflı mastektomi kullanılan cerrahi teknikler arasındadır (Sleeckx ve ark. 2011).

Cerrahi türü, tümör boyutu ve konumu, bölgesel lenf düğümlerine olası yayılım, tümörün dokuya yapışması ve fiksasyonu ve toplam lezyon sayısı gibi belirli kriterlere göre seçilir. Lumpektomi veya nodülektomi, küçük (<0,5-1 cm), sert ve fiksasyona uğramamış iyi huylu nodüllerin çıkarılması için endikedir. Basit (tek) mastektomi, tek bir meme bezinin çıkarılması anlamına gelir ve meme bezinde merkezi bir konuma sahip ve alttaki dokulara veya üstteki deriye fiksasyon gösteren büyük lezyonlar için endikedir. Bölgesel mastektomi, ardışık bezlerde veya iki bez arasında lokalize olan büyük meme tümörlerinin çıkarılmasıdır. 1'den 5'e kadar meme bezlerinin bir ünite olarak çıkarılması, tek bir zincirdeki bezlerdeki birden fazla tümör için endike olan tek taraflı mastektomi ile gerçekleştirilir. Her iki zincirde de lokalize olan birden fazla tümörde iki taraflı mastektomi yapılır. Hastalığın daha düşük klinik evrelerine sahip, küçük, invaziv olmayan ve iyi yerleşmiş tümörleri olan köpekler ameliyatla tedavi edilir. Metastatik gelişime yatkınlığı olan daha yüksek dereceli tümörlere sahip dişi köpeklerde ek tedavi seçenekleri kullanılmalıdır (Nosalova ve ark. 2024).

Ameliyattan önce uzak metastazları tespit edilen köpeklerde ameliyat, köpeğin sağkalım süresini uzatmaz, ancak ülserli ve/veya ağrılı lezyonları olan hastaların yaşam kalitesini artırabilir (Cassali vd. 2020). Cerrahi tedavi tercih edilen tedavi yöntemi olsa da kemoterapi, nüksü ve metastaz oluşumunu önlemeye yardımcı olabilir ve ayrıca ameliyat edilemeyen tümörlerde ve hastanın uzak metastazları varsa da endikedir (Rueda ve ark. 2024). Mikropapiller karsinom, solid karsinom, karsinosarkom ve pleomorfik lobüler karsinom teşhisi konan dişi köpeklerde metastaz riski artmıştır ve bu vakalarda klinik evreden bağımsız olarak adjuvan kemoterapi önerilir. Lenf düğümlerinde veya akciğerlerde metastazı olan, klinik evre IV ve V olan hastalar her zaman kemoterapiden fayda görecektir (Cassali ve ark. 2011, Cassali ve ark. 2020).

KEMOTERAPİ

Kanser tedavisinde farmakolojik ajanların modern kullanımı ilk olarak 1940'ların ortalarında gerçekleştirilmiştir. Günümüzde klinik kullanımda 1955'te Ulusal Kanser Enstitüsü'nde kanser kemoterapisi için oluşturulan çerçeveden faydalanılmaktadır (Chabher ve Roberts 2005, DeVita 2008). Kemoterapi cerrahi müdahaleye ek olarak neoplaztik oluşumların tedavisinde

yaygın olarak kullanılmaktadır. Antikanser ilaç uygulamasının temel amacı hücre bölünmesi aşamalarına etki etmektir (Chun ve ark. 2007, Kıvrak ve Aydın 2017).

Kemoterapötiklerin anafilaksi, kusma ve ishal, anoreksi, miyelosupresyon, alopesi, kaşıntı ve kutanöz hiperpigmentasyon, nefrotoksisite, hematüri, nötropeni, anemi, lenfositopeni, immunsupresyon gibi ciddi yan etkileri vardır. Hastaları, kemoterapötik ajanları ve doğru dozu belirlemek bu yüzden kritik öneme sahiptir. Kemoterapötikler çoğunlukla vücut yüzey alanına göre dozlanır. Vücut yüzey alanı, vücut ağırlığına göre hazırlanan bir formülle hesaplanır (Chun ve ark. 2007, Kıvrak ve Aydın 2017). Vücut ağırlığının kilogram cinsinden değerini, vücut yüzey alanının metre kare cinsinden değerine göre hesaplanmış değerleri Tablo 1 de verilmiştir.

Tablo 1. Köpeklerde vücut yüzey alanı ile ağırlık arasındaki ilişki (Gustafson ve Page 2013).

Köpeklerde Kilo ile Vücut Yüzey Alanı Arasındaki İlişki					
kg	**m²**	**kg**	**m²**	**kg**	**m²**
3.0	0.210	20.0	0.744	48.0	1.334
4.0	0.255	21.0	0.769	50.0	1.371
5.0	0.295	22.0	0.785	52.0	1.412
6.0	0.333	23.0	0.817	54.0	1.448
7.0	0.370	24.0	0.840	56.0	1.484
8.0	0.404	25.0	0.864	58.0	1.519
9.0	0.437	26.0	0.886	60.0	1.554
10.0	0.469	28.0	0.931	62.0	1.588
11.0	0.500	30.0	0.975	64.0	1.622
12.0	0.529	32.0	1.018	66.0	1.656
13.0	0.553	34.0	1.060	68.0	1.689
14.0	0.581	36.0	1.101	70.0	1.722
15.0	0.608	38.0	1.142	72.0	1.755
16.0	0.641	40.0	1.181	74.0	1.787
17.0	0.668	42.0	1.220	76.0	1.819
18.0	0.694	44.0	1.259	78.0	1.851
19.0	0.719	46.0	1.297	80.0	1.882

Kemoterapide kullanılan sitotoksik ilaçlar, etki biçimlerine göre genellikle altı sınıfa ayrılmaktadırlar (Chun ve ark. 2007, Gustafson ve Page 2013):

1. Alkilleyici ajanlar; etkilerini DNA'ya kovalent bağlanarak gösterir ve sonuçta hücre bölünmesini durdurur ve programlı hücre ölümüne (apoptoz) yol açar.

Cyclophosphamide, Köpeklerde oral (PO) veya IV yolla bolus doz (250 mg/m²) olarak etkili bir şekilde uygulanır. Bazı protokollerde fraksiyonlu bir dozlama programı da kullanılır (doksorubisinden sonra 3 ila 4 ardışık gün boyunca 50 mg/m²)

Chlorambucil, Köpeklerde kronik oral doz, 1-2 hafta boyunca günde 3-6 mg/m² PO ile başlamalı ve rutin hematolojik tarama ve kanser kontrolüne göre gün aşırı 3-6 mg/m² PO'ya düşürülmelidir.

Lomustine, 3 haftada bir 70-80 mg/m² PO çoğunlukla tek başına veya çoklu ajan protokollerinde kullanılır.

Dacarbazine, tek başına bir ajan olarak, 3 haftada bir 800-1000 mg/m² IV infüzyon dozu olarak, diğer sitotoksiklerle birlikte kullanıldığında, 600 mg/m² IV dozu bildirilmektedir.

Melphalan, 10 ila 14 gün boyunca günlük 0,1 mg/kg PO başlangıç dozu, paraproteinemi kontrolü ve hematolojik taramaya göre günlük 0,05 mg/kg PO'ya düşürülmelidir. Köpekler için alternatif doz rejimleri de kullanılmıştır: 3 haftada bir 5 gün boyunca günlük 7 mg/m² PO veya 10 gün ara ile 10 gün boyunca günlük 2 mg/m² PO ve gerektiğinde tekrarlama şeklinde kullanılmaktadır.

2. Antitümör Antibiyotikler; çeşitli etki mekanizmalarına sahip klinik olarak yararlı bileşikler üreten antrasiklinler, mitomisinler ve aktinomisinler dahil olmak üzere mikrobiyal fermantasyondan elde edilen doğal ürünlerden oluşur. DNA ve RNA sentezini önleyerek etki göstermektedirler. Hücre bölünmesini önler ve bölünen hücrelerde apoptozu indükler.

Doxorubicin, geleneksel doz rejimleri, 15 kg'dan büyük köpeklerde 3 haftada bir 30 mg/m² yavaş IV bolus veya infüzyon (10 ila 30 dakika), 15 kg'dan küçük köpeklerde 1 mg/kg'dır.

Mitoxantrone, 3 haftada bir 5 ila 6 mg/m² IV yavaş bolus, DOX'un kümülatif seviyesine ulaşmış veya kardiyomiyopati belirtileri gösteren ve doksorubisin uygulamasıyla daha fazla hasar riski altında olan köpeklerde kalp koruyucu antrasiklin olarak kullanılır.

Aktinomisin D, köpeklerde çoklu ajan protokollerinde veya kalp anomalileri olan köpeklerde doksorubisin yerine kullanılır. Her 3 haftada bir 0,5 ila 0,75 mg/m² dozunda intravenöz olarak uygulanır.

3. Antimetabolitler; hücre büyümesi ve bölünmesi sırasında hücresel metabolitlerin kullanımını engelleyen maddelerden oluşur. Bu nedenle, bu maddeler genellikle normal metabolizma sürecinde ve kanser kemoterapötiklerinde, özellikle DNA replikasyonu ile ilişkili anabolik süreçlerde kullanılan bileşiklerin analoglarıdır.

Gemcitabine, Köpeklerde kullanılan doz rejimleri, protokoldeki diğer sitotoksik ilaçların kullanımına bağlı olarak, yüksek doz (4 hafta boyunca her hafta 20 ila 30 dakika boyunca 800 mg/m² IV) veya düşük doz (protokol başına haftada bir veya iki kez 25 ila 50 mg/m² IV) seçeneklerini içermektedir.

Methotrexate, 0,1 mg/kg dozunda PO, gün aşırı şeklinde uygulanabilmektedir. Daha az toksik ve daha güçlü diğer ajanların geliştirilmesiyle birlikte, geleneksel tedavi rejimlerinden çıkarılmış ve veteriner onkolojisinde nadiren kullanılmaktadır.

5-Fluorouracil, bildirilen doz haftada 150 mg/m² IV' dir. Köpeklere topikal ve lezyon içi olarak da uygulanabilir ancak etkinliği net değildir.

4. Antimikrotübül Ajanlar; veteriner hekimliğinde şu anda kullanılan antimikrotübül ajanlar, taksan veya vinka alkaloid sınıfına ait bileşiklerin yapısal olarak karmaşık ajanlarıdır. Bu ajanların etki mekanizması, hücre fonksiyonu ve bölünmesinde kritik rol oynayan mikrotübüllerin polimerizasyonu veya depolimerizasyonunu engellemeye dayanır.

Paklitaksel, köpeklerde veya kedilerde kullanımı sıklıkla tanımlanmamıştır. Bunun nedeni, antihistaminikler ve steroidlerle önemli bir ön tedavi gerekliliği ve ardından akut aşırı duyarlılık için sürekli izleme ile uzun süreli infüzyon gerekliliği olabilir. Yapılan çalışmalarda ön tedaviye rağmen aşırı duyarlılık sık görülmüş ve önemli kemik iliği toksisitesi gözlemlenmiştir, bu da köpeklerde daha ileri değerlendirme için önerilen dozun her 3 haftada bir 132 mg/m² dozunda yavaş IV infüzyon olduğu bildirilmektedir.

Docetaxel, köpekler ve kediler üzerinde araştırılmıştır. Aşırı duyarlılık reaksiyonlarını önlemek için, emilimi kolaylaştırıcı olarak siklosporin ile birlikte oral docetaxel uygulamak üzere bir strateji geliştirilmiştir. Doketakselin maksimum tolere edilen dozu, siklosporin (5 mg/kg PO) ile kombine edildiğinde, sırasıyla 2 ila 3 haftada bir 1,63 mg/kg ve 1,75 mg/kg PO (gavage ile) olarak belirtilmektedir.

Vinka alkaloidler, doğal olarak bulunan vinkristin (VCR) ve vinblastin (VBL) ile VBL'nin yarı sentetik türevi ve metaboliti olan vindesin (VDS) ve VBL'nin yarı sentetik türevi olan vinorelbin (VRL) içerir. *Vinkristin* dozu, köpekler ve kedilerde haftada 0,5 ila 0,75 mg/m² IV bolus olarak veya protokolde tanımlandığı şekilde uygulanır. Tüm vinka alkaloidler, doku dışı verildiklerinde doku tahriş edicidir, ancak doksorubisin kadar ciddi değildir. Enjeksiyon sırasında son derece dikkatli olunmalıdır. *Vinblastin*, tek başına veya diğer ajanlarla kombinasyon halinde, 1 ila 2 haftada bir 2,5 mg/m² IV veya 2 ila 3 haftada bir 3,0 ila 3,5 mg/m² IV olarak uygulanabilir.

5. Steroidler; Prednizon veya prednizolon, glukokortikoid reseptörü ile etkileşime girerek ve apoptozu indükleyerek hematopoietik kanser hücrelerinin ölümünü tetiklediği düşünülen bir kortikosteroiddir.

Prednizon, köpek ve kedilerde lenfoid maligniteler, mast hücreli tümörler ve beyin tümörlerinin tedavisinde yaygın olarak kullanılır. Köpeklere, lenfoma için çoklu ajan protokollerinin başlangıcında genellikle günde 2 mg/kg (veya 40 mg/m²) PO dozunda verilir ve 3 ila 4 hafta içinde ilacın kullanımı kesilir.

6. Çeşitli ajanlar; Platin içeren antitümör ajanların aktivitesi, bifonksiyonel lezyonlara ve iplikler arası veya iplik içi çapraz bağlara neden olan yer değiştirme reaksiyonları yoluyla DNA'ya kovalent bağlanma yoluyla gerçekleşir.

Cisplatin, 3 haftada bir diüretik ve antiemetiklerle birlikte 50 ila 70 mg/m² IV infüzyon şeklinde kullanılır.

Carboplatin, 3 haftada bir 10 ila 15 dakika boyunca 300 mg/m² IV, mide bulantısı/kusma insidansının azalması, nefrotoksisite olmaması ve uygulama kolaylığı nedeniyle sisplatine göre daha çok tercih edilir. Miyelosüpresyon, dozu sınırlayan toksisitedir. Köpeklerde osteosarkomun yanı sıra çeşitli sarkom ve karsinomların tedavisinde kullanılır (Chun ve ark. 2007, Gustafson ve Page 2013).

Köpek meme tümörlerinde farklı kemoterapötik ilaçlar ile yapılmış çalışmalar aşağıdaki tablolarda sunulmuştur.

Tablo 2. Köpeklerde meme bezi tümörlerinde kullanılan farklı adjuvan temelli hedefe yönelik tedavi türleri (Rath ve ark. 2024)

İlaçlar	**Hedef molekül tanımı / klinik sonuçlar / olası yan etkiler**	**Tür**	**Kaynak**
Doksorubisin (30 mg m^{-2} i.v. 3 haftada bir) + Dosetaksel (30 mg m^{-2} i.v.)	Evre II–III malign meme tümörlü 31 köpekte uygulanmıştır. Tedavi edilen grupta ortalama sağkalım süresi kontrol grubuna göre daha yüksektir.	Köpek	Simon, D., Schoenrock, D., Nolte, I., Baumgärtner, W., Barron, R., & Mischke, R. (2009). Cytologic examination of fine-needle aspirates from mammary gland tumors in the dog: diagnostic accuracy with comparison to

			histopathology and association with postoperative outcome. Veterinary Clinical Pathology, 38(4), 521-528.
Gemcitabin (800 mg m^{-2} i.v.)	Rekürrens, metastaz ve genel sağkalım üzerinde olumlu etki göstermiştir; hematolojik veya gastrointestinal toksisite gözlenmemiştir.	Köpek	Marconato, L., Lorenzo, R. M., Abramo, F., Ratto, A., & Zini, E. (2008). Adjuvant gemcitabine after surgical removal of aggressive malignant mammary tumours in dogs. Veterinary and Comparative Oncology, 6(2), 90-101.
5-Florourasil (150 mg m^{-2}) + Siklofosfamid (100 mg m^{-2} i.v.), haftada bir × 4 kür	Kombine adjuvan kemoterapi hastalıksız sağkalım ve sağkalımı anlamlı ölçüde uzatmıştır.	Köpek	Karayannopoulou, M., & Lafioniatis, S. (2016). Recent advances on canine mammary cancer chemotherapy: a review of studies from 2000 to date.Rev. Méd. Vét. 167, 192.
Gemcitabin (3 mg kg^{-1} 60 dk i.v.) + Karboplatin (10 mg kg^{-1} 20 dk i.v.), 21 gün aralıkla 3 kür	Güvenli ve iyi tolere edilmiştir; yalnızca geçici hematolojik / gastrointestinal yan etkiler görülmüştür.	Köpek	Israel, C. B., Maués, T., Ferreira, A. M. R., & Ferreira, M. D. L. G. (2021). Clinical and Laboratory Findings in Dogs Undergoing Adjuvant Chemotherapy with Gemcitabine/Carboplatin Combination for Mammary Neoplasia. World's Veterinary Journal, 11(2), 289-299.
Paklitaksel (132 mg m^{-2} i.v. 3 haftada bir)	Vakaların %25'inde kısmi yanıt alınmıştır; ciddi aşırı duyarlılık ve nötropeni bildirilmiştir.	Köpek	Poirier, V. J., Hershey, A. E., Burgess, K. E., Phillips, B., Turek, M. M., Forrest, L. J., ... & Vail, D. M. (2004). Efficacy and toxicity of paclitaxel (Taxol) for the treatment of canine malignant tumors. Journal of veterinary internal medicine, 18(2), 219-222.
Karboplatin (300 mg m^{-2} i.v.) + Siklofosfamid (12.5	Anemi, trombositopeni ve nötropeni gözlenmiştir.	Köpek	Machado, M. C., Yamamoto, P. A., Pippa, L. F., de Moraes, N. V., Neves,

mg m^{-2}/gün oral) 8 ay			F. M. F., Portela, R. D., ... & Estrela-Lima, A. (2022). Pharmacokinetics of carboplatin in combination with low-dose cyclophosphamide in female dogs with mammary carcinoma. Animals, 12(22), 3109.

Tablo 3. Köpeklerde meme tümörü için kemoterapi protokolleri (Vazquez ve ark. 2023).

İlaçlar	**Doz**	**Hasta Sayısı**	**Sonuçlar**	**Kaynak**
5-Fluorourasil ve siklofosfamid	150 mg/m² ve 100 mg/m²	16	Grup 1 (8 cerrahi): İlk 2 yıl içinde %71,4'ü metastazdan öldü. Grup 2 (8 cerrahi + kemoterapi): %100'ü 2 yıldan uzun yaşadı. Genel sağkalım süresinde anlamlı fark: 24 ay (Grup 2), 6 ay (Grup 1). Toksisite: Grup 2'de kemoterapiye bağlı geçici lökopeni.	Karayannopoulou, M.; Kaldrymidou, E.; Constantinidis, T.C.; Dessiris, A. Adjuvant Post-operative Chemotherapy in Bitches with Mammary Cancer. J. Vet. Med. Ser. A 2001, 48, 85–96.
Doksorubisin veya dosetaksel	30 mg/m² veya 30 mg/m²	31	Grup 1 (19 cerrahi): Sadece cerrahi yapılan hastalarda ortalama sağkalım 390 gün. Grup 2 (12 cerrahi + kemoterapi): Cerrahi + kemoterapi uygulananlarda 231 gün. Nüksüz interval, metastaz süresi ve genel sağkalım arasında anlamlı fark yok. Toksisite: Dosetakselde hafif alerjik deri reaksiyonları.	Simon, D.; Schoenrock, D.; Baumgärtner,W.; Nolte, I. Postoperative adjuvant treatment of invasive malignant mammary gland tumors in dogs with doxorubicin and docetaxel. J. Vet. Intern. Med. 2006, 20, 1184–1190.
Karboplatin ve piroksikam/firokoksib	300 mg/m², 0,3 mg/kg/gün veya 5 mg/kg/gün	29	Grup 1 (7 cerrahi): Yalnızca cerrahi yapılanlarda sağkalım 63 gün. Grup 2 (8 cerrahi + karboplatin): Cerrahi + kemoterapi yapılanlarda medyan sağkalıma ulaşılmadı. Grup 3 (5 cerrahi + karboplatin + piroksikam): Sağkalım 390 gün.	LaValle, G.E.; De Campos, C.B.; Bertagnolli, A.; Cassali, G.D. Canine malignant mammary gland neoplasms with advanced clinical staging treated with

			Grup 4 (9 cerrahi + karboplatin + firokoksib): Sağkalım 570 gün. Piroksikam ve firokoksib gruplarında medyan sağkalım artışı (390 ve 570 gün; yalnız cerrahi grubunda 63 gün). Toksisite: Grup 3'te piroksikama bağlı advers etki nedeniyle 1 ölüm.	carboplatin and cyclooxygenase inhibitors. In Vivo 2012, 26, 375–379.
Mitoksantron ve firokoksib	5,5 mg/m² ve 5 mg/kg/ gün	28	Grup 1 (13 cerrahi): Sadece cerrahi yapılanlarda sağkalım 12,7 ± 0,8 ay. Grup 2 (8 cerrahi + mitoksantron): Cerrahi + kemoterapi yapılanlarda sağkalım 16,5 ± 2,6 ay. Grup 3 (7 cerrahi + firokoksib): Cerrahi + kemoterapi + firokoksib yapılanlarda sağkalım 19,4 ± 2,1 ay.	Arenas, C.; Peña, L.; Granados-Soler, J.L.; Pérez-Alenza, M.D.; DVM, C.A.P.; Peña, D.E.L.; Dvm, J.L.G.-S.; Pérez-Alenza, D.M.D. Adjuvant therapy for highly malignant canine mammary tumours: Cox-2 inhibitor versus chemotherapy: A case–control prospective study. Vet. Rec. 2016, 179, 125.

Siklofosfamid ile 5-florourasil veya siklofosfamid ile mitoksantron ve vinkristin gibi çeşitli kemoterapötik ilaçların kombinasyonu, sağkalım süresini önemli ölçüde artırmıştır (Karayannopoulou ve ark. 2001, Clementeve ark. 2009). Karboplatin ve gemsitabin kombinasyonu ile tedavi edilen hastalarda %13'lük bir genel yanıt oranı bulunmuştur (Dominguez ve ark. 2009). Bu sitotoksik ilaç kombinasyonları yalnızca hafif yan etkilere (gastrointestinal veya hematolojik toksisite) neden olmuştur (Karayannopoulou ve ark. 2001, Clementeve ark. 2009, Dominguez ve ark. 2009). Gemcitabine tek başına, docetaxel ile doksorubisin kombinasyonu veya doksorubisin, siklofosfamid ve 5-florourasil kombinasyonunun tedavisi, genel sağkalım süresi ve metastaz süresinde anlamlı bir fark göstermemiştir (Simon ve ark. 2006, Marconato ve ark. 2008, Souza ve ark. 2009). Karboplatin, doksorubisin ve gemcitabine kullanan kemoterapi protokolleri, meme neoplazmaları olan dişi köpekler için endikedir ve tek başına veya siklofosfamid ve COX-2 inhibitörleri ile kombinasyon halinde kullanılabilir. Hem insan hem de veteriner hekimliğinde, selektif COX-2 inhibitörleri, diğer antitümör ilaçlarla ilişkili meme karsinomlarının tedavisinde kullanılmaktadır (Rueda ve ark. 2024).

CMT'lerin, özellikle de kötü huylu formlarının risk faktörlerinden biri, Siklooksijenaz-2 (COX-2) ekspresyonunun artmasıdır (Dore ve ark. 2003). Siklooksijenaz-2; büyüme faktörleri, inflamatuar uyarıcılar ve çeşitli onkogenler tarafından indüklenebilir. Cox-2, tümör anjiyogenezinin uyarılması, tümör apoptozunun azaltılması, invazyon ve metastazın ve tümörle ilişkili inflamasyonun artırılması da dahil olmak üzere karsinogenetik sürecin farklı adımlarında rol oynar (Souza ve ark. 2009). COX-2 inhibitörlerinin farklı köpek tümörlerinde

potansiyel bir tedavi olarak kullanımı tanımlanmıştır (Nosalova ve ark. 2024). COX-2'yi inhibe eden anti-inflamatuar ilaçlar iki gruba ayrılabilir: seçici olmayan ve seçici COX-2 inhibitörleri (Valdivia ve ark. 2021). Steroid olmayan anti-inflamatuar ilaçlar (NSAID'ler), etki mekanizmaları her iki COX izoenziminin blokajını içerdiğinden seçici olmayan gruba aittir. COX-1 inhibisyonundan kaynaklanan olumsuz etkilerden, özellikle gastrointestinal kanamadan kaçınmak için, "koksibler" adı verilen seçici COX-2 inhibitörleri tasarlanmıştır (Derry ve Loke 2000). Deneysel olarak hem seçici olmayan NSAID'lerin hem de seçici koksiblerin, apoptozu düzenleyerek, kanser hücresi büyümesini baskılayarak, proliferasyonu inhibe ederek ve hücrelerin metastatik potansiyelini azaltarak tümör oluşumunu engellediği bulunmuştur. NSAID'ler piroksikam ve meloksikam, CMT hücrelerinde in vitro hücre döngüsü durması, apoptoz ve göç baskılanmasını indükleyebilmiştir (Nosalova ve ark. 2024). İn vitro çalışmalar, bazı COX-2 inhibitörlerinin (piroksikam ve meloksikam) meme karsinomu da dahil olmak üzere farklı köpek kanseri hücre hatlarında hücre çoğalmasını engelleyebildiğini göstermiştir (Knottenbelt ve ark. 2006). Ek olarak, in vivo bir çalışma, piroksikam ile tedavi edilen inflamatuar meme karsinomu olan dişi köpeklerin, geleneksel kemoterapi ile tedavi edilenlere göre hastalık stabilitesinde iyileşme ve daha iyi sonuçlar elde ettiğini göstermiştir (De Mello Souza ve ark. 2009). Bir vaka-kontrol prospektif çalışma, firokoksibin kötü huylu CMT'li köpeklerde hastalıksız sağkalımı ve genel sağkalımı artırma yeteneğini göstermiştir (Arenas ve ark. 2016). Son zamanlarda, Brandi ve ark. (2023), firokoksibin CMT hücre hatlarında in vitro ve in vivo proapoptotik etkisini göstermişlerdir; bu nedenle, CMT'li köpekler için potansiyel bir neoadjuvan tedavi olarak kabul edilebileceğini ifade etmektedirler. İn vitro çalışmalar, bazı COX-2 inhibitörlerinin (piroksikam ve meloksikam) meme karsinomu da dahil olmak üzere farklı köpek kanseri hücre hatlarında hücre çoğalmasını engelleyebildiğini göstermiştir (Knottenbelt ve ark. 2006). Ek olarak, in vivo bir çalışma, piroksikam ile tedavi edilen inflamatuar meme karsinomu olan dişi köpeklerin, geleneksel kemoterapi ile tedavi edilenlere göre hastalık stabilitesinde iyileşme ve daha iyi sonuçlar elde ettiğini göstermiştir (De Mello Souza ve ark. 2009). Daha ileri çalışmalara ihtiyaç duyulmasına rağmen, COX-2 seçici inhibitörlerinin meme kanseri olan köpeklerde adjuvan tedavinin bir parçası olarak düşünülmesi gerektiği vurgulanmaktadır. Ayrıca son zamanlarda, dişi köpeklerde meme karsinomuna karşı terapötik etkinliklerini artırmak için konvansiyonel kemoterapi ile birlikte anti-anjiyogenetik stratejiler geliştirilmiştir. Bu antianjiyogenetik ilaçların temel amacı, karsinogenez sürecinde önemli bir rol oynayan vasküler endotelyal büyüme faktörlerini (VEGF) ve reseptörlerini hedeflemektir. Lee ve ark. (2019) tam kan hücrelerindeki VEGFR-2 reseptörlerini seçici olarak hedef alarak kanserli hücrelerin göçünü ve çoğalmasını azaltan yeni bir antianjiyojenik ilaç olan Rivoceranib'i geliştirmişlerdir.

5. SONUÇ

Köpeklerde meme tümörlerinin tedavisinde etkili olduğu bildirilen kemoterapi protokolleri vardır. Fakat bu protokoller her hayvanda ya da her meme tümörü vakasında aynı başarıyı göstermemektedir. Kemoterapötik ilaçlar ciddi toksisiteye sahiptir bu nedenle kemoterapötik ilaçları, doğru dozu ve etkili kombinasyonları belirlemek tedavide kritik öneme sahiptir. Kemoterapötiklerin ortalama yaşam süresini ve hastalığın prognozunu nasıl etkilediği hala tartışmalıdır. Köpeklerde kemoterapi protokollerini belirlemek için, meme karsinomu olan daha büyük köpek gruplarında farklı ilaç kombinasyonlarının daha fazla araştırılması gerekmektedir. Sonuç olarak; meme bezi tümörlü köpeklerde kemoterapinin etkinliği hakkındaki bilgiler hala tartışmalı olduğundan kullanımına ilişkin kılavuzlar oluşturmak için daha derinlemesine çalışmalara ihtiyaç vardır.

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Halyomorpha halys (STAL, 1855) (HEMIPTERA: PENTATOMIDAE) ZARARI VE MÜCADELE YÖNTEMLERİNE GENEL BİR BAKIŞ

Doç. Dr., Nurver ALTUN

Recep Tayyip Erdoğan University, Faculty of Arts and Sciences, Department of Biology

Rize, TÜRKİYE

Email: nurver.altun@erdogan.edu.tr

ORCID: 0000-0002-2657-9263

ÖZET

Halyomorpha halys (Stål, 1855) (Hemiptera: Pentatomidae), Doğu Asya kökenli istilacı bir bitki zararlısıdır (Göktürk, 2020). Türkiye'deki varlığı 2017 yılında İstanbul'da (Çerçi ve Koçak 2017) ve Artvin'de (Göktürk vd., 2018), 2020 yılında Kemalpaşa, Hopa, Arhavi (Artvin), Fındıklı, Ardeşen (Rize) ilçelerinde olmak üzere Trabzon, Giresun ve Ordu illerine kadar yayılmıştır (Göktürk ve Tozlu 2019). 2020 yılında İzmir'de de tespit edilen zararlı 2023 yılında Adana'da belirlenmiştir (Kalkan ve Satar, 2023). Ülkemizde başta fındık, daha sonra kivi, mısır, narenciye, fasulye, armut, biber, böğürtlen, domates, elma, frenk üzümü, süs bitkileri, şeftali, yaban mersini ve yabancı otlarda beslenmektedir (Kalkan ve Satar, 2023). Zararlı ile mücadelede Göktürk (2020), ışık tuzağı ve feromon etkinliğini araştırmıştır. İçerilerinde feromon bulunan tuzaklar ve ışık tuzakları Nisan-Ekim aylarında asılı kalmıştır. Kontrollerde bir ışık tuzağına 30.12 (0-85), feromon tuzağına ise 24.72 (1-69) erginin yakalandığı tespit edilmiştir. Araştırmanın yapıldığı 27 hafta boyunca bir feromon tuzağına toplam 618, bir ışık tuzağına da 753 adet ergin düşmüştür. Altanlar ve Tuncer (2023) ise zararlıya karşı feromon kaynağının saha etkinliğini, 3 farklı tuzak tipinin 3 farklı bitki ekositemindeki yakalama etkinliğini test etmişlerdir. 2021 yılında (Temmuz-Eylül) Artvin ilinde, Fındık, kivi ve mısır alanlarında yürütülen çalışmada funnel, bidon ve yapışkan tuzak olmak üzere 3 farklı tuzak tipi denenmiştir. Feromon kaynağının saha etkinliği kontrol tuzaklarla karşılaştırıldığında, yapışkan ve bidon tip tuzaklarda % 100, funnel tip tuzakta ise % 99,9 olarak belirlenmiştir. Mevsim boyunca en fazla *H. halys* funnel tip tuzakta yakalanmış, yakalanan böcek sayısı funnel, yapışkan ve bidon tip tuzakta 145,65±17,52 a, 99,1±10,82 b ve 96,95±8,18 b böcek/tuzak olarak saptanmıştır. Özdemir (2023), Sakarya'da farklı habitatlarda H. halys'in yerli yumurta parazitoitlerini ve bu türlerin etkinliklerini belirlemiştir. Toplanan yumurtaların genel parazitlenme oranı %7,5 olmasına rağmen, bu yumurtalardan başarılı bir şekilde yalnızca üç parazitoit çıkışı meydana gelmiştir. Parazitoidin Telenomus turesis (Walker) olduğu belirlenmiştir. Aşkın vd. (2022), entomopatojen fungusları içeren ticari preparatlar ile bitkisel ekstraktlı preparatları laboratuar koşullarında *H. halys* 'a karşı biyolojik etkinliklerini belirlemiştir. Ticari entomopatojenler içinde Nibortem 7.gün sonunda %72.2 etki göstererek zararlı üzerinde en etkili preparat olarak belirlenmiştir. Çalışmada kullanılan diğer preparatlardan Bio-Magic %55.6, Nostalgist %38.9 etki göstermiştir. Azadirachtin ise en etkili preparat olmuş olup; 5 ml dozda %94.4 etki sağlamıştır. Sonuç olarak zararlıya karşı mücadelede henüz tam bir entegre mücadele stratejisi oluşturulmamıştır. Bu çalışma ile *H. halys*'in etkinlik durumu ve mücadele yöntemlerini gözden geçirmek amaçlanmıştır.

Anahtar Kelimeler: *Halyomorpha halys*, İstilacı tür, Biyolojik mücadele

AN OVERVIEW OF THE DAMAGE AND CONTROL METHODS OF *Halyomorpha halys* (STÅL, 1855) (HEMIPTERA: PENTATOMIDAE)

ABSTRACT

Halyomorpha halys (Stål, 1855) (Hemiptera: Pentatomidae) is an invasive plant pest that is native to East Asia (Göktürk, 2020). It was first reported in Turkey in Istanbul in 2017 (Çerçi and Koçak, 2017) and in Artvin in 2018 (Göktürk et al., 2018). By 2020, it had spread to Kemalpaşa district in İzmir province, as well as to Hopa, Arhavi (Artvin), Fındıklı and Ardeşen districts in Rize province, reaching as far as Trabzon, Giresun and Ordu provinces (Göktürk and Tozlu, 2019). The pest was also detected in Izmir in 2020 and Adana in 2023 (Kalkan & Satar, 2023). In Turkey, *H. halys* primarily feeds on hazelnuts, followed by kiwis, corn, citrus fruits, beans, pears, peppers, blackberries, tomatoes, apples, currants, ornamental plants, peaches, blueberries and various weeds (Kalkan and Satar, 2023). In studies on its control, Göktürk (2020) investigated the effectiveness of light and pheromone traps. Traps containing pheromone and light traps were hung from April to October. During monitoring, an average of 30.12 (range 0–85) adults were captured in light traps and 24.72 (range 1–69) in pheromone traps. Over the 27-week study period, a total of 618 adults were captured per pheromone trap and 753 per light trap. Altanlar and Tuncer (2023) tested the field efficiency of pheromone sources and the trapping performance of three different trap types across three plant ecosystems. Conducted in Artvin Province between July and September 2021, the study took place in hazelnut, kiwi and corn fields and used funnel, bucket and sticky traps. Compared with control traps, the field efficiency of the pheromone sources was found to be 100% in the sticky and bucket traps and 99.9% in the funnel traps. Throughout the season, funnel traps caught the highest number of *H. halys* individuals, with mean captures per trap recorded as 145.65 ± 17.52 a, 99.1 ± 10.82 b and 96.95 ± 8.18 b for funnel, sticky and bucket traps respectively. Özdemir (2023) identified the native egg parasitoids of *H. halys* and evaluated their activity in various habitats in Sakarya. While the overall parasitism rate of the collected eggs was 7.5%, only three successful parasitoid emergence events were observed, all of which were identified as Telenomus turesis (Walker). Aşkın et al. (2022) evaluated the biological effectiveness of commercial entomopathogenic fungal preparations and plant-extract-based formulations against *H. halys* under laboratory conditions. Among the commercial entomopathogens, Nibortem demonstrated the greatest effectiveness, reaching 72.2% after seven days. The other products, Bio-Magic and Nostalgist, showed effectiveness rates of 55.6% and 38.9%, respectively. Azadirachtin was the most effective overall, providing 94.4% control at a dose of 5 ml. In conclusion, a fully integrated management strategy for *H. halys* has yet to be developed. The aim of this study is to review the current status and control methods of *H. halys*.

Keywords: *Halyomorpha halys*, Invasive species, Biological control

1. INTRODUCTION

With the expansion of global trade and the growing movement of people across regions, the transport of pets, livestock, nursery plants, and agricultural or forestry products has also increased. As a result, many species are now being moved beyond their native habitats (Skendzic et al., 2021). Species that manage to establish stable populations outside their natural distribution range are generally described as alien species (Göktürk, 2019). When these introduced organisms spread rapidly in the new environment and begin to cause noticeable economic damage, they are considered invasive (Dursun and Fent, 2022). Such invasive species can disrupt ecosystems by changing patterns of biological diversity and producing genetic effects that appear at the individual, population, or even community level.

The brown marmorated stink bug, *Halyomorpha halys* (Stål, 1855) (Hemiptera: Pentatomidae), is one of the most well-known invasive pest species. Its native range includes East Asia (China, Japan, Taiwan, and Korea), but since 1998 it has spread to many countries across Asia, Europe, and particularly the United States (Altanlar and Tuncer, 2023).

In Turkey, it was first detected in Istanbul in 2017 (Çerçi and Koçak, 2017) and in Artvin in the same year (Güncan and Gümüş, 2017). It has subsequently spread most intensively to the provinces of Trabzon, Giresun, and Ordu (Göktürk and Tozlu, 2019), and further west to Samsun (Özdemir and Tuncer, 2021), particularly in the distrincts of Kemalpaşa, Hopa, Arhavi (Artvin), and Fındıklı, Ardeşen (Rize). Although *H. halys* is present in the Central Black Sea Region, it has not yet been recorded in the provinces of Sinop and Kastamonu (Özdemir and Tuncer, 2021). The species has also been reported in Bursa in 2018 (Erdoğan, 2019), and in İzmir in the Aegean Region (Çerçi, 2021), as well as in Sakarya-Akyazı and Yalova (Ak et al., 2023). More recently, it was found in Adana in 2023 (Kalkan and Satar, 2023).

As with many other invasive species, this pest has begun to cause serious problems in both agricultural areas and human dwellings due to the absence of natural predators in the regions it has invaded. *H. halys* has become a major pest of both annual and perennial crops in the countries where it has become established. It is a polyphagous species capable of feeding on more than 300 plant species (Altanlar and Tuncer, 2023). Its broad host range, which includes important agricultural products such as kiwis, tomatoes, beans, corn, persimmons, and citrus fruits, poses a significant potential risk to many crops grown in Turkey. In the Black Sea Region, *H. halys* is a well-known major pest of hazelnuts, which are one of the region's key crops (Tuncer, 2019). Both adults and nymphs damage host plants by feeding on their sap. In addition, fruit feeding leads to lesions, depressions, deformities, and discolouration, while secretions released during feeding cause the fruit to develop a bitter taste and a hard texture (Aşkın et al., 2022).

1.2. Control Methods

1.2.1. Chemical Control

Numerous studies have been conducted on chemical control methods against this pest (Nielsen et al., 2008; Leskey et al., 2012; Luo et al., 2025). One of the first insecticide efficacy experiments on *H. halys* in the United States was carried out by Nielsen et al. (2008). In this study, an insecticide-treated glass vial bioassay (scintillation vial) was used, and the most effective insecticide group was identified as bifenthrin, a pyrethroid. Another effective insecticide was dinotefuran, which belongs to the neonicotinoid group. Details of the study and some of the other insecticides tested are presented in Table 1.

Table 1. Some chemical insecticides and their effects

Active Ingredient	Experimental Conditions	Results / Key Findings	Reference
Acetamiprid (neonikotinoid)	Laboratory studies; adults and residual (dry film) bioassays	The initial mortality rate was quite high (approximately 93%), but it decreased to around 10% after seven days. In this case, acetamiprid may be limited in terms of long-term effectiveness for controlling the pest.	Leskey et al. (2012)
Bifenthrin	Direct exposure on eggs, nymphs, and adults	Full mortality was achieved in adults within 24 hours. A rapid neurotoxic effect was observed, with the highest immediate mortality recorded among the pyrethroid group.	Cira et al. (2017)
Sulfoxaflor	Adult and nymph stages, post-exposure monitoring	Mortality was observed in adults 14 days after exposure. A reduction in feeding behavior was noted among the surviving adults.	Cira et al. (2017)
Spinosad	Adult and nymph	Full mortality was not observed.	Cira et al. (2025)
Fenpropathrin (pyrethroid)	Laboratory residue (dry film) tests; early instar nymphs	After 24 hours of exposure, mortality rates were determined as 83% in second instar nymphs, 52.8% in third instars, and 19.4% in fourth instars.	Luo et al. (2025)

1.2.2. Botanical-Based Control

The use of chemical insecticides is becoming less popular due to their accumulation in nature over time and their harmful effects on non-target organisms within ecosystems. For this reason, plant-based insecticides have become increasingly common in ecological agriculture (Popescu et al., 2024). Table 2 presents some of the plant-derived insecticides used to control *H. halys*.

Table 2. Some plant-based insecticides and their effects

Plant-based insecticide / active compound	Application method / environment	Target stage	Key findings	Reference
Azadirachtin (Neem), Pyrethrin, Kaolin, Oil-based organic products	Laboratory; dry film and contact test (4.5 hours)	Adult	Neem oil and some organic products reduced adult mobility and feeding; however, mortality rates were low. In groups treated with pyrethrins and pyrethrins + kaolin, mortality rates were higher	Lee et al.(2014)

			compared to the control group.	
Neem oil, Insecticidal soap, Pyrethrin	Laboratory; direct spray and dry surface test	Nympf, adult	Products containing pyrethrins were more effective (>80% mortality). Nymphs were more susceptible than adults.	Bergmann and Raupp (2014)
Essential oils (clove, lemongrass, turmeric, cinnamon, lavender)	Laboratory; Y-tube olfactometer (repellency test)	adult	Clove and turmeric oils have the strongest repellent effects. They are not directly lethal but act as deterrents.	Bulgarini et al. (2021)
Azadirachtin, orange oil, potassium salts of fatty acids, kaolin, basalt powder, diatomaceous earth (kieselguhr), zeolite, sulfur formulations, calcium polysulfide, and mixtures of sulfur with diatomaceous earth or zeolite.	Laboratory and field trials (conducted in pear orchards)	Nympf, adult	Neem and clove oils demonstrated up to 70% mortality in laboratory tests. Their effectiveness in the field was reduced due to UV exposure and temperature. Diatomaceous earth, when used alone or alternated with sulfur or calcium polysulfide, generally provided pest control levels comparable to field trials based primarily on neonicotinoids (acetamiprid).	Chierici et al. (2025)

According to the results presented in Table 2, products such as neem (azadirachtin), clove, and lemongrass oils primarily act as feeding deterrents. Although mortality rates in groups treated with these products were low to moderate, reductions in mobility and suppressed feeding behavior were clearly observed. Pyrethrins exhibited the highest lethal effect, achieving mortality rates of over 80% in both direct spray and dry film tests. When used in combination with kaolin, mortality rates increased significantly. Neem and clove oils were effective under laboratory conditions, achieving up to 70% mortality; however, their efficacy in the field was weak. This was due to the rapid degradation of the active ingredients by UV light.

1.2.3. Biological Control

Various studies are being conducted as part of a classical biological control program for *H. halys*. As a result of these studies, four species of egg parasitoids in the genus *Trissolcus* (Hymenoptera: Scelionidae) have been identified as potential biological control agents (Santacruz et al., 2017). Among these, *Trissolcus japonicus* (Ashmead) appears particularly promising due to its short development time (10.5 days at 25 °C), multiple generations per year, a female-biased sex ratio, and parasitism rates of 50–80% on *H. halys* within its natural Asian range (Yang et al., 2009). A second candidate species, *Trissolcus cultratus* (Mayr), is also being evaluated; however, its parasitism rates are lower than those of *T. japonicus* (Santacruz et al.,

2017). Mele et al. (2024) studied the life cycles of *T. japonicus* and *T. mitsukurii*. Their study concluded that *T. japonicus* has a longer lifespan than *T. mitsukurii* and exhibits higher net reproductive rates at 26 °C and 31 °C. However, *T. mitsukurii* demonstrates higher fitness at lower temperature ranges compared to *T. japonicus*.

Luo et al. (2025) investigated the residual effects of eight pesticides on *H. halys* and three parasitoid species: *Anastatus japonicus, T. japonicus, and T. cultratus*. The pesticides tested included fenpropathrin, acetamiprid, cyfluthrin, dinotefuran, abamectin, azadirachtin, rotenone and chlorantraniliprole. The study found that *A. japonicus* was the most resistant species, while *T. japonicus* was the most sensitive. Chlorantraniliprole exhibited the lowest overall toxicity. Fenpropathrin caused up to 80% mortality in early-instar nymphs. Azadirachtin and acetamiprid showed low toxicity to the parasitoids and are recommended as compatible options for integration into biological control programs.

Özdemir (2023) identified native parasitoid species from *H. halys* eggs collected in various habitats in Sakarya. The native egg parasitoid *Telenomus turesis* was recorded in Turkey for the first time. The overall parasitism rate of *T. turesis* on the eggs was 7.5%, with live parasitoids emerging from only three egg masses. Despite its low natural effectiveness, this species has the potential to be important in biological control programmes.

Entomopathogenic fungi are microorganisms that can infect, parasitise and kill arthropod pests (Bihal et al., 2023). Aşkın et al. (2022) investigated the biological efficacy of commercial entomopathogenic fungi and plant-based preparations against *H. halys* in a laboratory setting. The study found that Nibortem (Verticillium lecanii) was 72.2% effective on the 7^(th) day, while Bio-Magic (*Metarhizium anisopliae*) was 55.6% effective. Nostalgist BL (*Beauveria bassiana*) demonstrated 38.9% effectiveness. Parth et al. (2024) examined the efficacy of various strains on eggs and nymphs. The *Metarhizium brunneum* GT7 strain caused 100% mortality, while *B. bassiana* XG/2B induced 70–91.9% mortality in nymphs, with no effect on eggs. The lowest mortality was observed in groups treated with *Beauveria pseudobassiana* AWLB. Mortality was primarily detected in first-instar nymphs.

1.2.3.4. Examples of Other Control Methods

In integrated pest management, pheromone and light traps are commonly used. These traps are used for monitoring population density and for capturing large numbers of pests (Göktürk, 2020). Nielsen et al. (2013) reported that pentatomids were captured in black light traps, suggesting that these traps could be used as effective monitoring tools. In recent years, many studies have focused on trap design, colour, pheromone formulation, deployment strategy and capture mechanism. Ak et al. (2019) deployed pheromone traps in 2018 across 49 districts in the provinces of Samsun, Ordu, Giresun, Trabzon, Rize, and Artvin to determine the distribution of *H. halys* in the Eastern Black Sea Region. Göktürk (2020) monitored population density in kiwi orchards in Arhavi, Artvin, in 2019 using both pheromone and light traps. The study lasted 27 weeks, using four pheromone traps containing PHEROCON® pheromone and four light traps. Over the entire season, an average of 618 adults were caught per pheromone trap and 753 per light trap. By the end of the 27-week study, a total of 2,472 adults had been captured in the pheromone traps and 3,012 in the light traps. Altanlar and Tuncer (2023) evaluated the effectiveness of pheromone sources in controlling pests in three different crop areas using three trap types. In a study conducted in Artvin between July and September 2021, funnel, bucket and sticky traps were tested in hazelnut, kiwi and corn fields. Compared to control traps, the field effectiveness of the pheromone source was found to be 100% for sticky and bucket traps and 99.9% for funnel traps. Throughout the season, funnel traps captured the highest number of H. halys adults, with an average of 145.65 ± 17.52, 99.1 ± 10.82 and 96.95 ± 8.18 adults per trap for funnel, sticky and bucket traps, respectively.

Another important control approach focuses on the symbiotic relationship between H. halys and its gut bacteria. Laboratory and field studies have confirmed that this pest is sensitive to disruptions in its obligate symbiosis with gut bacteria, providing a foundation for the development of symbiont-targeted control strategies. In a study by Dho et al. (2025), egg surfaces were treated with a biocomplex containing copper, zinc, and citric acid. This complex effectively inhibited the acquisition of the endosymbiont Candidatus Pantoea carbekii by H. halys nymphs, leading to high nymph mortality under laboratory conditions. Based on these findings, anti-symbiont biocomplex applications were conducted in *H. halys*-infested hazelnut orchards in 2022 and 2023. To evaluate the product's effectiveness, *H. halys* egg masses were attached to cardboard tags and placed in different parts of the plant canopy, and the wetting rates according location were measured prior to application. Nymph mortality was monitored, and symbiont acquisition was quantified using qPCR. As a result, a significant reduction in damaged hazelnuts was observed in treated plots, confirming the efficacy of the symbiont-targeted control method in orchards.

A similar study by Prieto et al. (2025) was conducted in a hazelnut orchard in Northwestern Italy. In three years of field trials, *H. halys* population dynamics, the damage caused to harvested hazelnuts, and the effects of the anti-symbiont biocomplex on local entomofauna were assessed. In plots where the symbiont-targeted approach was applied, the control of *H. halys* populations and the level of damage to hazelnuts varied across years. The study used Dentamet®, a biocomplex containing zinc (Zn) and copper (Cu) salts with citric acid as a companion. The effects of the biocomplex were compared with lambda-cyhalothrin insecticide. While the insecticide consistently reduced non-target insect diversity in the field, the anti-symbiont biocomplex showed no such effect. The biocomplex applied to the eggs reduced symbiont acquisition in *H. hal*ys nymphs, thereby increasing mortality and demonstrating its effectiveness against the target pest. In local pentatomid species, the effect of the treatment varied by species: symbiont acquisition decreased and mortality increased in some species, while no significant effect was observed in others.

In conclusion, research on this pest indicates that a single control method is insufficient and that effective management requires the integration of multiple strategies. To develop an effective and sustainable integrated pest management strategy, chemical, biological, plant-based, and symbiont-targeted approaches need to be evaluated synergistically, supported by long-term field trials and regional adaptation studies. This integrated approach will help ensure environmental sustainability while reducing economic losses in agricultural production.

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TÜTÜNDE POLEN HASADI VE DEPOLAMA

Erdem KARAKOÇ*

Yozgat Bozok Üniversitesi, Kenevir Araştırmaları Enstitüsü, Tarım ve Gıda Anabilim Dalı, Yozgat, Türkiye

*Sorumlu yazar, erdem.karakoc45@gmail.com

ORCID: 0000-0001-7908-4793

Ahmet KINAY

Tokat Gaziosmanpaşa Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü, Tokat, Türkiye

Email: ahmetkinay@gmail.com,

ORCID: 0000-0003-4554-2148

ÖZET

Tütün (*Nicotiana tabacum* L.) dünyada genel olarak gıda dışı kullanım amacıyla yaygın bir şekilde üretilmektedir. Tüm bitkilerde olduğu gibi tütünde de hibrit çeşitlerin verim ve kalite özellikleri daha üstün olmaktadır. Hibrit çeşitlerin tohumluğunun üretimi için bazı teknikler kullanılabilmektedir. Bu çalışmada sitoplazmik erkek kısır anne bireye, baba bireyden polen hasat yöntemiyle elde edilen ve farklı koşullarda saklanan polenler ile yapılan melezleme sonuçlarının paylaşılması amaçlanmıştır. Araştırma açık arazi şartlarında Tokat-Kazova ekolojisinde 2021-2022 yıllarında yürütülmüştür. Araştırmada KINAY hibrit tütün çeşidinin baba ebeveyni olan TT5 basma tütün hattı polen donörü olarak kullanılmıştır. Bu hattan anterler korollanın uzayıp şişkinleştiği ve antosiyanin birikiminin başladığı aşamada toplanmıştır. Anterler etüvde 35 °C'de 23 saatte kurutulmuştur. İnce bir elekle hafifçe sallanarak alınan polenler depolama sürecine alınmıştır. Elde edilen polenlerin stigma üzerindeki canlılıkları ve tohum oluşturma kabiliyetleri KINAY hibrit tütün çeşididin anne bireyi olan TT2 (BC_6F_1) basma tütün hattı kullanılarak belirlenmiştir. Elde edilen polenler +4 °C ve -20 °C'de ev tipi buzdolabında muhafaza edilmiştir. Polen hasat edildiği anda ve hasat edildikten bir yıl sonra melezleme işlemlerinde kullanılmıştır. Polenler hasat edildiği anda yapılan melezlemelerde kapsül başına elde edilen tohum miktarı 0,2135 g bulunmuştur. Bir yıl sonra yapılan melezlemelerde +4 °C'de depolanan polenden elde edilen kapsül başına tohum miktarı 0,1780 g iken -20 °C'de 0,2000 g olarak belirlenmiştir. Polen hasadı yapıldığı anda yapılan melezleme ile elde edilen tohum miktarına göre +4 °C'de bir yıl depolanan polenle yapılan melezleme sonucu elde edilen tohum miktarında %16,63, -20 °C'de bekletilenle yapılan melezleme sonucunda elde edilen tohum miktarında ise %6,32 azalma olduğu görülmüştür. Bir yıllık depolamada -20 °C'nin +4 °C'ye göre daha uygun bir depolama sıcaklığı olduğu ortaya çıkmıştır. Elde edilen tohumlardan fide üretilmiş ve herhangi bir fizyolojik bozukluk gözlemlenmemiştir. Her ne kadar taze polene göre depolanan polenlerle yapılan melezlemelerde tohum miktarında azalma olsa da polenin depolanarak uzun süreler kullanılabileceği ve hibrit tohumluk üretiminde çok önemli bir avantaj sağlayacağı görülmüştür. Ek olarak tütün ıslahında polenin hasat edilmesi, depolanması ve taşınması konularında yeni araştırmalar yürütülmesi gerekmektedir.

Anahtar Kelimeler: *Nicotiana tabacum* L., polen hasadı, polen depolama, melezleme, tohum miktarı

POLLEN HARVESTING AND STORAGE IN TOBACCO

ABSTRACT

Tobacco (Nicotiana tabacum L.) is widely cultivated worldwide for non-food purposes. As with all crops, hybrid varieties of tobacco exhibit superior yield and quality characteristics. Certain techniques can be used to produce seeds for hybrid varieties. This study aims to share the results of hybridization using pollen obtained from the male parent through pollen harvesting methods and stored under different conditions, applied to the cytoplasmic male sterile female parent. The research was carried out in open field conditions in the Tokat-Kazova ecology in 2021-2022. The TT5 basma tobacco line, which is the paternal parent of the KINAY hybrid tobacco variety, was used as the pollen donor in the study. Anthers were collected from this line at the stage when the corolla elongated and swelled and anthocyanin accumulation began. The anthers were dried in an oven at 35 °C for 23 hours. The pollen was gently shaken through a fine sieve and stored. The viability of the pollen on the stigma and its seed-forming ability were determined using the TT2 (BC_6F_1) basma tobacco line, which is the maternal parent of the KINAY hybrid tobacco variety. The pollen obtained was stored in a household refrigerator at +4 °C and -20 °C. The pollen was used in hybridization procedures immediately after harvest and one year after harvest. The amount of seed obtained per capsule in the hybridizations performed at the time of pollen harvest was found to be 0.2135 g. In the hybridizations performed one year later, the amount of seed obtained per capsule from pollen stored at +4 °C was determined to be 0.1780 g, while that from pollen stored at -20 °C was 0.2000 g. Compared to the seed quantity obtained from the hybridization performed at the time of pollen harvest, a 16.63% decrease in seed quantity was observed in the hybridization performed with pollen stored at +4 °C for one year, and a 6.32% decrease was observed in the hybridization performed with pollen stored at -20 °C. It was found that -20 °C is a more suitable storage temperature than +4 °C for one-year storage. Seedlings were produced from the seeds obtained, and no physiological abnormalities were observed. Although there was a decrease in seed quantity in crossbreeding with stored pollen compared to fresh pollen, it was seen that pollen can be stored and used for long periods and provides a significant advantage in hybrid seed production. Additionally, new research is needed on the harvesting, storage, and transportation of pollen in tobacco breeding.

Keywords: *Nicotiana tabacum* L., pollen harvesting, pollen storage, hybridization, seed quantity

1. INTRODUCTION

Tobacco (*Nicotiana tabacum* L.) is one of the most widely cultivated non-food crops in the world. In 2023, 6.02 million tons of tobacco were produced on 3.2 million hectares worldwide, with a yield of 186 kg per hectare (Anonymous, 2025a). In Turkey, 94,000 tons of tobacco were produced on 96,000 hectares in 2024, with a yield of 97 kg per decare (Anonymous, 2025b). Virginia, Burley, and Maryland varieties account for approximately 89% of global tobacco production (Anonymous, 2024). In contrast, Oriental tobacco varieties represent only 4% of the world market (Filiposki et al., 2010). Turkey dominates the Oriental tobacco market with a 60% global share (Gay, 2020). Oriental tobaccos are considered the most distinct market type because they have undergone over 300 years of evolution and selection (Wolf and Wolf 1948; Moon et al. 2009). Isolation, stressful environments, and specific agricultural conditions have led to the formation of a genetic pool distinct from Virginia and Burley tobaccos (Davalieva et al. 2010; Fricano et al. 2012). Considering all these factors, oriental tobacco occupies a unique position compared to other market types.

The deliberate transfer of pollen from one plant to the stigma of another plant is called hybridization. It is known that the Babylonians and Assyrians did this on date palms. These civilizations did this without knowing the scientific truth underlying pollination and fertilization. These ancient efforts were not aimed at creating variation; they were primarily aimed at fertilization for fruit production. Science-based artificial pollination began after Camerarius discovered sex in plants and Koelreuter's subsequent work (Acquaah, 2012). It is a model plant used in many tobacco plant breeding methods. Variety development studies in tobacco plants began in the United States in 1903 (Shamel and Cobey, 1907). It is known that variety development continued in areas such as yield, quality, aroma, and taste following these studies. In Turkey, various institutions have made efforts to develop disease-resistant tobacco varieties between 1975 and 1997. These efforts resulted in the development of disease-resistant tobacco varieties such as İzmir-Özbaş, Akhisar-97, Ege-97, Otan-97, Usturalı-97, and Trakya-Özbaş for different production regions (Peksüslü, 1998). A series of studies have been conducted in Turkey on hybridization in tobacco and the hybrids obtained (Kara, 1993; Çamaş, 1998; Kinay, 2014; Kinay and Yılmaz, 2016; Kinay et al., 2019; Kinay et al., 2020; Kinay, 2020; Kinay and Kurt, 2022). Most of these studies have not reached the hybrid variety registration stage. However, the hybrid tobacco variety named KINAY was registered in 2021 and is currently the only hybrid tobacco variety among the 42 tobacco registration records in the National Variety List (Anonymous, 2025c).

Virginia and Burley type tobacco was produced in limited quantities in Turkey (TADB, 2025). However, in November 2020, the “LAW ON CERTAIN REGULATIONS IN THE FIELDS OF FOOD, AGRICULTURE, AND FORESTRY” was published in the Official Gazette No. 31294. Article 12 of this law adds the following to Article 6 of Law No. 4733: "Tobacco product manufacturers shall, within a calendar year, for the purpose of supplying the domestic market, produce and import; cigarettes, hookah tobacco products, shredded tobacco products for rolling, and pipe tobacco products must be at least thirty percent domestically produced tobacco per category. The President is authorized to increase this ratio up to forty-five percent" (Anonymous, 2025d). With this regulation, the production of Virginia and Burley type tobacco is increasing in Turkey. This is because the majority of imports in this chapter are these types of tobacco. It is necessary to reduce tobacco imports and produce this raw material with local resources. There is a need for domestic tobacco varieties of similar quality to the types to be produced. The varieties named EGE BRL and EGE VRG were registered in 2023 and included in the National Variety List. However, it is not known how much area these varieties are actually produced in.

For commercial hybrid seed production, the parent plants must be male sterile. Once this precondition is achieved, the other stages of hybrid seed production can be carried out on large fields. In hybrid seed production, in addition to agricultural principles (environmental requirements, land needs, and isolation distance), issues such as stigma receptivity, pollen viability, pollination control, and flowering synchronization must be carefully addressed (Chakrabarty et al., 2023). The aim of this study is to determine the conditions for obtaining and storing pollen to be used in commercial seed production in both Oriental type and Virginia and Burley type tobacco hybrids.

2. MATERIAL and METHOD

The research was carried out in open field conditions in the Tokat-Kazova ecology during 2021-2022. The TT5 basma tobacco line, which is the paternal parent of the KINAY hybrid tobacco variety, was used as the pollen donor, and the TT2 (BC_6F_1) line was used as the maternal parent. Seedlings obtained from these lines and seedlings obtained from seeds obtained from subsequent crossbreeding were grown in a foam viol in a peat environment using a float system. The plants were supplied with a nutrient mixture containing 100 ppm nitrogen (N), phosphorus (P), and potassium (K) and 0.4% microelements at a rate of 35 g/ton via the float system (Karakoç, 2021; Kurt et al., 2023). To obtain healthy and mature seedlings, the seedlings were pruned twice (Ekren and İlker 2017). The flowers of the TT5 line were collected at the stage when the anthers elongated and swelled and anthocyanin accumulation began (Figure 1a).



Resim 1. Polen donörü TT5 hattının polen hasadı için toplanmış çiçekleri.

Figure 1. Pollen harvest from the TT5 tobacco line; **(a)** stage of flower collection, **(b)** opening of the corolla and separation of the anthers, **(c)** anthers placed on the drying tray, **(d)** dried anthers, **(e)** pollen before storage.

The collected flowers were brought to the laboratory. The corolla of the flowers was carefully opened and the anthers were separated from the filament (Figure 1 b). The anthers were collected and spread in a thin layer on a tray lined with drying paper (Figure 1 c). This tray was placed in an MMM Medcenter ECOCELL™ oven. The drying conditions were set at 35 °C for 23 hours. After drying, the tray was removed from the oven (Figure 1 d). The drying paper was carefully collected, placed on a sieve, and sifted (Figure 1 e). The sifted pollen was collected in Eppendorf tubes and labeled with the date of collection. These pollen grains were stored in a household refrigerator at +4 °C and -20 °C. The stored pollen grains were removed from the refrigerator one year later and used in cross-pollination experiments (Figure 2). The tips of the corollas of the flowers of the TT2 tobacco line that reached the hybridization stage were gently

removed (Figure 2a). The pollen stored in Eppendorf tubes was applied to the stigma of these flowers using a hair brush (Figure 2b). Hybridizations were performed in 20 capsules each.



Figure 2. Crossbreeding in the TT2 tobacco line; **(a)** removal of the tip of the corolla from the flowers, **(b)** transferring pollen from the Eppendorf tube to the stigma using a hair brush, **(c)** capsules harvested after crossbreeding, **(d)** hybrid seeds obtained.

After cross-pollination, the corollas were isolated using a pipette of appropriate size with one end closed to prevent possible contamination. Once capsule formation began in the plants and the stigma dried, the pipette was removed from the plant to avoid damaging the development. These capsules were marked at the beginning of formation. The capsules that reached the harvest stage were harvested separately (Figure 2c). These capsules were carefully and manually sorted (Figure 2d). The sorted seeds were placed in paper bags and stored in a seed cabinet.

3. RESULTS and DISCUSSION

This study was conducted to make the hybridization process more practical in hybrid tobacco seed production. The recommended hybridization method for tobacco plants is intended for small-scale seed production for R&D purposes (Wernsman and Matzinger, 1980). This method cannot be applied commercially in hybrid tobacco seed production. If applied, the resulting seed would be very costly. For this reason, pollen must be collected, stored, and used in the hybridization process in a practical manner. This will reduce costs in hybrid seed production.

In this study, the TT5 line was used as a pollen donor, and the pollen obtained was crossed with the TT2 (BC_6F_1) maternal line to produce seeds. Pollen stored in a refrigerator at +4 °C and -20 °C for one year was used in the crossbreeding process. During these processes, crossbreeding was also performed with harvested fresh pollen to serve as a control. The amount of seed per capsule obtained after the crossbreeding process was as follows:

(1) Crossing with fresh pollen; 0.2135 g/capsule

(2) Crossbreeding using pollen stored at +4 °C for one year; 0.1780 g/capsule

(3) Crossbreeding using pollen stored at -20 °C for one year; 0.2000 g/capsule was obtained.

When these seed quantities were examined, it was observed that the seed quantity obtained from cross-pollination using pollen stored at +4 °C for one year decreased by 16.63% compared to the seed quantity obtained from cross-pollination using pollen harvested at the time of pollination, while the seed quantity obtained from cross-pollination using pollen stored at -20 °C decreased by 6.32%. It was found that -20 °C is a more suitable storage temperature than +4 °C for one-year storage. Some previous studies have examined the storage responses of tobacco pollen. Dean (1965) stored pollen at 0°C and below 5% relative humidity for 130 weeks and observed 40% in vitro germination. Jensen (1964) stored tobacco pollen under vacuum at

5°C for 716 days and obtained seeds through hybridization. Gwynn and Main (1967) found that tobacco pollen could withstand the effects of freeze-drying, but its viability was zero after 71 days of storage in a laboratory environment. At the same time, similar pollen stored at -18°C maintained high levels of viability for up to 388 days. A study on the storage of tobacco pollen was initiated in 1969 with the aim of developing a storage method whereby pollen could be (a) easily prepared for storage, (b) kept viable for long periods, and (c) preserved with minimum expense or effort. Two years later, all methods produced viable and functional pollen, but the germination abilities of the pollen differed (Gwynn, 1972). Gwynn presented the results of viability tests conducted after seven and a half years of storage on the remaining original pollen samples from the research he initiated in 1969, which had been stored under original conditions. Gwynn (1978) preserved pollen for 90 months using four different methods. When he used pollen stored at low temperatures for 90 months in hybridizations, he observed seed formation. He produced seedlings from these seeds and observed no abnormalities. In the studies mentioned, only Jensen (1964) and Gwynn (1978) tested the pollen they stored on the stigma and observed seed formation. Other studies have examined pollen viability in vitro. Pollen viability is not always related to in vitro germination, because pollen that has lost its germination ability may retain its ability to metabolize (Engelmann and Takagi 2000). This may be related to the unique environment on the stigma for pollen germination being superior to the in vitro germination environment. For this reason, no pollen viability test was performed in our study, and crossings were only performed to evaluate seed development. We produced seedlings from the seeds we obtained and did not observe any abnormal seedling formation, as mentioned by Gwynn (1978). Consequently, pollen with moisture content reduced to a level that will not cause any adverse effects at the low temperature at which it will be stored can be kept at -20 °C in a household refrigerator.

4. CONCLUSION

Turkey maintains its leading position in the production of oriental tobacco. Furthermore, it is anticipated that the production of Virginia and Burley tobacco will increase due to regulatory changes. It is known that 40 oriental, one Virginia, and one Burley tobacco varieties are registered in the national variety list. Among these varieties, only the KINAY variety is a hybrid. Hybrid varieties are known to be more productive and of higher quality than non-hybrid varieties. Virginia and Burley tobacco are planted less frequently than oriental tobacco. To maintain stable productivity and quality in tobacco production areas and prevent variety confusion, the use of hybrid varieties in all areas may be considered. Using the method we have described, hybrid tobacco seed production can be carried out for both Virginia and Burley as well as oriental type tobacco. Furthermore, by planting only male sterile mothers in seed production areas, time and resources can be saved and costs reduced. Finally, in this type of production, the preservation of the father variety is facilitated, contributing to the rights of breeders.

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AI-ENHANCED SOLAR-POWERED WATER PUMPING SYSTEM FOR SUSTAINABLE IRRIGATION IN RURAL WEST BENGAL

Biswarup Mukherjee

Brainware University, Kolkata, West Bengal, India

Email: bsm.cse@brainwareuniversity.ac.in

ABSTRACT

Agriculture in rural India struggles with unreliable irrigation, rising fossil fuel costs, and environmental degradation caused by diesel-dependent pumps. This paper delineates the design, deployment, and anticipated outcomes of an AI-enhanced solar-powered water pumping system implemented in Faldi village, Barasat, Kolkata. The system supplants inefficient diesel pumps with renewable solar energy augmented by artificial intelligence for intelligent control, ensuring optimal water distribution across 50 acres of farmland. Core elements encompass photovoltaic panels (3 kWp capacity), a submersible pump, storage reservoirs, distribution conduits, and an AI-driven controller utilizing machine learning algorithms for predictive irrigation scheduling based on real-time soil moisture, weather forecasts, and crop needs. The methodology encompasses site assessment, bespoke system engineering, community-centric installation, and skill enhancement workshops for 50 local farmers. Foreseen results project a 25% uplift in crop yields, 80% diminution in operational expenditures, and yearly CO_2 emission reductions of 5 tons. Comparative scrutiny with analogous Indian deployments underscores scalability and endurance. This innovation not only amplifies agricultural output but also galvanizes rural stakeholders toward autonomous integration of AI and renewables, aligning with imperatives for ecological and economic resilience.

Keywords: Solar-powered irrigation, AI-based control, renewable energy, rural development, sustainable agriculture, smart water management

INTRODUCTION

Agriculture remains the cornerstone of India's economy, contributing approximately 18% to the gross domestic product (GDP) in FY24 and employing about 46% of the workforce [1]. Despite this pivotal role, the sector is increasingly vulnerable to water scarcity and inefficient irrigation practices, particularly in the eastern Indo-Gangetic plains of West Bengal, where groundwater extraction relies heavily on diesel-powered pumps due to limited access to subsidized electricity [2]. In rural settings like Faldi village, Barasat (Kolkata-700125), smallholder farmers face high operational costs from diesel pumps, compounded by emissions that intensify climate risks and operational unreliability during dry seasons [2].

Such inefficiencies result in substantial crop yield reductions, with groundwater depletion trends projecting up to a 20% nationwide decline in cropping intensity and even higher losses (up to 68%) in stressed regions, exacerbating food insecurity and economic instability [3]. While solar-powered irrigation systems have emerged as a viable alternative to mitigate fossil fuel dependency, their integration with artificial intelligence (AI) for predictive control remains underexplored in resource-constrained rural contexts, representing a critical gap in achieving precision agriculture at scale [4].

Related Work

Prior studies have underscored the economic and environmental burdens of diesel-dependent irrigation in India. For instance, research on pump preferences in West Bengal highlights the high operational costs of diesel sets, which dominate groundwater extraction and contribute to escalating farmer expenses amid volatile fuel prices [2]. Complementary analyses reveal that modifications to diesel pumps can improve fuel efficiency by up to 50%, yet adoption remains low due to upfront costs and maintenance challenges [5]. On the sustainability front, projections from hydrological models indicate that unchecked groundwater depletion could curtail cropping intensity by 20% nationally and up to 68% in overexploited aquifers, necessitating urgent shifts to renewable alternatives [3].

Recent advancements in solar irrigation have shown promise, with deployments in arid regions reducing reliance on fossil fuels and extending cultivable land [6]. However, the infusion of AI for optimization—such as machine learning-driven scheduling based on soil and weather data—is nascent, with systematic reviews emphasizing its potential for water savings (15-30%) but noting sparse field trials in rural India [7]. Emerging works on AI-solar hybrids, including IoT-enabled predictive models, demonstrate yield improvements of 20-25% in pilot settings, yet scalability in low-literacy contexts like West Bengal remains a barrier [8]. This study builds on these foundations by deploying an integrated AI-solar system tailored to local needs, addressing gaps in community-driven implementation and long-term monitoring.

This study addresses these challenges through the design and deployment of an AI-enhanced solar-powered water pumping system in Faldi village, led by a multidisciplinary team from Brainware University. Informed by participatory assessments with local stakeholders, the intervention targets reliable irrigation for 50 acres of farmland, leveraging machine learning for optimized water scheduling based on real-time environmental data. The primary objectives are: (1) to ensure consistent water supply, reducing intermittency; (2) to achieve at least 80% reduction in operational costs; (3) to enhance crop yields by 20-30%; (4) to facilitate adoption of integrated renewable-AI technologies; and (5) to build local capacity for system maintenance and scaling.

The remainder of this paper is organized as follows: Section II details the methodology, including system design and implementation; Section III presents results and analysis with

comparative insights; and Section IV concludes with implications for broader rural sustainability initiatives.

Methodology

The methodology employed a structured, participatory approach to ensure the project's alignment with local needs, technical feasibility, and long-term sustainability. This involved iterative phases encompassing site assessment, system engineering, procurement, installation, capacity building, and ongoing monitoring. The overall project workflow is illustrated in Fig. 1, which outlines the sequential and interdependent stages from initiation to evaluation.

A. Site Selection

Site selection was conducted through a comprehensive technical survey to evaluate key parameters, including average solar insolation (5.5 kWh/m²/day), proximity to groundwater sources (<100 m), and accessibility for maintenance. Priority was given to south-facing, unshaded locations adjacent to agricultural fields to minimize pipeline losses (<5% water dissipation). Community consultations with 30 farmers and the local Gram Panchayat were integral to the process, resulting in the selection of a 500 m² site bordering the village pond for optimal integration.

B. System Design

Water requirements were estimated at 50,000 L/day to irrigate 50 acres, based on crop evapotranspiration rates (4–6 mm/day for predominant crops such as paddy and vegetables). The system architecture, depicted in the class diagram of Fig. 2, integrates hardware and software components for efficient operation and community management. Key elements include:

- Solar photovoltaic (PV) array: 3 kWp polycrystalline modules comprising 12 panels (250 W each).
- Submersible pump: 1 HP AC motor delivering 100 m³/h at a 20 m head.
- Storage reservoirs: 10,000 L elevated tanks equipped with solenoid valves for automated control.
- Distribution network: 2 km of high-density polyethylene (HDPE) pipelines (50 mm diameter) extending to fields.
- AI controller: A Raspberry Pi-based unit implementing a random forest machine learning model, trained on historical datasets from the Indian Council of Agricultural Research (ICAR) repositories. This module enables predictive irrigation scheduling using IoT sensors (e.g., soil moisture probes and anemometers) and API-integrated weather forecasts. The AI achieves 15–20% optimization in water flux, preventing over-irrigation and yielding 10–15% energy savings.

System sizing was performed using HOMER Pro software simulations to guarantee 95% reliability during monsoon periods. All components were sourced from Bureau of Indian Standards (BIS)-certified suppliers to withstand tropical humidity and dust.

C. Procurement and Installation

Procurement totaled INR 95,000, allocated as follows: PV array (INR 60,000), pump and reservoirs (INR 15,000), AI module (INR 5,000), and pipelines (INR 15,000). Competitive bidding ensured cost-effectiveness and quality. Installation engaged 10 local laborers over 7 days, encompassing foundation preparation, panel mounting at a 25° tilt, pump submersion,

pipeline trenching, and AI controller calibration. Post-installation verifications confirmed wiring efficiency (>95%) and leak-proof connections.

D. Training and Capacity Building

Capacity-building sessions were conducted biannually for 50 farmers, focusing on system operation (e.g., AI auto-calibration), maintenance (e.g., bi-weekly panel cleaning), and troubleshooting (e.g., machine learning-based anomaly detection). Materials included vernacular user manuals and a Telegram group for real-time queries. A five-member farmer committee was established to oversee daily operations and foster community ownership.

E. Monitoring Framework

The system incorporates embedded IoT sensors for real-time logging of water flow, energy output, and uptime on a cloud-based dashboard. AI-driven analytics provide anomaly alerts, supplemented by quarterly audits from university experts to maintain performance efficacy.

The deployed system's layout in Faldi village, including solar panels, pump, storage tank, and field distribution, is visualized in Fig. 3, highlighting its integration with the local agrarian landscape.

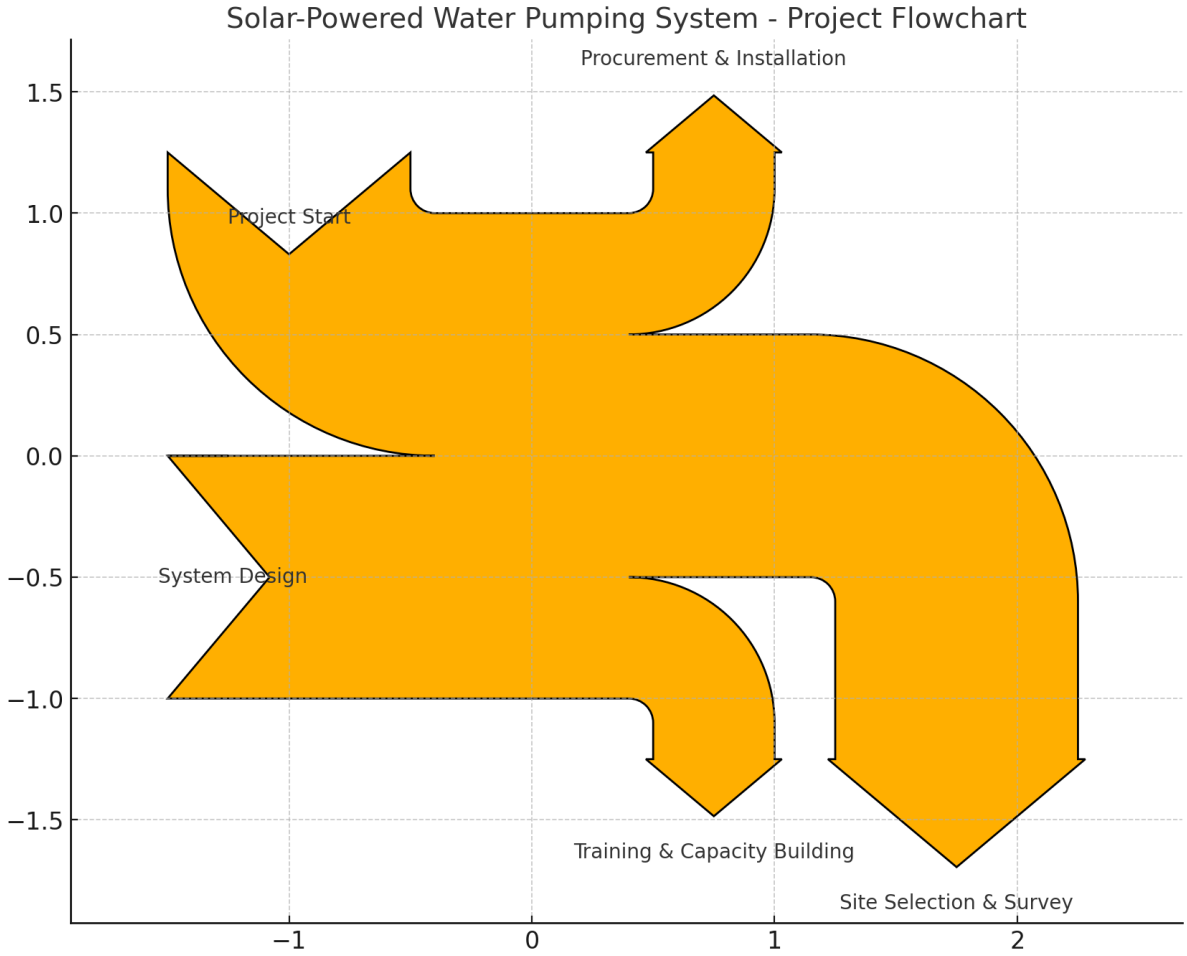


Fig. 1. Project flowchart illustrating the sequential phases of the solar-powered water pumping system implementation, from initiation through monitoring.

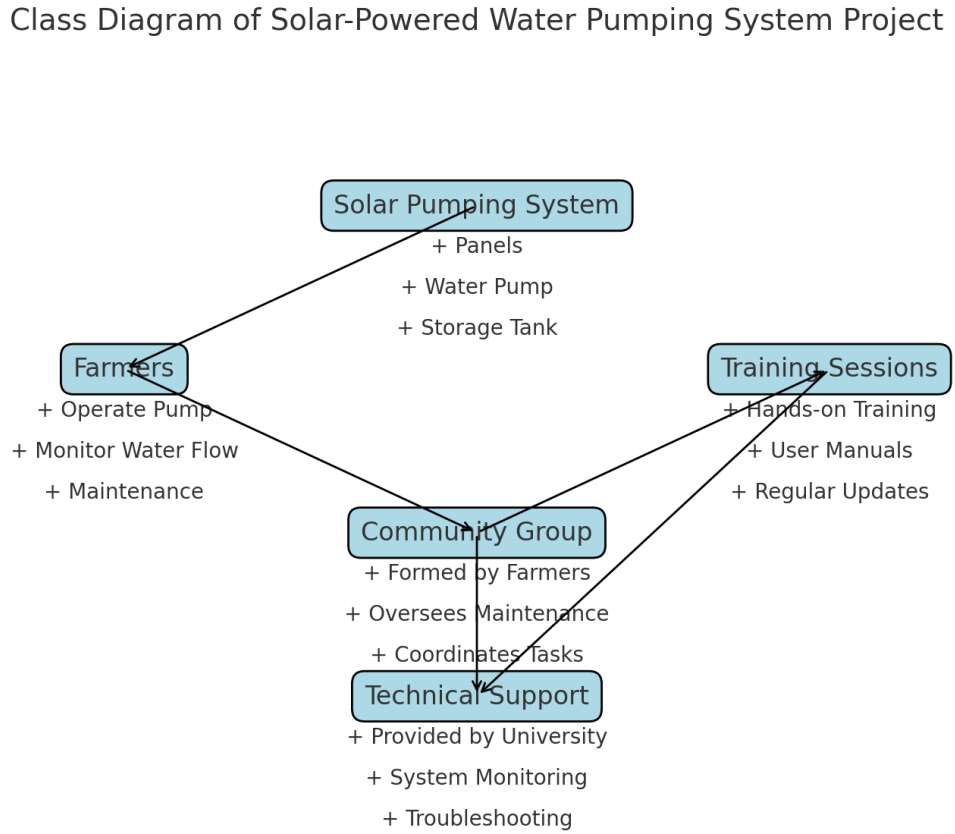


Fig. 2. UML class diagram depicting the relationships among system components, stakeholders (e.g., farmers and community group), and support elements (e.g., training sessions and technical support).

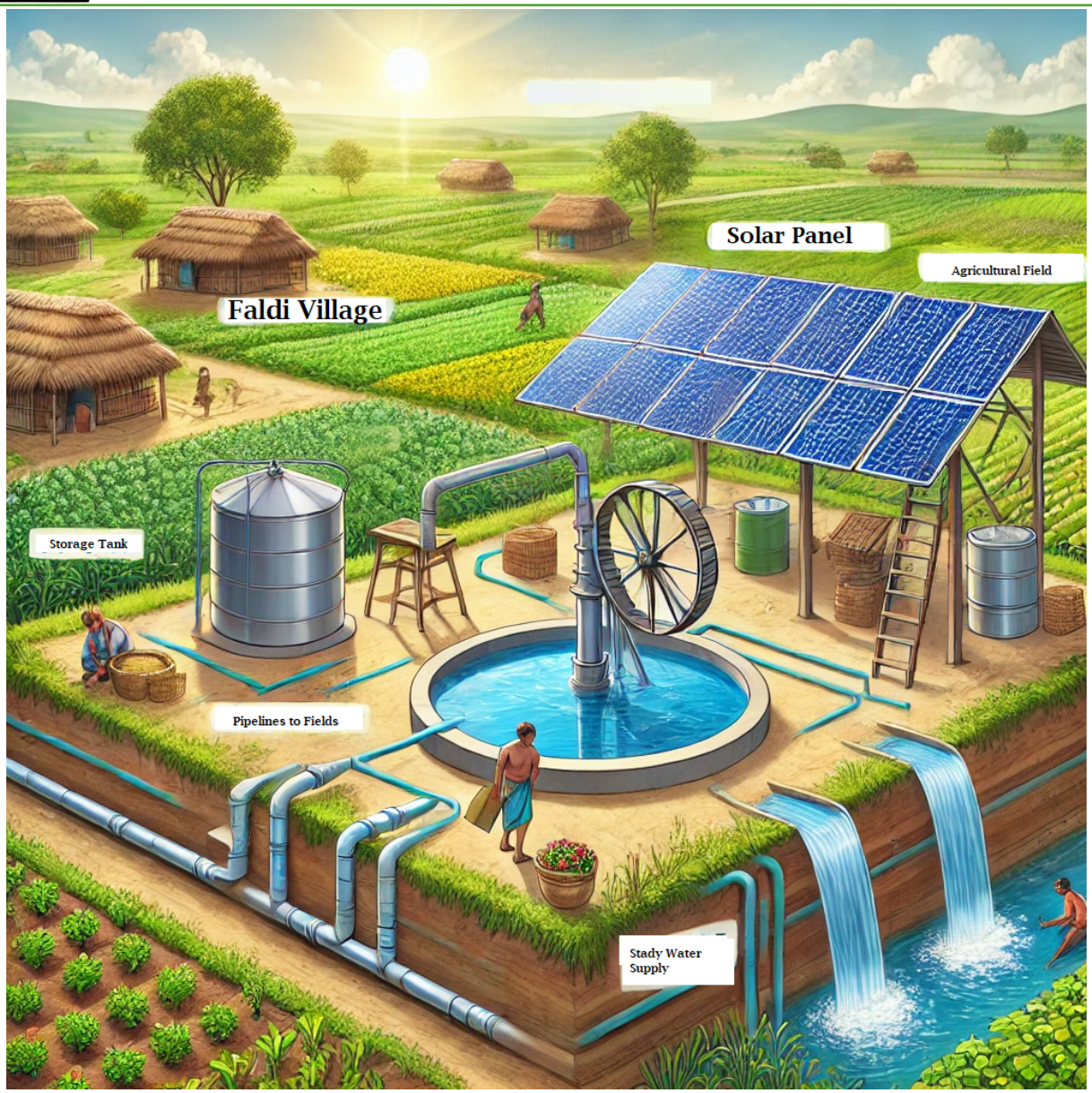


Fig. 3. Schematic representation of the installed solar-powered irrigation system in Faldi village, showing key infrastructure (solar panels, pump, storage tank, and pipelines) within the agricultural context.

Results and Analysis

Since inception (June 2024), the apparatus has functioned 15 months (as of September 2025), dispensing 4.5 million liters at 98% availability. Preliminary telemetry evinces diurnal yields of 45,000-55,000 liters, gratifying 92% zenith requisites.

Agricultural Productivity

Agrarians evince a 24% yield escalation for rabi paddy (4.5 to 5.6 tons/ha), ascribed to AI-orchestrated equity mitigating vegetative desiccation. Horticultural diversification (e.g., aubergine, ladyfinger) amplified tilled expanse by 16 acres. Analogies with Maharashtra's AI-solar hybrids corroborate 22-28% accruals, wherein predictive heuristics enabled perennial rotations. Edaphic humidity surged 20%, attenuating denudation.

Economic and Environmental Impacts

Energetic thrift: INR 8,200/farmer/year (82% decrement). Amortization horizon: 2.3 years. CO_2 abatement: 5.1 tons/year, akin to 110 arboreal plantings. Tamil Nadu benchmarks affirm 75-88% fiscal alleviations and 4-6 ton CO_2 mitigations per unit. Vocations: 6 intermittent sinecures in AI-monitored conservation, augmenting hamlet revenue by INR 60,000/month aggregate.

Adoption and Challenges

97% agrarian approbation; didactic fidelity at 88% (pre/post assays). Impediments encompassed aerosol occlusion (remedied via electrostatic veils) and nascent AI reticence (alleviated via demos). Catalysts like 30% MNRE incentives and collectivist tenure echo uptake vectors in Punjab analogs. Extensibility: Disseminate to 12 contiguous hamlets.

To visualize the key performance improvements, the following charts illustrate the baseline versus post-implementation metrics across agricultural, economic, and environmental indicators.

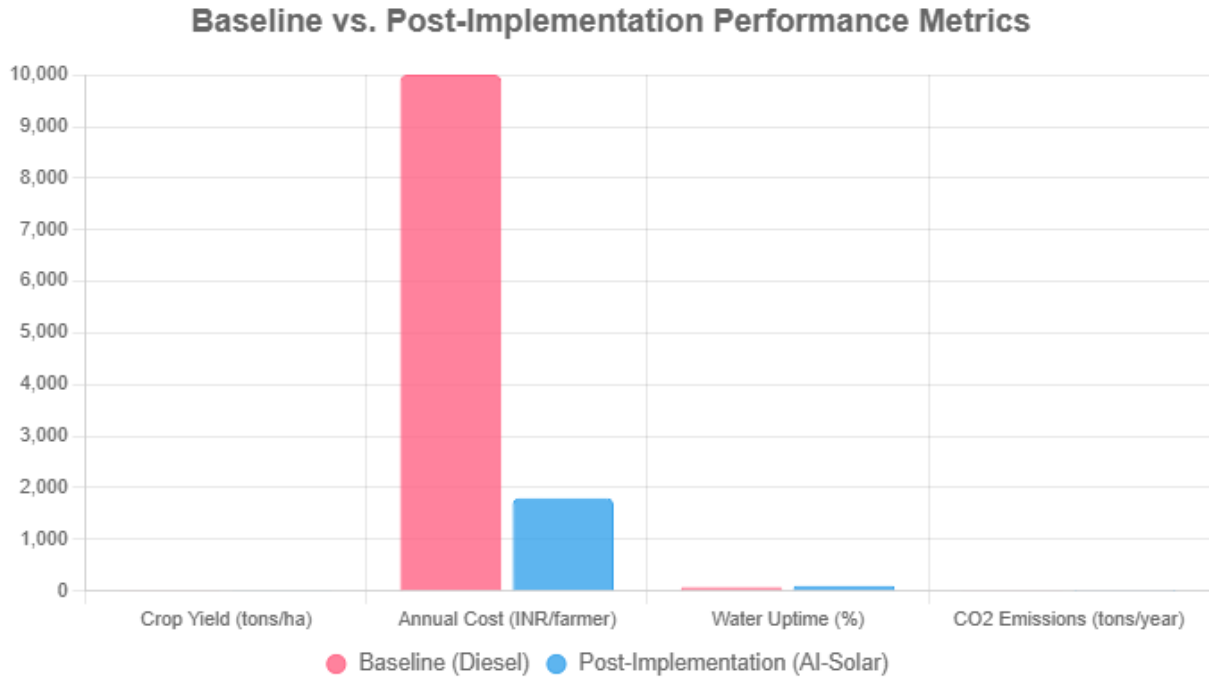


Fig. 4. Bar chart comparing baseline performance metrics under diesel-powered irrigation against post-implementation values with the AI-enhanced solar system, illustrating improvements in crop yield (tons/ha), annual operational cost (INR/farmer), water uptime (%), and CO_2 emissions (tons/year).

The bar chart in Fig. 4 compares baseline diesel system values against the AI-solar implementation, highlighting substantial gains in yield and uptime alongside sharp reductions in costs and emissions.

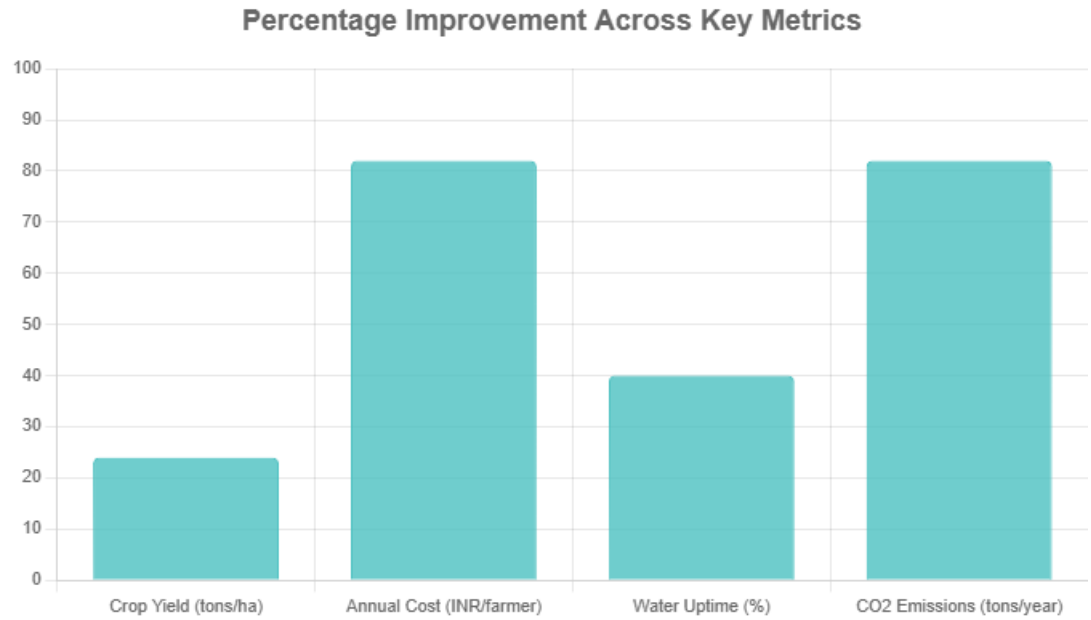


Fig. 5. Bar chart depicting the percentage improvements across key performance metrics following the deployment of the AI-enhanced solar-powered water pumping system, highlighting gains in agricultural productivity, cost efficiency, reliability, and environmental sustainability.

The bar chart in Fig. 5 depicts the percentage improvements, underscoring the system's transformative impact, particularly in cost and emission reductions.

Table 1. Summary of key performance metrics comparing baseline diesel-powered irrigation with the post-implementation AI-enhanced solar system, including crop yield (tons/ha), annual operational cost (INR/farmer), water uptime (%), and CO_2 emissions (tons/year), along with percentage improvements

Metric	**Baseline (Diesel)**	**Post-Implementation (AI-Solar)**	**Improvement (%)**
Crop Yield (tons/ha)	4.5	5.6	24
Annual Cost (INR/farmer)	10,000	1,800	82
Water Uptime (%)	70	98	40
CO2 Emissions (tons/year)	6	1.1	82

Conclusion

This AI-augmented solar irrigation venture in Faldi village exemplifies the potency of amalgamated renewables and intelligence in reshaping rustic agronomy. Yielding steadfast hydration, fiscal relief, and communal autonomy, it attains holistic viability. Envisaged 25% output surges and ecologic boons render it exemplary for India's 140 million agrarian units. Prospective augmentations encompass neural network refinements for nocturnal flux and micro-sprinkler synergies. Such paradigms spotlight the imperative for augmented R&D in AI-agri fusions, advocating fiscal buttresses for pan-Indian proliferation.

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INNOVATION METHOD OF THE OBTAINIG ELECTRIC ENERGY FROM DRAINAGE WATER IN TURKMENISTAN

Yuldashow Bahadir

Annamyradow Dowlet

Yollyyewa Ayna

Yollyyew Hydyrgeldi

Under the wise leadership of our esteemed President Serdar Berdimuhamedov, in the New Era of the Revival of the Sovereign State, in the Year of International Peace and Trust, our Motherland - our Independent and Eternally Neutral State - is achieving great progress. Our esteemed President is implementing major reforms to improve the education system and bring it to the level of developed countries in the world.

The motto of the national leader “The Motherland is only the Motherland with its people! The State is only the State with its people!” is evidence of his great concern for his people. The development of the state is primarily associated with the development of the education and science sector, the introduction of new technologies and equipment into our country.

Turkmenistan strives to keep pace with world development and use new technologies. Developed industrial systems have been created and are being improved. The living and social conditions of our people are steadily improving. In this regard, large investments are being made in the electric power sector, and this sector is being developed in a modern way. Great work is being done in our country to study advanced technologies. The support of our esteemed President for these works ensures their rapid implementation.

"Relying on the achievements of scientific and technological progress of our time, new technologies, knowledge and innovations, we have accumulated extensive experience in developing science, education and culture in our country. We attach great importance to raising a scientifically-educated, broad-minded, healthy generation. Guided by advanced world technologies, we create broad opportunities for the younger generation to receive modern education, engage in science and creativity. We are modernizing educational work, successfully implementing national programs and concepts," said our Honorable President Serdar Berdimuhamedov.

Before any major reforms are launched in our country, aimed at the interests of our people, their scientific and legal basis is first created and studied. The development of our country's energy sector is also based on scientific foundations, a solid legal framework, and clearly developed programs. Let's mention some of them that are currently in operation.

"The country has adopted the "State Program for Energy Conservation for 2018-2024," the "Program for the Development of Energy Diplomacy of Turkmenistan for 2021-2025," the "National Strategy of Turkmenistan for the Development of Renewable Energy Sources until 2030," and the Law of Turkmenistan "On Renewable Energy Sources." These documents define the legal, economic, organizational, and social foundations, tasks, and obligations of activities implemented in the energy sector.

Currently, in accordance with the development program of the power industry in our country, comprehensive work is being carried out to increase the capacity of the power industry, strengthen its material and technical base, and systematically modernize all infrastructures of the system.

In all countries of the world, rapidly developing industrial sectors are characterized by high electricity consumption. Additionally, due to changes in people's living conditions, the types and number of appliances used in daily life are increasing. Today, multiple refrigerators, televisions, air conditioners, and other devices are used in every household. These items necessitate increased and reliable electricity generation[1,8].

Numerous activities, such as the country's more active integration into the global economy, the widespread introduction of electricity-consuming industrial equipment, the creation of new industries, modern villages and cities, the opening of broad avenues for trade, and the establishment of agricultural product processing enterprises, require high electricity production. Therefore, the use of alternative energy is attractive not only from an economic standpoint but also from an ecological one.

The energy sector's activity is to generate electricity and supply it to consumers. As we can see, all major projects implemented in the energy sector are of both regional and international significance. Our country also adopts a highly responsible approach to environmental protection [9,12]. The active introduction of energy-saving, environmentally friendly technologies, and the use of highly efficient, reliable equipment are the main directions of our project work and socio-economic programs. In accordance with the priorities of Turkmenistan's energy policy, measures aimed at protecting the environment are consistently implemented in our country. When constructing industrial facilities, including energy facilities, great attention are paid to the introduction of modern technologies that help reduce the amount of harmful waste emitted into the environment."

"Turkmenistan has also established wide-ranging cooperation with the United Nations. The programs it has initiated are currently being implemented to a commendable extent. Within the framework of the program to ensure the availability and rational use of water resources for all, water treatment plants, modern technologies that help save water resources and innovative scientific and technical developments are being introduced into production. Turkmenistan is actively involved in developing balanced solutions to key issues in enhancing peace, security, and stability, achieving the Sustainable Development Goals, protecting the environment, and rationally using water resources. Environmental protection and conservation of water resources are currently a priority area of state policy. The country is carrying out significant work in such areas as preserving land, water, biological, and landscape diversity, combating desertification and deforestation.

The main goal of the environmental policy is to ensure the preservation of nature, which is a source of human life and work, and the rational use of its resources. Natural resources and their reserves are being used systematically and thoughtfully. When extracting all mineral resources (oil, natural gas, etc.), the impact on the environment is strictly taken into account, and environmental safety standards are strictly observed. Much attention is paid to the scientific development of the country's national economy, the complete replacement of all industrial enterprises with new, environmentally friendly and safe equipment and technologies, and the compliance of newly constructed production facilities with ecological requirements.

Cooperation in the energy sector is the key to maintaining peace and stability. As we know, energy is one of the most valuable commodities in the world, therefore the use of energy from alternative sources and the role of innovative methods for obtaining energy are among the most important issues.

Project Importance. Environmental issues, protection of the environment from negative technical impacts have become one of the most important issues in the world today. The People's Conference of the National Assembly of Turkmenistan adopted the "State Program for the Modernization of Biotechnology in Turkmenistan for 2024-2028." The new program will

give an additional impetus to the development of state institutions, ministries, and industrial institutions of the country, investment policy, foreign trade and commodity circulation, and overall economic growth. In accordance with this National Program, this thesis proposes the use of salt water for energy production. As we know, energy is one of the most valuable commodities in the world, and the use of energy from alternative sources and the role of innovative methods for energy production are among the most important issues. One such innovative method is the production of electricity from salt water. Therefore, the possibility of obtaining environmentally friendly electricity from salt water, along with its convenient form, is a good incentive to ensure the ecological well-being of the environment and achieve the goals of the "Sustainable Development" goal.

The Purpose of the Project. The purpose of the work is to develop environmentally friendly and economically viable electricity from drainage and stream waters in Turkmenistan.

The Novelty of the Project. The work on the production of electricity from salt water in foreign scientific centers and higher educational institutions was studied, and a lamp was made that produces electricity in salt water. Thus:

1. For the first time in Turkmenistan, electricity was produced from drainage water;

2. The existing technologies for producing energy from salt water were improved and the economic efficiency of production was increased.

Research and experiments conducted abroad on the scientific topic were studied, and based on them, a number of experiments were conducted and new methods were developed at the Scientific Production Center "Ecological Biotechnology" of the Oguz Khan University of Engineering and Technology of Turkmenistan.

Renewable energy sources theoretically have a greater capacity than the energy of the salt gradient.

A new type of rechargeable battery has been developed that works on salt water, and its peculiarity is that salt water serves not only as an electrolyte, but also as an energy source. It works by means of the reduction and oxidation reactions of the gaseous phases in salt water at the cathode, as well as the reduction and oxidation of Na+ ions at the anode. Currently, we are monitoring the amount of O2 and Cl2 gases and their ratio during the charging process using modern analytical instruments, such as differential electrochemical mass spectrometry."

This is a detailed and technical explanation of the research being conducted, including references to existing scientific work. Here's a breakdown of the translation, with explanations where necessary:

"Renewable energy sources theoretically have a greater capacity than the energy of the salt gradient. A new type of rechargeable battery has been developed that works on salt water, and its peculiarity is that salt water serves not only as an electrolyte, but also as an energy source. It works by means of the reduction and oxidation reactions of the gaseous phases in salt water at the cathode, as well as the reduction and oxidation of Na+ ions at the anode. Currently, we are monitoring the amount of O_2 and Cl_2 gases and their ratio during the charging process using modern analytical instruments, such as differential electrochemical mass spectrometry.

Before starting any scientific work, several previous experimental works and theoretical knowledge on the selected topic of the scientific work are reviewed and practical and theoretical knowledge is collected. For example: Balqis HUSNI, *Liyana Amalina ADNAN, Muhammad Amirul Firdaus MUHAMMAD ARIFF, Yahaya BASIRONKolej GENIUS Insan, Universiti Sains Islam Malaysia, Bandar Baru Nilai, 71800 Nilai, Negeri Sembilan, Malaysia

*liyanaamalina@usim.edu.my. A scientific article published in the International Research Journal in 2021 describes it as follows:

Zinc and copper are connected using a metal conductor. The Zn_2+ ions, with their excess electrons remaining in the left cell, jump from the external circuit and to the right electrode, joining the Cu_2+ ions. That is, they are converted into Cu atoms on the copper electrode. The net reaction is the oxidation of zinc by copper (II) ions, as shown in the following equation:

$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$

The electrode potential for copper is +0.34 V and for zinc -0.75 V. The voltmeter measures the sum of these two voltages. It also tracks the anodic reactions in the open circuit.

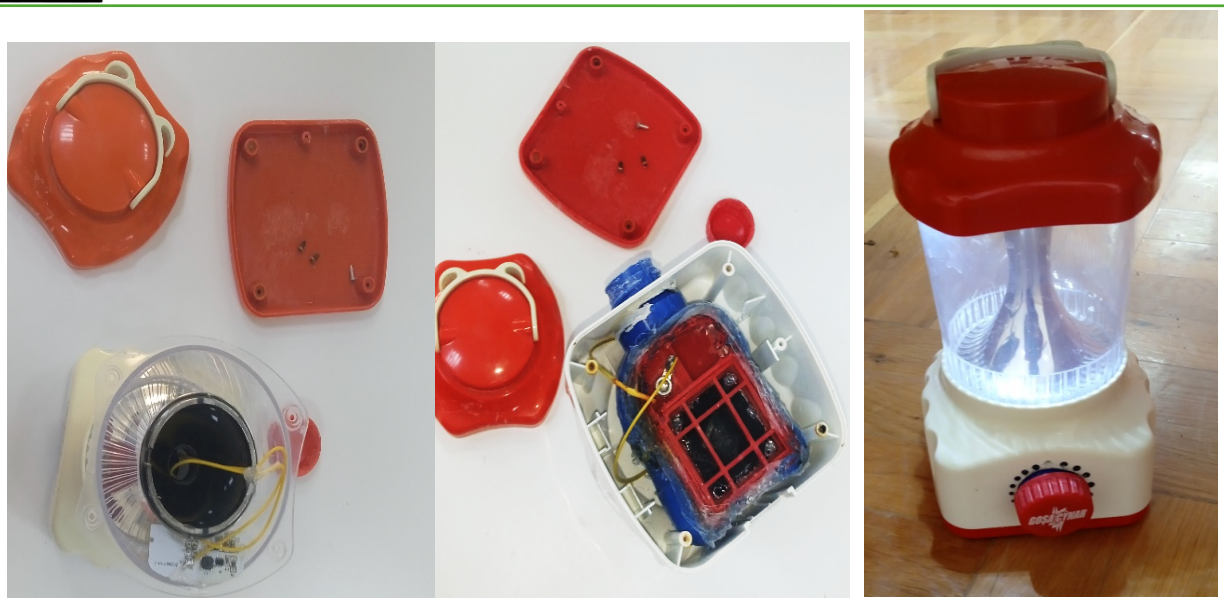
Renewable energy sources theoretically have a greater capacity than the energy of the salt gradient. A new type of renewable battery has been developed that works on salt water, and its peculiarity is that salt water serves not only as an electrolyte, but also as an energy source. It works by the reaction of the gaseous phases in salt water at the cathode, as well as the reduction and oxidation of Na+ ions at the anode. Today, using modern analytical equipment, for example, specialized equipment equipped with differential electrochemical mass spectrometry, we can monitor the amount of O_2 and Cl_2 gases and their ratio during the charging process. Energy is the ability to do work. Work is the conversion of energy from one form to another. In practical terms, energy is what we use to control our environment. Be it electrical energy or the use of mechanical devices such as cars. Energy comes in many forms — heat (thermal), light (radiation), mechanical, electrical, chemical, and nuclear.

Energy creates change, it serves as the power we use. It moves cars on roads and boats on water. It lights our homes [13,18]. Energy helps our bodies grow and our minds function. Scientists define energy as the ability to do work. Humans have learned how to convert energy from one form to another, making things easier and more comfortable. Historians of science have written perhaps more articles on the development of energy than on any other subject. The concept was first described by Empedocles (490–430 BC) as one of the four basic “elements” of nature, and was developed by Aristotle (384–322 BC) as “fire,” the other three being earth, water, and air. This view has become better understood over the past two thousand years [19,27]. Electric charges, when passed through wires, become electricity.

The use of renewable energy sources is suitable for small, autonomous systems, which is convenient for remote or mobile areas, where energy plays an important role in human development. Such small energy systems can help create local economies and jobs.

To implement the research:

1. The body of the lamp was made using metals and PLA plastic material.
2. The internal structure was designed for the electrolysis process and nichrome (cathode) and aluminum (anode) plates were installed.
3. A 3.5 W LED lamp was installed.
4. 300 ml of distilled water was used as the electrolyte.



***1.Photo*.Lighting system**

The use of nichrome and aluminum electrodes from a galvanic cell in salt water provided efficient performance, and gave 0.5–0.6 V over a 6-hour period. The level of change of the anode material continued to increase with increasing current output. The highest current was found at a high level, especially at short distances. A total of 4 electrodes were placed inside the lamp housing. 2 of them were nichrome cathodes and 2 were aluminum anodes. The efficiency of the current of a salt water battery in the electrolysis process is closely related to the efficiency of the electron flow, which depends on how good the electrocatalytic properties of the anode are [33]. The short electrode distance allows for the production of high current, because the process of efficiently conducting electrons between the anode and cathode is related to the amount of internal resistance of the battery. The internal resistance rarely increases with increasing current, and the greatest energy is generated as the electrode distance is increased. A small electrode spacing significantly reduces the osmotic resistance and consequently the overall internal resistance [34]. Closer electrode spacing significantly reduces the resistance and increases energy efficiency [35]. Increasing the energy level at a short distance will increase the current output to generate electricity as needed.

Positive ions move from the anode to the cathode through the electrolyte during electrochemical cell operation. The ability of the electrolyte to produce the desired current depends on the surface area of the electrode. The anode collects negative charges, while the cathode collects positive charges, creating a surface voltage V(t). Negative electrons flow from the anode to the cathode, creating a countercurrent current. The positive current is directed in the opposite direction of the electron flow[29,31]. The surface area current is proportional to the surface area of the electrode as an active material. A large surface area of the electrode can accelerate the electrochemical reaction and produce a higher current. In addition to providing a higher current, the surface area also has a significant impact on the capacity of the electrochemical cell. A linear relationship between current (y) and surface area (x) was demonstrated for the nichrome and aluminum anodes. A strong relationship was found for all electrode combinations, with correlation coefficients ranging from 0.9630 to 0.9988[37,39].

A large increase in field strength, while maintaining the same distance, accelerates a higher current in the nichrome anode compared to the aluminum anode. Linear relationship between surface field level and current:

Distance (cm) Linear equation Correlation coefficient (r) Nichrome anode 1 y = 0.0577x - 0.0773 0.9856.

Result

The nichrome plate was used as the cathode and aluminum as the anode.To record the amount of electricity,electric current measuring devices were used.Thus,300ml of salt water was measured at a voltage of 3V and current of 0,02A.

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CRISPR TABANLI HIZLI TANI TESTLERİ: MİKROBİYOLOJİ VE KLİNİK UYGULAMALARDA YENİ BİR DÖNEM

Doç.Dr. Tülin Güven Gökmen

Çukurova Üniversitesi, Ceyhan Veteriner Fakültesi, Klinik Öncesi Bilimler Bölümü, Mikrobiyoloji Anabilim Dalı, Adana

Email: tulinguven01@hotmail.com

ORCID: 0000-0001-9673-097X

Doç.Dr.Hatice Yazgan

Çukurova Üniversitesi, Ceyhan Veteriner Fakültesi, Gıda Hijyeni ve Teknolojisi Bölümü, Gıda Hijyeni ve Teknolojisi Anabilim Dalı, Adana

Email: hyazgan@cu.edu.tr

ORCID: 0000-0002-7520-3342

ÖZET

CRISPR-Cas sistemleri, bakterilerin fajlara karşı geliştirdiği adaptif bağışıklık mekanizmasından türetilmiş olup, son yıllarda tanı teknolojilerinde devrim niteliğinde bir dönüşüm sağlamıştır. Geleneksel kültür, PCR ve serolojik yöntemlerin zaman, maliyet ve teknik sınırlılıkları nedeniyle hızlı, özgül ve taşınabilir tanı araçlarına olan ihtiyaç artmıştır. Bu bağlamda, özellikle Cas12 ve Cas13 proteinlerinin özgül nükleik asit tanıma ve "trans-cleavage" aktivitelerine dayanan CRISPR tabanlı hızlı tanı testleri, hem laboratuvar hem saha koşullarında dakikalar içinde yüksek hassasiyetli sonuçlar sunabilmektedir. SHERLOCK ve DETECTR gibi platformlar, COVID-19 pandemisinde RNA ve DNA virüslerinin hızlı tespitinde etkin bir şekilde kullanılmıştır. Mikrobiyolojide bu sistemler; S*almonella, Campylobacter jejuni, Mycobacterium tuberculosis* gibi bakterilerin ve SARS-CoV-2, Zika, Avian Influenza gibi virüslerin tanımlanmasında önemli bir potansiyel taşımaktadır. Ayrıca *blaNDM, mecA* ve *mcr-1* gibi antimikrobiyal direnç genleri dakikalar içinde saptanabilmektedir. Klinik uygulamalarda, izotermal amplifikasyon teknikleriyle entegre edilen taşınabilir testler sayesinde hasta başında tanı mümkün hale gelmiştir. Bu durum, hızlı tedavi kararları, salgın kontrolü ve epidemiyolojik sürveyans açısından büyük avantaj sağlar. CRISPR tabanlı testlerin yüksek özgüllük, hız ve düşük maliyet gibi üstünlükleri yanında saha standardizasyonu, regülasyon süreçleri ve çoklu patojen tarama kapasitesi gibi alanlarda hâlen geliştirmelere ihtiyaç vardır. Gelecekte nanoteknoloji ve yapay zekâ ile entegrasyon, bu testlerin veteriner ve insan sağlığında erken tanı ve direnç takibinde rutin kullanıma geçmesini sağlayacaktır.

Anahtar Kelimeler: CRISPR-Cas, Tanı yöntemi, Enfeksiyon

ABSTRACT

CRISPR-Cas systems, derived from bacterial adaptive immunity against phages, have recently brought a revolutionary shift to diagnostic technologies. Due to the time, cost, and technical limitations of traditional culture, PCR, and serological methods, there is an increasing demand for rapid, specific, and portable diagnostic tools. CRISPR-based rapid tests, particularly those using Cas12 and Cas13 proteins with their unique nucleic acid recognition and trans-cleavage activities, enable highly sensitive detection within minutes, both in laboratories and field settings. Platforms such as SHERLOCK and DETECTR proved highly effective during the COVID-19 pandemic for the rapid detection of RNA and DNA viruses.

In microbiology, these systems have shown great potential for identifying bacterial pathogens such as *Salmonella, Campylobacter jejuni*, and *Mycobacterium tuberculosis*, as well as viruses including SARS-CoV-2, Zika, and Avian Influenza. Additionally, antimicrobial resistance genes such as *blaNDM, mecA,* and *mcr-1* can be detected within minutes. In clinical applications, the integration of isothermal amplification techniques with portable CRISPR-based devices has enabled point-of-care diagnostics, allowing for rapid treatment decisions, outbreak control, and epidemiological surveillance.

While CRISPR-based tests offer major advantages high specificity, speed, and low cost further developments are needed in areas such as field standardization, regulatory frameworks, and multiplex pathogen detection capabilities. Future integration with nanotechnology and artificial intelligence is expected to facilitate the routine use of these tests in both veterinary and human health, contributing to early detection and antimicrobial resistance monitoring within the One Health framework.

Keywords: CRISPR-Cas, Diagnostic method, Infection

CRISPR-BASED RAPID DIAGNOSTIC TESTS: A NEW ERA IN MICROBIOLOGY AND CLINICAL APPLICATIONS

The CRISPR-Cas system operates as a protective mechanism which bacteria and archaea use to defend themselves against bacteri bacteriophages. The system functions as a protective mechanism which allows bacteria to identify and neutralize incoming genetic materials. Scientists use CRISPR technology as their main tool to edit genes while fighting antimicrobial resistance and performing selective breeding and gene therapy and running molecular diagnostic tests (Aman et al., 2023).

Bacterial cells use their natural enzymes to extract DNA fragments from infecting bacteriophages which they store as spacers within their CRISPR locus. The bacterium stores genetic information through spacers which enable it to defend against specific phages when they attempt to infect again. The CRISPR locus produces pre-crRNA through transcription after its alternating repeat and spacer sequences are transcribed. The Cas proteins transform pre-crRNA into shorter crRNAs which direct the Cas proteins to find matching DNA or RNA sequences. The Cas enzyme identifies target sequences through recognition which leads to the destruction of foreign nucleic acids (Jinek et al. ,2012).

The Cas9, Cas12 and Cas13 proteins show exceptional DNA and RNA sequence detection capabilities which enables them to locate pathogens and resistance genes with high precision. The combination of CRISPR-based assays with RPA and LAMP isothermal amplification methods enables researchers to conduct field-based testing through simple equipment that does not need complex laboratory facilities (Xu et al. ,2024). The systems achieve superior results because they detect targets with high accuracy at fast speeds while maintaining affordable operational expenses. The SHERLOCK system and DETECTR system demonstrate the broad diagnostic capabilities of Cas13 and Cas12 enzymes. The developed methods show effective fast SARS-CoV-2 detection when used in outdoor settings (Gootenberg et al.,2017; Broughton et al.,2020; Myhrvold et al.,2018). The diagnostic method enables researchers to detect bacterial infections and antibiotic resistance genes through the same approach.

The CRISPR-Cas System Functions as a Diagnostic Tool

The system uses Cas protein target specificity to develop fast and highly sensitive biosensor systems (Aman et al., 2023). The DNA cleavage activity of Cas9 occurs at specific sites but it does not have the ability to perform trans-cleavage reactions which require additional amplification steps. The Cas12 and Cas13 enzymes activate to perform collateral (trans) cleavage which results in the production of fluorescent or colorimetric signals through the cleavage of nearby reporter oligonucleotides (Li S.-Y. et al.,2018).

The SHERLOCK system uses Cas13 to detect RNA targets at high sensitivity levels according to Gootenberg et al. (2017) and Myhrvold et al. The system depends on Cas12 from to detect DNA targets which generate powerful signals according to Broughton et al. (2020) and Tsou et al. (2023).

The process of isothermal amplification allows nucleic acid replication to occur at a fixed temperature which eliminates the need for thermocyclers. The diagnostic methods RPA and LAMP operate best for fast field-based testing because they do not need complex laboratory equipment (Lobato & O'Sullivan, 2018). The complete amplification process enables Cas proteins to detect targets which produces results within short time frames (Xu et al.,2024).

Applications in Microbiology

Determination of Antimicrobial Resistance

The current antimicrobial susceptibility tests which use culture-based methods face major challenges because they take too long to produce results and cannot be used in field settings. The urgent need for antibiotic resistance gene identification demands immediate solutions to fulfill this increasing requirement. The CRISPR-Cas system enables fast detection of essential antibiotic resistance genes including *blaCTX-M, blaTEM, KPC, NDM, mcr-1* and *mecA* within short periods of time (Quan et al.,2019; Wang et al.,2022; Xu et al.,2024). The Cas12 and Cas13 systems achieve fast results through their cutting mechanism which enables fluorescence and lateral-flow tests that outperform conventional diagnostic methods.

Rapid Detection of Bacterial Pathogens

The fast identification of bacterial contamination in food safety requires CRISPR-Cas technologies as new solutions for food safety. The diagnostic systems that employ Cas12 technology achieve better results for fast *Salmonella* serovar identification which allows for quick outbreak response (Liu et al.,2022; Gong et al.,2024). The combination of CRISPR/Cas12a assays with LAMP technology enables affordable and simple detection of *Campylobacter jejuni* from fresh food materials which allows on-site testing at farms and slaughterhouses and retail locations. The medical field benefits from Cas13-driven assays because these tests enable fast *Mycobacterium tuberculosis* detection from sputum samples in basic laboratory settings of resource-limited areas (Aman et al.,2023).

Detection of Viral Pathogens

The worldwide spread of pandemics requires ongoing protection of public health through fast deployable viral detection systems. The CRISPR/Cas13 system detects SARS-CoV-2 and Zika and Dengue viruses at high speed because it has sensitive RNA target recognition (Gootenberg et al.,2017; Myhrvold et al.,2018; Broughton et al.,2020). The technology successfully detects zoonotic viral pathogens including Newcastle disease virus and avian influenza which supports biosecurity and surveillance operations (Wu et al.,2023; Xue et al.,2023; Zhou et al.,2023).

Point-of-Care and Field-Applicable Testing

The diagnostic process becomes possible through isothermal amplification when combined with CRISPR-based detection because it eliminates the need for conventional laboratory equipment. The integrated platforms generate quick results which researchers can apply to study various settings including outbreak areas and manufacturing facilities and open spaces (Tsou et al.,2023). The development of portable diagnostic equipment enables healthcare professionals to detect avian influenza in poultry farms and identify bacterial and viral pathogens and vector-borne diseases in small clinics and food production facilities and Zika and Dengue outbreak settings (Gootenberg et al.,2017; Broughton et al.,2020; Liu et al.,2022; Wang et al.,2022; Zhou et al.,2023).

Use in Clinical Samples

Researhers conduct clinical tests on specimens through CRISPR platforms which perform isothermal amplification with exact results in facilities outside traditional hospital laboratories. The diagnostic method serves as an effective solution for areas that do not have enough diagnostic centers. The combination of mobile testing devices enables farmers to detect avian influenza directly on their farms and healthcare facilities to identify SARS-CoV-2 and bacterial pathogens and food production facilities to track Salmonella contamination. The use of CRISPR-based tools for Zika and Dengue virus detection during field investigations allows for

quick outbreak identification which helps stop virus spread (Gootenberg et al.,2017; Broughton et al.,2020; Liu et al.,2022; Wang et al.,2022; Zhou et al.,2023).

Epidemiological Surveillance

The use of CRISPR systems now extends past basic diagnostic tests because scientists use them to monitor large populations. The surveillance systems which track SARS-CoV-2 and enteric pathogens in wastewater allow public health officials to detect community transmission before people show symptoms thus making these tools vital for early warning systems (Zhou et al.,2025). The method shows promise to become an operational tool for future public health monitoring activities.

The diagnostic features of CRISPR-based tests outperform traditional molecular diagnostic methods because they provide portable and affordable testing with high precision according to Aman et al. 2023; Myhrvold et al.,2018; Tsou et al.,2023). Standardized procedures and quality-assurance frameworks and independent validation procedures must be implemented for CRISPR-based diagnostic deployment in field environments to produce reliable results (Xu et al.,2024; Zhou et al.,2025). Scientists continue their research to create multiplex CRISPR systems which can identify multiple pathogens and resistance determinants at the same time.

The One Health approach needs immediate pathogen detection of Salmonella and Escherichia coli and Staphylococcus aureus to defend human and animal wellness. The future of diagnostic technology will unite CRISPR diagnostics with nanotechnology and artificial intelligence and digital health platforms to develop sophisticated diagnostic systems that deliver fast accurate results at budget-friendly prices (Zhou et al.,2025).

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RUMINANT HAYVANLARIN İÇME SUYU KALİTE ÖZELLİKLERİ*

Cemal BUDAĞ*

*Doç Dr. Cemal BUDAĞ. Van Yüzüncü Yıl Üniversitesi Ziraat Fakültesi Zootekni Bölümü.

Email: cbudag@yyu.edu.tr

ORCID : 0000-0003-3532-7727

ÖZET

Su, ruminant beslenmesinde en hayati ancak çoğu zaman göz ardı edilen besin öğesidir. Suyun miktarının yanı sıra, kalitesi de hayvan sağlığı, refahı ve verimliliği üzerinde derin bir etkiye sahiptir. İçme suyunun fiziksel (sıcaklık, bulanıklık, pH), kimyasal (nitrat, nitrit, sülfat, toplam çözünmüş madde, iz elementler, ağır metaller) ve mikrobiyolojik (*E. coli*, patojen bakteriler, siyanobakteri toksinleri) özellikleri; yem tüketiminden sindirime, metabolizma ve genel performansa kadar birçok süreci etkiler.
Yükselmiş nitrat ve nitrit düzeyleri methemoglobinemiye yol açabilirken, aşırı sülfat düzeyleri polioensefalomalasi ile ilişkilidir. Ayrıca, bakır–molibden–kükürt etkileşimleri sekonder iz mineral dengesizliklerine neden olabilir.

Bu nedenle, su kalitesi parametrelerinin düzenli olarak izlenmesi ve saha koşullarında doğru şekilde yorumlanması, metabolik bozuklukların önlenmesi ve optimal üretimin sürdürülmesi açısından kritik öneme sahiptir.

Uluslararası kılavuzlar ruminantlar için eşik değerler tanımlasa da, birçok standart —Türk Standartları (TS) ve Yüzeysel Su Kalitesi Yönetmeliği dâhil— esas olarak insan tüketimi temelinde hazırlanmıştır. Bu nedenle, ruminantların fizyolojik ve üretimle ilişkili özel gereksinimlerinin pratik değerlendirmelerde vurgulanması gerekmektedir.

Bu derlemenin amacı, ruminant türleri için içme suyu kalitesiyle ilgili mevcut bilgileri sentezlemek, tolerans aralıklarını özetlemek ve üreticiler ile araştırmacılar için uygulanabilir öneriler sunmaktır.

Sonuç olarak, su kalitesinin hayvan sağlığının, verimliliğin ve sürdürülebilir hayvansal üretimin geliştirilmesinde belirleyici rolünü vurgulamaktadır.

Anahtar Kelimeler: Ruminant su kalitesi, nitrat, sülfat, ağır metaller, siyanotoksinler, hayvan refahı, sürdürülebilir hayvancılık

QUALITY CHARACTERISTICS OF DRINKING WATER FOR RUMINANT ANIMALS

ABSTRACT

Water is the most vital yet often overlooked nutrient in ruminant nutrition. Beyond its quantity, the quality of drinking water exerts a profound influence on animal health, welfare, and productivity. The physical (temperature, turbidity, pH), chemical (nitrate, nitrite, sulfate, total dissolved solids, trace elements, heavy metals), and microbiological (E. coli, pathogenic bacteria, cyanobacterial toxins) characteristics of water collectively affect feed intake, digestion, metabolism, and overall performance. Elevated nitrate and nitrite concentrations can induce methemoglobinemia, while excessive sulfate levels are linked to polioencephalomalacia. Furthermore, copper–molybdenum–sulfur interactions may lead to secondary trace mineral imbalances.

Regular monitoring and precise interpretation of water quality parameters under field conditions are therefore essential to prevent metabolic disorders and maintain optimal production.

International guidelines define threshold values for ruminants, yet many standards—including Turkish Standards (TS) and the Surface Water Quality Regulation—are primarily designed for human consumption. Hence, ruminant-specific physiological and productive requirements must be emphasized in practical assessments.

This review aims to synthesize current knowledge on drinking water quality criteria relevant to ruminant species, outline tolerance ranges, and provide applied recommendations for producers and researchers. Ultimately, it underscores the pivotal role of water quality in advancing animal health, productivity, and the sustainability of livestock systems.

Keywords: Ruminant water quality, nitrate, sulfate, heavy metals, cyanotoxins, animal welfare, sustainable livestock production

1. GİRİŞ

Su, ruminant hayvanların yaşamında en temel besin öğesidir ve enerji, protein, mineral ya da vitaminlerden çok daha yüksek miktarlarda gereksinim duyulur. Vücut ağırlığının yaklaşık %60–70'ini oluşturan su, sindirim, besin maddelerinin taşınması, termoregülasyon, asit–baz dengesi ve metabolik atıkların uzaklaştırılması gibi çok sayıda yaşamsal süreçte kritik rol oynar. Ruminantlarda su tüketimi; canlı ağırlık, süt verimi, gebelik durumu, çevre sıcaklığı, yem tipi ve yemle alınan kuru madde miktarı gibi birçok faktörden etkilenir. Örneğin, süt verimi yüksek bir inek, laktasyon döneminde günde 100 litreyi aşabilen su tüketimine ihtiyaç duyabilir.

Suyun yalnızca miktarı değil, **kalitesi** de hayvan sağlığı ve performansı açısından belirleyicidir. Uygun olmayan içme suyu; iştah azalması, yem tüketiminde düşüş, verim kaybı, mineral dengesizlikleri, hatta toksik tablolar ve ölümlerle sonuçlanabilmektedir. Özellikle **nitrat, nitrit, sülfat, ağır metaller** ve **mikrobiyolojik kontaminasyon** gibi risk faktörleri hem hayvan sağlığı hem de halk sağlığı açısından önemlidir. Buna karşın kaliteli içme suyu, yemden yararlanmayı ve üretim verimliliğini artırırken, bağışıklık sistemini de desteklemektedir.

Ruminant içme suyu kalitesi, farklı ülkelerde çeşitli kılavuz ve standartlarla tanımlanmıştır. **Canada CCME** ve **Australia & New Zealand Livestock Drinking Water Guidelines** gibi uluslararası referansların yanı sıra, Türkiye'de de **TS 266 İnsani Tüketim Amaçlı Sular Standardı** ve **Yerüstü Su Kalitesi Yönetmeliği** dikkate alınmaktadır. Ancak bu düzenlemeler çoğu zaman insanlar için geliştirilmiş kriterlere dayandığından, ruminantlara özgü eşik değerlerin saha koşullarında daha dikkatli yorumlanması gerekir (Caux ve ark., 1994; Khan ve ark., 2005; Bilgin, 2018).

Türkiye'de ruminant hayvanların içme suyu kalitesi, doğrudan hayvancılığın sürdürülebilirliği ve verimliliğiyle ilişkilidir. Ülkenin farklı ekolojik bölgelerinde kullanılan su kaynakları (kuyular, akarsular, göletler ve şebeke suyu) kalite açısından önemli farklılıklar göstermektedir. Özellikle tarımsal faaliyetlerin yoğun olduğu bölgelerde nitrat ve pestisit kirliliği; endüstriyel bölgelerde ise ağır metal ve kimyasal kontaminasyon riskleri öne çıkmaktadır ((Garipağaoğlu, 2016; Sünal ve Erşahin 2012).

Mevzuat açısından, Türkiye'de doğrudan ruminantlara özgü su kalite kriterleri tanımlanmamış olmakla birlikte, iki temel düzenleme dikkate alınmaktadır:

- **TS 266 – İnsani Tüketim Amaçlı Sular Standardı** (Enstitüsü, 2005): İnsan sağlığına uygunluk açısından parametreler belirler. Hayvancılıkta kullanılan içme sularının bir kısmı da bu standartlara tabi şebeke sistemlerinden sağlanmaktadır. Ancak hayvanların tolerans aralıkları insanlardan farklı olabildiği için, bu standartların ruminantlara uygulanmasında dikkatli olunmalıdır.

- **Yerüstü Su Kalitesi Yönetmeliği** (Gazete, 2004): Akarsu, göl ve baraj gibi yüzeysel sular için kalite sınıflarını tanımlar. Özellikle **Nitrat Hassas Bölgeleri** kavramı, tarımsal kaynaklı kirliliğin azaltılması açısından önemlidir. Bu düzenleme, hayvancılık tesislerinin bulunduğu alanlarda kullanılan yüzey sularının nitrat ve fosfor yükleriyle ilişkilendirilerek değerlendirilmelidir.

Saha bulguları Türkiye'de bazı bölgelerde özellikle **nitrat ve sülfat düzeylerinin yüksek** seyrettiğini göstermektedir. Güneydoğu Anadolu ve İç Anadolu'daki yeraltı sularında, gübre kullanımı ve sulama geri dönüşleri nedeniyle nitrat birikimi gözlenmektedir (Dokuz ve ark., 2025). Doğu Anadolu'da ise volkanik jeolojik yapıdan kaynaklanan yüksek sülfat ve florür seviyeleri rapor edilmiştir (Atıcı, 2020). Bu durum, ruminantlarda hem üretim kaybına hem de metabolik bozukluklara zemin hazırlayabilmektedir.

Uygulama açısından, Türkiye'de hayvancılık işletmelerinde su analizleri çoğunlukla rutin yem analizleri kadar yaygın değildir. Bu nedenle üreticilerin düzenli su analizi yaptırması, zooteknistlerin de rasyon formülasyonunda **su kaynağını bir besin öğesi gibi** dikkate alması gereklidir. Özellikle yüksek sülfat veya nitrat düzeyleri bulunan bölgelerde yem katkılarının (ör. vitamin E, organik mineral kaynakları) yeniden düzenlenmesi gerekebilir. Ayrıca su temininde hijyenik olmayan açık kanallar yerine kapalı sistemlerin teşviki, mikrobiyolojik risklerin azaltılmasına katkı sağlayacaktır (Yaylak ve Yavuz, 2016).

Sonuç olarak, Türkiye'de ruminant içme suyu kalitesi, insan sağlığı temelli standartlar ve yüzey suları yönetmelikleri çerçevesinde değerlendirilmektedir. Ancak hayvanların türlere özgü toleransları dikkate alınarak bölgesel saha çalışmaları ve düzenli izleme programları geliştirilmesi, sürdürülebilir hayvancılık için kritik bir gerekliliktir.

Bu derlemede, ruminant hayvanların içme suyu kalitesi açısından kritik fiziksel, kimyasal ve mikrobiyolojik parametreler ele alınacak, farklı türler için tolerans aralıkları özetlenecek ve saha uygulamalarına yönelik öneriler sunulacaktır. Amaç, araştırmacılar, zooteknistler, veteriner hekimler ve üreticiler için hem güncel bilimsel verileri hem de pratik uygulamaları içeren bütüncül bir çerçeve sunmaktır.

2. TÜR BAZINDA SU İHTİYACI VE EŞİKLER

Su, hayvan organizmasındaki moleküllerin neredeyse %98'ini kapsar (NRC, 2001). Vücutta, hücre dışı ve hücre içi sıvılar da dahil olmak üzere dağılır ve toplam vücut suyunun sırasıyla %31 ila %38'ini ve %62 ila %69'unu içerir. Ayrıca tüm canlılar arasında en bol bulunan ve hayati önem taşıyan kimyasal substrat olarak kabul edilir (NRC, 2007).

Yetişkin hayvanların vücut kütlesinin yaklaşık %60'ını su oluştururken, yavrularda bu oran daha da yüksektir. Hayvanların metabolik faaliyetlerini sürdürebilmeleri için düzenli şekilde su tüketmeleri zorunludur. Sıvı gereksinimleri yalnızca içme suyu ile değil, aynı zamanda tükettikleri yemlerden ve metabolik süreçler sonucunda ortaya çıkan sudan da karşılanabilmektedir. Su, vücut sıcaklığının düzenlenmesinde, canlı ağırlığın korunmasında, sindirim sisteminin sağlıklı çalışmasında ve boşaltım işlevlerinde temel bir unsurdur. Bununla birlikte hayvanlar idrar, dışkı, solunum ve terleme yoluyla sürekli su kaybederler; bu kaybın yerine konulması yaşamsal önem taşır. Dolayısıyla hayvanların suya erişimi olmadan 3–4 günden fazla yaşamlarını sürdürmeleri mümkün değildir. Yeterli düzeyde su tüketmeyen hayvanlarda, dış görünüşleri üzerinden sağlık problemleri kolayca fark edilebilmektedir (NRC, 2007; Akinmoladun ve ark., 2019).

Ruminantların su gereksinimleri, içtikleri suyun yanı sıra yemlerde bulunan su ve metabolik faaliyetler sonucu oluşan sudan karşılanmaktadır (NRC, 2001). Bununla birlikte, hayvanın türü, yaşı, çevre sıcaklığı, üretim düzeyi, yemin nem oranı, enerji kaynağı ve protein miktarı gibi birçok faktör, ihtiyaç duyulan toplam su miktarını belirlemektedir (NRC, 2007; Araújo ve ark., 2010). Ayrıca, hayvanların istedikleri zaman temiz ve yeterli miktarda suya ulaşabilmeleri, hayvan refahının vazgeçilmez bir bileşeni olarak kabul edilmektedir (Yaylak ve Yavuz, 2016). Ancak, yetiştiricilerin önemli bir kısmı suyun miktarı ve kalitesi hakkında yeterli bilgiye sahip değildir (Beede, 2012).

Ruminantların içme suyuna karşı toleransları tür, üretim dönemi ve çevresel faktörlere bağlı olarak farklılık gösterebilir. Özellikle toplam çözünmüş madde (TDS), nitrat/nitrit ve sülfat seviyeleri bu açıdan kritik parametreler arasında yer almaktadır (Araújo ve ark., 2010). Örneğin, sığırlarda süt yaklaşık %87, gübre %88 ve vücut kütlesi %56–65 oranında sudan oluşmaktadır. Laktasyondaki ineklerin, canlı ağırlıklarına kıyasla diğer türlere göre daha yüksek düzeyde suya gereksinim duyduğu bilinmektedir (Beede, 1993). Sığırların suya olan ihtiyacı; rumen fermantasyonunun sağlıklı şekilde gerçekleşmesi, yemlerin sindirim kanalından uygun hızda

ilerlemesi, besin öğelerinin sindirilip emilmesi, iyon ve kan hacmi dengesinin korunması, metabolik atıkların vücuttan uzaklaştırılması, vücut ısısının dengelenmesi, fetüsün uygun ortamda gelişimi ile dokulara besin öğelerinin taşınması gibi birçok yaşamsal fonksiyonla doğrudan ilişkilidir. Bu nedenle bol, temiz ve kaliteli suyun sürekli olarak sağlanması büyük önem taşımaktadır (Adams ve Sharpe, 1995; NRC, 2001).

Çizelge 1. Ruminant türlerine ve çeşitli fizyolojik durumlarına göre günlük su tüketim aralıkları*

Tür/Fizyolojik durum	Günlük su tüketimi	Notlar
Süt sığırı – laktasyonda	70–155+	Süt verimine bağlı olarak artar; 1 L süt için ≈ 4 L su gereklidir.[1,2]
Süt sığırı – kuru/gebelik	34–49	Ortalama değerler; laktasyon dönemi dışı.[2]
Besi sığırı	40–80	Ağırlık ve çevre sıcaklığına bağlı; sıcaklık arttıkça ihtiyaç artar.[2]
Koyun – koç/gebelik	3.8–7.6	Üretim evresine göre değişir.[2]
Koyun – laktasyon	7.6–11.4	Süt verimine bağlı olarak artar.[2]
Kuzu	0.4–1.1	Yaşa ve büyüme hızına bağlıdır.[2]
Keçi – erişkin (bakım)	3.8–11.4	Bakım koşullarında ortalama değerler.[3]
Keçi – laktasyon	1.9–2.0 L su / 1 L süt	Süt verimine ek su ihtiyacı.[3,4]

*Linn ve Raeth-Knight, 2010; Meehan ve ark. 2015; Giger-Reverdin ve Gihad, 1991; Ehrlenbruch ve ark., 2010

Hesaplama kuralları

• Genel başparmak kuralı: Canlı ağırlığın yaklaşık her 45 kg için 3.8–7.6 L su/gün.
• Süt sığırlarında: ≈0.5 gal su / 1 lb süt (yaklaşık 4 L su / 1 L süt).
• Murphy denklemi (süt sığırı): GSİ (kg/gün) = 15.99 + 1.58×KMT + 0.90×GSM + 0.05×GNaT + 1.20×MOS.
• Keçi için pratik denklemler:
– Su (L/gün) = 3.86×GKT (kg/gün) − 0.99
– Su (L/gün) = 0.0795×CA(kg) + 0.4907

- **GST** → Günlük su alımı (kg ≈ litre)
- **GKT** → Kuru madde tüketimi (kg/gün)
- **GSM** → Süt üretimi (kg/gün)
- **GNaT** → Sodyum alımı (g/gün)
- **MOS** → Minimum ortam sıcaklığı (°C)

- **CA** → Canlı ağırlık (kg)

Ruminantlarda su tüketimi çevre sıcaklığı, rasyonun bileşimi ve suyun kalitesi gibi faktörlerden önemli ölçüde etkilenmektedir. Sıcaklık arttıkça su tüketimi artar ve özellikle süt sığırlarında sıcak stresi dönemlerinde su tüketimi iki katına çıkabilmektedir. Ayrıca, rasyonun tuz ve protein içeriği arttıkça hayvanların su ihtiyacı da yükselir. Su kalitesinin düşük olması (örneğin yüksek tuzluluk düzeyleri) yem tüketimini ve dolayısıyla performansı olumsuz etkileyebilmektedir (Beede, 1993).

Süt üretimi, gebelik ve büyüme/gelişme dönemi gibi faktörler su tüketimini önemli ölçüde artırmaktadır. Bu nedenle su ihtiyacının doğru belirlenmesi ve kaliteli suya sürekli erişimin sağlanması hayvan sağlığı ve verimliliği açısından kritik öneme sahiptir.

2.1. Su Kalitesinin önemi

İçme suyunun kalitesini olumsuz etkileyen birçok unsur, doğrudan ölüm ya da hastalığa yol açmasa da, hayvanların büyüme, gelişme, süt verimi ve üreme performansını olumsuz etkileyerek ciddi ekonomik kayıplara sebep olabilmektedir. Sığırlar, insanlar kadar düşük kaliteli sudan etkilenmeseler de bazı bileşiklerin yüksek düzeylerde bulunması, su tüketim isteğini azaltmaktadır (Braul ve Kirychuk, 2001). Hayvanların bu tür sulara verdikleri tepki; yaş, fizyolojik durum ve rasyonun içeriği gibi faktörlere göre değişiklik göstermektedir. Özellikle buzağılar ve laktasyonun erken dönemindeki inekler, kötü kaliteli sulara karşı daha hassastır. Ayrıca, suyun taşıdığı olumsuz unsurlar, sindirim sistemindeki diğer besin öğeleri ile etkileşime girerek emilimi azaltabilmektedir (Beede, 2012). Örneğin, içme suyunda yüksek düzeyde molibden ve sülfat bulunması, bakırın emilimini baskılamaktadır.

Dolayısıyla hayvancılıkta kullanılan suyun kalitesi söz konusu olduğunda yalnızca hayvanların verimliliği değil, aynı zamanda suyun hastalık yapıcı etkisi ve ürünün insan sağlığına olası yansımaları da göz önünde bulundurulmalıdır. Kötü kaliteli suyun olumsuz etkileri yalnızca hayvanla sınırlı kalmayıp, aynı zamanda su borularında mineral birikimine ve mikroorganizmaların çoğalmasına bağlı olarak tıkanmalara yol açabilmektedir. Bu durum su akışını azaltırken, işletmenin sürdürülebilirliğini de olumsuz etkilemektedir (Araújo ve ark., 2010; Cemek ve ark., 2011; Anonim, 2013).

Sığırlar, yüksek süt verimleri nedeniyle fazla miktarda suya ihtiyaç duymakta, rumen ve sindirim kanalı ülserleri gibi sağlık sorunlarına yatkınlık göstermekte ve metabolizmanın sağlıklı işleyebilmesi için rumen pH'sının 6.4–7.0 aralığında tutulması gerekmektedir. Rumen mikroflorası ve metabolizması suya doğrudan bağlı olduğundan, bu tür nedenlerle sığırlar su kalitesine karşı oldukça duyarlıdır (Adams ve Sharpe, 1995).

2.2 Ruminatların içme suyu kalite ölçütleri

Bir suyun "içilebilir" kabul edilebilmesi için belirli kriterleri karşılaması gerekir. Bu kriterler, fiziksel (renk, koku, sıcaklık gibi), kimyasal (sertlik, pH) ve biyolojik (bakteri, virüs ve diğer zararlı mikroorganizmalar) özellikler temelinde değerlendirilir. İçme suları, bu özelliklere göre çok sayıda parametreye tabi tutularak analiz edilir ve yalnızca sonuçlar uygun çıktığında kullanım için şebekelere verilir (NRC, 2007).

Temel olarak içme sularında aranan başlıca özellikler şunlardır:

- Renksiz, kokusuz ve berrak olması,
- Uygun sertlik düzeyine sahip olması,
- Hastalık yapıcı mikroorganizmaları barındırmaması,
- Demir, mangan ve hidrojen sülfür gibi istenmeyen maddeleri içermemesi,

- Arsenik, kurşun, cıva, radyoaktif maddeler ve amonyum gibi zararlı kimyasallardan arındırılmış olması (Araújo ve ark., 2010; Beede, 2012; Bozorg-Haddad ve ark., 2016; Pandit ve Kumar, 2019).

İnsanlar için geçerli olan bu kriterler, ruminantlar için de büyük ölçüde benzerlik göstermektedir. Sığırların içme suları açısından beş temel kalite ölçütünden söz edilebilir. Bunlar: **organoleptik özellikler** (tat ve koku), **fizikokimyasal parametreler** (pH), toplam çözünmüş madde, toplam çözünebilen tuz, **toksik bileşikler** (ağır metaller, toksik mineraller, organofosfatlar ve hidrokarbonlar), **aşırı miktarda bulunan mineraller ve bileşikler** (nitratlar, sodyum sülfatlar, demir) ve **mikroorganizmaların varlığıdır** (Beede, 1993).

Çizelge 2. Çiftlik hayvanlarının içme suları çeşitli parametreleri: Verime etki tablosu

Parametre	Sorunsuz	Hafif uyumsuzluk	Verim kaybı riski
Toplam çözünmüş madde	0–960.0	960.0–3000.0	>3000.0
pH	6.0–8.5	8.5	>8.5
Alüminyum	0–5.0	5.0–10.0	>10.0
Arsenik	0–0.2	0.2	>0.2
Baryum	0–1.0	1.0	>1.0
Bikarbonat	0–1000.0	1000.0	>1000.0
Bor	0–5.0	5.0–30.0	>30.0
Kadmiyum	0–0.01	0.01–0.05	>0.05
Kalsiyum	0–100.0	100.0–200.0	>200.0
Klorid	0–100.0	100.0–300.0	>300.0
Krom	0–0.1	0.1–1.0	>1.0
Bakır	0–0.2	0.2–0.5	>0.5
Florür	0–2.0	2.0	>2.0
Demir	0–0.2	0.2–0.4	>0.4
Kurşun	0–0.05	0.05–0.1	>0.1
Magnezyum	0–50.0	50.0–100.0	>100.0
Manganez	0–0.05	0.05–0.5	>0.5
Civa	0–0.01	0.01	>0.01
Molibden	0–0.03	0.03–0.06	>0.06
Nikel	0–0.25	0.25–1.0	>1.0
Nitrat-Nitrojen	0–20.0	20.0–100.0	>100.0
Fosfor	0–0.7	0.7	>0.7
Potasyum	0–20.0	20.0	>20.0
Selenyum	0–0.05	0.05–0.1	>0.1
Gümüş	0–0.05	0.05	>0.05

Sodyum	0–50.0	50.0–300.0	>300.0
Sülfatlar	0–150.0	150.0–900.0	>900.0
Vanadyum	0–0.1	0.1	>0.1
Çinko	0–5.0	5.0–25.0	>25.0

*pH hariç diğer özelliklerin konsantrasyon birimi mg/L'dir.(Chase, 2002; Socha ve ark., 2003; Swistock, 2023; Afzal & Mahreen, 2024; Kamal, ve ark., 2024).

2.2.1 Suyun organoleptik özellikleri

Organoleptik özellikler, içme suyunun tat, koku, renk ve bulanıklık gibi duyularla algılanabilen nitelikleridir. Bu özellikler, suyun içilebilirlik açısından değerlendirilmesinde önemli ölçütler arasında yer almaktadır.

İçme suyunda hoş olmayan tat ve kokuların ortaya çıkmasının sebepleri genellikle suyun fizikokimyasal yapısı, bazı maddelerin normalin üzerinde bulunması ya da bakteriler ve onların metabolik yan ürünlerinin varlığı ile ilişkilidir (Beede, 2006). Ayrıca dışkı bulaşı, suyun tat ve kokusunu bozarak kalitesini düşürmektedir. Nitekim sudaki dışkı kalıntısının %0.25'in üzerine çıkması, sığırların su tüketimini belirgin şekilde azaltmaktadır (Braul ve Kirychuk, 2001). Bununla birlikte, demir ve mangan gibi minerallerin yüksek düzeylerde bulunması da suyun tat ve kokusunu olumsuz etkileyerek hayvanların suyu içmekten kaçınmasına ve farklı kaynaklardan su arayışına yönelmesine neden olmaktadır.

Çizelge 3. Ruminantlar için içme suyundaki parametreler, sınır değerleri ve olası olumsuzluklar*

Parametre (mg/L)	Ruminantlar üzerindeki olasi olumsuzluk etkileri
Toplam çözünmüş madde (TDS)	İştah azalması, su tüketiminde düşüş, elektrolit dengesizlikleri, ishal, verim kaybı
pH	Aşırı alkali pH → iştah azalması, mineral biyoyararlanımının bozulması
Alüminyum (Al)	Fosfor emiliminin engellenmesi, kemik gelişiminde bozulma, sinirsel etkiler
Arsenik (As)	Kronik zehirlenme, iştahsızlık, kilo kaybı, gastrointestinal sorunlar
Baryum (Ba)	Kas zayıflığı, kardiyak ritim bozukluğu, sinir sistemi bozuklukları
Bikarbonat (HCO_3^-)	Metabolik alkaloz, mineral emilim bozuklukları
Bor (B)	İshal, böbrek hasarı, üreme bozuklukları
Kadmiyum (Cd)	Böbrek ve karaciğer hasarı, hematolojik anormallikler, büyüme geriliği
Kalsiyum (Ca)	Hipomagnezemi riski, böbrek taşı, süt veriminde azalma
Klorid (Cl^-)	Tuz zehirlenmesi, iştah kaybı, dehidrasyon
Krom (Cr)	Oksidatif stres, karaciğer ve böbrek hasarı
Bakır (Cu)	Kronik bakır zehirlenmesi (özellikle koyunlarda), karaciğer nekrozu

Florür (F^-)	Dental fluorozis, kemik deformasyonları, süt veriminde düşüş
Demir (Fe)	Su tadında bozulma, iştah azalması, sekonder bakır ve çinko eksikliği
Kurşun (Pb)	Sinir sistemi bozuklukları, anemi, böbrek hasarı, gelişim bozuklukları
Magnezyum (Mg)	Laksatif etki, süt veriminde azalma
Manganez (Mn)	Büyüme geriliği, üreme bozuklukları, sinir sistemi etkileri
Cıva (Hg)	Şiddetli nörotoksisite, böbrek ve karaciğer hasarı
Molibden (Mo)	Bakır emilimini engeller → sekonder Cu eksikliği (anemi, ishal, pigment kaybı)
Nikel (Ni)	İştahsızlık, büyüme geriliği, toksisite
Nitrat-N (NO_3^--N)	Methemoglobinemia (hipoksi, ölümler), iştah azalması
Fosfor (P)	Üriner taş riski, Ca/P dengesizliği
Potasyum (K)	DCAD dengesizliği, doğum felci riskinde artış
Selenyum (Se)	Kronik Se zehirlenmesi → 'alkali disease' (tırnak deformasyonu, zayıflık)
Gümüş (Ag)	Yüksek düzeylerde gastrointestinal bozukluklar
Sodyum (Na)	Tuz zehirlenmesi, sinir sistemi bozuklukları, su tüketiminde artış
Sülfatlar (SO_4^{2-})	Polioencephalomalacia, ishal, iştah kaybı
Vanadyum (V)	İshal, sinir sistemi bozuklukları, büyüme geriliği
Çinko (Zn)	Kronik aşırı alım → anemi, bakır eksikliği, iştahsızlık

*Beede, 2012: Oraby ve ark., 2021; Florea, ve Büsselberg, 2006; Smedley ve Kinniburgh, 2002; Clarkson ve Magos, 2006; WHO. 2017; Jomova ve ark., 2011; Slivinska at al., 2020).

2.2.2 Suyun fizikokimyasal özellikleri

Su kaynaklarının değerlendirilmesinde en çok kullanılan ölçütlerden biri, suyun fizikokimyasal özellikleridir. Bu kavram; fiziksel nitelikleri, kimyasal bileşimi, tuzluluk, sertlik ve pH gibi parametreleri kapsamaktadır (Yaylak ve Yavuz, 2016). Söz konusu özellikler çoğunlukla doğrudan hayvan sağlığı için risk oluşturmaz; ancak bazı durumlarda çeşitli hastalıkların ortaya çıkmasında etkili faktörlerden biri olabilir (Adams ve Sharpe, 1995; NRC, 2001). Aşağıda, içme suyunun başlıca fizikokimyasal özelliklerinden bazıları ele alınmıştır.

2.2.3 Toplam çözünmüş madde (TDS)

Toplam çözünmüş madde (TDS), bir suyun içerdiği toplam mineral miktarını gösterir ve doğrudan hayvanın iştahını, yem tüketimini ve verimliliğini etkiler. Genel kabul gören görüşe göre, TDS düzeyinin 500 mg/L'nin altında olması tüm hayvan türleri için güvenli kabul edilmektedir. Bununla birlikte, farklı türler TDS seviyelerine karşı değişen tolerans aralıklarına sahiptir.

Çizelge 4. Türlere göre TDS düzeyleri (mg/L)*

Tür	Sorunsuz	Hafif uyumsuzluk	Verim kaybı riski	Uygun değil
Besi sığırı	0–4000	4000–5000	5000–10000	>10000
Süt sığırı	0–2400	2400–4000	4000–7000	>7000
Koyun	0–4000	4000–10000	10000–13000	>13000
Keçi	0–4000	4000–10000	10000–13000	>13000

*Soltanpour ve Raley, 1999; Lipson ve ark., 2019; McGregor March, 2004; De Camillis, ve ark., 2023; Swistock, 2023; Patra ve ark., 2024.

Süt ineklerinde yüksek TDS seviyeleri, özellikle **laktasyon döneminde süt verimini azaltabilmekte** ve **ishal ile mineral dengesizliklerine** yol açabilmektedir (NRC, 2001). Koyun ve keçiler, sığırlara kıyasla daha yüksek mineral yüküne tolerans gösterebilmekle birlikte, 10.000 mg/L üzerindeki değerler bu türlerde de üretim ve sağlık sorunlarına neden olmaktadır (Akinmoladun ve ark., 2019; CCME, 2002).

2.2.3.1 Suyun asitliği

Suyun asidik ya da alkali yapısını ifade etmek için pH kavramı kullanılmaktadır. pH değeri 7 olduğunda nötr, 7'nin altına düştüğünde asidik, 7'nin üzerine çıktığında ise alkali özellik göstermektedir. Suyun pH derecesinin hayvan sağlığı, verimi ve su tüketimi üzerindeki etkileri hakkında sınırlı sayıda araştırma bulunmaktadır. Bununla birlikte, sığırlar için ideal pH aralığı 6–8 olarak kabul edilmektedir. Bu aralığın dışındaki değerler; sindirim sistemi rahatsızlıkları, ishal, yemden yararlanmanın düşmesi, yem ve su tüketiminde azalma gibi olumsuzluklara yol açabilmektedir. Özellikle pH'nın 5.5'in altına düşmesi, hafif asidozis kaynaklı problemlerin görülmesine neden olurken; pH'nın 8.5'in üzerine çıkması durumunda su alkali özellik kazanmakta ve hayvanda hafif alkalozis belirtileri ortaya çıkabilmektedir (Göncü-Karakök ve ark., 2008).

2.2.3.2 Suyun tuzluluğu

Suyun tuzluluğu, toplam çözünmüş madde (TÇM), toplam çözünmüş tuzlar (TÇT) ve suda çözünebilen maddelerin bir göstergesi olup, genellikle **mg/L** veya **elektriksel iletkenlik (µmhos/cm)** cinsinden ifade edilmektedir (Bagley ve ark., 1997). Tuzluluk çoğunlukla sodyum klorür kaynaklıdır; ancak bikarbonat, sülfat, kalsiyum, magnezyum ve silisyum seviyeleri de bu duruma katkı sağlayabilmektedir (Yaylak ve Yavuz, 2016). Ayrıca kalsiyum, magnezyum ve sodyum iyonlarının; klor, sülfat, nitrat, karbonat ve bikarbonatlarla birleşmesi sonucunda oluşan inorganik tuzlar, çiftlik hayvanlarının sulama sularında yaygın şekilde görülmektedir (Thiex ve German, 2004; German ve ark., 2008).

Suya tuzluluk kazandıran minerallerin fazlalığı toksik etki gösterebilmekte ya da diğer elementlerle etkileşime girerek zararlı sonuçlar doğurabilmektedir. Örneğin fazla miktarda sodyum alımı kan basıncını yükseltebilir; farklı tuz türleri birlikte bulunduğunda ise eklemeli etkiler nedeniyle hayvan sağlığı daha ciddi şekilde olumsuz etkilenebilir. Bu nedenle, yalnızca toplam tuz miktarının değil, suda bulunan tuzların türlerinin de belirlenmesi önemlidir. Nitekim sülfat tuzlarının, klorür ve karbonat tuzlarına kıyasla daha fazla sağlık sorunu oluşturabileceği bildirilmektedir (Thiex ve German, 2004; German ve ark., 2008).

Çiftlik hayvanları için en uygun suyun tuzluluk seviyesi **0–1000 mg/L** aralığındadır. Tuzluluk değeri 3000 mg/L'yi aşan sular düşük kaliteli kabul edilmektedir. Tuz konsantrasyonu 10000 mg/L düzeyine ulaştığında su "yüksek tuzlu" sınıfına girmektedir. Yetişkin sığırlar bu

düzeydeki suları tüketebilmelerine rağmen, tuzluluk 35000 mg/L'nin üzerine çıktığında suyun yapısı deniz suyu veya salamura özelliği kazanmakta ve tüketim açısından ciddi risk oluşturmaktadır (Bagley ve ark., 1997; Yirga ve ark., 2024).

Çizelge 5. Sığırların içme sularında toplam çözünmüş tuzların (tçt) seviyeleri*

Tuz İçeriği (mg/L)	Sınıflandırma Kaynak 1 (UF)	Sınıflandırma Kaynak 2 (NMSU Extension)
0–1 000	Sorun yaratmaz; düşük tuzluluk	Mükemmel su; tüm hayvanlar için ideal
1 000–2 999	Genelde iyi; hafif ishal olabilir	Çok tatmin edici; geçici ishal riski
3 000–4 999	Tatmin edici (büyükbaş için); kanatlılar için kötü	Tatmin edici (büyükbaş için); kanatlılar için kötü
5 000–6 999	Makul güven; hamile/süt veren ve kanatlı hayvanlara uygun değil	Marjinal kalite; hamile ve süt veren hayvanlara uygun değil; kanatlıya uygun değil
7 000–10 000	Riskli; kaçınılmalı	Kanatlılar/domuzlar için uygun değil; riskli
> 10 000	Hiç önerilmez; riskli	Ciddi risk; kullanılmamalı
~35 000	Tuzlu su / salamura grubuna girer	Belirtilmemiş

*Bagley ve ark., 1997; Yirga ve ark., 2024.

2.2.3.3 Suyun sertliği

Bir suyun sertliği, içerdiği başlıca çözünmüş **kalsiyum ve magnezyum tuzlarından** kaynaklanmakta ve suyun sabunu çöktürme kapasitesi ile ilişkilendirilmektedir. Sertlik kavramı, sıklıkla tuzluluk ile karıştırılsa da aynı anlama gelmemektedir. Sabun, özellikle suda yaygın olarak bulunan kalsiyum ve magnezyum iyonları tarafından çökeltilirken; demir (Fe), alüminyum (Al), mangan (Mn) ve çinko (Zn) gibi diğer çok değerli metallerin yanı sıra hidrojen iyonları da bu etkiye katkı sağlayabilmektedir. Ancak bu iyonlar, genellikle oldukça düşük konsantrasyonlarda bulunduklarından sertlik açısından belirleyici değildir.

Suyun sertliği, çoğunlukla **kalsiyum ve magnezyum iyonlarının kalsiyum karbonat ($CaCO_3$) cinsinden toplam konsantrasyonu** şeklinde ifade edilir. Bununla birlikte, ölçülebilecek düzeylerde bulunan sertlik oluşturan diğer iyonları da kapsayabilmektedir. Sertlik iki ana kategoriye ayrılmaktadır:

- **Geçici (karbonat) sertlik**: Kalsiyum ve magnezyum bikarbonatlarının varlığından kaynaklanır. Kaynatma işlemi ile giderilebilir.
- **Kalıcı (karbonat olmayan) sertlik**: Kalsiyum ve magnezyum sülfat ile klorürlerden ileri gelir ve kaynatmayla ortadan kaldırılamaz.

Her iki sertliğin toplamına ise **toplam sertlik** adı verilmektedir. Sertlik derecesi, ülkemizde genellikle **Fransız sertliği (°Fr)** ya da **mg/L $CaCO_3$** birimleri ile sınıflandırılmaktadır. Bu ölçümler, suda bulunan iyonların miktarını tanımlamada kullanılır.

Mevcut bulgulara göre, sığırların sert su tüketmesi durumunda sağlık açısından olumsuz bir etki gözlenmemiştir (NRC, 2001; Yaylak ve Yavuz, 2016; Cervantes ve ark., 2024).

Çizelge 6. Su sertlik sınıflandırma değerleri*

Su sertlik dereceleri	Fransız sertliği(Fr derecesi)	sertlik Suda çözünmüş tuzların ağırlığına (mg/L) göre
Çok yumuşak su	0-5	
Yumuşak su	5-10	[1] Yumuşak 0-60 mg/l.
Orta sert su	10-20	[2] Orta sertlikte 61-120 mg/l.
Sert su	20-30	[3] Sert121-180 mg/l
Çok sert su	> 30	[4] Çok sert -180 mg/l'nin üzerinde

* NRC, 2021.

2.2.4 İçme sularında mineral veya bileşiklerin fazla miktarda bulunması

Nitratlar, sodyum, sülfatlar ve demir gibi element ya da iyonlar bu başlık altında incelenebilmektedir. İçme sularında mineral ve bileşiklerin fazla miktarda bulunması hayvanlarda verim düşmelerine, hastalıklara veya su tüketiminin azalmasına yol açabilmektedir. İçme sularında bulunan bazı mineral ve bileşikler aşağıda açıklanmıştır.

2.2.4.1 Nitratlar

Nitrat (NO_3^-) ve Nitrit (NO_2^-)

Ruminantlar için **nitrat (NO_3^-) ve nitrit (NO_2^-)** düzeyleri önemli toksikolojik riskler taşımaktadır.

Nitrat: Genel olarak güvenli kabul edilen düzey 100 mg/L'nin altıdır. Sığırlarda 400 mg/L'nin üzerine çıkıldığında yem tüketiminde azalma, methemoglobinemi ve verim kayıpları görülebilmektedir.

Nitrit: Daha yüksek toksisiteye sahiptir ve 10 mg/L'nin üzerindeki değerler riskli kabul edilmektedir (CCME, 2002; Kamra ve ark., 2015).

Nitrat ve nitrit seviyelerinin özellikle yoğun gübreleme yapılan tarım alanlarındaki kuyularda daha yüksek olduğu bildirilmektedir (Dokuz ve ark., 2025). Nitekim gübreler, içme sularındaki nitratın temel kaynaklarından biridir. Yeraltı ve yüzey sularındaki nitrat kirliliği, genellikle gübre depoları veya kimyasal gübrelerden kaynaklanan doğrudan bulaşma ile ilişkilidir (Beede, 2006). Nitrat, nitrite göre suda daha yüksek yoğunlukta bulunur (Thiex ve German, 2004; German ve ark., 2008). Rumen bakterileri nitratı nitrite indirgerken; nitrit, kanın oksijen taşıma kapasitesini azaltarak oksijen yetersizliğine bağlı ölümlere yol açabilmektedir (NRC, 2001). Bu nedenle hem su hem de yem kaynaklı nitrat miktarları birlikte değerlendirilmelidir.

Sığırların içme sularında **önerilen üst sınır** nitrat-nitrojen (N) için 100 mg/L veya nitrat (NO_3^-) için 450 mg/L'dir (Braul ve Kirychuk, 2001). Nitrat-nitrojen seviyesinin 100 mg/L'yi aşmasıyla olumsuz etkiler görülmeye başlamakta; 500–1000 mg/L arasında orta düzey belirtiler, 1000 mg/L'nin üzerinde ise akut klinik bulgular ortaya çıkmakta ve ölüm gerçekleşebilmektedir (Adams ve Sharpe, 1995). Zehirlenme genellikle nitrat alımını takiben 3–5 saat içerisinde ölümle sonuçlanabilir. Ancak nitratla kirlenmiş sularda çoğunlukla **akut yerine kronik zehirlenme** görülmektedir (Braul ve Kirychuk, 2001). Kronik vakalar klinik belirtiler göstermeksizin ilerleyebilir.

Akut nitrat/nitrit zehirlenmesinin belirtileri arasında koordinasyon bozukluğu, ayağa kalkamama, kas titremeleri, çırpınma, solunum güçlüğü, nabız artışı, ağızda köpüklenme, ağız

ve burunda siyanoz, göz çevresinde mavimsi renk değişimi ve kanın koyu kahverengi görünümü yer almaktadır (NRC, 2001; Thiex ve German, 2004; German ve ark., 2008). Kronik zehirlenmelerde ise iştahsızlık, kilo kaybı, bağışıklığın zayıflaması, düşük yapma riskinin artması gibi etkiler ortaya çıkmaktadır. Orta düzey maruziyetler, büyüme geriliğine, A vitamini kullanımında azalmaya ve genel sağlık sorunlarına yol açabilmektedir (NRC, 2001; Anonim, 2013). Ayrıca yapılan bazı çalışmalarda, sudaki nitrat düzeyinin artmasının tohumlama sayısını yükselttiği ve ilk tohumlamada gebelik oranını düşürdüğü belirlenmiştir (Kahler ve ark., 1975).

Çizelge 7. Ruminantların içme sularındaki nitrat düzeyleri*

Nitrat (NO_3,mg/L)	Nitrat-Nitrojen (NO_3N,mg/L)	Tavsiyeler
0-44	0-10	Ruminantlar için güvenli
45-132	10-20	Genellikle düşük nitratlı dengeli rasyonlarda güvenli
133-220	20-40	Uzun süre tüketildiğinde zararlı olabilir
221-660	40-100	Sığırlar için riskli ve ölüme neden olabilir
661	100	Güvenli değil, ölüm görülebilir ve su kaynağı olarak kullanılmamalı.

NRC, 2001.

2.2.4.2 Sülfür ve sülfatlar

Sülfat (SO_4^{2-}) düzeyi de ruminantlarda kritik bir parametredir.

- **<500 mg/L:** Genellikle güvenli.
- **500–1000 mg/L:** Bazı rehberlere göre hâlâ tolere edilebilir; ancak sıcak iklimlerde veya yüksek kükürt içerikli yemlerle beraber risk artmaktadır.

>2000–3000 mg/L: Özellikle genç ruminantlarda **polioensefalomalasi (PEM)** ve ishal riski önemli derecede yükselmektedir (Kandylis, 1984; Knight, 1985; Veenhuizen ve Shurson, 1992; Loneragan ve ark., 2001; Weeth ve Hunter, 1971).

Sülfatın rasyon mineralleriyle etkileşimi de dikkate alınmalıdır. Özellikle **yüksek sülfat + molibden varlığında** bakır emilimi azalır ve ikincil bakır yetersizliği gelişebilir (Suttle, 2010).

Suda **hidrojen sülfür** bulunması, suya çürük yumurta kokusu vermekte ve bu durum sığırların su tüketimini azaltabilmektedir (Beede, 2006). İçme suyunda sülfatın kabul edilebilir düzeyleri, hayvanın yaşına göre değişiklik göstermektedir. Önerilen sınır buzağılar için **500 mg/L**, yetişkin sığırlar için ise **1000 mg/L**'dir. Özellikle 1200 mg/L düzeyinde sülfat içeren suların, erken laktasyondaki ineklerde yem ve su tüketimini azalttığı, ayrıca gecikmiş plasenta atımı ile abomasum deplasmanını artırdığı bildirilmiştir (Beede, 2006).

Suyun sülfat içeriği 500 mg/L'nin üzerine çıktığında, bu değer sülfür formunun potansiyel toksisite riski açısından kritik kabul edilmektedir. Bu nedenle, sulardaki sülfat ve sülfürün hangi tuz formunda bulunduğunun belirlenmesi gereklidir. Zira farklı sülfat formlarının toksisite düzeyleri farklıdır (Socha ve ark., 2003). En yaygın sülfat tuzları; **kalsiyum, demir, magnezyum ve sodyum sülfatlar**dır. Bunlar arasında en zehirli form hidrojen sülfittir ve litrede yalnızca 0.1 mg gibi düşük konsantrasyonlarda bile su tüketimini azaltabilmektedir (NRC, 2001; Beede, 1993).

Sülfatlar genel olarak **laksatif etkiye** ve acı bir tada sahiptir. Bu formlar içerisinde en güçlü etkiyi gösteren **sodyum sülfat**, en fazla su tüketimini azaltan ise **demir sülfat** olarak bilinmektedir (Socha ve ark., 2003; Beede, 1993). Yüksek sülfat içeren sular (2000–2500 mg/L) sığırlar tarafından ilk tüketildiğinde ishale yol açmakta, fakat zamanla hayvanlarda bu etkiye karşı tolerans gelişmektedir. Bununla birlikte, aşırı sülfat seviyesi, **bakır ve selenyum gibi temel minerallerin emilimini** de olumsuz etkilemektedir (Socha ve ark., 2003).

Sülfat fazlalığının bir diğer olumsuz etkisi ise **sinir sistemi üzerindedir**. 3000 mg/L veya daha yüksek sülfat içeren suların tüketimi, **polioencephalomalacia (PEM)** olarak bilinen, beyinde yangı, ödem ve doku nekrozu ile seyreden ciddi bir nörolojik hastalığa yol açabilmektedir (Patterson ve ark., 2002; Patterson ve ark., 2003). PEM'in ortaya çıkmasında iki temel mekanizma rol oynamaktadır:

1. **Tiamin eksikliği**: Aşırı sülfür tüketimi sonucu gelişmekte, hayvanlara tiamin takviyesi yapıldığında önlenebilmektedir.

2. **Hidrojen sülfür toksisitesi**: Yüksek sülfatlı sular, rumende hidrojen sülfür (H_2S) üretimini artırmakta ve toksik etki oluşturmaktadır (Loneragan ve ark., 2001).

Yoğun yem tüketimi sonucu rumen pH'sının düşmesi de sülfüre bağlı PEM gelişimini kolaylaştırmaktadır. Ayrıca yüksek sülfür tüketimi, ruminantlarda **bakır eksikliğine** neden olabilmektedir. Özellikle genç sığırlarda sülfür düzeyi yüksek suların tüketilmesi, karaciğerdeki bakır depolarının hızla tükenmesine yol açmaktadır (Wright ve ark., 2000; Wright ve Patterson, 2005). Bu durum, hayvanların büyümesini, bağışıklığını ve üreme performansını olumsuz etkilemektedir (Thiex ve German, 2004; German ve ark., 2008).

2.2.4.3 Ağır metaller

Çiftlik hayvanlarının içme sularında bulunan ağır metaller, düşük düzeylerde dahi uzun süreli maruziyetle toksik etkiler gösterebilir. Ağır metaller çevresel açıdan kalıcıdır, biyobirikim yapabilir ve gıda zinciri yoluyla insan sağlığı için de risk oluşturur (WHO, 2017).

Ağır Metallerin Çevresel Kaynakları

- **Endüstriyel faaliyetler:** Madencilik, metal işleme, enerji santralleri ve kimyasal fabrikalar su kaynaklarına Pb, Cd, Cr, Hg gibi metallerin geçişine neden olabilir (Ali et al., 2019).

- **Tarımsal kaynaklar:** Fosfatlı gübrelerde Cd, pestisitlerde As bulunabilmekte, bu da sulama ve yeraltı sularına taşınabilmektedir.

- **Doğal jeolojik yapı:** Özellikle arsenik ve krom, bazı bölgelerde doğal kayaç yapılarından sulara karışabilir (Smedley & Kinniburgh, 2002).

Hayvan Sağlığı Üzerindeki Etkiler

Ağır metaller, ruminantlarda ve diğer çiftlik hayvanlarında metabolik, hematolojik ve üreme bozukluklarına yol açabilir:

- **Kadmiyum (Cd):** Uzun süreli maruziyet böbrek ve karaciğer hasarı, hematolojik parametrelerde düşüş ve oksidatif stres artışı ile ilişkilidir. Oraby ve ark. (2021) Ossimi koyunlarında Cd maruziyetinin rumen fermentasyonu ve kan değerlerinde ciddi bozulmalara neden olduğunu rapor etmiştir.

- **Kurşun (Pb):** Nörotoksik etki, anemi, böbrek fonksiyon bozukluğu ve büyüme geriliği ile ilişkilidir (Florea & Büsselberg, 2006).

- **Arsenik (As):** Kronik maruziyet deri lezyonları, gastrointestinal bozukluklar ve bazı kanser türleri ile ilişkilidir. Hayvanlarda üreme bozuklukları da bildirilmiştir (Jomova et al., 2011).

- **Cıva (Hg):** Sinir sistemi toksisitesi ön plandadır. Balıkla beslenen su kuşlarında ve suya yakın yetiştirilen hayvanlarda birikim gösterebilir (Clarkson & Magos, 2006).

Türkiye ve Dünyadan Bulgular

Türkiye'de farklı bölgelerde yapılan çalışmalar, içme sularında ağır metallerin varlığını ortaya koymuştur. Örneğin Iğdır'da yapılan bir çalışmada, Pb ve Cd düzeylerinin çoğunlukla sınırların altında olduğu, ancak düzenli izleme gerekliliğinin altı çizilmiştir (Karademir ve ark., 2020) Mısır'da yapılan çalışmalarda ise Cd maruziyetinin koyunlarda rumen metabolizmasını ve antioksidan kapasiteyi bozduğu gösterilmiştir (Oraby et al., 2021). Dünya genelinde özellikle Güney Asya'da arsenik kontaminasyonu yaygın olup, hem insan hem de hayvan sağlığında kritik sorunlara yol açmaktadır (Smedley & Kinniburgh, 2002).

Tolerans Değerleri ve Düzenlemeler

Çiftlik hayvanları için spesifik sınır değerler uluslararası kuruluşların önerilerine dayanmaktadır:

- **FAO/WHO (2011)**: İçme sularında Pb için <0.01 mg/L, Cd için <0.003 mg/L sınır değeri.

- Cotruvo **(2018)**: İçme suyunda Pb için maksimum kontaminant seviyesi 0.015 mg/L.

- Türkiye'de **TS 266 İçme Suyu Standardı** ve **Yüzeysel Su Kalitesi Yönetmeliği** esas alınmaktadır; ancak bu değerlerin çoğu insan sağlığına yönelik olup, hayvan fizyolojisine uyarlanması gereklidir.

Yönetim ve Önleme Stratejileri

- **Düzenli su analizi:** Mevsimsel olarak ağır metal analizlerinin yapılması.

- **Kaynak yönetimi:** Endüstriyel deşarjların kontrolü, tarımda ağır metal içeriği düşük girdilerin kullanılması.

- **Filtrasyon ve arıtım:** Aktif karbon, iyon değiştirici reçineler ve membran teknolojileri kullanılarak ağır metallerin sudan uzaklaştırılması (Fu & Wang, 2011).

- **Besleme desteği:** Selenyum, vitamin E ve C gibi antioksidanların kullanımı ile ağır metal kaynaklı oksidatif stresin azaltılması (Habeeb et al., 2019).

İçme sularında **mangan**, çoğunlukla **demir** ile birlikte değerlendirilmelidir. Sulama sistemlerinde, filtrelerde veya borularda görülen siyah lekeler ve tortular, sudaki mangan seviyesinin yüksek olduğuna işaret eder (Beede, 2006).

Süt sığırlarında sorun oluşturan en önemli minerallerden biri de demirdir. Özellikle sülfat ve klorür anyonları ile birlikte düşünüldüğünde, demir düzeyinin yüksekliği suyun kalitesini olumsuz etkileyebilir. Yem katkı maddelerinde bol miktarda **ferrik demir (Fe^{3+})** bulunduğundan demir eksikliği genellikle bir problem oluşturmaz. Ancak içme suyunda **0.3 mg/L'den fazla demir** bulunması, sığır sağlığı açısından riskli kabul edilmektedir (Beede, 2005).

Suda bulunan **ferro (Fe^{2+})** formu, yemlerdeki ferrik (Fe^{3+}) demire kıyasla daha kolay çözünebilmekte ve bu da suyla fazla miktarda demir alımına neden olarak zehirlenme riskini artırabilmektedir (Beede, 2006). Demirin yüksek düzeyde bulunması yalnızca su tüketimini azaltmakla kalmaz; aynı zamanda **demir bakterilerinin çoğalmasına** yol açarak suluklarda

koyu renkli çamur tabakaları oluşturur. Bu durum hem suyun akış hızını düşürmekte hem de hayvanların **bakır ihtiyacını artırmaktadır** (Adams ve Sharpe, 1995).

Ağır metaller genel anlamda çiftlik hayvanlarının sağlığı ve verimliliği üzerinde ciddi tehditler oluşturmaktadır. Bu minerallere maruziyet yalnızca hayvan refahını etkilemekle kalmaz, hayvansal ürünler yoluyla **insan sağlığı** açısından da risk taşır. Dolayısıyla düzenli izleme yapılması, hayvanlara özgü tolerans değerlerinin belirlenmesi, uygun su arıtma yöntemlerinin uygulanması ve çiftlik yönetiminde sürdürülebilir yaklaşımların benimsenmesi kritik önem taşımaktadır.

2.2.4.4 İçme sularında mikroorganizmalar

Hayvanların tükettiği sularda **virüs, bakteri, mavi-yeşil algler ve protozoaların** bulunması, düşük su kalitesinin göstergesidir. Patojenler doğrudan tespit edilemediğinde, genellikle indikatör organizmalar aracılığıyla suyun hijyen durumu belirlenmektedir (Yaylak ve Yavuz, 2016). Bu amaçla en sık kullanılan indikatörler **fekal koliformlar**dır. Toplam bakteri sayısı ise hem zararlı hem de zararsız bakterilerin varlığını gösterir (Popescu ve ark., 2011). **Toplam koliform bakteriler**, çevresel (toprak, bitki vb.) ve fekal (dışkı kaynaklı) türlerin toplamını ifade etmektedir (Beede, 1993; Popescu ve ark., 2011).

Araştırmalar, sığırların tükettikleri sularda mikrobiyal yük için üst sınırların farklı olduğunu göstermektedir. Looper ve Waltner (2002), toplam bakteri için **5000 adet/L,** toplam koliform için **150 adet/L,** fekal koliform için ise **100 adet/L** sınır değer bildirmiştir. Socha ve ark. (2003) ise bu sınırları sırasıyla **1000 adet/100 mL, 0.5 adet/100 mL** ve **0.1 adet/100 mL** olarak belirtmiştir. Buzağılarda toplam ve fekal koliform sınırı **1 adet/100 mL**, yetişkinlerde ise sırasıyla **10** ve **15 adet/100 mL** olmalıdır. Ayrıca fekal streptokokların, buzağılarda **3 adet/100 mL**, yetişkinlerde ise **30 adet/100 mL**'yi aşmaması önerilmektedir. Toplam bakteri sayısının **1 milyon/100 mL**'yi geçtiği durumlarda hiçbir çiftlik hayvanının bu suyu tüketmemesi gerektiği bildirilmiştir (Beede, 1993).

Su kaynağı türü, bulaşma riskini doğrudan etkilemektedir. Yüzey sularında bulaşma ihtimali daha yüksekken, kuyu suyunda koliform bakterilerin varlığı yüzeysel bir kirlenmeyi göstermektedir (Pfost ve ark., 2001). Ayrıca geçirgen toprak, kaya çatlakları ve delikler mikroorganizmaların suya karışmasını kolaylaştırır. Gübre depoları ve hayvanların bulunduğu alanlardan taşınan sular, bakterilerin ve parazitlerin depolara ulaşmasına neden olabilir (Braul ve Kirychuk, 2001).

ABD'de yapılan bir çalışmada, içme sularında fekal bakteriler yaygın bulunurken, gıda kaynaklı patojenlerin düşük seviyelerde görüldüğü bildirilmiştir (LeJeune ve ark., 2001). Romanya'da yapılan bir araştırmada ise çiftlik suluklarından alınan örneklerin %92'sinde bakteri, %70'inde toplam koliform, %63'ünde ise fekal koliform tespit edilmiştir (Popescu ve ark., 2011).

Fekal bulaşmış sularda **E. *coli, Cryptosporidia, Salmonella*** ve ***Leptospira* spp.** gibi patojenler yaygın olup, bunlar ishal, yavru atma ve kısırlığa yol açabilmektedir (Pfost ve ark., 2001). Ayrıca **Fusobacterium** türleri, sığırlarda tırnak çürüklüğü ve topallık vakalarının başlıca nedenlerindendir. Yeni veya yabancı patojenlerin suya bulaşması durumunda özellikle genç hayvanlarda hızla hastalık görülmesi mümkündür (Anonim, 2013).

2.2.4.5 Mavi ve yeşil algler

Mavi-yeşil algler, sıcak havalarda, suyun besin maddelerince zenginleşmesi, akış hızının azalması ve rüzgârla taşınan organik maddeler nedeniyle çoğalarak toksin üretirler (Beede, 2006). Bu toksinler sığırların iştahsızlaşmasına, ishal ve halsizlik gelişmesine, ileri vakalarda

zayıflama ve ölüme neden olabilir. Alg toksinleri, suya küf kokusu verirken, aynı zamanda TÇM, azot ve fosfor seviyelerini yükseltmektedir (Beede, 1992; Yaylak ve Yavuz, 2016).

Alglerin ürettiği toksinler iki grupta incelenmektedir:

1. **Nörotoksinler** → Ani ölümlere yol açabilir.

2. **Hepatotoksinler (karaciğer toksinleri)** → 1–2 saat ile birkaç gün arasında ölüme sebep olabilir. Klinik belirtiler, maruziyetten sonraki ilk 15 dakikada ortaya çıkabilmektedir. Yüksek toksin maruziyeti, şiddetli karaciğer hasarı ve ölümle sonuçlanabilmektedir (Beede, 2006).

Bu tür risklerden korunmanın en etkili yolu, **sulara besin maddesi girişini engellemek** ve **su kaynağını düzenli havalandırmaktır** (Braul ve Kirychuk, 2001).

3. SU VE HAYVANSAL VERİM ARASINDAKİ İLİŞKİ

Su, çiftlik ve kümes hayvanlarının temel bileşenlerinden biridir; vücut ağırlıklarının %50–80'ini oluşturur. Çözücü özelliği sayesinde vücut sıcaklığının dengelenmesinde, süt üretiminde, sindirim ve metabolizmanın düzenlenmesinde, atıkların uzaklaştırılmasında, ozmotik basıncın korunmasında ve üreme gibi pek çok yaşamsal işlevde kritik rol oynar (Cemek ve ark., 2011). Hayvanlar su ihtiyaçlarını, doğrudan içme suyu, kar/buz tüketimi, yemlerdeki su ve metabolik süreçlerden karşılamaktadır.

Yüksek kalitede, bol ve sürekli içme suyu, hayvan sağlığı ve üretim verimliliği için zorunludur. Düşük kaliteli su ise yem tüketiminin azalmasına, besin öğelerinden yararlanmanın bozulmasına, verim kaybına ve dolayısıyla işletme karlılığının düşmesine neden olur (Adams ve Sharpe, 1995; NRC, 2001; Socha ve ark., 2003).

Sığır yetiştiriciliğinde suyun kalitesi ile üretim performansı arasında güçlü bir ilişki vardır. Sığırların su tüketimi, kuru madde alımı ve süt verimi arasında yüksek korelasyon bulunmaktadır. Suyun yetersiz veya kalitesiz olması süt üretimini doğrudan düşürür. Vücuttaki suyun %2'sinin azalması ısı dengesini bozar; %7'lik azalma aşırı yorgunluk, halüsinasyon ve solunum sıkıntısı oluşturur; %10'luk azalma ise dolaşım ve böbrek yetmezliği ile ölüme yol açar (Göncü-Karakök ve ark., 2008).

Yapılan araştırmalara göre süt veren bir ineğin vücudunun yaklaşık %56'sı sudan oluşur ve ürettiği sütün %87'si sudur. Bir litre süt üretebilmek için 3–4 litre su tüketmesi gerekir. Bu nedenle su, süt verimi için en kritik girdilerden biridir. Ayrıca suların mineral içeriği, hayvanların mineral alımına katkı sağlayabilmektedir. Nitekim ABD'de süt sığırcılığı işletmelerinden alınan 3618 su örneğinin mineral analizleri, suların sığırların mineral tüketiminde önemli bir paya sahip olduğunu ortaya koymuştur (Socha ve ark., 2003; Erickson & Kalscheur, 2020; Golher ve ark., 2021).

Buna rağmen, birçok yetiştirici suyun önemini yeterince dikkate almamaktadır. Su kalitesinin düşük olmasının hayvan sağlığını ve performansını olumsuz etkilediği bilinmesine karşın, çoğu yetiştirici suyun kalitesini düzenli olarak kontrol etmemektedir (Socha ve ark., 2003; Popescu ve ark., 2011).

3.1 Fizyolojik dönemler ve çevresel stres

- **Laktasyon:** Süt ineklerinin su ihtiyacı çok yüksektir; bu nedenle TDS, sülfat ve nitrat sınır değerleri daha sıkı yorumlanmalıdır.

- **Büyüme:** Genç ruminantlar toksik etkilere karşı daha duyarlıdır; bu nedenle yüksek sülfat veya nitrat içeren sularda risk artar.

- **Sıcaklık stresi:** Yüksek çevre sıcaklıklarında su tüketimi artar ve hayvan daha fazla mineral yüküne maruz kalır. Bu nedenle yaz aylarında güvenli kabul edilen eşik değerlerin dahi sorun yaratabileceği unutulmamalıdır (NRC, 2016).

4. NUMUNE ALMA, İZLEME VE LABORATUVAR

İçme suyu kalitesinin güvenilir biçimde değerlendirilebilmesi için uygun numune alma ve analiz süreçlerinin titizlikle yürütülmesi gereklidir. Yanlış alınmış veya taşınmış numuneler, gerçek saha koşullarını yansıtmayarak hatalı sonuçlara yol açabilmektedir.

4.1 Numune alma yöntemi

Numuneler doğrudan **hayvanın içtiği noktadan** alınmalıdır. Eğer su boru hattı veya çeşmeden sağlanıyorsa, en az 2–3 dakika akıtıldıktan sonra numune alınması önerilmektedir (APHA, 2017). Numune kapları temiz, tercihen steril cam veya polietilen şişeler olmalı; **mikrobiyolojik analiz için kullanılan şişeler sodyum tiyosülfat ile hazırlanmalı** ve kontaminasyondan korunmalıdır. Şişeler üzerine **kaynak, tarih, saat ve örnekleyici bilgisi** etiketlenmeli; çapraz karışıklıkların önüne geçilmelidir (WHO, 2017).

4.2 Saklama ve taşıma

Alınan numuneler **4 °C'de soğuk zincir** altında taşınmalı ve mümkünse aynı gün içinde laboratuvara ulaştırılmalıdır. Mikrobiyolojik analiz için numuneler **24 saat içinde** işleme alınmalıdır; aksi halde sonuç güvenilirliğini kaybeder. Kimyasal parametreler (ör. nitrat, sülfat, ağır metaller) daha uzun süre stabildir; ancak yine de 48 saat içinde analize alınması önerilir (APHA, 2017).

4.3 İzleme sıklığı

Su kalitesi **mevsimsel ve hidrometeorolojik koşullara** bağlı olarak değişkenlik gösterebilir. Özellikle yağışlı dönemlerde yüzey sularında bulanıklık, mikrobiyal yük ve besin elementleri artabilmektedir. Bu nedenle:

- **Yeraltı suları:** Yılda en az 1–2 kez analiz edilmeli.
- **Yüzey suları (gölet, akarsu):** Mevsimsel değişiklikler göz önünde bulundurularak en az 3–4 ayda bir kontrol edilmeli.

Acil durumlar: Alg çiçeklenmesi, ani koku/tat değişimi veya hayvanlarda sağlık problemi gözlendiğinde ek analiz yapılmalıdır (Hammoumi ve ark., 2024).

4.4 Sahada hızlı testler ve laboratuvar analizleri

Bazı parametreler (pH, sıcaklık, elektriksel iletkenlik, çözünmüş oksijen) **taşınabilir cihazlarla sahada** ölçülebilir. Bu yöntem, hızlı karar vermek için avantaj sağlar. Ancak **mikrobiyolojik kalite (*E. coli*, toplam koliformlar)** ve spesifik kimyasal analizler (ör. ağır metaller, siyanotoksinler) için **akredite laboratuvar testleri** gereklidir (WHO, 2017; CCME, 2002).

Sonuç olarak, güvenilir bir izleme sistemi; doğru numune alma, uygun taşınma koşulları, düzenli izleme sıklığı ve sahada hızlı testlerle desteklenen laboratuvar doğrulamasına dayanmaktadır. Böylece hayvan sağlığını tehdit edebilecek olası riskler zamanında tespit edilip önleyici tedbirler alınabilir.

5. RİSK YÖNETİMİ VE İYİLEŞTİRME SEÇENEKLERİ

Ruminant içme suyu kalitesi yalnızca düzenli izleme ile değil, aynı zamanda etkin risk yönetimi ve iyileştirme stratejileri ile güvence altına alınabilir. Bu stratejiler hem **su kaynağının korunmasını** hem de **kalitenin sürdürülebilir şekilde iyileştirilmesini** kapsar.

5.1 Kaynak koruma

Su kaynağının korunması, risk yönetiminin ilk basamağıdır. Hayvanların doğrudan su kaynağına (ör. gölet, akarsu) girişinin sınırlandırılması, **erozyon ve dışkı kaynaklı mikrobiyal kontaminasyonu** azaltır (Jarvis et al., 2019). Ayrıca drenaj kontrolü, tarımsal alanlardan gelen gübre ve pestisit yükünün suya karışmasını engelleyerek nitrat ve fosfat kirliliğini düşürür.

5.2 Basit arıtım yöntemleri

Su kalitesinin iyileştirilmesinde çeşitli düşük maliyetli arıtım yöntemleri kullanılabilir:

- **Ön çökeltim ve filtrasyon**, bulanıklığın ve partikül yükünün azaltılmasını sağlar.
- **Klorlama**, özellikle mikrobiyal kontaminasyon için etkili bir yöntemdir. Serbest klor düzeyi **0.2–0.5 mg/L** arasında tutulmalı, pH'ın yüksek olduğu sularda klor etkinliğinin düştüğü göz önünde bulundurulmalıdır (WHO, 2017).
- Yerinde uygulanan **ultraviyole (UV) sistemleri**, küçük ölçekli işletmelerde bakteri inaktivasyonu için alternatif yöntemdir (APHA, 2017).

5.3 Siyanobakteri çiçeklenmeleri

Sıcak mevsimlerde gölet ve barajlarda siyanobakteri (mavi-yeşil alg) çiçeklenmeleri ortaya çıkabilmektedir. Bu durum, özellikle **mikrosistin-LR gibi hepatotoksinlerin** suya salınımına neden olabilir. Çiçeklenme şüphesi durumunda suyun hemen hayvan tüketiminden çekilmesi, alternatif bir kaynak sağlanması ve suyun laboratuvar testleri yapılana kadar kullanılmaması önerilmektedir. Gerekirse yüzey suyu yerine **derin kuyu suyu** veya tanker ile temiz su temini sağlanmalıdır (Hammoumi ve ark., 2024).

5.4 Mineraller arası etkileşimler ve rasyon ayarlamaları

Su kaynaklı yüksek sülfat düzeyleri, ruminantlarda **polioensefalomalasi (PEM)** riskini artırabilmektedir (Kandylis, 1984; Knight, 1985). Ayrıca sülfat ve molibdenin birlikte yüksek olması, **bakır emilimini azaltarak ikincil bakır yetersizliğine** yol açmaktadır (Suttle, 2010). Bu durumlarda veteriner hekim ve beslenme uzmanları tarafından rasyona **bakır takviyesi** yapılması veya organik mineral formlarına yönelinmesi gerekebilir. Benzer şekilde, yüksek nitrat içeren sularda enerji kaynağı olarak kolay fermente olabilen karbonhidratların rasyona eklenmesi, toksisite riskini azaltabilir (Loneragan & Gould, 2002).

6. Türkiye Bağlamı ve Uygulama Notları

Türkiye'de ruminant hayvancılıkta kullanılan içme suyu kaynakları çoğunlukla **yeraltı kuyuları, göletler, akarsular ve yerleşim şebekeleri** üzerinden sağlanmaktadır. Su kalitesinin değerlendirilmesinde çoğunlukla **insan sağlığına yönelik standartlar** veya **genel çevresel mevzuat** referans alınmaktadır.

6.1 TS 266 STANDARDI VE HAYVANCILIK TESİSLERİ

Türkiye'de en temel yasal düzenleme, **TS 266 – İnsani Tüketim Amaçlı Sular Standardı**dır (Enstitüsü, 2005). Bu standart, insan tüketimine yönelik parametre sınırlarını (ör. pH, nitrat, ağır metaller, florür) tanımlamakla birlikte, hayvancılıkta kullanılan şebeke suları da çoğunlukla bu kriterlere göre değerlendirilmektedir. Ancak ruminantların mineral toleransları insanlardan farklı olduğundan, bu standartların doğrudan hayvanlara uygulanması her zaman uygun değildir. Özellikle **sülfat ve toplam çözünmüş madde (TDS)** açısından ruminant toleranslarının daha geniş aralıklara sahip olabileceği göz önünde bulundurulmalıdır.

6.2 Yerüstü su kalitesi yönetmeliği ve nitrat hassas bölgeler

Yerüstü Su Kalitesi Yönetmeliği (Gazete, 2016), göl, akarsu ve baraj gibi yüzeysel sular için kalite sınıflarını belirler. Bu yönetmelikte, **tarımsal kaynaklı kirliliğin azaltılması** amacıyla **Nitrat Hassas Bölgeleri** kavramı tanımlanmıştır. Gübreleme ve hayvansal atık yönetiminin yetersiz olduğu alanlarda nitrat yükü hızla artabilmekte, bu durum hem ekosistem hem de ruminant sağlığı açısından risk oluşturmaktadır (Sünal ve Erşahin 2012).

6.3 Bölgesel saha bulguları

Türkiye'nin farklı bölgelerinden yapılan saha çalışmaları, **nitrat ve sülfat konsantrasyonlarının bölgesel farklılıklar gösterdiğini** ortaya koymaktadır:

- **İç Anadolu ve Güneydoğu Anadolu'da** yoğun tarımsal faaliyetler nedeniyle yeraltı sularında **yüksek nitrat (>100 mg/L NO_3^-)** rapor edilmiştir (Dokuz ve ark., 2025).
- **Doğu Anadolu Bölgesi'nde**, volkanik jeolojik yapı nedeniyle özellikle **sülfat ve florür düzeylerinin yüksek** seyrettiği belirtilmiştir (Atıcı, 2020).

Ege ve Marmara'da bazı endüstriyel bölgelerde **ağır metal kontaminasyonu (As, Pb)** riskine işaret eden çalışmalar bulunmaktadır (Garipağaoğlu, 2016).

Bu bulgular, su kalitesinin bölgesel ekolojik, jeolojik ve tarımsal faktörlere bağlı olarak değiştiğini göstermektedir. Bu nedenle, **Türkiye'de ruminant içme suyu için tek tip bir değerlendirme yerine, bölgesel saha verilerine dayalı risk analizlerinin yapılması** gereklidir.

7. SONUÇ

Ruminant hayvanlarda içme suyu kalitesi, hayvan sağlığı, refahı ve üretim verimliliği açısından kritik bir faktördür. Su kalitesinin bozulması, yem tüketiminde azalma, mineral dengesizlikleri, metabolik bozukluklar ve verim kayıplarıyla sonuçlanabilmektedir. Bu nedenle içme suyunun yalnızca miktarının değil, aynı zamanda kalitesinin de sürekli izlenmesi ve yönetilmesi gereklidir.

7.1 Sahada uygulanabilir karar ağacı

Uygulamada etkin bir yaklaşım için **izleme–müdahale–önleme döngüsüne dayalı bir karar ağacı** önerilmektedir:

1. **İzleme:** Düzenli numune alma ve saha ölçümleri ile pH, TDS/EC, nitrat/nitrit, sülfat, E. coli gibi kritik parametrelerin takip edilmesi.
2. **Müdahale:** Eşik değerler aşıldığında su kaynağının değiştirilmesi, basit arıtım yöntemleri (filtrasyon, klorlama) veya rasyon ayarlamaları (bakır, enerji katkıları) ile riskin azaltılması.
3. **Önleme:** Kaynak koruma önlemleri (drenaj yönetimi, hayvan erişiminin sınırlandırılması) ve düzenli saha analizleri ile kontaminasyonun oluşmadan engellenmesi (Jarvis et al., 2019).

7.2 Gelecek araştırma alanları

Mevcut kılavuzlar (CCME, 2002) çoğunlukla klasik parametrelere odaklanmıştır. Ancak yeni çevresel riskler dikkate alınmalıdır:

- **Per- ve polifloroalkil maddeler (PFAS):** Son yıllarda su kaynaklarında tespit edilen bu kalıcı organik kirleticilerin ruminant sağlığı üzerindeki etkileri büyük ölçüde belirsizdir (Brase et al., 2021).

- **Pestisit kalıntıları:** Tarımsal alanlarda yoğun kullanılan herbisit ve insektisitlerin uzun vadede su kalitesi ve hayvan sağlığına etkileri hakkında saha verileri sınırlıdır (Sünal ve Erşahin 2012).

- **Bentik siyanobakteriler:** Yüzeysel sularda daha az görünür olan ancak toksin üretme potansiyeline sahip bentik türlerin ruminantlar üzerindeki riskleri yeterince araştırılmamıştır (Wood et al., 2020).

7.3 Genel değerlendirme

Ruminant hayvanlarda içme suyu kalitesi, hayvan sağlığı, refahı ve üretim verimliliği açısından kritik bir faktördür. Su kalitesinin bozulması, yem tüketiminde azalma, mineral dengesizlikleri, metabolik bozukluklar ve verim kayıplarıyla sonuçlanabilmektedir. Bu nedenle içme suyunun yalnızca miktarının değil, aynı zamanda kalitesinin de sürekli izlenmesi ve yönetilmesi gereklidir. Sonuç olarak, Türkiye'de ruminant içme suyu yönetimi insan sağlığına dayalı standartlarla yönlendirilse de, **hayvanlara özgü tolerans değerlerinin saha gerçeklerine uyarlanması** gerekmektedir. Araştırmacıların ve üreticilerin işbirliğiyle geliştirilecek saha odaklı izleme programları, hem hayvan sağlığını koruyacak hem de sürdürülebilir üretime katkı sağlayacaktır.

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RUMİNANTLARIN İÇME SUYU KALİTESİNDE GÜNCEL YAKLAŞIMLAR: KİMYASAL, MİKROBİYOLOJİK VE EMERGİNG KİRLETİCİLER, DİJİTAL İZLEME VE POLİTİKA PERSPEKTİFLERİ

***Doç Dr. Cemal BUDAĞ**

Van Yüzüncü Yıl Üniversitesi Ziraat Fakültesi Zootekni Bölümü.

E mail: cbudag@yyu.edu.tr

ORCID : 0000-0003-3532-7727

ÖZET

Bu derleme, ruminantların içme suyu kalitesini etkileyen kimyasal, biyolojik ve yeni ortaya çıkan kirleticileri kapsamlı bir şekilde değerlendirmektedir. pH, sertlik, tuzluluk, nitrat, sülfat, ağır metaller ve mikrobiyolojik kontaminasyon gibi klasik parametrelerin yanı sıra; pestisit kalıntıları, per- ve polifloroalkil maddeler (PFAS), siyanotoksinler ve mikroplastikler gibi yeni risk faktörleri de son yıllarda giderek daha fazla önem kazanmıştır. 2023–2025 yıllarına ait güncel literatürün sentezi, su kalitesinin yalnızca metabolik sağlık ve üretim performansını değil, aynı zamanda hayvan refahını, davranışsal göstergeleri ve antimikrobiyal direnç riskini de doğrudan etkilediğini ortaya koymaktadır.

Buna ek olarak, Nesnelerin İnterneti (IoT) sensörleri, yakın kızılötesi spektroskopi (NIR) ve yapay zekâ destekli modelleme gibi dijital teknolojilerin entegrasyonu, hayvancılık sistemlerinde su kaynaklarının gerçek zamanlı, öngörücü ve sürdürülebilir yönetimi açısından yeni olanaklar sunmaktadır.

Politika ve mevzuat düzeyinde ise FAO, WHO, Avrupa Birliği ve Türkiye tarafından oluşturulan çerçeveler incelenmiş; özellikle 2026 yılında yürürlüğe girecek olan AB'nin PFAS düzenlemelerinin uyum süreçlerindeki belirleyici rolü vurgulanmıştır.

Genel olarak bu çalışma, kimyasal, mikrobiyolojik ve yeni kirleticilerin değerlendirilmesini; refah göstergeleri ve dijital izleme teknolojileriyle bütünleştiren, çok disiplinli ve bütüncül bir yaklaşımın ruminant içme suyu yönetiminde benimsenmesi gerektiğini ortaya koymaktadır.

Anahtar Kelimeler: Ruminant, içme suyu kalitesi, PFAS, mikrobiyolojik risk, hayvan refahı, dijital izleme

CURRENT APPROACHES TO RUMINANT DRINKING WATER QUALITY: CHEMICAL, MICROBIOLOGICAL AND EMERGING CONTAMINANTS, DIGITAL MONITORING AND POLICY PERSPECTIVES*

***Assoc. Prof. Dr. Cemal BUDAĞ**

Van Yuzuncu Yil University, Faculty of Agriculture, Department of Animal Science.

Email: cbudag@yyu.edu.tr

ORCID: 0000-0003-3532-7727

ABSTRACT

This review provides a comprehensive evaluation of the chemical, biological, and emerging contaminants influencing the drinking water quality of ruminants. Beyond classical parameters such as pH, hardness, salinity, nitrate, sulfate, heavy metals, and microbiological contamination, recent attention has focused on emerging risk factors including pesticide residues, per- and polyfluoroalkyl substances (PFAS), cyanotoxins, and microplastics. A synthesis of recent studies (2023–2025) demonstrates that water quality affects not only metabolic health and production performance but also animal welfare, behavioral indicators, and the risk of antimicrobial resistance.

In addition, the integration of digital technologies—such as Internet of Things (IoT) sensors, near-infrared spectroscopy (NIR), and artificial intelligence (AI)-assisted modeling—offers new opportunities for real-time, predictive, and sustainable management of water resources in livestock systems.

At the policy and regulatory level, frameworks established by the FAO, WHO, European Union, and Türkiye were examined, with particular emphasis on the EU's forthcoming PFAS regulations (effective 2026) and their implications for harmonization efforts.

Overall, this review underscores the necessity of a multidisciplinary and holistic approach to ruminant water management, integrating chemical, microbiological, and emerging contaminant assessments with welfare indicators and digital monitoring technologies to ensure sustainable livestock production.

Keywords: Ruminant, driking water quality, PFAS, emerging contaminants, antimicrobial resistance, animal welfare, digital monitoring

1. GİRİŞ

Su, tüm canlılar için yaşamın temel bileşenidir ve ruminantlarda besin maddelerinin sindirimi, metabolizması, termoregülasyon ve homeostazın sürdürülmesi açısından vazgeçilmezdir. Bir ineğin süt üretiminin yaklaşık %87'si sudan oluşmakta, bu nedenle günlük su alımı doğrudan süt verimi ve hayvan refahı ile ilişkilendirilmektedir. Ruminantların su gereksinimleri yalnızca içme suyundan değil; yemlerdeki nem içeriği ve metabolik süreçler sonucu ortaya çıkan sudan da karşılanmaktadır. Ancak suyun miktarının yanı sıra kalitesi, hayvan sağlığı ve performansı üzerinde belirleyici bir faktör olarak öne çıkmaktadır (Tulu ve ark., 2024).

Su kalitesi, fizikokimyasal (pH, toplam çözünmüş madde, sertlik, tuzluluk, nitrat ve sülfat gibi parametreler), mikrobiyolojik (koliform bakteriler, *E. coli*, enterokoklar), kimyasal kirleticiler (ağır metaller, pestisitler, emerging kirleticiler/PFAS) ve organoleptik özellikler (tat, koku, renk, berraklık) çerçevesinde değerlendirilmektedir. Son yıllarda yapılan araştırmalar, içme suyunda görülen olumsuzlukların yem tüketimini azalttığını, rumen fermantasyonunu bozduğunu, elektrolit ve mineral dengesizliklerine yol açtığını ve özellikle genç hayvanlarda mortaliteyi artırabildiğini ortaya koymuştur. Ayrıca eutrofik koşulların tetiklediği alg patlamaları sonucu gelişen siyanotoksinler, ruminantlarda hepatotoksik etkilerle ilişkili bulunmuş; PFAS gibi kalıcı organik kirleticilerin ise sığır serumunda ve sütünde biriktiği bildirilmiştir (Kamal ve ark., 2024; Llonch ve ark., 2024; Bensalem ve ark., 2025; Villalobos ve ark., 2025).

Küresel iklim değişikliği, artan sıcaklıklar ve su kaynaklarının azalması, ruminant yetiştiriciliğinde suyun hem miktar hem de kalite açısından daha stratejik bir unsur hâline gelmesine yol açmaktadır. Bu bağlamda, güncel literatürün değerlendirilmesi ve su kalitesi parametrelerinin ruminant sağlığı, verimliliği ve gıda güvenliği üzerindeki etkilerinin bütüncül bir bakış açısıyla ele alınması büyük önem taşımaktadır.

1.1. Ruminantlarda su gereksinimleri ve güncel yaklaşımlar

Ruminantların su gereksinimleri yalnızca doğrudan içilen suyla sınırlı değildir. Yemlerde bulunan serbest ve bağlı su miktarı ile metabolik faaliyetler sonucu oluşan su da toplam su ihtiyacına katkı sağlamaktadır. Bununla birlikte, hayvanın türü, yaşı, çevresel sıcaklık, üretim düzeyi, yemin nem oranı, kullanılan enerji kaynağı ve protein içeriği gibi çok sayıda faktör, bireysel su gereksiniminin düzeyini belirlemektedir (NRC, 2021).

Son yıllarda yapılan çalışmalar, ruminantlarda su gereksiniminin **dinamik ve çevresel koşullara duyarlı bir parametre** olduğunu ortaya koymuştur. Örneğin, iklim değişikliğiyle artan **ısı stresi**, su tüketiminde belirgin artışa yol açmakta; aynı zamanda suyun kalitesi ve erişilebilirliği, hayvanların sağlık ve performansını doğrudan etkilemektedir (Chamberlain ve ark., 2023). 2023 sonrası literatürde özellikle **su verimliliği (water use efficiency)** kavramı öne çıkmış ve yem-su etkileşimlerinin ruminant beslemede kritik rol oynadığı vurgulanmıştır (Wisser ve ark., 2024; FAO, 2024). Ayrıca, dijital izleme teknolojileri (otomatik suluk sensörleri, davranışsal izleme sistemleri) sayesinde bireysel hayvan düzeyinde su tüketim profilleri daha doğru biçimde belirlenebilmekte, böylece **su yönetiminde hassas hayvancılık yaklaşımları** giderek önem kazanmaktadır (Kaur ve ark., 2023; Džermeikaitė ve ark., 2023).

1.2. Küçük ruminantlarda su stresi, iklim değişikliği ve adaptasyon

Pérez ve ark. (2023), küçük ruminantlarda su stresine karşı geliştirilen adaptasyon mekanizmalarını incelemiştir. Çalışmaya göre koyun ve keçiler gibi türler, suya erişimin kısıtlandığı koşullarda fizyolojik adaptasyonlar geliştirmekte, ancak bu durum uzun vadede üretim verimliliğini olumsuz etkilemektedir. Araştırma, özellikle iklim değişikliğine bağlı sıcaklık artışlarının küçük ruminantlarda suya duyulan ihtiyacı artıracağını vurgulamaktadır.

Son yıllarda yapılan çalışmalar, küçük ruminantların **su kıtlığına karşı nispeten daha yüksek tolerans gösterdiğini**, ancak bu toleransın **fizyolojik ve metabolik maliyetlerle** sınırlı olduğunu ortaya koymuştur (Pérez ve ark., 2023). Örneğin, dehidratasyon koşullarında plazma osmolalitesinde artış, idrar konsantrasyonunda yükselme ve yem tüketiminde azalma tipik adaptasyon mekanizmaları olarak rapor edilmiştir (Koluman veGöncü, 2025). Bununla birlikte, kronik su stresi koşulları **büyüme performansı, süt verimi ve üreme parametrelerinde** düşüşlere neden olmaktadır (Sözcü ve Altınçekiç, 2024).

İklim değişikliğine bağlı olarak artan sıcaklık dalgaları ve kuraklık periyotları, küçük ruminantların **suya erişimini kısıtlayan en önemli çevresel faktörler** arasında yer almaktadır. Bu nedenle, son dönem literatürde özellikle **ısıl stres – su stresi etkileşimi** ve bunun üretim verimliliği üzerindeki sinerjik etkileri üzerinde durulmaktadır (FAO, 2024). Ayrıca, **genetik seleksiyon ve yerel ırkların dayanıklılık özelliklerinin korunması**, küçük ruminant yetiştiriciliğinde iklim değişikliğine adaptasyon için öne çıkan stratejilerden biridir (Wanjala, 2024).

Wanjala, G. (2024). *Genome-Wide Analysis of the Genetic Diversity of Native Sheep Breeds and Determination of Potential Selection Signatures for Climate Change Adaptation* (Doctoral dissertation, Debreceni Egyetem (Hungary)).

1.3. Sığırların içme davranışları ve davranışsal izleme teknolojileri

Islam ve ark. (2023) tarafından yapılan deneysel çalışmada, etçi sığırların su kısıtlamasına verdikleri içme davranışı yanıtları incelenmiştir. Bulgular, suyun yalnızca miktarının değil, aynı zamanda erişim süresi ve düzenliliğinin de yem tüketimi ve canlı ağırlık artışı üzerinde etkili olduğunu göstermektedir. Bu sonuçlar, yetiştiricilik uygulamalarında suyun planlı yönetiminin önemini ortaya koymaktadır.

Son yıllarda yapılan araştırmalar, sığırların içme davranışlarının **sağlık, refah ve üretim performansının dolaylı bir göstergesi** olabileceğini ortaya koymuştur. İçme frekansı, süre ve zamanlama parametreleri; hem su kalitesi hem de çevresel stres faktörlerinden etkilenmektedir (Kok, 2024). Özellikle sıcaklık-hastalık ilişkisi kapsamında, **ısı stresi altındaki sığırların içme davranışlarında belirgin değişiklikler** gözlemlenmiştir (Antanaitis ve ark., 2024).

Davranışsal izleme teknolojilerindeki gelişmeler, bu alanda yeni olanaklar sunmaktadır. Otomatik suluklara entegre **IoT tabanlı akış sensörleri**, RFID tabanlı bireysel takip sistemleri ve bilgisayarla görme (computer vision) tabanlı kamera analizleri, sığırların içme davranışlarını gerçek zamanlı olarak ölçebilmektedir (Kok, 2024). Ayrıca yapay zekâ algoritmaları, büyük veri setleri üzerinden içme davranışındaki sapmaları analiz ederek **erken hastalık tanısı ve refah izlemi** için kullanılmaya başlanmıştır (Islam ve ark., 2023). Bu gelişmeler, **hassas hayvancılık (precision livestock farming)** uygulamalarının su yönetiminde de giderek daha fazla yer bulduğunu göstermektedir.

1.4. Su kullanımı, iklim değişikliği ve küresel su stresi

Wisser ve ark. (2024), hayvancılık sistemlerinde doğrudan içme suyu tüketiminin yanı sıra yem üretimi için kullanılan suyun da küresel su stresine katkısını modellemiştir. Çalışma, ruminantların su ayak izini değerlendirirken hem doğrudan hem de dolaylı su kullanımının dikkate alınması gerektiğini vurgulamaktadır.

Son yıllarda yapılan çalışmalar, hayvancılık sektörünün küresel su tüketiminde önemli bir paya sahip olduğunu ve özellikle **gizli su tüketiminin (virtual water)** yem üretimi aracılığıyla giderek daha kritik bir boyuta ulaştığını göstermektedir (Higazy ve ark., 2024). Bu bağlamda ruminant yetiştiriciliği, tarımsal su ayak izinin en büyük bileşenlerinden biri olarak değerlendirilmektedir.

İklim değişikliğiyle birlikte artan kuraklık, sıcaklık dalgaları ve su kıtlığı, yalnızca hayvanların **doğrudan içme suyu tüketimini** değil, aynı zamanda **yem üretiminde kullanılan sulama suyunu** da ciddi şekilde etkilemektedir (FAO, 2024). Bunun sonucunda, ruminant yetiştiriciliğinde **su verimliliği (water productivity)** kavramı önem kazanmış; üretim sistemlerinin su kullanımına göre sınıflandırılması ve sürdürülebilir stratejilerin geliştirilmesi yönünde yeni yaklaşımlar ortaya çıkmıştır (Ridoutt ve ark., 2023).

Ayrıca, 2025 itibarıyla yayınlanan senaryolar, su stresi altındaki bölgelerde hayvancılığın gelecekteki sürdürülebilirliği için **alternatif yem kaynakları, entegre su yönetimi politikaları ve bölgesel adaptasyon stratejilerinin** zorunlu hale geleceğini ortaya koymaktadır (Asif ve ark., 2023). Bu kapsamda, **iklim değişikliği ile uyumlu su yönetimi** hem çevresel sürdürülebilirlik hem de gıda güvenliği için temel bir gereklilik olarak öne çıkmaktadır.

1.5. Su kalitesi, üreme, üretim performansı, sağlık ve refah ilişkisi

Su, ruminantların yaşamı için temel bir gereksinim olmasının ötesinde, **üreme verimliliği, üretim performansı, sağlık durumu ve hayvan refahı** üzerinde doğrudan ve dolaylı etkilere sahiptir. Tulu ve ark. (2024), kurak bölgelerden elde edilen veriler ışığında su kalitesinin hayvansal üretim üzerindeki etkilerini derlemiş ve yüksek mineral içerikli veya kontamine olmuş su kaynaklarının ruminantlarda verim kayıplarına, metabolik bozukluklara ve refah sorunlarına yol açabileceğini bildirmiştir.

Üreme ve döl verimi

Son dönem çalışmalar, özellikle **nitrat, sülfat ve ağır metaller** ile kontamine olmuş içme sularının üreme üzerinde olumsuz etkiler yarattığını göstermektedir. Bu etkiler arasında **azalmış döl tutma oranı, embriyo kaybı, abortus ve infertilite** gibi sorunlar yer almaktadır (De Camillis 2023). Ayrıca, suyun aşırı tuzluluğu ve sertliği, üreme performansında indirekt kayıplara neden olabilmektedir.

Verim performansı

Suyun kalitesi, **süt verimi ve bileşimi, et üretimi** ve **yemden yararlanma etkinliği** ile doğrudan ilişkilidir. Yüksek sülfat düzeyleri, genç ruminantlarda kobalt ve bakır metabolizmasını bozarak büyüme performansını düşürmekte; aşırı tuzluluk ise yem tüketimini kısıtlayarak süt veriminde azalmaya yol açmaktadır (Chamberlain & Sinclair, 2023).

Sağlık ve metabolik bozukluklar

Su kalitesindeki dengesizlikler, **hipomagnezemi, asidoz, enterotoksin kaynaklı ishaller** ve mineral eksiklikleri gibi metabolik bozukluklara neden olabilmektedir. Ayrıca, mikrobiyolojik olarak kirlenmiş su kaynakları, **enterik enfeksiyonların** (ör. *E. coli*, *Salmonella*) yayılımını kolaylaştırmaktadır. Bu da hem hayvan sağlığı hem de gıda güvenliği açısından ciddi bir risk oluşturmaktadır (Jurkovich ve ark., 2024)

Hayvan refahı

Dünya Hayvan Sağlığı Örgütü (WOAH), **temiz, güvenilir ve sürekli içme suyuna erişimi** hayvan refahının beş temel özgürlüğünden biri olarak tanımlamaktadır. Kirli veya yetersiz su kaynakları yalnızca fizyolojik stres yaratmakla kalmamakta, aynı zamanda **davranışsal değişikliklere** (su için rekabet, içme süresinde artış, yem tüketiminde azalma) de neden olmaktadır (Jurkovich ve ark., 2024). Bu durum, hayvan refahı ve sürdürülebilir üretim sistemleri açısından kritik önemdedir.

1.6. Çevresel faktörler ve su tüketimi dinamikleri

He ve ark. (2023) tarafından yürütülen çalışma, soğuk mevsimlerde içme suyunun ısıtılmasının sığırlarda büyüme performansını ve rumen fonksiyonlarını iyileştirdiğini göstermiştir. Bu bulgu, çevresel sıcaklıkların su tüketimi ve hayvan sağlığı üzerindeki dolaylı etkilerini açıkça ortaya koymaktadır.

Son yıllarda yapılan araştırmalar, ruminantlarda su gereksinimlerinin yalnızca miktar değil, aynı zamanda **su kalitesi, erişim düzeni ve çevresel faktörlerle birlikte** ele alınması gerektiğini ortaya koymuştur (Jones ve ark., 2024). Özellikle **yüksek çevre sıcaklıkları**, hayvanlarda terleme ve solunum yoluyla su kayıplarını artırmakta; bu durum, **ısı stresi ile ilişkili su tüketiminde belirgin artışlara** yol açmaktadır (Antanaitis ve ark., 2024). Bunun tersine, düşük sıcaklıklarda hayvanların su tüketimi azalmakta, fakat suyun sıcaklığının artırılması bu negatif etkiyi azaltabilmektedir (He ve ark., 2023).

Nem oranı, rüzgar hızı, barınak koşulları ve suyun fiziksel özellikleri (ör. sıcaklık, akış hızı, erişim kolaylığı) gibi çevresel parametreler de **su içme davranışlarını** doğrudan etkilemektedir (Ferreira ve ark., 2025). Ayrıca, iklim değişikliğinin neden olduğu **kuraklıklar ve su kaynaklarındaki kalitesel bozulmalar**, ruminant yetiştiriciliğinde su yönetimini stratejik bir unsur haline getirmiştir (FAO, 2024).

Güncel yaklaşımlar, bu bağlamda **çevresel faktörleri entegre eden su tüketim modelleri** ve **hassas hayvancılık teknolojilerinin (IoT sensörler, akıllı suluklar, davranışsal izleme sistemleri)** kullanımı üzerine odaklanmaktadır. Böylece su tüketimi ile çevresel değişkenler arasındaki ilişki daha doğru biçimde belirlenebilmekte ve **proaktif su yönetim stratejileri** geliştirilebilmektedir (Islam ve ark., 2023).

1.7. Su kalitesi, sürdürülebilir ruminant yetiştiriciliği ve sağlıklı yaşam (One Health) perspektifi

Ruminant yetiştiriciliğinde su kalitesi, hayvan sağlığı ve üretim performansının korunmasında kritik bir rol oynamaktadır. Kurak ve yarı kurak bölgelerde yapılan çalışmalar, yüksek mineral içerikleri, toksik elementler ve mikrobiyal kontaminasyonun verimlilik üzerinde olumsuz etkilere yol açtığını göstermektedir (Tulu ve ark. 2024). Güncel yönergeler, büyük ve küçükbaş hayvanların içme suyunda nitrat, sülfat ve alg toksinleri gibi parametrelerin sınır değerler dâhilinde tutulması gerektiğini vurgulamaktadır (Australian & New Zealand Guidelines, 2023). Benzer şekilde, Oklahoma ve Texas'ta yürütülen saha çalışmaları, bölgesel farklılıkların suyun fiziksel ve kimyasal özelliklerini etkileyerek hayvan performansını değiştirdiğini ortaya koymuştur (Water Quality for Livestock Across Oklahoma and Texas, 2025). Etçi sığırlar üzerine hazırlanan teknik raporlar da sülfat ve nitrat gibi unsurların yüksek düzeylerde bulunmasının yem tüketimi ve canlı ağırlık artışı üzerinde sınırlayıcı etki oluşturabileceğini bildirmektedir (University of Tennessee, 2023). Türkiye'de yapılan araştırmalarda ise, hayvan refahı ve iyi tarım uygulamaları standartlarının su kalitesiyle doğrudan ilişkili olduğu ve bu bağlamda izleme ve denetim mekanizmalarının güçlendirilmesi gerektiği belirtilmektedir (Aydın, 2023).

Ruminantlarda içme suyu kalitesine ilişkin çalışmalar, kimyasal (nitrat, sülfat, tuzluluk/TDS), mikrobiyolojik ve yönetimsel ölçütlerin birlikte değerlendirilmesi gerektiğini ortaya koymaktadır. Llonch ve ark., (2024)'nın yürüttüğü kontrollü bir denemede, içme suyunda 220 mg/L NO_3^- düzeyine kadar yaklaşık beş ay süreyle yüksek konsantre diyetle beslenen ruminantlarda sağlık, yem tüketimi ve rumen fermantasyonu üzerinde olumsuz etki gözlenmemiştir. Ancak araştırmacılar, bu bulgunun rasyon bileşimine duyarlı olduğuna dikkat çekmektedir. Sülfat üzerine yapılan bir çalışmada Evans ve ark., (2023), etçi düvelerde suya sodyum sülfat ilavesiyle birlikte sülfat konsantrasyonu arttıkça su tüketiminin doğrusal biçimde

arttığını bildirmiştir. Literatürde ise kaba yem oranı yüksek rasyonlarla beslenen sığırlarda yaklaşık 2500 mg/L sülfatın tolere edilebildiği sıkça vurgulanmaktadır. Tuzluluk konusunda Yirga ve ark., (2024), Blackhead Ogaden koyunları ve Somali keçileri üzerinde yaptıkları deneysel çalışmada, artan su tuzluluğunun su alımı, ısı düzenleme parametreleri ve hematolojik-biyokimyasal göstergeleri anlamlı biçimde etkilediğini, ayrıca türler arasında tuzluluk toleransının farklılık gösterdiğini ortaya koymuşlardır. Mikrobiyolojik kaliteye yönelik olarak Soares ve ark., (2023), Portekiz'de süt sığırı işletmelerinden elde edilen içme suyu örneklerinde *Koliform* ve *Enterococcus* türlerinin varlığını raporlamış; bu bulgu, suluk hijyeni ve düzenli dezenfeksiyonun önemini göstermiştir. Benzer biçimde, Kamal ve ark., (2024)'nın yürüttüğü saha çalışmasında yüksek toplam çözünmüş madde, sülfat, nitrat ve mikrobiyal yüklerin özellikle buzağılarda mortalite artışı ile ilişkili olabileceği belirlenmiştir. Tüm bu sonuçlar, içme suyunda kimyasal ve mikrobiyolojik parametrelerin düzenli analizlerle izlenmesi gerektiğini ortaya koymaktadır.

2. SU KALİTESİ PARAMETRELERİ

2.1. Organoleptik özellikler bağlamında ruminant içme suyu kalitesi

Ruminantların içme suyu kalitesinde organoleptik özellikler — yani **tat, koku, renk ve berraklık** — önemli bir belirleyici faktördür. Tulu ve ark. (2024)'nın kurak ve yarı kurak bölgelerde su kalitesini inceledikleri derleme çalışmasında, suyun duyusal özelliklerinin (örneğin hoş olmayan tat veya koku) hayvanların su tüketiminde belirleyici rol oynadığı vurgulanmıştır. Benzer biçimde, *Water Quality for Dairy Cattle* rehberinde (University of Arkansas, 2023), süt sığırlarının hoş olmayan tat ve kokuya sahip suları içmekten kaçınabileceği, bu durumun ise su tüketimini ve dolayısıyla yem alımını azaltarak üretim performansına olumsuz yansıyabileceği belirtilmiştir.

Çiftliklerde yapılan saha çalışmalarında da, su örneklerinde **renk, bulanıklık ve koku gibi organoleptik parametreler** incelenmiş ve bu özelliklerin hayvanların suya olan isteğini doğrudan etkileyebileceği ortaya konmuştur (Soares ve ark., 2024). Ayrıca, son yıllarda yapılan çalışmalar, **alg patlamaları, fenolik bileşikler ve mikroplastik kirliliğinin** de suyun tat ve kokusunu değiştirerek ruminantların su tüketiminde kısıtlamalara yol açabileceğini göstermiştir (Wolfe, 2021).

Tüm bu bulgular, içme suyu kalitesinin yalnızca kimyasal ve mikrobiyolojik değil, aynı zamanda **duyusal nitelikleriyle de düzenli olarak değerlendirilmesi gerektiğini** göstermektedir. Bu bağlamda, organoleptik özelliklerin rutin izlenmesi, ruminantların **su tüketim davranışlarını optimize etme, yemden yararlanmayı artırma ve refah koşullarını iyileştirme** açısından kritik öneme sahiptir.

2.2. Suyun fizikokimyasal özellikleri ve ruminantlarda önemi

İçme suyunun fizikokimyasal özellikleri — **pH, toplam çözünmüş maddeler (TDS), elektriksel iletkenlik, sertlik, klorür, sülfat, nitrat gibi iyon konsantrasyonları ve sıcaklık** gibi parametreler — ruminantların su tüketimini, sağlık durumunu ve üretim performansını doğrudan etkilemektedir.

Kibara ve ark. (2023) tarafından yürütülen saha çalışmasında, buzağı ölüm nedenleri ile suyun pH, TDS, sertlik, klorür, nitrat ve sülfat gibi parametreleri arasında anlamlı korelasyonlar bulunmuş; özellikle **nitrat düzeyi en güçlü yordayıcı** olarak rapor edilmiştir. Aynı araştırma grubunun 2025 yılında yayımladığı başka bir çalışmada da, farklı kimyasal ölçütlerin (örneğin TDS, sertlik, sülfat) hayvan mortalitesi ile yakından ilişkili olduğu vurgulanmıştır (Kamal ve ark., 2025).

ABD'de yürütülen *Water Quality for Livestock Across Oklahoma and Texas* çalışmasında (Congio ve ark., 2025), 72 gölet su örneği incelenmiş; suyun kimyasal bileşiminin özellikle iyonik içerik açısından bölgesel farklılıklar gösterdiği bildirilmiştir. Benzer şekilde, Chamberlain ve Sinclair, (2023) tarafından yapılan bir değerlendirmede, su örneklerinin pH, iletkenlik, TDS ve bulanıklık gibi fiziksel-kimyasal parametrelerinin çoğunlukla kabul edilebilir sınırlar içinde olduğu; ancak bazı örneklerde **kontaminasyon izlerine** rastlandığı rapor edilmiştir.

Tulu ve ark. (2024) ise kurak ve yarı kurak bölgelerde yaptıkları derlemede, **yüksek iyonik yüklerin yem tüketimini azalttığını, büyüme verimliliğini düşürdüğünü ve metabolik stres oluşturduğunu** bildirmiştir. Son dönemde literatür, özellikle **yüksek TDS ve sülfat düzeylerinin rumen mikroflorasında dengesizlik, mineral emiliminde bozulma ve suyun lezzetliliğinde azalma** gibi olumsuz etkiler yaratabileceğini vurgulamaktadır (De Camillis ve ark., 2023).

Bu bulgular birlikte değerlendirildiğinde, içme suyunun fizikokimyasal dengesinin bozulması, ruminantlarda **su alımını azaltmakta, iyonik stres yaratmakta ve sonuç olarak verim, sağlık ve refah parametrelerinde olumsuzluklara** yol açabilmektedir. Dolayısıyla fizikokimyasal kalite parametrelerinin düzenli olarak izlenmesi, hem **hayvan sağlığının korunması** hem de **sürdürülebilir üretimin sağlanması** açısından kritik önemdedir.

2.3. Toplam çözünmüş madde (TDS), tuzluluk ve ruminantlarda önemi

Toplam çözünmüş madde (TDS), içme suyundaki **iyonik ve organik çözeltilerin toplamını** ifade eden temel bir fizikokimyasal parametredir. Son yıllarda yapılan çalışmalar, TDS düzeylerinin ruminantların **su tüketimi, yem alımı, sindirim süreçleri, metabolik dengeleri ve verim performansı** üzerinde belirleyici rol oynadığını göstermektedir.

Patra ve ark. (2023), farklı TDS konsantrasyonlarına sahip suların keçi ve koyunlarda **yem alımı, besin madde sindirimi, enerjetik denge, metan emisyonu, rumen fermentasyonu ve kan bileşenleri** üzerindeki etkilerini karşılaştırmış; 8300 mg/kg'ye kadar olan TDS seviyelerinde olumsuz etkilerin sınırlı olduğunu, ancak daha yüksek düzeylerde metabolik stresin ve performans kayıplarının ortaya çıktığını rapor etmiştir. Benzer şekilde, Patra (2024) tarafından yürütülen bir çalışmada, çözünmüş tuzların bileşimi ve konsantrasyonu artırıldığında **su tüketiminde değişimler, plazma elektrolit dengesinde kaymalar ve rumen fermentasyonunda bozulmalar** gözlenmiştir.

Kamal ve ark. (2025), içme suyu kalitesi parametrelerini inceledikleri çalışmada, özellikle **TDS düzeyleri ile hayvansal performans göstergeleri** arasında anlamlı korelasyonlar bulmuş; yüksek TDS'nin canlı ağırlık artışı, süt verimi ve buzağı yaşama gücü üzerinde olumsuz etkiler yaratabileceğini belirtmiştir.

Tulu ve ark. (2024)'nın derlemesinde ise, TDS'nin **1000 ppm altındaki düzeylerinin genellikle güvenli** olduğu; ancak **3000 ppm'in üzerindeki konsantrasyonlarda yem alımı ve su tüketiminde düşüşler, iyonik stres ve mineral metabolizmasında bozulmalar** görülebileceği vurgulanmıştır. Ayrıca, yalnızca TDS'nin toplam miktarı değil, suyun içerdiği iyonların türü ve oranı da kritik öneme sahiptir. Özellikle **Na^+, Cl^- ve SO_4^{2-} iyonlarının yüksek düzeyleri**, hayvanlarda laksatif etkilere, iştah azalmasına ve elektrolit dengesizliklerine neden olabilmektedir.

Tüm bu bulgular, ruminantlarda içme suyu yönetiminde TDS'nin yalnızca **toplam miktarının değil**, aynı zamanda **bileşimsel özelliklerinin** (özellikle tuz tiplerinin) düzenli olarak izlenmesi gerektiğini ortaya koymaktadır.

2.4. Suyun Asitliği (pH) ve ruminantlar

İçme suyunun pH değeri, ruminantların **su tüketimi, metabolik dengeleri ve genel fizyolojik fonksiyonları** açısından kritik bir parametredir. University of Tennessee (2023) tarafından hazırlanan *Water Quality for Beef Cattle* rehberinde, sığırlar için ideal pH aralığının **6,5–8,5** olduğu, 5'in altındaki veya 9'un üzerindeki değerlerin ise su tüketiminde azalmaya, yem alımında kısıtlanmaya ve dolayısıyla üretim performansında bozulmalara yol açabileceği belirtilmektedir.

Kamal ve ark. (2024), buzağı ölümleri üzerine yaptıkları saha çalışmasında pH ile birlikte TDS, sülfat ve nitrat gibi parametreleri de değerlendirmiş ve **pH sapmalarının neonatal mortalite riskini artırabileceğini** rapor etmiştir. Benzer şekilde, Tulu ve ark. (2024) tarafından yapılan derlemede, suyun düşük veya yüksek pH değerlerinin **iyon dengesini bozarak mineral metabolizmasını olumsuz etkilediği** ve yem-su etkileşimlerini zayıflattığı bildirilmiştir.

Son dönem çalışmalarda, pH'nın yalnızca su kalitesiyle sınırlı kalmadığı, aynı zamanda **rumen ekosistemi ile etkileşim halinde olduğu** da gösterilmiştir. Iritz ve ark. (2025), süt ineklerinde tuzlu içme suyunun rumen pH'sı üzerinde etkili olduğunu; yüksek tuzluluk koşullarında rumen pH'sında artış eğilimi gözlendiğini ortaya koymuştur. Bu durum, **su pH'sı ile rumen fermantasyonu arasındaki bağlantının** önemini göstermektedir.

Dolayısıyla, içme suyunun asitliği yalnızca **kimyasal kalite parametresi** olarak değil, aynı zamanda **fizyolojik, metabolik ve davranışsal düzeylerde etkileri olan bütüncül bir faktör** olarak ele alınmalıdır. Düzenli su pH ölçümleri, ruminant sağlığının ve üretim verimliliğinin korunması için kritik bir izleme aracı olarak öne çıkmaktadır.

2.5. Suyun tuzluluğu ve ruminantlarda önemi

Ruminantların içme sularındaki **tuzluluk düzeyi (salinite)**, hem üretim performansı hem de sağlık açısından kritik bir parametredir. Iritz ve ark. (2025)'ın çalışmasına göre, yüksek tuzluluk düzeyine sahip sular süt ineklerinde **su tüketimini artırmakla birlikte lif sindirimini olumsuz etkileyebilmektedir**. Abera ve ark. (2024) ise Somali keçileri ve Blackhead Ogaden koyunlarında **11 g/L TDS'nin üzerindeki tuzlu su tüketiminin karkas ağırlığı, sakatat oranları ve et kalitesi parametrelerinde düşüşlere** yol açtığını bildirmiştir.

Patra (2024), farklı tuzluluk düzeylerine sahip suların **yem alımı, enerji dengesi, rumen fermentasyonu ve kan biyokimyası** üzerindeki etkilerini incelemiş ve hayvanların tuzluluğa karşı belirli bir adaptasyon kapasitesine sahip olduğunu, ancak bu kapasitenin sınırları aştığında **iyonik stres, iştah azalması ve mineral metabolizmasında bozulmaların** ortaya çıktığını vurgulamıştır. Benzer şekilde, Nguyen ve ark. (2024), süt ineklerinde sulandırılmış deniz suyu uygulamalarıyla yapılan deneylerde, artan tuzluluğun **su ve yem davranışlarını değiştirdiğini** ve özellikle belirli eşik değerler aşıldığında **performans kayıpları ve fizyolojik stres** yarattığını göstermiştir.

Tulu ve ark. (2025), pastoral üretim sistemlerinde yaptıkları çalışmada, yüksek tuzluluğun küçükbaş hayvanlarda **su alımı, elektrolit dengesi, yem kullanımı ve verim parametreleri** üzerinde sınırlandırıcı bir etkiye sahip olduğunu belirtmiştir. Güncel literatür ayrıca, tuzluluğun yalnızca toplam TDS düzeyine bağlı olmadığını; **Na^+, Cl^-, SO_4^{2-} ve Mg^{2+} iyonlarının oranları** gibi suyun bileşimsel farklılıklarının da hayvan sağlığı üzerinde farklı etkilere sahip olduğunu ortaya koymaktadır.

İçme sularındaki tuzluluk yalnızca **su miktarı** üzerinden değil, aynı zamanda **iyonik bileşim ve hayvanın adaptasyon kapasitesi** göz önünde bulundurularak değerlendirilmelidir. Bu parametrelerin düzenli takibi, **performans kayıplarını önlemek ve sağlık sorunlarını azaltmak** açısından önemlidir.

2.6. Suyun Sertliği ve ruminantlarda önemi

Suyun sertliği, **kalsiyum (Ca^{2+}) ve magnezyum (Mg^{2+}) iyonlarının derişimiyle** tanımlanmakta olup, ruminantlarda hem fizyolojik hem de üretim performansı açısından önemli bir parametredir. University of Tennessee (2023) tarafından hazırlanan rehberde, **500 mg/L'ye kadar olan sertliğin genellikle güvenli** olduğu, ancak bu sınırın üzerindeki değerlerin özellikle genç hayvanlarda **ishal, su tüketiminde azalma ve büyüme performansında gerilemeye** yol açabileceği belirtilmektedir.

Kamal ve ark. (2024), saha çalışmalarında yüksek sertlik değerlerine sahip sularda **buzağılarda mortalite oranlarının arttığını** ve sertliğin özellikle **TDS ve nitrat gibi diğer parametrelerle birlikte** değerlendirilmesi gerektiğini rapor etmiştir. Benzer şekilde, Tulu ve ark. (2024)'nın derlemesinde, kurak ve yarı kurak bölgelerde yüksek sertliğin **mineral dengesizlikleri yoluyla yemden yararlanmayı azalttığı, süt verimini düşürdüğü ve metabolik stres oluşturabileceği** vurgulanmıştır.

Chamberlain ve Sinclair, (2023), hayvan çiftliklerinden aldıkları içme suyu örneklerinde pH, TDS ve sertlik parametrelerini ölçmüş; bazı örneklerde sertlik değerlerinin kabul edilebilir sınırları aştığını ve bunun hayvan sağlığı için **potansiyel risk faktörü** oluşturabileceğini bildirmiştir. Güncel literatür, yüksek su sertliğinin yalnızca **su lezzetliliğini ve tüketim davranışını** etkilemekle kalmadığını, aynı zamanda **elektrolit dengesi, mineral emilimi (özellikle Ca ve Mg) ve metabolik süreçler** üzerinde de etkili olduğunu ortaya koymaktadır (Wolfe, 2021).

Bulgular, sertliğin yalnızca bir kimyasal parametre değil, aynı zamanda **hayvan sağlığı, üretim performansı ve refahını doğrudan etkileyen kritik bir unsur** olduğunu göstermektedir. Bu nedenle, içme suyu yönetiminde sertlik değerlerinin düzenli olarak izlenmesi ve gerektiğinde suyun arıtılması sürdürülebilir hayvancılık için gereklidir.

2.7. Nitratlar ve ruminantlarda önemi

Ruminantların içme sularında **nitrat (NO_3^-)** ve **nitrit (NO_2^-)** düzeyleri, özellikle rumende gerçekleşen mikrobiyal indirgeme süreçleri nedeniyle kritik öneme sahiptir. Aşırı nitrat alımı, nitrit birikimine ve bunun sonucunda **methemoglobin oluşumuna** yol açarak oksijen taşınmasını sınırlamakta ve akut ya da kronik **nitrat/nitrit zehirlenmelerine** neden olabilmektedir.

Llonch ve ark. (2024), sütçü-etçi sığırlar üzerinde yaptıkları uzun süreli deneysel çalışmada, içme suyunda **220 mg/L NO_3^- seviyesine kadar beş aylık bir dönemde herhangi bir olumsuz etki gözlenmediğini**; sağlık, yem tüketimi ve rumen fermentasyon parametrelerinin stabil kaldığını rapor etmişlerdir. Bununla birlikte, araştırmacılar **rasyon bileşiminin, özellikle konsantre yem düzeyinin nitrat toleransını etkileyebileceğini** vurgulamışlardır.

Kamal ve ark. (2024), saha çalışmalarında buzağı ölümlerini analiz etmiş ve **nitrat, sülfat ve TDS** gibi parametreler arasında özellikle **yüksek nitrat düzeylerinin mortalite için en güçlü yordayıcı** olduğunu bildirmiştir. Benzer şekilde, Tulu ve ark. (2024) yaptıkları derlemede, kurak bölgelerde sulardaki nitrat kirliliğinin özellikle **yoğun gübre uygulamaları ve yüzey sularındaki tarımsal akışa** bağlı olarak arttığını, bunun da **yem tüketimi ve verimlilik üzerinde sınırlayıcı etkiler** yaratabileceğini belirtmiştir.

University of Tennessee (2023) tarafından hazırlanan rehberde ise, sığırlar için güvenli kabul edilen **üst sınırın yaklaşık 100–200 mg/L NO_3^-** olduğu; bu seviyelerin aşılması durumunda özellikle **genç hayvanlarda methemoglobinemi ve ani ölümler** gibi ciddi riskler ortaya çıkabileceği belirtilmektedir. Güncel literatür ayrıca, nitratın **subklinik düzeylerde dahi yem**

tüketiminde azalma, rumen mikrobiyal aktivitesinde bozulma ve üreme performansında düşüş ile ilişkili olabileceğini göstermektedir (Llonch ve ark., 2024).

Son çalışmalar, nitratın yalnızca **su kalitesinde izlenmesi gereken temel bir parametre** olmakla kalmadığını, aynı zamanda **yem bileşimi ve çevresel kirlilik kaynaklarıyla birlikte** ele alınması gerektiğini ortaya koymaktadır. Düzenli nitrat analizleri, ruminant sağlığının ve üretim verimliliğinin korunması açısından kritik önemdedir.

2.8. Sülfür ve sülfatların ruminantlarda etkisi

İçme suyundaki **sülfat (SO_4^{2-}) düzeyi**, ruminantların **su ve yem tüketimi, mineral dengesi, sinir sistemi sağlığı ve performansı** üzerinde belirleyici bir rol oynamaktadır. Wyffels ve ark. (2023), farklı sülfat konsantrasyonlarının besleme alanında su ve yem alımı, sindirilebilirlik ve rumen fermentasyon parametreleri üzerindeki etkilerini incelemiş; yüksek sülfatlı sularda **su tüketiminde artış gözlenirken, yem tüketimi ve besleme verimliliğinde olumsuzluklar** rapor edilmiştir.

Evans ve ark. (2023), etçi danalar üzerinde yürüttükleri çalışmada, sodyum sülfattan zenginleştirilmiş içme sularında **sülfat konsantrasyonu arttıkça su tüketiminin lineer olarak arttığını, ancak kuru madde alımının (DMI) değişmediğini** bildirmişlerdir. Bununla birlikte artan sülfat yükü, rumende **hidrojen sülfür (H_2S) üretimini teşvik ederek toksisite riskine** yol açabilmektedir. H_2S birikimi özellikle rumende gaz fazında toksik etkilere neden olabilir ve **polioensefalomalasi (PEM)** gibi sinir sistemi bozukluklarıyla bağlantılıdır (Malyugina, 2023).

Sülfat içeriği yüksek suyun **hoş olmayan tadı** hayvanların su tüketimini kısıtlayabilir (MSU Extension, 2022). Ayrıca, **su ve yem kaynaklarında yüksek sülfat kombinasyonu**, özellikle **bakır (Cu) metabolizmasını bozarak sekonder bakır eksikliğine** neden olabilmektedir. Bu durum, performans kayıpları, bağışıklık sisteminde zayıflama ve üreme problemleri ile ilişkilendirilmektedir (Evans ve ark., 2023).

Montana State University Extension rehberinde, sülfat konsantrasyonlarının **500 mg/L altında tutulmasının güvenli olduğu, 1.000 mg/L ve üzerindeki seviyelerin ise ishal, performans düşüşü ve sinir sistemi bozuklukları (örneğin PEM) riskini artırdığı** belirtilmektedir. 2024 sonrası literatür de, özellikle kurak bölgelerde **yüksek sülfatlı yeraltı sularının** artan risk faktörü olduğuna işaret etmektedir (Tulu ve ark., 2024).

Dolayısıyla, sülfat düzeylerinin düzenli izlenmesi ve yem-su kombinasyonunun mineral metabolizması üzerindeki etkileşimlerinin dikkate alınması, ruminant sağlığı ve üretim verimliliği açısından kritik bir önlemdir.

2.9. Ağır metaller ve element toksisiteleri (Pb, Cd, As, Al, Fe, Mn vb.)

Ruminantların içme sularında **ağır metallerin varlığı,** özellikle **kurşun (Pb), kadmiyum (Cd), arsenik (As), cıva (Hg) ve krom (Cr)** gibi elementler, hem sağlık hem de üretim performansı açısından ciddi riskler taşımaktadır. Bu elementler su kaynaklarına genellikle **jeolojik yapı, endüstriyel faaliyetler, tarımsal uygulamalar (pestisit, gübre) ve maden işletmeleri** aracılığıyla ulaşmaktadır.

Soares ve ark. (2023), Portekiz'de süt sığırı işletmelerinden alınan su örneklerinde mikrobiyolojik parametrelerle birlikte ağır metal düzeylerini de incelemiş ve bazı çiftliklerde **arsenik ve kurşun gibi elementlerin sınır değerlere yakın olduğunu** rapor etmiştir. Kamal ve ark. (2024), saha çalışmasında buzağı mortaliteleri ile su kalitesi parametreleri arasındaki ilişkiyi incelemiş; özellikle **arsenik ve kadmiyum varlığının mortalite riskini artırabileceğini** ortaya koymuştur.

Tulu ve ark. (2024) tarafından yapılan derlemede, **kurak ve yarı kurak bölgelerde jeolojik yapı ve antropojenik kirlilik kaynaklarının** yeraltı sularında ağır metal birikimini artırabileceği; bunun da **yem tüketimi, büyüme performansı ve üreme sağlığı** üzerinde olumsuz etkilere yol açtığı vurgulanmıştır. Chamberlain ve Sinclair, (2023) ise çiftliklerde yaptıkları su kalite analizlerinde özellikle **Cd ve Pb gibi ağır metallerin toksik potansiyel taşıdığını**, bu nedenle düzenli kimyasal analizlerin yapılmasının zorunlu olduğunu bildirmiştir.

Güncel literatür ayrıca ağır metallerin yalnızca akut toksisiteye değil, aynı zamanda **kronik ve subklinik etkilerle** de ilişkili olduğunu göstermektedir. Örneğin düşük dozda arsenik alımı, **karaciğer ve böbrek fonksiyon bozuklukları, oksidatif stres artışı ve bağışıklık sisteminde zayıflama** ile bağlantılı bulunmuştur. Kadmiyumun ise **Ca ve Zn metabolizmasını bozarak kemik sağlığı ve üreme performansını** olumsuz etkileyebileceği rapor edilmiştir (Chowdhury, 2025).

Bu bulgular, ruminant yetiştiriciliğinde ağır metallerin düşük düzeylerde bile **kümülatif ve kronik etkilere** yol açabileceğini ve suyun düzenli analizlerle sürekli izlenmesi gerektiğini ortaya koymaktadır.

3. KİRLETİCİLER VE RİSK FAKTÖRLERİ

3.1. Mikrobiyolojik kalite ve antimikrobiyal direnç riski

Ruminant işletmelerinde içme suyunun **mikrobiyolojik kalitesi**, başlıca **toplam koliformlar, fekal koliform/*Escherichia coli* ve enterokok düzeyleri** üzerinden değerlendirilmekte olup; bu kalite, suluk hijyeni, suyun kaynağı ve çevresel/iklimsel koşullara bağlı olarak değişkenlik göstermektedir.

Soares ve ark. (2023), Portekiz'de süt sığırı işletmelerinde yaptıkları saha çalışmasında, sulardan sıklıkla **koliformlar ve *Enterococcus* spp.** izole etmiş; mikrobiyolojik kalitede **işletme hijyeni ve dezenfeksiyon uygulamalarının belirleyici** olduğunu ortaya koymuştur. Burkhardt ve ark. (2024), ticari bir sürüde **8.000'den fazla içme epizodunu** izledikleri çalışmalarında, **çevre sıcaklıklarının artışıyla birlikte hem su tüketiminin hem de yalaklardaki mikrobiyal çoğalma riskinin arttığını** bildirmiştir. Aynı çalışmada, **yalak tipi ve temizlik sıklığının** mikrobiyolojik kalite üzerinde kritik etkiye sahip olduğu vurgulanmıştır.

Douglas ve Pandey, (2025), süt sığırlarının içme sularında **yüksek nitrat yüküyle birlikte bakteriyel yükün de arttığını**, özellikle buzağılar için koliform eşiklerinin düşük tutulması gerektiğini belirtmiştir. Nitekim Kamal ve ark. (2024), saha verilerinde **buzağı mortalitesiyle suyun mikrobiyolojik parametreleri arasında anlamlı ilişkiler** bulmuştur. Silva ve ark. (2025) ise çiftlik ölçeğinde **mikrobiyolojik kalite izlemesinin (özellikle suluklardaki biyofilm oluşumunun) düzenli ve şematik şekilde yapılmasının** zorunlu olduğunu güncel verilerle ortaya koymuştur.

Güncel literatürde öne çıkan bir diğer risk de **antimikrobiyal direnç (AMR)** faktörüdür. Mikrobiyal açıdan kontamine olmuş sularda, özellikle **Enterobacteriaceae üyelerinin ve *Enterococcus* spp.'nin** çoklu antibiyotik direnç genleri taşıyabildiği gösterilmiştir (Pandey ve ark., 2024). Bu durum yalnızca hayvan sağlığını değil, aynı zamanda **One Health perspektifi** bağlamında insan sağlığını da tehdit etmektedir.

Dolayısıyla, ruminant işletmelerinde içme suyu kalitesinin yalnızca **koliform sayımıyla değil, antimikrobiyal direnç göstergeleriyle birlikte** düzenli olarak değerlendirilmesi; suluk biyofilmlerinin izlenmesi ve mevsimsel risk faktörlerinin göz önünde bulundurulması, sürdürülebilir hayvancılık ve gıda güvenliği açısından kritik bir gerekliliktir.

3.2. Pestisitler, ilaç kalıntıları ve yeni ortaya çıkan kirleticiler (PFAS odağı)

Pestisitlerin **tarımsal drenaj ve yüzey akışıyla su kaynaklarına taşınması**, ruminant içme suyu açısından önemli bir **kronik maruziyet riski** oluşturmaktadır. Son yıllarda yapılan çalışmalar, ruminant performans göstergeleri ile suyun kimyasal kalitesi arasındaki bağlantıları daha net ortaya koymuştur (Kamal ve ark., 2025). Pestisit kalıntılarının uzun vadeli etkileri yalnızca **yem tüketimi ve büyüme performansını** etkilemekle kalmamakta, aynı zamanda **üreme ve bağışıklık fonksiyonları** üzerinde de baskı yaratabilmektedir.

Emerging kirleticiler son zamanlarda konu edinmeye başlayan bu kavram, Bu başlıkta özellikle **kalıcı organik florlu maddeler (PFAS: Per- and Polyfluoroalkyl Substances)** öne çıkmaktadır. PFAS bileşikleri, **biyobirikim potansiyeli yüksek, yarı ömürleri uzun ve çevrede kalıcılık gösteren emerging kirleticiler** arasında yer almaktadır. Wanjala ve ark. (2025), yaşam boyu PFAS'a maruz kalan süt sığırlarında **kanda ve deride anlamlı birikim** rapor etmiştir. Mikkonen ve ark. (2023) ile Edhlund ve ark. (2025), özellikle **perfluorooktansülfonik asit (PFOS)** için günlük birikim ve dokulara geçişi öngören modeller geliştirmiş, bu modellerin **gıda güvenliği risk değerlendirmelerinde kullanılabileceğini** belirtmiştir.

Yeni ortaya çıkan kirleticiler, klasik kirleticiler dışında kalan, çevrede yeni fark edilen, toksikolojik etkileri tam bilinmeyen veya mevzuatta henüz düzenlenmemiş maddeleri kapsar. Bunlar genellikle şunlardır (Li ve ark., 2024).

- **Farmasötikler ve kişisel bakım ürünleri (PPCPs)**
  - İlaç kalıntıları (antibiyotik, analjezik, antidepresan vb.)
  - Kozmetik ürün bileşenleri (parabenler, UV filtreleri vb.)
- **Endokrin bozucular**
  - Bisfenol A (BPA)
  - Ftalatlar
  - Nonilfenoller
- **Mikro kirleticiler**
  - Mikroplastikler, nanoplastikler
  - Sentetik elyaf parçacıkları
- **Yeni tarım ve endüstri kaynaklı kimyasallar**
  - Yeni nesil pestisitler ve herbisitler
  - Per- ve polifloroalkil maddeler (PFAS, "forever chemicals")
- **Biyolojik kirleticiler**
  - Antibiyotik direnç genleri ve dirençli bakteriler
  - Yeni patojenik mikroorganizmalar
- **Diğer emerging gruplar**
  - Yan ürünler (ör. dezenfeksiyon yan ürünleri – DBPs)
  - Yangın geciktiriciler (polibromlu difenil eterler)
  - Tat–koku veren yeni organik bileşikler (Li ve ark., 2024; Pandey ve ark., 2024; Lupton ve ark., 2025).

Mikkonen ve ark. (2025), çiftlik koşullarında PFAS'ın **yem-su-toprak rotaları** üzerinden dinamik bir maruziyet paterni oluşturduğunu; hayvanların **kirlenmemiş su kaynağına erişim sağladığında kısmi eliminasyon** gösterebildiğini ortaya koymuştur. Bu bulgular, maruziyetin sürekli izlenmesi gerektiğini ve **biyobirikim riskinin çevresel koşullara bağlı olarak değişebileceğini** göstermektedir.

Resmî belgeler de bu konuda paralel uyarılar yapmaktadır. Minnesota Tarım Dairesi (2023), ve USDA-ARS (2024) raporlarında, sığırlarda PFAS'ın **su ve yem yoluyla birikebildiği, süte geçebildiği ve insan sağlığı açısından risk oluşturabileceği** belirtilmiştir. Aynı raporlarda, PFAS için **plazma tabanlı arıtma teknolojileri, adsorban bazlı sistemler ve ileri oksidasyon yöntemleri** gibi yeni nesil çözümler üzerinde çalışıldığı vurgulanmıştır. Bu bulgular, pestisit kalıntıları ve PFAS'ın ruminant içme suyunda **izlenmesi gereken yeni "zorunlu parametreler"** haline geldiğini ortaya koymaktadır. Bu durum yalnızca **hayvan sağlığı** için değil, aynı zamanda **ürün güvenliği ve tüketici sağlığı** açısından da kritik önemdedir (Lupton ve ark., 2025).

3.3. Alg ve siyanotoksinler: iklim değişikliği ile ilişkisi

Eutrofik koşullarda siyanobakteri artışı, ruminantların içme sularında **mikrosistinler, anatoksinler ve silindrospermopsin** gibi toksinlerin birikmesine yol açabilmekte, bu da uzun süreli **subklinik ve klinik etkiler** oluşturabilmektedir. Özellikle **mikrosistin-LR**, karaciğer üzerine güçlü hepatotoksik etkileriyle öne çıkmakta ve **oksidatif stres, histopatolojik bozulmalar ve üretim kayıpları** ile ilişkilendirilmektedir.

Bensalem ve ark. (2025), Cezayir'de Ramsar alanındaki sığır sürülerinde yürüttükleri çalışmada, **kronik mikrosistin maruziyetinin biyokimyasal, histolojik ve oksidatif stres göstergeleri üzerinden hayvan sağlığını olumsuz etkilediğini** raporlamıştır. Rodríguez Uro ve ark. (2024), Yüksek And havzasındaki barajlarda **toksijenik siyanobakteri ve siyanotoksin varlığını doğrulamış** ve bu durumun hem sulama hem de hayvan içme suyu için **risk yönetimi** gerektirdiğini vurgulamıştır.

Douglas ve Pandey, (2025) ise süt sığırlarında, içme suyunda **yüksek nitrat ve bakteriyel yükün alg gelişimi için uygun ortam yarattığını,** bunun da hem **duyusal riskleri (tat, koku, bulanıklık)** hem de **toksik etkileri** artırabileceğini ortaya koymuştur. Bu bulgular, suyun yalnızca kimyasal ve mikrobiyolojik değil, aynı zamanda **fitoplanktonik dinamikler** açısından da düzenli değerlendirilmesi gerektiğini göstermektedir.

İklim değişikliği, artan **sıcaklık ve düzensiz yağış rejimleri** yoluyla yüzey sularında **alg patlamaları** daha sık ve yoğun hale getirmektedir (Igwaran ve ark., 2024). Bu nedenle, ruminant içme suyu yönetiminde özellikle sıcak mevsimlerde **siyanotoksin taraması (ör. mikrosistin-LR) ve görsel alg izleme protokollerinin** uygulanması önerilmektedir (Bensalem ve ark., 2025).

3.4. Organik kirleticiler: fenoller, deterjanlar, mikro/nano plastikler ve farmasötikler

Ruminant içme sularında fenolik bileşikler ve deterjan kalıntıları gibi organik kirleticiler suyun tat-koku profilini bozarak tüketimi azaltabilir ve subklinik toksisite riskini yükseltebilir; güncel saha rehberleri bu tür organik kirlenmelerin performansı baskılayabileceğini belirtir (University of Tennessee, 2023). Emerging kirleticiler arasında mikroplastikler ve PFAS'lar öne çıkmaktadır: ruminantlarda plastik partiküllerinin emilimi sınırlı görünmekle birlikte iz miktarlarının süte çıkışı deneysel koşullarda gösterilmiştir (USDA-ARS, 2024). PFAS'ların su/yem yoluyla alınması ve sığır sütüne geçişi, hayvan ve insan sağlığı açısından çok disiplinli izlem gerektirmektedir (Wanjala ve ark., 2025; Minnesota Tarım Dairesi, 2023; Edhlund ve ark., 2025). Bu çerçevede, ruminant su kalitesi programlarına organik kirletici taramaları

(fenoller/deterjanlar için hedef bileşikler; PFAS için panel bazlı analiz) eklenmesi önerilmektedir (Kamal ve ark., 2025; Lupton ve ark., 2025).

4. RUMİNANT İÇME SULARINDA GÜNCEL YAKLAŞIMLAR

4.1. İçme suyu kalitesi, ruminant refahı ve davranışsal göstergeler

İçme suyu kalitesi, ruminantlarda yalnızca **fizyolojik sağlık ve üretim performansını** değil, aynı zamanda **hayvan refahını** ve **davranışsal yanıtları** da doğrudan etkilemektedir. Suyun **tat, koku, bulanıklık, mineral yükü ve mikrobiyal kontaminasyonu**, hayvanların suya ulaşma motivasyonunu, su içme davranışını ve yem tüketim paternlerini değiştirebilmektedir (Pandey ve ark., 2025).

Davranışsal göstergeler

Düşük kaliteli suyun sunulduğu sürülerde yapılan gözlemlerde, hayvanların **su yalaklarına erişim için rekabet ettiği, içme süresinin uzadığı, yem tüketiminde azalma görüldüğü ve geviş getirme süresinin kısaldığı** bildirilmiştir (Burkhardt ve ark., 2024). Bu tür davranışsal değişimler, hayvan refahının bozulduğuna dair **erken uyarı göstergeleri** olarak kabul edilmektedir.

Stres ve fizyolojik yanıtlar

Su kalitesi ile **stres biyobelirteçleri** arasında güçlü bir ilişki vardır. Özellikle yüksek TDS, sülfat veya nitrat yüküne sahip sularda yetiştirilen hayvanlarda **kortizol düzeylerinde yükselme, oksidatif stres belirteçlerinde artış** ve **bağışıklık fonksiyonunda zayıflama** rapor edilmiştir (Malyugina, 2023). Bu durum, içme suyu kalitesinin sadece metabolik değil, aynı zamanda **refah temelli bir parametre** olduğunu göstermektedir.

Refah protokollerinde içme suyu

Dünya Hayvan Sağlığı Örgütü (WOAH, 2024) ve Avrupa Gıda Güvenliği Otoritesi (EFSA, 2025) tarafından yayımlanan refah protokollerinde, **hayvanların sürekli, temiz ve uygun suya erişimi**, refahın temel kriterlerinden biri olarak tanımlanmaktadır. Bu nedenle**, su kalitesi izleme sonuçlarının refah değerlendirme protokollerine dahil edilmesi** önerilmektedir. Örneğin, davranışsal göstergeler (su yalaklarında bekleme süresi, suya yaklaşma sıklığı) ile suyun kimyasal/mikrobiyolojik parametreleri birlikte analiz edilerek **refah odaklı izleme sistemleri** geliştirilmektedir (Silva ve ark., 2025).

4.2. Dijital teknolojiler ve su kalitesi izleme (IoT, NIR, yapay zekâ destekli modeller)

Ruminant yetiştiriciliğinde içme suyu kalitesinin düzenli ve doğru izlenmesi, hem **hayvan sağlığı ve performansı** hem de **sürdürülebilir üretim** açısından kritik öneme sahiptir. Geleneksel laboratuvar analizleri çoğunlukla **yüksek maliyetli, zaman alıcı ve kesintili ölçümler** sunmaktadır. Son yıllarda dijital teknolojiler (IoT sensörleri, yakın kızılötesi spektroskopi – NIR, yapay zekâ tabanlı modellemeler) bu alanda **devrimsel çözümler** olarak öne çıkmaktadır.

IoT tabanlı sensör sistemleri

IoT destekli su kalite sensörleri, **pH, sıcaklık, çözünmüş oksijen, iletkenlik ve TDS gibi parametreleri gerçek zamanlı olarak ölçerek** çiftlik yönetim yazılımlarına entegre edilebilmektedir. Bu sistemler, **uzaktan erişim ve erken uyarı mekanizmaları** sayesinde, su kalitesindeki ani değişimlerin hayvan sağlığına yansımadan kontrol edilmesine olanak sağlamaktadır (Posam ve Vidhyapathi, 2025).

NIR spektroskopisi ve taşınabilir cihazlar

Yakın kızılötesi (NIR) spektroskopisi, son dönemde **su örneklerinde nitrat, sülfat ve organik madde konsantrasyonlarını hızlı ve non-invaziv** şekilde belirlemek için kullanılmaktadır. Çiftlik koşullarında taşınabilir NIR cihazları ile yapılan analizler, **laboratuvar analizlerine benzer doğruluk oranları** vermektedir (Agiomavriti ve ark., 2025).

Yapay zekâ (AI) ve büyük veri analitiği

Makine öğrenmesi (ML) ve derin öğrenme (DL) algoritmaları, su kalitesine ilişkin **büyük veri setlerini analiz ederek kontaminasyon tahmin modelleri** geliştirmektedir. Bu modeller, **iklimsel veriler, gübre kullanımı, hidrolojik koşullar ve çiftlik içi sensör çıktıları** ile entegre edilerek, nitrat, ağır metal veya mikrobiyal kontaminasyon risklerini önceden tahmin edebilmektedir (Hardas ve Tomar, 2024).

Sürdürülebilirlik ve karar destek sistemleri

Dijital teknolojiler yalnızca izleme değil, aynı zamanda **karar destek mekanizmaları** da sunmaktadır. Blockchain tabanlı izlenebilirlik sistemleri ile su kalitesi kayıtları güvence altına alınabilmekte, **çiftlik düzeyinde sürdürülebilir su yönetimi stratejileri** geliştirilebilmektedir (FAO, 2024). Bu sayede hem **hayvan refahı ve verimliliği artırılmakta** hem de **tüketici güveni** güçlendirilmektedir.

4.3. Politika, düzenleme ve standartlar (FAO, WHO, EU ve Türkiye karşılaştırması)

Ruminant içme suyu kalitesi; farklı uluslararası kurumların, bölgesel otoritelerin ve ulusal mevzuatların kesişiminde şekillenen çok katmanlı bir düzenleme alanıdır. Bu alandaki temel referans noktaları **FAO, Dünya Sağlık Örgütü (WHO), Avrupa Birliği (AB)** ve **Türkiye**'deki ulusal standartlardır.

FAO (Food and Agriculture Organization of the United Nations), hayvancılıkta su kalitesi yönetimini hayvan sağlığı ve üretim performansı bağlamında ele alır. FAO'nun "*Water Quality for Agriculture*" başlıklı teknik rehberi, özellikle elektriksel iletkenlik, tuzluluk, nitrat ve sülfat düzeyleri için sınır değerler belirlemekte; 5 dS/m'nin üzerindeki iletkenliğin ruminantlarda performans kaybı riskini artırabileceğini bildirmektedir (FAO, 2019). Bu yaklaşım, suyun sadece toksikolojik değil **fizyolojik ve üretimsel etkilerini** de içermesi bakımından özgündür.

WHO (World Health Organization) ise su kalitesi politikalarını insan sağlığı odağında belirler. Nitrat, nitrit, florür ve arsenik gibi parametreler için bağlayıcı olmayan *Guidelines for Drinking-Water Quality* eşikleri tanımlar; ülkeler bu değerleri genellikle kendi içme suyu mevzuatlarına referans olarak alır (Andries ve ark., 2024). Hayvancılık için doğrudan WHO limiti bulunmamakla birlikte, birçok ülke bu değerleri dolaylı biçimde **hayvan içme suyu değerlendirmelerinde** de kullanmaktadır.

Avrupa Birliği (EU) düzeyinde, 2020/2184 sayılı *İçme Suyu Direktifi* içme suyu parametrelerini güncellemiş, özellikle **PFAS** (per- ve polifloroalkil maddeler) için iki yeni grup limit getirmiştir: "sum of 20 PFAS = 0.1 µg/L" ve "PFAS total = 0.5 µg/L" European Commission, 2020 (Andries ve ark., 2024). Üye ülkeler bu sınırları 12 Ocak 2026 itibarıyla uygulamakla yükümlüdür. Avrupa Çevre Ajansı (EEA, 2023) bu yeni politikaların su kaynaklı PFAS birikimini izleme ve azaltma açısından kritik bir dönüm noktası olduğunu vurgulamaktadır.

Türkiye'de ise ruminant içme suyu kalitesi için bağımsız bir düzenleme bulunmamakta; **TS 266 (İnsani Tüketim Amaçlı Sular Standardı) ve İnsani Tüketim Amaçlı Sular Hakkında Yönetmelik** esas alınmaktadır. Bu kapsamda pH, iletkenlik, nitrat gibi temel parametreler için WHO ve AB standartlarıyla uyumlu sınır değerler kullanılmakta, PFAS gibi yeni kirleticiler

konusunda ise AB'nin 2026 limitleriyle **uyumlaştırma süreci** devam etmektedir (Gazete, 2016; BfR, 2023).

Sonuç olarak, ruminant içme suyu kalitesi politikaları küresel ölçekte henüz tam bir bütünlük kazanmış değildir. FAO performans temelli; WHO insan sağlığı temelli; AB çevre ve kimyasal güvenlik temelli; Türkiye ise uyumlaştırma temelli bir yaklaşım benimsemektedir. Bu çok katmanlı yapı, özellikle PFAS ve diğer emerging kirleticiler açısından, hayvansal üretim güvenliğini doğrudan etkileyen **yeni nesil su kalite politikalarının** geliştirilmesini zorunlu kılmaktadır (Wisser ve ark., 2024).

Ruminant içme suyu uyum kontrol çizelgesi*

Parametre	İzleme Sıklığı (öneri)	Eylem Planı (eşik aşıldığında)
pH	3 ayda bir	pH düzeltme (asit/baz dozajı, aerasyon)
Nitrat (NO_3^-)	3 ayda bir (özellikle buzağılar için)	Kaynağın değiştirilmesi, arıtım (iyon değiştirici, biyolojik denitrifikasyon)
Nitrit (NO_2^-)	3 ayda bir	Kuyu kapatma, biyolojik filtrasyon
Tuzluluk / İletkenlik (EC)	6 ayda bir	Alternatif kaynak, sulandırma, karıştırma
Sertlik (Ca^{2+} + Mg^{2+})	6 ayda bir	Yumuşatma (iyon değiştirici)
Sülfat (SO_4^{2-})	3 ayda bir	Alternatif kaynak, karıştırma, RO
Ağır metaller (As, Pb, Cd)	Yılda 1	Kaynağı devre dışı bırakma, arıtım (adsorban, membran)
Mikrobiyolojik (koliform/E. coli)	Aylık	Dezenfeksiyon, suluk temizliği
PFAS	Yılda 1 (AB'ye uyumlu izleme)	İleri arıtım (adsorban, plazma oksidasyon, GAC/RO)

***FAO** eşikleri performans odaklıdır; özellikle **tuzluluk ve TDS** için "kullanılabilirlik" sınıfları tanımlar.

WHO değerleri çoğunlukla insan sağlığına yöneliktir ancak ülkeler bunları referans alır.

AB (2020/2184) içme suyu direktifi 2026'dan itibaren PFAS parametrelerini zorunlu hale getirmektedir.

Türkiye TS 266 ve İTASHY ile büyük ölçüde AB/WHO ile uyumludur; PFAS için uyumlaştırma aşamasındadır.

SONUÇ

Bu çalışmada ruminantların içme sularında karşılaşılabilecek **kimyasal, biyolojik ve emerging kirleticiler** kapsamlı biçimde ele alınmış, 23 alt başlık altında güncel literatür (2023–2025) ışığında değerlendirilmiştir. Bulgular, su kalitesinin yalnızca fizyolojik sağlık ve üretim performansı açısından değil, aynı zamanda **hayvan refahı, davranışsal göstergeler, antimikrobiyal direnç riski ve gıda güvenliği** boyutlarında da belirleyici olduğunu ortaya koymaktadır.

Nitrat, sülfat, ağır metaller ve mikrobiyolojik parametreler gibi klasik risklerin yanında, **PFAS, pestisit kalıntıları, mikroplastikler ve siyanotoksinler** gibi yeni nesil kirleticilerin de ruminant sağlığı ve ürün güvenliği açısından dikkate alınması gerektiği görülmektedir.

Özellikle **iklim değişikliği ve tarımsal uygulamaların etkisiyle artan su kirliliği**, gelecekte su kalitesinin daha dinamik ve bütüncül bir yaklaşımla ele alınmasını zorunlu kılmaktadır.

Geleneksel analiz yöntemleri yanında, **IoT tabanlı sensörler, NIR spektroskopisi ve yapay zekâ destekli tahmin modelleri**, içme suyu kalitesinin gerçek zamanlı ve düşük maliyetle izlenmesine olanak tanımaktadır. Bu teknolojilerin çiftlik düzeyinde uygulanabilirliği, hem **erken uyarı sistemleri** geliştirilmesini hem de **sürdürülebilir su yönetimi** stratejilerinin hayata geçirilmesini kolaylaştırmaktadır.

Politika ve düzenleme boyutunda ise FAO, WHO (2024), AB ve Türkiye'nin ortaya koyduğu çerçeveler, büyük ölçüde **insan içme suyu standartlarını** temel almakta; ancak ruminantlar için özel eşik değerler ve saha uyarlamaları çoğunlukla **rehber düzeyinde** kalmaktadır. AB'nin 2026'dan itibaren geçerli olacak **PFAS limitleri**, Türkiye dâhil birçok ülke için uyum sürecinde kritik bir dönüm noktası olacaktır.

Sonuç olarak, ruminant içme suyu yönetiminde **multidisipliner bir yaklaşım** benimsenmeli; su kalitesi izleme çalışmaları **kimyasal, mikrobiyolojik, emerging kirleticiler, refah göstergeleri ve dijital teknolojiler** ile bütünleşik şekilde yürütülmelidir. Bu yaklaşım yalnızca hayvan sağlığı ve verimliliğini değil, aynı zamanda **gıda güvenliğini, tüketici sağlığını ve sürdürülebilir hayvancılık politikalarını** güvence altına alacaktır.

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DESTEK SULAMA KOŞULLARINDA BAZI EKMEKLİK BUĞDAY *(Triticum aestivum* l.*)* GENOTİPLERİNİN VERİM VE KALİTE BAKIMINDAN DEĞERLENDİRİLMESİ

Doç. Dr. Mehmet KARAMAN

Muş Alparslan Üniversitesi, Uygulamalı Bilimler Fakültesi, Bitkisel Üretim ve Teknolojileri Bölümü, Muş

ORCID: 0000-0002-6176-9580

ÖZET

Bu çalışma, Adıyaman ilinde 2015-2016 yetiştirme sezonunda destek sulama koşullarında yürütülmüştür. Deneme, tesadüf blokları deneme deseni esas alınarak 4 tekerrürlü olarak kurulmuştur. Araştırmada, 20 ileri kademe ekmeklik buğday hattı ve 5 tescilli (kontrol) ekmeklik buğday çeşidi karşılaştırılmıştır. Çalışmada amaç, Adıyaman ilinde destek sulama koşullarında adaptasyonu yüksek, verim ve kalite yönünden kontrol çeşitlerden daha üstün hatları belirlemektir. Araştırılan tüm özelliklerde genotipler arasında $p \leq 0.01$ düzeyinde önemli farklılıklar olduğu tespit edilmiştir. Tane verimi 110.72-376.04 kg da^{-1}, hektolitre ağırlığı 76.20-84.05 kg hl^{-1}, bin tane ağırlığı 24.63-47.00 g, protein oranı %13.70-19.05 ve zeleny sedimantasyon miktarı 22.50-41.00 ml arasında değişim göstermiştir. Çalışmada, tane veriminde 2, hektolitre ağırlığında 4, protein oranında 6 ve zeleny sedimantasyon miktarında 4 hattın tüm kontrol çeşitlerden üstün olduğu belirlenmiştir. Tane veriminde G1 (376.04 kg da^{-1}) ve G19 (375.74 kg da^{-1}) ileri kademe ekmeklik buğday hatlarının ön sırada yer aldığı tespit edilmiştir. Fiziksel kalite özelliklerinde G8 (83.80 kg hl^{-1}), G9 (84.05 kg hl^{-1} ve 42.73 g), Hilar (47.00 g) ve G19 (83.95 kg hl^{-1}) en iyi genotiplerdir. Teknolojik kalite özelliklerinde G1 (39.00 ml), G6 (41.00 ml), G7 (%18.85 ve 39.00 ml), G17 (%18.80 ve 41.00 ml) ve G22 (%19.05) en iyi genotiplerdir. Son olarak, verim veya kalite bakımından öne çıkan genotiplerin gözlem altına alınarak çalışmanın en az bir yıl daha devam ettirilmesinin faydalı olacağı sonucuna varılmıştır.

Anahtar Kelimeler: Buğday, kalite, destek sulama

EVALUATION OF SOME BREAD WHEAT *(TRITICUM AESTIVUM* L.*)* GENOTYPES IN TERMS OF YIELD AND QUALITY UNDER SUPPLEMENTARY IRRIGATION CONDITIONS

ABSTRACT

This study was carried out under supplementary irrigation conditions in Adıyaman province during the 2015-2016 growing season. The trial was established based on a randomized experiment block design with 4 replications. In the study, 20 advanced bread wheat lines and 5 registered bread wheat varieties (controlled) were compared. The aim of the study was to determine the lines that were highly adaptable to the supplementary irrigation conditions in Adıyaman province and were superior to the control varieties in terms of yield and quality. It was determined that there were significant differences between genotypes at the $p \leq 0.01$ level in all investigated traits. Grain yield 110.72-376.04 kg da^{-1}, test weight 76.20-84.05 kg hl^{-1}, thousand-grain weight 24.63-47.00 g, protein ratio 13.70-19.05% and zeleny sedimentation varied between 22.50-41.00 ml. In the study, it was determined that 2 lines in grain yield, 4 lines in test weight, 6 lines in protein content and 4 lines in zeleny sedimentation amount were superior to all control varieties. It was determined that G1 (376.04 kg da^{-1}) and G19 (375.74 kg da^{-1}) advanced bread wheat lines were in the first place in grain yield. In terms of physical quality traits, G8 (83.80 kg hl^{-1}), G9 (84.05 kg hl^{-1} and 42.73 g), Hilar (47.00 g) and G19 (83.95 kg hl^{-1}) were the best genotypes. In terms of technological quality characteristics, G1 (39.00 ml), G6 (41.00 ml), G7 (18.85% and 39.00 ml), G17 (18.80% and 41.00 ml) and G22 (19.05%) were the best genotypes. Finally, it was concluded that it would be beneficial to continue the study for at least one more year by observing the genotypes that stand out in terms of yield or quality.

Keywords: Wheat, quality, supplementary irrigation

1. GİRİŞ

Buğday, dünya nüfusunun yaklaşık 1/3'ünün ana besin kaynağı olması nedeniyle stratejik tarla bitkilerden biri olmakla beraber dünya nüfusunun ihtiyaç duyduğu kalorinin ve proteinin önemli bir kısmını karşılamaktadır (Ali, 2017; Akan ve ark., 2021). Türkiye'de buğday ekiliş ve üretim durumu Türkiye İstatistik Kurumu'nun (TÜİK) verilerine göre değerlendirildiğinde 663 milyon dekarlık alanda ekim ve 19.8 milyon ton üretim yapıldığı bildirilmiştir (Güney ve ark., 2024; Daşkın ve Alp, 2025).

Buğdayın, B vitamini ve mineral maddeler açısından zengin olmasının yanı sıra dünya nüfusunun enerji ihtiyacının %20'sini karşıladığı vurgulanırken (Özberk ve ark., 2016), farklı araştırıcılar insan ve hayvan beslenmesinde temel proteinlerin %20'sini, kalorinin ise %19'unu karşıladığını bildirmiştir (Bozoğlu ve ark., 2022; Özer ve ark., 2023; Daşkın ve Alp, 2025).

Buğdaydan elde edilen ekmek, bulgur, kuskus gibi ürünler Türkiye nüfusunun temel besin kaynağıdır. Buğdaydan elde edilen farklı ürünlerin tüketimi dikkate alındığında yıllık kişi başı ortalama buğday tüketiminin >200 kg olduğu belirlenmiştir. Bu tüketim miktarı ile Türkiye'nin dünyada en ön sırada yer aldığı tespit edilmiştir (Morgounov ve ark., 2016; Atak ve ark., 2021).

Buğdayda kalite genotipik ve çevresel faktörlerin etkisi altında gelişmektedir. Fiziksel kalite özelliklerinden olan hektolitre ağırlığı ve bin tane ağırlığı buğday tanesini kalite açısından değerlendirmede önem arz etmektedir (Kün, 1996; Elgün ve ark., 2002; Ulucan & Atak, 2020). Başka çalışmalarda, bin tane ağırlığının genotipik özellik olmasının yanı sıra yüksek sıcaklık, kuraklık ve toprak verimliliği gibi unsurlardan etkilendiği bildirilmiştir (Çölkesen ve ark., 2002; Aktaş ve ark., 2017).

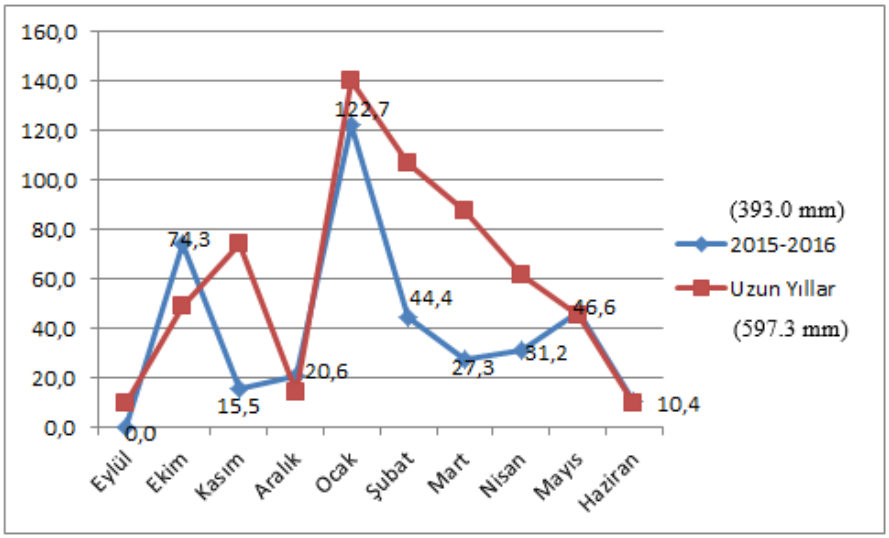
Bu çalışmanın amacı, yurt dışından temin edilen ileri kademe ekmeklik buğday hatlarını Adıyaman ili koşullarında adaptasyon yeteneği bakımından test etmenin yanı sıra verim, kalite özellikleri bakımından kontrol çeşitlerden üstün ve bölgede gelecek vadeden, tescil adayı olabilecek materyali belirlemektir.

2. MATERYAL VE YÖNTEM

Çalışma, Adıyaman ilinde 2015-2016 yetiştirme sezonunda destek sulamalı koşullarda tesadüf blokları deneme desenine göre 4 tekrarlamalı olarak yürütülmüştür. Çalışma materyalini 20 adet ileri kademe ekmeklik buğday hattı ve 5 adet tescilli (kontrol) çeşit (Dinç, Hilar, Tekin: GAP Uluslararası Tarımsal Araştırma ve Eğitim Merkezi Müdürlüğü, Pehlivan: Trakya Tarımsal Araştırma Enstitüsü Müdürlüğü, Ceyhan-99: Doğu Akdeniz Tarımsal Araştırma Enstitüsü Müdürlüğü) oluşturmuştur.

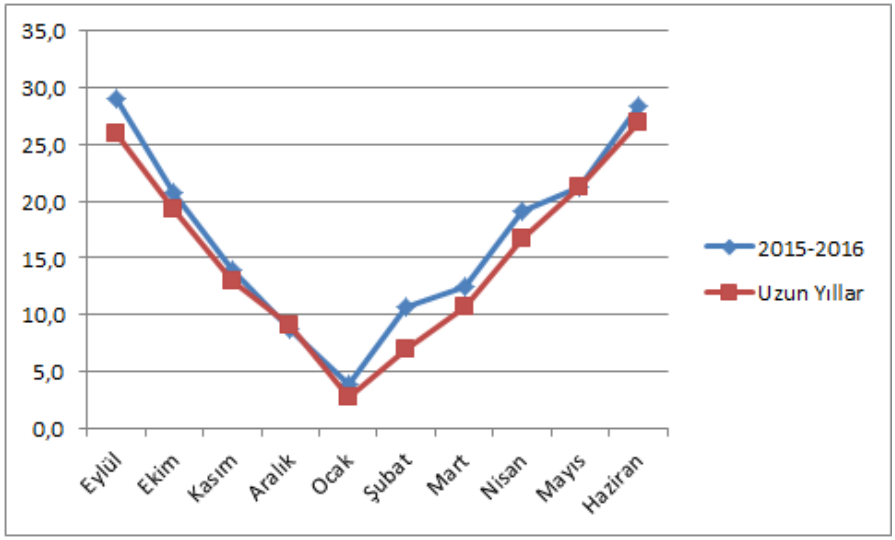
Deneme alanı topraklarının; killi-tın sınıfta, hafif tuzlu, fosfor içeriği az ve organik madde yönünden yetersiz olduğu tespit edilmiştir. Bitki besin elementi takviyesi için saf madde üzerinden 6 kg da^{-1} fosfor (P_2O_5) ve 6 kg da^{-1} azot (N) ekim ile beraber verilmiş olmakla beraber bitkilerin kardeşlenme döneminde olduğu dönemde de ilave olarak 8 kg da^{-1} N üst gübre olarak tatbik edilmiştir. Çalışmada, buğday bitkisinin süt olum döneminin sonlarına doğru her parsel suya doyuncaya kadar karık sulama usulüyle bir defa sulanmıştır. Hasat-harman işlemi, 25 Haziran 2016 tarihinde parsel biçerdöveri ile tamamlanmıştır.

Çalışmada, gerçekleşen yağış miktarının uzun yıllar ortalaması ile kıyaslandığında, yağışın aylar bazında dağılımının düzensiz olduğu, Ekim ve Aralık aylarında daha fazla, Mayıs ve Haziran aylarında benzer, diğer aylarda ise daha az yağış meydana geldiği gözlemlenmiştir (Şekil 1).



Şekil 1. Adıyaman ilinin 2015-2016 ve uzun yıllar ortalama yağış görseli

Sezona ilişkin aylar bazında gerçekleşen ortalama sıcaklık verilerine göre Mayıs ayında uzun yılların ortalamasıyla aynı veriler gerçekleşirken, Aralık ayında daha düşük ve geriye kalan tüm aylarda ise daha yüksek sıcaklıkların meydana geldiği saptanmıştır (Şekil 2).



Şekil 2. Adıyaman ilinin 2015-2016 ve uzun yıllar ortalama sıcaklık görseli

Araştırmada; tane verimi, hektolitre ağırlığı, bin tane ağırlığı, protein oranı ve zeleny sedimantasyon parametreleri araştırılmıştır. Denemede, tane verimi 4 tekerrür üzerinden değerlendirilirken, kalite özellikleri iş yoğunluğu ve maliyet nedeniyle 3 tekrar üzerinden değerlendirilmiştir. İstatistiki analizler, J.M.P 13.0 pro paket programı kullanılarak yapılmış olup, oluşan gruplar, gruplar arası farklılıklar ve önem düzeyleri LSD ($p \leq 0.05$) testi dikkate alınarak belirlenmiştir (Gomez ve Gomez, 1984).

3. BULGULAR VE TARTIŞMA

Araştırmada, incelenen tüm özelliklerde genotipler arasında $p \leq 0.01$ düzeyinde anlamlı farklılıklar olduğu gözlemlenmiştir. Araştırmada, tane verimi yönünden genotipler arasında geniş varyasyon olduğu gözlemlenirken tane veriminin 110.72-376.04 kg da^{-1} arasında değişim gösterdiği belirlenmiştir. Deneme ortalamasının 241.38 kg da^{-1} olduğu ve 14 adet genotipin deneme ortalamasının üzerinde tane verimi verdiği tespit edilmiştir. Çalışmada, G1 (376.04 kg

da^{-1}) ve G19 (375.74 kg da^{-1}) ileri kademe ekmeklik buğday hatlarının tüm kontrol çeşitlerden daha verimli olduğu ve ön sırada yer aldıkları belirlenmiştir (Tablo 1). Birim alandan elde edilen tane verimi, kalıtımın yanı sıra çevre koşullarının etkisi altında şekillenmektedir (Erdem ve Sakin, 2023).

Hektolitre ağırlığı, tane verimi ve un randımanı üzerinde etkili olan önemli fiziksel kalite özelliklerinden biridir. Hektolitre ağırlığının 76.20-84.05 kg hl^{-1} arasında farklılık gösterdiği belirlenmiştir. Deneme ortalamasının 81.23 kg hl^{-1} olduğu ve 4 adet genotipin deneme ortalamasının üzerinde hektolitre ağırlığı verdiği gözlemlenmiştir. Araştırmada, G8 (83.80 kg hl^{-1}), G9 (84.05 kg hl^{-1}), G18 (83.25 kg hl^{-1}) ve G19 (83.95 kg hl^{-1})'un tüm kontrol çeşitlerden daha yüksek hektolitre ağırlığına sahip olduğu saptanmıştır (Tablo 1). Yozgat ili koşullarında 14 ekmeklik buğday çeşidi ile yürütülen çalışmada hektolitre ağırlığının 76-82 kg hl^{-1} arasında değişim gösterdiği bildirilmiştir (Özen ve Akman, 2015). Çalışmamızda elde edilen sonuçlar paralellik arz etmektedir.

Tablo 1. İncelenen özellikler ile oluşan gruplar ve önem düzeyleri ($p<0.01$ düzeyinde)

Genotipler	TV (kg da^{-1})		HL (kg hl^{-1})		BTA (g)		PRT (%)		ZS (ml)	
G1	376.04	a	81.40	efg	31.63	fgh	14.05	jk	39.00	ab
G2	307.06	bcd	81.05	efg	31.75	fgh	16.50	cde	27.50	hı
G3	270.44	def	82.45	a-e	37.38	cd	16.15	def	36.00	b-e
G4	233.61	fgh	80.45	fgh	31.50	gh	16.95	cd	36.50	bcd
Dinç	251.11	efg	81.15	efg	34.13	d-g	16.70	cde	22.50	j
G6	278.55	b-e	80.30	gh	32.25	fgh	17.60	bc	41.00	a
G7	148.22	jk	76.20	j	25.63	ı	18.85	ab	39.00	ab
G8	268.50	def	83.80	abc	36.38	c-f	14.10	jk	32.00	efg
G9	170.85	ıj	84.05	a	42.73	ab	15.50	e-ı	31.00	fgh
Pehlivan	315.02	bc	82.00	d-g	35.13	d-g	13.70	k	32.00	efg
G11	259.39	ef	82.35	a-e	35.00	d-g	13.75	k	24.50	ıj
G12	125.31	k	81.70	d-g	33.38	d-h	14.25	ıjk	34.00	c-g
G13	272.06	c-f	81.60	d-g	37.13	cde	15.40	e-j	30.00	gh
G14	260.78	ef	82.30	b-e	37.75	cd	15.00	f-k	24.00	ıj
Hilar	319.71	b	82.40	a-e	47.00	a	14.25	ıjk	36.00	b-e
G16	210.00	ghı	82.10	c-f	40.38	bc	15.95	d-g	35.00	b-f
G17	120.78	k	77.55	ıj	24.63	ı	18.80	ab	41.00	a
G18	246.13	e-h	83.25	a-d	33.75	d-h	15.65	d-h	30.00	gh
G19	375.74	a	83.95	ab	31.88	fgh	14.35	h-k	38.00	abc
Tekin	205.00	hı	81.90	d-g	36.00	c-g	16.60	cde	38.00	abc
G21	182.56	ıj	79.05	hı	33.88	d-h	16.75	cde	36.50	bcd

G22	110.72	k	79.05	hı	35.38	d-g	19.05	a	33.50	d-g
G23	234.06	fgh	78.80	hı	32.00	fgh	15.75	d-g	31.50	fgh
G24	281.63	b-e	79.30	h	29.25	hı	15.70	d-h	22.50	j
Ceyhan-99	211.33	ghı	82.60	a-e	32.38	e-h	14.70	g-k	36.50	bcd
Maksimum değer:	376.04		84.05		47.00		19.05		41.00	
Minimum değer:	110.72		76.20		24.63		13.70		22.50	
G.ortalama:	241.38		81.23		34.33		15.84		33.10	
KÜHS:	2		4		0		6		4	
LSD (0.05):	44.2**		1.73**		4.86**		1.38**		4.41**	
DK (%):	13.0		1.3		8.6		5.3		8.10	

G.ortalama: genel ortalama, TV: tane verimi, HL: hektolitre ağırlığı, BT: bin tane ağırlığı, ZS: zeleny sedimantasyon miktarı, KÜHS: kontrolden üstün hatların sayısı

Bin tane ağırlığı tane iriliğine bağlı olarak artan veya azalan teknolojk kalite özelliklerindendir. Araştırmada, bin tane ağırlığı bakımından genotipler arasında geniş bir varyasyon olduğu belirlenmiş olmakla birlikte bin tane ağırlığının 24.63 g-47.00 g arasında değiştiği saptanmıştır. Çalışmada, ortalama bin tane ağırlığının 34.33 g olduğu ve 11 adet genotipin deneme ortalamasının üzerinde bin tane ağırlığı verdiği gözlemlenirken, Hilar kontrol çeşidinden daha yüksek bin tane ağırlığı veren hattın olmadığı saptanmıştır (Tablo 1). Yozgat ili koşullarında ekmeklik buğdayda bin tane ağırlığı ile ilgili yapılan çalışmada bin tane ağırlığının 33-44 g arasında farklılık gösterdiği belirlenmiştir (Özen ve Akman, 2015). Çalışmamızda benzer değerler tespit edilmiş olmakla birlikte genotipler arasında daha geniş varyasyon olduğu gözlemlenmiştir.

Protein oranı önemli kalite özelliklerinden olmakla birlikte ekmeklik buğdayın hangi ürüne işleneceğine karar vermede önemlidir. Protein oranının %13.70-19.05 arasında farklılık gösterdiği, deneme ortalamasının %15.84 olduğu ve 11 adet genotipin deneme ortalamasının üzerinde protein oranı verdiği tespit edilmiştir. Araştırmada; G4 (%16.95), G6 (%17.60), G7 (%18.85), G17 (%18.80), G21 (%16.75) ve G22 (%19.05) ileri kademe ekmeklik buğday hatlarının tüm kontrol çeşitlerden daha yüksek protein oranı verdiği saptanmıştır (Tablo 1). Özen ve Akman (2015), tarafından ekmeklik buğdayda protein oranı ile ilgili yapılan çalışma sonucunda protein oranının %8-13, Eliş ve ark. (2024), tarafından yapılan çalışmada ise %14.5-18.1 aralığında olduğu vurgulanmıştır. Çalışmamızda elde edilen sonuçlar Eliş ve ark. (2024) ile benzer, Özen ve Akman (2015)'nın sonuçlarından daha yüksek değerler olmuştur.

Zeleny sedimantasyon miktarı un kalitesini belirlemede önemli kalite özelliklerinden biridir. Çalışmada, zeleny sedimantasyon miktarının 22.50-41.00 ml arasında değişim gösterdiği gözlemlenirken deneme ortalamasının 33.10 ml olduğu tespit edilmiştir. Denemede 14 adet genotipin deneme ortalamasının üzerinde zeleny sedimantasyon değeri verdiği belirlenmiştir. Kontrol çeşitler ile kıyaslandığında G1 (39.00 ml), G6 (41.00 ml), G7 (39.00 ml) ve G17 (41.00 ml) ileri kademe ekmeklik buğday hatları daha yüksek zeleny sedimantasyon miktarını vermiştir (Tablo 1).

Zeleny sedimantasyon miktarı yönünden genotipler arasındaki farklılıkların kalıtımın etkisinden kaynaklandığı, iklim gibi çevre faktörlerinin etkisi göz ardı edilmemekle beraber zeleny sedimantasyonda çevresel etkilerin diğer kalite özelliklerine nazaran minimum düzeyde olduğu bildirilmiştir (Atlı ve ark., 1999; Karaman ve ark., 2012).

4. SONUÇ VE ÖNERİLER

Araştırmada, bin tane ağırlığı hariç incelenen tüm özelliklerde kontrol çeşitlerden daha üstün ekmeklik buğday hatları olduğu gözlemlenmiştir. Tane veriminde G1 ve G19 ileri kademe ekmeklik buğday hatları ön sırada yer alırken, fiziksel kalite özelliklerinde (hektolitre ve/veya bin tane ağırlığı) G8, G9, G19, Teknolojik kalite özelliklerinde (protein ve/veya zeleny sedimantasyon) ise G1, G6, G7, G17 ve G22 ileri kademe ekmeklik buğday hatlarının tüm kontrol çeşitlerden daha üstün olduğu tespit edilmiştir. İncelenen özellikler bakımından kontrol çeşitlere göre daha iyi olan ileri kademe ekmeklik buğday hatları gelecekte tescil adayı olmaya yönelik umut vermekle beraber çalışmanın en az bir yıl daha tekrar edilmesinin güvenilir sonuçlara ulaşma açısından önem arz etmektedir.

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TÜRKİYE'DE TESCİLLİ KIRMIZI MERCİMEK (*Lens culinaris medik.)* ÇEŞİTLERİNİN MUŞ İLİ KOŞULLARINDA VERİM VE BAZI MORFOLOJİK ÖZELLİKLER BAKIMINDAN DEĞERLENDİRİLMESİ

Doç. Dr. Mehmet KARAMAN

Muş Alparslan Üniversitesi, Uygulamalı Bilimler Fakültesi, Bitkisel Üretim ve Teknolojileri Bölümü, Muş

ORCID: 0000-0002-6176-9580

ÖZET

Kırmızı mercimek, zengin besin içeriği ve havadaki serbest azotu toprağa fikse etme yeteneği sayesinde, önemli yemeklik tane baklagil türlerinden biridir. Kırmızı mercimek, yüksek protein içeriği ile birlikte A, B, C ve D vitaminlerini içermesi ve Fe, Mg, Ca, P, K gibi mikro ve makro elementlerce zengin olması nedeniyle beslenme açısından önemli bir baklagil türüdür. Mercimek, kurak iklim koşullarına dayanıklı olması, erken hasat edilmesi, kendisinden sonra ekilen bitkilere azotça zengin bir toprak bırakması ve toprak yapısını iyileştirici ile koruyucu özellik göstermesi nedeniyle münavebe sistemlerinde önemli bir yere sahiptir.

Bu çalışma, 2023 yılında Muş ilinde yağışa dayalı koşullarda, geç ilkbahar ekim döneminde yürütülmüştür. Araştırmada amaç, Türkiye'de tescilli bazı kırmızı mercimek çeşitlerini verim ve bazı tarımsal özellikler bakımından incelemektir. Çalışmada, çiçeklenme süresi ($p \leq 0.05$) hariç incelenen tüm özelliklerde genotipler arasında $p \leq 0.01$ düzeyinde önemli farklılıklar olduğu tespit edilmiştir. Tane verimi 9.08-83.47 kg da^{-1}, ana dal sayısı 1.30-2.10 adet $bitki^{-1}$, ilk bakla yüksekliği 8.75-14.25 cm, bitki boyu 17.38-23.75 cm, çiçeklenme süresi 50.67-57.33 gün ve bin tane ağırlığı 22.58-35.58 g arasında değişim göstermiştir.

Çalışmada, Altıntoprak kırmızı mercimek çeşidinin tane verimi bakımından ilk sırada olduğu gözlenmekle beraber birim alan tane verimlerinin genel olarak düşük olduğu saptanmıştır. Sonuç olarak, bir yıllık çalışma sonuçları dikkate alındığında geç ilkbahar ekimi koşullarında kırmızı mercimek yetiştiriciliğinin ticari anlamda uygun olmadığı ön görülürken bölgede kırmızı mercimek ile ilgili farklı ekim zamanlarını içeren çalışmaların yapılması bölge üreticilerine ve bilim camiasına katkı sağlayacaktır.

Anahtar Kelimeler: Kırmızı mercimek, verim, morfoloji

EVALUATION OF RED LENTIL *(LENS CULINARIS* MEDIK*.)* VARIETIES REGISTERED IN TURKEY IN TERMS OF YIELD AND SOME MORPHOLOGICAL CHARACTERISTICS IN CONDITIONS OF MUŞ PROVINCE

ABSTRACT

Red lentil *(Lens culinaris* Medik*.)* is one of the most important edible legume species due to its rich nutritional content and its ability to fix atmospheric nitrogen into the soil. Its high protein content, along with vitamins A, B, C and D, and its richness in micro and macro lements such as Fe, Mg, Ca, P, and K, make it a valuable food source for human nutrition. Furthermore, red lentil is well adapted to dry climatic conditions, reaches maturity early, enriches the soil with nitrogen for subsequent crops, and improves soil structure, thus holding an important place in crop rotation systems.

This study was conducted under rainfed conditions during the late spring sowing period in Muş province in 2023. The aim was to evaluate some registered red lentil cultivars in Türkiye in terms of grain yield and certain agronomic characteristics. Except for flowering time ($p \leq 0.05$), significant differences ($p \leq 0.01$) were found among genotypes for all other examined traits. Grain yield ranged from 9.08 to 83.47 kg da^{-1}, number of main branches from 1.30 to 2.10 per plant, first pod height from 8.75 to 14.25 cm, plant height from 17.38 to 23.75 cm, flowering time from 50.67 to 57.33 days, and thousand-grain weight from 22.58 to 35.58 g.

In the study, it was observed that the Altıntoprak red lentil variety was in the first place in terms of grain yield, but the grain yields per unit area were generally low. In conclusion, considering the results of a one-year study, it is predicted that red lentil cultivation in late spring planting conditions is not commercially viable, while conducting studies that include different planting times for red lentils in the region will contribute to the regional producers and the scientific community.

Keywords: Red lentil, yield, morphology

1. GİRİŞ

Yemeklik tane baklagiller zengin protein, vitamin, karbonhidrat, mineral, diyet lifi ve fitokimyasal madde içerikleri sebebiyle birçok ülkede insan beslenmesinde temel besin kaynağı olarak değerlendirilmektedir (Amarowicz ve ark., 2010; Nilüfer-Erdil ve Gedik, 2018). Yemeklik tane baklagiller, havadaki serbest azotu toprağa fikse edip toprağı azot yönünden zenginleştirmesi sebebiyle tarla bitkileri yetiştiriciliğinde önem arz etmektedir (Özdemir, 2002, Doğan ve Doğan, 2020). Yemeklik tane baklagil yetiştiriciliğinin yapıldığı alanlarda toprağın kimyasal, fiziksel ve biyolojik özelliklerinin düzeldiği bildirilmiştir (Şehirali ve ark., 1995). Ayrıca, toprağa 6.4-21.6 kg da^{-1} arasında saf azot bağlandığı, mercimek yetiştiriciliğinde ise bu miktarın 8.4 kg da^{-1} olduğu bildirilmiştir (Sepetoğlu, 1987; Doğan ve Doğan, 2020).

Mercimek, toprak tekstürünü ve strüktürünü koruması, kendisinden sonra ekilecek olan bitkiye azotça zengin bir toprak bırakması ve kuraklığa karşı mukavemetinin yüksek olması nedeniyle yemeklik tane baklagil bitkileri içerisinde öne çıkmaktadır (Tullu ve ark., 2001). Kırmızı mercimek, Türkiye'de tane olarak tüketilmesinin yanı sıra samanı da hayvan beslenmesinde çok değerlidir.

Türkiye'de tarım yapılan alanlarının %3.9'luk kısmında baklagil yetiştiriciliği yapılmaktadır. Mevcut baklagil ekiminin %36.7'si ise mercimek ekim alanlarından oluşmaktadır. Türkiye'de toplam mercimek üretiminin dağılımı incelendiğinde %93'lük payı kırmızı mercimek ve %7'lik payı ise yeşil mercimek oluşturmaktadır (TÜİK, 2018). Mercimek yetiştiriciliğinde özellikle fide döneminde bitki gelişiminin yabancı otlar ile kıyaslandığında yavaş olması sebebiyle erken dönemde yabancı ot mücadelesine önem verilmesi gerektiği vurgulanmıştır (Basler, 1981; Özer ve ark, 1998; Aksoy ve ark., 2014; Sırrı, 2020).

Bu çalışmada amaç, Türkiye'de tescilli kırmızı mercimek çeşitlerinin Muş ili koşullarında adaptasyon kabiliyetini test etmenin yanı sıra tane verimi bazı morfolojik özellikler bakımından değerlendirmektir.

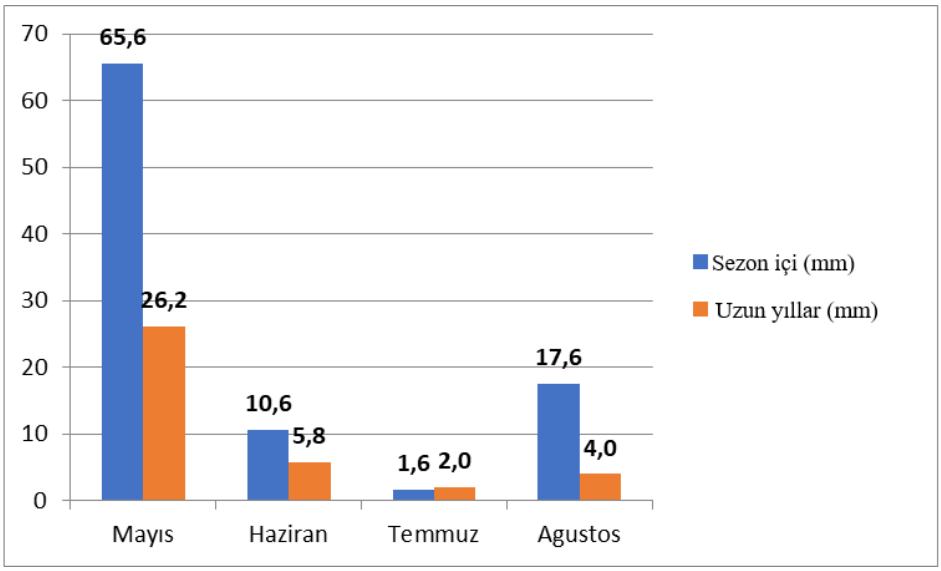
2. MATERYAL VE YÖNTEM

Bu araştırma, Muş ilinde 2023 yılının yağışa dayalı ve geç ilkbahar ekimi koşullarında yürütülmüştür. Deneme, tesadüf blokları deneme deseni dikkate alınarak 10 adet kırmızı mercimek çeşidi ile 3 tekerrürlü olarak tasarlanmıştır. Çeşitler ve orijin merkezleri Tablo 1'de verilmiştir.

Tablo 1. Çalışmada yer alan çeşitlere ilişkin bilgiler

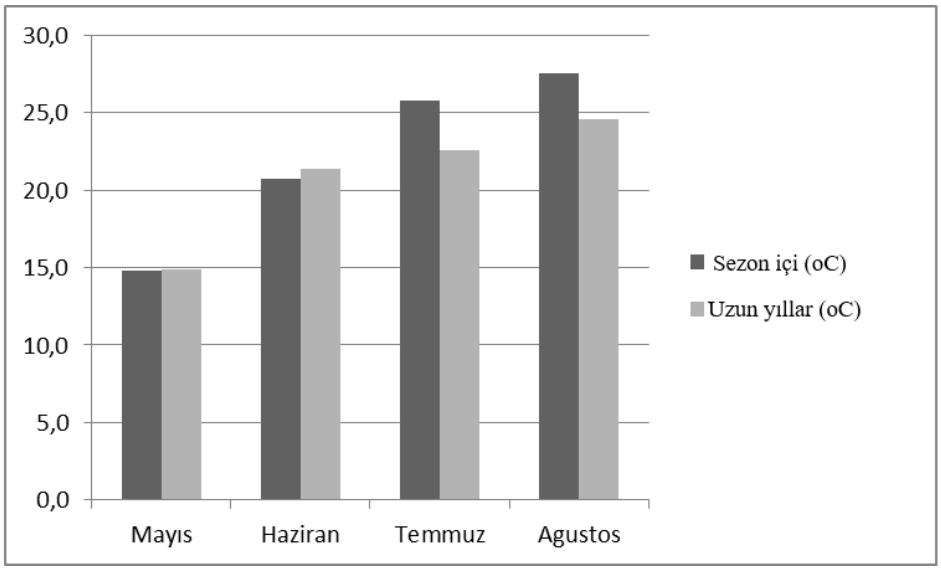
Çeşitler	Orijin Merkezi/Islahçı kuruluş
Atacan	GAP Tarımsal Araştırma Enstitüsü Müdürlüğü
Şakar	Dicle Üniversitesi Ziraat Fakültesi
Çiftçi	Tarla Bitkileri Merkez Araştırma Enstitüsü Müdürlüğü
Şanlıbey	GAP Tarımsal Araştırma Enstitüsü Müdürlüğü
Seyran-96	GAP Uluslararası Tarımsal Araştırma ve Eğitim Merkezi Müdürlüğü
Evirgen	Mersin Ticaret Borsası Toh. A.Ş.
Kafkas	Tarla Bitkileri Merkez Araştırma Enstitüsü Müdürlüğü
Tigris	GAP Uluslararası Tarımsal Araştırma ve Eğitim Merkezi Müdürlüğü
Özbek	Tarla Bitkileri Merkez Araştırma Enstitüsü Müdürlüğü
Altıntoprak	GAP Uluslararası Tarımsal Araştırma ve Eğitim Merkezi Müdürlüğü

Denemede, her parsel 4 sıra, sıra arası 20 cm ve 4 m uzunluğunda kurulmuştur. Ekim işlemi, metrekareye 300 kırmızı mercimek tanesi düşecek şekilde 11.05.2023'te yapılmıştır. 2023 yılı üretim sezonuna ait iklim verilerine bakıldığında Temmuz ayı hariç tüm aylarda meydana gelen yağışın uzun yıllar ortalamasından fazla ve toplam yağış miktarının 95.4 mm olduğu tespit edilmiştir (Şekil 1). Üretim sezonundaki sıcaklık değerlerinin ise Temmuz ve Ağustos aylarında uzun yıllar ortalamasının üzerinde geriye kalan aylarda birbirine yakın değerler olduğu gözlemlenmiştir (Şekil 2).



Şekil 1. Muş ilinin 2023 sezonuna ve uzun yıllara ilişkin ortalama yağışı (mm)

Araştırmada, deneme alanı topraklarının tuzsuz %0.35, hafif bazik Ph:7.91, fosfor içeriği az 2.2 kg.da^{-1} ve organik madde içeriğinin ise %1.67 yetersiz olduğu tespit edilmiştir. Bitki besin maddesi eksikliğini gidermek için ekimle beraber saf madde üzerinden 6 kg P_2O_5 ve 2.3 kg N verilmiştir. Denemede, üst gübreleme için herhangi bir gübre uygulanmamıştır. Denemede bitkilerin yaklaşık 5 cm ve 10 cm olduğu iki farklı dönemde yabancı otlar el ile yolunarak mücadele yapılmıştır.



Şekil 2. Muş ilinin 2023 sezonuna ve uzun yıllara ilişkin ortalama sıcaklığı (ºC)

Hasat yapılmadan önce her parselin başından ve sonundan 0.5 m kesilip, parselin 1. ve 4. sırası devre dışı bırakılıp atıldıktan sonra ortadaki 2 sıra 11.08.2023 tarihinde el ile hasat edilmiştir. Harmanlama işlemi ise farklı çaptaki elekler yardımıyla Ağustos ayı içerisinde tamamlanmıştır.

Çalışmada, her parselde rastgele seçilen 10 bitki üzerinden; ana dal sayısı (ADS), ilk bakla yüksekliği (İBY), bitki boyu (BB) ölçülmüş ve aritmetik ortalaması alınarak özellik bazında ortalama değerler elde edilmiştir. Çiçeklenme süresi (ÇS) tespiti için ekimden parselin >%50'si çiçekleninceye kadar geçen süre gün cinsinden belirlenerek tespit edilmiştir.

Bin tane ağırlığı, 4 farklı gruptan oluşan 100'er mercimek tanesinin ağırlığı 0.001 hassas terazide tespit edildikten sonra aritmetik ortalaması alınmış ve ardından 10 ile çarpılarak belirlenmiştir. Tane verimi için her parselin ortadaki iki sırasından (1.2 m^2) hasat ve harman işleminin ardından 0.001 hassas terazide verimi $kg.da^{-1}$ cinsinden belirlenmiştir.

Araştırmada, istatistiki analizler J.M.P 5.0 paket programında yapılmıştır. Oluşan gruplar ve önem düzeyleri LSD testine göre $p \leq 0.05$ seviyesinde saptanmıştır (Gomez & Gomez, 1984).

3. BULGULAR VE TARTIŞMA

Araştırmada, incelenen tüm özelliklerde çeşitler arasında anlamlı ($p \leq 0.01$) farklılıklar olduğu belirlenmiştir.

Tablo 2. İncelenen özelliklere ait ortalama değerler ve oluşan gruplar

Çeşit	TV ($kg\ da^{-1}$)		BTA (g)		ADS (adet)		İBY (cm)		ÇS (gün)		BB (cm)	
Atacan	9.08	ı	28.52	cd	1.30	d	10.50	c	50.67	c	18.38	cd
Şakar	30.67	f	30.33	bc	1.90	ab	13.88	a	51.67	bc	23.75	a
Çiftçi	38.60	e	23.44	ef	1.70	bc	11.88	b	57.33	a	18.63	cd
Şanlıbey	18.27	h	35.58	a	1.70	bc	9.13	d	50.67	c	19.50	bc
Seyran-96	28.50	fg	33.60	ab	1.60	c	8.75	d	51.00	c	17.38	d
Evirgen	63.90	c	23.85	def	1.60	c	11.88	b	53.67	abc	19.88	bc
Kafkas	76.80	b	22.58	f	2.10	a	14.25	a	55.33	ab	20.13	bc
Tigris	43.90	d	27.80	cde	1.50	cd	11.38	bc	51.00	c	21.13	b
Özbek	25.21	g	31.12	abc	1.90	ab	10.88	c	51.33	c	20.00	bc
Altıntoprak	83.47	a	28.09	cde	1.70	bc	10.50	c	52.67	bc	21.00	b
Maksimum değer	83.47		35.58		2.10		14.25		57.33		23.75	
Minimum değer	9.08		22.58		1.30		8.75		50.67		17.38	
Genel ortalama	41.84		28.49		1.70		11.3		52.53		19.98	
LSD (0.05)	3.35**		4.85**		0.28**		0.99**		3.76*		1.99**	
CV (%)	4.70		9.93		9.53		5.1		4.17		5.82	

TV: tane verimi, BTA: bin tane ağırlığı, ADS: ana dal sayısı, İBY: ilk bakla yüksekliği, ÇS: çiçeklenme süresi, BB: bitki boyu

Araştırmada, kırmızı mercimek verimlerinde çeşitler arasında geniş varyasyon olduğu tespit edilmiştir. Tane verimlerinin 9.08-83.47 kg da^{-1} arasında farklılık gösterdiği, deneme ortalamasının ise 41.84 kg da^{-1} olduğu belirlenmiştir (Tablo 2). Altıntoprak kırmızı mercimek çeşidi mevcut materyal içerisinde en yüksek tane verimi ile ilk sırada yer almıştır. Kırmızı mercimekte tane veriminin kalıtsal etkenlere bağlı olarak değiştiği, iklim ve toprak yapısından da önemli ölçüde etkilendiği bildirilmiştir (Aydoğan ve ark., 2008; Beşok Küçükay ve ark., 2019). Ayrıca, özellikle ekim zamanının birim alan tane verimi üzerinde etkili olduğu düşünülmektedir.

Bin tane ağırlığına ilişkin değerler incelendiğinde 22.58-35.58 g arasında değişen farklı tane iriliğine sahip çeşitler olduğu gözlemlenmiştir. Bin tane ağırlığı bakımından deneme ortalamasının 28.49 g olduğu ve Şanlıbey, Seyran-96, Özbek kırmızı mercimek çeşitlerinin aynı grupta yer alarak çalışma materyali içerisinde en iri taneli çeşitler olarak ön sırada yer aldıkları belirlenmiştir (Tablo 2). Sivas ve Adana illerinde birçok mercimek hattı ile yapılan çalışmada bin tane ağırlığının 12.0-51.7 g arasında farklılık gösterdiği tespit edilmiştir (Toklu ve ark, 2017). Çalışmamızda elde edilen sonuçlar referans sınırları içerisinde yer almaktadır.

Mercimek çeşitlerinde ana dal sayısının 1.30-2.10 adet arasında farklılık gösterdiği tespit edilmiştir (Tablo 2). Çalışmada, ana dal sayısına ilişkin deneme ortalamasının 1.70 adet olduğu, Kafkas ve Özbek kırmızı mercimek çeşitleri ana dal sayısı yönünden aynı grupta yer alarak en yüksek ana dal sayısını vermiştir. Konya koşullarında kışlık ekim koşullarında kırmızı mercimekte yapılan bir çalışmada ana dal sayısının 4.53-4.67 adet arasında değişim gösterdiği belirlenmiştir. Çalışmamız, geç ilkbahar koşullarında yapıldığından dolayı daha düşük ana dal sayısı değerleri elde edilmiştir (Hakkoymaz ve Önder, 2021).

Tablo 3. Özellikler arası ilişkiler ve önem düzeyleri ($p \leq 0.05$ veya $p \leq 0.01$)

Özellikler	TV	ADS	İBY	BB	ÇS
ADS	0.342				
İBY	**0.3929***	**0.4158***			
BB	0.2255	0.3364	**0.5829****		
ÇS	**0.3905***	0.2711	**0.3866***	-0.0763	
BTA	**-0.5465****	-0.1094	**-0.5642****	-0.079	**-0.5563****

TV: tane verimi, BTA: bin tane ağırlığı, ADS: ana dal sayısı, İBY: ilk bakla yüksekliği, ÇS: çiçeklenme süresi, BB: bitki boyu

Kırmızı mercimek çeşitlerinde ilk bakla yüksekliğinin 8.75-14.25 cm arasında değişim gösterdiği gözlemlenmiştir. İlk bakla yüksekliği deneme ortalamasının 11.3 cm olduğu, Kafkas ve Şakar kırmızı mercimek çeşitlerinin aynı grubu paylaşarak en yüksek ilk bakla yüksekliği değerlerini verdiği tespit edilmiştir. Makineli hasat için ilk bakla yüksekliğinin minimum >10 cm olması önem arz etmektedir. Bu bağlamda, Şanlıbey, Seyran-96 kırmızı mercimek çeşitleri hariç diğer çeşitlerin geç ilkbahar ekimi koşullarında makineli hasada uygun olduğu belirlenmiştir (Tablo 2). Isparta ilinin kışlık ekim koşullarında kırmızı mercimekte yapılan çalışmada ilk bakla yüksekliğinin 9.23-20.20 cm arasında farklılık gösterdiği tespit edilmiştir. Çalışmamız, geç ilkbahar koşullarında yapıldığından dolayı daha düşük değerler elde edilmiştir (Beşok Küçükay ve ark., 2019).

Mercimek çeşitlerine ilişkin çiçeklenme süresinin 50.67-57.33 gün arasında farklılık gösterdiği saptanmıştır. Çiçeklenme süresi deneme ortalaması 52.53 gün olmakla birlikte Çiftçi, Evirgen

ve Kafkas kırmızı mercimek çeşitlerinin aynı grupta yer alarak en uzun çiçeklenme süresini verdiği tespit edilmiştir (Tablo 2). Ceylanpınar kışlık ekim koşullarında kırmızı mercimek ile yapılan çalışmada çiçeklenme süresinin 158.0-163.0 gün olduğu bildirilmiştir (Koç ve Akdeniz, 2019). Çalışmamız geç ilkbahar koşullarında yapıldığından dolayı çiçeklenme süresinin çok daha kısa olduğu belirlenmiştir. Çiçeklenme süresinin kısa olmasının birim alan tane verimlerini olumsuz etkilediği düşünülmektedir. Nitekim, çiçeklenme süresi ile tane verimi arasında pozitif ve önemli ilişki olduğu saptanmıştır (Tablo 3).

Çalışmada yer alan çeşitlere ait bitki boylarının 17.38-23.75 cm arasında değişen değerler gösterdiği tespit edilmiştir. Deneme ortalamasının 19.98 cm, Şakar kırmızı mercimek çeşidinin en uzun bitki boyu ile ilk sırada yer aldığı gözlemlenmiştir (Tablo 2). Isparta koşullarında kırmızı mercimek ile ilgili yapılan çalışmada bitki boyunun 27.50-32.80 cm arasında değişim gösterdiği tespit edilmiştir (Beşok Küçükay ve ark., 2019). Çalışmamızda daha düşük bitki boylarının elde edilmesi yazlık ekim koşullarından kaynaklandığı düşünülmektedir.

Korelasyon analizi sonuçlarına göre tane verimi ile ilk bakla yüksekliği (r=0.3929*) ve çiçeklenme süresi (r=0.3905*) arasında pozitif ve önemli ilişki olduğu belirlenirken, bin tane ağırlığı (-0.5465**) ile negatif ve önemli ilişki olduğu saptanmıştır(Tablo 3).

4. SONUÇ

Geç ilkbahar ekim sezonu koşullarında yapılan bu çalışmada, Altıntoprak kırmızı mercimek çeşidinin tane verimi yönünden en verimli çeşit olduğu belirlenirken, Kafkas ve Evirgen çeşitlerinin tane verimi yönüyle takip eden çeşitler olduğu gözlemlenmiştir. Çalışmada, ilk bakla yüksekliği ve çiçeklenme süresinin tane verimi ile pozitif ilişkili olduğu, çiçeklenme süresi uzadıkça bin tane ağırlığının düştüğü tespit edilmiştir. Denemede; Şanlıbey, Seyran-96 kırmızı mercimek çeşitleri hariç diğer çeşitlerin makineli hasada uygun olduğu saptanırken, deneme materyalinin en az bir yıl daha ekilerek çalışmanın tekrarlanmasının sağlıklı yorum yapabilmek için gerekli olduğu sonucuna varılmıştır.

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IMPROVING SEED GERMINATION IN *LAVANDULA ANGUSTIFOLIA* MILL. WITH PRIMING AND PHYTOHORMONE APPLICATIONS

İbrahim Halil ŞINDAK[1]*, Adem GÖKÇÖL[2], Sıdıka EKREN[1]

[1]Ege University, Faculty of Agriculture, Department of Field Crops, 35100 Bornova, Izmir, Turkey

[2] Ege University, Seed Technology Center, 35100, Bornova, Izmir, Turkey

*Corresponding author: ibrahim.sindak@ege.edu.tr

ABSTRACT

Lavandula angustifolia Mill. is one of the most important medicinal and aromatic plants cultivated worldwide, with expanding production in Turkey due to its essential oil quality and economic value. Despite its growing importance, large-scale cultivation is limited by low, irregular, and delayed seed germination, which restricts uniform seedling supply. This study was conducted to evaluate the efficiency of different pre-sowing treatments in improving germination performance. Seeds from three local populations collected in the Isparta and Burdur regions were subjected to potassium nitrate (KNO_3), gibberellic acid (GA_3), hydropriming, osmopriming, and their combined applications. Laboratory trials were performed under controlled conditions in accordance with ISTA rules.

The results revealed statistically significant differences among treatments ($p < 0.05$). Control seeds exhibited poor performance, with germination percentages ranging from 38% to 44% and mean germination times exceeding 11 days. In contrast, all enhancement treatments improved seed performance, though to varying degrees. The most effective treatment across all populations was osmopriming combined with GA_3, which achieved germination rates of 66–69% and reduced the mean germination time to approximately 9.2 days. Hydropriming + GA_3 and osmopriming + KNO_3 also promoted germination compared to the control, but their effects were less pronounced.

These findings indicate that the integration of priming techniques with hormonal stimulators can successfully overcome dormancy barriers and ensure more rapid and uniform seedling emergence. The application of osmopriming + GA_3, in particular, stands out as a practical and reliable strategy for lavender seedling production. The outcomes of this research provide a scientific basis for improving propagation practices, supporting the sustainable expansion of lavender cultivation in Turkey and other regions with similar agroecological conditions.

Keyword: Lavander, Priming, GA_3, KNO_3, Seed

INTRODUCTION

Lavandula angustifolia Mill. is a leading medicinal-aromatic plant that has spread from the Mediterranean basin to the rest of the world due to its volatile oil composition, wide range of uses in the pharmaceutical and cosmetic industries, and contribution to rural development. However, irregular and delayed emergence, low germination rates, and significant heterogeneity between populations in seed propagation create a critical bottleneck in the production chain (ISHS, 1978; Miclea et al., 2018; Lahsen et al., 2020). Heterogeneous germination in lavender seeds is related to intraspecific genetic variation as well as dormancy type, intensity and seed coat (ISHS, 1978). In controlled production, seedling supply highlights seed enhancement approaches in terms of uniform emergence in the field and stability of yield components (Devika et al., 2021; Sano et al., 2021).

The fundamental hormonal axis governing processes at the seed level is the opposing balance between abscisic acid (ABA) and gibberellin (GA). ABA establishes dormancy during maturation; for germination, the ABA signal must decrease and GA biosynthesis/response must increase (Nonogaki, 2014; Shu et al., 2016; Tuan et al., 2018; Sano et al., 2021; Abley et al., 2021). Small changes here significantly affect germination timing distributions and ultimate success (Abley et al., 2021). Various studies have shown that GA_3 applications in L. angustifolia can increase germination rate and speed; its effect is enhanced when used in combination with classical pretreatments such as stratification (cold-moist conditioning), scarification, and surface sterilization (Miclea et al., 2018; Lahsen et al., 2020).

The second prominent approach in seed enhancement is priming applications. Hydro-priming, osmo-priming (PEG, mannitol), salt-priming (especially KNO_3), nutrient, biostimulant, and hormone-based priming approaches use controlled soaking-drying cycles to "kick-start" metabolism and prepare the seed for faster and more uniform germination before radicle emergence. (McDonald, 2000; Devika et al., 2021; Debbarma and Das, 2017). KNO_3 is one of the most frequently used salts in the literature for its ability to reduce dormancy and accelerate germination in many species (Hernández et al., 2021; Steiner et al., 2018; Rehman et al., 2024). Specifically for L. *angustifolia*, osmotic priming has been reported to reduce the average germination time and increase the germination rate (Demirkaya et al., 2018). These findings highlight the practical importance of systematically comparing different priming agents (KNO_3, PEG, etc.) in lavender (Emiralioğlu, 2022).

In addition to environmental factors that determine germination (water, temperature, oxygen, light), species-specific coating layers (testa/endosperm) with mechanical and chemical barriers, population origin, and seed quality parameters such as harvest, maturity also play a critical role (Nonogaki, 2014; Nalwa and Seth, 2017). The most frequently used combinations for lavender are cold-humid stratification (e.g., 2–6 weeks at around 4 °C), light scarification, pre-treatment with GA_3, KNO_3 priming, and appropriate light-temperature regimes (ISHS, 1978; Lahsen et al., 2020; Miclea et al., 2018; Hernandez et al., 2021). In the Isparta and Burdur basins of Turkey, where lavender is rapidly spreading, the limiting factors for seed production interact with local ecology and population origin; therefore, the comparative testing of germination enhancers on local population seeds will provide results that can be directly transferred to the field (Cantürk, 2023; Sezgin, 2020; Emiralioğlu, 2022).

This study aims to comparatively reveal the effectiveness of different germination-promoting applications on lavender seeds from three selected village populations in the Isparta and Burdur regions.

MATERIALS AND METHODS

All laboratory analyses for this study were conducted at the Ege University Seed Technology Application and Research Center (TOTEM) laboratories. *Lavandula angustifolia* Mill. seeds were used as research material in the study. Lavender seeds were collected from the producer's field in the Isparta Burdur region in 3 different populations (population I, II, III).

Chemical applications

To promote germination and overcome seed dormancy, KNO_3 and GA_3—two substances recommended by the International Seed Testing Association (ISTA)—were incorporated into the moistening medium during germination and emergence tests for each seed type. Their potential effects on seed performance were then evaluated.

KNO_3 applications

During sowing, a 0.2% potassium nitrate solution was applied directly at the germination and emergence stages. This treatment enhanced both germination and emergence rates of black cumin seeds (ISTA, 2022).

GA_3 applications

Gibberellins, which are plant growth regulators, have a crucial role in breaking seed and bud dormancy as well as in regulating and stimulating germination. They occur naturally in high concentrations in developing seeds. Gibberellins induce the production of enzymes that are important for the mobilization of stored food reserves, particularly by converting starch into sugars during the early germination phase (Hartmann et al., 1990). In this experiment, gibberellic acid (GA_3) was applied at a concentration of 1,000 ppm. Seeds were treated with GA_3 for 24 h prior to being tested in germination assays (ISTA, 2022).

Priming (pre-germination) applications

Osmotic seed priming has shown the efficiency of the aerated container technique. Polyethylene glycol (PEG 6000), used as the osmoticum, generates osmotic pressure that regulates radicle protrusion during treatment. Due to its high molecular weight, PEG allows limited water absorption by seeds, maintaining a balance between the internal and external environments. Consequently, radicle emergence is delayed, but the compound itself does not penetrate the cell wall and can be removed from seeds easily through washing.

In this study, osmotic priming was conducted with PEG 6000 at −1.0 MPa for 1, 2, or 3 days in aerated (bubble-column, BK) containers. A solution containing 273 g/L PEG was used. Seeds placed in permeable bags within the aerated container were exposed to the PEG solution for the designated durations. Following treatment, they were washed under tap water for 4 minutes, rinsed with distilled water, and then dried for 2 hours (McDonald, 2000).

Germination tests

Seed germination capacity and percentage were assessed following ISTA guidelines. Seeds were placed on filter paper inside Petri dishes, and the experiment was arranged as a randomized block design with four replications, each containing 100 seeds. Germination tests were carried out under optimal temperature conditions of 20°C, in accordance with ISTA standards.

To calculate the mean germination time, daily counts were carried out. Seeds that developed a radicle of at least 2 mm were considered “germinated” and subsequently removed from the Petri dishes. The germination rate (%) value was determined according to Larsen and Andreasen (2004).

$CG = \Sigma n / N \times 100$

n: number of germinated/emerged seeds

N: total number of seeds

The germination rate was calculated according to Pederson et al. (1993).

Average germination time (T50) = $\Sigma(g \times n) / \Sigma n$ □

gx: day of counting from the start of the test

nx: Number of germinated seeds on the day of counting

Σnx: total number of germinated seeds

Combined treatments

Germination assays were also performed with combined treatments involving osmotic priming, KNO_3, and GA_3. Seeds were coated in three different ways: only with polymer, with polymer containing 0.2% KNO_3, and with polymer containing 0.1% GA_3. After coating, seeds were dried for 24 hours. Additionally, seeds that had undergone priming were subjected to the same coating process after drying.

The experimental design therefore included all possible treatment combinations derived from these applications.

1. Control
2. KNO_3
3. GA_3
4. Hydropriming
5. Osmopriming
6. Hydropriming + GA_3
7. Osmopriming + KNO_3
8. Osmopriming + GA_3

Statistical analysis

Analysis of variance (ANOVA) was conducted to evaluate seed germination and growth parameters. Differences among treatment means were compared using the LSD test at a significance level of $p < 0.05$, performed with the TotemStat statistical software (Acikgoz et al., 2004).

RESEARCH RESULTS AND DISCUSSION

The effects of the treatments applied to seeds from *Lavandula angustifolia* Mill. population I on germination parameters are summarized in Table 1 and Figures 1 and 2, while the daily germination progression is shown in Figure 3.

As indicated in Table 1, both germination percentage and mean germination time differed significantly among treatments. The highest germination percentage (68%) was observed in the Osmopriming + GA_3 treatment, followed by GA_3 alone at 56%. The control group exhibited a germination percentage of 40%.

Regarding mean germination time, the shortest times were recorded in the Osmopriming + GA_3 (9.16 days) and Osmopriming (9.22 days) treatments, whereas the control group required 11.42 days for germination.

Table 1. Effect of treatments on germination values of *Lavandula angustifolia* Mill. seeds collected from Population. I.

Application	***Germination rate (%)***		***Average Germination Time (days)***	
Control	**40.00**	d	**11.42**	d
KNO_3	**41.00**	cd	**11.59**	d
GA_3	**56.25**	b	**9.91**	b
Hydropriming	**46.00**	c	**10.11**	bc
Osmopriming	**45.00**	cd	**9.22**	a
Hydropriming+GA_3	**52.00**	b	**10.72**	c
Osmopriming+KNO_3	**45.00**	cd	**10.11**	bc
Osmopriming+ GA_3	**68.00**	a	**9.16**	a
p≤0.05	***LSD: 5.990***		***LSD: 0.635***	

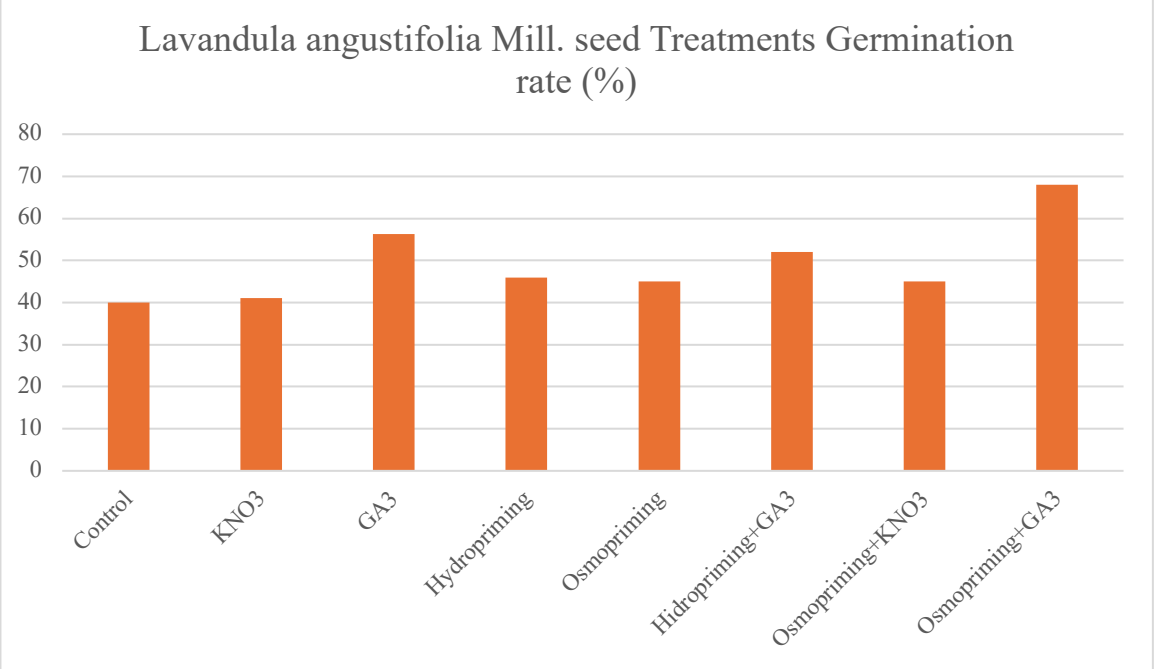


Figure 1. Effects of Applications on Germination Rate in Population 1 Seeds

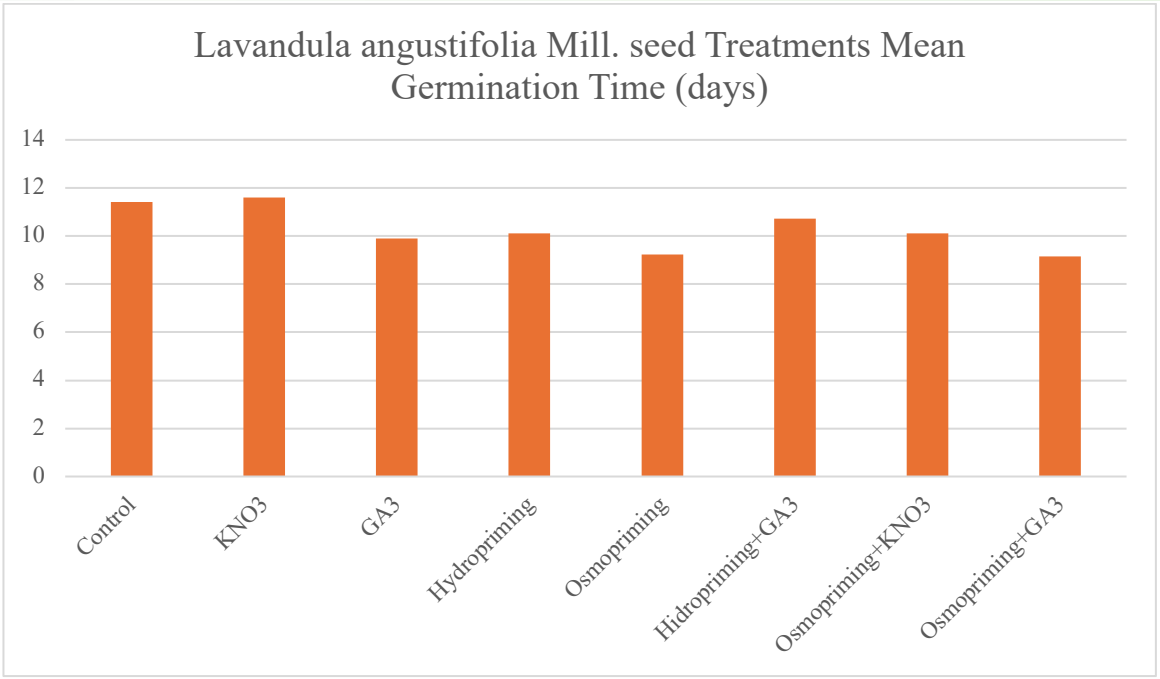


Figure 2. Effects of Applications on the Average Germination Time of Population I Seeds

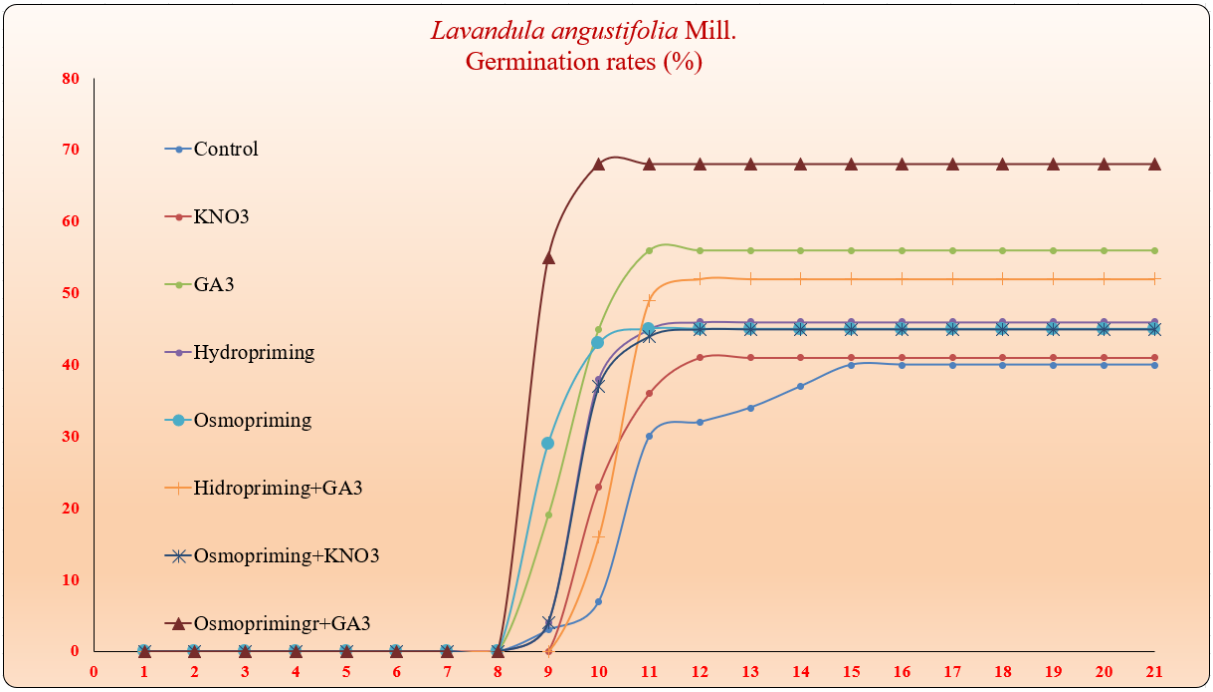


Figure 3. Daily germination values of Lavandula seeds collected from population I after treatments

Table 2 shows that the difference between the treatments is statistically significant and that the seeds reached the highest germination power after the Hydropriming+GA_3 and Osmopriming+GA_3 treatments (Figures 4, 5). The effects of the treatments on daily germination values are shown in Figure 6.

Our study determined that the Hidropriming+GA_3 and Osmopriming+ GA_3 treatments increased germination compared to the control. The highest germination rate was determined to be 66.0%. This was followed by the GA_3 treatment with 53.0%.

The effect of the applications on the average germination time (days) was also found to be statistically significant. The best result in terms of average germination time was found in the Osmopriming+ GA_3 application with 9.17 days.

Table 2. Effect of applications on germination values of *Lavandula angustifolia* Mill. seeds collected from Population II

Application	***Germination rate (%)***	***Average Germination Time (days)***
Control	**38.00** d	**11.50** c
KNO_3	**38.00** d	**11.39** c
GA_3	**53.00** b	10.09 b
Hydropriming	**48.00** bc	10.15 b
Osmopriming	**44.00** c	10.07 b
Hydropriming+GA_3	**66.00** a	9.92 b
Osmopriming+KNO_3	**44.00** c	10.05 b
Osmopriming+ GA_3	**66.00** a	9.17 a
p≤0.05	***LSD: 5.670***	***LSD: 0.580***

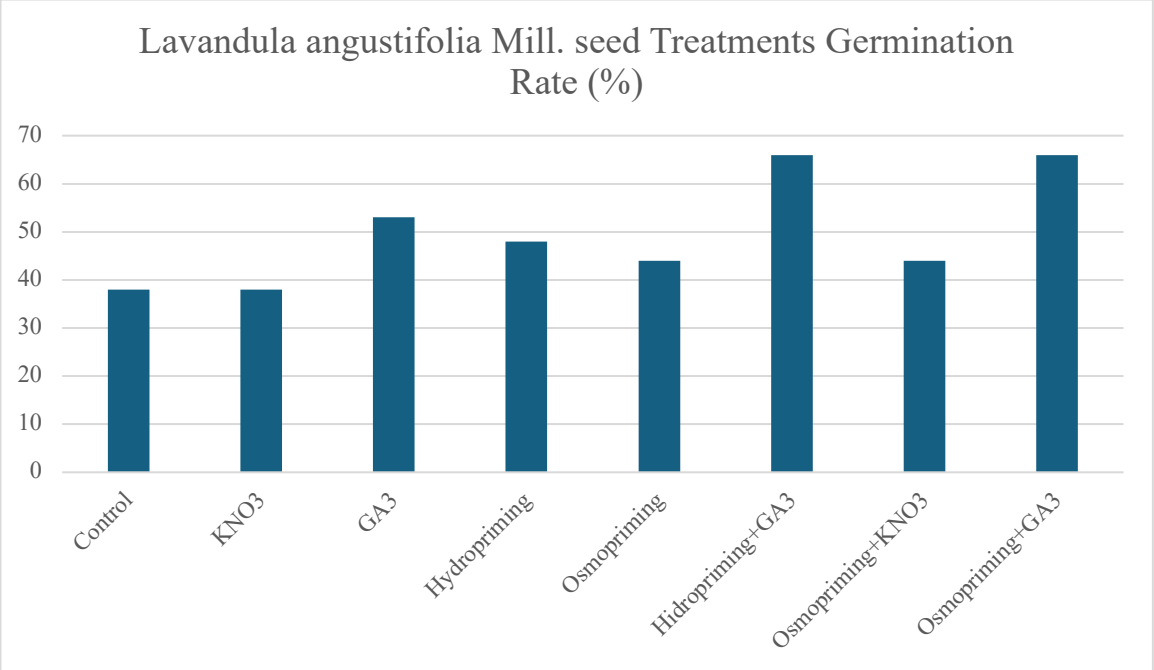


Figure 4. Effects of Applications on Germination Rate in Population II Seeds

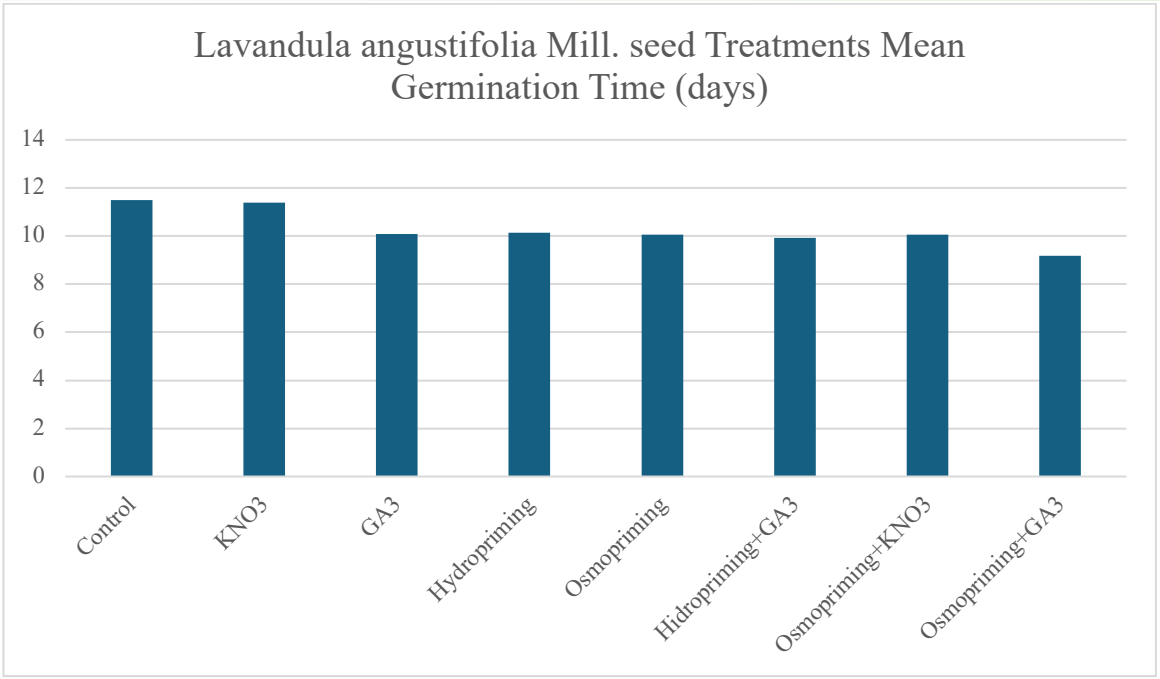


Figure 5. Effects of Applications on the Average Germination Time of Population II Seeds

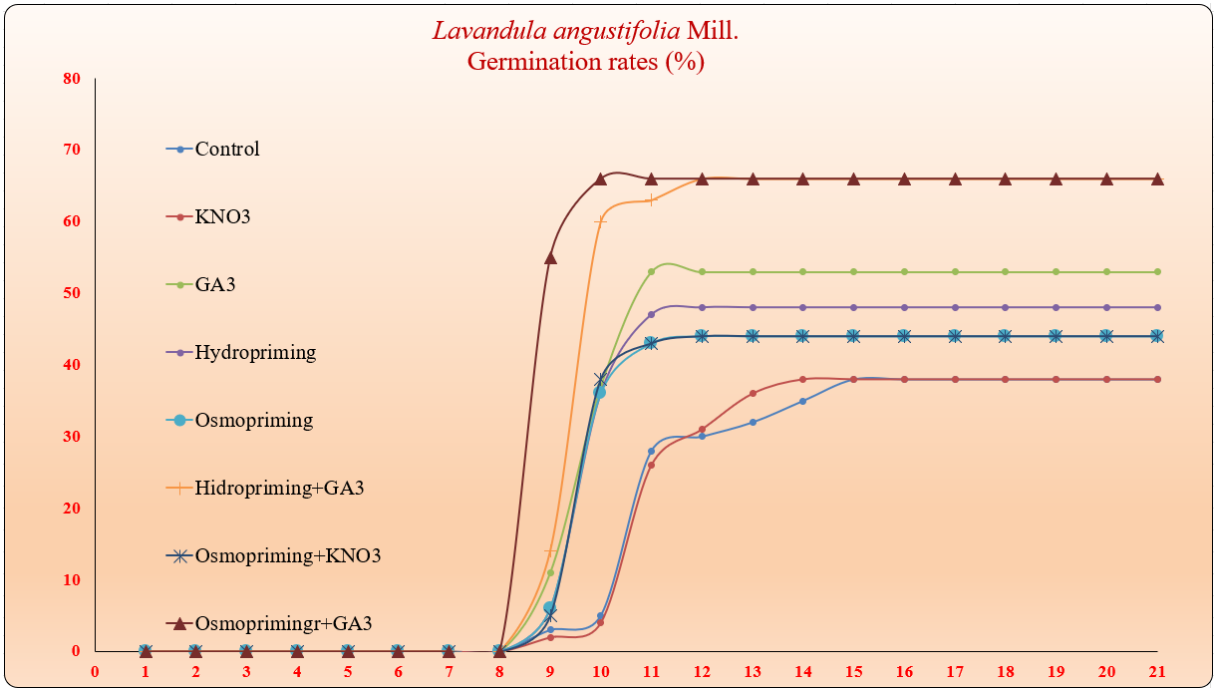


Figure 6. Daily germination values of Lavandula seeds collected from Population II after treatments

Statistical analysis of the germination power figures revealed significant differences at the $p<0.05$ level (Table 3). The highest germination power, 69.0%, was obtained from the Osmopriming+GA_3 application. This application was followed by Osmopriming and Osmopriming+KNO_3 (64.0%). The germination power of the control group was found to be 44.0% (Figures 7, 8).

When the results for germination time were examined, the Osmopriming+ GA_3 application (9.20 days) ranked first, followed by the Osmopriming+KNO_3 application (9.80 days). The germination time of the control group was found to be 11.02 days (Figure 9).

Table 3. Effect of treatments on germination values of *Lavandula angustifolia* Mill. seeds collected from Population III

Application	***Germination rate (%)***	***Average Germination Time (days)***
Control	**44.00** e	**11.02** c
KNO_3	**45.00** e	**10.98** c
GA_3	**52.00** d	**10.04** b
Hydropriming	**52.00** d	**9.98** b
Osmopriming	**64.00** b	**9.83** b
Hydropriming+GA_3	**58.00** c	**9.90** b
Osmopriming+KNO_3	**64.00** b	**9.80** ab
Osmopriming+ GA_3	**69.00** a	**9.20** a
p≤0.05	***LSD: 4.940***	***LSD: 0.620***

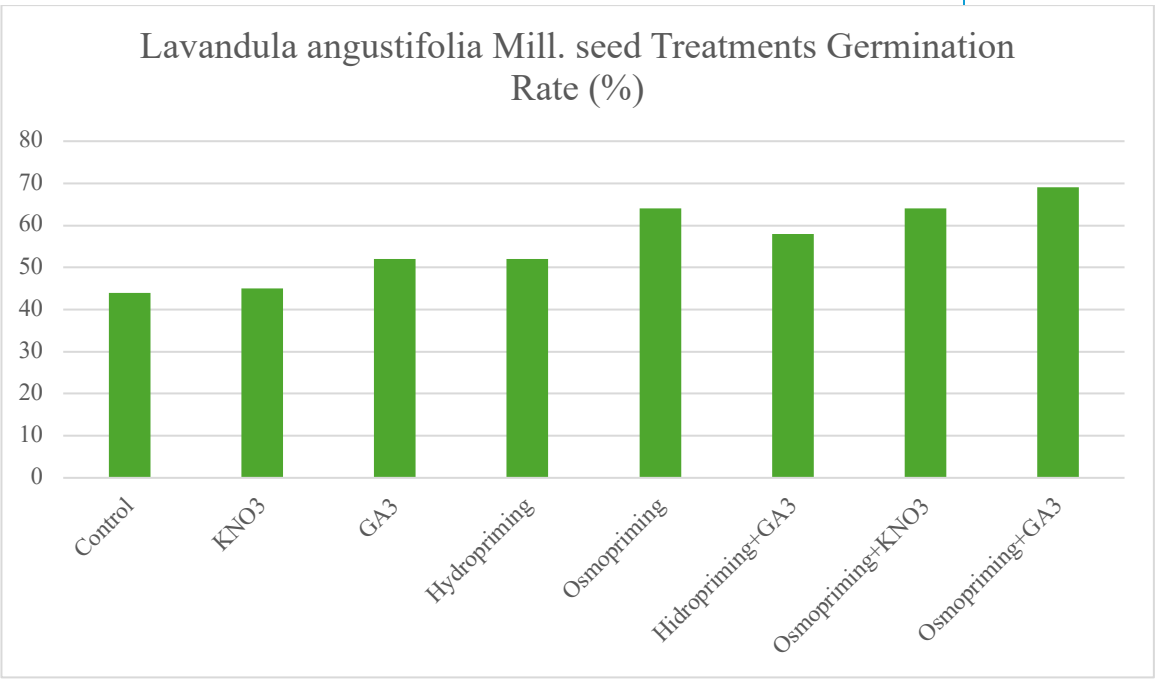


Figure 7. Effects of Applications on Germination Rate in Population III Seeds

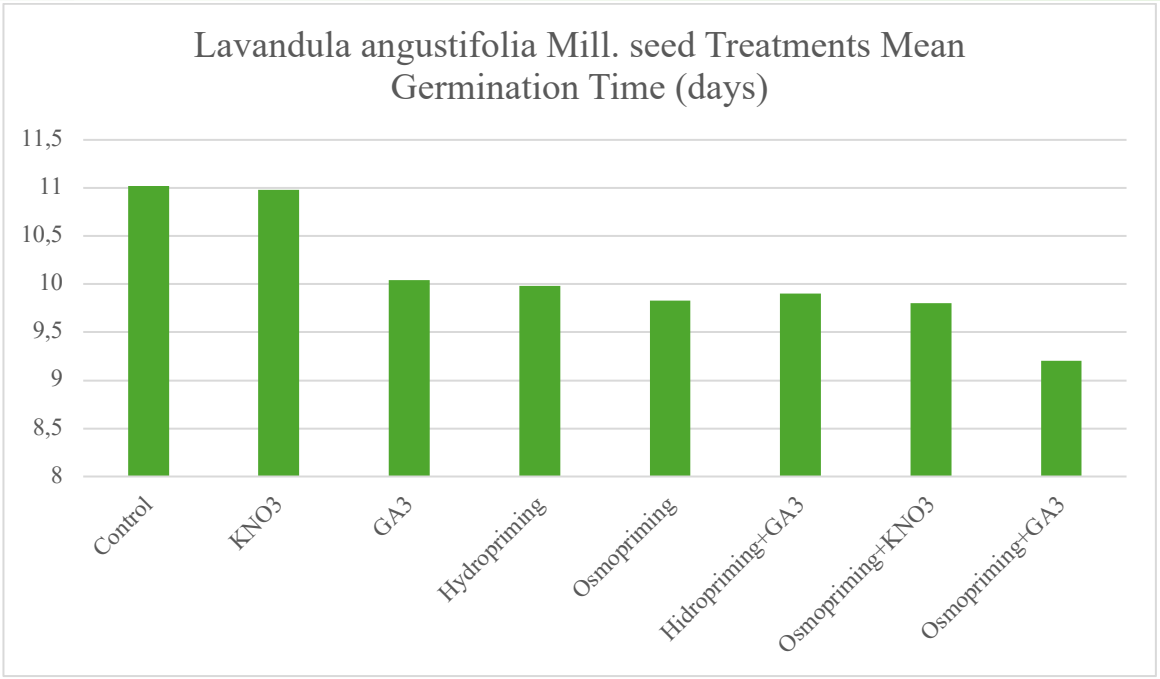


Figure 8. Effects of Applications on the Average Germination Time of Population III Seeds

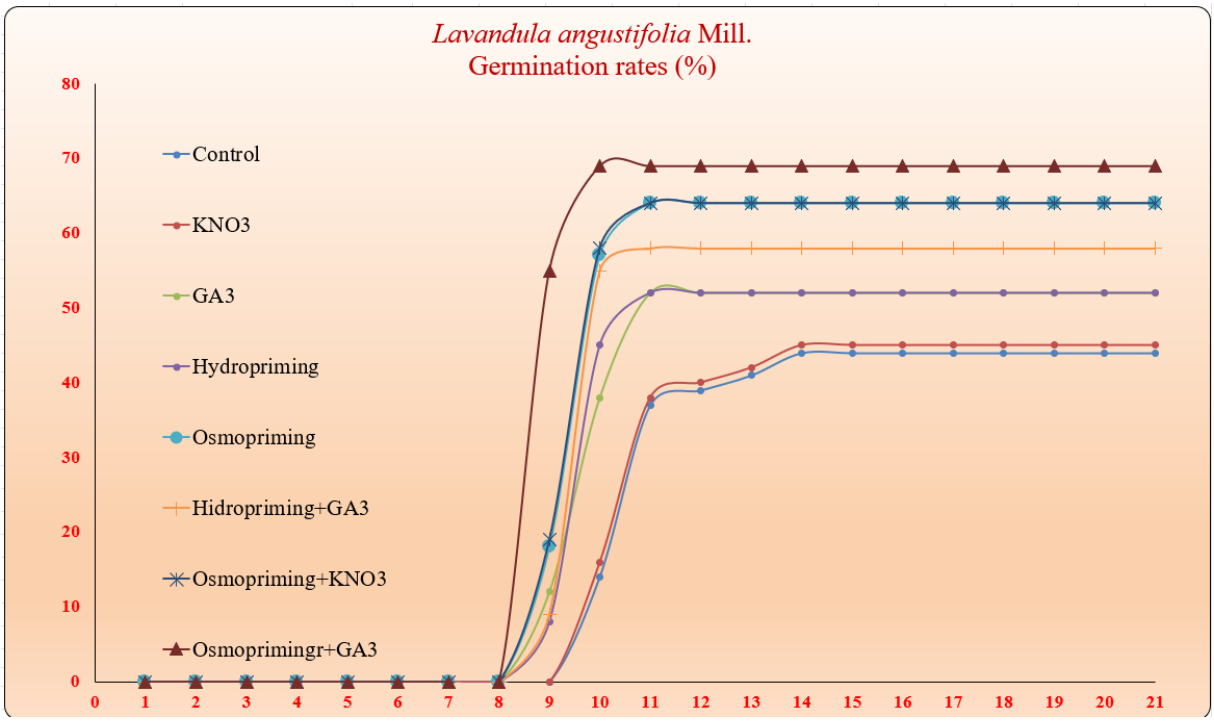


Figure 9. Daily germination values of Lavandula seeds collected from Population III after treatments

Lavandula angustifolia Mill. seeds were exposed to different concentrations of GA_3 (100, 200, and 300 ppm). The treatments demonstrated that GA_3 was effective in breaking seed dormancy and enhancing germination. Furthermore, germination showed a positive correlation with the increasing doses of GA_3 (Varga et al. 2021). In a study on germination techniques of species from the Labiatae family, it was indicated that suitable germination could be achieved at constant temperatures of 15 °C or 20 °C, as well as under alternating temperature regimes of 10–30 °C and 15–25 °C. (Ellis et al. 1985).

Previous studies have shown that priming treatments accelerate germination (Asaduzzaman et al., 2021; Kayacetin, 2021). In addition, numerous reports highlight that pre-sowing applications such as priming, KNO_3, and GA_3 positively influence germination percentage and average germination time (Ajouri et al., 2004; Duman et al., 2011; Ahmadian et al., 2015).

For the seeds of Izmir oregano (*Origanum onites* L.), lavender (*Lavandula stoechas* L.), and basil (*Ocimum basilicum* L.) In this study, the Priming + Polymer + GA_3 and Priming + Polymer + KNO_3 treatments provided the most favorable outcomes in terms of germination percentage and mean germination time compared to the control (Ekren et al., 2024). Similarly, our findings support these results, showing that combined applications were more effective.

CONCLUSIONS

In this research, pre-sowing treatments were applied to seeds from populations I, II, and III of *Lavandula angustifolia* Mill. with the aim of improving germination performance and seed quality. For this purpose, seven different treatments were applied to all seeds from the three populations: KNO_3 application, GA_3 application, Hydropriming, Osmopriming, Hydropriming+GA_3, Osmopriming+KNO_3, and Osmopriming+GA_3. Osmopriming+GA_3 treatments. The effects of these treatments on seed germination and emergence rates, as well as on the average speed of germination and emergence, were evaluated in comparison with the control group. The findings indicate that the Osmopriming + GA_3 application in the cultivation of *Lavandula angustifolia* Mill. is effective and provides positive outcomes.

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MUŞ OVASINDA YETİŞTİRİCİLİĞİ YAPILAN YONCA(*MEDICAGO SATIVA* L.) GENOTİPLERİNİN VERİM ÖZELLİKLERİNİN BELİRLENMESİ*

Samet AŞKIN

Zir. Yük. Müh. Muş İl Tarım ve Orman Müdürlüğü

Email: samet.askin@tarimorman.gov.tr

Yaşar KARADAG

Prof. Dr. Necmettin Erbakan Üniversitesi, Ereğli Ziraat Fakültesi

Email: yasar.karadag@erbakan.edu.tr (sorumlu yazar)

Mahir ÖZKURT

Doç. Dr. Muş Alparslan Üniversitesi, Uygulamalı Bilimler Fakültesi

Email: m.ozkurt@alparslan.edu.tr

ÖZET:

Bu çalışma, Muş ovası sınırları dâhilinde yetiştiriciliği yapılan Bilensoy-80 yonca çeşidinin ve yerel yonca genotiplerinin verim ve özelliklerinin tespit edilmesi amacıyla 2022 yılında yapılmıştır. Çalışmanın yürütüldüğü 13 ayrı köyde (Bağlar, Bozbulut, Çöğürlü, Karakuyu, kepenek, Kıyıbaşı, Kızılağaç, Muratgören, Özdilek, Serinova, Suboyu, Sungu ve Taşoluk) toplam 52 adet yonca (22 adet Bilensoy-80 yonca çeşidi parseli ve 30 adet yerel yonca genotipleri parseli) parseli ürünün %10 çiçeklenme dönemine ve ürünün birinci biçimine denk gelen dönemde ziyaret edilmiştir. Çalışmada 10 adet bitki bir tekerrür olacak şekilde her parselden rastgele seçilen 15 bitkinin boyu en alt noktasından en üst noktasına kadar olan kısmı cm cinsinden ölçülmüş ve bitkilerin ortalama ölçümleri alınarak bitki boyları tespit edilmiştir. Her tesadüf bloku deneme deseninden dört tekerrürlü olarak alınan toplam 208 adet örnek laboratuvar ortamına alınmıştır. Son olarak dört ayrı tekerrürden rastgele alınan bir kilogram yonca kurutulmaya bırakılarak kuru ot verimleri hesaplanmıştır. Kurutulan yonca örnekleri öğütüldükten sonra kalite parametreleri NIRS cihazı ile analiz edilmiş ve Bilensoy-80 yonca çeşidinde, bitki boyu 67.80-134.00 cm, yeşil ot verimi dekara 1901.25-6782.50 kg, kuru ot verimi dekara 360.75-1380.76 kg, kuru ot oranı %17.67-29.60, ham protein verimi dekara 73.32-224.95 kg arasında, yerel genotiplerin üretimlerinde ise bitki boyu 58.87-125.27 cm, yeşil ot verimi dekara 1770.00- 4723.00 kg, kuru ot verimi dekara 415.25-875.28 kg, kuru ot oranı %18.14-26.57, ham protein verimi dekara 67.41-175.95 kg ise 99.42-113.17 arasında değişim gösterdiği saptanmıştır. Bilensoy-80 yonca çeşidi ile yerel yonca genotiplerin üretim parametreleri karşılaştırıldığında, analiz edilen koşullar arasındaki farklar Duncan testi kullanılarak karşılaştırılmış ve tüm koşullar arasında gözlenen farklılıklar istatistiksel olarak önemli bulunmuştur.

Anahtar Kelimeler: Bilensoy-80, Muş Ovası, Sertifikalı Çeşit, Yerel Çeşit, Yonca

DETERMINATION OF YIELD CARACTERISTICS OF ALFALFA (*MEDICAGO SATIVA* L.) GENOTYPE CULTURED IN MUS PLAIN

ABSTRACT

This study was conducted in 2022 to determine the yield and characteristics of Bilensoy-80 alfalfa variety and local alfalfa genotypes grown within the borders of the Muş plain. In 13 different villages (Bağlar, Bozbulut, Çöğürlü, Karakuyu, kepenek, Kıyıbaşı, Kızılağaç, Muratgören, Özdilek, Serinova, Suboyu, Sungu and Taşoluk) where the study was carried out, a total of 52 clover (22 Bilensoy-80 clover variety plots and 30 local clover plots) were collected. genotypes plot) was visited during the period corresponding to the 10% flowering period of the crop and the first form of the crop. In the study, the height of 15 plants randomly selected from each plot, 10 plants in one replication, was measured in cm from the lowest point to the highest point, and the plant heights were determined by taking the average measurements of the plants. A total of 208 samples, taken from each randomized block trial design with four replications, were taken into the laboratory environment. Finally, one kilogram of alfalfa randomly taken from four separate replicates was dried and the hay yield was calculated. After the dried alfalfa samples were ground, the quality parameters were analyzed with the NIRS device and in Bilensoy-80 alfalfa variety, plant height was 67.80-134.00 cm, green grass yield was 1901.25- 6782.50 kg per decare, hay yield was 360.75-1380.76 kg per decare, dry grass rate was 17.67%. 29.60, crude protein yield 73.32-224.95 kg per decare is between 100.23-116.39, in the production of local genotypes, plant height is 58.87-125.27 cm, green grass yield is 1770.00-4723.00 kg per decare, hay yield is 415.25-875.28 kg per decare, dry grass rate is 18.14-26.57%, crude protein yield 67.41-175.95 kg per decare was found to vary between 99.42-113.17. When the production parameters of Bilensoy-80 alfalfa variety and local alfalfa genotypes were compared, the differences between the analyzed conditions were compared using the Duncan test and the differences observed between all conditions were found to be statistically significant.

Keywords: Alfalfa, Bilensoy-80, Certified Variety, Mus Plain, Native Variety

1. GİRİŞ

Üretimi çok eski zamanlara dayanan yonca (Medicago sativa L.) dünya genelinde geniş üretim sahasına sahip en önemli yem bitkilerindendir (Uluocak, 1984). Eski kaynaklarda yonca bitkisinin Türkiye'deki tarihinin üç bin üç yüz yıl öncesine dayandığı bildirilmiştir (Hanson ve ark., 1988). Yonca bitkisine ilişkin verilen bilgiler incelendiğinde yoncanın kültüre alınma çalışmalarının çok eski zamanlara dayandığı görülmektedir (Michaud ve ark., 1988).

Yonca, dünya genelinde hem **yüksek besleme değeri**, hem de **iklim uyum yeteneği** nedeniyle en önemli çok yıllık yem bitkilerinden biridir. "Yem bitkilerinin kraliçesi" olarak adlandırılan bu tür, hem kuru hem yaş ot üretiminde temel kaynaklardan biridir (Yeşil ve Şengül, 2009).

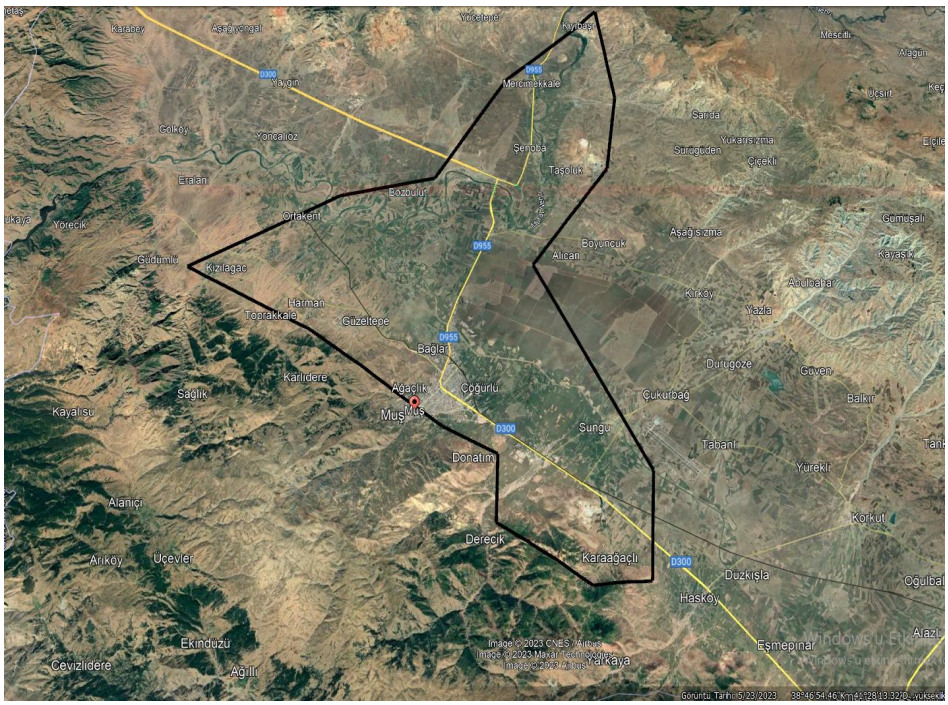
Türkiye'de 2022 TÜİK verilerine göre yonca üretim alanları toplam tarım alanlarının yalnızca **%2,7'sini** oluşturmakta, bu da kaliteli kaba yem açığının sürdüğünü göstermektedir. Doğu Anadolu'da, özellikle **Muş Ovası**, sahip olduğu **geniş tarım alanları**, **yüksek hayvan varlığı** ve **geleneksel üretim alışkanlıkları** nedeniyle bu açıdan kritik bir konumdadır.

Yem bitkileri yetiştiriciliği kapsamında dünyanın en büyük üretim alanına sahip olan yoncanın ülkemizde de gerekli önemi kazanması gerekmektedir. Türkiye'de 2022 TUİK verileri incelendiğinde yonca üretim alanlarının toplam tarım alanlarına oranı %2,71 olduğu görülmektedir (Anonim, 2022). Bu kapsamda yapılacak çalışmalar neticesinde en verimli yonca çeşitlerin bulunup ıslah çalışmalarına dâhil edilmesi ülkemizde yonca bitkisinin üretim alanlarını arttıracaktır. Muş ili toplam 1 206.030 küçükbaş hayvan varlığı ile ülke sıralamasında 13. ve bölgede 4. sırada yer almaktadır. Büyükbaş hayvan varlığında ise toplam 298.404 adet baş ile ülke sıralamasında 15. ve bölgede 5. sırada yer almaktadır (Anonim, 2022a). Doğu Anadolu Bölgesinin bütün illerinde hayvan yetiştiriciliğinin ana girdisi olan kaliteli yem ihtiyacı mera ve çayır alanlarından elde edilen çayır otunun yanında yem bitkileri (yonca, s. mısır, korunga, fiğ vb.) yetiştiriciliği yapılarak karşılanmaktadır (Anonim 2022b). Muş'ta yonca yetiştiriciliği büyük oranda tescil edilmemiş yerel tohum genotipleriyle yapılmaktadır. Yetiştiriciler tarafından tercih edilen bu yerel genotiplerin verim ve kalite özelliklerinin belirlenmesi oldukça önemlidir.

Ancak bölgede kullanılan tohumların büyük çoğunluğu **sertifikasız, yerel genotiplerdir**. Bu nedenle bu çalışma, **yerel genetik kaynakların performansını**, **sertifikalı bir çeşitle** bilimsel olarak kıyaslayan ilk detaylı çalışmalardan biridir.

2. MATERYAL ve YÖNTEM

2.1. Materyal



Şekil 1. Tez çalışma lokasyonlarına ait uydu görüntüsü

Araştırma 2022 yılında, Muş Ovası'na bağlı **13 farklı köyde** (Bağlar, Bozbulut, Çöğürlü, Karakuyu, Kepenek, Kıyıbaşı, Kızılağaç, Muratgören, Özdilek, Serinova, Suboyu, Sungu ve Taşoluk) yürütülmüştür.

Toplam **52 parsel**de;

- 22 parsel **Bilensoy-80 sertifikalı çeşidi**,
- 30 parsel ise **yerel genotipler** içermektedir.

Denemeler, **tesadüf blokları deneme deseninde dört tekerrürlü** olarak planlanmıştır.Her parselde, ürünün %10 çiçeklenme döneminde rastgele seçilen bitkilerden **bitki boyu (cm)**, **yeşil ot ve kuru ot verimi (kg/da)**, **ham protein oranı (%), ADF, NDF, SKM, KMT ve Nispi Yem Değeri (NYD)** gibi 12 farklı parametre ölçülmüştür.

Laboratuvar analizleri **NIRS cihazı** ile yapılmış, istatistiksel farklar **Duncan testi (P<0.01)** ile değerlendirilmiştir.

2.2. İklim Özellikleri

Çizelge 3.2. Muş ili uzun yıllar iklim verileri ortalaması

MUŞ	**Ortalama Sıcaklık (°C)**		**Ortalama Nispi Yem (%)**		**Toplam Yağış (ml)**	
Aylar	**Uzun Yıllar**	**2022**	**Uzun Yıllar**	**2022**	**Uzun Yıllar**	**2022**
Ocak	-6.95	-7.50	84.02	85.97	89.5	72.90
Şubat	-4.32	-4.28	82.64	87.98	96.5	41.45
Mart	2.38	-1.68	76.82	85.22	108.5	159.65

Nisan	9.87	10.08	64.08	60.78	101.9	27.35
Mayıs	14.58	12.38	64.30	68.50	69.1	67.05
Haziran	20.16	19.88	50.89	52.62	27.1	21.43
Temmuz	24.75	24.16	37.83	34.17	7.7	1.15
Ağustos	24.98	25.54	34.38	28.67	5.4	0.77
Eylül	19.96	19.94	38.82	38.02	15.6	17.18
Ekim	12.87	13.68	56.86	57.92	52.8	27.73
Kasım	4.58	5.72	73.22	76.85	86.7	37.87
Aralık	-2.09	2.02	83.92	82.35	88.1	6.57
Ort./Toplam	10.06	10.00	62.36	63.25	758.9	481.10

Muş ilinde uzun yıllar ortalama sıcaklık **10,06°C**, yıllık yağış **758,9 mm** iken 2022 yılı araştırma döneminde yağış **481 mm** olarak kaydedilmiştir. Bu durum, bitki gelişim döneminde **nispeten kurak bir sezon** yaşandığını göstermektedir.

2.2.1. Toprak Özellikleri

Çizelge 3.3. Muş ili BTG (Büyük Toprak Gruplarının)kapladıkları alanlar

Büyük Toprak Grubu (BTG)	**Alan**	
	ha	**%**
Vertisoller	65.526	7,53
Alüviyaller	43.078	4,95
Kireçsiz Kahverengi Topraklar	19.423	2,23
Kestanerengi Topraklar	134.173	15,41
Bazaltik Topraklar	6.937	0,80
Kolüviyaller	9.889	1,14
Kireçsiz Kahverengi Orman Toprakları	4.329	0,50
Regosoller	5.345	0,61
İşlenmeyen	582.065	66,85
Toplam	870.768	100,00

Yaşar M., Turgut Y.Ş., Koca Y. K., 2020. / Anemon Muş Alparslan Üniversitesi Sosyal Bilimler Dergisi, 2020 8 (UMS'20) 81-90

Toprak analizleri, Muş Ovası'nın **kestanerengi-killi yapıda**, **pH'sı nötr**, **tuzluluk oranı düşük** bir karaktere sahip olduğunu ortaya koymuştur. Dolayısıyla yonca üretimi için **uygun bir fizyolojik zemin** mevcuttur.

3. ARAŞTIRMA SONUÇLARI

3.1. Bitki Boyu (cm)

Farklı alanlarda yetiştirilen yonca (*Medicago sativa* L.) genotiplerinin bitki boyları arasında istatistiksel açıdan %1 önem düzeyinde ($p<0.01$) anlamlı fark bulunmuştur. Bu sonuç, incelenen genotiplerin bitki boyu bakımından önemli farklılıklar gösterdiğini ortaya

koymaktadır.

Çizelge 3.1. Yerel yonca popülasyonlarına ait bitki boyları

Sıra No:	Popülasyon	Bitki Boyu (cm)	Sıra No:	Popülasyon	Bitki Boyu (cm)
1	Kıyıbaşı-1	78.87 q1	**16**	Kepenek-3	89.60 c1
2	Kıyıbaşı-2	87.13 g1	**17**	Kepenek-4	105.93 p
3	Kıyıbaşı-3	89.27 d1	**18**	Bağlar-1	104.87 r
4	Kıyıbaşı-4	102.07 u	**19**	Sungu-4	124.80 d
5	Serinova-3	91.87 y	**20**	Çöğürlü-1	125.27 c
6	Taşoluk-1	83.87 j1	**21**	Çöğürlü-3	120.07 f
7	Taşoluk-2	77.40 t1	**22**	Çöğürlü-4	94.47 w
8	Taşoluk-3	77.47 s1	**23**	Subouyu-1	83.33 k1
9	Taşoluk-4	78.87 p1	**24**	Subouyu -2	116.80 g
10	Muratgören Tarla-1	92.93 x	**25**	Subouyu -3	109.73 n
11	Muratgören Tarla-2	114.47 ı	**26**	Subouyu-4	104.40 s
12	Muratgören Tarla-3	58.87 z1	**27**	Kızılağaç-1	115.40 h
13	Muratgören Tarla-4	112,87 k	**28**	Kızılağaç-2	78.13 r1
14	Kepenek Tarla-1	99.87 v	**29**	Karakuyu-3	103.67 t
15	Kepenek Tarla-2	80.60 n1	**30**	Karakuyu-4	111.80 l
		ORTALAMA			**97.16**

Çizelge 3.2. Bilensoy-80 yonca çeşidine ait bitki boyları

Sıra No:	Popülasyon	Bitki Boyu (cm)	Sıra No:	Popülasyon	Bitki Boyu (cm)
1	Serinova-1	75.00 u1	**12**	Özdilek-2	131.33 b
2	Serinova-2	80.27 o1	**13**	Özdilek-3	67.80 y1
3	Serinova-4	91.27 z	**14**	Özdilek-4	82.33 l1
4	Bağlar-2	73.80 v1	**15**	Kızılağaç-3	80.87 m1
5	Bağlar-3	67.87 x1	**16**	Kızılağaç-4	105.13 q
6	Bağlar-4	71.80 w1	**17**	Karakuyu-1	90.60 a1
7	Sungu-1	110.60 m	**18**	Karakuyu2	84.40 ı1
8	Sungu-2	108.67 o	**19**	Bozbulut-1	87.60 f1
9	Sungu-3	90.53 b1	**20**	Bozbulut-2	89.07 e1
10	Çöğürlü-2	134.00 a	**21**	Bozbulut-3	120.07 e

11	Özdilek-1	113.07 j	**22**	Bozbulut-4	86.87 h1
		ORTALAMA			**92.86**

Yerel yonca popülasyonlarının ortalama bitki boyları Çizelge 3.1'de, Bilensoy-80 çeşidine ait değerler ise Çizelge 3.2'de verilmiştir. Yerel popülasyonlarda bitki boyu 58.87–125.27 cm arasında değişmiş ve ortalama 97.16 cm olarak belirlenmiştir. Bilensoy-80 çeşidinde ise bu değerler 67.80–134.00 cm aralığında olup ortalama 92.86 cm olarak saptanmıştır.

Yerel popülasyonlarda en yüksek bitki boyu Çöğürlü Köyü birinci parselde, en düşük değer ise Muratgören Köyü üçüncü parselde; Bilensoy-80 çeşidinde ise en yüksek boy Çöğürlü Köyü ikinci, en düşük boy ise Özdilek Köyü üçüncü parselde belirlenmiştir.

Farklı zaman, lokasyon ve çalışmalarda elde edilen sonuçların benzerlik göstermesi, bitki boyundaki farklılıkların hem genetik yapıdan hem de çevresel faktörlerden kaynaklandığını ortaya koymaktadır (Smith ve ark., 1989; Smith ve ark., 1991; Juan ve ark., 1993).

3.2. Yeşil Ot Verimi (kg/da)

Muş Ovası sınırları dâhilinde yetiştirilen yonca genotiplerine ait yeşil ot veriminin varyans analizi sonuçlarına göre, farklı alanlarda yetiştirilen yerel ve Bilensoy-80 yonca genotiplerinin yeşil ot verimleri arasında istatistiksel olarak %1 önem düzeyinde ($p<0.01$) anlamlı fark tespit edilmiştir. Bu durum, incelenen genotiplerin yeşil ot verimi bakımından önemli farklılıklar gösterdiğini ortaya koymaktadır.

Çizelge 3.3. Yerel yonca popülasyonlarına ait yeşil ot verimleri

Sıra No:	Popülasyon	Yeşil Ot Verimi (kg/da)	Sıra No:	Popülasyon	Yeşil Ot Verimi (kg/da)
1	Kıyıbaşı-1	1848.75 tu^{+}	**16**	Kepenek-3	2435.00 l-s
2	Kıyıbaşı-2	2552.50 k-r	**17**	Kepenek-4	2768.75 ı-p
3	Kıyıbaşı-3	2958.50 k-m	**18**	Bağlar-1	4353.75 cd
4	Kıyıbaşı-4	2553.50 k-r	**19**	Sungu-4	4723.75 bc
5	Serinova-3	2330.75 n-u	**20**	Çöğürlü-1	2237.50 p-u
6	Taşoluk-1	2548.75 k-r	**21**	Çöğürlü-3	3584.75 fgh
7	Taşoluk-2	2812.00 ı-o	**22**	Çöğürlü-4	3712.50 efg
8	Taşoluk-3	3570.00 fgh	**23**	Subouyu-1	1881.00 su
9	Taşoluk-4	2968.50 ı-l	**24**	Subouyu-2	3710.00 efg
10	Muratgören-1	4137.25 def	**25**	Subouyu-3	3940.00 def
11	Muratgören-2	4184.75 cdg	**26**	Subouyu-4	2686.25 j-q
12	Muratgören-3	1771.25 u	**27**	Kızılağaç-1	2772.25 ı-p
13	Muratgören-4	3732.00 efg	**28**	Kızılağaç-2	2356.25 n-t
14	Kepenek-1	3185.75 g-j	**29**	Karakuyu-3	2638.50 k-r
15	Kepenek-2	1770.25 u	**30**	Karakuyu-4	2333.75 n-u
		ORTALAMA			**2971.29**

+: Aynı sütun içerisinde benzer harf ile gösterilen ortalamalar Duncan testine göre P≤0,01 hata sınırları içinde birbirinden farksızdır

Çizelge 3.4. Bilensoy-80 yonca çeşidine ait yeşil ot verimleri

Sıra No:	Popülasyon	Yeşil Ot Verimi (kg/da)	Sıra No:	Popülasyon	Yeşil Ot Verimi (kg/da)
1	Serinova-1	3055.50 h-k^{+}	**12**	Özdilek-2	5157.50 b
2	Serinova-2	2081.00 r-u	**13**	Özdilek-3	2568.75 k-r
3	Serinova-4	2782.50 ı-p	**14**	Özdilek-4	2391.25 m-t
4	Bağlar-2	2887.50 ı-n	**15**	Kızılağaç-3	1935.50 su
5	Bağlar-3	2505.00 k-r	**16**	Kızılağaç-4	3711.25 efg
6	Bağlar-4	2297.00 o-u	**17**	Karakuyu-1	1923.75 su
7	Sungu-1	2790.00 ı-p	**18**	Karakuyu-2	2196.25 q-u
8	Sungu-2	3321.00 ghj	**19**	Bozbulut-1	3910.00 def
9	Sungu-3	1901.25 su	**20**	Bozbulut-2	2513.50 k-r
10	Çöğürlü-2	3665.00 efg	**21**	Bozbulut-3	5137.50 b
11	Özdilek-1	6782.50 a	**22**	Bozbulut-4	3261.25 ghı
		ORTALAMA			**3122.48**

+: Aynı sütun içerisinde benzer harf ile gösterilen ortalamalar Duncan testine göre P≤0,01 hata sınırları içinde birbirinden farksızdır

Yerel ve Bilensoy-80 yonca popülasyonlarına ait yeşil ot verimlerine ilişkin sonuçlar Çizelge 3.4 ve Çizelge 3.5'de verilmiştir. Yerel popülasyonlarda yeşil ot verimi dekara 1770.00–4723.00 kg arasında değişmiş ve ortalama 2971.29 kg olarak belirlenmiştir. Bilensoy-80 çeşidinde ise bu değerler 1901.25–6782.50 kg arasında değişmiş, ortalama 3122.48 kg olarak tespit edilmiştir.

Yerel popülasyonlarda en yüksek yeşil ot verimi Sungu Beldesi'ndeki dördüncü parselde, en düşük verim ise Kepenek Köyü ikinci parselde belirlenmiştir. Bilensoy-80 çeşidinde en yüksek verim Özdilek Köyü birinci parselde, en düşük verim ise Sungu Beldesi üçüncü parselde elde edilmiştir.

Aynı köy sınırları içinde yapılan değerlendirmelerde, bazı lokasyonlarda yerel genotiplerin, bazı lokasyonlarda ise Bilensoy-80 çeşidinin daha yüksek yeşil ot verimi gösterdiği belirlenmiştir. Ancak genel ortalamalar dikkate alındığında Bilensoy-80 çeşidinin yeşil ot veriminin daha yüksek olduğu görülmüştür.

Literatürde Saruhan ve Kuşvuran (2011), yerel genotipte dekara 4640 kg, Bilensoy çeşidinde ise 3515 kg yeşil ot verimi bildirmiştir. Altınok ve Karakaya (2002) 1242–1644 kg, Şeker (2003) 4735.6–5804.1 kg, Karaköy ve Saraç (2018) 3519–7481 kg, Kır ve Soya (2008) 931–1359 kg, Gündel ve ark. (2014) ise 5094.5 kg değerleri belirlemişlerdir. Bu sonuçlar, çalışmadan elde edilen verilerle genel olarak uyumluluk göstermektedir.

3.3. Kuru Ot Verimi (kg/da)

Muş Ovası'nda yetiştirilen yonca genotiplerinin kuru ot verimine ait varyans analizi *sonuçları Farklı alanlarda yetiştirilen yerel ve Bilensoy-80 yonca popülasyonlarının kuru ot verimleri arasındaki fark istatistiksel olarak %1 önem düzeyinde (p<0.01) anlamlı bulunmuştur.*

Çizelge 3.5. Yerel yonca popülasyonlarına ait kuru ot verimleri

Sıra No:	Popülasyon	Kuru Ot Verimi (kg/da)	Sıra No:	Popülasyon	Kuru Ot Verimi (kg/da)
1	Kıyıbaşı-1	446.76 v-z^{+}	**16**	Kepenek-3	508.25 q-y
2	Kıyıbaşı-2	476.33 s-z	**17**	Kepenek-4	576.24 l-t
3	Kıyıbaşı-3	540.82 o-k	**18**	Bağlar-1	885.25 cd
4	Kıyıbaşı-4	517.79 q-y	**19**	Sungu-4	934.75 bc
5	Serinova-3	486.03 r-y	**20**	Çöğürlü-1	447.75 u-z
6	Taşoluk-1	545.50 n-w	**21**	Çöğürlü-3	665.00 h-m
7	Taşoluk-2	602.78 j-r	**22**	Çöğürlü-4	711.14 g-j
8	Taşoluk-3	849.60 c-f	**23**	Subouyu-1	426.16 xz
9	Taşoluk-4	592.94 k-s	**24**	Subouyu -2	723.31ghı
10	Muratgören-1	875.28 cde	**25**	Subouyu-3	754.40 fgh
11	Muratgören-2	851.61 c-f	**26**	Subouyu-4	534.17 p-x
12	Muratgören-3	415.25 yz	**27**	Kızılağaç-1	592.27 k-s
13	Muratgören-4	759.86 e-h	**28**	Kızılağaç-2	600.33 j-r
14	Kepenek-1	663.17 h-n	**29**	Karakuyu-3	565.24 m-u
15	Kepenek-2	469.75 t-z	**30**	Karakuyu-4	523.01 q-y
		ORTALAMA			**618.02**

+: Aynı sütun içerisinde benzer harf ile gösterilen ortalamalar Duncan testine göre P≤0,01 hata sınırları içinde birbirinden farksızdır

Çizelge 3.6. Bilensoy-80 yonca çeşidine ait kuru ot verimleri

Sıra No:	Popülasyon	Kuru Ot Verimi (kg/da)	Sıra No:	Popülasyon	Kuru Ot Verimi (kg/da)
1	Serinova-1	654.60 h-o^{+}	**12**	Özdilek-2	1.031.94 b
2	Serinova-2	526.14 q-y	**13**	Özdilek-3	529.22 p-y
3	Serinova-4	644.57 h-p	**14**	Özdilek-4	477.92 s-z
4	Bağlar-2	561.00 m-v	**15**	Kızılağaç-3	530.45 p-y
5	Bağlar-3	472.00 t-z	**16**	Kızılağaç-4	741.97 fgh
6	Bağlar-4	441.59 w-z	**17**	Karakuyu-1	566.60 l-t
7	Sungu-1	515.00 q-y	**18**	Karakuyu2	621.48 ı-q

8	Sungu-2	587.00 k-t	**19**	Bozbulut-1	785.75 d-g
9	Sungu-3	360.75 z	**20**	Bozbulut-2	683.99 g-l
10	Çöğürlü-2	726.83 ghı	**21**	Bozbulut-3	1.051.64 b
11	Özdilek-1	1386.76 a	**22**	Bozbulut-4	703.00 g-k
		ORTALAMA			**663.65**

+: Aynı sütun içerisinde benzer harf ile gösterilen ortalamalar Duncan testine göre P≤0,01 hata sınırları içinde birbirinden farksızdır

Yerel ve Bilensoy-80 yonca popülasyonlarına ait kuru ot verimleri Çizelge 3.5 ve Çizelge 3.6'da verilmiştir. Yerel popülasyonlarda kuru ot verimi dekara 415.25–875.28 kg arasında değişmiş ve ortalama 618.02 kg olarak belirlenmiştir. Bilensoy-80 çeşidinde ise bu değerler 360.75–1380.76 kg arasında olup ortalama 663.65 kg olarak saptanmıştır.

Yerel popülasyonlarda en yüksek kuru ot verimi Sungu Beldesi dördüncü parselde, en düşük verim ise Muratgören Köyü üçüncü parselde belirlenmiştir. Bilensoy-80 çeşidinde ise en yüksek verim Özdilek Köyü birinci parselde, en düşük verim Sungu Beldesi üçüncü parselde tespit edilmiştir.

Aynı köy sınırları içinde yapılan değerlendirmelerde, bazı lokasyonlarda yerel genotiplerin, bazı lokasyonlarda ise Bilensoy-80 çeşidinin kuru ot veriminin daha yüksek olduğu belirlenmiştir. Ancak genel ortalamalar dikkate alındığında Bilensoy-80 çeşidinin kuru ot veriminin daha fazla olduğu görülmüştür.

Literatürde Şeker (2003) 1101.7–1333.5 kg, Gündel ve ark. (2014) 1135 kg, Karaköy ve Saraç (2018) 884–1766 kg, Şengül ve ark. (2003) 1445–1893 kg, Dumlu ve ark. (2017) 1270.5–1555.1 kg, Engin ve Mut (2017) 1326.2–2508.9 kg, Saruhan ve Kuşvuran (2011) 945–1266 kg, Kır ve Soya (2008) ise 191.7–289.5 g/da kuru ot verimi bildirmiştir. Bu değerler, çalışmadan elde edilen sonuçlarla genel olarak uyum göstermektedir.

3.4. Kuru Ot Oranı (%)

Muş Ovası sınırları dâhilinde yetiştirilen yonca genotiplerine ait kuru ot oranlarının varyans analizi sonuçları Çizelge 3.10'da sunulmuştur. Analiz sonuçlarına göre, farklı lokasyonlarda yetiştirilen yerel ve Bilensoy-80 yonca genotiplerinin kuru ot oranları arasındaki fark istatistiksel olarak %1 önem düzeyinde ($p<0.01$) anlamlı bulunmuştur. Bu durum, incelenen genotiplerin kuru ot oranı bakımından önemli farklılıklar gösterdiğini ortaya koymaktadır.

Çizelge 3.7. Yerel yonca popülasyonlarına ait kuru ot oranları

Sıra No:	**Popülasyon**	**Kuru Ot Oranı (%)**	**Sıra No:**	**Popülasyon**	**Kuru Ot Oranı (%)**
1	Kıyıbaşı-1	24.29 def^{+}	**16**	Kepenek-3	21.01 h-p
2	Kıyıbaşı-2	18.66 m-q	**17**	Kepenek-4	20.84 h-p
3	Kıyıbaşı-3	18.31 opq	**18**	Bağlar-1	20.33 j-g
4	Kıyıbaşı-4	20.28 j-q	**19**	Sungu-4	19.92 j-q
5	Serinova-3	20.90 h-p	**20**	Çöğürlü-1	19.85 k-q
6	Taşoluk-1	21.43 f-n	**21**	Çöğürlü-3	18.15 pq
7	Taşoluk-2	21.48 f-m	**22**	Çöğürlü-4	19.27 l-q

8	Taşoluk-3	24.07 d-g	**23**	Subouyu-1	22.86 e-j
9	Taşoluk-4	19.95 j-q	**24**	Subouyu -2	19.75 k-q
10	Muratgören-1	21.19 g-o	**25**	Subouyu-3	19.23 l-q
11	Muratgören-2	20.34 ı-q	**26**	Subouyu-4	19.87 k-q
12	Muratgören-3	23.55 e-h	**27**	Kızılağaç-1	21.64 f-l
13	Muratgören-4	20.35 ı-q	**28**	Kızılağaç-2	25.63 cde
14	Kepenek-1	20.90 h-p	**29**	Karakuyu-3	21.47 f-m
15	Kepenek-2	26.57 bdc	**30**	Karakuyu-4	22.52 f-k
		ORTALAMA			**21.15**

+: Aynı sütun içerisinde benzer harf ile gösterilen ortalamalar Duncan testine göre P≤0.01 hata sınırları içinde birbirinden farksızdır

Çizelge 3.8. Bilensoy-80 yonca çeşidine ait kuru ot oranları

Sıra No:	**Popülasyon**	**Kuru Ot Oranı (%)**	**Sıra No:**	**Popülasyon**	**Kuru Ot Oranı (%)**
1	Serinova-1	21.59 f-m^{+}	**12**	Özdilek-2	19.96 j-q
2	Serinova-2	25.53 cde	**13**	Özdilek-3	20.64 h-p
3	Serinova-4	23.29 e-ı	**14**	Özdilek-4	19.96 j-q
4	Bağlar-2	19.49 l-q	**15**	Kızılağaç-3	27.37 abc
5	Bağlar-3	18.92 l-q	**16**	Kızılağaç-4	20.06 j-q
6	Bağlar-4	19.20 l-q	**17**	Karakuyu-1	29.60 a
7	Sungu-1	18.50 n-q	**18**	Karakuyu2	28.60 ab
8	Sungu-2	17.67 q	**19**	Bozbulut-1	20.05 j-q
9	Sungu-3	18.95 l-q	**20**	Bozbulut-2	27.27 abc
10	Çöğürlü-2	20.34 ı-q	**21**	Bozbulut-3	20.50 ı-q
11	Özdilek-1	20.45 ı-q	**22**	Bozbulut-4	21.56 f-m
		ORTALAMA			**21.80**

+: Aynı sütun içerisinde benzer harf ile gösterilen ortalamalar Duncan testine göre P≤0.01 hata sınırları içinde birbirinden farksızdır

Yerel ve Bilensoy-80 yonca popülasyonlarına ait kuru ot oranları Çizelge 3.7 ve Çizelge 3.8'de verilmiştir. Muş Ovası sınırları dâhilinde yetiştirilen yerel yonca popülasyonlarında kuru ot oranı %18.14–26.57 arasında değişmiş ve ortalama %21.15 olarak belirlenmiştir. Kuru ot oranı en yüksek Kepenek Köyü ikinci parselde, en düşük ise Çöğürlü Köyü üçüncü parselde tespit edilmiştir.

Bilensoy-80 yonca çeşidinde kuru ot oranı %17.67–29.60 arasında değişmiş, ortalama %21.80 olarak saptanmıştır. Bu çeşitte en yüksek kuru ot oranı Karakuyu Köyü birinci parselde, en düşük oran ise Sungu Beldesi ikinci parselde belirlenmiştir.

Elde edilen bulgular, yerel ve Bilensoy-80 genotiplerinin kuru ot oranı bakımından birbirine yakın değerlere sahip olduğunu göstermektedir. Çaçan ve ark. (2012), Güneydoğu Anadolu Bölgesi doğal meralarından toplanan bazı *Medicago* türlerinde ortalama kuru ot oranını %22.4 olarak bildirmiştir. Bu çalışma sonuçlarıyla karşılaştırıldığında, Muş Ovası koşullarında elde edilen kuru ot oranı değerlerinin literatürde bildirilen sonuçlardan bir miktar düşük olduğu görülmektedir.

3.5. Ham Protein Verimi (kg/da)

Muş Ovası sınırları dâhilinde yetiştirilen yonca genotiplerine ait ham protein verimlerinin varyans analizi sonuçlarına göre, Muş Ovası'nda farklı alanlarda yetiştirilen yerel ve Bilensoy-80 yonca genotiplerinin ham protein verimleri arasındaki fark istatistiksel olarak %1 önem düzeyinde ($p<0.01$) anlamlı bulunmuştur. Bu sonuç, incelenen genotiplerin ham protein verimi bakımından önemli farklılıklar gösterdiğini ortaya koymaktadır.

Çizelge 3.9. Yerel yonca popülasyonlarına ait ham protein verimleri

Sıra No:	Popülasyon	Ham Protein Verimi (kg/da)	Sıra No:	Popülasyon	Ham Protein Verimi (kg/da)
1	Kıyıbaşı-1	74.65 vwx^{+}	**16**	Kepenek-3	93.43 o-w
2	Kıyıbaşı-2	85.55 r-x	**17**	Kepenek-4	111.66 j-p
3	Kıyıbaşı-3	99.49 n-u	**18**	Bağlar-1	164.61 cde
4	Kıyıbaşı-4	92.05 p-w	**19**	Sungu-4	175.95 bc
5	Serinova-3	84.12 r-x	**20**	Çöğürlü-1	83.14 s-x
6	Taşoluk-1	97.94 n-u	**21**	Çöğürlü-3	123.12 h-m
7	Taşoluk-2	99.28 n-u	**22**	Çöğürlü-4	134.29 f-j
8	Taşoluk-3	139.55 f-j	**23**	Subouyu-1	78.90 u-x
9	Taşoluk-4	88.47 q-x	**24**	Subouyu -2	143.61 e-h
10	Muratgören-1	148.94 d-g	**25**	Subouyu-3	144.38 d-h
11	Muratgören-2	154.81 c-f	**26**	Subouyu-4	105.32 k-s
12	Muratgören-3	67.41 x	**27**	Kızılağaç-1	106.67 k-r
13	Muratgören-4	126.12 h-l	**28**	Kızılağaç-2	99.77 n-u
14	Kepenek-1	115.13 j-o	**29**	Karakuyu-3	98.99 n-u
15	Kepenek-2	80.36 t-x	**30**	Karakuyu-4	96.55 n-v
		ORTALAMA			**110.48**

+: Aynı sütun içerisinde benzer harf ile gösterilen ortalamalar Duncan testine göre P≤0.01 hata sınırları içinde birbirinden farksızdır

Çizelge 3.10. Bilensoy-80 yonca çeşidine ait ham protein verimleri

Sıra No:	Popülasyon	Ham Protein Verimi (kg/da)	Sıra No:	Popülasyon	Ham Protein Verimi (kg/da)
1	Serinova-1	118.06 ı-n^{+}	**12**	Özdilek-2	166.53 cd

2	Serinova-2	93.70 o-w	**13**	Özdilek-3	98.80 n-u
3	Serinova-4	125.47 h-l	**14**	Özdilek-4	73.32 wx
4	Bağlar-2	113.67 j-p	**15**	Kızılağaç-3	102.37 m-t
5	Bağlar-3	92.68 o-w	**16**	Kızılağaç-4	126.07 h-l
6	Bağlar-4	79.59 u-x	**17**	Karakuyu-1	104.50 l-s
7	Sungu-1	97.58 n-u	**18**	Karakuyu2	109.93 k-q
8	Sungu-2	99.06 n-u	**19**	Bozbulut-1	144.46 d-h
9	Sungu-3	73.54 wx	**20**	Bozbulut-2	132.93 f-j
10	Çöğürlü-2	141.52 fgh	**21**	Bozbulut-3	198.34 b
11	Özdilek-1	224.95 a	**22**	Bozbulut-4	127.77 g-k
		ORTALAMA			**120.22**

+: Aynı sütun içerisinde benzer harf ile gösterilen ortalamalar Duncan testine göre P≤0.01 hata sınırları içinde birbirinden farksızdır.

Yerel ve Bilensoy-80 yonca popülasyonlarına ait ham protein verimleri Çizelge 3.9 ve Çizelge 3.10'te sunulmuştur. Muş Ovası sınırları dâhilinde yetiştirilen yerel yonca popülasyonlarında ham protein verimi dekara 67.41–175.95 kg arasında değişmiş ve ortalama 110.48 kg olarak belirlenmiştir. Bilensoy-80 yonca çeşidinde ise ham protein verimi dekara 73.32–224.95 kg arasında değişmiş, ortalama 120.22 kg olarak saptanmıştır.

Yerel popülasyonlarda en yüksek ham protein verimi Sungu Beldesi'ndeki dördüncü parselde, en düşük verim ise Muratgören Köyü üçüncü parselde belirlenmiştir. Bilensoy-80 çeşidinde ise en yüksek ham protein verimi Özdilek Köyü birinci parselde, en düşük verim aynı köyün dördüncü parselinde tespit edilmiştir.

Elde edilen sonuçlar, bazı lokasyonlarda yerel genotiplerin, bazı lokasyonlarda ise Bilensoy-80 çeşidinin daha yüksek ham protein verimi gösterdiğini ortaya koymaktadır. Genel ortalamalar dikkate alındığında ise Bilensoy-80 çeşidinin ham protein veriminin yerel popülasyonlara göre daha yüksek olduğu görülmüştür.

Ham protein verimine ilişkin elde edilen bulgular; Şengül ve Tahtacıoğlu (1996) tarafından dekara 208.3 kg, Turan (2010) tarafından 121–185 kg ve İnal (2015) tarafından 88.2–112.9 kg olarak bildirilen sonuçlarla uyum göstermektedir. Ancak Görgülü (2018)'in 16–69 kg olarak, Manga (1981)'in 307–445 kg, Kır (2010)'un 254.4–332.7 kg, Avcı ve ark. (2011)'ın 327.1 kg ve Yılmaz ve Albayrak (2016)'ın 317.4–383.8 kg olarak belirlediği değerlerle karşılaştırıldığında, çalışmada elde edilen ham protein verimlerinin bu araştırmalara göre daha düşük olduğu görülmektedir.

4. SONUÇLAR ve ÖNERİLER

Bu çalışma, Muş Ovası ekolojik koşullarında 13 farklı köyden temin edilen 52 parselde yetiştirilen yerel ve sertifikalı (Bilensoy-80) yonca çeşitlerinin ot verimi ve kalite özelliklerinin belirlenmesi amacıyla yürütülmüştür. En yüksek bitki boyu, Çöğürlü Köyü'nde yetiştirilen Bilensoy-80 çeşidinde 134.00 cm olarak belirlenmiştir. Ortalama değerlere göre yerel genotipler (97.16 cm), Bilensoy-80 çeşidine (92.86 cm) göre daha fazla boylanmıştır. En yüksek yeşil ot verimi Özdilek Köyü birinci parselde 6782.50 kg/da (Bilensoy-80) olarak saptanmıştır. Ortalama değerlere göre Bilensoy-80 çeşidi (3122.48 kg/da), yerel genotiplerden

(2971.29 kg/da) daha yüksek yeşil ot verimi göstermiştir. En yüksek kuru ot verimi Özdilek Köyü birinci parselde 1380.76 kg/da (Bilensoy-80) olarak belirlenmiştir. Ortalama kuru ot verimi Bilensoy-80 çeşidinde 663.65 kg/da, yerel genotiplerde ise 618.02 kg/da'dır. En yüksek kuru ot oranı Karakuyu Köyü birinci parselde %29.60 (Bilensoy-80) olarak tespit edilmiştir. Ortalama olarak Bilensoy-80 çeşidi (%21.80), yerel genotiplere (%21.15) göre daha yüksek kuru ot oranı göstermiştir. En yüksek ham protein verimi Özdilek Köyü birinci parselde 224.95 kg/da (Bilensoy-80) olarak belirlenmiştir. Ortalama ham protein verimi Bilensoy-80 çeşidinde 120.22 kg/da, yerel genotiplerde 110.48 kg/da'dır. Sonuçlar genel olarak göstermiştir ki: **Bilensoy-80 çeşidi**, yüksek **yeşil ot**, **kuru ot** ve **ham protein verimi** ile öne çıkmaktadır. **Yerel genotipler** ise özellikle **iklim adaptasyonu**, **sindirilebilirlik istikrarı** ve **lif dengesi** bakımından avantajlıdır. Buna göre: Muş Ovası'nda **sertifikalı Bilensoy-80** gibi çeşitlerin yaygınlaştırılması, bölgesel verimi artıracaktır. Yerel genotiplerin **ıslah programlarına dâhil edilmesi**, genetik çeşitliliğin korunmasına katkı sağlayacaktır. Bölgeye özgü **yonca tohum üretim merkezleri** kurulmalı, **yerel tohum bankaları** oluşturulmalıdır. Çiftçilere yonca tarımı, biçim zamanı ve yem kalitesi konularında **yayım eğitimi** verilmesi önerilmektedir. Bu bulgular doğrultusunda **üreticilerin sertifikalı Bilensoy-80 yonca tohumlarını kullanmaları** önerilmektedir. Bununla birlikte araştırmadan kesin bir sonuç elde edilmesi için araştırmanın en az bir yıl daha yürütülmesi gerekmektedir.

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FARKLI ÇÖZGENLER KULLANILARAK ELDE EDİLEN HANIMELİ ÇİÇEĞİ (*Lonicera japonica* thunb.) EKSTRAKTLARININ FENOLİK İÇERİK VE ANTİOKSİDAN AKTİVİTESİ

Dr. Öğr. Üyesi Merve USAL

Kırklareli Üniversitesi, Mühendislik Fakültesi, Gıda Mühendisliği Bölümü

Email: merveusal@klu.edu.tr

ORCID: 0009-0001-7208-9505

ÖZET

Lonicera cinsi, tatlı kokulu çiçekleri nedeniyle süs bitkisi olarak dikilen dekoratif çalılar olarak bilinmektedir. *Lonicera japonica* Thunb. (hanımeli çiçeği), Çin, Kore ve Japonya dâhil olmak üzere Doğu Asya'ya özgü bir hanımeli türüdür ve büyüme sırasında ağaçların veya çeşitli bitkilerin etrafına sarılarak gelişir. Farmakolojik çalışmalar, *Lonicera japonica* Thunb. ekstraktlarının hepatoprotektif, sitoprotektif, antimikrobiyal, antibiyotik, antioksidatif, antiviral ve antiinflamatuvar etkilere sahip olduğunu göstermiştir. Aynı zamanda *Lonicera japonica* Thunb., başta fenolik asitler, flavonoidler, terpenoidler olmak üzere çeşitli aktif bileşenler içermektedir. Bu çalışmada, hanımeli bitkisinin çiçeklerinden farklı solventler kullanılarak elde edilen ekstraktların toplam fenolik içerikleri ve antioksidan kapasiteleri incelenmiştir. Kurutulmuş bitki örnekleri üç farklı çözgenle ekstrakte edilmiştir: etanol ile maserasyon, metanol ile maserasyon ve su ile hazırlanan infüzyon. Elde edilen ekstraktların toplam fenol miktarı Folin-Ciocalteu yöntemiyle belirlenmiş ve sonuçlar mg GAE/g dw olarak ifade edilmiştir. Antioksidan kapasiteleri ise CUPRAC ve ABTS yöntemleriyle belirlenmiş, sonuçlar mg TE/g dw olarak verilmiştir. Analizler sonucunda, metanol ile yapılan maserasyon en yüksek fenol içeriği ve antioksidan kapasiteye sahip bulunmuştur (toplam fenol: 37,12 ± 0,36 mg GAE/g dw; CUPRAC: 126,06 ± 0,57 mg TE/g dw; ABTS: 33,68 ± 0,67 mg TE/g dw). Etanol ekstraktı ve infüzyon ise daha düşük değerler göstermiştir. Bu sonuçlar, hanımeli yapraklarındaki biyolojik olarak aktif bileşenlerin veriminde kullanılan çözgen ve yöntemlerin belirleyici olduğunu ortaya koymaktadır. Ayrıca, çalışmadan elde edilen bulgular hanımeli ekstraktlarının doğal antioksidan kaynağı olarak değerlendirilebileceğini ve gıda, kozmetik ile farmasötik ürünlerde potansiyel uygulamalara sahip olduğunu göstermektedir.

Anahtar Kelimeler: Hanımeli çiçeği, *Lonicera japonica* Thunb., Antioksidan aktivite, Toplam fenolik madde.

PHENOLIC CONTENT AND ANTIOXIDANT ACTIVITY OF HONEYSUCKLE FLOWER (*Lonicera japonica* thunb.) EXTRACTS OBTAINED USING DIFFERENT SOLVENTS

ABSTRACT

The *Lonicera* genus is known as decorative shrubs planted as ornamental plants because of their sweet-scented flowers. *Lonicera japonica* Thunb. is a species of honeysuckle native to East Asia, including China, Korea, and Japan, and develops by twining around trees or various plants during growth. Pharmacological studies have shown that *Lonicera japonica* Thunb. extracts have hepatoprotective, cytoprotective, antimicrobial, antibiotic, antioxidative, antiviral, and anti-inflammatory activities. *Lonicera japonica* Thunb. also contains various active compounds, primarily phenolic acids, flavonoids, and terpenoids. In this study, total phenolic contents and antioxidant capacities of extracts obtained from honeysuckle flowers using different solvents were investigated. Dried plant samples were extracted with three different solvents: ethanol maceration, methanol maceration, and water infusion. The total phenol content of the extracts was determined by the Folin-Ciocalteu method, and the results were expressed as mg GAE/g dw. Antioxidant capacities were determined by CUPRAC and ABTS methods, and the results are given as mg TE/g dw. As a result of the analyses, maceration with methanol was found to have the highest phenol content and antioxidant capacity (total phenol: 37.12 ± 0.36 mg GAE/g dw; CUPRAC: 126.06 ± 0.57 mg TE/g dw; ABTS: 33.68 ± 0.67 mg TE/g dw). Ethanol extract and infusion showed lower values. These results reveal that the solvent and methods used are determinant in the yield of biologically active components in honeysuckle leaves. Additionally, the findings from the study indicate that honeysuckle extracts can be considered as a natural antioxidant source and have potential applications in food, cosmetics and pharmaceutical products.

Keywords: Honeysuckle flower, *Lonicera japonica* Thunb., Antioxidant activity, Total phenolic substance.

1. INTRODUCTION

Lonicera species, belonging to the Caprifoliaceae family, include approximately 250 plant species distributed in the Northern Hemisphere, from temperate to subarctic climate zones. (Bieniasz et al., 2019). The fruits of many *Lonicera* plants are inedible and are cultivated as ornamental shrubs or climbing plants because of their long blossoming season, fragrant flowers, and appealing fruit. Fruit colors range from white or yellow to deep red or navy blue, which is considered an indicator of the plant's maturity. Some *Lonicera* species are widely cultivated as ornamental groundcovers in Australia, Argentina, the United States, Brazil, Mexico, New Zealand, and China. However, a few species have sweet and edible fruits. For example, *L. caerulea* fruit is commercially produced as an edible crop in the northern United States, Russia, and Japan. Additionally, some *Lonicera* plants are extensively grown for their tolerance to extreme cold. Approximately 98 *Lonicera* species are found in various regions of China, with the largest number occurring in the southwestern part of the country. *Lonicera japonica* Thunb. is a species of honeysuckle listed in the Chinese Pharmacopoeia. It has recently attracted considerable attention as a health food and is the most widely used and researched plant of the *Lonicera* genus (Ge et al., 2022, Li et al., 2019).

Through GC and GC–MS analyses, the essential volatile constituents of honeysuckle (*Lonicera japonica Thunb.*) were comprehensively profiled, resulting in the detection of nearly 150 compounds spanning multiple chemical classes such as hydrocarbons, alcohols, aldehydes, ketones, and esters. Compounds like linalool and several jasmonate derivatives were identified as the main aroma determinants. Time-based headspace measurements demonstrated that the strongest fragrance emission occurred around midnight (Ikeda et al., 1994). Extensive pharmacological evaluations have verified that *L. japonica* displays broad therapeutic potential due to its antibacterial, antiviral, anti-inflammatory, and anticancer attributes. The plant's pharmacological potency is linked to its diverse phytochemical composition, including flavonoids, iridoids, triterpenoid saponins, and other polyphenolic metabolites. Traditionally, it has been regarded in Chinese medicine as a valuable remedy against respiratory and inflammatory illnesses. Contemporary studies have expanded these findings, showing the plant's effectiveness in addressing arthritis, hepatitis, gastrointestinal disturbances, and infectious diseases (Xiong et al., 2013; Muro et al., 2025). The aqueous extract particularly exhibits potent bacteriostatic activity against *E. coli*, *Staphylococcus*, and other pathogenic species, with phenolic acids playing a central role in this activity (Xu et al., 2023). The present research explores how different solvents influence the phenolic composition and antioxidant strength of honeysuckle flower extracts.

2. MATERIALS AND METHODS

2.1. MATERIALS

Plant material of *Lonıcera Japonıca* Thunb. flowers was obtained from a local botanical garden located in Kırklareli, Turkey (Figure 1). Folin-Ciocalteu's phenol reagent, sodium carbonate, copper (II) chloride, ammonium acetate, neocuproine, ethanol, nutrient broth, nutrient agar were obtained from Merck (Darmstadt, Germany). tetramethylchromane-2-carboxylic acid (Trolox), Gallic acid, ABTS (2,20-azino-bis-3-ethylbenzthiazoline-6-sulphonic acid), potassium persulfate were obtained from Sigma-Aldrich (Steinheim, Germany).



Figure 1. Fresh *Lonıcera Japonıca* Thunb. flowers (a), Dried *Lonıcera Japonıca* Thunb. flowers (b).

2.2. EXTRACTION OF PLANT MATERIAL

Fresh plants were dried in the shade at 25 ± 2 °C. The dried plants were subjected to three different extraction methods (Figure 2): Ethanolic/Methanolic maceration: Five grams of milled dried plants were extracted with 50 mL of an ethanol–water mixture (80:20, v/v)/methanol-water mixture (80:20, v/v) for 24 h at 200 rpm in an orbital shaker at room temperature, following the method described by Xu et al. (9). Aqueous infusion: 5 g of dried plants were steeped in 50 mL of freshly boiled water for 5 min, as reported by Özkan et al. (10). All extracts were filtered through Whatman No. 1 filter paper and subsequently centrifuged at 8,000 rpm for 10 min at 4 °C The resultant supernatants were gathered and kept at -18 °C until analysis.

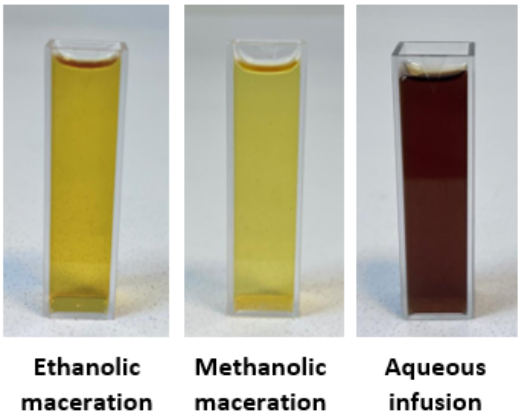


Figure 2. Extracts of *Lonicera japonica* Thunb. obtained by 3 different solvents.

2.3. DETERMINATION OF TOTAL PHENOLIC CONTENT

The total phenolic content of the extracts was determined using the Folin-Ciocalteu method (Singleton et al. 1999). An aliquot of 0.5 mL of appropriately diluted extract was mixed with 2.5 mL of 0.2 N Folin-Ciocalteu reagent, followed by the addition of 2 mL of 7.5% Na_2CO_3 solution. After incubation in the dark at room temperature (25 °C) for 30 minutes, the absorbance was measured at 760 nm using a UV/VIS spectrophotometer (Shimadzu UV-1800, Kyoto, Japan). The results were expressed as mg gallic acid equivalents per gram of dry sample (mg GAE/ g dw).

2.4. ANTIOXIDANT CAPACITY ASSAYS

The copper reducing antioxidant capacity (CUPRAC) assay was carried out following the procedure described by Apak et al. (2004). Briefly, 1 mL each of $CuCl_2$ solution (0.01 M), neocuproine solution (7.5 mM), and ammonium acetate buffer (1 M, pH 7.0) were mixed in a test tube. Subsequently, 0.1 mL of the extract and 1 mL of distilled water were added. The

reaction mixtures were incubated in the dark at 25 °C for 30 minutes. Absorbance was then recorded at 450 nm using a UV/VIS spectrophotometer. The antioxidant capacity was expressed as mg Trolox equivalents per g of dried samples (mg TE/g dw).

The Re et al. (1999) method was applied to ascertain the extracts' ABTS radical scavenging activity. 2.45 mM $K_2S_2O_8$ and 7 mM ABTS were combined to create the ABTS radical cation stock solution and allowing the mixture to stand in the dark at 25 °C for 16 h. Prior to analysis, the stock solution was diluted with distilled water to obtain an absorbance of 0.700 at 734 nm. Subsequently, 0.1 mL of appropriately diluted extract was mixed with 2 mL of the diluted ABTS solution. After 6 min of incubation, the absorbance of the reaction mixture was measured at 734 nm using a UV/VIS spectrophotometer. The antioxidant capacity was expressed as mg Trolox equivalents per g of dried samples (mg TE/g dw).

2.5. STATISTICAL ANALYSIS

The data was statistically evaluated using SPSS software (version 18.0; IBM Corp., Armonk, NY, USA). The mean ± SD is used to express the results. Duncan's multiple range test, with statistical significance set at $p < 0.05$, was used to ascertain mean differences.

3. RESULTS AND DISCUSSION

The antioxidant potential and total phenolic content (TPC) of *Lonicera japonica* extracts varied significantly depending on the extraction solvent used (Table 1). The methanolic maceration extract exhibited the highest TPC value (37.12±0.36 mg GAE·g^{-1}), followed by aqueous infusion (28.30±0.18 mg GAE·g^{-1}), while ethanolic maceration showed the lowest phenolic content (22.94±0.02 mg GAE·g^{-1}). A similar trend was observed for antioxidant capacity assessed by CUPRAC and ABTS assays. The methanolic extract demonstrated superior antioxidant activity (CUPRAC: 126.06±0.57 mg TE·g^{-1}; ABTS: 33.68±0.67 mg TE·g^{-1}) compared to both aqueous (88.87±0.00 mg TE·g^{-1}; 24.65±0.60 mg TE·g^{-1}) and ethanolic extracts (83.09±1.25 mg TE·g^{-1}; 19.39±0.05 mg TE·g^{-1}). These findings indicate that methanol is more efficient in extracting phenolic compounds with high radical-scavenging capacity from *L. japonica*, potentially due to its polarity and better solubilization of diverse phenolic constituents. Conversely, ethanol showed lower extraction performance, which may be attributed to its relatively lower polarity compared to methanol. Overall, the results highlight that solvent selection is a critical factor influencing the recovery of bioactive compounds and the resulting antioxidant properties of *L. japonica* extracts.

Table 1. Bioactive properties of *Lonıcera Japonıca* extracts obtained by different solvents

Solvent type	TPC	CUPRAC	ABTS
Methanolic maceration	37.12±0.36^{c}	126.06±0.57^{c}	33.68±0.67^{c}
Ethanolic maceration	22.94±0.02^{a}	83.09±1.25^{a}	19.39±0.05^{a}
Aqueous infusion	28.30±0.18^{b}	88.87±0.00^{b}	24.65±0.60^{b}
Unit	mg GAE.g-1	mg TE.g-1	mg TE.g-1

Consistent with the present findings, Hsu et al. (2016) evaluated the antioxidant potential of *Lonicera japonica* (LJ) flower bud extracts prepared using different extraction methods, including aqueous, ethanolic, and supercritical CO_2 techniques. Their study demonstrated that

extracts derived from dried LJ samples exhibited stronger antioxidant capacity compared to those from fresh materials. Moreover, the aqueous extracts were found to contain higher total phenolic and flavonoid levels, as well as greater amounts of chlorogenic acid and luteolin-7-O-glucoside, than the other extraction types. Similarly, Yu et al. (2019) analyzed the distribution of free phenolic compounds across different plant organs—flowers, leaves, and stems—and observed that the flower fraction possessed the highest phenolic concentration. In another related investigation, Wang et al. (2015) incorporated honeysuckle flower extract (HCE) into chitosan-based active packaging films and demonstrated that HCE supplementation enhanced both the antioxidant and antimicrobial properties of the films. The DPPH radical scavenging activity increased proportionally with HCE concentration, reaching its peak when 30% HCE was added. Collectively, these earlier reports align closely with the outcomes of the present research, supporting the view that *L. japonica* extracts are rich in bioactive phenolics contributing significantly to antioxidant performance.

4. CONCLUSION

In this study, the phenolic compound contents and antioxidant activities of extracts obtained from the *Lonicera japonica* plant using different solvents were evaluated. It was revealed that the extraction solvent is one of the most important factors determining the efficiency of bioactive compounds. Methanol was the most effective solvent for the extraction of phenolic compounds, providing the highest antioxidant activity values. Aqueous extracts, on the other hand, showed moderate performance, while ethanolic extracts had the lowest bioactive capacity. The obtained data indicate that *L. japonica* is a potent natural antioxidant source and that its potential for food, pharmaceutical, and nutraceutical applications can be enhanced, particularly through the selection of appropriate solvents. Based on these findings, it is believed that the plant can be utilized in functional product development studies, and that further studies are important to elucidate its phenolic profile and health effects.

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YERLİ VE YABANCI KETEN (*Linum usitatissimum* l.) ÇEŞİTLERİNDE YAĞ VERİMİ VE YAĞ ASİDİ KOMPOZİSYONLARININ KARŞILAŞTIRMALI OLARAK BELİRLENMESİ

Doç. Dr. Mehmet Zeki KOÇAK

Iğdır Üniversitesi Ziraat Fakültesi, Tarla Bitkileri Bölümü, Iğdır / Türkiye

Email: mehmetzekikocak@gmail.com

ORCID: 0000-0002-8368-2478

ÖZET

Keten (*Linum usitatissimum* L.), yüksek katma değerli yağı ve çok yönlü kullanım alanlarıyla dikkat çeken önemli bir endüstriyel tarım bitkisidir. Tarihsel süreçte lif, yağ ve tıbbi amaçlı olarak değerlendirilen keten, günümüzde aynı zamanda fonksiyonel bir gıda bileşeni olarak da büyük öneme sahiptir. Keten tohumu, zengin kimyasal bileşimiyle öne çıkmakta olup; yüksek düzeyde yağ (özellikle omega-3 ve omega-6 yağ asitleri), α-linolenik asit, linoleik asit, protein, diyet lifi, lignan ve secoisolariciresinol diglukozit (SDG) içermektedir. Bu bileşenler, keten tohumuna kardiyovasküler hastalıklar, diyabet, kanser, artrit ve osteoporoz gibi kronik rahatsızlıklara karşı koruyucu etkiler kazandırmakta; ayrıca antibakteriyel, antiviral ve antiinflamatuvar özellikler de sağlamaktadır.

Bu çalışmada, Sarı-85, Yılmaz, Beyaz Gelin, Antares, Florinda ve Dakota olmak üzere altı farklı tescilli keten çeşidinin yağ verimi ve yağ asidi kompozisyonu karşılaştırmalı olarak incelenmiştir. Analizler sonucunda elde edilen veriler, çeşitler arasındaki ilişkileri ve varyasyonları ortaya koymak amacıyla Temel Bileşenler Analizi (PCA) ve hiyerarşik kümeleme (heatmap, SRplot) yöntemleriyle değerlendirilmiştir.

Elde edilen bulgulara göre, en yüksek yağ verimi 2,34 g ile Sarı-85 çeşidinde belirlenirken, en düşük yağ verimi 1,55 g ile Yılmaz çeşidinde kaydedilmiştir. Yağ asidi profili açısından değerlendirildiğinde, α-linolenik asit oranının en yüksek olduğu çeşit yine Sarı-85 (%56,47) olurken, en düşük oran Florinda (%51,24) çeşidinde tespit edilmiştir.

Bu araştırmanın temel amacı, yerli ve yabancı kökenli tescilli keten çeşitlerinin yağ verimi ve yağ asidi kompozisyonlarını belirleyerek, çeşitler arası farklılıkları bilimsel olarak ortaya koymaktır. Elde edilen verilerin, yağ kalitesi ve biyokimyasal bileşim açısından keten genotiplerinin değerlendirilmesinde referans oluşturması; aynı zamanda araştırmacılar ve endüstriyel uygulayıcılar için karar destek verisi sağlaması hedeflenmektedir.

Anahtar Kelimeler: Keten, *Linum usitatissimum* L., Yağ asitleri, Çeşitler, α-Linolenik asit

COMPARATIVE ANALYSIS OF OIL YIELD AND FATTY ACID COMPOSITION IN LOCAL AND FOREIGN FLAX (*Linum usitatissimum* l.) CULTIVARS

ABSTRACT

Flax (*Linum usitatissimum* L.) is an important industrial crop characterized by its versatile oil and wide range of applications. Historically utilized for fiber, oil, and medicinal purposes, flax has recently gained prominence as a functional food due to its rich biochemical composition. Flaxseed contains high levels of oil (particularly omega-3 and omega-6 fatty acids), α-linolenic acid, linoleic acid, protein, dietary fiber, lignans, and secoisolariciresinol diglucoside (SDG). These bioactive compounds confer significant cardioprotective, antidiabetic, anticancer, antibacterial, antiviral, and anti-inflammatory properties, as well as potential benefits against arthritis and osteoporosis.

In the present study, six registered flax cultivars (Sarı-85, Yılmaz, Beyaz Gelin, Antares, Florinda, and Dakota) were analyzed to compare their oil yield and fatty acid composition. The relationships and variations among cultivars were evaluated using Principal Component Analysis (PCA) and hierarchical clustering (heatmap via SRplot). The findings revealed that the highest oil yield was recorded in the Sarı-85 cultivar (2.34 g), while the lowest was observed in Yılmaz (1.55 g). Regarding fatty acid composition, the α-linolenic acid content was highest in Sarı-85 (56.47%) and lowest in Florinda (51.24%).

The main objective of this study is to characterize and compare the oil yield and fatty acid profiles of both local and foreign registered flax cultivars, thereby elucidating their biochemical diversity. The results provide valuable decision-support data for researchers and industrial sectors focusing on oil quality assessment, cultivar improvement, and functional product development in flax.

Keywords: Flax, *Linum usitatissimum* L., Fatty acids, Cultivars, α-Linolenic acid

1. GİRİŞ

Dünya nüfusunun hızla artması ve çevresel kaynakların kirlenmesi, insanlığın temel gıda kaynaklarına erişimini ciddi biçimde tehdit etmektedir. Bu olumsuz gelişmeler, beslenme alışkanlıklarında değişimlere yol açmakta ve özellikle bitkisel kaynaklı ürünlere yönelik talebi giderek artırmaktadır (Bennett et al., 2012; Koçak, 2023). Artan bu talebin sürdürülebilir biçimde karşılanabilmesi için yalnızca hammadde temini yeterli olmayıp, aynı zamanda endüstriyel üretime uygun bitki türlerinin seçilmesi büyük önem arz etmektedir (Ruttan, 1999). Bu çerçevede, keten üretimi de dâhil olmak üzere çeşitli bitki türlerinin tarımı ön plana çıkmıştır. Tek yıllık, otsu yapıya sahip olan ve kendine tozlaşma özelliği gösteren keten (*Linum usitatissimum* L.), Linaceae familyasının bir üyesi olup, 2n=30 kromozoma sahip diploid bir türdür. Bu bitki, genellikle ılıman iklim kuşağında yayılım göstermekte ve toplamda 22 cins ile yaklaşık 300 türü içeren bir familyaya aittir (Tchoumtchoua et al., 2019; Koçak et al., 2022). Türkiye'de ise keten bitkisi yöresel olarak "bezir, bızıktan, cimit, kön, siyelek ve zeyrek" gibi farklı isimlerle bilinmektedir (Koçak et al., 2023). Arkeolojik bulgular, ketenin yaklaşık 10.000 yıl öncesine uzanan bir kullanım geçmişine sahip olduğunu ve ilk kez Orta Doğu'da, özellikle de Tell Abu Hureyra (Kuzey Suriye) bölgesinde eski Mısır ve Mezopotamya medeniyetleri tarafından kültüre alındığını göstermektedir (Saha & Hazra, 2004). Ayrıca, "Etiyopya, Orta Asya ve Hindistan" ketenin ikincil yayılım ve genetik çeşitlilik merkezleri olarak tanımlanmaktadır (Vavilov, 1951).

Günümüzde keten, birçok ülkede sınırlı ölçekte yetiştirilmekle birlikte, küresel ölçekte başlıca üretici ülkeler arasında Kanada, Çin, Rusya ve Hindistan öne çıkmaktadır (Saleem et al., 2020). Tohumunun endüstriyel kullanımı oldukça çeşitlidir. Özellikle hızlı kuruma özelliği sayesinde boya, vernik, sabun, macun ve polimer üretimi gibi alanlarda kullanılmakta; ayrıca biyodizel üretiminde ve gıda endüstrisinde önemli bir yer tutmaktadır (Sulas et al., 2019). Keten tohumu, %35-65 arasında değişen yağ içeriği ile öne çıkan önemli bir yağ bitkisidir. Bu yağ; "başta α-linolenik asit (omega-3), linoleik asit (omega-6), oleik asit, palmitik asit ve stearik asit" olmak üzere çeşitli yağ asitlerini içerir. Ayrıca, "lignan, diyet lifi, protein, vitamin ve mikro besin öğeleri" bakımından da zengin bir kompozisyona sahiptir (Xie et al., 2020). Yapısındaki biyoaktif bileşenler sayesinde keten tohumu, meme, kan, kolon ve deri kanserleri gibi çeşitli kanser türlerinin önlenmesi ve destekleyici tedavisinde potansiyel bir kaynak olarak değerlendirilmektedir (Kajla vd, 2015).

Mevcut tez çalışmasında Türkiye genelinde kullanılan ve bazı kamu ve özel kuruluşlardan temin edilen bazı yerel keten çeşitleri ve yabancı orjinli keten çeşitlerinin yağ oranları ve kalite analizleri detaylı bir şekilde yapılmıştır. Analizler sonucunda elde edilen bu veriler ile hem Türkiye'de hem de farklı ülkelerde bu çeşitlerin yağ verimleri ve yağ asitleri komposizonları araştırıcılar için kayda değer bir kaynak oluşturması bakımından bilime katkı sağlanmış olacaktır.

2. MATERYAL ve METOT

2.1. Materyal

Tez çalışmamızda önceden belirlenmiş olan çeşitlerin; ülkemizin farklı şehirlerinde bulunan, bazı kamu ve özel kuruluşlardan temin edilen yurtiçi ve yurtdışı tescilli çeşitler materyal olarak kullanılmıştır. Tablo 1 "de çeşitlerin elde edildikleri yer ve orjini oldukları ülkeler verilmiş olup, çalışmanın diğer aşamalarında da kullanılan çeşit numaraları belirtilmiştir".

Tablo 1. Çalışmada kullanılan keten (*L. usitatissimum* L.) çeşit ve özellikleri

Çeşit/Genotip Numarası	Genotipin Adı	Orjin ülke	Temin Edilen Yer	Yetişme formu	Çiçek rengi	Tane rengi
1	Beyaz Gelin	Türkiye	T.T.A.Enst.	Yazlık	Mavi	Kahve
2	Antares	Fransa	K.T.A.Enst	Yazlık	Mavi	Kahve
3	Dakota	K.D.B. Dev.	T.T.A.Enst.	Yazlık	Mavi	A.Kahve
4	Sarı-85	Türkiye	T.T.A.Enst.	Yazlık	Beyaz	Sarı
5	Yılmaz	K.D.B. Dev.	T.T.A.Enst.	Kışlık	Mavi	Kahve
6	Florinda	Romanya	Türkiye Ziraat Enstitüsü	Yazlık	Mavi	Kahverengi

2. METOT

2.1.1. Keten Tohumu Yağ Ekstraksiyonu;

Tez çalışması kapsamında temin edilen her bir tescilli yerli ve yabancı keten çeşidi için yaklaşık 10 gram keten tohumu bir laboratuvar blenderi tarafından öğütülerek toz haline getirildi. Sonrasında, öğütülmüş keten tohumu 30 mL hekzan ile 4 gün boyunca oda sıcaklığında (25°C±1) ekstrakte edildi. Yapılan işlem sonunda, ekstre edilen tohum çözeltisi bir filtre kağıdı ile süzüldükten sonrasında darası alınmış 50 mL plastik falkon tüpe aktarıldıktan sonra, 40°C'de düşük basınç altında uzaklaştırılmıştır.

Toplam yağ miktarı, "ağırlık kaybı dikkate alınarak % 0 nem oranına göre hesaplanmıştır. Yağ asidi analizi için, elde edilen keten yağı amber renkli cam kaplara aktarıldıktan sonra analiz için +4°C'de"muhafaza edilmiştir (Koçak, 2022).

Keten tohumundan elde edilen yağ verimi aşağıdaki formül yardımıyla hesaplanmıştır;

Yield (%) = $\frac{We}{Wt}$ x 100 (Capar ve ark., 2021).

W_e = ekstrakte edilen yağın ağırlığı, W_t = ekstraksiyon için alınan numunenin ağırlığı

2.1.2. Gaz Kromatografi Alev İyonlaşma Dedektörü (GC-FID)

Elde edilen keten tohumu örneklerine ait yağlardan "0.2 g 15 ml'lik kapaklı santrifüj tüplerine alınarak üzerlerine 10 mL hekzan eklenip iyice çalkalanmıştır. Daha sonra örneklerin bulunduğu tüplerde 0.2 mL 1 N metanolde çözülerek hazırlanan KOH ilave edilmiştir. Daha sonra iyice çalkalanıp faz ayrımı görülür ve üst faz berraklaşıncaya kadar 2 saat karanlık ortamda bekletilmiştir. Berraklaşma işlemi gerçekleştikten sonra üst fazdan bir miktar viallere alınarak, alev iyonlaşma dedektörü (FID) bulunan SP 2560 100m*0,25mm*0,2µm kapiler kolon takılı Agilent 7820 A GC-FID" cihazı ile "yağ asitleri analizi yapılmıştır. Enjeksiyon portu ve FID sıcaklığı 240ºC, split enjeksiyon modunda 400ml/min basınçta 1/10 split" oranındadır. Kolon sıcaklığı "140ºC'de 5 dakika bekledikten sonra dakikada 4ºC artarak 250ºC'ye ulaşıp 15 dakika bekledikten sonra 260ºC'ye" çıkılmıştır. Helyum taşıyıcı gaz "41 cm/sec(Hydrogen)" olarak kullanılmıştır. Cihaza 1 µL enjekte edilen örnekler "Supelco ® 37 Component FAME Mix-Sigma-Aldrich" standart karışımının toplam 37,75 dakikalık analizinde elde edilen GC-FID kromatogramı ile karşılaştırılmıştır. Palmitik asit "(C16:0),

stearik asit (C18:0), oleik asit (C18:1n9c), linoleik asit (C18:2n6c), α-linolenik asit (C18:3n6)" yağ asitleri miktarları % olarak bulunmuştur (Koçak, 2021).

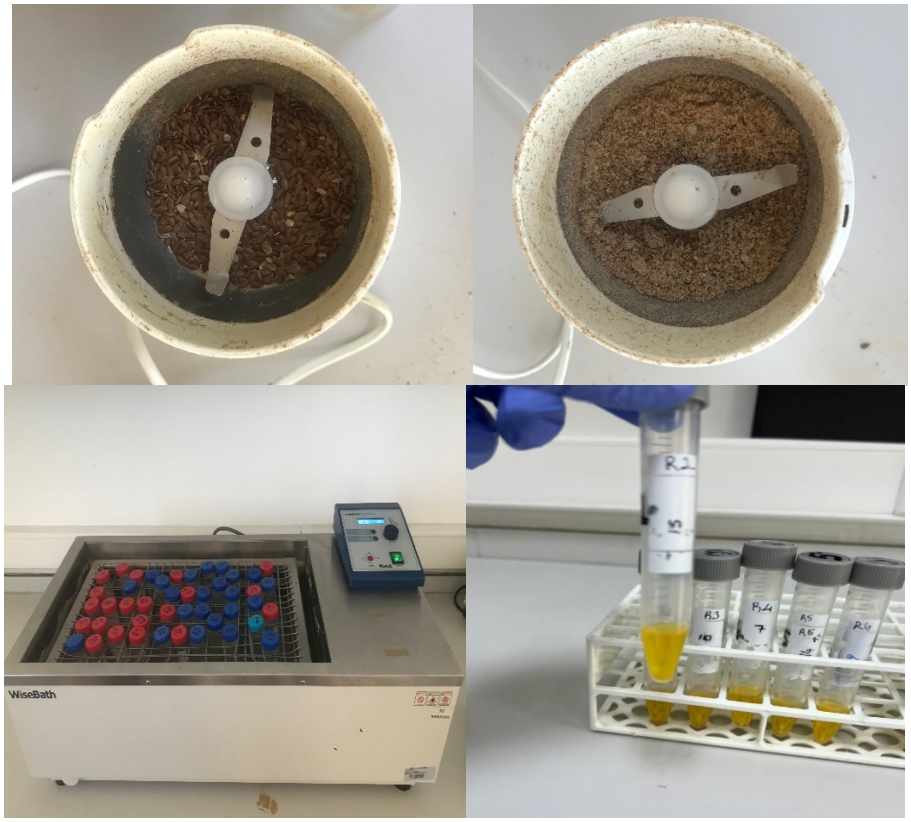
Bitkisel Kalite Analizleri ve Verim Unsurları Değerlendirilmesi

2.1.3. Ham Yağ Oranı (%)

Elde edilen keten tohumları 10 gram tohum öğütme işlemi yaplarak 50 ml plastik falkon tüpüne koyulmuş daha sonra üzerine 30 ml n-hekzan ile hazırlanan numuneler 4 gün boyunca IKA KS 400 model sallayıcı yardımıyla beklenen ham yağ elde edilmiştir.

2.1.4. Yağ Asitleri Bileşimi (%)

Temin edilen 6 tescilli çeşit keten tohumlarından ham yağ elde edilmiştir. Bunlara ek olarak, "hem yağ Iğdır Üniversitesi Araştırma Laboratuvarı Uygulama ve Araştırma Merkezi (ALUM)'nde, Gaz Kromatografi Alev İyonlaşma Dedektörü (GC-FID)" cihazı yardımyla yağ asitlerinin metil esterlerinin sonuçları elde edilmiştir.



Şekil 1. Ekstraksiyon yöntemi ve ketende yağın elde edilme durumu

2.2. Çalışmada Kullanılan Bitki Materyali

Tez çalışmamızda kullanılan çeşitlerin; ülkemizin farklı şehirlerinde bulunan, bazı kamu ve özel kuruluşlardan temin edilen yurtiçi ve yurtdışı tescilli çeşitler materyal olarak kullanılmıştır (Tablo 2).

Tablo 2. Çalışmada kullanılan keten (*Linum usitatissimum* L.) çeşitleri

No	Çeşit
1	Beyaz Gelin
2	Antares

3	Dakota
4	Sarı-85
5	Yılmaz
6	Florinda

2.3. İstatistiksel Değerlendirmeler

Bu tez çalışmasında yapılan her uygulama için incelenen özelliklerde toplam 6 keten çeşidi kullanılmıştır. Analiz ve gözlem sonuçlarının değerlendirilmesi için çeşitlerde; ayrıca, incelenen parametrelere ilişkin verilerin görselleştirilmesi, ayrımlanması ve birbiri ile korelasyonunu belirlemek amacıyla, Principal Component Analysis (PCA) (PAST Software) ve heatmap ile kümelendirme çalışması yapılmıştır (SRplot).

3. BULGULAR ve TARTIŞMA

Çalışmada kullanılan keten "(*L. usitatissimum* L.) çeşitlerin yağ oranı ve yağ asidi kompozisyonu Tablo 3'de, temel bileşenler analizi (PCA) Şekil 2'de ve ısı haritası (heatmap) kümelemesi Şekil 3"de sunulmuştur**.**

3.1. Yağ Asitleri Bileşimi

Ülkemizde yağ ihtiyacı, hem bitkisel hem de hayvansal kaynaklardan temin edilmekle birlikte, özellikle bitkisel yağlar bu ihtiyacın karşılanmasında önemli bir rol üstlenmektedir. Bitkisel yağlar genellikle tohum ve meyvelerden elde edilmekte olup, farklı bitki türlerinden çeşitli yağ bileşenleri sağlanmaktadır (Yuan vd., 2014).

α-Linolenik Asit (ALA), Omega-3 (C18:3) grubunda yer alan esansiyel birçoğu doymamış yağ asididir. Hücresel fonksiyonlarda kritik rol oynamakta, özellikle hücre zarlarında lokalize olmaktadır. İnsan vücudunda sentezlenemediği için dışarıdan besin yoluyla alınması zorunludur. ALA eksikliği; büyüme bozuklukları, depresyon ve öğrenme güçlükleri gibi çeşitli sağlık sorunlarına yol açabilmektedir. Bu yağ asidine en yüksek oranda keten tohumu yağı başta olmak üzere, "susam, kanola, zeytin ve Ayçiçek" yağında rastlanmaktadır (Barceló-Coblijn ve Murphy, 2009).

Linoleik Asit (C18:2) ise omega-6 grubuna ait, çoklu doymamış bir yağ asididir ve bitkisel yağların majör bileşenlerinden biridir. Özellikle keten tohumu yağı ve diğer bitkisel yağlarda yüksek oranda bulunmaktadır. İnsan vücudu bu asidi sentezleyemediğinden, dışarıdan alınması gerekmektedir. Eksikliğinde beyin ve göz gelişiminde gerilik, davranış bozuklukları ve depresyon gibi ciddi sağlık problemleri ortaya çıkabilmektedir. Ayrıca bağışıklık sistemini güçlendirici ve büyüme-gelişmeyi destekleyici etkileri mevcuttur. Bu asit, keten, fındık, zeytin, mısır, soya ve yer fıstığı yağlarında yüksek oranda bulunmaktadır (Uken vd., 2021).

Oleik Asit, insan vücudunda en yaygın bulunan tekli doymamış yağ asididir. Yüksek yoğunluklu lipoprotein (HDL) düzeylerini artırırken, düşük yoğunluklu lipoprotein (LDL) düzeylerini azaltması gibi kardiyovasküler sağlığa olumlu etkileriyle bilinmektedir. Ayrıca antiinflamatuar, antihipertansif, glikoz metabolizmasını düzenleyici ve bağışıklık sistemini güçlendirici etkileri de rapor edilmiştir. Fındık, zeytinyağı ve ceviz yağı bu asidin en zengin kaynakları arasında yer alırken, keten yağı da dikkate değer bir miktarda oleik asit içermektedir (Powell ve Rokach, 2014).

Palmitik Asit, yaygın olarak zoometrik asit olarak da bilinmekte olup, tekli doymamış yağ asitleri grubunda yer almaktadır. Bitkisel yağlarda genellikle %1'in altında bulunur. A, B1, B12, C, E ve K vitaminlerinin metabolizmasında rol oynamasının yanı sıra, antioksidan özelliklere

de sahiptir. Omega-7 bakımından zengin olan palmitik asit, tıbbi açıdan yanık tedavisi, egzama, yaşlanma karşıtı uygulamalar, ülser ve bazı kanser türlerinin önlenmesinde destekleyici olarak değerlendirilmektedir (Tang vd., 2021).

Stearik Asit, doymuş bir yağ asidi olup, bitkisel sıvı yağlarda genellikle gliserit stearin formunda bulunmaktadır. Endüstriyel olarak vernik ve yüzey aktif madde üretiminde yaygın olarak kullanılmaktadır. Keten yağı, "palm yağı, ayçiçek yağı ve pamuk" yağı ile karşılaştırıldığında, stearik asit içeriği açısından daha düşük bir düzeye sahiptir (Denke, 1994).

3.2 Ham Yağ Oranı (%)

Karbonhidratlar, proteinler ve yağlar birçok canlı organizmada temel yapı taşları olarak yer almakta ve hayatta kalma için gerekli başlıca enerji kaynaklarını oluşturmaktadır (Mobarhan ve ark., 2016). Bu çerçevede, keten yağı hem gıda hem de sanayi endüstrisinde önemli bir hammadde olarak geniş kullanım alanlarına sahiptir. Ayrıca, hayvan beslenmesinde yem katkısı olarak da değerlendirilmektedir. Keten tohumu, diğer yağlı tohumlarda olduğu gibi yüksek yağ içeriğine sahip bir ürün olup bu özelliği ile ekonomik açıdan da dikkat çekmektedir (Wang ve ark., 2020).

Yürütülen bu tez çalışmasında, incelenen keten çeşitleri için ortalama ham yağ verimi oranı %27 olarak belirlenmiştir. Elde edilen veriler doğrultusunda, en yüksek ham yağ verimi %37,6 ile Sarı-85 çeşidinde tespit edilirken, en düşük verim ise %27 ile Yılmaz çeşidinde gözlemlenmiştir (Tablo 3). Ancak, literatürde bildirilen önceki bulgularla karşılaştırıldığında elde edilen değerlerin daha düşük olduğu dikkat çekmektedir. Örneğin Eliasson ve ark. (2003) çalışmasında %46, Tayınmak (2019) tarafından ise %47,29 oranında ham yağ verimi rapor edilmiştir. Bu farkın, kullanılan keten çeşitlerinin yetiştirildiği ekolojik koşullar, tohumların hasat sonrası depolama şartları ve denemeye alınmadan önce geçen süre gibi faktörlerden kaynaklanabileceği düşünülmektedir.

3.3 Yağ Asitleri Bileşimi

Keten tohumlarında bulunan yağlar, büyük oranda tekli doymamış yağ asitleri (MUFA) ve çoklu doymamış yağ asitleri (PUFA) içermektedir. Yağ asitleri, sahip oldukları biyolojik işlevler ve çeşitli hastalıkların önlenmesine yönelik potansiyel etkileri nedeniyle birçok çalışmada önemli araştırma konusu olmuştur (Orsavova ve ark., 2015). Genel olarak tüm yağ bitkilerinde olduğu gibi, keten de "α-linolenik asit (C18:3), linoleik asit (C18:2), oleik asit (C18:1), palmitik asit (C16:0) ve stearik asit (C18:0)" gibi başlıca yağ asitleri ile karakterize edilmektedir. Ayrıca, bu yağ asitlerinin doymuş ya da doymamış yapıda olmaları ve birbirlerine oranları, hem insan sağlığı açısından hem de bitkinin çevresel koşullara adaptasyonu bakımından büyük önem arz etmektedir (Shramko ve ark., 2020)

Mevcut tez çalışmasında yapılan GC-FID analizleri sonucunda, çeşitler arasında yağ asidi bileşimi bakımından önemli farklılıklar gözlemlenmiştir. α-linolenik asit içeriği bakımından en yüksek oran Sarı-85 çeşidinde %56,47 olarak tespit edilirken, en düşük oran %51,14 ile Florinda çeşidinde belirlenmiştir. Ayrıca, Sarı-85 çeşidinde elde edilen sonuç, literatürde Mohamed Ahmed (2023) tarafından bildirilen %55,27'lik değere yakınlık göstermektedir. Öte yandan, Florinda çeşidine ait α-linolenik asit oranı, Kınay ve Yılmaz (2016) tarafından bildirilen %53,46'lik değere kıyasla belirgin şekilde daha düşük bulunmuştur. Bu farklılıkların, kullanılan çeşitlerin muhafaza koşulları, tohumların yetiştirildiği bölgelerin ekolojik özellikleri ve hasat zamanlaması gibi faktörlerden kaynaklandığı düşünülmektedir. Benzer şekilde, linoleik asit oranı en yüksek %17,06 ile Florinda çeşidinde, en düşük ise %11,73 ile Yılmaz çeşidinde belirlenmiştir. Oleik asit içeriği açısından ise en yüksek oran %22,98 ile yine Yılmaz çeşidinde saptanırken, en düşük oran %17,73 ile Antares çeşidinde kaydedilmiştir. Bu bulgular, literatürle karşılaştırıldığında bazı farklılıklar göstermektedir. Örneğin, Kınay ve Yılmaz (2016)

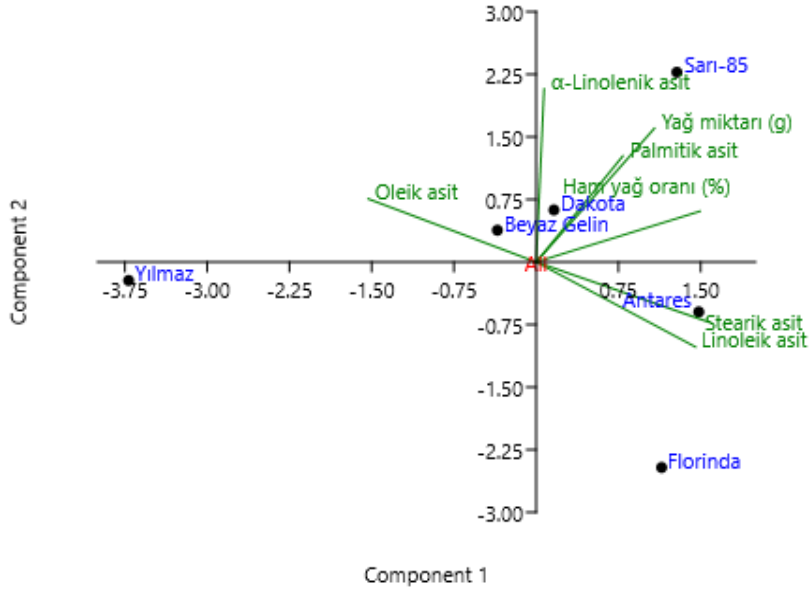
tarafından Florinda çeşidinde bildirilen oleik asit oranı %17,94 olup, bu çalışmada elde edilen değerle paralellik göstermektedir. Bu farklılıklar, genetik çeşitlilik ve çevresel etmenlerin yanı sıra analiz öncesi uygulanan işleme ve muhafaza koşullarından da etkilenebileceği yönünde önemli ipuçları sunmaktadır.

Tablo 3. Keten (*Linum usitatissimum* L.) çeşitlerine ait yağ oranı ve yağ asitleri değerleri

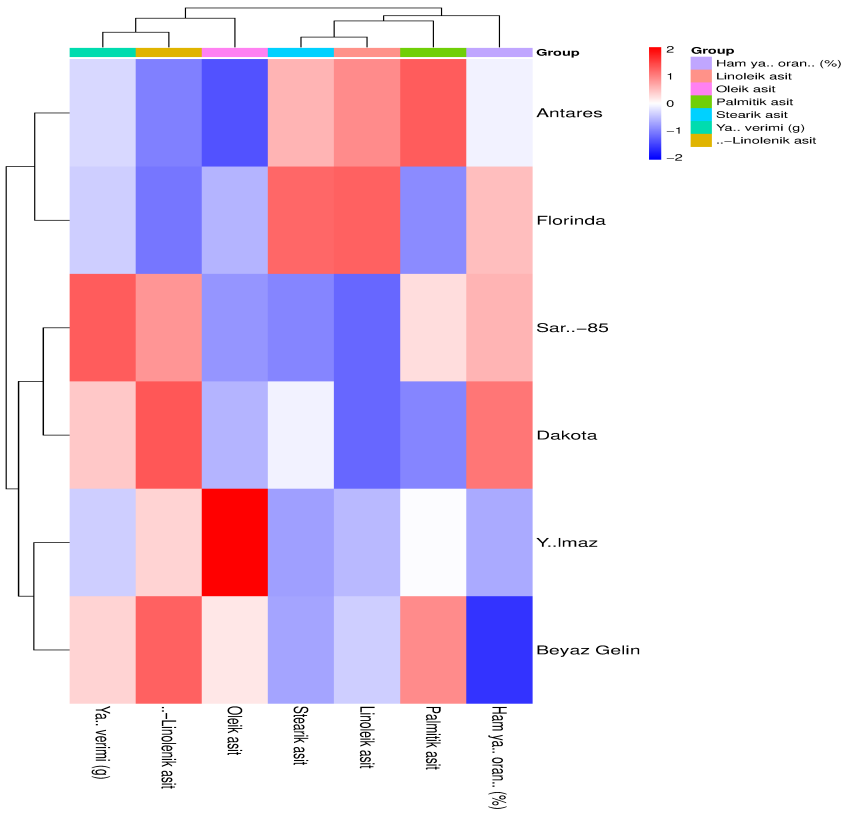
Çeşit	Yağ miktarı (g)	Ham yağ oranı (%)	Palmitik asit	Stearik asit	Oleik asit	Linoleik asit	α-Linolenik asit
Sarı-85	2.34	37.6	6.79	5.83	19.98	14.59	56.47
Yılmaz	1.55	27	5.94	5.02	22.98	11.73	53.28
Beyaz Gelin	1.92	31.2	6.45	5.66	19.58	14.34	54.63
Antares	1.88	33.6	6.91	6.06	17.73	16.51	52.73
Florinda	1.73	34.6	5.73	6.27	17.82	17.06	51.24
Dakota	1.97	35.4	6.15	5.78	19.16	13.69	55.22

3.4. Temel Bileşenler Analizi (PCA) ve Isı Haritası (Heatmap) Yardımıyla Keten Çeşitlerinin Yağ Verimi ve Yağ Asidi Kompozisyonları

Temel Bileşenler Analizi (PCA) sonuçlarına göre, analizde değerlendirilen 13 değişkenin, özdeğeri (Eigenvalue) 1'in üzerinde olan üç faktör altında toplandığı belirlenmiştir. Bu faktörlerden birincisi (PC1, özdeğer: 3,823), yağ asidi kompozisyonundaki toplam varyansın %54,62'i açıklarken; ikinci faktör (PC2, özdeğer: 2,436), varyansın %34,80'i açıklamaktadır (Şekil 2). İlk iki temel bileşen birlikte değerlendirildiğinde, toplam varyansın %89,42'sini açıklanmakta olup, bu oran yağ asidi bileşenlerinin çeşitler arasında anlamlı farklılıklar gösterdiğine işaret etmektedir. Araştırma bulgularına göre, en yüksek yağ verimi Sarı-85 ve Dakota çeşitlerinden elde edilmiştir. PCA analizine ek olarak, ısı haritası kullanılarak gerçekleştirilen hiyerarşik kümeleme analizinde iki ana küme belirlenmiştir (Şekil 3). Çeşitlerin dağılımına göre; Sarı-85 ve Dakota aynı kümede, Antares, Florinda aynı küme içerisinde ve Yılmaz, Beyaz Gelin ise aynı küme içerisinde toplanmıştır. Yağ asidi bileşenlerine ilişkin yapılan değerlendirmelerde; α-linolenik asit, oleik asit ve yağ verimi benzer varyasyon göstererek aynı grupta yer almış; buna karşılık ham yağ miktarı, linoleik asit, stearik asit ve palmitik asit farklı bir grupta kümelenmiştir.



Şekil 2. Keten (*Linum usitatissimum* L.) çeşitlerinde yağ ve yağ asitlerinde temel bileşenler analizi [Principal Component Analysis (PCA)]



Şekil 3. Keten (*Linum usitatissimum* L.) çeşitlerinde yağ ve yağ asitlerine ait ısı haritası (heatmap clustering)

4. SONUÇ

Keten tohumu (*Linum usitatissimum* L.), yağ asitleri, organik asitler, diyet lifi, protein, fenolik bileşikler ve flavonoidler bakımından zengin bir bileşime sahiptir. Bu bitkinin ekonomik ve tarımsal öneminin artırılabilmesi için, bölgesel ekolojik koşullara uygun yağ asidi profiline sahip keten çeşitlerinin belirlenmesi büyük önem taşımaktadır. Bu durum, bitkisel yağ ithalatçısı konumunda bulunan ülkemiz açısından hem pazarların çeşitlendirilmesi hem de üreticilere sunulacak ürün seçeneklerinin artırılması açısından stratejik bir değere sahiptir. Farklı çalışmalarda ortaya konduğu üzere, bu çalışmada da bazı tescilli yerli ve yabancı keten tohumu çeşitlerinin yağ asidi profilleri karşılaştırmalı olarak incelenmiştir. Elde edilen verilere göre, yağ miktarı (g) ve ham yağ oranı (%) bakımından en yüksek değerler Sarı-85 çeşidinde tespit edilmiş, en düşük değerler ise Yılmaz çeşidinde belirlenmiştir. Ayrıca, keten tohumunda baskın yağ asidi bileşeni α-linolenik asit olup, bu bileşiğin oranı çeşitler arasında değişiklik göstermiştir. α-Linolenik asit içeriği en yüksek Sarı-85 ve Dakota da, en düşük ise Antares ve Florinda çeşitlerinde tespit edilmiştir. Keten tohumu yağının yüksek oranda çoklu doymamış yağ asitleri (PUFA) içermesi, bu yağların oksidatif stabilitesini azaltmakta ve buna bağlı olarak yemeklik yağ olarak kullanım potansiyelini sınırlamaktadır. Ancak bu yağ asitlerinin sağlık açısından taşıdığı besleyici değer, keten tohumu yağının fonksiyonel gıda ve sağlık ürünleri kapsamında değerlendirilmesini mümkün kılmaktadır.

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İNEKLERİN AKTİVİTE DAVRANIŞLARININ İKLİM İLE İLİŞKİSİ

Dr. Çağrı Melikşah SAKAR

International Center for Livestock Research and Training, Ankara/Türkiye

Email: melikksahi@gmail.com

ORCID: 0000-0002-6692-763X

Dr. Burak ARTUT

International Center for Livestock Research and Training, Ankara/Türkiye

Email: burakartut55@gmail.com

ORCID: 0000-0002-3237-7692

Dr. Hasan Hüseyin ŞENYÜZ

Necmettin Erbakan University, Faculty of Veterinary Medicine, Department of Animal Nutrition and Nutritional Disease, Konya/Türkiye

Email: hasanhuseyin.senyuz@erbakan.edu.tr

ORCID: 0000-0002-3695-1794

ÖZET

İklimsel değişkenler, süt sığırı yetiştiriciliğinde hayvan refahı, üretim verimliliği ve genel sağlık durumunu doğrudan etkileyen temel çevresel faktörler arasında yer almaktadır. Özellikle son yıllarda küresel iklim değişikliğine bağlı olarak artan sıcaklıklar, aşırı nem oranları ve dengesiz hava koşulları, hayvanların fizyolojik ve davranışsal tepkilerini önemli ölçüde değiştirmektedir. Süt inekleri, homeotermik canlılar olarak çevresel stres faktörlerine karşı çeşitli davranışsal adaptasyonlar geliştirerek termal dengeyi korumaya çalışır. Bu nedenle, davranışsal göstergeler; hayvanın bulunduğu çevre koşullarına uyum sağlayıp sağlamadığını ve ne derece stres altında olduğunu değerlendirmede önemli birer araçtır.

Bu derleme çalışmasında, başta sıcaklık, nem ve sıcaklık-nem indeksi (SNİ) olmak üzere iklimsel parametrelerin süt ineklerinin temel aktivite davranışları üzerindeki etkileri kapsamlı bir şekilde incelenmiştir. Yatma, ayakta durma, yem tüketimi, geviş getirme, su içme, hareketlilik ve gölgelik kullanımı gibi davranışlar, hayvanın çevresel stres faktörlerine verdiği tepkileri yansıtan önemli göstergeler olarak ele alınmıştır. Literatürde farklı ülkelerde ve üretim sistemlerinde yapılmış çalışmalar ışığında, özellikle sıcaklık artışına bağlı olarak gözlenen davranışsal değişimler karşılaştırmalı olarak değerlendirilmiştir. Örneğin, yüksek SNİ değerlerinde yatma süresinde azalma, su tüketiminde artış ve yem alımında düşüş gibi davranışlar yaygın olarak gözlemlenmiştir. Ayrıca çalışmada, modern sensör teknolojilerinin kullanımıyla hayvan davranışlarının gerçek zamanlı olarak izlenebilmesi ve bu sayede ısı stresine bağlı gelişen değişimlerin erken dönemde tespit edilebilmesi üzerinde de durulmuştur. Akselerometreler, geviş getirme sensörleri ve sıcaklık izleme sistemleri gibi teknolojiler, erken uyarı mekanizmaları açısından büyük avantaj sağlamaktadır.

Sonuç olarak, süt ineklerinin iklimsel değişkenlere verdiği davranışsal yanıtların izlenmesi, hem hayvan refahını korumak hem de sürdürülebilir hayvancılık uygulamalarını desteklemek açısından kritik öneme sahiptir. Bu bağlamda, iklim dostu barınak tasarımları, uygun yemleme stratejileri ve çevresel kontrol sistemlerinin geliştirilmesi, hem hayvan sağlığı hem de verimlilik açısından stratejik bir gereklilik olarak değerlendirilmektedir.

Anahtar Kelimeler: İnek Davranışları, Sıcaklık-Nem İndeksi, Isı Stresi, Hayvan Refahı

THE RELATIONSHIP BETWEEN COW ACTIVITY BEHAVIORS AND CLIMATE

ABSTRACT

Climatic variables are among the most critical environmental factors directly affecting animal welfare, production efficiency, and overall health in dairy cattle farming. In recent years, due to global climate change, increased ambient temperatures, excessive humidity, and unstable weather conditions have significantly altered the physiological and behavioral responses of dairy cows. As homeothermic animals, cows attempt to maintain thermal balance by developing various behavioral adaptations in response to environmental stressors. Therefore, behavioral indicators serve as valuable tools for evaluating the animal's adaptation to its environment and the degree of heat stress it experiences.

This review comprehensively examines the effects of key climatic parameters, particularly temperature, humidity, and the temperature-humidity index (THI), on the core activity behaviors of dairy cows. Behaviors such as lying, standing, feed intake, rumination, drinking, mobility, and shade-seeking are analyzed as critical indicators of environmental stress. Based on a wide range of international studies and research conducted under different climatic and production systems, the review highlights significant behavioral changes associated with increased THI. For example, reduced lying time, decreased dry matter intake, and increased water consumption are among the most frequently reported responses to heat stress. Additionally, the review emphasizes the role of advanced sensor technologies in monitoring animal behavior in real time. Devices such as accelerometers, rumination sensors, and thermal sensors enable early detection of behavior changes linked to heat stress, facilitating timely and appropriate management interventions.

In conclusion, monitoring behavioral responses to climatic stressors is essential not only for maintaining animal welfare but also for ensuring sustainable dairy production. Climate-responsive housing designs, strategic feeding management, and environmental control systems must be implemented to mitigate the adverse effects of heat stress and improve overall herd productivity and well-being.

Keywords: Cow Behavior, Temperature-Humidity Index, Heat Stress, Animal Welfare

1. GİRİŞ

Süt sığırı yetiştiriciliği, dünya genelinde önemli bir hayvansal üretim sektörü olup, ekonomik ve sosyal açıdan büyük bir öneme sahiptir. Ancak bu üretim dalı, iklimsel faktörlerin etkilerine karşı oldukça hassastır. Küresel iklim değişikliği sonucunda artan ortalama sıcaklıklar, değişken yağış rejimleri ve yükselen nem oranları, süt sığırlarının fizyolojik durumlarını ve davranış kalıplarını doğrudan etkilemektedir (West, 2003; Herbut ve ark., 2018). Bu değişiklikler, özellikle sıcaklık nem indeksi (SNİ) gibi çevresel stres göstergelerinin yükselmesiyle birlikte hayvanların termoregülasyon mekanizmalarını zorlamakta, sonuçta hayvan refahı, verim ve üreme performansında ciddi düşüşlere neden olmaktadır (Rhoads ve ark., 2009).

Süt inekleri, homeotermik canlılar olarak vücut sıcaklıklarını dar bir aralıkta tutabilmek için çeşitli davranışsal ve fizyolojik adaptasyonlar geliştirirler. Bu adaptasyonların başında, yatma, ayakta durma, yem tüketimi, içme sıklığı ve süresi, geviş getirme gibi temel davranışların değişimi gelmektedir (Cook and Nordlund, 2009; Borchers ve ark., 2016). Örneğin, yüksek sıcaklık ve nem koşullarında hayvanlar, ısı yükünü azaltmak için yatma sürelerini kısaltıp daha fazla ayakta durabilir, bu da enerji harcamasını ve dolayısıyla stres düzeyini artırabilir (Grant ve Albright, 2001). Benzer şekilde, yem tüketimi ve geviş getirme davranışlarında görülen azalmalar, sindirim sistemi fonksiyonlarını olumsuz etkileyerek süt üretiminde düşüşe yol açar (West, 2003).

Bu derlemenin amacı, farklı iklim koşullarının süt ineklerinin davranışları üzerindeki etkileri kapsamlı bir şekilde inceleyerek, hayvan refahı ve üretim verimliliği açısından ortaya çıkan riskleri ve potansiyel adaptasyon stratejilerini ortaya koymaktır. Ayrıca, iklim değişikliğine bağlı artan çevresel stres faktörlerinin izlenmesi ve yönetimi için davranışsal göstergelerin önemi vurgulanarak, güncel teknolojik gelişmeler ışığında erken uyarı sistemlerine yönelik yaklaşımlar değerlendirilmiştir.

2. İKLİMSEL FAKTÖRLER VE ISI STRESİ

Süt ineklerinin sağlıklı ve verimli bir şekilde yaşamalarını sürdürebilmeleri için bulundukları çevrenin iklimsel koşulları kritik öneme sahiptir. Her tür gibi ineklerin de belirli bir konfor sıcaklık aralığı bulunmaktadır. Bu aralıkta hayvanlar minimum enerji harcamasıyla vücut ısılarını dengede tutabilirler. Süt inekleri için konfor sıcaklık genellikle 5–20 °C aralığında tanımlanmıştır (Collier ve ark., 2011). Bu sınırın üzerindeki sıcaklık değerlerinde, özellikle nem oranlarının da yüksek olması durumunda, ineklerde ısı stresi gelişir ve bu durum hem hayvan refahı hem de üretim performansı açısından olumsuz sonuçlar doğurur.

Isı stresinin tanımlanmasında en yaygın kullanılan çevresel ölçütlerden biri Sıcaklık-Nem İndeksi (SNİ)'dir. SNİ, sıcaklık ve nemin kombinasyonunu hesaplayarak hayvanların termal stres düzeyini nicel olarak ifade eder. Genel kabul görmüş SNİ eşikleri aşağıda sunulmuştur (Armstrong, 1994):

- SNİ < 68: Termal konfor bölgesi, stres yok
- SNİ 68–72: Hafif ısı stresi
- SNİ 72–78: Orta düzey ısı stresi
- SNİ > 78: Şiddetli ısı stresi

SNİ'nin artması, hayvanların vücut ısısını dengelemek için daha fazla çaba göstermesine neden olur. Bu durum, metabolik stresin artması, yem tüketiminin azalması ve dolayısıyla süt veriminde azalma gibi zincirleme olumsuzluklara yol açar (Rhoads ve ark., 2009). Isı stresine maruz kalan inekler, vücut sıcaklıklarını düşürmek ve ısı yükünü azaltmak amacıyla çeşitli davranışsal ve fizyolojik adaptasyonlar geliştirirler. Davranışsal olarak, inekler:

- Yatma süresini kısaltır, çünkü ayakta durmak vücut ısısının daha iyi dağıtılmasına yardımcı olur (Herbut ve ark., 2018).
- Daha sık ve hızlı solunum yaparak vücut ısısını düşürmeye çalışır (Borchers ve ark., 2016).
- Gölgelik arar ve doğrudan güneş ışığından kaçınır, böylece terlemeyle kaybedilen suyu yerine koyarlar (Schütz ve ark., 2014).
- Yem tüketimini azaltarak metabolik ısı üretimini sınırlar, ancak bu durum süt üretimini olumsuz etkiler (West, 2003).
- Su tüketimini artırır, çünkü sıcaklıkla birlikte artan terleme ve solunum kayıplarını dengelemek için daha fazla hidrasyona ihtiyaç duyar (Legrand ve ark., 2011).

Isı stresi altında kalan ineklerde kalp atış hızı, solunum sayısı, vücut sıcaklığı ve terleme oranında belirgin artışlar gözlemlenmektedir (West, 2003; Rhoads et al., 2009). Buna ek olarak, hormonal dengenin bozulması ve stres proteinlerinin (örneğin HSP70) artışı gibi moleküler yanıtlar da bu fizyolojik değişikliklere eşlik etmektedir (Collier et al., 2011). Küresel iklim değişikliği ve artan sıcaklık dalgalanmaları, süt inekleri için ısı stresinin daha sık ve şiddetli yaşanmasına neden olmaktadır. Bu nedenle, yetiştiricilik sistemlerinin termal konforu artıracak şekilde planlanması, gölgelik alanlarının sağlanması ve su kaynaklarının erişilebilir olması büyük önem taşımaktadır. Ayrıca, erken ısı stresi tespiti için davranışsal ve fizyolojik göstergelerin izlenmesi ve uygun yönetim stratejilerinin uygulanması gerekmektedir.

3. İKLİM KOŞULLARININ AKTİVİTE DAVRANIŞLARINA ETKİSİ

Süt ineklerinin günlük yaşamında sergilediği temel aktivite davranışları, hayvan refahı ve sağlık durumu hakkında önemli bilgiler sunar. Bu davranışların süre ve dağılımı, hem fizyolojik ihtiyaçların karşılanması hem de çevresel koşullara adaptasyonun göstergesi olarak değerlendirilir. Grant ve Albright (2001) tarafından yapılan çalışmalar, sağlıklı ve konforlu bir ortamda bulunan süt ineklerinin 24 saatlik (günlük) süreçteki aktivite dağılımlarını genel olarak şu şekilde ortaya koymuştur:

- Yatma süresi: 12–14 saat/gün
- Ayakta durma süresi: 4–6 saat/gün
- Yem tüketimi: 3–5 saat/gün
- Geviş getirme: 7–10 saat/gün
- Su içme: 0.5–1 saat/gün

Çevresel iklim koşulları, süt ineklerinin temel aktivite davranışlarını doğrudan etkileyerek hayvan refahı ve üretim performansında önemli değişikliklere yol açmaktadır. Özellikle sıcaklık ve nem artışları, ineklerin termal konforunu bozar ve davranışsal adaptasyon mekanizmalarını tetikler. Bu bölümde, iklimsel faktörlerin süt ineklerinin yatma, ayakta durma, yem tüketimi, geviş getirme, içme davranışı ve hareketliliğine olan etkileri ayrıntılı olarak incelenmektedir.

3.1. YATMA VE AYAKTA DURMA DAVRANIŞI

Yatma davranışı, özellikle dinlenme ve sindirim için kritik bir aktivitedir. Uzun süreli yatma, enerji tasarrufu sağlarken, geviş getirme gibi sindirim sürecinin etkinliği için elzem olan davranışları da destekler (Cook ve Nordlund, 2009). Ayakta durma süresi ise genellikle yem arama ve termoregülasyon amaçlıdır. Yatma süresi, süt ineklerinde hem rahatlık hem de sindirim fonksiyonları için kritik bir parametredir. İnekler yüksek sıcaklık ve nem koşullarında,

vücuttan ısı kaybını artırmak amacıyla yatma süresi azalmakta ve hayvanlar daha fazla ayakta durmayı tercih etmektedir (Cook ve Nordlund, 2009).

Nordlund ve ark. (2019) tarafından gerçekleştirilen çalışmada, THI'nin 79'a yükseldiği koşullarda süt ineklerinin yatma sürelerinde günlük ortalama 2.8 saatlik önemli bir azalma gözlenmiştir. Benzer şekilde, Polonya'da Herbut ve ark. (2018) tarafından yapılan saha çalışmasında, ısı stresi yaşanan günlerde ineklerin % 20 oranında daha az yattığı ve % 25 oranında daha fazla ayakta kaldığı raporlanmıştır. Bu durum, hayvanların ısı kaybını artırma çabalarının bir göstergesidir. Hayvanlar, özellikle termal stres altında, sabahın geç saatleri ve öğleden sonranın erken saatlerindeki en yüksek aktivite, gölge veya daha serin bölgeler aramak için daha fazla ayakta durma veya hareket etme gibi davranışsal termoregülasyon çabalarını yansıtabilir (Sakar ve ark., 2025). Bu davranış değişikliği, hem termal stresin hem de alan kullanımının hayvan davranışları üzerindeki etkisini ortaya koymaktadır.

3.2. YEM TÜKETİMİ VE GEVİŞ GETİRME

Yem tüketimi, süt verimi ve genel sağlık için doğrudan bir göstergedir. Stres faktörleri, yem alımında azalmaya yol açarak beslenme yetersizliklerine ve buna bağlı olarak süt üretiminde düşüşe neden olabilir (West, 2003). Benzer şekilde, geviş getirme davranışındaki azalma sindirim sistemindeki fonksiyonel bozuklukların belirtisi olarak kabul edilir ve genellikle sıcak stres altında gözlemlenir (Rhoads ve ark., 2009).

Sıcaklık-nem indeksindeki (SNİ) artışla birlikte, süt sığırlarında kuru madde alımında anlamlı bir azalma gözlemlenmiştir (Rhoads ve ark., 2009). West (2003), THI'de meydana gelen her bir birimlik artışın, günlük kuru madde tüketimini ortalama 0,45 kg azaltabileceğini belirtmiştir. Bu bulgular, ısı stresinin yem tüketimi üzerindeki baskılayıcı etkisini açıkça ortaya koymaktadır. Ayrıca, Rhoads ve ark. (2009), yüksek sıcaklık koşullarında geviş getirme süresinde yaklaşık %15 oranında bir azalma tespit etmiş ve bu durumun sindirim sisteminin termal strese verdiği doğrudan bir fizyolojik yanıt olduğunu vurgulamıştır.

3.3. SU İÇME DAVRANIŞI

Su içme davranışı, hayvanın hidrasyon durumunu koruması ve termal konforunu sürdürebilmesi açısından kritik öneme sahiptir. Özellikle sıcaklık ve nemin arttığı koşullarda, hayvanların su ihtiyacı artar ve buna bağlı olarak daha sık ve daha fazla su tüketirler (Legrand ve ark., 2011). Bu durum, ineklerde termal stres altında gözlemlenen su tüketim artışıyla da uyumludur. Su alımındaki bu artış, hayvanların vücut ısısını düzenlemeye yönelik doğal bir tepki olup, ısıyı dışarı atma mekanizmasının önemli bir parçasıdır. Bu nedenle su içme davranışının izlenmesi, hem hayvan refahı hem de çevresel koşullara uyum açısından önemli bir gösterge niteliğindedir. Schütz ve ark. (2014) sıcaklık 30 °C'ye ulaştığında ineklerin su tüketiminde % 40'a varan artış olduğunu raporlamıştır. Ayrıca, ısı stresine karşı adaptasyon amacıyla ineklerin soğuk suyu tercih ettiği ve içme sıklığını artırdığı gözlemlenmiştir. Bu davranışlar, vücudun termoregülasyonunu destekleyerek aşırı ısınmayı önlemeye yöneliktir.

3.4. HAREKETLİLİK VE GÖLGELİK KULLANIMI

Isı stresi, ineklerin hareketlilik düzeyini azaltmakta ve özellikle açık alanlarda gölgede bulunma davranışını teşvik etmektedir. Bu, hayvanların termal konforu artırmak ve doğrudan güneş ışığından kaçınmak için geliştirdiği önemli bir davranışsal adaptasyondur. Schütz ve ark. (2014) merada bulunan ineklerin sıcak günlerde gölgelik alanlara yönelme oranının % 90'a kadar çıktığını bildirmiştir. Bu yüksek orandaki gölgede kalma davranışı, ısı stresinin etkilerini azaltmak için tercih edilen stratejilerden biridir. Legrand ve ark. (2011) ise gölgede bulunan ineklerin yatma süresinin, açık alandaki ineklere kıyasla % 25 daha fazla olduğunu göstermiştir. Bu sonuç, gölgelik alanların hayvan refahı ve davranışlarının düzenlenmesinde kritik bir rol oynadığını vurgulamaktadır.

Süt ineklerinin temel davranışlarındaki süre ve sıklık değişimleri, çevresel stresin erken ve güvenilir göstergeleri olarak değerlendirilir (Schütz ve ark., 2014). Bu nedenle hayvanların aktivitelerinin detaylı ve sürekli izlenmesi, hem hayvan refahının korunması hem de üretim kayıplarının önlenmesi açısından büyük önem taşır. Günümüzde bu izleme işlemi, teknolojik gelişmeler sayesinde daha hassas ve gerçek zamanlı olarak gerçekleştirilebilmektedir. İklim koşullarının süt inekleri üzerindeki davranışsal etkileri, ısı stresine karşı etkili yönetim stratejilerinin geliştirilmesine temel oluşturur. Bu bağlamda, uygun barınak tasarımı, etkin sulama sistemleri, gölgelik alanların sağlanması ve davranışların sürekli izlenmesi gibi uygulamalar, sürdürülebilir hayvancılık için kritik rol oynamaktadır.

4. DAVRANIŞSAL İZLEME VE ERKEN UYARI SİSTEMLERİ

Süt ineklerinin refahı ve üretim verimliliğinin korunmasında, çevresel stres faktörlerinin erken tespiti büyük önem taşımaktadır. Özellikle ısı stresi gibi iklim kaynaklı sorunların hızlı ve doğru biçimde belirlenmesi, etkili müdahalelerin yapılabilmesi için kritik bir gerekliliktir. Geleneksel yöntemlerle hayvan davranışlarının manuel gözlemi hem zaman alıcı hem de subjektif sonuçlar doğurabilmektedir. Ancak teknolojik gelişmeler, bu süreci daha objektif, hızlı ve hassas hale getirmiştir. Günümüzde süt ineklerinin davranışsal aktiviteleri, gelişmiş sensör teknolojileri kullanılarak gerçek zamanlı ve kesintisiz şekilde izlenebilmektedir. Bu teknolojiler arasında en yaygın kullanılanlar şunlardır (Borchers ve ark., 2016):

- Akselerometreler (ivmeölçerler): Hayvanların hareketlerini, yatma ve ayakta durma sürelerini, yürüyüş ve dinlenme döngülerini ölçer. Bu sayede hareketlilikteki ani değişiklikler veya aktivitelerde azalma gibi stres belirtileri kolayca tespit edilir.
- Ruminasyon sensörleri: Özellikle geviş getirme süresi ve sıklığını ölçen bu sensörler, sindirim sistemi sağlığının ve yem tüketim alışkanlıklarının değerlendirilmesinde kullanılır. Isı stresi durumunda geviş getirme süresindeki kısalma, bu sensörlerle erken dönemde fark edilir.
- Sıcaklık ve nem sensörleri: Barınak içi ve dış ortam sıcaklık-nem değerlerinin sürekli ölçülmesi, sıcaklık nem indeksi (SNİ) gibi kritik parametrelerin hesaplanmasını sağlar. Bu veriler, davranışsal değişikliklerle birlikte analiz edilerek hayvanların termal konfor durumları izlenir.
- Biyometrik ve video analiz sistemleri: Kameralar ve yapay zeka destekli görüntü işleme teknikleri, ineklerin pozisyon, hareket ve sosyal davranışlarını analiz ederek stres belirtilerinin belirlenmesine katkı sağlar.

Bu sensör tabanlı sistemler sayesinde ineklerin davranışlarında ısı stresine bağlı değişiklikler ortaya çıkar çıkmaz sistemler tarafından algılanır ve üreticiye anlık bildirimler gönderilir; bu sayede sıcaklık stresinin hayvan üzerindeki olumsuz etkileri büyümeden önleyici tedbir alınabilir (Ranzato ve ark., 2023). Ayrıca, bu teknolojiler sayesinde elde edilen davranışsal veriler (örneğin yatarak geçirme süresi, aktivite, yemleme davranışı) ile iklim parametreleri (sıcaklık, nem, THI gibi) arasında makine öğrenmesi ve istatistiksel modeller kullanılarak önemli ilişkiler tespit edilmiştir; bu da bireysel hayvan ve sürü düzeyinde uyum stratejilerinin geliştirilmesine olanak verir (Hut ve ark., 2022).

Sonuç olarak, sensör tabanlı davranış izleme ve erken uyarı sistemleri, süt sığırcılığında iklim kaynaklı stresin yönetiminde yenilikçi ve sürdürülebilir çözümler sunmaktadır. Bu teknolojilerin yaygınlaşması, hayvan refahının artırılması ve üretim kayıplarının minimize edilmesi açısından gelecekte daha da kritik bir rol oynayacaktır.

5. ISI STRESİYLE MÜCADELE YÖNTEMLERİ

Süt ineklerinde ısı stresinin önlenmesi ve etkilerinin azaltılması, hayvan refahının korunması ve üretim kayıplarının minimize edilmesi için hayati önem taşımaktadır. İklim değişikliğinin

etkilerinin giderek arttığı günümüzde, çiftliklerde uygun yönetim ve çevresel düzenlemelerin yapılması gerekmektedir. Bu amaçla kullanılan başlıca yöntemler aşağıda detaylandırılmıştır.

5.1. BARINAK TASARIMI

Barınak tasarımı, süt sığırlarının termal konforunu sağlamak açısından kritik bir rol oynar. Özellikle yüksek tavanlar ve doğal havalandırma sistemleri, sıcak havanın yükselerek ortamdan uzaklaşmasına ve ısının birikmesinin önlenmesine katkı sağlar. Bu tür yapısal önlemler, ısı stresinin etkilerini azaltmakla kalmaz, aynı zamanda hayvan davranışlarını da olumlu yönde etkileyerek verimliliği destekler (Cook ve Nordlund, 2009; Herbut ve ark., 2018).

5.2. GÖLGELİK SİSTEMLERİ

Açık alanlarda hayvanların doğrudan güneş ışığına maruz kalmasını engellemek için UV geçirgen olmayan tente veya gölgelik sistemleri kullanılmaktadır. Bu gölgelikler, özellikle meralarda ve açık otlak alanlarında ısı yükünü azaltarak hayvanların termal konforunu artırır (Schütz ve ark., 2014). Gölgelik alanlar, ineklerin sıcak saatlerde dinlenme ve serinleme ihtiyaçlarını karşılamak için kritik öneme sahiptir.

5.3. SUYA ERİŞİM

Isı stresinin etkilerini azaltmada su tüketimi en önemli faktörlerden biridir. Süt ineklerinin yeterli miktarda ve temiz suya kolay erişimi sağlanmalıdır. Çiftliklerde, yeterli sayıda ve yaygın otomatik suluklar kurulmalı, suyun özellikle sıcak günlerde soğuk tutulmasına özen gösterilmelidir (Legrand ve ark., 2011). Su temininin kesintisiz ve kolay olması, hayvanların hidrasyonunun korunmasına ve termoregülasyonun etkin yürütülmesine katkı sağlar.

5.4. YEMLEME ZAMANLAMASI

Isı stresi dönemlerinde yem tüketimi azalabildiğinden, yemleme zamanlamasının günün daha serin saatlerine kaydırılması önerilir. Genellikle yemleme sabah erken saatlerde ve akşam geç saatlerde yapılmalıdır (West, 2003). Bu uygulama, ineklerin yem tüketimini optimize ederek metabolik ısı üretimini azaltmaya yardımcı olur. Ayrıca, yüksek enerjili ve sindirimi kolay yemlerin tercih edilmesi, stresin etkilerini hafifletmek için önem taşır.

5.5. SERİNLETME SİSTEMLERİ

Evaporatif soğutma sistemleri, özellikle fan ve sprey kombinasyonları, sıcaklığın yüksek olduğu dönemlerde süt sığırları için etkili bir serinletme yöntemi olarak kullanılmaktadır (Armstrong, 1994; West, 2003). Bu sistemlerde, hayvanların üzerine su püskürtülürken aynı anda hava akımı sağlanarak buharlaşma yoluyla vücut ısısı düşürülür. Fanların düzenli ve yeterli güçte çalışması, spreylerin ise uygun miktarda su püskürtmesi, serinletme etkinliğini artırır. Bunun yanı sıra, su spreyi ve rüzgar kombinasyonu ile yapılan mekanik serinletme uygulamaları da ineklerin termal konforunu artırmaktadır (Collier ve ark., 2011). Ancak bu sistemlerin aşırı nem oluşturabilecek kapalı ortamlarda dikkatli kullanılması gerekmektedir.

6. SONUÇ

İklimsel faktörler, süt ineklerinin davranışları üzerinde doğrudan etkili olup, hayvan refahı ve süt verimi açısından kritik sonuçlar doğurmaktadır. Özellikle sıcaklık ve nem artışıyla birlikte yatma süresi azalmakta, ayakta durma süresi artmakta, yem alımı ve geviş getirme davranışları olumsuz yönde etkilenmektedir. Bu davranışsal değişiklikler, çevresel stresin erken göstergeleri olarak değerlendirilmekte ve üretim kayıplarının önlenmesinde önemli rol oynamaktadır. Bu bağlamda, sensör tabanlı davranış izleme sistemleri, ısı stresinin erken tespitine olanak sağlayarak adaptif yönetim stratejilerinin zamanında devreye alınmasını mümkün kılmaktadır. İklim değişikliğiyle birlikte çevresel stres faktörlerinin daha sık ve şiddetli hale geleceği öngörüldüğünden, iklime duyarlı hayvan yönetimi ve davranış temelli erken uyarı sistemleri, sürdürülebilir süt sığırcılığı için vazgeçilmez araçlar haline gelmektedir.

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PLASTİK AMBALAJLARDAN TEREYAĞINA FİTALAT ASİT ESTERLERİNİN GÖÇÜ: LİTERATÜR DEĞERLENDİRMESİ

Dr. Ögr. Üyesi Zeynep GÜRBÜZ KAÇAN

(Atatürk Üniversitesi, Ziraat Fakültesi, Gıda Mühendisliği Bölümü, Erzurum)

Email: zeynepgurbuz@atauni.edu.tr

ORCID: 0000-0003-4066-0241

ÖZET

Polimer ambalajlarda kullanılan plastikleştirici katkı maddesi fitalat asit esterlerinin (PAE'ler) oyuncaklar, kişisel bakım ürünleri ve gıda ambalajları dahil olmak üzere çok çeşitli tüketici ürünlerinde yaygın olarak kullanılmaktadır. Plastik matrise kovalent olarak bağlı olmadıklarından, üretim, kullanım, depolama ve imha süreçleri sırasında çevreye kolaylıkla salınmakta ve yaygın çevresel kirliliğe neden olmaktadırlar. Son yıllarda yalnızca çevresel sistemlerde değil, aynı zamanda gıda güvenliği alanında da önemli bir endişe kaynağı haline gelmiştir. PAE'ler, ağırlıklı olarak ambalaj kaynaklı olarak gıdalarda sıkça tespit edilen kontaminantlardır ve potansiyel toksik ile kanserojen etkileri nedeniyle önemli bir halk sağlığı sorunu oluşturmaktadır. Plastik bazlı ambalaj malzemelerinin ve süt ürünlerinin yaygın kullanımı göz önüne alındığında, PAE'lere maruziyet açısından bu ürünler önemli bir gıda grubunu oluşturmaktadırlar. Bazı ürünlerin ambalaj malzemeleri, PAE'lerin gıdalara göç etmesinde birincil kaynağı teşkil etmektedir. Özellikle yüksek yağ içeriğine sahip gıdalar, ambalajdan gıdaya PAE göçüne daha duyarlıdır; bu durum, tereyağı gibi ürünlerde maruziyet riskini artırmaktadır.

Gıdadan göç, ambalaj malzemesinin fiziksel özellikleri, gıdanın matris yapısı (özellikle su veya yağ fazı), depolama sıcaklığı ve süresi gibi çeşitli faktörlerden etkilenmektedir. Özellikle düşük moleküler ağırlıklı PAE'ler bileşenlerinin göçü için yüksek lipofilikli gıdalar uygun bir ortam sağlamaktadır. Bununla birlikte, doğrudan tereyağı ürünleri ile yapılan spesifik çalışmaların eksikliği, bu alanda yeni araştırmalara ihtiyaç olduğunu göstermektedir. Yüksek tüketim değerine sahip değerli bir süt ürünü olan tereyağında olası kontaminasyonun araştırılması, en önemli bilimsel hedeflerden biri olmalıdır. Bu derlemenin amacı, tereyağında PAE göçünü ve potansiyel maruziyeti literatür ışığında değerlendirmektir. Böylece, tüketici sağlığı açısından risklerin daha iyi anlaşılması ve gelecekteki güvenlik önlemlerinin geliştirilmesine katkı sağlanması hedeflenmektedir.

Anahtar kelimeler: fitalat, migrasyon, tereyağı, gıda ambalajı

MIGRATION OF PHTHALATE ACID ESTERS FROM PLASTIC PACKAGING INTO BUTTER: A LITERATURE-BASED PERSPECTIVE

ABSTRACT

Phthalate acid esters (PAEs), which are plasticizer additives used in polymer packaging, are widely present in many consumer products, including toys, personal care items, and food packaging. Because they are not covalently bound to the plastic matrix, PAEs are easily released into the environment during production, use, storage, and disposal, leading to widespread environmental pollution. In recent years, they have become a significant concern not only in environmental systems but also in food safety. PAEs are frequently detected as contaminants in foods, primarily originating from packaging, and pose a major public health problem due to their potential toxic and carcinogenic effects. Given the extensive use of plastic-based packaging materials and dairy products, these products represent a significant food group in terms of PAE exposure. Packaging materials for certain products are a primary source of PAE migration into foods. Foods with high fat content are particularly susceptible to PAE migration from packaging, increasing the risk of exposure in products such as butter.

Migration from food packaging is influenced by several factors, including the physical properties of the packaging material, the matrix structure of the food (particularly the water or oil phase), storage temperature, and storage duration. Highly lipophilic foods create a favorable environment for the migration of low-molecular-weight PAE compounds. However, the lack of specific studies on butter products underscores the need for further research in this area. Investigating potential contamination in butter, a valuable and widely consumed dairy product, should be a key scientific objective. The purpose of this review is to assess PAE migration and potential exposure in butter based on existing literature. This will help improve understanding of the risks to consumer health and support the development of future safety measures.

Key words: phthalate, mıgratıon**,** butter, food packaging

1. GİRİŞ

Ambalaj, gıdaların taşınabilirliğini ve kullanım kolaylığını artırmanın yanı sıra, mikroorganizmalar ile biyolojik ve kimyasal bozunmalara karşı koruma sağlayarak ürünlerin raf ömrünü uzatmaktadır. Dolayısıyla ambalaj, gıda üretim zincirinin temel unsurlarından biri olarak kabul edilmektedir (Boyce et al., 2008). Bununla birlikte, gıdaların genel kalitesi ve güvenliği konusundaki endişeler son zamanlarda önemli ölçüde artmıştır. Endişelerin çoğu, hem gıdalara bilerek eklenen hem de ambalaj malzemesi veya işleme ekipmanından gıdalara geçen bileşenlere odaklanmış durumdadır.

Son yıllarda, gıda endüstrisinin artan ihtiyaçlarını karşılamak üzere gıda ambalajlarının geliştirilmesi alanında önemli ilerlemeler kaydedilmiştir. Günümüzde 30'dan fazla farklı plastik, ambalaj malzemesi olarak kullanılmaktadır (Marsh & Bugusu, 2007). Bu polimerik malzemelerin işlenmesi, üretimi veya kullanımı sırasında performans özelliklerini geliştirmek amacıyla plastikleştiriciler (örneğin fitalatlar), antioksidanlar, stabilizatörler, yağlayıcılar, antistatik ve antiblokaj ajanları gibi çeşitli katkı maddeleri eklenmektedir (Perestrelo et al., 2021).

Plastikleştiriciler, plastik üretiminde yaygın olarak kullanılan düşük moleküler ağırlıklı organik bileşiklerdir. Polimer malzemelere esneklik, dayanıklılık ve işlenebilirlik kazandırmak amacıyla katkı maddesi olarak kullanılmaları, bu bileşiklerin endüstriyel önemini artırmaktadır. Bu nedenle, otomotiv ürünleri, tekstil elyafları, elektronik cihazlar, gıda ambalajları ve oyuncaklar gibi çok çeşitli sektörlerde kullanımları hızla yaygınlaşmıştır (Erythropel et al., 2014). Nitekim, plastikleştirici pazarının son yıllarda önemli bir büyüme gösterdiği ve 2034 yılına kadar yaklaşık 28,64 milyar ABD dolarına ulaşmasının beklendiği bildirilmektedir (Sun and Syren, 2025).

Bu geniş kullanım alanı, plastikleştiricilerin çevreye ve gıda zincirine olası geçiş risklerini de beraberinde getirmektedir. Özellikle PAE'leri plastik ambalajlardan gıdalara migrasyon potansiyelleri nedeniyle son yıllarda dikkat çeken önemli bir plastik katkı maddesi grubunu temsil etmektedir**.** Lipofilik özellikleri nedeniyle yağ içeriği yüksek gıdalar, bu bileşiklerin birikimine karşı daha hassas olup; tereyağı bu açıdan önemli bir örnek teşkil etmektedir. Ambalaj malzemesi ile gıda matriksi arasındaki etkileşimin incelenmesi, hem gıda güvenliği hem de ambalaj malzemelerinin uygunluğunun değerlendirilmesi açısından büyük önem taşımaktadır.

Bu derleme, "**Piyasa tereyağlarında bazı kalite kriterlerinin tespiti ve fitalat esterlerinin varlığı ile ilgili sağlık riski değerlendirmesi**" projesi kapsamında yürütülen literatür taramasının bir parçası olarak hazırlanmıştır.

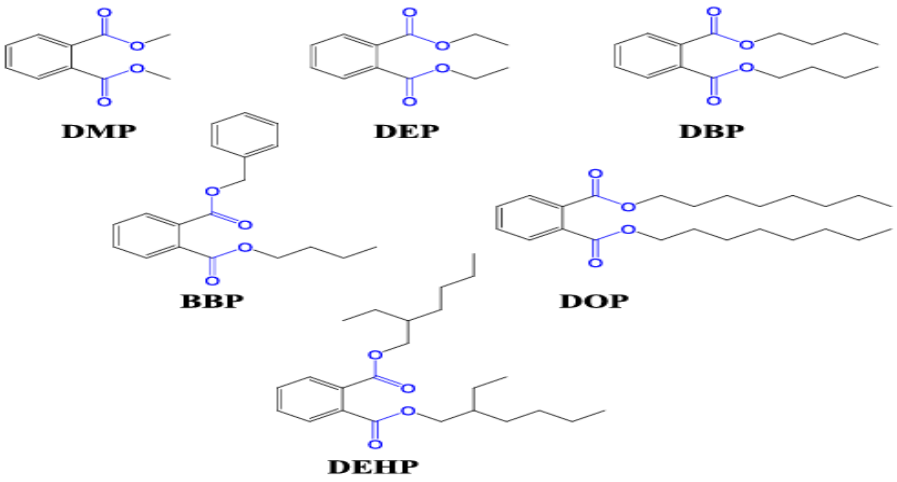
2. Fitalat Asit Esterleri (PAE'ler)

Fitalat esterleri (PAE'ler), genellikle orto-ftalik asit türevlerinden elde edilen organik bileşiklerdir. Fitalik asidin benzende bitişik (1,2) konumda bulunan iki karboksil grubunun esterleşmesi ile oluşan bu bileşikler, polimerlere esneklik, elastikiyet ve dayanıklılık kazandıran plastikleştiricilerdir (Huang et al., 2021). Kimyasal yapılarında bir fitalik asit molekülüne ester bağlarıyla bir veya daha fazla alkil grubu bağlanmıştır; bu yapı, polimer zincirleri arasındaki etkileşimleri azaltarak plastiklerin mekanik özelliklerini ve işlenebilirliğini artırır. PAE'ler, özellikle polivinil klorür (PVC) gibi sert polimerlerde yaygın olarak kullanılmakta olup, toplam plastikleştirici üretiminde yaklaşık %70–80 paya sahiptir. Bu durum, hem endüstriyel önemlerini hem de çevresel ve insan sağlığı açısından potansiyel risklerini ortaya koymaktadır (Li et al., 2021).

Plastik kirliliği, günümüzde dünyadaki en ciddi çevre sorunlarından biri olarak kabul edilmektedir (Williams and Rangel-Buitrago, 2022). Bu bağlamda, plastik katkı maddeleri de

çevresel ve sağlık açısından önemli bir endişe kaynağı haline gelmiş; özellikle PAE'lerin gıdalar ve çevre ile temas yoluyla insanlara geçişi potansiyel toksik etkilere yol açabilmektedir (Iroegbu et al., 2021). Bu özellikleri ve yaygın kullanım alanları (ambalaj malzemeleri, otomotiv ürünleri, inşaat malzemeleri, oyuncaklar ve elektrikli cihazlar) PAE'leri hem endüstriyel olarak vazgeçilmez kılmakta hem de maruziyet ve risk açısından dikkatle değerlendirilmesini gerektirmektedir.

Çevre üzerindeki önemli olumsuz etkileri nedeniyle, bazı PAE'leri öncelikli çevre kirleticileri olarak listelenmiştir. Bu kapsamda farklı alkil yan zincir uzunluklarına sahip, yaygın olarak kullanılan 6 yaygın PAE; DMP-dimetil fitalat, DEP-dietil fitalat, DBP-dibütil fitalat, BBP-benzil bütil fitalat, DOP-dioktil fitalat, DEHP-di(2-etilhekzil) fitalat şeklinde ifade edilmektedir (Şekil 1).



Şekil 1. Yaygın olarak kullanılan bazı PAE'lerinin yapısal formülleri

3. PAE'lerine Maruziyet

PAE'lerine maruziyet, plastik malzemelerden salınım sonucunda kontamine olan hava yolu ile, gıda ile ve deri ile temas yolu ile gerçekleşmektedir. Maruziyet çoğunlukla, oral/gıda yoluyla sindirim ile gerçekleşmektedir (Serrano et al., 2014). Avrupa Birliği'nde fitalatların çoğu gıda ambalajında ağırlıkça %0,1'den yüksek seviyelerde bulunması yasaktır (Perestrelo et al., 2021). Buna ragmen PAE'lerinin kontaminasyonlarının, çoğunlukla gıdalarda kullanılan ambalaj malzemelerinden migrasyon kaynaklı olduğu bildirilmiştir (Fierens et al., 2012; da Costa et al., 2023). Gıdayla temas eden polimer bazlı ambalajlardan plastikleştirici bileşiklerin gıdaya migrasyonu, 80'lerden bu yana gıda güvenliği, toksisite ve tüketici sağlığı açısından kritik bir araştırma alanı olarak önemini korumaktadır (Arvanitoyannis & Bosnea, 2004; Adly et al., 2025).

Plastik ambalaj malzemelerinden gıdalara uçucu maddelerin, katkı maddelerinin, monomerlerin ve oligomerlerin göçü konusunda çok sayıda araştırma yapılmıştır. Moleküler yapıları itibarıyla endojen hormonlarla yapısal benzerlik gösteren PAE'ler, endokrin sistem üzerinde bozucu etki oluşturan çevresel kontaminantlar olarak tanımlanmakta ve hava, su ve toprak gibi farklı çevresel ortamlarda sıkça rapor edilmektedir (Zhang et al., 2022; Tuan Tran et al., 2022).

PAE'lere maruziyet farklı gıda gruplarında yaygın olarak bildirilmiştir. Meyve ve sebzeler, süt ve süt ürünleri, tahıllar, et, balık, yağlar, atıştırmalıklar, soslar ve bebek mamalarında di-(2-etilheksil) ftalat (DEHP), dibütil ftalat (DBP), benzilbütil ftalat (BBP), diizononil ftalat (DINP) ve diizodesil ftalat (DIDP) dahil olmak üzere on dokuz PAE tespit edilmiştir. Bu değerlerin bir kısmı ülkelerin yasal sınırlarını aşmaktadır. DEHP en sık tespit edilen PAE olup, özellikle süt

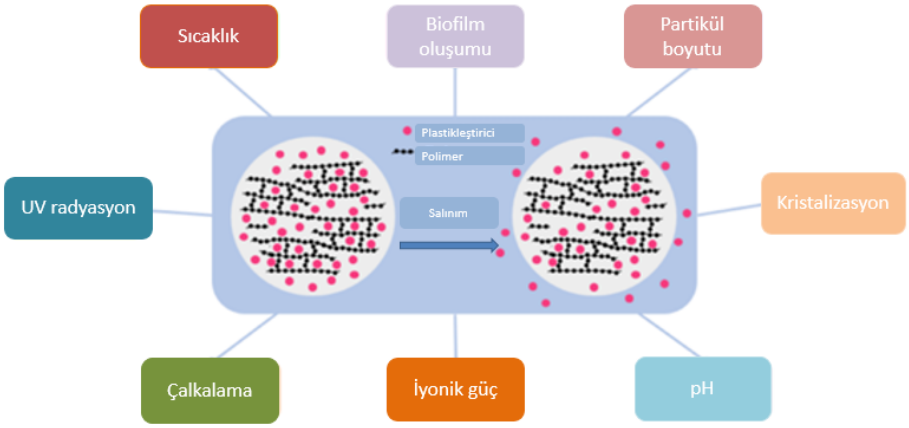
ve süt ürünleri, yağlar, balık ve tahıllar gibi yüksek yağ içeriğine sahip gıdalarda özgül göç sınırının üzerinde konsantrasyonlarda bulunmuştur. Bu gruplarda DEHP ve DBP'ye bağlı tolere edilebilir günlük alım (TDI) riskinin hem çocuklar hem de yetişkinler için yüksek olduğu bildirilmektedir. PAE göçü; sıcaklık, temas süresi, gıdanın yağ oranı ve asitliği gibi faktörlerle pozitif ilişki göstermekte olup kontaminasyon üretim zincirinin farklı aşamalarında ortaya çıkabilmektedir (da Costa et al., 2023).

4. PAE'lerin Plasikten Geçiş Mekanizması

Kimyasal katkı maddelerinin (PAEs) su sistemlerine geçiş mekanizması temel olarak üç ana süreçle açıklanabilir;

- plastik matris içerisindeki difüzyon
- plastik-su arayüzündeki faz ayrımı
- sulu sınır tabakasındaki difüzyon

Ancak, bu süreçlerin etkinliği yalnızca bu temel mekanizmalarla sınırlı değildir; çok sayıda fizikokimyasal ve çevresel faktör, katkı maddelerinin çevreye salınım hızını ve kapsamını önemli ölçüde etkileyebilir (Şekil 2). Zayıf ikincil moleküler etkileşimler nedeniyle, söz konusu analitler polimer matrisine fiziksel olarak bağlıdır. Dolayısı ile bileşikler (PAE'ler) matrise kimyasal olarak bağlanmadığından polimerlerden kolayca salınabilir ve solunum, gıdalar ve temas yolu ile çevreyi (hava, su, toprak) ve canlıları kontamine edebilirler (Kwon et al., 2017; Mirzaeı et al., 2023; Chen, 2024).



Şekil 2. Plastikleştiricilerin salınımını etkileyen faktörler

5. Fitalatların (PAE'ler) Metabolizması ve Vücutta Davranışı

Biyotransformasyon Süreci

- PAE'ler vücuda genellikle solunum, sindirim ve temas yoluyla kontamine olur.
- Emilim sonrası, karaciğerde ve kısmen bağırsak mukozasında, esteraz enzimleri tarafından monoester türevlerine (ör. DEHP → MEHP) hidrolize edilir.
- Bu monoesterler, daha sonra oksidatif metabolizma süreciyle suda çözünür metabolitlere dönüştürülür (Fan et al., 2022).

Eliminasyon (Atılım) Yolları

- Metabolitler ağırlıklı olarak idrar yoluyla, daha az oranda dışkı ve ter ile atılır.
- Düşük molekül ağırlıklı ftalatlar (DMP, DEP, DBP, BBzP) genellikle 24–48 saat içinde atılır.

- Yüksek molekül ağırlıklı ftalatlar (DEHP, DiNP, DiDP) ise yağ dokularında kısa süreli depolanabilir ve daha yavaş elimine edilirler (Meeker et al., 2012).

Maruziyetin Kanıtları

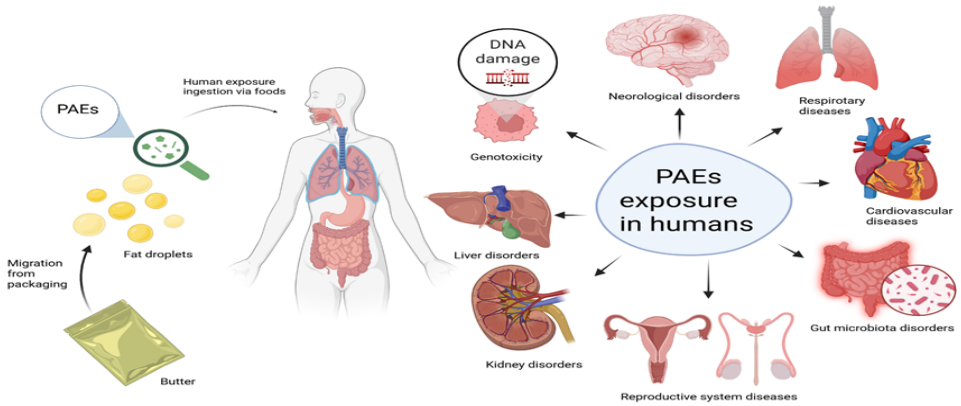
- PAE metabolitleri, kan, idrar, anne sütü, plasenta ve amniyotik sıvıda yaygın olarak tespit edilmiştir.

- Bu durum, düşük dozlarda ancak sürekli maruziyetin insan popülasyonunda yaygın olduğunu göstermektedir (Meeker et al., 2012).

Ancak vücuttan atıldıkları kadar yeniden alınırlar bu durum da kronik (sürekli) düşük doz maruziyet oluşturur. Ayrıca hormon sistemine etkilerinden (endokrin bozucu) dolayı çok düşük dozlarda bile üreme, gelişim, nörolojik ve metabolik süreçleri bozabilirler. Embriyonik ve çocukluk dönemlerinde düşük dozlarda bile maruziyet, geri dönüşü olmayan etkilere (gelişim geriliği vb.) sebep olabilir. Bazı metabolitleri oksidatif stres ve DNA hasarı gibi hücresel düzeyde toksisite oluşturabilirler (Sicińska et al., 2021). Asıl tehlike, bu bileşiklerin vücutta kalıcılığından ziyade, **sürekli maruziyet** sonucu hassas biyolojik sistemler üzerinde bozucu etki oluşturma potansiyelleridir.

6. PAE'lerin Sağlığa Etkileri

Çevrede yaygın bulunan PAE'ler, insan sağlığı üzerinde çeşitli potansiyel olumsuz etkiler oluşturabilmektedir (Şekil 3). Bu nedenle, Avrupa Gıda Güvenliği Otoritesi (EFSA), gıdalardaki PAE kontaminasyonunu sınırlamak üzere düzenlemeler geliştirmiştir. EFSA'ya göre, 0–50 µg/kg arasındaki PAE konsantrasyonları düşük, 50–300 µg/kg arasındakiler ise orta düzey olarak kabul edilmektedir; düşük düzeylerdeki göç ise sınırlı maruziyet olasılığına işaret etmektedir (Serrano et al., 2014; Dobaradaran et al., 2020; Sicińska et al., 2021).



Şekil 3. PAE'ler, insan sağlığı üzerinde çeşitli potansiyel olumsuz etkileri (Created in https://BioRender.com by Zeynep GÜRBÜZ)

PAE'ler lipofilik (yağda çözünen) bileşikler olduklarından (da Costa et al., 2023), tereyağı, krema ve yüksek yağlı peynir gibi ürünler bu bileşikler için birikim alanı oluşturmaktadır. Süt yağı, fitalatların adsorbe olabileceği uygun bir ortam sağladığından, ürünün yağ içeriği arttıkça ambalaj malzemesinden veya üretim sürecinden ürüne geçebilecek fitalat miktarı da artış göstermektedir (Mirzaei et al., 2023). Buna karşılık, düşük yağlı süt ürünlerinde maruziyet genellikle daha düşüktür. Ancak yüksek yağlı ürünlerin sık veya aşırı tüketimi, günlük toplam fitalat maruziyetini artırarak özellikle endokrin sistem üzerindeki bozucu etkiler gibi potansiyel sağlık risklerini gündeme getirebilmektedir.

7. Tereyağı ve Diğer Yağlı Süt Ürünlerinde PAE Migrasyonu

Süt ve süt ürünleri (örneğin peynir ve tereyağı), yüksek düzeyde makro ve mikro besin bileşenleri içermeleri nedeniyle çocuklar, yetişkinler ve bebekler için temel bir gıda grubunu oluşturarak insan beslenmesinde hayati bir rol oynamaktadır. Ancak bu ürünler, ambalajlama, işleme veya hayvan yemleri yoluyla PAE'ler ile kontamine olabilmektedir (Dobaradaran et al., 2020; Mirzaei et al., 2023). Gıdaya ambalaj malzemesinden gerçekleşen göç; ambalajın fiziksel özellikleri, gıdanın matris yapısı (özellikle su ve yağ fazı oranı), depolama sıcaklığı ve süresi gibi çeşitli faktörlerden etkilenmektedir. Düşük moleküler ağırlığa sahip fitalat esterlerinin (PAE'ler) göçü, özellikle yüksek lipit içeriğine sahip gıdalarda daha kolay gerçekleşmekte olup, bu durum bu tür ürünlerin fitalat migrasyonu açısından daha yüksek risk taşımasına neden olmaktadır. Bu çerçevede yapılan bir çalışmada, sulu ve yağlı gıda simülanları kullanılarak gerçekleştirilen ekstraksiyonlar ve GC-MS analizleri ile kullanılan polietilen gıda ambalaj malzemelerinin fitalat migrasyonu ve buna bağlı olarak güvenlik ve kalite durumu değerlendirilmiştir. Yağlı gıda simülanı olarak PFC (polietilen gıda kapları) ve TAB (düz polietilen poşet/filmler) malzemeleri incelenmiştir. Sonuç olarak DEHP, tüm boş örneklerde iz miktarda bulunmasına rağmen yağlı simülanda en yüksek konsantrasyona sahip fitalat olarak tespit edilmiştir. Bu fitalatleri sırasıyla DEP ve DBP izlemiş, DEP sulu simülanda yalnızca en yüksek sıcaklık ve temas süresinde düşük seviyelerde tespit edilirken, zeytinyağında çoğu örnekte anlamlı konsantrasyonlarda bulunmuştur (Ayamba et al., 2020).

Farklı ülkelerde ve çeşitli ürün gruplarında yapılan piyasa araştırmaları, süt ve süt ürünlerinde değişen düzeylerde fitalat kalıntılarının tespit edildiğini ortaya koymuştur. Tahran'daki süpermarketlerden temin edilen plastik ambalajlı tereyağı ve peynir örneklerinde altı PAE analiti (DMP, DnOP, DEP, DEHP, DBP ve BBP) MSPE-GC/MS yöntemiyle analiz edilmiş; sonuçlar, yüksek yağ içeriğine sahip peynirlerin ve yerli üretim tereyağlarının daha yüksek kontaminasyon seviyelerine sahip olduğunu ortaya koymuştur. Bununla birlikte, tüketimin beslenme uzmanlarının önerdiği düzeylerde sürdürülmesi hâlinde tüketiciler için risk olasılığının düşük olduğu bildirilmiştir (Mirzaei et al., 2023). Lin et al. (2015) tarafından yürütülen bir diğer çalışmada, plastik, cam ve metal ambalajlı ticari tam yağlı süt ürünlerinde fitalat tespiti amacıyla bir analiz yöntemi geliştirilmiş ve 2,60–156,4 ng/g aralığında değişen konsantrasyonlarda fitalat varlığı saptanmıştır. Özellikle cam ve metal ambalajlardaki süt örneklerinde fitalat miktarlarının, plastik ambalajlı ürünlere kıyasla belirgin biçimde daha düşük olması, plastik ambalajların olası bir kontaminasyon kaynağı olduğunu göstermektedir.

Benzer şekilde, Sharman et al. (1994) süt örneklerinde DEHP ve toplam fitalatın düşük seviyelerde (<0,01–0,28 mg/kg) bulunduğunu, ancak yağlı süt ürünlerinde (krema, peynir, tereyağı) kontaminasyonun arttığını ve bazı örneklerde DEHP düzeylerinin 17 mg/kg'a, toplam fitalat miktarının ise 114 mg/kg'a kadar ulaştığını bildirmiştir. Wu et al. (2015) ise süt ürünlerinde fitalat esterleri konsantrasyonlarının 0,01–0,12 mg/kg aralığında değiştiğini rapor etmiştir. Türkiye'de yürütülen bir çalışmada (Korkmaz and Küplülü, 2019) ise, yaygın olarak tüketilen süt ürünlerinde altı farklı PAE (DBP, DEHP, BBP, DINP, DNOP ve DIDP) LC-MS/MS yöntemiyle analiz etmişlerdir. Bazı örneklerde DBP, DEHP ve BBP tespit edilirken, diğer PAE'leri analiz edilebilir sınırın (20 µg/kg) altında bulunmuştur. DBP, DEHP ve BBP konsantrasyonlarının 6–229 µg/kg arasında değiştiği belirlenmiş; araştırmacılar, DEHP ve DBP'nin tüm örneklerde baskın fitalat esterleri olduğunu, ancak düzeylerinin mevcut yasal sınırların altında kaldığını ifade etmişlerdir.

SONUÇ

Literatür verileri, plastik ambalajlardan tereyağı ve diğer süt ürünlerine fitalat asit esteri bileşiklerinin göçünün genel olarak düşük seviyelerde gerçekleştiğini göstermektedir. Süt ve düşük yağlı ürünlerde fitalat düzeyleri genellikle sınır değerlerin altında kalırken, kremaya,

tereyağına ve yüksek yağlı peynir ürünlerine geçişin fazla olduğu belirtilmiştir. Plastik ambalajlar, süt ürünlerinde olası bir fitalat kaynağı olup, fitalatların bir kısmı protein ve yağ fazına adsorbe olabildiği yapılan çalışmalarla tespit edilmiştir. Mevcut bulgular, kontrollü tüketim koşullarında tereyağı ve süt ürünlerinin insan sağlığı için risk oluşturma olasılığının düşük olduğunu göstermektedir; ancak tüketim miktarı ve sıklığı toplam maruziyeti etkileyebileceğinden, risk değerlendirmeleri yalnızca kontaminasyon seviyelerine değil, aynı zamanda günlük tüketim miktarlarına da bağlı olarak yapılmalıdır. Ayrıca, farklı ambalaj tipleri, üretim ve işleme süreçleri ile kontaminasyon düzeylerinin değerlendirilmesi, risk yönetimi ve güvenlik için önemli olduğu kanısına varılmıştır.

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ZEYTİN AĞAÇLARINDA TERMAL GÖRÜNTÜLERDEN ELDE EDİLEN Tc-Ta İLE STOMA İLETKENLİĞİ ARASINDAKİ İLİŞKİNİN BELİRLENMESİ

Öğr. Gör. Erkal ERTEM

Doktora Öğrencisi, Ege Üniversitesi, Fen Bilimleri Enstitüsü, Tarımsal Yapılar ve Sulama Anabilim Dalı

İzmir Bakırçay Üniversitesi, Kalite Koordinatörlüğü

Email: erkal.ertem@bakircay.edu.tr

ORCID: 0000-0001-6551-5492

(Sorumlu Yazar)

Prof. Dr. Erhan AKKUZU

Ege Üniversitesi, Ziraat Fakültesi, Tarımsal Yapılar ve Sulama Bölümü

Email: erhan.akkuzu@ege.edu.tr

ORCID: 0000-0002-9069-2922

ÖZET

Küresel ısınma nedeniyle Akdeniz Havzasında artan sıcaklıklar ve azalan yağışlar, tarımsal su yönetiminde ciddi kısıtlar yaratmaktadır. Bu durum, bitki su tüketimi ve verimliliği açısından önemli riskler oluştururken, kısıtlı sulama stratejileri su kaynaklarının sürdürülebilir kullanımını destekleyen ve evapotranspirasyon (ETc) ihtiyacının altında su uygulayarak su verimliliğini artırmayı hedefleyen bir yaklaşım olarak öne çıkmaktadır. Bitkilerin su stresine karşı fizyolojik tepkilerini bitkiye zarar vermeden gözlemlemek için stoma iletkenliği (gs) ve termal görüntüleme yöntemleri sıklıkla kullanılmaktadır. Bu çalışma, farklı düzeyde su uygulanan ve yağışa dayalı koşullarda yetişen zeytin ağaçlarında (*Olea europaea L. cv. Memecik*) insansız hava aracı (İHA) ile alınan termal görüntülerden elde edilen kanopi-hava sıcaklığı farkı (Tc-Ta) ile stoma iletkenliği (gs) arasındaki ilişkileri incelemektedir. Ağaçlara tesadüf blokları deneme desenine göre dört farklı sulama rejimi uygulanmıştır. Bu amaçla; konular, K1: Susuz (yağışa dayalı); K2: %100×ETc, K3: %66×ETc ve K4: %33×ETc şeklinde oluşturulmuştur. Beş farklı tarihe ait Tc-Ta haritaları oluşturularak zamansal-mekânsal değişimler incelenmiş ve istatistiksel analizler sonucunda, ilk ölçüm tarihinden itibaren konular arasında anlamlı farklılıklar olduğu ortaya konulmuştur. Buna göre K2 konusu en düşük Tc-Ta değerini alırken K1 konusu en yüksek değeri almıştır. Yüksek Tc-Ta değerleri su stresi altındaki bitkileri, düşük değerler ise iyi sulanan bitkileri ifade etmektedir. İHA uçuşlarıyla eşzamanlı yapılan ölçümlerde stoma iletkenliği tüm tarihlerde konular arasında anlamlı farklılık göstermiş; K2 en yüksek, K1 ve K4 ise en düşük gs değerlerine sahip olmuştur. Yüksek gs değerleri iyi sulanan bitkileri, düşük değerler ise su stresi altındaki bitkileri ifade etmektedir. Araştırmada, Tc-Ta ile stoma iletkenliği arasında istatistiksel olarak anlamlı ve negatif yönlü bir ilişki saptanmış ($r = -0.619$, $r^2 = 0.383$); Tc-Ta azaldıkça stoma iletkenliği ve transpirasyonun arttığı belirlenmiştir.

Anahtar Kelimeler: İHA, Termal Görüntüleme, Zeytin, Kuraklık, Su Stresi

DETERMINATION OF THE RELATIONSHIP BETWEEN STOMATAL CONDUCTANCE AND Tc-Ta OBTAINED FROM THERMAL IMAGES IN OLIVE TREES

ABSTRACT

Global warming has caused rising temperatures and decreasing rainfall in the Mediterranean Basin, creating serious constraints in agricultural water management. This situation poses significant risks regarding plant water consumption and productivity, while deficit irrigation strategies are emerging as an approach that supports the sustainable use of water resources and aims to increase water efficiency by supplying water below the evapotranspiration (ETc) requirement. Stomatal conductance (gs) and thermal imaging methods are commonly used to observe plants' physiological responses to water stress without damaging the plant. This study examines the relationships between canopy-air temperature difference (Tc-Ta) and stomatal conductance (gs), obtained from thermal images taken by an unmanned aerial vehicle (UAV) on olive trees (*Olea europaea L. cv. Memecik*) grown under different water application levels and rainfall-dependent conditions. Four irrigation regimes were applied to the trees according to the randomized block design: K1 (no irrigation, rain-fed), K2 (100%×ETc), K3 (66%×ETc), and K4 (33%×ETc). Tc-Ta maps for five different dates were created to assess spatio-temporal changes, and statistical analyses revealed significant differences between treatments from the first measurement date. The results showed that treatment K2 had the lowest Tc-Ta value, while treatment K1 had the highest. High Tc-Ta values indicate plants under water stress, whereas low values indicate well-watered plants. Measurements taken simultaneously with UAV flights showed significant differences in stomatal conductance across treatments on all dates; K2 had the highest gs values, while K1 and K4 had the lowest. High gs values suggest well-watered plants, while low values indicate plants under water stress. The study found a statistically significant and negative relationship between Tc-Ta and stomatal conductance ($r = -0.619$, $r^2 = 0.383$); it was determined that as Tc-Ta decreased, stomatal conductance and transpiration increased.

Keywords: UAV, Thermal Imaging, Olive, Drought, Water Stress

1. GİRİŞ

Son yıllarda, iklim değişikliği, özellikle yaz aylarında yağışların az olduğu ve sıcaklıkların yüksek olduğu bölgelerde, tarımda suyun bulunabilirliği ve kullanımı konusunda ciddi sorunlar yaratmıştır (Konapala ve ark., 2020; Pokhrel ve ark., 2021; Carella ve ark., 2024). Tarımsal su kullanımı, artan su kıtlığı için birincil değişkendir ve sulama, dünyadaki tatlı su kullanımının yaklaşık %70'ini oluşturmaktadır (Tshwene ve Oladele, 2016; Awais ve ark., 2023). Su kaynaklarının sınırlı doğası göz önüne alındığında, sulama uygulamalarının iyileştirilmesi ve sürdürülebilir su yönetimi stratejilerinin geliştirilmesi, suyu korurken bitki verimliliğini korumak için çok önemlidir (Ramírez-Cuesta ve ark., 2025). Küresel ısınma senaryosunda, sulama yönetimi tarımda su kullanımının optimizasyonu için önemlidir (Howell, 2001; Marques ve ark., 2020). Kısıtlı sulama (DI) stratejileri, bitkinin evapotranspirasyon (ETc) gereksinimlerinin altında su uygulamayı ve minimum verim düşüşüne neden olmayı amaçlamaktadır (Ramírez-Cuesta ve ark., 2025). Bu strateji, belirli bir dönemde veya tüm büyüme mevsimi boyunca uygulanabilir (English, 1990; Marques ve ark., 2020).

Zeytin ağaçları özelinde, su kullanım verimliliğini artırmak için çok sayıda sulama stratejisi geliştirilmiş ve değerlendirilmiştir. Bu stratejilerde öncelikli olarak verim kayıplarının azaltılması ve zeytinyağı kalitesinin potansiyel olarak iyileştirilmesi hedeflenmiştir (Gucci ve ark., 2019; Marques ve ark., 2023). Bitkilerin su stresine fizyolojik tepkisine dayalı olarak, kısıtlı sulama (DI) yönteminin benimsenmesi çeşitli araştırmalarda önemli bir odak noktası olmuştur (Fernandes-Silva ve ark., 2013; Akkuzu ve ark. 2013; Shackel ve ark., 2021; Trentacoste ve ark., 2019; Vita Serman ve ark., 2011; Marques ve ark., 2023; Mengü ve ark., 2024). Ancak, bu yöntemleri pratikte başarıyla uygulamak ve verim üzerindeki olumsuz etkileri en aza indirmek için, bitkilerin su stresine nasıl tepki verdiklerini iyice anlamak çok önemlidir. Bu bilgi, su stresinin sürekli izlenmesi ile birleştiğinde, son derece önemli hale gelir. Yaygın olarak kullanılan su durumu göstergeleri arasında stoma iletkenliği (g_s) bulunur (Marques ve ark., 2023; Mengü ve ark., 2024). Son zamanlarda yapılan çalışmalar, optik veya termal görüntülerin kullanıldığı uzaktan algılama tekniklerinin de bitki su stresini izlemek için kullanılabileceğini göstermiştir (Jamshidi ve ark., 2021; Sepulcre-Canto ve ark., 2005; Veysi ve ark., 2017; Zhang ve ark., 2019a; Zhang ve ark., 2019b; Brewer ve ark., 2022).

Uzaktan algılama teknikleri, termal, multispektral ve hiperspektral kameralar kullanılarak geniş alanlarda ağaçların su durumundaki mekânsal değişkenliğin hızlı bir şekilde tespit edilmesini sağlar (Carella ve ark., 2024a; Carella ve ark., 2024b). Ayrıntılı ölçekli sulama yönetimi için uzaktan algılamada en yaygın olarak kullanılan platformlar arasında İnsansız Hava Araçları (İHA) bulunmaktadır (Roma ve Catania, 2022; Carella ve ark., 2024b). Termal sensörlerle donatılmış İHA'lar, meyve bahçelerindeki yüzey sıcaklığı değişimlerini hassas bir şekilde yakalayarak, su durumundaki mekansal farklılıkların tespitini kolaylaştırmaktadır (Ramírez-Cuesta ve ark., 2025). Birkaç çalışma, zeytin bahçeleri üzerinde uzaktan algılamanın ağaçların su durumunun doğru bir tahminini sağlayabileceğini ortaya koymuştur. Çoğu çalışma, termal kameralarla uzaktan algılamanın bitkilerin su durumu ile yüksek korelasyon gösterdiğini vurgulamaktadır (Ben-Gal ve ark., 2009; Caruso ve ark., 2022; Egea ve ark., 2016; Carella ve ark., 2024b).

Bitkilerin su durumunu gerçek zamanlı olarak gösteren önemli ve maliyet etkin bir gösterge, bitki örtüsü sıcaklığıdır (Bian ve ark., 2019; Costa ve ark., 2020; de Almeida ve ark., 2024). Bitkilerdeki su eksikliğini değerlendiren bu yöntem, sıcaklıktaki azalmanın, buharlaşma soğutma süreci nedeniyle bitki terleme oranıyla orantılı olduğu ilkesine dayanmaktadır (Costa ve ark., 2018; Khorsandi ve ark., 2018; Zia ve ark., 2013; de Almeida ve ark., 2024). Kanopi sıcaklığı birçok çalışmada su stresi göstergesi olarak önerilmiştir (Idso ve ark., 1978; Jackson ve ark., 1977a; Jackson ve Pinter Jr., 1981; Sepulcre-Cantó ve ark., 2006). Jackson ve ark.,

(1977b) bitkilerin su durumunu incelemek için kanopi sıcaklığı (Tc) ile hava sıcaklığı (Ta) farkını bir indeks olarak kullanmış ve Tc-Ta değerlerini verimlilik ve bitkilerin su gereksinimleri ile ilişkilendirmiştir. Idso (1982) çevresel değişkenliğin önemli bir faktör olduğunu göstermiş, yüksek Tc-Ta değerlerinin su stresi altındaki bitkilerle, düşük değerlerin ise iyi sulanan parsellerle ilişkili olduğunu ortaya koymuştur (Sepulcre-Cantó ve ark., 2006).

Yaprak alanı, stoma iletkenliği ve hidrolik özellikteki değişiklikler bitkideki su durumunu kontrol eder (Jones, 1999, 2004; Gonzalez-Dugo ve ark., 2012; Blum ve ark., 2013) bu nedenle kanopi sıcaklığı su açığını değerlendirmek ve sulamayı planlamak için kullanılır (Blum ve ark., 2013).

Stoma iletkenliği, yaprak ve çevresindeki hava arasındaki su buharı ve karbondioksit değişiminin önemli bir düzenleyicisidir ve bitki büyümesini doğrudan etkiler (Iseki ve Olaleye, 2020). Stoma iletkenliği, değişen güneş radyasyonu, hava nemi, hava sıcaklığı, rüzgâr hızı ve toprak su içeriği seviyelerine sahip ortamlara uyum sağlamak için bitki su kaybını en aza indirmede de önemli bir rol oynar. Bu nedenle, stoma iletkenliği özellikle hafif-orta kuraklık stresi koşullarında bitki su durumu ve büyümesinin bir göstergesi olarak kullanılır (Flexas ve Medrano, 2002; Medrano ve ark., 2002; Iseki ve Olaleye, 2020). Önemli bir süre boyunca stoma kapanmalarının yaprak sıcaklığını artırdığı bilinmektedir (Kashiwagi ve ark., 2008; Kumar ve ark., 2017). Stoma iletkenliğini ölçmek için en doğru yöntem bir yaprak porometresi veya bir kızılötesi gaz analizörü (IRGA) kullanmaktır (Iseki ve Olaleye, 2020).

Stres olmayan koşullar altında, daha yüksek hava sıcaklığı ve güneş radyasyonu, stoma açılmasına yol açarken daha düşük nem stoma kapanmasına yol açar (Yu ve ark., 2004; Iseki ve Olaleye, 2020). Toprak nem açığı transpirasyon oranını azaltır ve bu da kanopi sıcaklığını artırır (Rebetzke ve ark., 2013; Lepekhov, 2022). Bu nedenle, kanopi sıcaklığı bitkilerde kuraklık ve ısı toleransını incelemek için kullanılabilir (Lepekhov, 2022).

Değerlendirme ve hesaplama kolaylığı nedeniyle, stoma iletkenliğinin yaprak sıcaklığına bağlı göstergeleri laboratuvar ve arazi çalışmalarında yaygın olarak uygulanmaktadır. Bu göstergelerle ilgili bir zorluk, yaprak sıcaklığı ile stoma iletkenliği arasındaki ilişkinin güneş radyasyonu, hava sıcaklığı, nem ve rüzgâr hızındaki değişikliklerle güçlü bir şekilde değişebilmesidir (Maes ve Steppe, 2012; Iseki ve Olaleye, 2020).

Bu çalışmada, Memecik zeytin çeşidine uygulanan farklı sulama rejimlerinin stoma iletkenliği ve termal görüntülerden oluşturulan Tc-Ta'nın değişimi araştırılmıştır. Ayrıca stoma iletkenliği ile Tc-Ta arasındaki ilişkinin belirlenmesi amaçlanmıştır.

2. MATERYAL VE YÖNTEM

Deneme Alanı ve Özellikleri

Çalışma, 2024 yılında İzmir Bornova Zeytincilik Araştırma Enstitüsü Müdürlüğü, Bornova Üretim ve Araştırma Sahası içerisinde 38° 27' 08.7" K, 27° 12' 01.5" D koordinatlarında, tınlı bünyeli toprak yapısına sahip arazide yürütülmüştür. Araştırma alanı; Akdeniz iklim kuşağında yer almaktadır. Uzun yıllar ortalama iklim verilerine göre; toplam yıllık yağış 600,1 mm ortalama sıcaklık 19,1 °C, ortalama oransal nem %63,2'dir (MGM, 2025). Denemede su kaynağı olarak derin kuyu kullanılmıştır. Suyun pH'ı ve elektriksel iletkenliği sırasıyla 7.56 ve 1 dS m^{-1}'dir.

Denemede, yetişkin 7 x 5 m (sıra arası x sıra üzeri) aralıklarla dikilmiş zeytin ağaçları (*O. europaea L. cv. Memecik*) kullanılmıştır. Ağaçlara tesadüf blokları deneme desenine göre dört farklı sulama rejimi uygulanmıştır. Bu amaçla; konular, K1: Susuz (yağışa dayalı); K2: %100×ETc, K3: %66×ETc ve K4: %33×ETc şeklinde oluşturulmuştur (Şekil 1). Sulama

miktarları, gravimetrik yöntemle kök derinliğinin ilk 90 cm'sindeki toprak nem içeriğine göre planlanmış, sulamalar 7 günde bir ve damla sulama yöntemiyle uygulanmıştır.



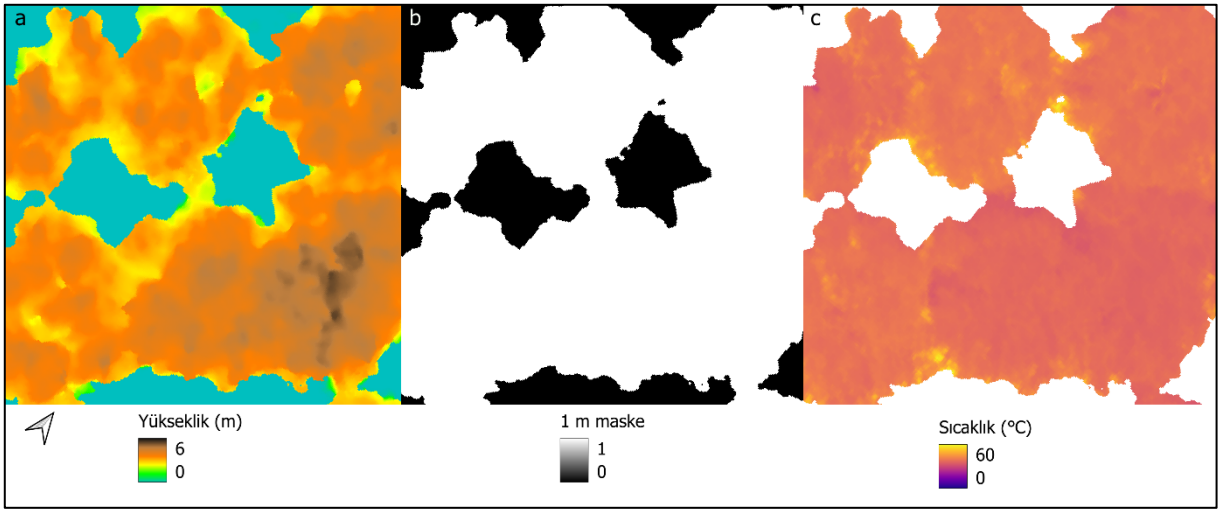
Şekil 1. Deneme alanı ve deneme deseni

İHA Uçuşları ve Veri Toplama

Çalışmada insansız hava aracı (İHA) olarak DJI Matrice 350 RTK kullanılmıştır. İHA multispektral ve termal ölçümler yapabilmek için MicaSense RedEdge-P DUAL multispektral ve DJI Zenmuse H20T termal kamera ile donatılmıştır. Uçuşlar arazi yüzeyinden 60 m yükseklikte ve öne ve yana en az %80 örtüşme oranı olacak şekilde yapılmıştır. Görüntülemeler gölgelenmeyi en aza indirmek ve bitki stresinin daha iyi gözlenebilmesi için güneş açısının dik olduğu 11:00 ile 14:00 saatleri arasında gerçekleştirilmiştir.

Multispektral ve termal görüntülerin hassas bir şekilde hizalanmasını sağlamak için, zeytin bahçesinin dört köşesine 4 adet yer kontrol noktası (YKN) yerleştirilmiştir. İHA uçuşları sırasında elde edilen ham multispektral ve termal görüntülerden, dijital yükseklik modeli (DEM), dijital arazi modeli (DTM) ve ortomozaikler oluşturmak için Agisoft Metashape yazılımı kullanılarak görüntüler işlenmiştir. Elde edilen ortomozaik, DEM ve DTM haritaları QGIS yazılımı ile analiz edilmiştir.

Kanopi sıcaklığını (Tc) hesaplamada yabancı otların ve arazi zemininin sıcaklık etkisini yok edebilmek için (Marques ve ark., 2019)'larının kullandığı metodolojiye benzer bir yöntem kullanılmıştır. Buna göre ilk aşamada, DEM ve DTM haritaları arasındaki fark hesaplanarak kanopi yükseklik modeli (CHM) türetilmiş, böylece deniz seviyesi ve arazi eğiminin etkisi yok edilerek yer seviyesinin üzerindeki nesne yüksekliğinin belirlenmesi sağlanmıştır (Şekil 2a). İkinci aşamada, arazi içinde kendiliğinden büyüyen yabancı otları ve kanopi gölgelerini ortadan kaldırmak için CHM haritası kullanılarak zeminden 1m'yi aşan yükseklikleri dikkate alarak maskeleme uygulanmıştır (Şekil 2b). Son aşamada ise sadece kanopi alanlarına ait sıcaklıkları hesaplayabilmek için 1m yüksekliğe göre maskelenen harita ile termal görüntülerden elde edilen ortomozaik haritası birleştirilmiştir (Şekil 2c). Kanopi sıcaklıkları (Tc) elde edildikten sonra, ölçüm saatlerine ait ortalama hava sıcaklıkları (Ta) çıkarılarak Tc-Ta değerleri hesaplanmıştır.



Şekil 2. Zeytin ağaçlarında (a) kanopi yükseklik modeli (CHM); (b) 1 m yükseklik maskesi; (c) kanopi sıcaklığı.

Stoma İletkenliği Ölçümleri

Çalışmada stoma iletkenliği (g_s, mmol m^{-2} s^{-1}) değerlerini ölçmek için Licor marka LI-6800 Portable Photosynthesis System cihazı kullanılmıştır. Yüksek hassasiyetli kızılötesi gaz analizörleri (IRGA'lar), bir numune tarafından karbondioksit (CO_2) alımını ve su buharı (H_2O) salınımını ölçer. Stoma iletkenliği, yaprak stomaları yoluyla gaz değişiminin (yani karbondioksit alımı) ve terlemenin (yani su buharı kaybı) ölçüsüdür ve stomaların yoğunluğu, boyutu ve açılma derecesinin bir fonksiyonudur (Handiganoor ve ark., 2018; Brewer ve ark., 2022). Stomaları açık olan yapraklar daha yüksek iletkenliğe izin verir ve dolayısıyla potansiyel olarak yüksek fotosentez ve terleme oranlarını gösterirken, kapalı yaprak gözenekleri potansiyel bitki stresini gösterir (Brewer ve ark., 2022).

Yaprak gaz alışverişi parametrelerinin belirlenmesi amacıyla, ölçümler sulamadan bir gün önce İHA uçuşlarına paralel olarak 11:00 – 14:00 saatleri arasında, tüm konularda her tekerrürde, ortada yer alan ağacın dış tarafından omuz hizasında dört farklı yönden seçilen tam olgunluğa ulaşmış 4 er yaprakta (her bir konuda toplam 12 yaprakta) gerçekleştirilmiştir.

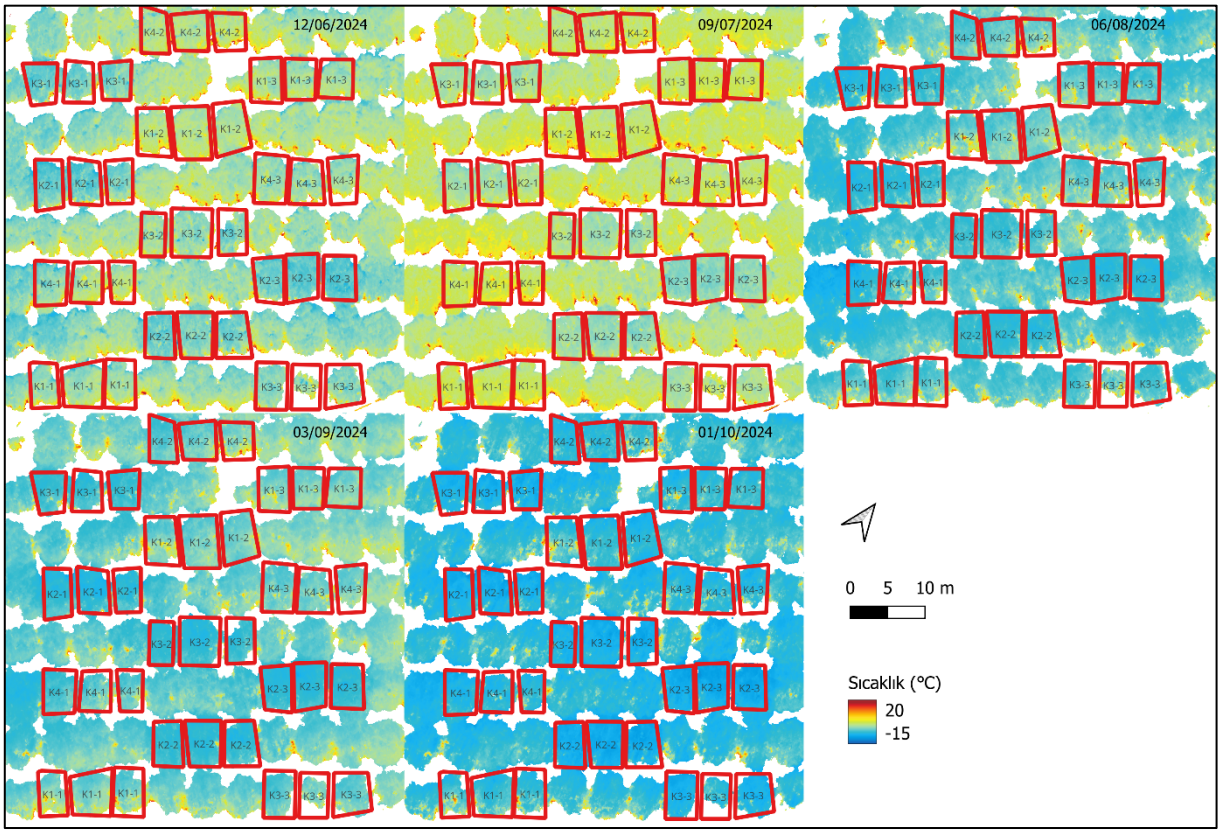
Analiz ve Değerlendirme

Denemede gerçekleştirilen uygulamaların sonucunda elde edilen veriler arasındaki farkın önemli olup olmadığı ($p<0.05$) tek yönlü varyans analizi (One-Way ANOVA) ile belirlenmiştir. Konular arasındaki farklılığı belirlemek için SPSS paket programı kullanılmış ve Duncan testi uygulanmıştır.

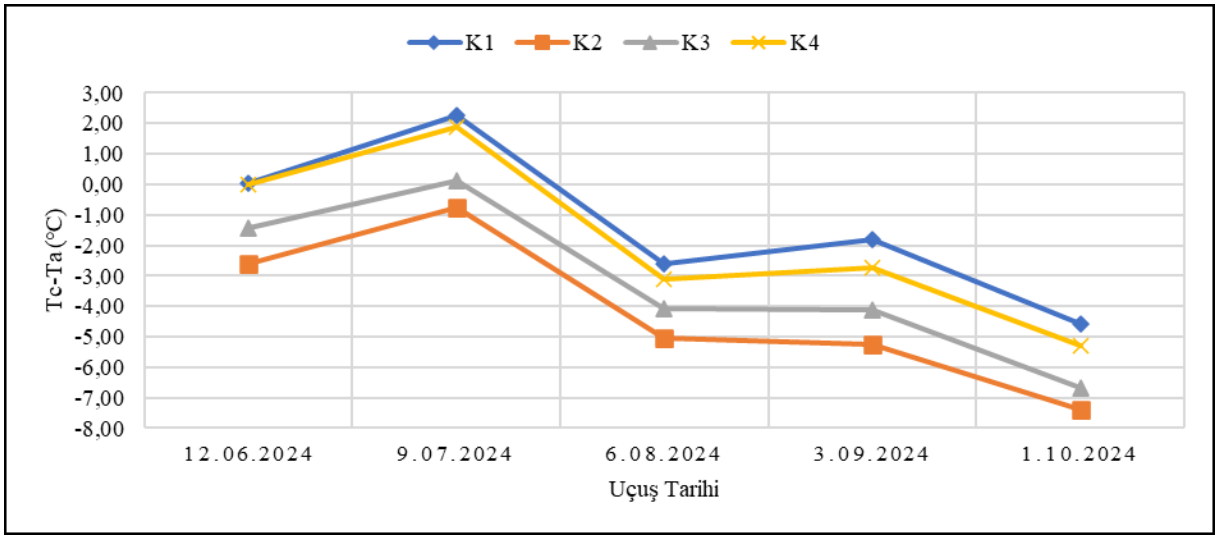
3. BULGULAR VE TARTIŞMA

Multispektral ve termal görüntülerden elde edilen kanopi ile hava sıcaklığı arasındaki fark (Tc-Ta)'ın, konulara ve zamana göre değişimi Şekil 3'te verilmiştir. Sulama sezonu boyunca kanopi sıcaklıklarının toprak nemi, hava sıcaklığı, güneş radyasyonu ve bağıl nem gibi ortam koşullarından etkilenmesi nedeni ile Tc–Ta değerleri dalgalanma göstermiştir (Şekil 4). Beklendiği gibi su kısıtı uygulanmayan K2 konusunda sezon boyunca eksi (-) değerler gözlenmiştir. Ancak hiç su uygulanmayan K1 konusunda haziran ve temmuz aylarında artı değerler (+) gözlenirken hava sıcaklıklarının düşmesiyle ağustos ayından itibaren eksi (-) değerler gözlenmiştir. Ekim ayında tüm konulardaki sıcaklık düşüşlerinin eylül ayındaki yağıştan kaynaklandığı düşünülmektedir. İstatistiksel olarak incelendiğinde tüm sezon boyunca konular arasında fark bulunmuştur (Çizelge 1). Sezon boyunca K2 konusu en düşük Tc-Ta değerini alırken, en yüksek değerleri K1 konusu almıştır. Sezon ortalamasına bakıldığında tam

sulanan konu (K2) ile susuz konu (K1)'su arasında yaklaşık 3°C'lik bir fark bulunmuştur. Bunun temel nedeni transpirasyonun serinletici etkisidir, transpirasyon arttıkça bitki dokularından meydana gelen ısı kaybı da artmaktadır. Tam konusunda toprakta nem potansiyeli daha yüksek olduğu için yağışa dayalı koşullarda yetişen (Susuz konusu) ağaçlara göre transpirasyon daha yüksektir. Tam konusunda sıcaklık değerleri hava sıcaklığının altında kalmıştır.



Şekil 3. Zeytin ağaçlarında kanopi sıcaklığı ve hava sıcaklığı farkının (Tc-Ta) zamansal ve mekânsal değişimi.



Şekil 4. Zeytin ağaçlarında yaprak sıcaklığı ve hava sıcaklığı farkı (Tc-Ta) değerlerinin değişimi (°C).

Çizelge 1. Zeytin ağaçlarında konulara göre ortalama Tc-Ta değeri (ºC) ve bazı iklim parametrelerinin değişimi.

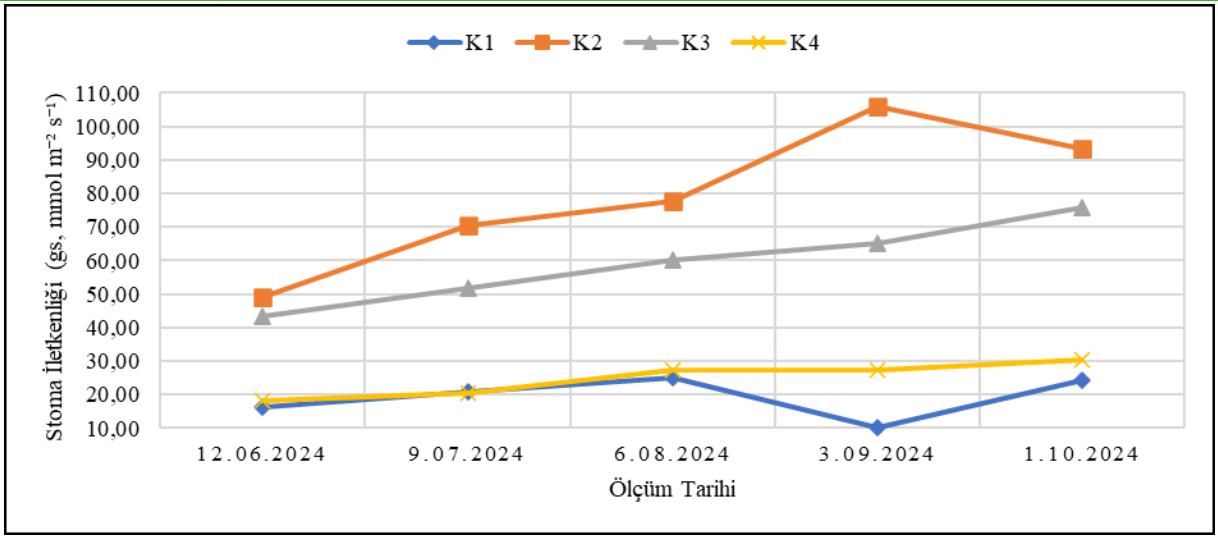
	12.06.2024	9.07.2024	6.08.2024	3.09.2024	1.10.2024	Ortalama
K1	0,05 (a)	2,25 (a)	-2,62 (a)	-1,82 (a)	-4,58 (a)	-1,34
K2	-2,61 (c)	-0,76 (b)	-5,03 (c)	-5,24 (c)	-7,40 (b)	-4,21
K3	-1,43 (b)	0,13 (b)	-4,08 (bc)	-4,13 (bc)	-6,70 (b)	-3,24
K4	0,01 (a)	1,91 (a)	-3,09 (ab)	-2,73 (ab)	-5,31 (a)	-1,84
Ta (°C)	40,35	38,80	31,90	31,40	24,40	
Bağıl Nem (%)	26,00	30,00	49,00	53,50	47,50	
Güneş Radyasyonu (W m^{-2})	890	930	800	720	730	

$p \geq 0.05$ ns : önemsiz $p < 0.05$ önemli

NOT: Tc-Ta değerleri arasındaki farklar duncan testine göre sınıflandırılıp, ayrı sınıflardaki konular küçük harflerle gösterilip, farkların istatistiksel olarak önemli olduğu belirtilmektedir.

Çamoğlu (2013) Ayvalık ve Gemlik su kısıtı uyguladığı zeytin fidanlarında yaptığı çalışmada sezonluk ortalama Tc-Ta değerlerinin Ayvalık çeşidinde -1,7 ila 0,9 °C (yaklaşık 3 °C fark), Gemlik çeşidinde ise -0,8 ila 1,9 °C (yaklaşık 3 °C fark) arasında değiştiğini gözlemlemiştir. Her iki çeşitte de en düşük değeri tam sulanan konuda en yüksek değeri de sulanmayan konuda tespit etmiştir. Poblete-Echeverría ve ark. (2016) zeytin ağaçlarında, su stresi olmayan uygulamada en düşük Tc-Ta değerini (ortalama 0,5°C), su stresi olan uygulamada en yüksek Tc-Ta değerini (ortalama 4,7°C) ölçmüşlerdir. İyi sulanan ve stres altındaki ağaçlar arasında yaklaşık 4°C'lik bir sıcaklık farkı bulmuşlardır. Ramírez-Cuesta ve ark. (2025) 4 farklı sulama stratejisi uyguladıkları zeytin ağaçlarında Tc-Ta değerlerinin -1 ila 7 °C arasında değiştiğini ve ağaçların stres seviyesi azaldıkça Tc-Ta değerlerinin de düştüğünü tespit etmişlerdir. Araştırmacıların bulguları da bu araştırmanın bulgularıyla paralellik göstermektedir.

Stoma iletkenliği değerleri de Tc–Ta ile benzer şekilde aynı ortam koşullarının etkisiyle, sulama sezonu boyunca K3 ve K4 konuları hariç dalgalı bir seyir izlemiştir (Şekil 5). Beklendiği gibi su kısıtı uygulanmayan K2 konusunda sezon boyunca en yüksek değerler gözlenmiştir. Çizelge 2'de verildiği gibi en düşük stoma iletkenliği değerleri K1 ve K4 konularında görülmüş ve bu iki konu da istatistiksel olarak sezon boyunca aynı grupta yer almıştır. K2 konusunda sezon ortalaması 79.29 mmol m^{-2} s^{-1}, K1 konusunda ise 19.32 mmol m^{-2} s^{-1} hesaplanmıştır. Ekim ayında K1, K3 ve K4 konularındaki stoma iletkenliği değerlerinin yükselmesinin sebebinin eylül ayındaki yağış olduğu düşünülmektedir.



Şekil 5. Zeytin ağaçlarında stoma iletkenliği (g_s) değerlerinin değişimi (mmol m^{-2} s^{-1}).

Çizelge 2. Zeytin ağaçlarında konulara göre ortalama stoma iletkenliği değeri (mmol m^{-2} s^{-1}) ve bazı iklim parametrelerinin değişimi.

	12.06.2024	**9.07.2024**	**6.08.2024**	**3.09.2024**	**1.10.2024**	**Ortalama**
K1	16,29 (b)	20,93 (b)	24,90 (c)	10,03 (c)	24,20 (c)	19,32
K2	48,92 (a)	70,51 (a)	77,92 (a)	105,88 (a)	93,33 (a)	79,29
K3	43,50 (a)	51,89 (ab)	60,16 (b)	65,23 (b)	75,85 (b)	59,33
K4	18,10 (b)	20,60 (b)	27,15 (c)	27,47 (c)	30,40 (c)	24,74
Ta (°C)	40,4	38,8	31,9	31,4	24,4	
Bağıl Nem (%)	26,0	30,0	49,0	53,5	47,5	
Güneş Radyasyonu (W m^{-2})	890	930	800	720	730	

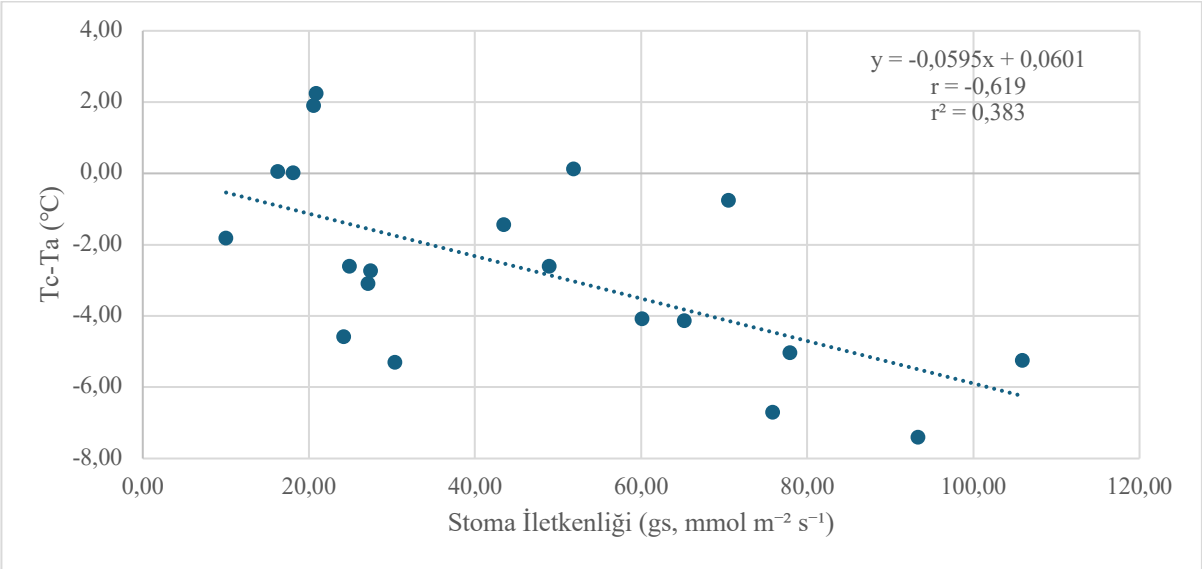
$p \geq 0.05$ ns : önemsiz $p < 0.05$ önemli

NOT: Stoma iletkenliği değerleri duncan testine göre sınıflandırılıp, ayrı sınıflardaki konular küçük harflerle gösterilip, farkların istatistiksel olarak önemli olduğu belirtilmektedir.

Pierantozzi ve ark., (2013) iki farklı zeytin çeşidinde yaptıkları çalışmada stoma iletkenliği değerlerinin sulanan ve sulanmayan konuları arasında Arbequina çeşidinde %69,7 Manzanilla çeşidinde ise %67,2 fark olduğunu gözlemlemişler ve kuraklık koşullarının stoma iletkenliği (gs) üzerinde güçlü bir etkiye sahip olduğunu belirlemişlerdir. Ahumada-Orellana ve ark., (2019) zeytin ağaçlarında yaptıkları çalışmada stoma iletkenliğinin 180 mmol m^{-2} s^{-1} değerinde su stresinin hafif olduğu veya hiç olmadığı, 90 mmol m^{-2} s^{-1} değerinde ise su stresinin olduğunu belirlemişlerdir. Guimarães ve ark., (2024) badem ağaçlarında yaptıkları çalışmada su stresinin düşük olduğu sırada stoma iletkenliği değerlerin yüksek olduğunu ancak su stresinin daha yüksek olduğu durumda transpirasyonu azaltarak su stresiyle başa çıkabilmek için daha düşük stoma iletkenliği değerleri gösterdiğini saptamışlardır. Jones ve Leinonen, (2003) yaptıkları çalışmada stomalar açıldıkça ve transpirasyon hızı arttıkça yaprak sıcaklığının azaldığını ve

yaprak sıcaklığı ölçümlerinin stoma iletkenliği ve transpirasyon oranlarındaki değişikliklerin bir göstergesi olarak kullanılabileceğini bildirmiştir. Araştırmacıların bulguları da bu araştırmanın bulgularıyla paralellik göstermektedir.

Benzer şekilde stomalar açıldığında yani stoma iletkenliği ve transpirasyon hızı arttıkça, transpirasyonun serinletici etkisi nedeniyle Tc-Ta değeri azalmaktadır. Buna göre stoma iletkenliği ve Tc-Ta arasında korelasyon katsayısının (r) -0,619, r^2 değerinin 0,383 olduğu negatif yönlü doğrusal, istatistiksel olarak zayıf ama anlamlı bir ilişki bulunmuştur.



Şekil 6. Stoma iletkenliği ile Tc-Ta değerlerinin arasındaki regresyon ve korelasyon analizi.

Çakır, (2015) Memecik zeytin çeşidinde yaptığı çalışmada da stoma iletkenliği ve Tc-Ta arasında negatif yönlü doğrusal bir ilişki bulmuştur (r = -0,450, r^2 = 0,202).

4. SONUÇ

Bu çalışmanın amacı, *cv. Memecik* zeytin ağaçlarının farklı sulama düzeylerinde su stresine tepkisini ortaya koyabilmek için İHA tabanlı termal görüntülerinden ve stoma iletkenliğinin kullanılabilirliğini değerlendirmektir.

Her iki yöntemde de tüm ölçüm tarihlerinde sulama konuları arasında su stresi göstergeleri tahmin edilebilmiş ve konular arasında istatistiksel olarak farklar belirlenmiştir. En iyi sonuçlar sulama kısıtı olmayan K2 konusunda (ortalama Tc-Ta= -4,21 °C, gs= 79,29 mmol m^{-2} s^{-1}) en yüksek su stresi sulama yapılmayan K1 konusunda (ortalama Tc-Ta= -1,34 °C, gs= 19,32 mmol m^{-2} s^{-1} elde edilmiştir. Ayrıca beş farklı tarihe ait termal görüntülerden elde edilen haritalar sayesinde arazi zamansal ve mekânsal olarak incelenebilmiş ve Tc-Ta değerlerinin değişimi özellikle K2 konusunda diğer konulara göre gözle görülebilir bir şekilde farklılık göstermiştir.

Çalışmada, stoma iletkenliği ve Tc-Ta arasında negatif yönlü bir korelasyon bulunmuştur (r= -0,619). Buna göre stres koşullarının bulunmadığı durumda stoma iletkenliği değeri yüksek sonuçlar verirken Tc-Ta değerleri transpirasyonun serinletici etkisi nedeniyle düşük sonuçlar vermiştir.

Sonuç olarak İHA tabanlı termal görüntüler ile stoma iletkenliği ölçümlerinin zeytin ağaçlarında su stresini belirlemede başarılı olduğunun yanısıra yine termal görüntülerden yararlanarak stoma iletkenliğinin tahmin edilebileceği söylenebilir.

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üretilmiştir. Stoma iletkenliği verileri TÜBİTAK 1003-Öncelikli Alanlar Ar-Ge Projeleri Destekleme Programı'nın 222O426 numaralı bilimsel araştırma projesinden alınmıştır. Çalışmaya katkılarından dolayı Zir. Yük. Müh. Şener ÖZÇELİK, Dr. Nurcan ULUÇAY ve Dr. Emrah ÖZÇAKAL ile çalışmanın yürütüldüğü Bornova Zeytincilik Araştırma Enstitüsü Müdürlüğüne teşekkürlerimizi sunarız.

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THE EFFECT OF NANO-SILVER APPLICATION UNDER SALINE WATER ON SOME GROWTH AND YIELD PARAMETERS IN TOMATO SEEDLINGS

İlyas DAYAN

Van Yüzüncü Yıl University, Faculty of Agriculture

Email: ilysdyn69@gmail.com

Dr. Öğr. Üyesi Özlem ÇAKMAKCI*

Van Yüzüncü Yıl University, Faculty of Agriculture

Email: ozlemguldigen@yyu.edu.tr,

ORCID: 0000-0001-6145-4442

*: Corresponding author

ABSTRACT

Salt stress is one of the main abiotic factors limiting plant growth and productivity, especially in sensitive plants such as tomatoes (*Solanum lycopersicum* L.). This study aimed to investigate the effect of nano-silver application on the growth and yield parameters of tomato seedlings grown under salt stress. Tomato seedlings treated with 3 doses of nano-silver (AgNP0: 0 ppm, AgNP1: 30 ppm, and AgNP2: 60 ppm) were subjected to control (S0: tap water, 0.8 dS/m) and saline irrigation water (S1: 3.6 dS/m) applications, and the experiment was repeated three times according to a randomized block design. As a result of the study, plant height, stem diameter, dry matter content, relative leaf water content, and chlorophyll value measured by SPAD were determined. The results showed that salinity stress significantly reduced growth and yield parameters compared to the control group. However, nano-silver applications partially mitigated the negative effects of salinity by improving chlorophyll content, increasing shoot growth, and enhancing biomass accumulation. The highest improvement was observed under the 60-ppm nano-silver application; plants treated with nano-silver showed higher tolerance compared to untreated plants. These findings suggest that nano-silver application may be an effective strategy to increase salt stress tolerance and maintain tomato productivity under saline conditions.

Keywords: Abiotic Stress, LRWC, Nano fertilizer, SPAD

INTRODUCTİON

Salinity is one of the major abiotic stress factors limiting plant growth and agricultural productivity worldwide. Excessive salt accumulation in soil affects more than 20% of irrigated land and continues to spread due to unsustainable irrigation practices, climate change, and soil degradation (Chele et al., 2021). High salinity levels cause osmotic and ionic imbalances in plants, leading to physiological disorders such as reduced water uptake, nutrient deficiency, and oxidative stress. These effects ultimately inhibit photosynthesis, biomass accumulation, and crop yield (Munns & Tester, 2008).

Tomatoes (*Solanum lycopersicum* L.) are a globally significant vegetable crop with high economic value and hold an important position among vegetables. Demand for tomatoes is steadily increasing due to their nutritional value: they are rich in carotenoids, fiber, vitamins, and minerals (Amr and Raie 2022). Additionally, tomatoes are a rich source of total antioxidants, which offer health benefits including reducing the risk of cancer and heart disease (Borguini et al. 2009; Erdinc et al. 2018; Sun and Shahrajabian 2023). According to the Food and Agriculture Organization, approximately 186.1 million tons of tomatoes were produced on about 5 million hectares worldwide in 2022 (FAO 2024). On the other hand, tomatoes are quite sensitive to salt stress. Even moderate salinity can significantly reduce the plant's vegetative growth, chlorophyll content, and fruit production (Cuartero & Fernández-Muñoz, 1998; Rosça et al., 2021). Therefore, developing effective and sustainable strategies to mitigate the harmful effects of salinity on tomato plants has become an important research topic.

Nanotechnology has recently emerged as a promising approach in agriculture due to its potential to enhance plant growth and stress tolerance. Nano fertilizers are defined as nanometer-scale materials in nanoparticle form, typically containing macro and micro nutrients that are delivered to plants in a controlled manner. Nanofertilizers can improve nutrient uptake, stimulate physiological processes, and protect plants from environmental stress factors (Zehra et al., 2021). Among various nanoparticles, silver nanoparticles (AgNPs) have attracted attention for their multifunctional roles in plant systems, including increased antioxidant activity, improved water retention capacity, and regulation of photosynthetic efficiency (Kale et al., 2021; Khan et al., 2023). Studies have reported that nano-silver can mitigate salt-induced damage by maintaining cell membrane stability and improving chlorophyll content and relative leaf water content (Al Salama et al., 2025). Nano fertilizers are defined as nanometer-scale materials in nanoparticle form, typically containing macro and micro nutrients that are delivered to plants in a controlled manner.

However, there is insufficient research on the effects of nano silver on tomato seedlings under saline conditions and its effectiveness in reducing stress. Therefore, this study aimed to evaluate the effects of different nano silver concentrations on the growth and physiological parameters of tomato seedlings grown under salt stress. The findings of this research may contribute to the development of new and sustainable strategies to improve salt tolerance and maintain tomato productivity in saline environments.

MATERIAL AND METHODS

Material

A standard tomato variety (Bursa seed) was used in the study. The AgNPs were obtained from Nanografi Nano Technology commercial firm. The particle size ranged from 28-48 nm and it have 99.9% purity. Tomato seeds were grown in trays containing a 2:1 mixture of peat and perlite until they developed 3-4 true leaves. The seedlings were then transplanted into 3-liter pots containing peat and perlite, with 4 plants per pot. The study was conducted under climate chamber conditions.

Experimental design

The study involved the application of three doses of nano silver (AgNP0: 0 ppm, control; AgNP1: 30 ppm; AgNP2: 60 ppm) and two doses of saline irrigation water (S0: 0.8 dS/m tap water, control; S1: 3.6 dS/m). Nano silver was applied twice using the root and foliar spray method. Salt applications began when the plants reached five true leaves. The experiment was set up according to a randomized block design with three replications.

Determination of growth parameters

Two plants were selected from each pot, and their height was measured using a ruler. The stem diameter of the same plants was determined using calipers.

Measurement of chlorophyll content (SPAD)

Six leaves were selected from each replicate and chlorophyll content was measured as SPAD (chlorophyll content index per unit leaf area). SPAD readings were determined using a chlorophyll meter (SPAD-502, Minolta, Osaka, Japan). Three readings were taken for each leaf at the midpoint of the leaf between the midrib and the leaf margin, and the average of the values was recorded.

Determination of leaf relative water content (LRWC)

To determine the relative water content (LRWC) of the leaves, leaf discs with a diameter of 10 mm were taken before harvest. The leaf discs were carefully weighed using a precision balance, and the recorded weight was referred to as the leaf fresh weight (LFW). The same samples were immersed in distilled water for 4 hours. After the immersion process, the same samples were weighed to determine the leaf turgor weight (LTW). The samples were then dried in an oven set at 65 °C for approximately 48 hours, and the leaf dry weight (LDW) was obtained. LRWC was calculated using the following equation described by Mullan and Pietragalla (2012):

$$LRWC(\%) = 100 * \frac{\mathrm{LFW-LDW}}{\mathrm{LTW-LDW}}$$

Dry matter content

For fresh weights leaves weighed to obtain fresh weight (FW). Subsequently, the same leaf samples were dried in an oven at 65°C for 48 hours, after which they were weighed again to obtain the dry weight (DW). The dry matter ratio (DMR) was determined according to the following formula

DMC (%) =100*(FW-DW)/FW

Statical analysis

All multivariate analyses were performed with IBM SPSS Statistics version 21.0. One-way analysis of variance (One-way ANOVA) was used for data comparison and Duncan's multiple comparison test (0.05% probability) was used to determine differences between groups.

RESULT

Nano silver applications at different doses positively affected plant height, with the highest value determined at 60 ppm nano silver application (Figure 1-A). However, this effect was not considered significant. On the other hand, the S1 salinity application also reduced plant height compared to the control (S0) application. The interaction between the applications in terms of plant height was not found to be statistically significant. Similarly, the stem diameter increased due to the effect of nano silver applications, with the highest value determined at 60 ppm nano silver application (AgNP2). The AgNP2 application increased plant height by approximately 6% compared to the control (AgNP0) application. However, this increase was not considered

significant. The salinity application had a negative effect on the stem diameter. No significant interaction was detected between the applications in terms of stem diameter.

Similarly, the stem diameter increased due to the effect of nano silver applications, with the highest value determined at 60 ppm nano silver application (Figure 1-B). The AgNP2 application increased the stem diameter by approximately 4% compared to the control. However, this increase was not considered significant. The salinity application had a negative effect on the stem diameter. No significant interaction was observed between the applications in terms of stem diameter.

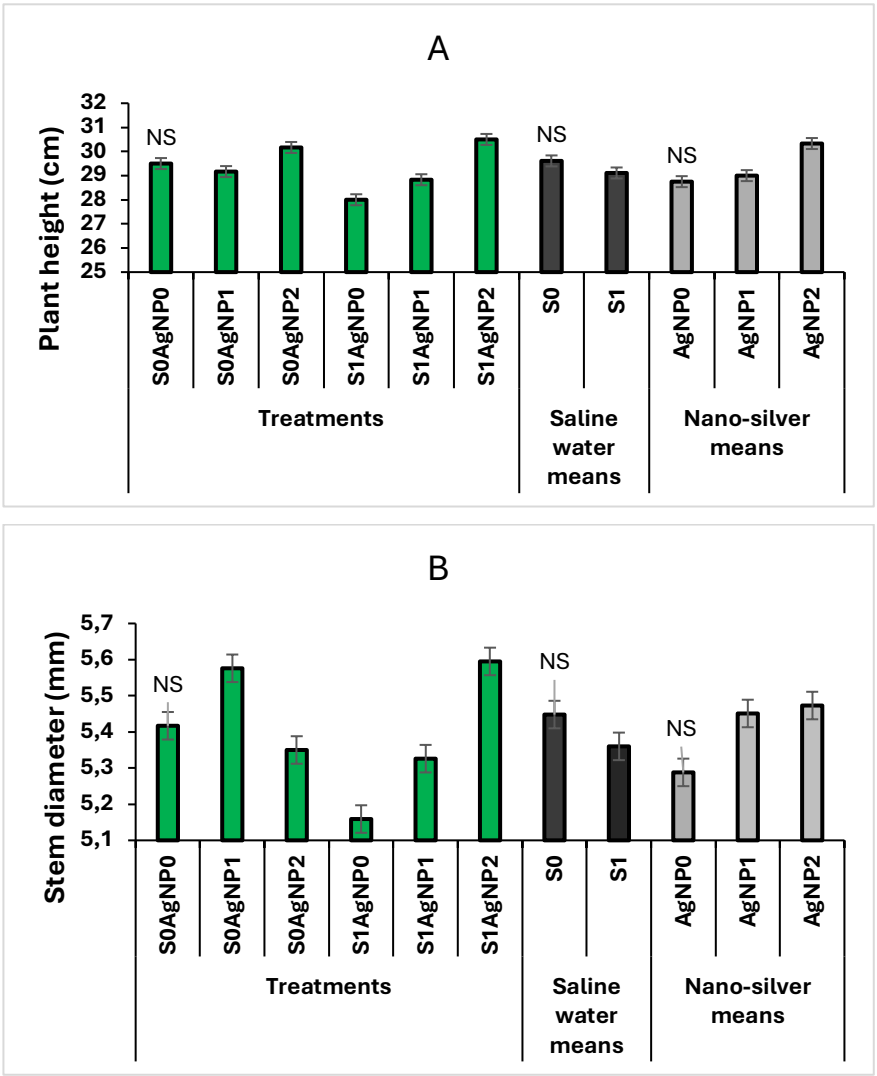


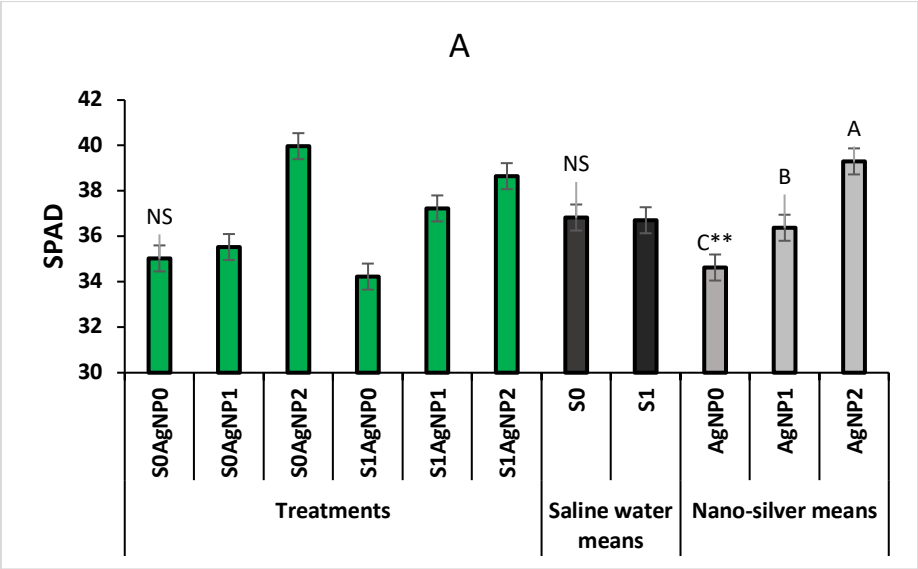
Figure 1. Effect of nano-silver treatments to plant height (A) and stem diameter (B) under saline water application. AgNP0: 0 ppm, AgNP1: 30 ppm, and AgNP2: 60 ppm nano silver treatment. S0: tap water, 0.8 dS/m; S1: 3.6 dS/m saline water application. NS: Not significant.

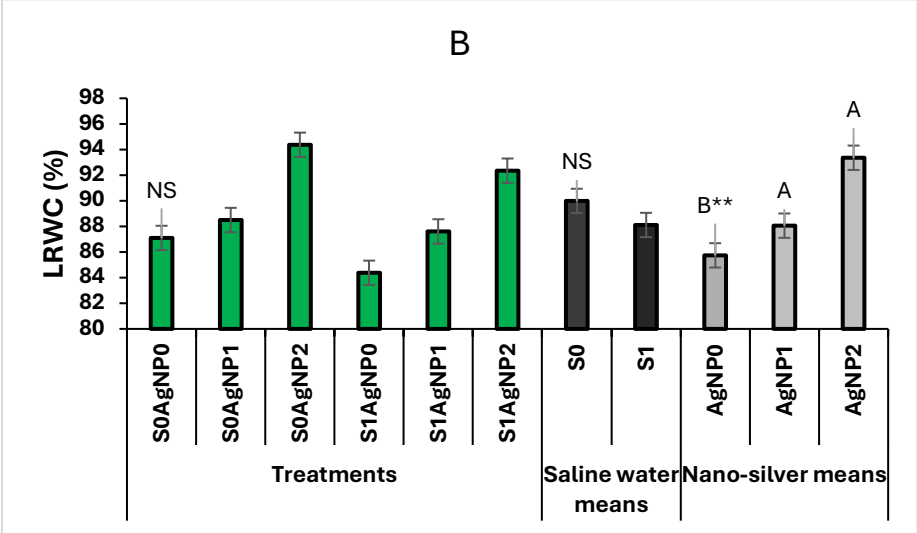
Nano silver applications significantly ($p<0.01$) increased the SPAD value in tomato leaves. The 60-ppm nano silver application increased the SPAD value by approximately 14% compared to the control, while the 30-ppm nano silver application increased it by approximately 5%. No significant effect of the salinity treatment on the SPAD value was determined (Figure 1-A).

Similarly, the leaf relative water content (LRWC) value increased progressively subject to the nano silver applications ($p<0.01$). The highest nano silver application (60-ppm) increased the relative water content of leaves by approximately 9% compared to the control, while the 30-

ppm nano silver application increased it by approximately 3%. Conversely, the saltwater application reduced the relative water content of leaves, but this effect was not considered significant (Figure 2-B).

The effect of saline water and nano silver applications on the dry matter content of leaves is shown in Figure 2-C. Leaf dry matter content progressively increased with nano silver applications. The 60-ppm nano silver application increased the dry matter content by approximately 15%, while the 30-ppm nano silver application increased the dry matter content by approximately 9%. On the other hand, the saline irrigation application reduced it by approximately 4% compared to the control, but this reduction was not statistically significant.





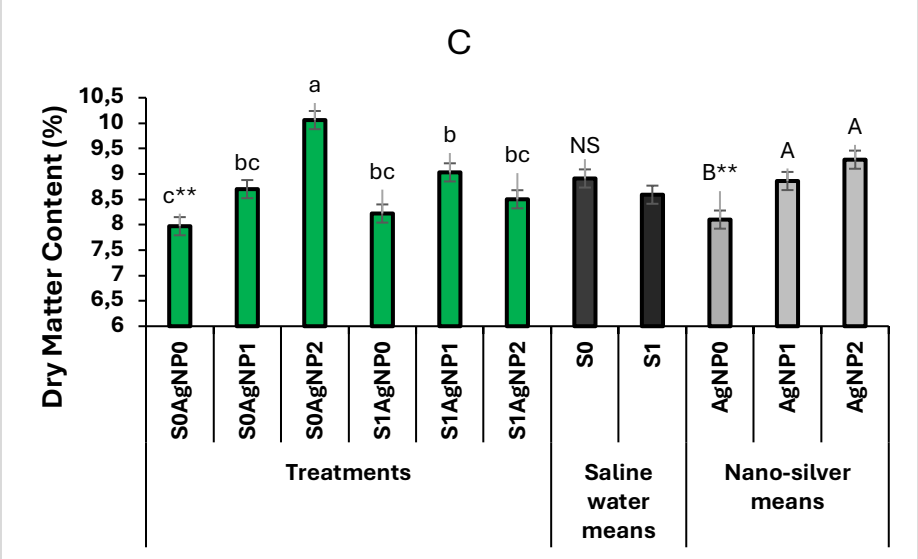


Figure 2. Effect of nano-silver treatments to SPAD (A), leaf relative water content (B) and dry matter content (C) under saline water application. LRWC: Leaf relative water content. AgNP0: 0 ppm, AgNP1: 30 ppm, and AgNP2: 60 ppm nano silver treatment. S0: tap water, 0.8 dS/m; S1: 3.6 dS/m saline water application. **:P<0.01¸ NS: Not significant.

DISCUSSION

The results indicate that nano silver (AgNPs) applications tend to improve plant height and stem diameter, but these increases are not statistically significant. This trend suggests that AgNPs may have a promoting effect on vegetative growth, possibly by increasing nutrient uptake and activating enzymatic activities involved in cell elongation and division (Kaveh et al., 2013; Almutairi, 2016).

Similar insignificant increases in plant height and stem diameter at low to moderate AgNPs doses have also been reported in tomato (*Solanum lycopersicum* L.) and wheat (Triticum aestivum L.) plants due to improved chlorophyll synthesis and water status (Rastogi et al., 2017; Mishra et al., 2025). Furthermore, it has been reported that nano silver applications promote growth and development under stress conditions in radish plants (Çakmakci et al., 2022). However, the lack of statistical significance in the current study may be related to the concentration-dependent effects of AgNPs, as high concentrations may cause oxidative stress and growth inhibition (Nair and Chung, 2014).

The positive effect of AgNP on chlorophyll synthesis or chloroplast stability in tomato leaves is indicated by the significant increase in SPAD values observed after AgNP application. This increase can be attributed to improvements in photosynthetic pigment biosynthesis and protection of chlorophyll molecules from oxidative degradation provided by AgNPs (Rastogi et al., 2017; Almutairi, 2016). Similar findings have been reported by Akhoundnejad et al. (2023), who observed an increase in SPAD values and improved photosynthetic performance in tomato plants treated with AgNPs. The stimulatory effects of nano-silver are generally associated with its role in enhancing enzymatic activity and nutrient uptake efficiency, particularly the uptake of nitrogen and magnesium, which are essential for chlorophyll formation (Nair and Chung, 2014; Afridi et al., 2023).

The progressive increase in leaf relative water content (LRWC) with increasing AgNP concentrations indicates that nano silver improves the plant's water status, possibly by enhancing root hydraulic conductivity or osmolite regulation. AgNPs have been reported to promote aquaporin expression and maintain cell membrane integrity under stress conditions,

thereby improving water retention capacity (Jalil et al., 2019; Elkelish et al., 2025). Although salinity slightly reduced LRWC, this effect was not statistically significant, suggesting that the tested salinity level was moderate and was partially mitigated by the protective effect of AgNPs.

Likewise, the increase in leaf dry matter content observed with nano silver applications reflects increased assimilation accumulation and metabolic activity. AgNPs can promote carbon fixation and biomass production by increasing photosynthetic efficiency and reducing cellular damage caused by reactive oxygen species (ROS) (Singh et al., 2021; Nair and Chung, 2014). In contrast, the slight but insignificant decrease in dry matter content observed under saline irrigation is consistent with the well-documented inhibitory effects of salinity on photosynthesis and carbohydrate metabolism, primarily due to osmotic stress and ionic toxicity (Munns & Tester, 2008; Acosta-Motos et al., 2017). Overall findings suggest that nano silver, particularly at 60 ppm, may enhance physiological performance and water balance in tomato plants and potentially increase tolerance to moderate salt stress.

CONCLUSION

The findings of this study indicate that nano silver (AgNP) applications generally have a positive effect on the physiological performance of tomato plants, particularly by increasing chlorophyll content (SPAD), leaf relative water content (LRWC), and dry matter accumulation. Although increases in plant height and stem diameter were not statistically significant, the general trends suggest that AgNPs may promote vegetative growth and enhance the plant's water relations and photosynthetic efficiency. Furthermore, a 60 ppm AgNP concentration appears to be the most effective dose that provides better growth responses without causing toxicity. The findings also suggest that AgNPs can partially mitigate the adverse effects of moderate salinity and support previous evidence of their protective role under abiotic stress conditions. In conclusion, the application of nano silver at optimal concentrations can be considered a promising approach to enhance the physiological resistance of plants and maintain productivity under saline conditions. Further studies are recommended to investigate the long-term effects of AgNPs, their mechanisms of action, and optimal dosages in different plant species and environmental conditions.

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HAYVANCILIKTA MEVCUT DURUM VE YENİ DESTEKLEME MODELİ

Ahmet ÖZDEN

Tarım ve Orman Bakanlığı, Ankara İl Tarım ve Orman Müdürlüğü, Ankara/Türkiye

Email: ozden.ahmet@tarimorman.gov.tr

ORCID: 0009-0009-6429-5833

Prof. Dr. Yusuf CUFADAR

Selçuk Üniversitesi, Ziraat Fakültesi, Zootekni Bölümü, Konya/Türkiye

Email: ycufadar@selcuk.edu.tr

ORCID: 0000-0001-9606-791X

ÖZET

Türkiye, köklü tarım geleneği ve zengin coğrafi yapısıyla hayvancılık açısından büyük bir potansiyele sahip ülkelerden biridir. Hayvancılık sektörü yalnızca ülkenin hayvansal gıda ihtiyacının karşılamakla kalmayıp, kırsal kesimde istihdam yaratması ve tarıma dayalı sanayinin desteklenmesi bakımından da stratejik bir öneme sahiptir. Türkiye'de büyükbaş ve küçükbaş hayvan varlığında son yıllarda bazı gerilemeler yaşanmış olsa da son on yıllık süreçte genel olarak artış gözlemlenmiştir. Büyükbaş hayvan varlığı, 2014 yılında 14,3 milyon baş iken yıllar içerisinde artış göstererek 2024 yılında 16,9 milyon başa ulaşmıştır. Manda varlığı, 2014 yılında 122,1 bin baş seviyesindeyken 2024 yılında 162 bin başa yükselmiştir. Küçükbaş hayvancılıkta da benzer bir artış gözlenmiştir. 2014 yılında 41,5 milyon baş olan küçükbaş hayvan varlığı, 2024 yılında 54,9 milyon başa ulaşmıştır. Keçi varlığı ise 2014 yılında 10,4 milyon baş iken, 2024 yılında 10,8 milyon baş olarak gerçekleşmiştir. Kanatlı hayvancılık sektörü, iç tüketimin yanı sıra ihracata yönelik üretim modeliyle gelişimini sürdürmektedir. Modern kümes ve entegre tesisleri her geçen gün artmaktadır. 2014 yılında 1,9 milyon ton olan tavuk eti üretimi 2024 yılında 2,5 milyon tona, 48,7 bin ton olan hindi eti üretimi 2024 yılında 52,3 bin tona, 17,1 milyar adet olan tavuk yumurtası üretimi 2024 yılında 21,2 milyar adete yükselmiştir.

Türkiye'de hayvancılık sektörü, tarımsal üretimin sürdürülebilirliği ve kırsal kalkınmanın desteklenmesi açısından kritik bir role sahiptir. Bu doğrultuda Tarım ve Orman Bakanlığı, gıda arz güvenliğini sağlamak, verimliliği artırmak ve sürdürülebilir bir üretim modeli oluşturmak amacıyla çeşitli hayvancılık destekleme programları yürütmektedir. En güncel hayvancılık destekleme modeli, 2024-2026 dönemini kapsamakta olup, 26 Temmuz 2024 tarihli ve 32613 sayılı Resmî Gazete' de yayımlanan Cumhurbaşkanlığı Kararı (Karar Sayısı: 8760) ile yürürlüğe girmiştir. Bu yeni model, önceki yıllardan farklı olarak üretim planlamasına ve performansa dayalı bir sistem üzerine kurgulanmıştır. Destekler, iki ana başlık altında toplanmaktadır: Temel Hayvancılık Destekleri: Büyükbaş ve küçükbaş hayvancılık, arıcılık ve ipek böceği yetiştiriciliğini kapsamaktadır. Ürün Geliştirme Destekleri: Çiğ süt, besilik erkek sığır (karkas) ve tiftik üretimine yönelik destekleri içermektedir. Bu sistem ile üretimin daha verimli, planlı ve sürdürülebilir şekilde yürütülmesi hedeflenmektedir.

Anahtar Kelimeler: Tarım, hayvancılık, hayvancılık destekleri, verimlilik, destekleme modeli

CURRENT SITUATION IN LIVESTOCK AND NEW SUPPORT MODEL

ABSTRACT

Türkiye, with its deep-rooted agricultural tradition and rich geographical structure, is one of the countries with great potential for animal husbandry. The livestock sector not only meets the country's animal food needs but also holds strategic importance in creating employment in rural areas and supporting agriculture-based industries. While Türkiye has experienced some declines in the number of cattle and small ruminants in recent years, a general increase has been observed over the last decade. While cattle numbers were 14.3 million in 2014, they have increased over the years, reaching 16.9 million in 2024. Buffalo numbers rose from 122.1 million in 2014 to 162,000 in 2024. A similar increase has been observed in small ruminants. Small ruminants, which stood at 41.5 million in 2014, reached 54.9 million in 2024. While the number of goats was 10.4 million in 2014, it was 10.8 million in 2024.

The poultry sector continues to develop with a production model geared towards both domestic consumption and export. Modern poultry houses and integrated facilities are increasing daily. Chicken meat production rose from 1.9 million tons in 2014 to 2.5 million tons in 2024, Türkiye meat production from 48.7 thousand tons to 52.3 thousand tons in 2024, and chicken egg production from 17.1 billion to 21.2 billion in 2024.The livestock sector in Türkiye plays a critical role in ensuring the sustainability of agricultural production and supporting rural development. To this end, the Ministry of Agriculture and Forestry implements various livestock support programs to ensure food supply security, increase productivity, and establish a sustainable production model.

The most current livestock support model covers the 2024-2026 period and entered into force with Presidential Decree (Decree No. 8760) published in the Official Gazette dated July 26, 2024, and numbered 32613. This new model, unlike previous years, is based on a system based on production planning and performance. Supports are categorized under two main headings: Basic Livestock Supports: Covers cattle and sheep farming, beekeeping, and silkworm breeding. Product Development Supports: Includes support for raw milk, beef cattle (carcasses), and mohair production. This system aims to ensure more efficient, planned, and sustainable production.

Keywords: Agriculture, livestock, livestock supports, productivity, support model

1. GİRİŞ

İnsanlığın ilk çağlarından itibaren ve özellikle göçebelik dönemlerinde, yapılan en önemli ekonomik faaliyet hayvancılık olmuştur. Açlık-tokluk, iyi-kötü beslenme gibi insan odaklı konular, günümüz dünya siyasetini de etkilemektedir. Nitekim gelişmiş ülkeler, geri kalmış olan ülkelere teknolojik ürünlerin yanı sıra damızlık materyal, canlı hayvan, tohumluk ve işlenmiş ürünler gibi tarımsal üretim maddelerini de pazarlayarak büyük bir gelir sağlamakta ve bu şekilde, özellikle tarımsal ürün ticareti yaptıkları ülkeler üzerindeki etkinliklerini artırmaktadırlar (TİGEM 2023).

Hayvancılık sektörü gelişmişlik seviyesine bakılmaksızın tüm ülkeler için büyük önem taşımaktadır (Saçlı, 2007). Hayvancılık hayvanların verimlerinden yararlanılan ve daha kısa sürede daha fazla verim sağlamaya yönelik bir zirai faaliyettir (Aydemir ve Pıçak, 2007).

Türkiye'de hayvancılık sektörü genel ekonomi içerisinde önemli bir yere ve potansiyele sahiptir. Hayvansal üretim faaliyetleri bazı bitkisel ve yan ürünlerin değerlendirilmesi, işgücü verimliliğinin artırılması, işletme karının artması, doğal ve ekonomik koşullardan kaynaklanan risk faktörünün azaltılması vb. faktörler işletmelere olumlu katkılar sağlamaktadır (Turan ve ark., 2017; Vural ve Fidan, 2007). Türkiye sahip olduğu doğal kaynaklar ve ekolojik koşullar dikkate alındığında, büyükbaş ve küçükbaş hayvan yetiştiriciliği bakımından elverişli şartlara sahiptir. İşletmelerin başarısında; kullanılan hayvan materyalinin ırkı, yaşı ve verim düzeyi belirleyici bir role sahiptir. Hayvan materyali ve yönetim kalitesi sonucunda ortaya konulan faaliyet birimlerinin üretim değeri ve işletmenin tarımsal geliri önemli ekonomik başarı ölçütlerindendir (Turan ve ark., 2017).

Türkiye'nin ekonomisinde hayvancılık, tarım sektörü ve genel ekonomi içerisinde önemli bir yer tutmaktadır. Hayvancılık sektörü, ülkenin milli gelirine ve istihdamına katkı sağlamaktadır. Bunların yanında hayvancılık, et, süt, tekstil, deri, kozmetik, ilaç gibi sanayi kollarına hammadde sağlamakta, yem sanayi, et sanayi gibi dallarda istihdam oluşturulması ve ürünlerin işlenmesi sonucunda ekonomide önemli katma değer oluşturmaktadır (Tapkı ve ark., 2018). 2023 yılına göre tarım, ormancılık ve balıkçılık sektörünün Türkiye GSYİH içindeki payı % 6,2'dir. (SGB 2025)

Bir ülkede tarım sektörünün kalkınması o ülkenin ekonomik gelişmişliğiyle ilgilidir. Dünya ülkeleri dikkate alındığında, gelişmiş ülkelerde tarım, gelişmekte olan ülkelere göre daha fazla desteklenmektedir. Bunun nedeni, stratejik öneme sahip olan tarım sektörünü desteklemede bu ülkelerin ekonomik güce sahip olmalarıdır (Yavuz, 2000). Gelişmiş ülkelerde tarımsal ekonominin lokomotifi olan hayvancılık, iki açıdan son derece önemlidir. Birincisi çok düşük maliyetli istihdam yaratması ve ikincisi ise kalitesiz veya insan beslenmesine uygun olmayan yem kaynaklarının kaliteli insan gıdasına dönüştürmesidir. (Ergün ve Bayram, 2021)

Türkiye'de 2024 yılı hayvancılık destekleme kararnamesi ile hayvansal üretim destekleri temel hayvancılık destekleri ve ürün geliştirme destekleri olmak üzere iki gruba ayrılmıştır: Temel hayvancılık destekleri, büyükbaş hayvancılık, küçükbaş hayvancılık, arıcılık ve ipek böcekçiliği faaliyetlerini, Ürün Geliştirme Destekleri; çiğ süt, besilik erkek sığır (karkas) ve tiftik üretimini kapsamaktadır. Her bir destek için temel destek tutarı belirlenmiştir. 2024 yılı için belirlenen temel destek tutarları, buzağı ve malaklar için 1.000 TL/baş, kuzu ve oğlaklar için 200 TL/baş, arıcılık için üretici/yetiştirici örgütlerine üye üreticilere 100 TL/kovan, üye olmayanlara 80 TL/kovan, ipekböceği için 1.000 TL/kg, besilik erkek sığır (karkas) için 500 TL/baş ve tiftik üretimi için 80 TL/kg'dır. Temel destek birim tutarları ve katsayılar her yıl yeniden belirlenecektir. Yönlendiricilik ve özendiricilik ilkelerini yerine getiren üretici ve yetiştiriciler ilave destekten yararlanacaktır. Aile işletmelerine, kadın/genç yetiştiriciler ile birinci derece tarımsal amaçlı örgütlerin üyelerine/ortaklarına, üretim planlaması kapsamında süt ve besi havzası olarak belirlenen illerde bulunan yetiştiricilere, hastalıktan ari işletmelere,

AB onaylı süt çiftliği sertifikasına sahip işletmelere, suni tohumlama, soy kütüğü, sütünü kendi tankında soğutma, karkas ağırlığı gibi ölçütleri sağlayan yetiştiricilere temel destekle birlikte ilave destek verilecektir. Küçükbaş destekleri ilk defa kuzu ve oğlaklar için ödenecektir. (TRGM 2025)

2. TÜRKİYE'DE HAYVANCILIK FAALİYETLERİ

2.1. BÜYÜKBAŞ HAYVANCILIK

Türkiye büyükbaş hayvan varlığının tamamına yakını sığırdan oluşturmaktadır. Sığırların süt veriminin yüksek olması, laktasyon süresinin uzun olması neticesinde yıl boyunca süt üretimi sağlaması, kaba ve kesif yemleri et ve süte dönüştürme yeteneklerinin yüksek olması, ülkemizin farklı iklim kuşaklarında yetiştirilme imkanının bulunması, genetik ıslah ve üremenin denetimine yönelik uygulamalara çok iyi uyum göstermesi gibi başlıca avantajlar, sığırcılığı büyükbaş hayvancılık içinde önemli kılmaktadır (Ergün ve Bayram, 2021).

Türkiye büyükbaş hayvan varlığında son on yıllık verilere bakıldığında 2014 yılında 14,3 milyon baş olan toplam büyükbaş hayvan varlığı 2024 yılında 16,9 milyon başa ulaşmış olsa da 2020 yılı göz önüne alındığında 1 milyon başın üzerinde bir düşüş göze çarpmaktadır.

Tablo 1. Büyükbaş Hayvan Varlığı (baş) (TÜİK)

Yılı	Sığır - Kültür	Sığır – Kültür Melezi	Sığır - Yerli	Manda	Toplam
2014	6.178.757	6.060.937	1.983.415	122.114	14.345.223
2015	6.385.343	5.733.803	1.874.925	133.766	14.127.837
2019	8.559.855	7.554.625	1.573.659	184.192	17.872.331
2020	8.838.498	7.594.127	1.532.857	192.489	18.157.971
2021	8.824.784	7.641.100	1.384.659	185.574	18.036.117
2022	8.295.825	7.324.866	1.231.265	171.835	17.023.791
2023	8.070.159	7.303.667	1.047.430	161.749	16.583.005
2024	8.213.136	7.669.922	941.150	162.051	16.986.259

2.2. KÜÇÜKBAŞ HAYVANCILIK

Küçükbaş hayvan varlığına ilişkin son on yıllık veriler incelendiğin de 2014 yılında 41,5 milyon baş olan küçükbaş hayvan varlığı 2024 yılında %32'lik bir artış göstermiş olsa da 2021 yılında ulaşılan 57,5 milyona ulaşan toplam hayvan varlığının gerisinde bulunmaktadır. Kıl keçisi ve tiftik keçisi varlıklarında son on yılda belirgin bir artış meydana gelmemiş iken yerli koyun ve merinos ırkı koyun varlığında yaşanan artış dikkat çekmektedir.

Tablo 2. Küçükbaş Hayvan Varlığı (baş) (TÜİK)

Yılı	Koyun - Yerli	Koyun - Merinos	Keçi - Kıl	Keçi - Tiftik	Toplam
2014	29.033.981	2.106.263	10.167.125	177.811	41.485.180
2015	29.302.358	2.205.576	10.210.338	205.828	41.924.100

2019	34.199.467	3.076.583	10.964.374	241.055	48.481.479
2020	38.579.748	3.547.033	11.698.825	287.020	54.112.626
2021	41.182.899	3.994.791	12.051.957	289.557	57.519.204
2022	40.728.954	3.958.934	11.320.208	257.654	56.265.750
2023	38.208.635	3.851.835	10.092.756	210.184	52.363.410
2024	39.871.852	4.208.732	10.619.841	202.243	54.902.668

2.3. ÇİĞ SÜT ÜRETİMİ

TÜİK tarafından revize edilerek son beş yıllık verilerin bulunduğu çiğ süt üretimi verileri incelendiğinde 2020 yılında inek sütünün toplam çiğ süt üretimindeki payı %92,5 iken 2024 yılında bu oran %93,5 oranına yükselmiştir. Toplam üretim 2020 yılında 23,5 milyon ton iken 2024 yılında 22,5 milyon tona gerilemiştir. Bu gerileme hızı manda, koyun ve keçi sütünde daha fazla gerçekleşmiştir.

Tablo 3. Çiğ Süt Üretimi (ton) (TÜİK)

Yıl	İnek	Manda	Koyun	Keçi	Toplam
2020	21.749.342	63.767	1.101.065	589.617	23.503.790
2021	21.370.116	63.643	1.143.762	622.785	23.200.306
2022	19.912.135	43.589	1.067.342	540.426	21.563.492
2023	19.961.908	43.025	933.576	543.058	21.481.567
2024	21.040.442	58.122	906.945	482.247	22.487.757

2.4. KIRMIZI ET ÜRETİMİ

Türkiye'de kırmızı et üretimi 2024 yılında on yıl öncesine göre %87,5 oranında artış göstermiştir. 2020 yılı sonrasında Kasaplık Güç Oranı (KGO) yöntemi kullanılarak ve2020 yılı öncesi veriler revize edilerek hesaplanan verilerdeki artış oranı dikkat çekicidir. Aynı zamanda 2014 yılında %72 oranında olan toplam üretimde sığır eti oranı 2024 yılında %70 sevilerinde gerçekleşmiştir. Sırasıyla Manda, koyun ve keçi etinin oranları %0,65, %24,2 ve %4,73 olmuştur.

Tablo 4. Kırmızı Et Üretimi (ton) (TÜİK)

Yılı	Sığır	Manda	Koyun	Keçi	Toplam
2014(r)	815.674	5.004	238.670	63.711	1.123.059
2015(r)	862.098	5.300	249.863	69.757	1.187.018
2019(r)	1.330.169	7.150	316.170	87.126	1.740.616
2020	1.341.446	8.424	345.639	90.443	1.785.952
2021	1.460.719	10.831	385.933	94.555	1.952.038

2022	1.572.747	13.586	489.354	115.938	2.191.625
2023	1.670.606	15.386	569.066	128.989	2.384.047
2024	1.483.042	13.781	509.539	99.532	2.105.895

(r) Revize edilmiştir. Kırmızı et üretim istatistiklerinde 2020 yılında metodoloji değişikliğine gidilmiş ve "Kasaplık Güç Oranı (KGO) " yöntemi kullanılmıştır. 2001-2019 dönemi kırmızı et üretim istatistikleri KGO yöntemine göre revize edilmiştir.

2.5. KANATLI HAYVAN SEKTÖRÜ

Tavuk ve hindi üretimine bakıldığında son on yılda %32'lik artış gerçekleştirerek 2,56 milyon ton olmuş, sektörün yıllar itibari ile orantılı bir büyüme gerçekleştirdiği görülmektedir. Hindi eti üretimi daha dalgalı bir üretim izlenirken tavuk eti üretimi belirli oranlarda yıllar itibari ile artış göstermiştir. Toplam üretimin %98'lik kısmı tavuk üretiminden gelmektedir. Yumurta üretimi ise son on yılda %23,4 artış gerçekleştirerek 21,5 milyar adet ulaşmıştır. Yumurta üretimi de tavuk etine benzer şekilde dalgalı bir üretim şekli göstermeden yıllar itibari ile düzenli olarak artmıştır. Sektörün iç tüketim ve ihracat odaklı gerçekleştirdiği üretimi son on yılda düzenli büyüme ile gerçekleştirdiği görülmektedir.

Tablo 5. Tavuk ve Hindi Eti Üretimi (ton) (TÜİK)

Yılı	Tavuk Eti	Hindi Eti	Toplam Et
2014	1.894.669	48.662	1.943.331
2015	1.909.276	52.722	1.961.999
2019	2.138.451	59.640	2.198.090
2020	2.136.263	58.212	2.194.475
2021	2.245.770	51.301	2.297.071
2022	2.417.995	53.646	2.471.641
2023	2.328.791	47.575	2.376.366
2024	2.512.131	52.355	2.564.486

Tablo 6. Tavuk Yumurtası (bin adet) (TÜİK)

Yılı	Tavuk Yumurtası
2014	17.145.389
2015	16.727.510
2019	19.898.126
2020	19.788.063
2021	19.297.591
2022	19.808.539
2023	20.637.732

2024	21.155.089

3. 2024-2026 YILLARI HAYVANCILIK DESTEKLEME MODELİ

Türkiye'de hayvancılık sektörü, tarımsal üretimin sürdürülebilirliği ve kırsal kalkınmanın desteklenmesi açısından kritik bir role sahiptir. Bu doğrultuda Tarım ve Orman Bakanlığı, gıda arz güvenliğini sağlamak, verimliliği artırmak ve sürdürülebilir bir üretim modeli oluşturmak amacıyla çeşitli hayvancılık destekleme programları yürütmektedir. En güncel hayvancılık destekleme modeli, 2024-2026 dönemini kapsamakta olup, 26 Temmuz 2024 tarihli Cumhurbaşkanlığı Kararı ile yürürlüğe girmiştir.

Hayvansal üretimde yeni destekleme programı temel hayvancılık ve ürün geliştirme destekleri olmak üzere iki gruba ayrılıyor.

Temel hayvancılık destekleri; büyükbaş hayvancılık, küçükbaş hayvancılık, arıcılık ve ipek böceği faaliyetlerinin desteklenmesinden oluşuyor. Her bir destek için temel destek tutarı belirlendi. Aile işletmeleri, genç ve kadınlar, birinci derece örgüt üyesi ile planlama bölgeleri gibi yönlendirici kriterleri sağlayan yetiştiricilere temel destek tutarına ilave destek verilecek. Ayrıca suni tohumlama, soy kütüğü, yerli sperma, ari işletme, sürü yöneticisi (çoban) gibi verimlilik kriterlerine ilave destek sağlanacak.

Ürün geliştirme destekleri başlığı da; çiğ süt, besilik erkek sığır (karkas), tiftik üretimi desteklerini kapsıyor. Her bir destek için temel destek tutarı belirlendi. Aile işletmeleri, genç ve kadınlar, birinci derece örgüt üyesi ile planlama bölgeleri gibi yönlendirici kriterleri sağlayan üreticilere temel destek tutarına ilave destek verilecek. Ayrıca ari işletme, kendi tankında soğutma, örgüt üzerinden pazarlama, karkas ağırlığı, kaliteli tiftik ve sözleşmeli üretim gibi verimlilik kriterlerine ilave destek verilecek. (TOB 2025)

Tablo 7. 2025 Yılı Temel Hayvancılık Desteklemeleri (Resmi Gazete 26.07.2024-14.09.2025)

Kategori	**Destekleme Türü**		**Katsayı**	**2025 Yılı Destek Tutarı (TL/Baş)**
Büyükbaş Hayvancılık Destekleri (1-500 Baş)	Buzağı-Malak Temel Desteği	Temel Destek	1	1.400/2.800
	Aile İşletmesi	Yönlendirici Kriterler	1	1.400
	Genç veya Kadın Yetiştirici		0,7	980
	Planlı Üretim		0,5	700
	Birinci Derece Örgüt Desteği		0,2	280
	Suni Tohumlama/Embriyo T.	Verimlilik Kriterleri	0,8	1.120
	Yerli Sperma		0,5	700
	Soy Kütüğü (A ve B İşletmeleri) ve Genomik		1,5	2.100
	Soy Kütüğü (C İşletmeleri)		0,8	1.120
	Ari İşletme		4	5.600
	Onaylı Süt İşletmesi		0,6	840
	Kuzu ve Oğlak Temel Desteği	Temel Destek	1	300

Küçükbaş Hayvancılık Destekleri	Aile İşletmesi (Dişi Kuzu/Dişi Erkek Oğlak)	Yönlendirici Kriterler	1	300
	Genç veya Kadın Yetiştirici (Dişi Kuzu/Dişi Erkek Oğlak)		0,7	210
	Birinci Derece Örgüt Desteği		0,2	60
	Sürü Yöneticisi (150 baş)	Verimlilik Kriterleri	1,8	540
Arılı Kovan Desteği	Temel Destek (Kovan Başı)	Temel Destek	1	100/140 TL/Adet
	Genç veya Kadın Yetiştirici	Yönlendirici Kriterler	0,4	40/56TL/Adet
	Planlı Üretim		0,3	30/42TL/Adet
	Birinci Derece Örgüt Desteği		0,2	28 TL/Adet
İpek Böceği Desteği	Temel Destek (kg başı)	Temel Destek	1	1.100
	Genç veya Kadın Yetiştirici	Yönlendirici Kriterler	0,4	440

Tablo 8. Ürün Geliştirme Destekleri

Kategori	**Destekleme Türü**		**Katsayı**	**Destek Tutarı (TL/Baş/Kg)**
Çiğ Süt Desteği	Temel Çiğ Süt Desteği	Temel Destek	1	Bakanlıkça Belirlenir
	Aile İşletmesi	Yönlendirici Kriterler	0.3	
	Genç veya Kadın Yetiştirici		0.3	
	Planlı Üretim		0.4	
	Kriter (Kendi Tankında Soğutma)	Verimlilik Kriterleri	2	
	Kriter (Birinci Derece Örgüt Üzerinden Pazarlama)		2	
	Kriter (Diğer Örgütler Üzerinden Pazarlama)		1,5	
	Kriter (Hastalıklardan Ari)		3	
	Manda/Koyun Keçi Sütü		0,8	
Besilik Sığır (Karkas) Desteği	Temel Destek (Manda ve Yerli Irklar En Az 200 Kg Karkas)	Temel Destek	1	500
	Aile İşletmesi	Yönlendirici Kriterler	4	2.000
	Genç veya Kadın Yetiştirici		0.3	150
	Birinci Derece Örgüt Desteği		0.4	100

	Sütçü ve Melezleri En Az 270 Kg Karkas	Verimlilik Kriterleri	0,6	300
	Kombine ve Melezler En Az 300 Kg Karkas		0,8	400
	Etçi ve Melezler En Az 300 Kg Karkas		1	500
Tiftik Desteği	Temel Tiftik Desteği	Temel Destek	1	160
	Genç veya Kadın Yetiştirici	Yönlendirici Kriterler	0,3	64
	Anamal Tiftiği	Verimlilik Kriterleri	0,7	112
	Oğlak Tiftiği		0,9	144
	Birinci Derece Örgüt Sözleşmeli Üretim		1	160
	Diğer Örgüt Sözleşmeli Üretim		0.9	144

4. SONUÇ

Son on yıllık mevcut veriler incelendiğinde 2014 yılında 14,3 milyon baş olan büyükbaş hayvan varlığının 2024 yılında 16,9 milyon başa yükseldiği, ancak 2020 yılına göre 1 milyon baş düşüş gerçekleştiği görülmektedir. Benzer şekilde küçükbaş hayvan varlığı 2021 yılında yakaladığı zirveyi koruyamamıştır. Kırmızı et üretimi son on yılda % 87,5 artmış, çiğ süt üretiminin 2020 yılından bu yana artış göstermemiştir. Bu veriler hayvan varlığının hayvansal üretimde tek başına yeterli olmayacağını verimliliğin artmasının hayvansal üretimde kritik rol oynadığını ortaya koymaktadır.

Tarım ve Orman Bakanlığı tarafından 2024-2026 yıllarını kapsayacak şekilde uygulamaya konan destekleme sisteminin performansa dayalı bir yaklaşım sergilemesi önemlidir. Temel desteklemelerin yanında yönlendirici kriterler (aile işletmeleri, genç/kadın yetiştiriciler vb.) verimlilik kriterleri (suni tohumlama, soy kütüğü, karkas ağırlığı vb.) hayvansal üretimde performansa dayalı bir yaklaşım getirildiği görülmektedir.

Sonuç olarak, yeni destekleme modelinin hayvancılık sektörünün geleceği açısından taşıdığı en önemli unsur, birim hayvandan daha fazla ve kaliteli ürün elde edilmesini teşvik etmesidir. Model, sadece sayısal artışları değil, aynı zamanda et, süt ve buzağı gibi hayvansal ürünlerin kalitesini ve miktarını yükseltmeyi hedeflemektedir. Bu yaklaşım, gıda arz güvenliğini sağlamanın yanı sıra, üretici gelirlerini artırarak ve tarıma dayalı sanayilere daha kaliteli hammadde sağlayarak ülkenin ekonomik kalkınmasına önemli katkılar sunacaktır. Dolayısıyla, bu modelin başarılı bir şekilde uygulanması, Türkiye hayvancılığının daha sürdürülebilir, rekabetçi ve planlı bir yapıya kavuşmasında kritik bir dönüm noktası olabilir.

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FARKLI KONSANTRASYONLARDA *Spirulina platensis* VE ANTEP FISTIĞI AROMASI EKLENMİŞ KEFİRLERİN FİKİKOKİMYASAL VE MİKROBİYOLAOJİK ÖZELLİKLERİNİN BELİRLENMESİ

Doç. Dr. Aysel GÜLBANDILAR
Eskişehir Osmangazi Üniversitesi, Ziraat Fakültesi
Email: aysel.gulbandilar@ogu.edu.tr
ORCID: 0000-0001-9075-9923
Öğrenci Barkın KOÇER
Eskişehir Osmangazi Üniversitesi, Ziraat Fakültesi
Email: barkinkocer59@gmail.com
ORCID: 0009-0001-9491-9653
Öğrenci Rumeysa BOZKURT
Eskişehir Osmangazi Üniversitesi, Ziraat Fakültesi
Email: rumeysabozkurt1406@gmail.com
ORCID: 0009-0000-8545-5028
Öğrenci Sıla GÖNÜL
Eskişehir Osmangazi Üniversitesi, Ziraat Fakültesi
Email: silagonul97@gmail.com
ORCID: 0009-0007-8834-5642

ÖZET

Çalışmada; *Spirulina platensis* farklı konsantrasyonlarda (0,50 ve 0,75gr), ticari olarak satışa sunulan Antep fıstığı aroması (1 mL) ve maya (0,25 gr) kullanılmış, pastörize inek sütüne (1lt) ilave edilerek kefir içeceği üretilmiştir. Kefir örneklerinin depolamanın 1. 7. 14. ve 21. günlerinde mikrobiyolojik ve fiziko- kimyasal özellikleri incelenmiştir.

Yapılan analizler sonucunda *S. platensis* ilavesinin konsantrasyon faktörleri ve depolama süresinin, kefirin mikrobiyolojik kalitesi üzerinde istatistiksel olarak anlamlı bir etkiye sahip olduğu belirlenmiştir ($p < 0.05$). Üretilen kefir örneklerinin titrasyon asitliğinde 1. ve 7. günlerde anlamlı farklılık bulunurken ($p<0.05$), 14. ve 21. günlerde, gruplar arasında nihai asitlik değeri açısından istatistiksel bir fark bulunmamıştır. pH değerleri arasında istatistiksel olarak anlamlı bir fark olduğu gözlemlenmiştir ($p<0.05$). Kefirin su aktivitesi, kuru madde miktarı ve kül içeriği üzerinde ise *S. platensis* ilavesinin istatistiksel olarak anlamlı bir etkisinin olmadığı belirlenmiştir ($p > 0.05$). Üretilen kefirin antimikrobiyal aktivite üzerinde etkisi çalışmada yer alan patojen mikroorganizma türüne göre istatistiksel olarak değişkenlik göstermiştir. Toplam fenolik madde içeriği üzerinde ise istatistiksel olarak anlamlı bir etkisinin olmadığı ($p > 0.05$); ancak depolamanın 7. ve 14. günlerinde kefirin fenolik madde içeriğinin istatistiksel olarak anlamlı derecede arttığı gözlenmiş ($p<0.05$), 21 günlük depolama sonunda ise tüm grupların fenolik madde seviyeleri aralarındaki farkın ortadan kalktığı belirlenmiştir ($p>0.05$). Özellikle daha yüksek konsantrasyonda *S. platensis* ilavesinin depolamanın orta dönemlerinde antioksidan kapasiteyi artırdığı, ancak uzun vadede bu etkinin azalabileceği

belirlenmiştir. Kefirin ortalama DPPH radikal süpürme kapasitesi üzerinde ise istatistiksel olarak anlamlı bir etkisi olmamış ($p > 0.05$); 7. günde ise anlamlı bir fark belirlenmiştir ($p<0.05$).

Yapılan çalışmada; yüksek doz (%0.75) *S. platensis* ilavesinin başlangıçta daha belirgin fizikokimyasal ve antimikrobiyal etkiler gösterdiği, düşük doz (%0.50) ilavesinin ise daha uzun süreli mikrobiyolojik stabilite sağladığı belirlenmiştir. Bu bulgular, *S. platensis* ile zenginleştirilmiş kefirin hem doz miktarının hem de depolama süresinin, tüm çalışılan parametrelerde sonuçları etkileyen kritik faktörler olduğunu göstermektedir.

Anahtar Kelimeler: Kefir, İnek Sütü, *Spirulina platensis,* Antep Fıstığı Aroması

DETERMINATION OF THE PHYSICOCHEMICAL AND MICROBIOLOGICAL PROPERTIES OF KEFIRS ENRICHED WITH DIFFERENT CONCENTRATIONS OF *Spirulina platensis* AND PISTACHIO FLAVOR

ABSTRACT

In this study, Spirulina platensis was incorporated into pasteurized cow's milk at varying concentrations (0.50, and 0.75 g), along with commercially available pistachio flavoring (1 mL) and yeast (0.25 g), to produce a kefir beverage. The microbiological and physicochemical properties of the kefir samples were evaluated on the 1st, 7th, 14th, and 21st days of storage.

The results revealed that both the concentration of *Spirulina platensis* and the storage duration had statistically significant effects on the microbiological quality of kefir ($p < 0.05$). While significant differences in titratable acidity were observed on days 1 and 7 ($p < 0.05$), no statistically significant differences were found among the groups on days 14 and 21 ($p > 0.05$). The pH values of the samples also showed statistically significant variation throughout the storage period ($p < 0.05$). However, the addition of *S. platensis* did not have a statistically significant impact on water activity, total solids, or ash content ($p > 0.05$). The antimicrobial activity of the kefir varied significantly depending on the type of pathogenic microorganism evaluated. While *S. platensis* addition did not significantly affect the total phenolic content ($p > 0.05$), a significant increase in phenolic compounds was observed on days 7 and 14 ($p < 0.05$). By the 21st day of storage, this difference had diminished, and no significant variation was detected among the groups ($p > 0.05$). Notably, higher concentrations of *S. platensis* were found to enhance antioxidant capacity during mid-storage, although this effect appeared to diminish over extended storage periods. The average DPPH radical scavenging activity of the kefir was not significantly influenced by *S. platensis* supplementation ($p > 0.05$), with the exception of day 7, where a statistically significant difference was observed ($p < 0.05$).

In conclusion, higher concentrations (0.75%) of *S. platensis* exhibited more pronounced initial physicochemical and antimicrobial effects, whereas the moderate concentration (0.50%) contributed to greater microbiological stability over time. These findings indicate that both the dose amount and storage time of *S. platensis* enriched kefir are critical factors affecting the results in all studied parameters.

Keywords: Kefir, Cow's Milk, *Spirulina platensis*, Pistachio Flavor

1. GİRİŞ

Kefir; bileşiminde probiyotik canlılar ile çok çeşitli laktik asit bakterilerini ve mayaları doğal olarak bulunduran, polisakkarit yapıdaki kefir tanelerinin su veya süt ile fermantasyona bırakılması ile elde edilen fermente bir üründür (Güzel-Seydim ve ark., 2011; Tomar ve ark., 2017). Fermantasyon sonunda sütten ayrılarak tekrar kullanılabilmekte ve bu süreçte mikrobiyal gelişim, ekzopolisakkarit üretimi gibi biyosentezler sonucu ağırlık oranlarında da artış gözlenmektedir (Wang vd., 2022).

Türk Gıda Kodeksi Fermente Sütler Tebliği'ne (2009/6) göre kefir; fermantasyonda *Lactobacillus kefiri*, *Leuconostoc, Lactococcus* ve *Acetobacter* cinslerinin değişik suşları ile laktozu fermente eden (*Kluyvremoyces marxianus*) ve etmeyen mayaları (*Saccharomyces cerevisiae, Saccharomyces unisporus, Saccharomyces exiguus*) içeren starter kültürlerle veya kefir taneleri ile elde edilen bir süt ürünüdür. Ekşimsi bir tat, sütten daha yoğun bir kıvama sahip olması ve içerdiği bir miktar alkol ile diğer fermente ürünlerden ayrılır. Kökeninin Kafkasya, Balkanlar ve Doğu Avrupa'ya dayandığı bilinmektedir (Prado ve ark., 2015). Kefir gibi süt ve süt ürünleri doğal olarak içerdikleri bileşenler sayesinde fonksiyonel gıda konusunda yüksek potansiyele sahiptirler (Playne ve ark., 2003).

Fonksiyonel gıda; besleyici özelliğinin yanında, insan vücudunu genel anlamda iyileştiren, hastalıkların önlenmesi ve tedavisinde kullanılabilen, fizyolojik olarak da faydalı olabilen özel bileşenler içeren gıdalar için kullanılmaktadır (Bibligardi ve ark., 2013). Belirli miktarlarda kullanıldığında konakçı sağlığını olumlu yönde etkileyen, fonksiyonel gıda bileşeni olarak da anılan mikrobiyal gıda katkıları probiyotik olarak adlandırılmaktadır. Probiyotiklerin immün sistemi iyileştirici, laktoz intoleransına karşı hafifletici etki göstermesinin yanı sıra bağırsak rahatsızlıklarının tedavisinde de olumlu sonuçlar verdiği bilinmektedir (Gülbandılar ve ark., 2017).

Probiyotik ürünler fonksiyonel gıdalar içerisinde önemli bir yere sahiptir. Bu ürünler çoğunlukla süt ve süt ürünleri arasında yer almaktadır. Probiyotik özellik sağlayan probiyotikler ise, bağırsaklarda mikrobiyal dengeyi olumlu etkileyen canlı mikroorganizmalardır. Bu mikroorganizmalardan bazıları; *Lb. acidophilus, Lb. plantarum, Lb. casei, B. bifidum, B.infantis ve Str. thermophilus* gibi bakteriler ve mayalardan *Sacchoramyces boulardii* olarak belirtilmektedir (Shah, 2007; Kara, 2024).

Kefirin fonksiyonel özellik kazanmasında bileşiminde doğal olarak bulunan bu probiyotik mikroorganizmaların etkisi sayesinde önemli antimikrobiyal, antikarsinojenik, antiinflamatuvar ve antihipertansif etki gösterdiği, ayrıca sindirim sisteminin düzenlenmesinde, vücut ağırlığının denetiminde, lipit profilinin ve glisemik yanıtın kontrolünde yardımcı olabileceği bildirilmektedir (Huseini ve ark., 2012, Koyu ve Demirel, 2018). Literatürde probiyotik mikroorganizmaların iyileştirici etkilerinden faydalanmak için en az 10^{8} kob/mL sayıda vücuda alınmaları ve bağırsak sindirimine kadar canlı kalmaları gerektiği bildirilmiştir (Çakır ve Çakmakçı, 2004).

Son yıllarda probiyotik mikroorganizmaların yanı sıra tüketici talebine göre farklı aromalarda kefir üretiminde artış görülmektedir. Bu aromalar arasında Antep fıstığı ile ilgili çalışmaya rastlanılmamıştır. Antep fıstığı kendine has bir lezzete sahip ve besin değeri bakımından oldukça zengin bir meyvedir. Çerez olarak tüketilmesinin yanı sıra tatlılarda ve yemeklerde de kullanılmaktadır. Antep fıstığı meyvesi besin içeriği açısından fındık, badem ve yerfıstığı gibi yağlı meyvelerle kıyaslandığında protein, karbonhidrat ve kalori değeri bakımından birinci, yağ oranı açısından ise fındıktan sonra ikinci sırada yer almaktadır. Antep fıstığının kandaki kolesterol düzeyini düşürerek, koroner kalp hastalığı riskini azalttığı, kan şekerinin yükselmesini önlediği ve insan vücuduna olumlu etkilerinin olduğu ifade edilmektedir (Ertürk vd., 2015).

Kefir üretiminde geleneksel ve ticari olmak üzere iki ayrı yöntemden yararlanılmaktadır. Ticari yöntem ile geleneksel yönteme kıyasla daha viskoz ve daha az maya içeren kefir elde edilirken, geleneksel yöntemle elde edilen kefir duyusal olarak daha üstün özelliklere sahip olduğu rapor edilmiştir. Danelerden elde edilen kefirin tadını güzelleştiren unsurun farklı mikroorganizmalar olduğu düşünülmektedir (Saygılı vd., 2023; Çalişir vd., Çalışır ve vd., Erken Erişim). Piyasada değişik katkı maddeleri ile zenginleştirilmiş çok sayıda kefir türü üretilmektedir. Ayrıca potansiyel yenilebilir uygulamaları olan bazı alternatif protein açısından zengin kaynaklar; mikrobiyal proteinler ve algler de gıdalarda kullanılmaktadır (mikro algler ve deniz yosunları) (Kumar ve ark., 2022). Mikroalgler binlerce yıldır insan beslenmesinde tüketilmektedir. Yüksek protein içeriği nedeniyle, artan nüfusun diyet gereksinimlerini karşılamak için büyük bir potansiyele sahiptirler. İyi bir protein kaynağı olmasının yanı sıra, çeşitli biyoaktif bileşenleri de bünyesinde bulundurarak ek bir sağlık yararı sağlarlar.

Günümüzde "süper gıda" olarak ifade edilen *Spirulina platensis*; yüksek protein, zengin vitamin ve pigment içeriği bakımından, ayrıca düşük yağ oranından dolayı ticari önemi olan bir mikroalg türüdür. Son zamanlarda bitkisel proteinlere ve alglere karşı araştırmacıların ilgisi artış göstermektedir. Besin özellikleri, farmakolojik etkileri, sürdürülebilir bir gıda alternatifi olması ve özellikle insan sağlığı üzerindeki pozitif etkileri bu artışı tetiklemektedir (Kurhan,2012; Bleakley ve Hayes 2017; Koyande ve ark., 2019; Martelli ve ark., 2020; Silva ve ark., 2020).

S. platensis)'in yüksek protein içeriğine (ağırlıkça %60-70), kozmetik ve gıda sektöründe kullanılan mavi pigmente sahip bir sağlıklı gıda kaynağı olarak yaygın şekilde kültürü yapılan bir siyanobakteri türü olduğu bilinmektedir (Coca ve ark., 2014; Parisi ve ark., 2020; Ahmed ve Kumar, 2022). Ek olarak, Spirulina türleri özellikle B12 vitamini, mineraller, protein ve karotenoidler olmak üzere zengin bir vitamin kaynağıdır ayrıca vücutta emilim oranı yüksek kalsiyum ve zengin demir içeriğine sahiptir (Çağlak ve ark., 2005; Selmi ve ark., 2013; Lupatini ve ark., 2017).

Yapılan bu çalışmada *S. platensis* ve Antep fıstığı aroması ile zenginleştirilmiş inek sütüne kefir mayası ilave edilerek geleneksel olarak fermente edilerek üretilen kefirlerin, mikrobiyolojik, fiziko-kimyasal toplam fenolik madde içeriği ile DPPH radikal süpürme kapasitesi 1. 7. 14. ve 21. Günlerinde araştırılmış; sonuçlar istatistiksel olarak değerlendirilmiştir.

2. MATERYAL VE METOT

2.1. Materyal

Çalışmada kullanılan; *S. platensis*, ENDEMİX Natural Ingredients tarafından toz halinde temin edilmiştir. Kullanım süresinde *Spirulina platensis* örnekleri, hava ve ışıktan korunarak -18 °C'de muhafaza edilmiştir. Antep fıstığı aroması; ZYMNOS tarafından sıvı halde; kefir mayası ise VİVO tarafından toz halinde; süt ise, satışa sunulan pastörize edilmiş (%3,3 yağlı süt) olarak temin edilmiştir.

2.2 Metot

%3,3 yağlı pastörize inek sütü, ticari satılan kefir taneleri, *S. platensis* (0,50 ve 0,75gr) ve Antep fıstığı aroması (1mL) kullanılarak kefirlerin üretimi gerçekleştirilmiş; analizleri gerçekleştirilmiştir.

Bu amaçla; pastörize edilmiş süte (1 lt), *S. platensis* 0,50 ve 0,75 konsantrasyonlarda, Antep fıstığı aroması (1 ml), kefir mayası (0,25g) aşılanarak, yaklaşık 25ºC sıcaklıkta 24 saat fermantasyona bırakılmış ve pH 4,7'ye ininceye kadar inkübasyon işlemine tabi tutulmuştur.

2.2.1. Mikrobiyolojik Analizler

Mikrobiyolojik analizler; fizyolojik tuzlu su (%0,85'lik NaCl) kullanılarak ve bazı mikroorganizmalar için önerilen selektif zenginleştirme besiyerleri ile hazırlanan dilüsyonlar kullanılarak dökme plak yöntemi ile gerçekleştirilmiştir. Toplam aerobik mezofilik bakteri sayısının (TAMB) belirlenmesinde (Urhan, 2012, Savaşan ve Göksoy, 2018), *Lactococcus* spp. ve *Lactobacillus* spp sayılarının belirlenmesinde (Halkman, 2005, Yıldız, 2009; Yerlikaya, 2018) ve koliform grubu bakterilerin sayılarının belirlenmesinde (Halkman,2005). tarafından önerilen yöntemler kullanılmıştır.

TAMB sayısının belirlenmesi için Plate Count Agar kullanılmış, ekimi yapılmış petri plakları 30°C'de 48 saat süre ile inkübe edilmiştir. *Lactococcus* spp. sayısı için M17 Agar (Merck) kullanılarak 30°C'de 48 saat inkübasyon gerçekleştirilmiştir. MRS Agar (De Man, Rogosa and Sharpe) (Merck) kullanılarak *Lactobacillus* spp. sayısı belirlenmiş, ekimi yapılan petriler 37°C'de 48 saat anaerobik olarak inkübe edilmiştir. Koliform grubu bakterilerin sayımı için VRBA (Violet Red Bile Agar) (Merck) besiyerine ekim yapılmış 37 °C 'de 24±2 saat inkübasyona bırakılmıştır. 1 mL kefir örneği petri kutularına alındıktan sonra Potato Dextrose Agar (PDA) (Merck) besiyerine steril filtre ile % 10'luk tartarik asit ilave edilmiştir. Dökme plak yöntemiyle ekimi yapılan petrilerde 28±2°C'de 96 saat süre sonunda oluşan koloniler, kültürel sayım yöntemi ile sayılmıştır (Özkaya ve Kuleasan 2000; Buran, 2020).

Tüm mikroorganizmaların identifikasonları literatürlerde belirtildiği gibi gerçekleştirilmiştir.

2.2.2. Antimikrobiyal aktivite

Farklı içeriklerle hazırlanan kefir örneklerinin antibakteriyel ve antifungal etkinliklerinin gözlenmesinde Agar kuyucuk difüzyon yöntemi kullanılmıştır. Katı besiyerlerinde tazelenen kültürden öze ile Mueller Hinton Broth (MBH) besiyerine ekim yapılmış ve 37 ºC'de bir gecelik inkübasyon sonucunda oluşan kültürlerden 10^8 kob/mL (0.5 McFarland bulanıklık tüpüne karşılık gelen bulanıklık) olacak şekilde dilüsyon hazırlanmıştır.

20 mL Mueller Hinton agar içeren petrilerin yüzeyine bakteri dilüsyonundan steril pipet yardımıyla 100 µL pipetlenmiş ve steril drigalski spatülü ile besiyeri üzerine homojen bir şekilde yayılmıştır. Kuruması için bekletilen petriler üzerinde daha sonra 6 mm çaplı kuyucuklar açılarak, kefir örnekleri ve pozitif kontrol olarak kullanılan bileşikler (antibakteriyel kontrol bileşiği; Levofloksasin, Vankomisin ve antifungal bileşik; 30 Flucanozol- [1 mg/mL]) çözeltisinden 50 µL ilave edilmiştir. 37 ºC'de bir gecelik inkübasyon sonunda disklerin çevresinde meydana gelen inhibisyon zonları mm bölmeli cetvel yardımıyla ölçülerek kaydedilmiştir. Sonuçlar, inhibisyon bölgelerinin çapı acısından; +++: Yüksek derece duyarlı (16 mm ve daha büyük), ++: Orta derece duyarlı (11- 15 mm), +: Düşük derece duyarlı (5-5-10 mm), –: Duyarlı değil (İnaktif, < 5. 5 mm) şeklinde yorumlanmıştır (Aytaç ve ark.2022).

2.2.3. Fizikokimyasal Analizler

2.2.3.1. Titrasyon Asitliği

Kefir örneklerinin asitliği % laktik asit cinsinden belirlenmiştir. Bir erlene 5 ml kefir numunesi üzerine 40 °C'deki distile sudan 95 ml ilave edilmiş, elde edilen karışım üzerine 2-3 damla %1'lik fenolfitalein damlatıldıktan sonra sabit pembe renk oluşuncaya dek 0,1 N NaOH ile titre edilmiştir. Harcanan 0.1 N NaOH miktarı literatürlerde tanımlanan formülle hesaplanmıştır (Arısoy ve Öner, 2019; Okumuş, 2019).

2.2.3.2. pH Değeri

Örneklerin pH değerleri dijital pH metre ile ölçülmüştür (Arısoy ve Öner, 2019; Okumuş, 2019).

2.2.3.3. Su Aktivitesi Analizi

Örneklerde su aktivitesinin tespiti; (aw) değerleri su aktivitesi tayin cihazı (Streoglass, Sweden) kullanılarak ölçülmüştür (Hallaç ve ark.,2021).

2.2.3.4. Toplam Kuru Madde Miktarının Belirlenmesi

Kefir örneklerinde kuru madde miktarının tespitinde etüvde kurutma yöntemi kullanılmıştır. Kurutma kaplarına 5 g örnek konulmuş, 105±2°C'de sabit ağırlığa gelinceye kadar kurutulmuş ve ağırlık kaybı dikkate alınarak kuru madde miktarı % kuru madde miktarı Gravimetrik yöntemle tespit edilmiştir (Hayaloglu ve Özer, 2011; Okumuş 2019).

2.2.3.5. Kül Miktarının Belirlenmesi

Örneklerde kül tayini için yaklaşık 5 g numune krozelerde tartılıp, kurutma dolabında 105°C'de kurutulmuştur. Kül fırınında 550°C"de kül rengi beyazlayıncaya kadar yakılarak sonra desikatörde soğutulup, tartılmış ve kül oranı % olarak hesaplanmıştır (Okumuş 2019).

2.2.4. Toplam Fenolik Madde Miktarı Analizi

Toplam fenolik madde derişimini belirlemek için modifiye Folin-Ciocaltaeu spektrofotometrik yöntemi esas alınmıştır. Daha önceden 1:40 oranında seyreltilmiş ve +4 derecede bekletilmiş olan propolis numunelerinden sırasıyla tüplere alınmış; 1 ml seyreltilmiş propolis numunesi, 8,25 ml saf su, 0,5 ml Folin-Ciocalteau reaktifinden tüplere konulmuştur. % 10'luk Na_2CO_3 çözeltisinden 0,5 ml eklenerek karanlıkta 30 dakika inkübasyona bırakılmıştır. Süre sonunda inkübe edilen örneklerin 765 nm' de UV-spektrofotometre kullanılarak, etanol körüne karşı absorbans değerleri ölçülmüştür. Sonuçlar, mg gallik asit eşdeğeri (GAE) / L olarak belirlenmiştir (Sağdıç ve vd., 2020; Keskin ve Kolaylı, 2019).

2.2.5. Antioksidan Aktivite Tayini

2.2.5.1. DPPH (2,2- difenil-1-pikrilhidrazil) Radikali Yakalama Aktivitesi Yöntemi ile Antioksidan Aktivitelerinin Araştırılması

Örnek ekstraktlarının radikal süpürme aktivitesi Brand Williams, Culivier ve Berset (1995) metoduna göre belirlenmiştir. Örneklerin antioksidan aktivitesini belirlemek için 3,9 mg DPPH maddesi etil alkol ile 100 mL' ye tamamlanarak çözündürülmüştür. Daha sonra örneklerden 0,1 mL alınarak, 2 mL DPPH stok çözeltisi ile karıştırılmıştır. Hazırlanan karışım, oda sıcaklığında 30 dakika boyunca karanlık ortamda bekletilmiş, süre sonunda UV spektrofotometre kullanılarak 515 nm dalga boyunda absorbans ölçümü yapılmıştır. Kontrol olarak örnek yerine 0,1 mL etil alkol ve 2mL DPPH stok çözeltisi karıştırılarak absorbans ölçümü yapılmıştır. Her numunenin DPPH radikallerini süpürme aktivitesi (%) aşağıdaki formüle göre hesaplanmıştır (Sağdıç vd., 2020; Keskin vd., 2019).

I (%) = (A0 - Anumune / A0) x 100

Bu değerlerden faydalanılarak DPPH serbest radikalinin yarısının süpürüldüğü andaki numune derişimi (IC50) değerleri hesaplanmıştır.

% DPPH = (ABS Kontrol – AB Örnek) x100

AB Kontrol

ABS Kontrol: Kontrol Bileşiğinin Konsantrasyon Miktarı

AB Örnek: Örnek Bileşiğinin Konsantrasyon Miktarı

2.2.6. İstatistiksel Analiz

Deneyler sonucunda toplanan veriler Windows tabanlı SPSS 18.0.1(SPSS Inc., Chicago, Illinois, US) ist atistik paket programı kullanılarak gruplar arasında istatistiksel olarak fark olup olmadığı tek yönlü ANOVA Tukey Çoklu Karşılaştırma Testi ile karşılaştırılmıştır. Grafikler için ise Python açık kaynak kodlu program kullanılmıştır.

3. BULGULAR VE TARTIŞMA

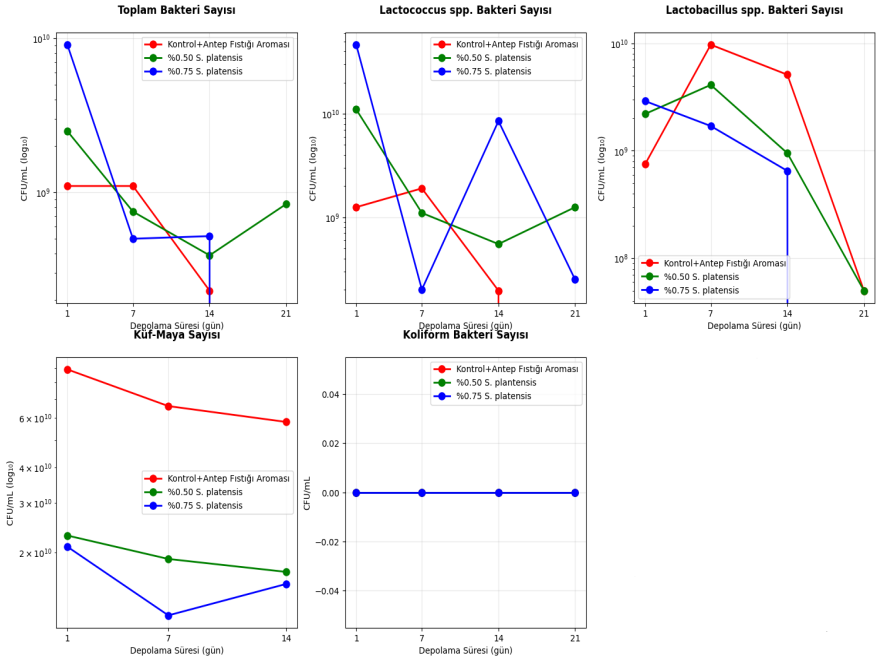
3.1. Mikrobiyolojik Analizler

Kefirlerin mikrobiyolojik analiz sonuçlarının değerlendirilmesinde Tek Yönlü ANOVA testi kullanılmıştır. ANOVA testi ile gruplar arasında anlamlı bir fark bulunduğunda ($p < 0.05$), hangi grupların farklı olduğunu belirlemek için ise; Tukey Post-Hoc testi uygulanmıştır.

S. platensis ilavesi, 1. günde tüm bakteri gruplarında (TMAB, *Lactococcus* spp., *Lactobacillus* spp.) istatistiksel olarak anlamlı bir artışa neden olurken, 7. ve 14. günlerde durum tersine dönmüştür. Özellikle *Lactobacillus* spp. üzerinde *S. platensis* ilavesi (konsantrasyon arttıkça) istatistiksel olarak anlamlı etki göstermiştir ($p<0.05$). Kontrol grubu ise, depolama boyunca en yüksek *Lactobacillus* spp. sayısını korumuştur. *S. platensis* ilavesi tüm depolama süresi boyunca küf ve maya gelişimi istatistiksel olarak anlamlı olarak bulunmuştur ($p<0.05$). Bu durum *S. platensis*'in raf ömrünü uzatmada etkili bir doğal antifungal ajan olarak kullanılabileceğini düşündürmektedir. Tüm gruplarda koliform bakteri üremesi, üretim koşullarının hijyenik olduğunu doğrulamıştır.

S. platensis ilavesinin konsantrasyonu ve depolama süresi, kefirin mikrobiyolojik kalitesi üzerinde istatistiksel olarak anlamlı bir etkiye sahiptir ($p < 0.05$).

S. platensis, başlangıçta LAB (Laktik Asit Bakterileri) gelişimini teşvik ederken, depolama sırasında özellikle Laktobasilleri baskılayıcı bir etki göstermiştir. Kefirlerin mikrobiyolojik analiz sonuçlarına ait grafikler Şekil 1' de verilmiştir.



Şekil 1. Kefirlerin mikrobiyolojik analiz sonuçları

S.platensis ilavesinin ve depolama süresinin kefir örneklerinin toplam aerobik mezofilik bakteri sayısı, *Lactococcus* spp., *Lactobacillus* spp. maya sayıları ve koliform bakteriler

üzerindeki etkisi.

Kontrol+Antep fıstığı aroması (Kontrol+AFA) grubunda, *Lactobacillus* spp ve *Lactococcus* spp. sayıları depolama süresi boyunca istatistiksel olarak anlamlı bir şekilde azalmıştır. *Lactobacillus* spp. 7. gün en yüksek seviyeye ulaşmış, ardından düşüşe geçmiştir. TMAB ve küf-maya sayılarında 21. güne gelindiğinde probiyotik bakteri popülasyonun azaldığı görülmüştür. 0.50 *S. platensis* ilaveli konsantrasyon grubunda, tüm mikrobiyolojik parametrelerde bir azalma gözlenmiştir.

En yüksek değerler genellikle 1. günde görülmüş, depolama boyunca düzenli bir düşüş izlenmiştir. TMAB ve *Lactococcus* spp. 21. günde canlılığını korumuştur. Küf-maya sayısında bir düşüş belirlenmiştir. 0.75 konsantrasyon grubunda ise, tüm parametrelerde bir düşüş görülmektedir. Özellikle *Lactococcus* spp. sayısında 1. günde artış gözlenirken, 7. günde düşüş meydana gelmiştir.

Kontrol+AFA grubu değerlendirildiğinde; zamanla yavaş bir bozulma görülmektedir. *Lactobacillus* spp. 'de 7. güne kadar bir artış gözlemlenmiştir. 0.50 konsantrasyon grubunun dengeli bir seviye izlediği görülmüştür. 0.75 konsantrasyon grubu için, başlangıçta güçlü bir artış görülürken daha sonra çok hızlı bir düşüş belirlenmiştir.

Fermente ürünlerin üretiminde kullanılan sütün kalitesi ve özellikleri ürün kalite özelliklerini etkilemektedir. Bu nedenle ürün özelliklerine bağlı olarak süt kullanılması önem arz etmektedir.

Konu ile ilgili yapılan çeşitli araştırmalarda (Yildiz-Akgul vd., 2018); Khaze Hagh, 2018; Buran vd., 2021) farklı üretim yöntemi, depolama süresi ve kefir üretiminde kullanılan süt kaynağı ve özelliklerine bağlı olarak TAMB sayısında önemli farklılıkların olduğu belirtilmiştir.

3.2.Kefir Örneklerine Ait Antimikrobiyal Aktivite Sonuçları

Kefir örneklerinin antimikrobiyal aktiviteleri *Staphylococcus aureus, Bacillus subtilis, Enterococcus faecalis, Listeria monocytogenes* (Gram pozitif), *Pseudomonas aeruginosa, Escherichia coli* (Gram negatif) ve *Candida albicans* (F89) (maya) mikroorganizmaları üzerinde belirlenmiş ve bu mikroorganizmalar üzerine farklı konsantrasyonlarda *S. platensis* ilavesi ve depolama süreleri ile ilgili test sonuçları Şekil 2'de verilmiştir. Kefir örneklerinin test edilen mikroorganizmalara karşı antimikrobiyal etkileri kontrol+antep fıstığı aroması bileşikleriyle kıyaslandığında daha küçük çaplı inhibisyon gösterse de değişen seviyelerde antimikrobiyal etkiye sahip oldukları belirlenmiştir. Antimikrobiyal aktivite sonuçları değerlendirildiğinde; 0.75 *S. platensis* ilavesine karşı en duyarlı mikroorganizmanın *P. aeruginosa,* olduğu ve diğer gruplardan istatistiksel olarak anlamlı derecede daha yüksek bir inhibisyon gösterdiği belirlenmiştir ($p<0.05$).

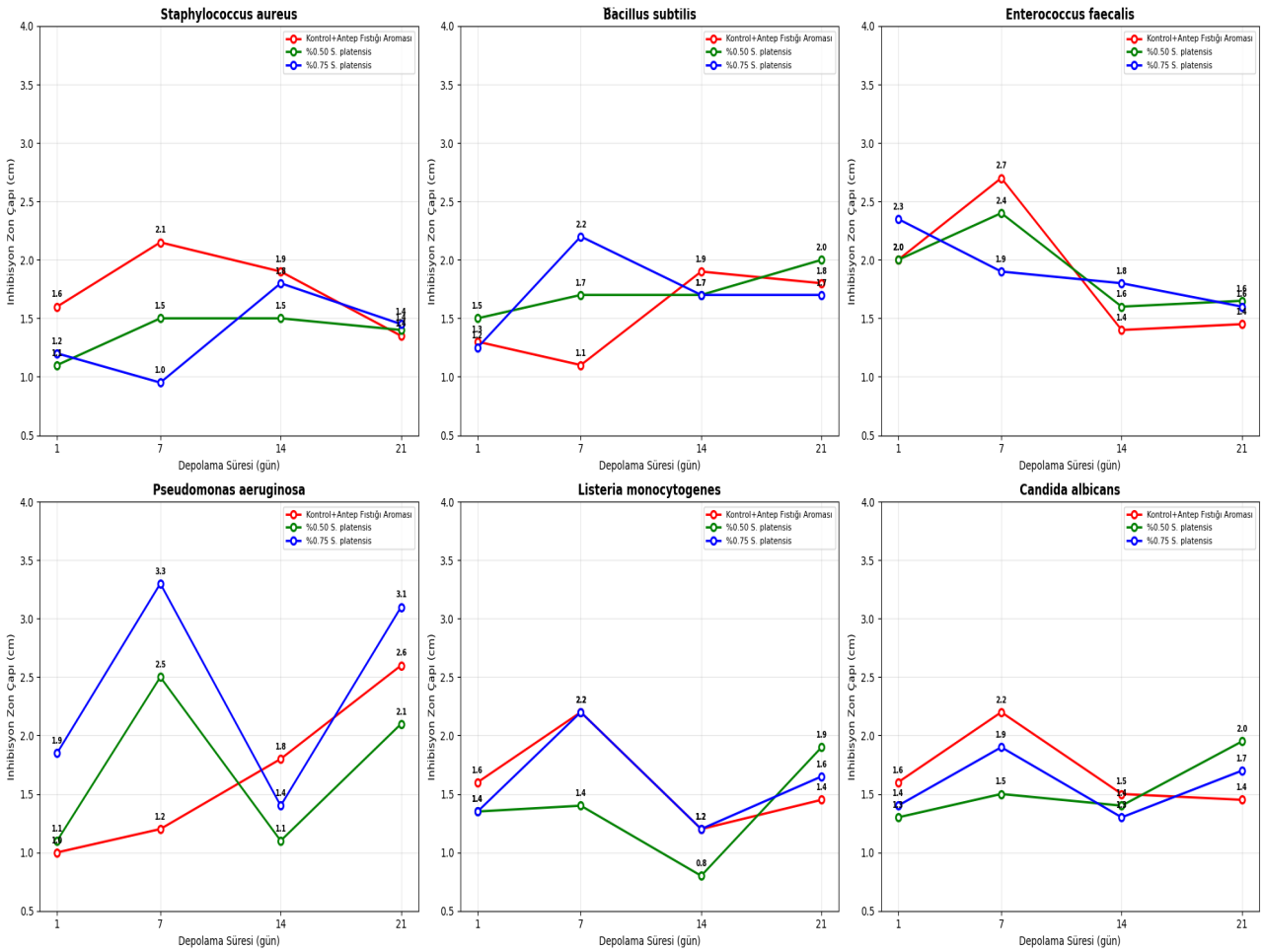
S. *platensis* ilavesinin her iki konsantrasyonununda (%0.50 veya %0.75) depolama süreci boyunca *Escherichia coli'* ye karşı antimikrobiyal aktivite üzerinde istatistiksel olarak anlamlı bir etkisi olmamıştır ($p > 0.05$). Şekil 2' de görüldüğü gibi %0.75 *S. platensis* ilavesinin kefirin *E. coli* 'ye karşı antimikrobiyal aktivitesini depolamanın 1. gününde istatistiksel olarak anlamlı şekilde artırmış, fakat depolamanın 7. 14. ve 21. günlerinde gruplar arasında anlamlı bir fark kalmadığı görülmüştür.

Depolama süresince kefirlerin *S. aureus*'a karşı antimikrobiyal aktiviteleri düzenli bir değişim göstermemiştir. Depolamanın 7. güne kadar artan antimikrobiyal etki 14. günde azalmış ve 21. günde tekrar artmıştır. Depolama süresince kefir örneklerinin orta derece duyarlılık gösterdikleri belirlenmiştir.

Bacillus subtilis, Enterococcus faecalis, Listeria monocytogenes (Gram pozitif) ve *Candida albicans* (F89) (maya) mikroorganizmaları ortalamaları arasında farklılık olmadığı tespit

edilmiştir (p>0.05).

Çalışmada; farklı konsantrasyonlardaki *S.platensis* ilaveli kefir örneklerinin mikroorganizmalara karşı gösterdikleri antimikrobiyal etki incelenmiş ve kontrol bileşikleri ile kıyaslanmış; bazılarının kontrol bileşiğiyle aynı ya da daha yüksek etki gösterdiği tespit edilmiştir.



Şekil 2. *S. platensis* İlaveli Kefirlerin Antimikrobiyal Etkileri

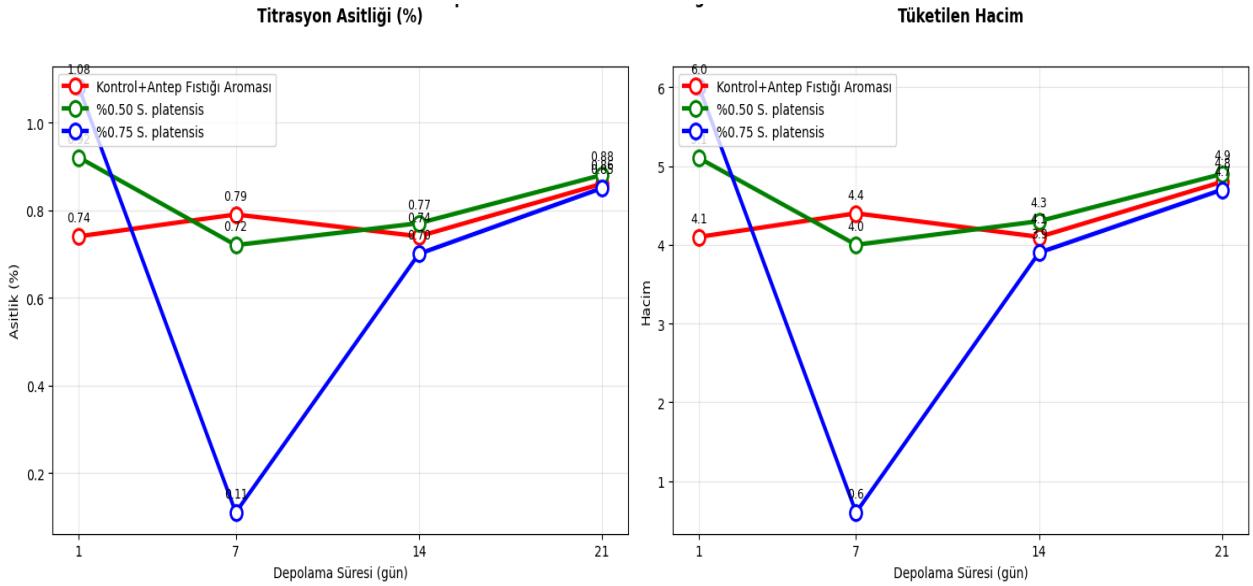
Mikroorganizmalara karşı antimikrobiyal aktivitenin depolama süresince değişkenlik göstermesi Kim vd., (2016) tarafından kefirde bulunan organik asitler, hidrojen peroksitler, etil alkol, diasetil, peptitler, bakteriyosinler gibi çeşitli metabolitlerin ve inhibitör bileşiklerin antimikrobiyal etkilerini arttırmak veya antagonize etmek için birbirleriyle etkileşime girmesinden kaynaklandığı belirtilmiştir. Bu nedenle kefirin antimikrobiyal aktivitesinin her fermantasyon aşamasında farklı bileşiklerden türetilebileceği ve bunun da zamanla tutarsız antimikrobiyal desene yol açabileceği belirtilmektedir.

Azizkhani vd., (2020). tarafından da farklı süt türlerinden üretilen kefir ve probiyotik yoğurt örneklerinde yapılan çalışmada; bulunan antimikrobiyal aktivite arasındaki farkın, yağ asitleri bileşimi, ürünün nihai pH'sı ve asitliği üzerinde önemli bir etkiye sahip olan laktoz içeriğinin, biyoaktif bileşiklerin üretiminde rol oynayan peptit türlerinin ve diğer kimyasalların bileşiminin, mikroorganizmaların türünün, popülasyonunun, kefir taneleri ile starter kültürün ayrıca enzim çeşitliliği gibi birçok parametreden kaynaklandığı belirtilmiştir.

3.3. Fizikokimyasal Analizler

Kefir örneklerinin titrasyon asitliği değerlerinin depolama süresince % 0,11-1,08 arasında değiştiği belirlenmiştir. En yüksek değerin ise; 0,75 *S.platensis* ilaveli örnekte 1. günde görüldüğü tespit edilmiştir.

Titrasyon asitliği için ilgili grafikler Şekil 3'de gösterilmiştir. %0.50 *S.platensis* ilaveli grubun sınırlı artan bir asitlik eğilimi gösterdiği; %0,75 ilaveli grubun ise başlangıçta çok hızlı bir asitlik artışı gösterdiği ve daha sonra bu durumun azaldığı görülmüştür.1. ve 7. günlerde asitlik bakımından farklılık mevcut iken ($p<0.05$), 14. ve 21. günlerde, gruplar arasında istatistiksel olarak bir fark kalmadığı tespit edilmiştir.



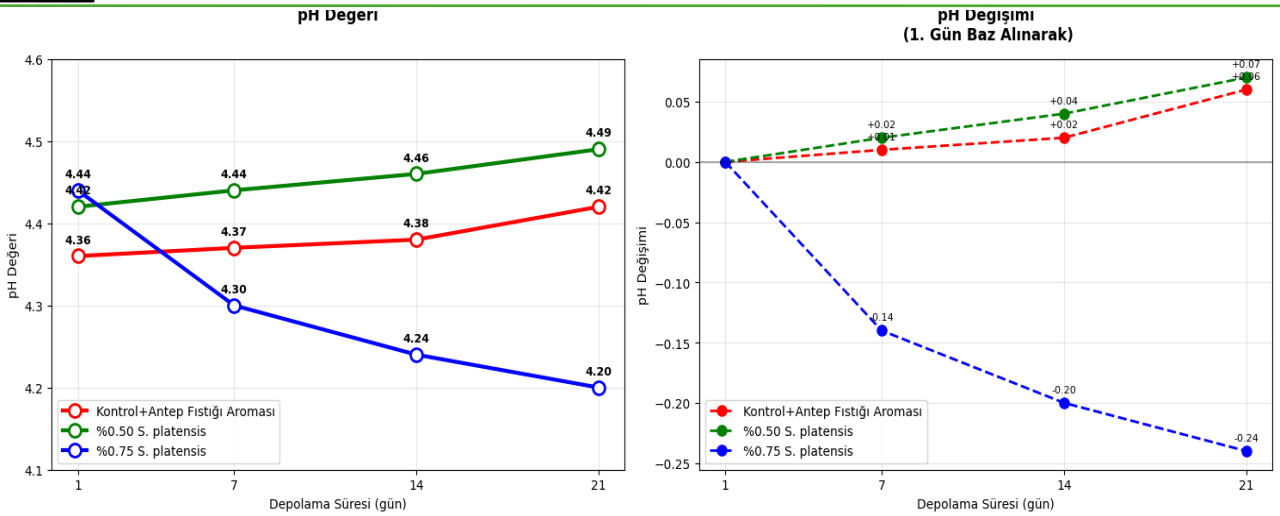
Şekil 3. Depolama süresince *S. platensis* ilavesinin titrasyon asitliği üzerine etkisi

Kefirdeki yoğun mikrobiyal floranın titrasyon asitliğindeki değişimlerin temel nedeni olduğu düşünülmektedir. Titrasyon asitliği üzerine *S. platensis'*in yüksek konsantrasyonunun önemli etkileri olduğu belirlenmiştir. Akdan (2020) manda ve diğer sütleri kullanarak kefir ürettiği çalışmasında, asitliği %0,91-1,04 aralığında tespit etmiş, en yüksek sonuca manda-koyun sütlerinin karışımıyla ürettiği kefirde rastlamıştır. Kefirlerde titrasyon asitliğinin artmasının azotlu maddelerden, depolama sürecinde LAB ve proteolitik bakterilerin faaliyetleri sonucu laktoz ve azotlu maddelerin hidrolizi ile oluşan bazı asitlerden ve fosfat, sitrat, laktat gibi metabolitlerden kaynaklandığını belirtilmektedir (Çalışır ve vd., Erken Erişim).

Yildiz-Akgul vd., (2018) çalışmalarında, asitliğin mikroorganizma faaliyeti neticesinde depolama süresince arttığını, farklı yağ oranlarının asitliği etkilemediğini ortaya koymuştur.

Depolama süresince pH değerlerinin karşılaştırmasında %0.75 *S. platensis* ilavesinin 14 ve 21 günlük depolama sonunda, kontrol ve %0.50 *S. platensis* ilaveli gruplara kıyasla istatistiksel olarak anlamlı derecede daha düşük pH değerlerine sahip olduğu belirlenmiştir ($p < 0.05$). pH değerlerinin 4,20-4,49 arasında olduğu ve en yüksek pH değerinin 0,50 *S. platensis* ilaveli örnekte, en düşük pH değerinin ise 0,75 *S. platensis* ilaveli örnekte 21. günde görüldüğü belirlenmiştir.

Bu durum, Şekil 4'te görüldüğü üzere, yüksek konsantrasyondaki *S. platensis'*in depolama süresince asit üretimini sürdürdüğünü göstermektedir.



Şekil 4. Depolama süresince *S. platensis* ilavesinin pH değeri üzerine etkisi

Kefir üretiminde kullanılan sütteki yağ oranının yüksek olması, son üründe pH değerini azaltmıştır. pH düşüşünün sebebinin, kefirde bulunan mikroorganizmaların özellikle de mayaların lipolitik aktivitesi sonucu oluşan serbest yağ asitleri olduğu düşünülmektedir. Tomar vd., (2020), inek ve manda sütü kefirlerini analiz ettiği çalışmasında, pH değerini 4,21-4,70 olarak belirlemiştir. Dane ile fermente edilenlerin starter kültüre göre; yağı az olanların yağlı olanlara göre daha düşük pH' a sahip oldukları sonucuna ulaşmıştır.

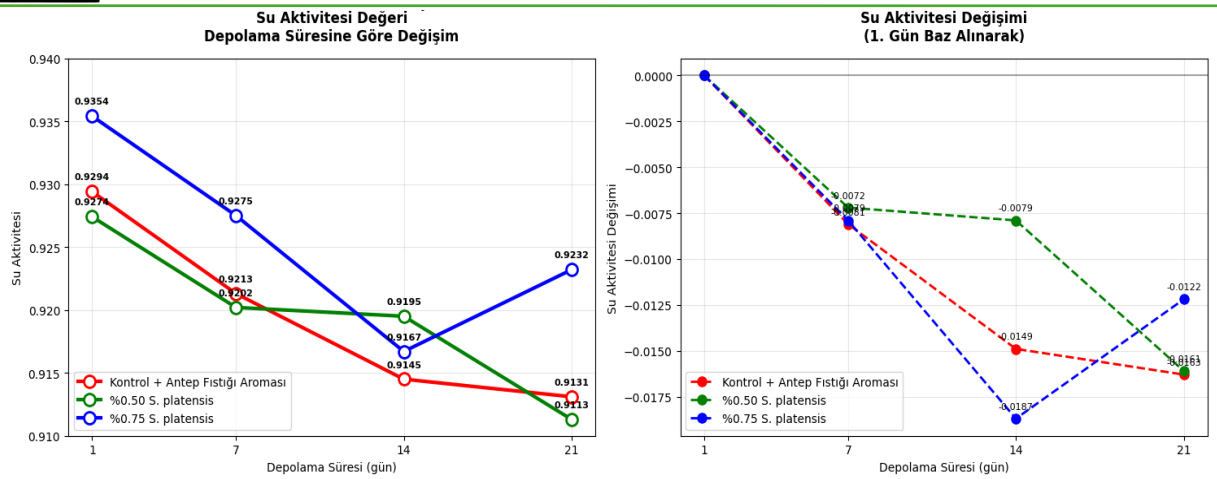
Buran vd., (2021), inek ve keçi sütü kullandığı kefirlerde 4,18-4,47 arasında pH değerleri kaydetmiştir. Mevcut araştırmada en yüksek pH ortalaması üzerine *S. platensis'*in yüksek konsantrasyonunun etkili olduğu belirlenmiştir.

Yildiz-Akgul vd., (2018), 23 gün depolanan kefirlerin pH değerlerinin 4,66-4,14 olduğunu ve düzenli olarak azaldığını belirlemiştir. Araştırıcı pH değerindeki azalmanın fermantasyon sonucu laktozun laktik asit bakterileri tarafından laktik aside parçalanması ile ortamda asitlik değerinin artmasının sonucu olduğunu belirtmiştir.

Çalışmamızda su aktivitesi analiz sonuçları incelendiğinde; 0,86-0,93 arasında değiştiği gözlenmiştir. En yüksek değerin; 0,75 *S.platensis* ilaveli örnekte 1. günde; en düşük değerin de kontrol grubunda 1. günde görüldüğü tespit edilmiştir. Depolama süresi boyunca *S. platensis* ilavesinin (%0.50 veya %0.75) kefirin su aktivitesi üzerinde istatistiksel olarak anlamlı bir etkisinin olmadığı belirlenmiştir ($p > 0.05$). Ancak, Şekil 5'ten görüleceği üzere, 21 günlük depolamanın sonunda, %0.75 ilaveli grubun su aktivitesi değerinin % 0.50 ilaveli grubun su aktivitesi değerinden yüksek olduğu belirlenmiştir.

Su aktivitesi; prebiyotik tipi, miktarı ve bunların kombinasyonundan etkilenmektedir. Stabilizatörlerin veya emülgatörlerin moleküler yapısı, su emme kapasiteleri, birbirleriyle ve içecekteki diğer bileşenlerle etkileşimleri, su aktivitesini farklı yönde etkileyebilmektedir (İlter ve Yılmaz, 2022).

Her ürünün sınırlı bir raf ömrü vardır ve kalitesi zaman geçtikçe düşme eğilimindedir. Prebiyotiklerin su tutma kapasiteleri ve çözünürlükleri birlikte değerlendirildiğinde zamanla artan çözünürlükle en yüksek değerin depolamanın 21. gününde görülmesi beklenen bir sonuçtur. Depolama süresince çözünürlük arttıkça su tutma kapasiteleri düşmektedir. Bununla beraber kefirde yapı bozulmaya başlamakta ve su aktivitesinde de artış göstermektedir (Çalışır ve vd., Erken Erişim). Kefir örnekleri de uzun bir süre bozulmadan stabil kalabilmekte, ancak belirli bir süre sonunda lipit oksidasyonu ve diğer zararlı reaksiyonlar artış göstererek bozulma hızlanmaktadır (Buran vd., 2021).



Şekil 5. *S.platensis* ilaveli kefirin su aktivitesi üzerine etkisi

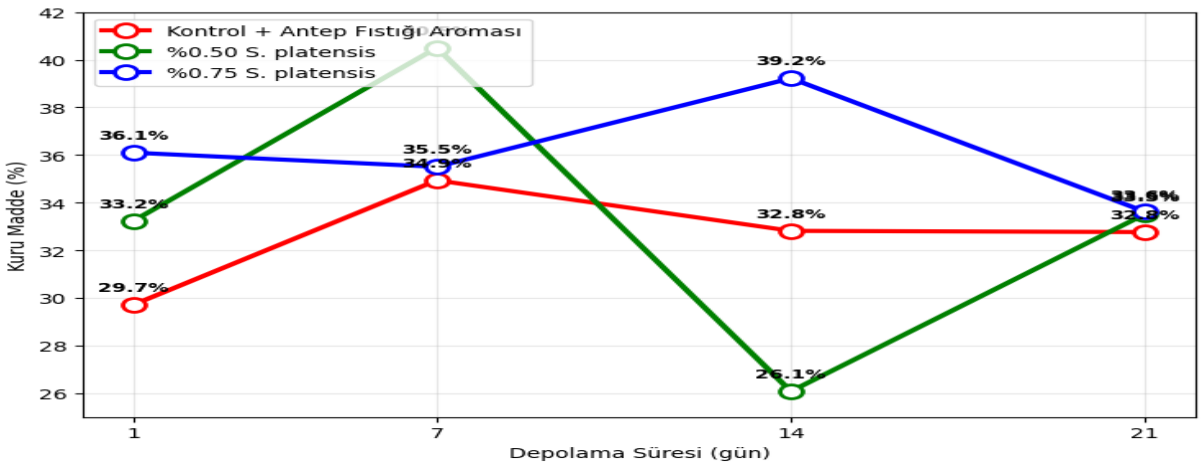
Kuru madde miktarının %26,07- %40,50 arasında değiştiği belirlenmiştir. En yüksek %0,50 *S. platensis* ilaveli grupta 7.günde; en düşük değerin ise aynı grupta 14. günde tespit edilmiştir. Depolama süresi boyunca *S.platensis* ilavesinin (%0.50 veya %0.75) kefirin toplam kuru madde miktarı üzerinde istatistiksel olarak anlamlı bir etkisinin olmadığı belirlenmiştir ($p > 0.05$). %0.75 *S.platensis* ilavesinin 1. ve 14. günlerde kontrol grubuna kıyasla istatistiksel olarak anlamlı bulunmuş ve Şekil 6'da görüldüğü gibi daha yüksek kuru madde içerdiği belirlenmiştir.

Kuru madde oranının, kefir üretiminde kullanılan sütün bileşimi ve yağ oranına bağlı olabileceği ifade edilmektedir (Tomar vd., 2019; Akdan, 2020). Mevcut araştırmamızda da kuru madde miktarı üzerinde süt yağ miktarına ilave olarak *S.platensis* ilavesinin ve depolama süresinin de önemli etkilerinin olduğu tespit edilmiştir.

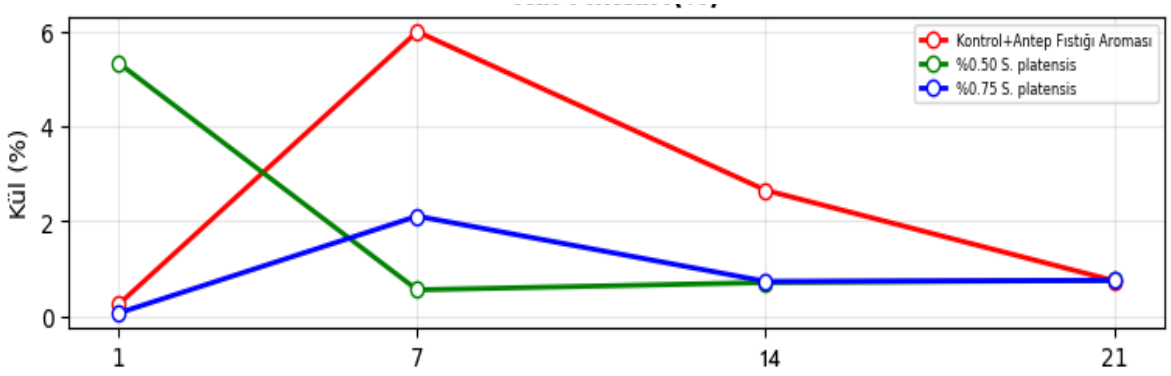
Buran vd., (2021) tarafından yapılan araştırmada üretilen kefirlerin 28 günlük depolama süresince sonunda tüm numuneler için kuru madde oranının azaldığı belirtilmiştir. Kefirin üretim tekniği, kullanılan sütün kalitesi, üretim esnasında uygulanan standardizasyon ve diğer işlem parametrelerindeki farklılıklar kefirin kuru madde miktarını etkileyebildiği belirtilmektedir (Öksüztepe vd., 2020).

Kül miktarı analiz sonuçlarına göre; % kül miktarının 6,00- 0,05 arasında değiştiği belirlenmiştir. En yüksek oranın kontrol grubunda 7.günde; en düşük değerin ise %0.75 *S.platensis* ilaveli grupta 1. günde tespit edildiği belirlenmiştir.

Kül miktarı üzerinde ise; *S.platensis* ilavesinin istatistiksel olarak anlamlı bir etkisinin olmadığı ($p > 0.05$) belirlenmiş; 1 ve 7. Günlerde bu etkinin anlamlı olduğu ($p<0.05$), depolamanın 14. ve 21. günlerinde ise; gruplar arasında istatistiksel bir farkın olmadığı görülmüştür ($p>0.05$) (Şekil 7).



Şekil 6. *S. platensis* ilaveli kefirin kuru madde miktarı üzerine etkisi



Şekil 7. *S.platensis* ilaveli kefirin kül miktarı yüzdesi üzerine etkisi

Kül miktarı genellikle gıda maddelerinde inorganik madde miktarı olarak tanımlanmaktadır. Ürünlerde çok fazla miktarda olması arzu edilmez. Çünkü bu değer ürünlerin hijyenik şartlarda üretilmediklerinin ve insan sağlığına zarar verebilecek bazı inorganik maddeleri içerebildiğinin bir göstergesi olarak kabul görmektedir. Kefirin yapımında kullanılan starter kültür kombinasyon farklılığı, kefirin üretim tekniği ve inkübasyon sıcaklığının farklılığının kül miktarı üzerinde etkili olduğu belirtilmektedir (Öksüztepe vd., 2020).

3.4. Toplam Fenolik Madde Miktarı

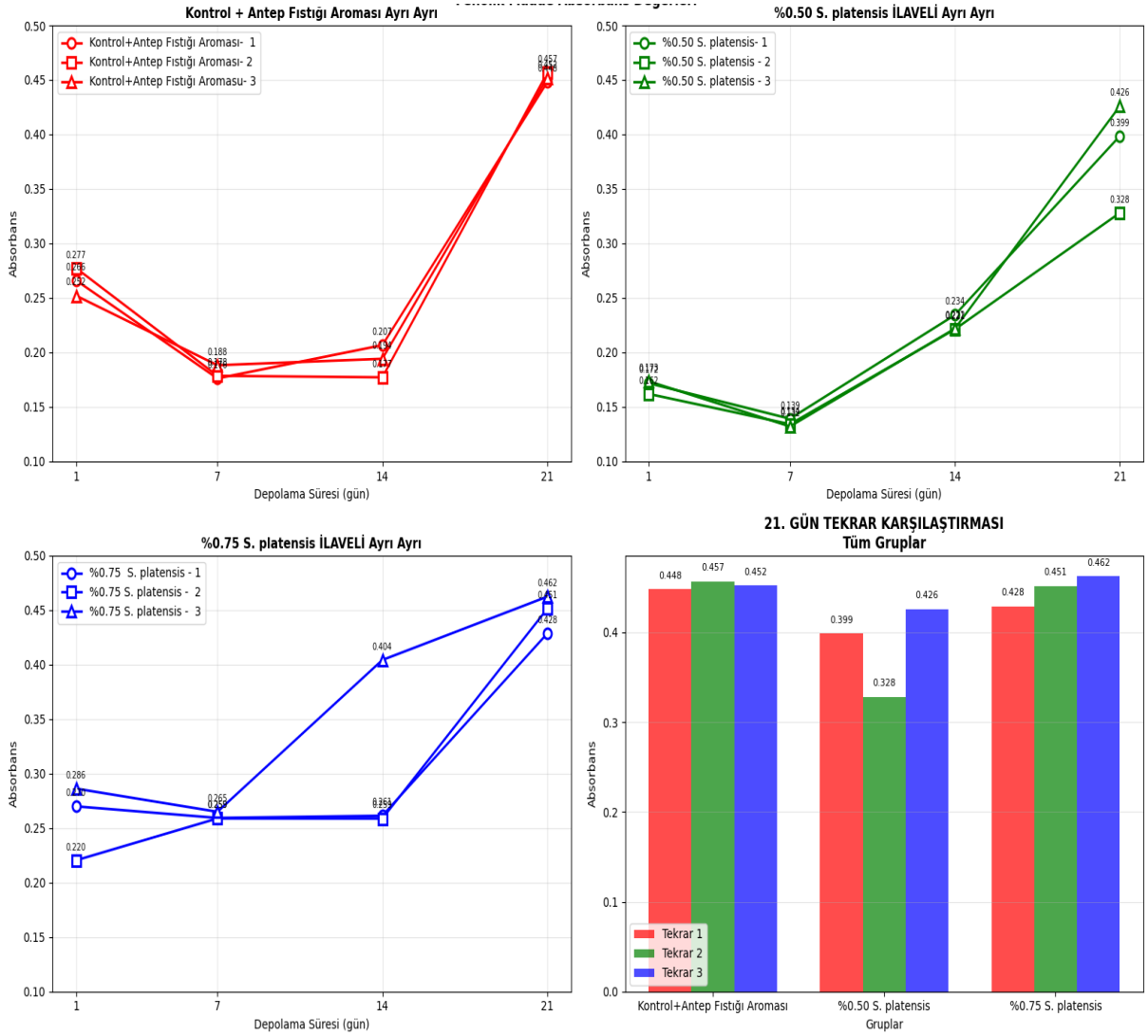
Toplam fenolik madde miktarı en yüksek oranda 0.75 *Spirulina platensis* ilaveli kefir örneğinde depolamanın 21. gününde 0.44 mg gallik asit/ml olarak belirlenmiştir. Toplam fenolik madde miktarı için ilgili grafikler Şekil 8'de gösterilmiştir. Tüm depolama süresi genelinde bakıldığında, *S.platensis* ilavesinin (%0.50 veya %0.75) kefirin toplam fenolik madde içeriği üzerinde istatistiksel olarak anlamlı bir etkisi olmamıştır ($p > 0.05$). %0. *S.platensis* ilavesinin, depolamanın 7. ve 14. günlerinde kefirin fenolik madde içeriğini istatistiksel olarak anlamlı derecede artırmıştır ($p<0.05$). Ancak, 21 günlük depolama sonunda tüm grupların fenolik madde seviyeleri benzer seviyelere yükselmiş ve aralarındaki fark ortadan kalkmıştır ($p>0.05$). Bu bulgular, yüksek doz *S.platensis* ilavesinin özellikle depolamanın orta dönemlerinde antioksidan kapasiteyi artırabileceğini, ancak uzun vadede bu etkinin azalabileceğini göstermektedir.

Fermantasyon sırasında kefir yapısında bulunan mikroorganizmalar fenolik bileşenler gibi biyoaktif bileşenlerin düzeyini etkilemektedir.

β-glukosidaz gibi enzimler fermantasyon sırasında fenolik bileşenleri daha basit yapılara hidrolize ederek toplam fenolik madde miktarını arttırabilmektedir.

Mikrobiyal kaynaklı bazı enzimler, süt türüne göre değişen proteinlerinin yapısı ile starter kültür bileşiminde yer alan laktik asit bakterileri ve diğer mikroorganizmalar da fenolik madde miktarını arttırabilmektedir (Coda ve ark. 2012; Sabokbar ve Khodaiyan 2016).

Barat ve Özcan (2016), fermente süt içecekleri üzerine gerçekleştirdikleri çalışmalarında toplam fenolik madde miktarını 0.38 mg gallik asit/ml olarak belirlemişler ve bulgularımızın yapılan çalışmada elde edilen değerlerle benzer olduğu görülmüştür.

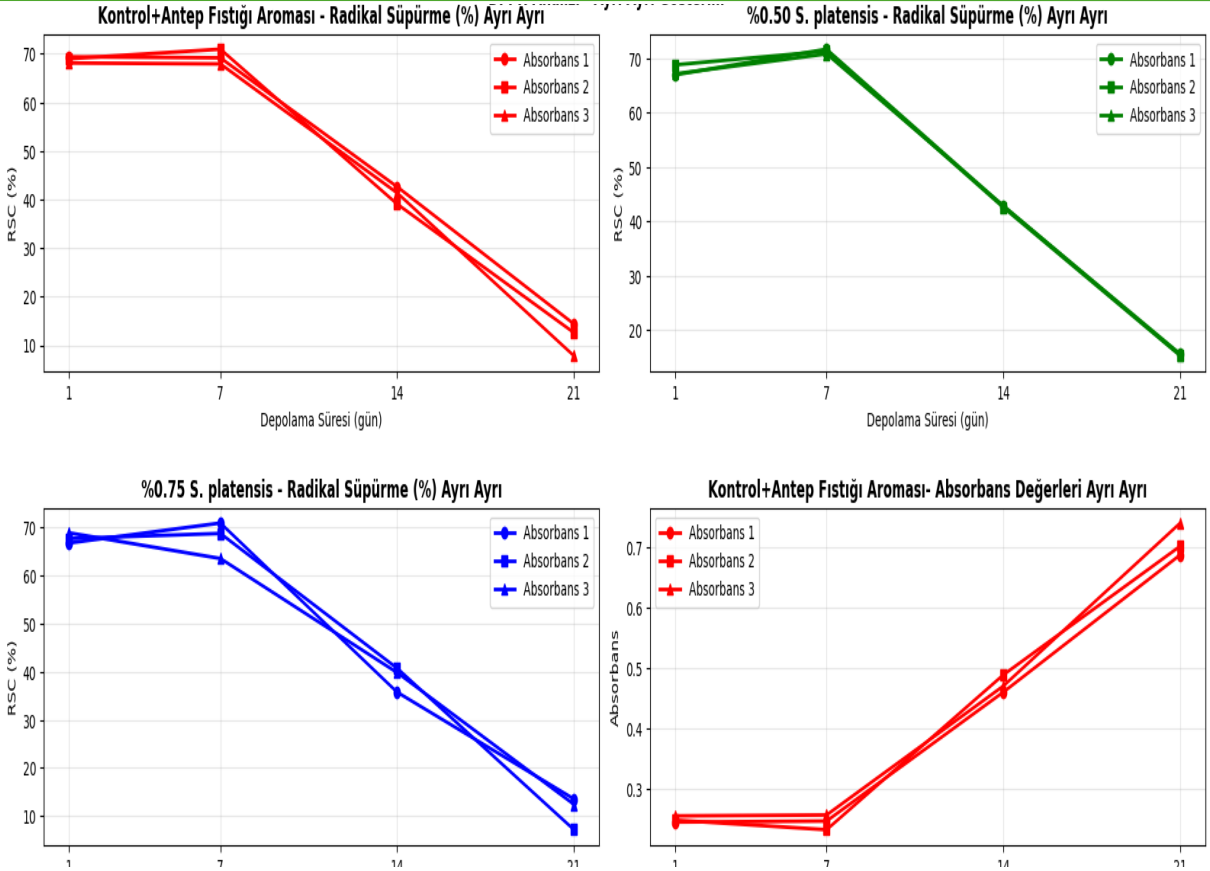


Şekil 8. *S.platensis* ilaveli kefirin fenolik madde miktarı üzerine etkisi

3.5. Antioksidan Aktivite Sonuçları

DPPH radikal süpürme reaksiyon, bileşiklerin serbest radikal temizleme kapasitesini veya hidrojen verici yeteneğini test etmek için yaygın olarak kullanılan bir yöntemdir. DPPH serbest radikal temizleme kapasitesinin depolama süresinin 7. gününde %0.50 ilaveli *S.platensis*'li kefirde en yüksek %71,27 oranında belirlenmiştir.

DPPH radikal süpürme kapasitesi grafikleri, Şekil 9'da gösterilmiştir. Tüm depolama süreci genelinde bakıldığında, *S.platensis* ilavesinin (%0.50 veya %0.75) kefirin ortalama DPPH radikal süpürme kapasitesi üzerinde istatistiksel olarak anlamlı bir etkisi olmamış ($p > 0.05$), 7. günde ise anlamlı bir fark bulunmuştur ($p<0.05$).



Şekil 9. DPPH radikal süpürme aktivitesi üzerine etkisi

DPPH serbest radikal giderme kapasitesinin 7. Günde elde edilen yüksek değerinin nedeninin, mikrobiyolojik aktiviteden kaynaklanıyor olabileceği yönündedir. Sonuçlar üzerinde süt bileşiminin ve *S. platensis* ilavesinin etkili olabileceğini; depolama sırasında serbest radikallerin ortamdaki serbest reaktif indirgen oksijen moleküllerini absorbe eden maddelerin biyoaktif molekülleri koruyucu etki gösterdiği düşünülmektedir.

Tüm örneklerin temizleme aktivitesi, depolama süresi boyunca dönemin başındaki temizleme aktivitesine kıyasla azalmıştır. Temizleme aktivitesindeki azalma, kefir kültüründe bulunan farklı mikroorganizma türlerinin fitaz enzimi üreterek fenolik bileşenleri kullanabilme yeteneğine bağlanabilir (Subrota vd.,2013). Ayrıca, fenolik bileşiklerin birbirleriyle veya diğer bileşiklerle sinerjik etkisi, antioksidan aktivitenin artmasına neden olabilir.

Ünal (2012), piyasadan temin ettiği kefir örneklerinde DPPH serbest radikal temizleme kapasitesi belirlemiş, çilekli ve orman meyveli kefir örneklerinin DPPH serbest radikal temizleme kapasitesinin, sade kefire göre daha yüksek olduğunu bulmuştur. Yılmaz-Ersan ve ark. (2016), inek sütünden elde edilen kefirde fermantasyon ve depolama süresinin DPPH serbest radikal temizleme kapasitesi üzerindeki etkisini araştırmışlardır. Fermantasyon süresi 0-20 saat, depolama süresi ise 1-21 gün olarak belirlenmiştir. Fermantasyon ve depolama süreleri karşılaştırıldığında, DPPH serbest radikal temizleme kapasitesinin 8. saatte (%7,20±0,283) ve 21. günde (%5,44±0,198) en yüksek olduğu bulunmuştur.

SONUÇ

Araştırmada *Spirulina platensis* farklı konsantrasyonlarda (0,50 ve 0,75gr), ticari olarak satışa sunulan Antep fıstığı aroması (1 mL) ve maya (0,25 gr) kullanılmış, pastörize inek sütüne (1lt) ilave edilerek kefir içeceği üretilmiştir. Kefir örneklerinin depolamanın 1. 7. 14. ve 21. günlerinde mikrobiyolojik ve fizikokimyasal özellikleri incelenmiştir.

S. platensis, viskoziteyi ve fonksiyonel özelliği arttırmak için kefir üretiminde kullanılabilir. Özellikle % 0,75 *S. platensis* ilave edilerek üretilen kefirlerin, fiziko -kimyasal, mikrobiyolojik, antimikrobiyal aktivite, toplam fenolik madde miktarı ve antioksidan aktivite üzerinde daha etkili olduğu belirlenmiştir. Bu kapsamda Antep fıstığı aromasının da tat açısından kefire ilave edilmesi tavsiye edilebilir. Elde edilen tüm verilerin gerçekleştirilecek yeni çalışmalarda kaynak olarak kullanılabilmesi ümit edilmektedir.

Bu çalışma Eskişehir Osmangazi Üniversitesi Bilimsel Araştırma Projeleri Koordinasyon Birimi'nin Desteklediği Proje Kodu FLO-2025-3515 olan **'Farklı Konsantrasyonlarda *Spirulina platensis* ve Antep Fıstığı Aroması Eklenmiş Kefirlerin Fiziko-Kimyasal ve Mikrobiyolojik Özelliklerinin Belirlenmesi'** Adlı Lisans Öğrencisi Katılımlı Araştırma Projesiyle Desteklenmiştir.

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BÜYÜKBAŞ VE KÜÇÜKBAŞ YETİŞTİRİCİLİĞİNDE MORFOLOJİK ÖLÇÜMLERDE YENİLİKÇİ YAKLAŞIMLAR

Arş. Gör. Dr. Murat TURAN
Van Yüzüncü Yıl Üniversitesi, Ziraat Fakültesi, Zootekni, Van
Email: muratturan@yyu.edu.tr
ORCID: 0000-0001-9286-3046
Zir. Yük. Müh. İrfan İNAN
Van Yüzüncü Yıl Üniversitesi, Ziraat Fakültesi, Zootekni, Van
Email: irfaninan45@gmail.com
ORCID: 0009-0007-0084-1394
Doç. Dr. Halit Deniz ŞİRELİ
Dicle Üniversitesi, Ziraat Fakültesi, Zootekni, Diyarbakır
Email: hdsireli@gmail.com
ORCID: 0000-0002-0711-0750
Zir. Yük. Müh. Müzeyyen Buse KARAMAN
Dicle Üniversitesi, Ziraat Fakültesi, Zootekni, Diyarbakır
Email: buseaslan2112@gmail.com
ORCID: 0000-0001-6846-0466

ÖZET

Büyükbaş ve küçükbaş hayvanlarda morfolojik ölçümler, uzun yıllar boyunca geleneksel yöntemlerle (mezura, cetvel, kumpas) gerçekleştirilmiş ve bu ölçümler verim tahmini, ırk tanımlaması, seleksiyon çalışmalarında ve hayvanların sağlık durumlarının belirlenmesinde temel veri kaynağı olarak kullanılmıştır. Geleneksel ölçüm yöntemleri genellikle temasa dayalı, zaman alıcı ve işgücü isterken, hayvanlarında strese girmelerine sebebiyet vermektedir. Ancak, son yıllarda gelişen teknolojik yaklaşımlar bu alana önemli yenilikler kazandırmıştır. Özellikle temassız ölçüm teknolojileri modern hayvancılıkta giderek yaygınlaşmakta olup hem hayvan refahının korunmasında hem de insan kaynaklı hataları azaltarak veri toplamada pratiklik, doğruluk ve tekrarlanabilirliği sağlamaktadır. Günümüzde, morfolojik ölçümlerde fotogrametri ve üç boyutlu görüntüleme teknikleri sayesinde hayvanların vücut yapıları temassız olarak yüksek doğrulukla ölçülebilmektedir. Bunun yanı sıra kamera sistemleri, makine öğrenimi ve yapay zekâ tabanlı uygulamalar modern hayvancılık işletmelerinde hayvanların vücut kondisyon skorlaması ve canlı ağırlık tahmininde kullanılabilmektedir. Yapay zekâ ve bilgisayarlı görü algoritmaları, kamera verilerinden otomatik morfolojik ölçüm çıkarımı sağlayarak ırk sınıflandırma ve büyüme eğrilerinin takibini mümkün kılmaktadır. Ayrıca taşınabilir ultrason cihazları ile kas kalınlığı ve yağ derinliği gibi iç morfolojik parametreler belirlenmekte, sensör tabanlı sistemlerle ise vücut ölçüleri ve canlı ağırlık değişimleri dolaylı olarak izlenebilmektedir. Bu teknolojik yöntemler, morfolojik ve canlı ağırlık ölçümlerinde insan kaynaklı hataları azaltmakta, hızlı ve sürekli veri üretimini kolaylaştırmakta ve hayvan refahını artırmaktadır. Sonuç olarak, büyükbaş ve küçükbaş hayvanlarda morfolojik ölçümlerin teknolojik yöntemlerle (sensör teknolojileri, yapay zekâ tabanlı uygulamalar vb.)

gerçekleştirilmesi, modern hayvancılıkta verimlilik, genetik ilerleme ve refah odaklı yaklaşımlar için önemli bir potansiyel taşımakla birlikte sürü yönetiminin de daha etkin ve güvenilir bir şekilde yürütülmesine olanak tanımaktadır.

Anahtar Kelimeler: Büyükbaş, küçükbaş, morfolojik ölçümler, hayvan refahı, yapay zekâ.

INNOVATİVE APPROACHES IN MORPHOLOGİCAL MEASUREMENTS IN CATTLE AND SHEEP BREEDİNG

ABSTRACT

Morphological measurements in cattle and sheep have been performed for many years using traditional methods (measuring tape, ruler, caliper), and these measurements have been used as a fundamental data source for yield estimation, breed identification, selection studies, and determining the health status of animals. Traditional measurement methods are generally contact-based, time-consuming, labor-intensive, and cause stress to the animals. However, technological advances in recent years have brought significant innovations to this field. Especially touchless measurement technologies are becoming increasingly widespread in modern animal husbandry, ensuring practicality, accuracy, and repeatability in data collection by both protecting animal welfare and reducing human-induced errors. Today, thanks to photogrammetry and 3D imaging techniques in morphological measurements, animals' body structures can be measured touchlessly with high accuracy. In addition, camera systems, machine learning, and artificial intelligence-based applications can be used in modern livestock operations for animal body condition scoring and live weight estimation. Artificial intelligence and computer vision algorithms enable automatic morphological measurement extraction from camera data, allowing for breed classification and growth curve tracking. Additionally, portable ultrasound devices are used to determine internal morphological parameters such as muscle thickness and fat depth, while sensor-based systems enable the indirect monitoring of body measurements and live weight changes. These technological methods reduce human-induced errors in morphological and live weight measurements, facilitate rapid and continuous data production, and enhance animal welfare. Consequently, performing morphological measurements in cattle and sheep using technological methods (sensor technologies, artificial intelligence-based applications, etc.) holds significant potential for efficiency, genetic progress, and welfare-focused approaches in modern animal husbandry, while also enabling more effective and reliable herd management.

Keywords: Cattle, sheep, morphological measurements, animal welfare, artificial intelligence

1. GİRİŞ

Canlı hayvanların vücut boyutları, ekonomik çıktının belirlenmesinde kritik bir göstergedir. Manuel ölçümler, iş gücü yoğun ve zaman alıcı olup, hayvanlarda stres tepkilerine yol açabilmektedir. Bilgisayar teknolojilerindeki ilerlemelerle birlikte, hayvanların canlı vücut boyutlarını ölçme teknikleri hızla gelişmiş ve önemli araştırma başarıları elde edilmiştir (Ma et al., 2024a). Hayvancılıkta vücut konformasyonu; vücut boyutu, şekli, oranları, tüy rengi, kas konturları ve iskelet yapısını kapsayan bir hayvanın üretim performansı, sağlık durumu ve damızlık değeri için kapsamlı bir göstergedir (Alders et al., 2021; Velado-Alonso et al., 2022; Ma et al., 2024b). İdeal konformasyona sahip hayvanlar genellikle üstün büyüme potansiyeli, hastalıklara direnç ve farklı yetiştiricilik ortamlarına uyum yeteneği sergileyerek ekonomik verimlilik ve hayvan refahını artırırlar. Bu morfolojik özellikler ırk standartlarıyla uyumlu olup, hayvanın fiziksel sağlamlığı ve verimliliğinin değerlendirilmesinde kritik bir rol oynar (Velado-Alonso et al., 2022; Gutiérrez-Reinoso et al., 2023).

Çiftlik hayvanlarında vücut konformasyonu, hayvanın üretim performansını, sağlık durumunu ve damızlık değerini değerlendirmek için temel bir göstergedir. Manuel ölçümlere ve görsel puanlamaya dayanan geleneksel konformasyon değerlendirme yöntemleri yalnızca zaman alıcı ve emek yoğun değil, aynı zamanda öznel hatalara da açıktır. Bilgisayarlı görme ve yapay zekâ teknolojilerinin hızlı gelişimiyle birlikte, iki boyutlu (2D) görüntüler, üç boyutlu (3D) nokta bulutu işleme ve çok modlu veri füzyonuna dayalı yeni yaklaşımlar, otomatik konformasyon değerlendirmesi alanında araştırma odak noktaları haline gelmiştir (Yang et al., 2025). Akıllı tarımda, temassız, otomatik vücut boyutu ölçümü hayvanlar için yaygın olarak kullanılmaktadır (Weng et al., 2024).

Hayvan verisi toplama, canlı vücut boyut ölçümlerinin ilk aşamasıdır; bu aşamada sensörler, doğru ölçümler için gerekli bilgileri elde etmek amacıyla veri toplama ekipmanı olarak kullanılmaktadır. Elde edilen veriler daha sonra işlenir; bu süreçte 3B (3D) görselleştirme teknolojisi, bilgisayar grafikleri, görüntü işleme ve derin öğrenme gibi teknikler kullanılarak ölçümler doğru bir şekilde hesaplanır (Ma et al., 2024a, Tablo 1). Hayvancılık, yapay zekâ ve ileri düzey görsel izleme teknolojilerinin entegrasyonu ile büyük bir dönüşüm yaşamaktadır. Entegre derin öğrenme algoritmaları aracılığıyla platform, kulak küpesi, vücut tabanlı ve yüz tabanlı sığır tanımlama, vücut kondisyon skoru (BCS), topallık tespiti, yemleme süresi tahmini ve gerçek zamanlı konumlandırma gibi temel sağlıkla ilgili görevleri yerine getirmektedir (Moe et al., 2025)

Tablo 1. Veri toplama ekipmanlarının karşılaştırması (Peng ve ark., 2024)

İşleyiş Prensibi	Amaç	Avantaj	Dezavantajlar
Derinlik Kamerası (DC)	Görüntüdeki her noktanın kameraya olan mesafesi ve 2D görüntüdeki koordinatları kullanılarak, her noktanın üç boyutlu uzamsal koordinatlarının çıkarılması	Belirli bir alandaki derinlik mesafesini ve uzamsal koordinat bilgisini yakalamak	Hızlı işlem süreleri, uzamsal koordinatlar
3D Tarama	Bir nesnenin uzamsal dış yapısı, yapısı ve renklerinin taranması; nesnenin yüzeyindeki uzamsal koordinatlar	Nesnenin geometrik yüzeyinin yüksek hassasiyetli nokta bulutu temsili	Yüksek doğruluklu uzamsal koordinatlar
2D RGB Kamera (2RC)	Optik görüntüleme prensiplerini kullanarak görüntü oluşturma	Optik görüntüleri elektronik sensörlerle elektronik verilere dönüştürür	Hızlı işlem süreleri, küçük veri setleri

Bilgisayarla görme sistemleri, süt sığırcılığında hayvan tanıma, davranış izleme, yem tüketiminin takibi, vücut ağırlığının tahmini ve hastalıkların tespiti gibi çeşitli uygulamalarda etkin biçimde kullanılmaktadır (Menezes et al., 2024).

Morfolojik ölçümler, hayvanların büyüme performansının izlenmesi, ırk tanımlaması, genetik seleksiyon ve verim üretim tahmini açısından belirleyici öneme sahiptir. Düzenli olarak yapılan ölçümler, hayvanların gelişim aşamalarını takip etmeyi, sürü yönetimi beslenme ve sağlık yönetimini iyileştirmeyi sağlar. Bununla birlikte, geleneksel ölçüm yöntemleri zaman alıcıdır, insan hatasına açıktır ve büyük sürülerde uygulanması zordur. Temassız insan müdahalesi olmadan gelişen teknolojiler ise bu dezavantajları azaltarak hızlı, objektif, sürekli ve doğru veri üretimi sağlar. Hayvana temas olmadan gerçekleştirilen morfolojik ölçümler, modern hayvancılıkta giderek önem kazanmaktadır. Temassız ölçüm yöntemleri sayesinde hem hayvanlara stres uygulanmaz hem de ölçüm sırasında güvenlik riski azalır. Ayrıca bu yöntemler, insan kaynaklı hataları en aza indirerek veri toplamada yüksek doğruluk ve tekrar edilebilirlik sağlar. Bu çalışmanın amacı, büyükbaş ve küçükbaş hayvanlarda morfolojik ölçümlerin görüntüleme, sensör ve yapay zekâ tabanlı teknolojiler kullanılarak gerçekleştirilmesinin avantajlarını, uygulama yöntemlerini ve hayvan refahına katkılarını incelemektir.

2. BÜYÜKBAŞ HAYVANLARDA MORFOLOJİK ÖLÇÜMLERDE GELİŞEN TEKNOLOJİK YENİLİKLER

Büyükbaş hayvanlarda vücut ölçümleri ve ağırlık tahmini, sürü yönetimi, besleme stratejilerinin optimize edilmesi ve hayvan refahının izlenmesi açısından kritik öneme sahiptir (De Oliveira et al., 2025; Xu et al., 2024). Geleneksel tartım ve fiziksel ölçüm yöntemleri emek yoğun ve invaziv olabilir; ayrıca anlık ve temassız veri toplama imkânı sunmazlar. Bu nedenle, bilgisayarlı görü, makine öğrenimi ve 3D görüntüleme sistemleri gibi teknolojik yaklaşımlar giderek önem kazanmaktadır.

Bilgisayarlı görme, hayvan sağlığı, davranışı ve verimliliğinin otomatik ve temas gerektirmeyen şekilde izlenmesini sağlayarak süt çiftçiliği yönetim alanını hızla dönüştürmektedir sığır tanımlama ve izleme, beslenme ve ruminasyon davranışlarının değerlendirilmesi, vücut kondisyon skoru, topallık ve yatma davranışı, mastitis ve süt verimi ile sosyal davranış ve östrus yer almaktadır. Son çalışmaların bulgularının sentezi ile bilgisayarlı görme sistemlerinin hayvan refahını iyileştirmeye ve verimlilik ile üreme performansını artırmaya nasıl katkıda bulunmaktadır (Antognoli et al., 2025). Sığırlarda morfolojik özelliklerin ve et verimliliğinin değerlendirilmesinde ultrasonik ve optik ölçümler büyük önem taşımaktadır. Bu teknikler; deri altı yağ kalınlığı, göz kası alanı ve etin mermerleşme derecesi gibi çeşitli parametreler hakkında doğru ve objektif verilerin toplanmasına imkân tanımaktadır. Elde edilen bilgiler, sığır endüstrisinde verimliliğin ve rekabet gücünün artırılmasına katkı sağlamaktadır (Ruchay et al., 2025).

Xu ve ark. (2024), semantik segmentasyon ve geri yayılım (BP) yapay sinir ağına dayalı bir akıllı yaklaşım sunmuştur. Önerilen model, ResNet-101-D ile Sıkıştırma–Uyarma (SE) dikkat mekanizmasını birleştirerek ineklerin görüntülerinden hassas morfolojik veriler çıkarmakta ve bunları regresyon tabanlı modellerle ağırlık tahmini için kullanmaktadır. BP yapay sinir ağı, 13,11 pound MAE ve 22,73 pound RMSE ile en iyi sonuçları göstermiştir. Bu yaklaşım, fiziksel temasa duyulan ihtiyacı ortadan kaldırarak hem hayvan refahını artırmakta hem de riskleri azaltmaktadır. De Oliveira ve ark. (2025), Holstein ineklerinde dorsal uzunluk, göğüs genişliği ve abdominal çevre gibi morfometrik verileri kullanarak yapay sinir ağları (ANN) ve Destek Vektör Regresyonu (SVR) modellerinin performansını karşılaştırmıştır. ANN en yüksek doğruluk (R^2 = 0,9125, RMSE = 25,86 kg) sağlarken, SVR ve çoklu regresyon modelleri de yüksek doğruluk göstermiştir. Bulgular, kompleks makine öğrenimi modellerinin saha

uygulamalarında daha doğru tahminler sağlarken, basit modellerin pratik kullanım açısından hâlâ değerli olduğunu ortaya koymaktadır. Alempijevic ve ark. (2025), çoklu kameraya sahip 3B görüntüleme sistemlerini işleme hattına entegre ederek sığırların kalça yüksekliği ve karkas ağırlığını tahmin etmiş, bu sistem farklı uzunluk ve ırklardaki sığırlarla etkili şekilde çalışmakta ve saha koşullarında uygulanabilirliği yüksek sonuçlar vermektedir. Bu tür sistemler, hayvancılıkta veri toplama ve sürü izleme süreçlerini otomatikleştirerek hassas tarım uygulamalarına olanak tanımaktadır. Lewis ve ark. (2025) tarafından yapılan çalışmada, 2B görüntüleme ve derin öğrenme algoritmaları kullanılarak üç kamera perspektifiyle (ön, arka, üst) vücut kondisyon skoru değerlendirilmiştir. Arka görüş açısı, en yüksek sınıflandırma doğruluğunu elde etmiş ve kritik morfolojik özelliklerin en iyi şekilde elde edildiğini göstermiştir. Bu yaklaşım, küçük ve orta ölçekli çiftlikler için ekonomik bir alternatif sunmakta ve sürekli izleme ile erken sağlık teşhisini mümkün kılmaktadır. Kaya ve Bardakçıoğlu (2021), laktasyondaki ineklerin vücut ağırlığı ve vücut kondisyon skorunu dijital görüntü analiz yöntemleri kullanılarak tahmin etmeye çalıştıkları çalışmalarında cidago yüksekliği, vücut uzunluğu ve kalça genişliği gibi ölçümleri ele almışlar ve çalışmacılar dijital görüntü analiz yönteminin güvenilir bir yöntem olduğunu bildirmişlerdir. Hayvan konformasyonu; vücut şekli, kas gelişimi, iskelet yapısı ve uzuv dengesi gibi morfolojik özellikleri kapsar. Bilgisayarla görme tabanlı konformasyon değerlendirme yöntemleri, 2D görüntüler ve 3D nokta bulutu verilerini entegre ederek kapsamlı bir analiz olanağı sunmaktadır. Makine öğrenmesi ve derin öğrenme algoritmaları sayesinde bu veriler, otomatik, hızlı ve objektif değerlendirmeler için kullanılmaktadır (Yang et al., 2025).

Son yıllarda yapılan çalışmalar, bilgisayarla görme ve derin öğrenme tabanlı modellerin, büyükbaş hayvanların morfolojik ölçümlerinin ve vücut ağırlığı tahminlerinin doğruluğunu önemli ölçüde artırdığını göstermektedir. Bu yaklaşımlar, fiziksel ölçüm ihtiyacını ortadan kaldırarak hayvan refahını iyileştirmekte, veri toplama süreçlerini otomatikleştirmekte ve hassas hayvancılık uygulamalarının yaygınlaşmasına katkı sağlamaktadır.

3. KÜÇÜKBAŞ HAYVANLARDA MORFOLOJİK ÖLÇÜMLERDE GELİŞEN TEKNOLOJİK YENİLİKLER

Koyun yetiştiriciliğinde doğum, üreme, ağırlık ve vücut kondisyonu gibi kritik biyolojik süreçlerin izlenmesi hem hayvan refahı hem de üretkenlik açısından büyük önem taşır. Geleneksel yöntemler, fiziksel ölçümler ve gözlem temelli kayıtlarla sınırlıdır; bu durum zaman alıcı, maliyetli ve hayvanlarda stres yaratıcıdır. Modern teknolojiler, insan müdahalesi olmayan sensörler, video tabanlı sistemler ve yapay zekâ algoritmaları kullanılarak bu süreçleri daha etkin objektif ve güvenilir bir şekilde izleme veri sağlama olanağı sunmaktadır.

Geleneksel koyun tartımı ve ölçümü invaziv, stresli ve işgücü yoğun yöntemlerdir. Bilgisayarla görme ve yapay zekâ teknikleri kullanılarak geliştirilmiş sistemler, invaziv olmayan ağırlık tahmini ve vücut ölçümüne imkân tanımaktadır. Microsoft Kinect V2 sensörü ve derin öğrenme modelleri (EfficientNetB3, DenseNet169, CNN) kullanılarak yapılan çalışmalarda, RMSE 3,44 kg ve R^2 0,90 ile yüksek doğruluk elde edilmiştir (Marques et al., 2025). Ayrıca, 3D nokta bulutu yeniden yapılandırma teknikleriyle koyun vücut ölçümleri invaziv olmadan ve yüksek doğrulukla sağlanabilmektedir; vücut uzunluğu için hata oranı %0,79'dur (Liang et al., 2024). Yapay zekâ tabanlı sistemler, koyunların üreme davranışlarını takip ederek damızlık seçiminde önemli katkılar sağlamaktadır. Kameralar, giyilebilir sensörler ve makine öğrenmesi algoritmaları ile kızgınlık, doğum ve maternal bakım gibi davranışlar belirlenebilmekte; bu sayede yetiştiriciler, daha bilinçli ve veri odaklı seçimler yapabilmektedir. Önerilen ReproBehaviorNet modeli, davranışsal verileri biyolojik işlevler ve YZ süreçleriyle ilişkilendirerek hem yoğun hem de yarı-yoğun sistemlerde karar desteği sunmaktadır (Emsen et al., 2025).

Hayvan davranışlarının müdahalesiz olarak izlenmesi, AnimalFormer gibi çok modlu yapay zekâ çerçeveleriyle mümkün hale gelmiştir. Bu sistemler, video ve sensör verilerini birleştirerek otlama, koşma, oturma ve yürüme gibi aktiviteleri ayrıntılı olarak analiz etmektedir. Böylece hayvan refahı ve üretkenlik optimize edilmekte, veri odaklı yönetim desteklenmektedir (Qazi et al., 2024). Ayrıca, TinyML tabanlı mikrodenetleyici sistemleri ile düşük gecikme süresi ve internet bağımsız çalışabilen otomatik izleme çözümleri geliştirilmiştir (Zhang & Kanjo, 2025).

Modern teknolojiler ve yapay zekâ destekli sistemler, koyun yetiştiriciliğinde sürü izleme doğum tespiti, üreme takibi, ağırlık ölçümü, vücut kondisyonu ve davranış analizi gibi önemli hayvan yetiştirme süreçlerin izlenmesini daha etkin, verilerin doğru objektif sürekli güvenilir ve hatasız odaklı hale getirmektedir. Bu yöntemler, hayvan refahını artırmak, işgücü maliyetlerini azaltmak ve sürü performansını optimize etmek için büyük potansiyel sunmaktadır. Gelişen teknolojik dönüşümle üretim sistemlerinde bu teknolojilerin ölçeklenebilir ve kapsayıcı şekilde uygulanması, sürdürülebilir ve verimli hayvancılığa katkı sağlayacaktır.

SONUÇ VE ÖNERİLER

Hayvancılıkta gelişen teknolojiler ve yapay zekâ entegrasyonu büyükbaş ve küçükbaş hayvancılıkta hayvan verilerinin temassız objektif ve doğru bir şekilde toplanmasını mümkün kılmaktadır. Bilgisayarlı görme, 3D görüntüleme, sensörler makine öğrenim sistemleri ve yapay zekâ algoritmaları ile desteklenmiş morfolojik ölçümler, ağırlık tahmini, vücut kondisyon skoru, topallık ve hastalık tespiti gibi önemli parametreler güvenilir biçimde izlenebilmektedir. Bu yaklaşımlar, geleneksel tartım ve fiziksel ölçüm yöntemlerinin işgücü yoğunluğu ve hayvana stres yaratma sorunlarını ortadan kaldırmakta, sürü yönetimi, besleme stratejileri üreme takibini ve hayvan refahını iyileştirmektedir Ayrıca, insan müdahalesi ve temassız ve veri odaklı izleme yöntemleri, hayvan refahını artırmakta, üretim verimliliğini yükseltmekte ve sürdürülebilir hayvancılık uygulamalarına katkı sağlamaktadır.

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ANALYSIS OF CUSTOMER LOYALTY ON SERVICE QUALITY ON INDONESIAN AIRLINES INDUSTRY

Jean Richard Jokhu[1*]

Sulthan Nahrawi Sinurat[1]

[1] President University

ABSTRACT

This research aims to analyze the effect of service quality on customer loyalty at Lion Air, focusing on Indonesians who are part of the millennial generation and reside in the Jabodetabek area. This study used quantitative research methods, with data collected through online questionnaires distributed to 120 respondents who have used Lion Air services. Data analysis was conducted using SPSS (Statistical Package for Social Science) software, employing multiple linear regression analysis. The results showed that service quality had a positive and significant impact on customer loyalty. These findings suggest that improving service quality could foster greater customer loyalty for Lion Air.

Keywords: service quality, customer loyalty, millennial, airlines

INTRODUCTION

Indonesia is a maritime country consisting of islands stretching from Sabang to Merauke, with a total of 17,508 islands (Sahara & Pradana, 2021). For a country that consists of many islands like Indonesia, good transport connectivity is needed. The function of good inter-island connectivity is to increase access between islands to make them easier to reach, as well as develop tourism activities, education and easy access to health equipment (Ghifari & Ahyudanari, 2021). Transport is an important means for society to facilitate the mobility of people and goods. Transport is the movement of people or goods by using tools or vehicles from geographically separated places (Steenbrink, 1974). Companies in the transport sector play an important role in meeting the mobility and distribution needs of goods, making them a key element in supporting economic growth and social activity amid increasing global mobility (Paminto, 2020). Air transport is one of the most important means of transport in Indonesia to connect from one region to another.

According to Law No. 1/2009 on Aviation, aviation is a unity consisting of the use of airspace, aircraft, airports, air transport, flight navigation, safety and security, the environment, as well as supporting facilities and other public facilities. Air transport has become an important component in the progress and growth of a country (Susanto & Keke, 2020). Aircraft are an efficient means of air transport for transporting goods and people at a much higher speed than other means of transport (Suprianto, 2020). In Indonesia, air transport plays a key role in connecting geographically separated islands, encouraging tourism, trade, and investment, and facilitating interregional mobility and exchange (Ayuningtyas, 2023). Data from the *Badan Pusat Statistik* (2024) shows that in July 2024, the number of domestic air passengers reached 6 million people, an increase of 11.04 per cent compared to the previous month. This increase is evident at major airports, as listed in Table 1.1 below:

Table 1.1 Number of Domestic Passengers at Major Airports

Airport	**Number of Passengers**		**Percentage Increase**
	Juni 2024	**Juli 2024**	
Soekarno-Hatta	1,584,802	1,767,891	11.55%
Juanda	448,073	519,012	15.82%
Ngurah Rai	395.723	456,189	15.29%
Kualanamu	190,287	216,423	13.72%
Hasanuddin	234.091	279,344	19.46%

Source: Badan Pusat Statistik, 2024 processed by researcher

Table 1.1 shows Soekarno-Hatta Airport recorded the highest number of domestic passengers at 1,767,891 people, which contributed 29.28 per cent of the total passengers. Juanda Airport in Surabaya recorded 519,012 passengers (8.60 per cent), Ngurah Rai in Denpasar 456,189 passengers (7.60 per cent), Kualanamu in Medan 216,423 passengers (3.61 per cent), and Hasanuddin in Makassar 279,344 passengers (4.65 per cent). This data reinforces the importance of air transport in supporting social and economic activities in Indonesia. In addition, a report from Angkasa Pura II (2024) added that the number of passengers at Soekarno-Hatta Airport in Semester I/2024 reached 26 million passengers, an increase of 6 per cent compared to the same period in 2023 and 2 per cent higher than 2019 before the pandemic. Overall, the 20 airports managed by Angkasa Pura II recorded a total of 40.05 million passengers in H1/2024, demonstrating the post-pandemic recovery and the important role of air

transport in economic growth. Airlines, including Lion Air, serve as key providers of air transport services that support inter-regional mobility and economic growth (Darmawan et al., 2023). With increasing passenger numbers at major airports, air transport is increasingly becoming a key pillar in supporting connectivity in an archipelago like Indonesia, while facilitating the growth of other important sectors such as tourism and trade (Yauwwarin & Siwabessy, 2023).

According to the information contained on the "*Cerita Kami*" page of Lion Air's official website (n.d.), Lion Air is a subsidiary of PT Langit Esa Oktagon (PT LEO Group) which is part of the wider Lion Group. Meanwhile, according to the "Our Network" page as a leading domestic airline and disciplined low-cost carrier, Lion Air offers flights to value-conscious customers that focus on price, flight frequency, and an extensive route network throughout Indonesia. As the largest airline company in Indonesia, Lion Air plays an important role in connecting passengers across Indonesia and to destinations in Asia. Indonesia, characterised as an archipelago, relies heavily on air transport, and Lion Air is able to fulfil that need with its extensive route network. (Lion Air, n.d.).

According to the "*Jaringan Kami*" page on Lion Air's official website (n.d.), as of September 2019, Lion Air operates an average of 449 flights daily on 269 scheduled and 211 chartered routes to 41 domestic and 20 international destinations. The airline is the sole service provider on 109 routes and has a market share of more than 50 per cent on 106 other routes based on total capacity. Collaboration with airlines such as Batik, Wings, Malindo, and ThaiLion enables Lion Air to offer an additional 694 routes and 157 destinations through interline arrangements. Lion Air's hub-and-spoke strategy optimises the route network to serve demand from smaller cities and remote areas to larger destinations, supporting business growth and growing passenger demand (Lion Air, n.d.). Recent data from OAG Aviation Worldwide Limited (2024) shows that Lion Air remains the largest airline in Southeast Asia with 3,159,818 seats, accounting for 9% of regional flight capacity. Compare this to AirAsia, which has a 7% market share, and Vietnam Airlines, which experienced the largest drop in capacity. The following table details the seat capacity of major airlines in Southeast Asia as of September 2024:

Table 1 Airline Seat Capacity Market Share in Southeast Asia (September 2024)

Airlines	**Seat Capacity (September 2024)**
Lion Air	3,159,818
AirAsia	2,558,652
Vietnam Airlines	1,901,415
Vietjet Air	1,892,815
Cebu Pacific	1,817,555
Singapore Airlines	1,642,282
Batik Air	1,623,600
Super Air Jet	1,548,360
Thai AirAsia	1,467,854
Philippine Airlines	1,330,224

This data emphasises Lion Air's strategic role in the Southeast Asian aviation market, demonstrating the airline's dominance in seat capacity and extensive route network. With its

market-leading position, Lion Air contributes significantly to air connectivity in Indonesia, supporting economic growth and strengthening its role in providing domestic and international air services that are essential to mobility and economic activity in the archipelago.

Along with the rapid development of technology and increasing community mobility, the need for efficient and quality transportation services is also increasing (Luwihono, Peranginangin, & Makanuay, 2020). Current globalisation technology requires companies to increase competitiveness in order to survive in fierce competition (Kirana, 2024). A significant increase in competition in the service industry is evident in recent years (Jokhu & Arnold, 2018). Service companies need to innovate to meet the needs of efficient and quality transportation services, and pay attention to customer comfort and safety (Luwihono, Peranginangin, & Makanuay, 2020). The company's ability to provide quality service is a key success factor (Jokhu & Armando, 2019). Service quality is a cognitive evaluation of consumers when receiving a product or service (Kotler & Keller, 2016). Good service results in consumer satisfaction and increases repurchase tendencies (Tufahati et al., 2021; Fared et al., 2021) Service quality includes various company activities to meet consumer expectations (Berinyuy, 2021). Service includes convenience, speed, relationship, ability, and hospitality, all of which aim for customer satisfaction (Saleh, 2024).

Service quality is a service concept that companies can rely on to maintain their reputation in the midst of fierce competition (Esmaeilpour et al., 2017). According to Zeithaml and Parasuraman (2004), there are five important dimensions of service quality: tangibles, reliability, responsiveness, assurance, and empathy. These dimensions include aspects such as tangibles, which refer to physical evidence such as buildings, equipment, and technology used by the company; reliability, which is the company's ability to deliver services as promised; responsiveness, which describes the speed of the company's response to customer complaints; assurance, which includes the ability of employees to build trust through attitude and knowledge; and empathy, which includes personal and sincere attention to customers. According to Sugiarto and Octaviana (2021), these five dimensions have a significant influence on customer satisfaction. In this study, the Servqual dimensions are applied to Lion Air employees. Tangibles reflect their ability to provide comfort through aircraft appearance and facilities. Reliability describes Lion Air's ability to deliver services as promised and maintain consistency for all passengers. Responsiveness is seen from the alertness of employees in providing fast and accurate services. Assurance relates to the attitude and knowledge of employees that builds passenger trust, while Empathy is reflected in genuine concern and understanding of customer needs.

Consumer loyalty is a form of service user or customer loyalty in continuing to use the product or service offered because of the satisfaction obtained, which often encourages them to recommend the product or service to others so that they can also experience similar satisfaction (Odem and Wakhidah, 2023). In addition, consumer loyalty can also be defined as the formation of consumer attitudes and behaviour towards product use resulting from previous consumption experiences (Karim et al., 2021 ; Ertemel, 2021). Both of these definitions emphasise that loyalty is formed from ongoing positive experiences and can influence consumers' decisions to continue using and promoting the product or service to others.

If consumers feel they have benefited from previous purchases, this indicates that they are likely to make repeat purchases. Loyalty is formed through four stages: cognitive loyalty (based on awareness), affective loyalty (based on feelings or emotions), cognitive loyalty (based on commitment to action), and action loyalty (which is realised in the form of concrete actions). This process begins with a strong motivation to overcome obstacles, such as loyalty actions (Qi & Ariffin, 2022). There is a close link between customer satisfaction and long-term loyalty,

where high-quality services that meet or exceed expectations can create a positive cycle, with ongoing satisfaction driving customer loyalty, strengthening mutually beneficial relationships, and encouraging them to remain loyal and recommend the service to others (Umatin et al., 2024). In Lion Air's operational context, customer loyalty is critical as it creates a stable customer base, enhances brand image and generates positive reviews that attract new customers. Therefore, improving service quality is a key strategy for Lion Air in an effort to increase customer loyalty and maintain its position in the competitive aviation industry.

In the airline industry, service quality plays an important role in shaping customer loyalty. As one of the largest airlines in Indonesia, Lion Air faces the same challenge. The quality of service provided will have a direct impact on customer loyalty. Therefore, understanding the relationship between service quality and customer loyalty is key for Lion Air to maintain and increase its market share. This study aims to analyse the extent to which Lion Air's service quality affects customer loyalty, and is expected to make a significant contribution to the literature on service management and customer loyalty in the airline industry, particularly in the context of Lion Air.

METHOD

This research uses quantitative methods to analyse the data needed (Firmansyah et al., 2021). This method was chosen because it allows researchers to numerically measure the level of service quality and customer loyalty. By using this method, researchers can collect data on customer perceptions of service quality and the level of customer loyalty to Lion Air. Statistical data analysis will be used to describe the relationship between service quality and customer loyalty in detail.Method This research uses a descriptive approach to describe the relationship between service quality and customer loyalty at Lion Air. This approach aims to identify factors that influence customer loyalty based on customer perceptions of the quality of service provided by the airline. By analysing descriptively, this research will describe in detail the quality of service provided by Lion Air and the extent to which it affects customer loyalty.

Table 1 Instrument/Operational Definition

No.	Variables	Definitions	Code	Statement	Source
1	Tangible (X1)	According to Tjiptono (1996) tangible is physical evidence of services, it can be in the form of physical equipment used, physical representation of services.	X1.1	Lion Air has modern and up-to-date equipment.	(Gabrielle and Harjati (2019).
			X1.2	Lion Air has modern and up-to-date facilities.	
			X1.3	Lion Air has a modern and up-to-date fleet of aircraft.	
			X1.4	Lion Air's stewards and flight attendants are well-groomed and professional.	

			X1.5	The facilities used by Lion Air to serve passengers are always in good condition.	
			X1.6	The equipment used by Lion Air to serve passengers is always in good condition.	
2	Reliability (X2)	By definition reliability in Tjiptono (1997) is the ability to provide the promised service quickly, accurately, and satisfactorily.	X2.1	Lion Air provides the service as promised.	(Gabrielle and Harjati (2019).
			X2.2	Lion Air is reliable when it comes to handling passenger issues.	
			X2.3	Lion Air's flight schedules are always on time.	
			X2.4	Lion Air is knowledgeable in answering passengers' questions.	
			X1.5	The facilities used by Lion Air to serve passengers are always in good condition.	
			X1.6	The equipment used by Lion Air to serve passengers is always in good condition.	
3	Responsiveness (X3)	According to Tjiptono (1996) responsiveness is the desire of staff to help customers and provide services responsively.	X3.1	Lion Air is always willing to help passengers.	Gabrielle and Harjati (2019).
			X3.2	Lion Air always provides fast service.	
			X3.3	Lion Air is always ready to handle	

				passenger requests.	
			X3.4	Lion Air is ready to provide solutions for every passenger's questions and complaints.	
4	Assurance (X4)	According to Kotler (1997) assurance is the knowledge and courtesy of employees, and the ability to gain trust and confidence.	X4.1	Lion Air is able to instill confidence in passengers.	Gabrielle and Harjati (2019).
			X4.2	Passengers feel safe when traveling with Lion Air.	
			X4.3	Lion Air has always been consistently polite with passengers.	
5	Empathy (X5)	According to Tjiptono (1996) empathy is the ease of making relationships, good communication, personal attention, and understanding the needs of customers.	X5.1	Lion Air that pays attention to passengers.	Gabrielle and Harjati (2019).
			X5.2	Lion Air understands the needs of passengers.	
			X5.3	Lion Air has a caring attitude when serving passengers.	
			X5.4	The interests of passengers always come first for Lion Air.	
6	Customer Loyalty (Y)	According to Arzena (2013), customer loyalty is the attitude of customers who honestly feel satisfaction from the purchase of products or services offered by producers or sellers, so that they will buy these	Y.1	I will use Lion Air again.	Gabrielle and Harjati (2019).
			Y.2	I will continue to use Lion Air and not switch to another airline.	
			Y.3	I would recommend Lion Air to my friends and family.	

		products repeatedly and create long-term relationships.			

RESULTS

The results, out of 120 respondents, 63 (52,5%) were male, 47 (47,5 %) were female. Most respondents 55 (45.8%) were live in Jakarta, 19 (15.8%) from Bogor, 14 (11.7%) from Depok, 15 (12.5%) from Tangerang, and 17 (14.2%) from Bekasi. SPSS was used to analyze the results. Several test particularly related to reliability, validity, and regression were measured using multiple regression approach.

The validity test serves to measure an item or statement item that is made is correct or not. The questionnaire used in this study consisted of 24 statement items. Testing to determine whether it is valid or not by comparing the value of r count and r table (Puspasari & Puspita, 2022). If, r count> r table then the statement item is said to be valid. To get the value of r table can be seen in the frequency distribution table r, so that df (n-2 = 120) on a two-way test with a significance level of 0.05 obtained the value of r table 0.177.

The reliability test was carried out on the question items in the questionnaire which had been declared valid. This test is used to test whether the measuring instrument used is consistent or not if repeated measurements are made. (Erida, 2021). Statement items are considered reliable if the Cronbach Alpha value is> 0.60. The following are the results obtained from the reliability test:

Table 2 Reliability Test

No.	Variable	*Cronbach Alpha*	Keterangan
1.	Tangible (X1)	0.897	Reliabel
2.	Reliability (X2)	0.700	Reliabel
3.	Responsiveness (X3)	0.799	Reliabel
4.	Assurance (X4)	0.807	Reliabel
5.	Empathy (X5)	0.861	Reliabel
6.	Customer loyalty (Y)	0.775	Reliabel

Based on the table above, it shows that the Cronbach Alpha value of X1, X2, X3, X4, X5 and Y> 0.60, so that the research instruments of all variables used have been tested for reliability and declared reliable or reliable to be used as a variable measuring instrument.

Table 3 T-test

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	.429	.624		.688	.493
1Tangible	.074	.030	.159	2.470	.015
Reliability	.150	.055	.200	2.741	.007

Responsiveness	.294	.068	.384	4.335	.000
Assurance	.063	.085	.067	.746	.457
Empathy	.131	.064	.177	2.040	.044

a. Dependent Variable: Customer Loyalty

Based on the results of the T test that has been carried out on a number of research data, the following results are obtained.

a. Partially, the t value of the tangible variable (X1) is 2.470 which is greater than the t table, namely 1.980 with a significance value of 0.015 <0.05. With these results it can be stated that the hypothesis is accepted, namely tangible has an influence on the overall regression model. So, when there is an increase in the tangible variable, it can affect the customer loyalty variable.

b. Partially, the reliability variable (X2) obtained a t value of 2.741 which is greater than the t table, namely 1.980 with a significance value of 0.007 <0.05. With these results it can be stated that the hypothesis is accepted, namely reliability has an effect on customer loyalty. So, the reliability variable has an influence on the entire regression model, so that when there is an increase in the reliability variable, it can affect the customer loyalty variable.

c. Partially, the t value of the responsiveness variable (X3) is 4.335 which is greater than the t table, namely 1.980 with a significance value of 0.000 <0.05. With these results it can be stated that the hypothesis is accepted, namely responsiveness has an influence on the overall regression model. So, when there is an increase in the responsiveness variable, it can affect the customer loyalty variable.

d. Partially, the assurance variable (X4) obtained a t value of 0.746 which is smaller than the t table, namely 1.980 with a significance value of 0.457> 0.05. With these results it can be stated that the hypothesis is not accepted, namely assurance has no effect on customer loyalty. So, the assurance variable has no influence on the overall regression model, so that when there is an increase in the assurance variable, it cannot affect the customer loyalty variable.

e. Partially, the t value of the empathy variable (X5) is 2.0440 which is greater than the t table, namely 1.980 with a significance value of 0.044 <0.05. With these results it can be stated that the hypothesis is accepted, namely empathy has an influence on the overall regression model. So, when there is an increase in the empathy variable, it can affect the customer loyalty variable.

Table 4 Coefficient of Determination (R^2) Result

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.857[a]	.735	.724	1.235

a. Predictors: (Constant), Tangible, Reliability, Responsiveness, Assurance, Empathy

Based on the results of the data table above, the Adjusted R Square (R^2) is 0.724. This result shows that only 72.4% of tangible, reliability, responsiveness, assurance, and empathy variables

affect customer loyalty. While the remaining 27.6% is influenced by factors other than tangible, reliability, responsiveness, assurance, and empathy. This means that there are still many other things outside of this study that affect customer loyalty, namely as much as 27.6%. Because respondents do not only consider these variables, so there are other factors outside this study.

Conclusion

Researchers tested service quality on Customer Loyalty. This research was conducted on customers who have used Lion Air airlines. The number of respondents or samples used in this study were 120 people. The conclusions in this study include:

This study analyses the influence of various dimensions of service quality, such as Tangible (X1), Reliability (X2), Responsiveness (X3), Assurance (X4), and Empathy (X5), on Lion Air's customer loyalty. The results show that Tangible, which includes the physical aspects of service, as well as Reliability, which reflects service consistency, have a positive and significant effect on customer loyalty. Responsiveness, which relates to the airline's speed and readiness to respond to customer needs, proved to have the greatest and most significant influence compared to other variables. Meanwhile, Assurance, which relates to the sense of security and confidence provided by staff, did not show a significant effect. Empathy, which reflects personal attention to customers, also had a positive and significant effect on loyalty. Overall, the findings confirm that Responsiveness is the key factor in building Lion Air's customer loyalty, followed by Tangible, Reliability, and Empathy, while Assurance has no significant impact..

The results obtained in the following study show that the variables tangible, reliability, responsiveness, and empathy have a significant influence on customer loyalty. The impact of policies that can be understood from the acquisition of this data is that it is important to improve the quality of services that can be felt by customers, then act swiftly on what they need. Companies need to ensure that these various elements continuously receive attention to their strategies for providing optimal service to customers.

Meanwhile, the assurance variable did not significantly influence customer loyalty using the regression model. This finding indicates an important additional focus on advancing and refining service strategies to strengthen customers' trust in the product. Further detailed approaches need to be taken to foster customer confidence, by implementing increasingly transparent and personalised interaction strategies, in order to increase customer loyalty levels.

To conclude, this study provides important insights into the influence of service quality on Lion Air's customer loyalty. With Responsiveness as the main factor influencing loyalty, followed by Tangible, Reliability and Empathy, the company is advised to continue improving these aspects in their service strategy. Although Assurance did not show a significant influence, this opens up opportunities for companies to develop more effective approaches to building customer security and trust. The implementation of more transparent and personalised interactions can be an important step in strengthening trust and increasing loyalty. This study also provides a foundation for future research to further explore other variables that may affect customer loyalty in the increasingly competitive airline industry.

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COLONIAL LAND POLICIES AND RURAL TRANSFORMATION IN COCHINCHINA (LATE 19TH - EARLY 20TH CENTURY)

M.A. Dinh Hong Khoa
Dong Thap University
Email: dhkhoa@dthu.edu.vn
ORCID: 0009-0007-4089-313X

ABSTRACT

This study examines the impact of French colonial land policies on the transformation of Cochinchina's rural economy and society from the late 19th to the early 20th century. Through the analysis of colonial decrees, cadastral records, and archival reports, the paper investigates how land concessions, privatization, and taxation mechanisms enabled the concentration of land in the hands of French landowners and segments of the Vietnamese elite. While colonial authorities promoted plantation capitalism, a dual structure emerged. Some French rural settlers, lacking capital, practiced traditional farming methods with buffalo-drawn plows and tenant labor-indicating a form of reverse acculturation. Simultaneously, many Vietnamese landowning families underwent internal transitions: their French-educated descendants adopted capitalist land management models, leasing lands, investing in rice mills, or participating in export-oriented agriculture. These shifts reshaped class relations in rural Cochinchina, fostering social inequality and generating early forms of peasant resistance. The study argues that colonial land policies not only transformed the rural landscape economically but also laid the foundation for political unrest and anti-colonial mobilization in southern Vietnam.

Keywords: Cochinchina, colonial land policy, rural transformation, land tenure, plantation capitalism, tenant farming, peasant resistance.

1. INTRODUCTION

The transformation of rural Cochinchina under French colonial rule (late 19th - early 20th centuries) reflects a deliberate restructuring of land relations designed to serve both economic extraction and territorial control. As the first territory fully integrated into the French empire in Indochina (1862), Cochinchina functioned as a "colonial laboratory" where land policies were experimented with as instruments for regulating social relations and reorganizing production space. Through a series of decrees, cadastral surveys, and concession regimes, the colonial administration redefined communal tenure, institutionalized private ownership, and transferred the most fertile lands to French investors and their indigenous collaborators.

Two interrelated mechanisms structured this process: legal normalization and economic reorganization. The decrees of November 11, 1878, and December 20, 1899, codified the notion of "vacant" lands and formalized exclusive proprietary rights, while the establishment of the Crédit foncier de l'Indochine provided the financial infrastructure necessary for large-scale agrarian ventures. This system simultaneously expanded commercial agriculture and bound rural Cochinchina to the circuits of colonial credit, embedding extraction within a broader network of financial dependency between metropole and colony.

Grounded in dependency theory and colonial political economy, this study interprets land policy not merely as an administrative mechanism but as a structural form of power through which the empire reproduced asymmetrical relations between core and periphery. From this perspective, land operated as both a productive resource and an instrument of spatial domination, where cadastral mapping, credit institutions, and legal reforms converged as interlocking technologies of control and accumulation. Such a framework illuminates how French colonial land policies reshaped the spatial organization of rural Cochinchina, intensified land concentration and social inequality, and generated new patterns of peasant displacement, resistance, and adaptation.

The dissolution of communal property and the rise of absentee landlordism profoundly transformed rural society. A small stratum of indigenous elites aligned with the colonial administration to consolidate land ownership, while the majority of peasants were relegated to tenancy and dependency. The Procès-verbaux du Conseil colonial (1901-1933) and related administrative reports reveal this dual process of state centralization and rural marginalization, which laid the foundations for latent forms of protest and negotiation within the colonial countryside.

By adopting an interdisciplinary approach and drawing upon French archival sources, colonial council minutes, and modern scholarship (Le, 2020; Son Nam, 2009; Merette, 2013), this paper seeks to elucidate the spatial logic of colonial power. It demonstrates how land governance operated as both an economic and political project one that reconfigured social hierarchies and incorporated Cochinchina into the global capitalist world-economy. In doing so, the study contributes to a deeper understanding of the dynamic interplay between land, space, and power in colonial contexts, positioning Cochinchina not merely as a passive periphery but as an active, structured site within the imperial system where extraction, inequality, and indigenous agency coexisted in complex and contested ways.

2. THEORETICAL FRAMEWORK AND METHODOLOGY

2.1. Theoretical Framework

This paper draws on the theoretical lens of colonial political economy and space-based governance to examine how colonial land policies functioned as instruments of domination and transformation in Cochinchina. Following the works of scholars such as Pierre Brocheux (1995) and David G. Marr (1981), the study views the land not only as an economic asset but also as a

tool for restructuring native society, asserting control over labor, and reconfiguring spatial relations to benefit the colonial power.

The study also integrates insights from dependency theory, particularly in the context of peripheral economies being reshaped to serve the core (France), as argued by André Gunder Frank and Immanuel Wallerstein. Land concessions, cadastral reforms, and the commercialization of rice production are interpreted not merely as economic acts but as mechanisms of colonial extraction and peripheralization.

In addition, this research engages with recent spatial-historical approaches, especially those emphasizing the material and institutional mechanisms of colonial extraction (Osborne, 1994; Rinaudo, 2023). These approaches underscore how colonial rule reorganized physical landscapes - rivers, canals, plots, and villages - as part of a broader logic of imperial governance.

2.2. Methodology

This study employs a multi-method qualitative approach integrating historical reconstruction, logical analysis, and critical interpretation of colonial documents to examine the transformation of land policy and rural structures in Cochinchina from the late nineteenth century to 1930.

The historical method situates land policies within the evolving administrative and economic context of French colonialism, tracing continuities and ruptures in the transition from communal to privatized land tenure. This approach reconstructs how legal, fiscal, and cadastral systems emerged as instruments of both governance and extraction.

The logical-analytical method explores the internal rationality of colonial decrees (arrêtés), council proceedings (procès-verbaux), and administrative texts, revealing the coherence between legal codification, property regimes, and the spatial organization of colonial authority.

Complementing these is critical discourse analysis, applied to legislative records, concession archives, and bulletins such as the Bulletin officiel de l'Indochine and Rapports du Gouverneur général. Through close reading, the study interprets how colonial language encoded ideology, hierarchy, and the spatial imagination of empire.

This methodological triangulation ensures both empirical precision and theoretical depth, allowing the research to interpret land policy not as a technical reform but as a structural mechanism of domination. It thus situates the colonial land regime of Cochinchina within broader debates in postcolonial studies and agrarian political economy, where land, power, and space intersect as core dimensions of dependency and transformation.

3. RESEARCH FINDINGS AND DISCUSSION

3.1. Colonial Land Policies and the Restructuring of Rural Space

3.1.1. Theoretical and Political Foundation of Colonial Land Policies

French colonial land policies in Cochinchina were grounded in a dual logic of political control and ideological conviction, reflecting the broader dynamics of imperial expansion and capitalist accumulation. Central to this framework was the mission civilisatrice the belief that France had a moral duty to "civilize" colonized societies. Within this discourse, land was not merely an economic asset but a symbol of order, sovereignty, and rational governance. Through land laws and concessionary systems, the colonial state sought to dismantle the Vietnamese communal land tenure structure and replace it with a legal and spatial order aligned with capitalist principles of property and productivity.

Colonial administrators portrayed indigenous land management especially village-based communal tenure as archaic and inefficient. Rooted in Confucian ethics and customary law, these systems prioritized social cohesion, collective security, and ancestral attachment to land

rather than market-oriented accumulation. French reformers considered such arrangements incompatible with modern economic development. Consequently, colonial legislation aimed to dissolve communal rights and impose individual land titles modeled on the Code Civil, thereby institutionalizing a new regime of contractual property relations.

One of the most powerful legal instruments underpinning this transformation was the doctrine of terres vacantes et sans maître ("vacant and ownerless lands"). It declared that any uncultivated or underutilized land belonged to the colonial domain, disregarding indigenous practices such as seasonal cultivation, rotational agriculture, and communal usufruct. The Décret du 20 mars 1899 authorized the Governor-General to allocate these lands to settlers, entrepreneurs, and concessionary companies under the guise of agricultural modernization. Temporary grants (concessions temporaires) could be converted into permanent titles (concessions définitives) once cultivation requirements were met, effectively legalizing the expropriation of indigenous lands.

This legal fiction restructured rural society by embedding new property regimes and transferring control from local communities to colonial and comprador elites. The imposition of French land law represented not only economic intervention but also symbolic domination an attempt to replace Vietnamese moral geography with a rationalized spatial order. Village institutions such as the communal council lost authority over land management, and collective memory rooted in ancestral land was progressively eroded. As land became a commodity, speculation intensified, and ownership concentrated in the hands of French settlers and pro-colonial intermediaries.

The trajectory of these reforms reflects the core assumptions of dependency theory, which posits that colonial economies were structurally subordinated to metropolitan interests. In Cochinchina, land policy reoriented agricultural production particularly rice cultivation toward export markets, generating capital outflows that reinforced economic dependency. The outcome also exemplified Boeke's dual economy model, wherein a capitalist enclave economy coexisted with, and marginalized, a subsistence agrarian sector. Spatially, this dualism was materialized through irrigation grids, cadastral divisions, and redefined village boundaries that privileged plantation zones over indigenous farmlands.

Ultimately, colonial land policy in Cochinchina functioned as an apparatus of social engineering. By reorganizing rural space, recoding property relations, and displacing traditional elites, the colonial regime sought to dismantle the socio-cultural foundations of Vietnamese peasant society. This rupture entrenched structural inequality and dependency conditions that would later fuel both economic discontent and anti-colonial mobilization across southern Vietnam.

3.1.2. Legal Frameworks for Public Land Concessions and Stratified Access

In the restructuring of Cochinchina's rural landscape, the French colonial administration issued a series of decrees to regulate the process of reclaiming and utilizing public land (terre domaniale). One of the earliest was the decree dated November 11, 1878, signed by Governor J. Lafont, which allowed individuals to apply for public land concessions in suburban and rural areas, provided they fulfilled tax obligations and adhered to formal procedures for registration and land use. Article 6 of the decree states: "Land cultivation permits must be written in French and Annamite, indicating as precisely as possible the area and boundaries of the property in question, as well as the minimum number of hectares to be cultivated annually. The permits must also state the date from which the land will be subject to tax and when it must be alienated definitively" (Arrêté du 11 novembre 1878, 1878, Art. 6).

This provision reveals the colonial state's intent to control land development not only administratively but also physically, ensuring that land was used productively and not left idle.

However, subsequent regulations became increasingly restrictive, differentiating access by land size, social class, and intended use. According to Son Nam's History of Southern Land Reclamation, from the late 19th to early 20th century, multiple decrees were issued that tightened conditions for concessions, thereby creating structural disparities in access to public land:

• The Decree of October 15, 1890 mandated that recipients must cultivate the land within five years or face reclamation by the state for public use (e.g., canal digging, road construction).

• The Decree of May 10, 1893 prohibited "frontage cultivation," limiting concessions to no more than one-quarter of the land perimeter along rivers or canals to prevent speculative acquisition of high-value waterfront properties.

• The Decree of October 13, 1910 authorized the official sale of reclaimed public land at negotiated prices (concessions à titre onéreux), especially for rubber plantations - opening the door to large-scale investment by French capital and local elites.

• The Decree of October 4, 1928 banned the practice of fait accompli land grabs (clearing land first and legalizing later), a measure that drastically reduced access for the rural poor and discouraged settlement in areas like Rach Gia and Bac Lieu.

• The Decree of June 25, 1930 restricted concession zones to about 150,000 hectares in Bac Lieu and 80,000 in Rach Gia - mostly acidic or poorly drained soils, making further reclamation increasingly difficult (Son, 2009, pp. 175-176).

These regulations produced a stratified legal system in which wealthy landlords - who could afford capital, navigate bureaucracies, and manipulate administrative processes - were able to secure large concessions. Meanwhile, poorer peasants, unable to meet the requirements or maintain cultivation schedules, were gradually excluded from land access.

As Son Nam observed: "The law stated that the 10-hectare plots granted by provincial administrators could not be sold during the temporary concession period… but the colonial authorities deliberately tolerated usurious lending practices, forcing small landowners to surrender their holdings to pay off debts." (Son, 2009, p. 146).

Through increasingly rigid and elitist decrees, the mechanism of temporary concession followed by definitive transfer became the legal backbone for transforming public land into private holdings. While framed as a policy of rural modernization and agricultural development, these colonial legal structures effectively facilitated land concentration among elite actors and French investors, undermined communal landholding traditions, and deepened social inequality in rural Cochinchina. These developments laid the groundwork for the patterns of agrarian stratification that will be explored in the following section.

3.1.3. Administrative Mechanisms and Local Implementation

The effectiveness of colonial land policies in Cochinchina did not depend solely on decrees issued from the metropole but rather on a multi-layered administrative apparatus designed to translate colonial intent into concrete local action. At the center of this apparatus were the Governor of Cochinchina, the Department of Lands and Survey (Service des Domaines), and the Colonial Council (Conseil Colonial) institutions that collectively managed the processes of land measurement, allocation, registration, and transfer.

At the top of the hierarchy stood the Governor of Cochinchina, who held near-absolute executive power to approve, amend, or revoke land concession decisions. The Governor was

the ultimate authority in converting temporary concessions into permanent ownership and had full discretion to grant land to individuals or companies deemed capable of "effective exploitation." During the administrations of Paul Beau and Albert Sarraut, this authority was exercised to accelerate land concessions for French investors under the pretext of boosting rice exports, often infringing upon customary land rights long held by local communities.

The Service des Domaines served as the technical and legal branch of the colonial state, responsible for identifying so-called "vacant and ownerless lands" (terres vacantes et sans maîtres), conducting cadastral surveys, classifying lands, and formalizing property titles. Between 1900 and 1925, the department carried out large-scale land measurement and mapping programs that redefined the rural geography of Cochinchina. This process reflected the colonial conviction that effective possession and productive exploitation required administrative and spatial mastery of the territory.

The Conseil Colonial represented the political and legislative dimension of the colonial administration. Although nominally consultative, the Council was composed primarily of French planters, commercial elites, and a small number of pro-colonial Vietnamese intellectuals. It approved taxation rules, long-term concession policies, and economic privileges for major estate owners, thus formalizing the alliance between the colonial state and the emerging indigenous landlord class. As Tran Nam Tien and Nguyen Thi Anh Nguyet (2022, p. 10) observed, "the colonial authorities actively supported and legitimized land accumulation by major landlords, who in turn dominated rural administrative structures". In the Procès-verbaux du Conseil Colonial of 9 October 1905 (p. 114), a Vietnamese representative declared: "We, the natives, express our gratitude to the Colonial Council for bringing us this new organization". This statement reveals the symbolic role assigned to Vietnamese representatives in colonial politics as passive beneficiaries rather than active participants in policy formation.

In practice, this administrative system enabled Franco-indigenous elites to consolidate both power and landownership. Local officials many themselves concession holders used their positions to adjust land classifications, legalize transfers, and pressure indebted peasants into relinquishing property. Under the rhetoric of "rational exploitation" and "agricultural progress", the colonial bureaucracy effectively legitimized land concentration and transformed local governance into an instrument for maintaining social inequality.

Thus, the colonial administrative system functioned not merely as a management structure but as an institutionalized mechanism of domination, where power operated through registration, taxation, and legal certification. Within this bureaucratic framework, colonial authority penetrated deeply into rural life, reshaping economic space and reinforcing structural dependency between the colonial state, the landlord elite, and the peasant population.

3.1.4. Spatial Restructuring of the Rural Landscape

French colonial land policies in Cochinchina not only redefined ownership structures but fundamentally transformed the spatial configuration of rural society. Between 1890 and 1930, the transition from communal, village-based agriculture to expansive plantation monoculture reshaped the countryside in accordance with the colonial agenda of export-oriented production and administrative control. Before colonization, Vietnamese rural communities operated under a communal landholding system in which fields were allocated according to family labor needs. This traditional framework was gradually dismantled through concessionary laws, particularly the 1899 decree, which converted village commons into privately held plantations. As Son Nam (2009) observes, the French authorities justified concession policies as a means of "reclamation", but in practice they enabled a small group of politically connected landowners to appropriate public lands without regard for traditional communal rights. The non-transparent allocation process, together with a biased legal framework and bureaucratic complexity, led to

persistent conflicts such as the Ninh Thanh Loi (1927) and Noc Nan (1928) cases. According to Son Nam: "The powerless villagers could only appeal… The investigating committee was composed entirely of officials unfamiliar with customary law, and the locals always lost the case. The colonial legal system regarding land reclamation was nothing more than a trap to ensnare honest people" (p. 268). The erosion of communal protections blurred the boundaries between public, communal, and private property, laying the foundation for enduring inequalities in land access and rural power.

The transformation of spatial organization was visible across the southern provinces, where traditional villages organized around shared rice paddies and collective labor were replaced by large-scale plantations and infrastructural corridors. In provinces such as Thu Dau Mot, Gia Dinh, Tay Ninh, and Ba Ria, French investors obtained concessions covering hundreds or even thousands of hectares. As Le Huu Phuoc (2017, p. 16) records, Thu Dau Mot had the largest plantation area in Cochinchina, totaling 14,078 hectares including the Loc Ninh, An Loc, Xa Cam, and Xa Trach estates. These estates were strategically located along transportation routes to facilitate export and to consolidate administrative supervision. This deliberate spatial reengineering reflected the colonial state's attempt to merge economic extraction with territorial management.

Such restructuring came at a profound human cost. The system of concessions définitives legalized long-term alienation of peasant land, forcing many farmers from ancestral holdings and converting them into tenants on estates that had once been communal. In My Tho, for example, French planter Taillefer claimed exclusive ownership over entire islets, declaring that the inhabitants were his "tenant farmers and coolies" and that "the government had no right to reestablish villages as in the old days" (Son, 2009, p. 163). This process of dispossession contributed to the emergence of a dependent rural labor class, often recruited as seasonal workers for expanding rubber plantations. By 1925, regions such as Thu Dau Mot had become centers of monoculture, where villages were absorbed into estate perimeters and local autonomy effectively dismantled.

The expansion of rice-producing corridors in the Mekong Delta further demonstrated the spatial logic of colonial governance. Between 1900 and 1930, cadastral surveys and land classification were conducted in My Tho and Sa Dec to reorganize traditional paddies into grid-like irrigation zones. Canal and dike systems were expanded to sustain year-round cultivation, while villages were relocated or restructured into linear clusters along transportation routes to facilitate both export and population control. This reordering of agricultural space blurred the distinction between economic policy and territorial discipline.

The administrative reorganization of rural Cochinchina was closely tied to this spatial transformation. The Service des Domaines, working with provincial officials, undertook extensive cadastral registration and boundary demarcation to replace communal ownership with individualized titles. As Vo Xuan Dan notes, the colonial government conducted large-scale cadastral registration… to fully control land resources and optimize extraction. Decrees issued in 1904 and 1927 redefined village governance, transforming previously autonomous communities into subordinate administrative units for taxation and labor mobilization. These processes deepened the reach of colonial authority into the rural landscape, eroding traditional institutions and embedding new hierarchies of power and dependency.

In sum, colonial land policies in Cochinchina did more than alter property relations; they restructured the entire spatial and social order of the countryside. Communal villages were replaced by plantation zones, subsistence farming gave way to monoculture production, and local autonomy was supplanted by bureaucratic control. This spatial reorganization not only

institutionalized inequality but also produced lasting patterns of dispossession and rural unrest that continued to shape Cochinchina's social fabric well into the twentieth century.

3.1.5. Colonial Infrastructure and the Reconfiguration of Land Relations

The development of colonial infrastructure in Cochinchina particularly roads, canals, and railways not only served as logistical support for economic exploitation, but also functioned as a tool to restructure land relations and rural social hierarchies. Under the guise of modernization, these projects undermined traditional land ownership systems and facilitated the concentration of land in the hands of colonial authorities and local elites.

Canal construction in provinces such as Sa Dec and My Tho helped expand the agricultural frontier and connected remote villages to colonial markets. However, this process also involved the appropriation of adjacent communal lands that were traditionally used by village communities. As Son Nam observes: When the French arrived, they recognized all cultivated land as colonial property. The colonial state became the de facto owner of all land within the colony, and anyone who wanted to claim legal ownership had to obtain approval from the Governor of Cochinchina (Son, 2009, p. 148). This redefinition of land status led to the dispossession of many local residents, stripping them of legal claims to ancestral lands they had occupied and cultivated for generations.

The same spatial logic applied to the construction of major roads such as Route Coloniale No. 1 and the Saigon - My Tho railway, which cut through village commons and facilitated surveying, cadastral registration, and concession allocation. Colonial infrastructure was not a neutral technical endeavor; it was an explicit manifestation of the extractive, controlling, and reorganizing logic of the colonial regime imposed upon rural space in Cochinchina.

The development of transportation infrastructure under French colonial rule in Cochinchina including roads, canals, and railways was not solely intended to support the logistical needs of economic exploitation; it also served as a powerful spatial mechanism for restructuring land ownership and rural relations. Major canal projects such as the Xa No and Rach Gia - Ha Tien canals penetrated deep into previously uncultivated regions of the Long Xuyen Quadrilateral, not only expanding rice cultivation zones but also resulting in the expropriation of communal village lands and ancestral holdings traditionally governed by customary usage rights. Many of these surrounding areas were reclassified as terres domaniales (public lands), subsequently auctioned or granted to French companies and Vietnamese landlords loyal to the colonial administration.

The construction of the Saigon - My Tho railway (completed in 1885) and later the Transindochinois line in the early 20th century further intensified the spatial fragmentation of rural territories. Roads such as Route Coloniale No.1 connected key economic regions, while railway lines traversed plantation zones, facilitating the large-scale collection and export of rice and rubber. As Ngo Minh Oanh and Banh Thi Hang Tam (2015) observed, "all transport routes were built with the aim of linking rivers, ports, and railways connecting local areas to the Saigon - Cho Lon center in order to stimulate large-scale exploitation of rice and commercial crops" (Ngo, 2015, p. 11).

These infrastructural developments not only enabled colonial economic extraction but also transformed the patterns of rural settlement, undermined customary land tenure, and accelerated land concentration. Villages that were once autonomous and self-contained were gradually restructured into nodes within a broader extractive economy centered on the interests of the colonial regime and the local elite.

In sum, colonial infrastructure in Cochinchina was not neutral; it was embedded within an extractive spatial logic that reconfigured rural land relations, enabling dispossession, enhancing surveillance, and transforming the very landscape into a colonial asset.

3.2. Land Concentration and the Rise of Agrarian Elites

3.2.1. Mechanisms of Land Concentration under Colonial Rule

The concentration of land in colonial Cochinchina was the deliberate outcome of a coordinated system of legal, financial, and administrative measures designed by the French colonial regime to institutionalize inequality and facilitate capital accumulation. Through a complex legal framework, the colonial authorities transformed communal and unclaimed lands into alienable private property, thereby dismantling traditional land tenure and concentrating ownership in the hands of colonial settlers and a small indigenous elite. As Pham Cao Duong (1985, pp. 263-264) explains, the administration relied on instruments such as the Arrêté du 20 décembre 1899 to codify concessions temporaires and concessions définitives, using these categories to distribute extensive tracts of so-called terres vacantes et sans maîtres to French investors and politically connected Vietnamese. This legal process was justified through a distorted interpretation of imperial sovereignty, whereby the French invoked the Annamese emperor's eminent domain rights to declare large areas as state property and subsequently allocate them to favored concessionaires after "sufficient improvement" and cadastral verification criteria that inherently favored those with financial and bureaucratic influence. Beneath the appearance of administrative rationality, the system functioned as a mechanism of exclusion, eroding indigenous rights and facilitating large-scale land accumulation. Financial institutions reinforced this concentration. The Banque de l'Indochine and the Banque Franco-Chinoise pour le Commerce et l'Industrie played decisive roles in channeling metropolitan capital into Cochinchina's plantation economy. Statistical data from the Annuaire Statistique de l'Indochine (1930, pp. 21, 211-214) show rapid growth in deposits and credit portfolios between 1925 and 1930, paralleling the expansion of large estates. The Banque de l'Indochine, headquartered in Paris with major branches in Saigon, Hanoi, and Haiphong, not only controlled currency issuance but also extended mortgage credit to concessionaires and plantation syndicates; its circulating assets rose from 38.9 million piastres in 1927 to 48.6 million in 1929, coinciding with the surge in colonial land speculation. Meanwhile, smallholders were systematically excluded from this financial network. Without definitive land titles or sufficient collateral, Vietnamese peasants were unable to obtain long-term credit, leaving them dependent on informal lenders and vulnerable to dispossession during economic downturns. As a result, the colonial banking system acted as a financial filter, channeling liquidity toward French and comprador elites while marginalizing the indigenous population. In addition to credit mechanisms, the colonial state institutionalized ventes domaniales public land auctions that reclassified communal holdings as domaines publics and sold them under the pretense of development. The proceedings of the Conseil Colonial de la Cochinchine (1906, p. 119) record a revealing case in which two settlers, Berquet and Luya, purchased 1,567 hectares of swamp land in the Plaine des Joncs for 1,784 piastres and later sought tax exemption, claiming the land was uncultivable. Their request was denied by Lieutenant-Governor De Lalande-Calan, who declared that by purchasing rice-suitable land, "they had engaged in speculation for which they alone must bear the risks". This decision, upheld by the Colonial Council, codified a distinction between concessionaires depicted as agents of progress and auction buyers portrayed as mere speculators. Such legal differentiation legitimized both the privatization of communal property and the concentration of land among elite actors. Ultimately, the convergence of legal authority, financial leverage, and administrative control transformed land in Cochinchina from a communal resource into a taxable commodity. This new agrarian order entrenched inequality,

subordinated the peasantry, and established the structural foundations of dependency that defined rural society under colonial rule.

3.2.2. Profiles of Agrarian Elites: From Traditional Notables to Capitalist Landlords

Under French colonial rule, the concentration of land in Cochinchina was accompanied by the emergence of a new agrarian elite whose influence extended beyond the economic domain into politics and culture. This elite class evolved through the fusion of traditional notability, commercial acumen, and colonial patronage, forming a hybrid social group that mediated between the colonial state and Vietnamese society. Many early members of this class descended from the mandarinate and village notables of the Nguyen dynasty, who adapted to colonial power through their literacy, administrative experience, and social prestige. Their ability to navigate new legal frameworks allowed them to convert communal lands into private holdings and secure colonial concessions. As Vo Xuan Dan notes, the introduction of cadastral surveys and Western-style property registration profoundly altered rural structures, giving rise to a class of large landowners both French colonists and Vietnamese collaborators who increasingly dominated local landholding. By the late nineteenth century, these traditional elites had been transformed into capitalist landlords, managing large monoculture estates supported by French legal decrees and networks of credit and patronage.

The career of Tran Trinh Trach in Bac Lieu epitomizes this transition. Emerging from modest origins as a trader, Trach accumulated wealth through colonial land auctions and concessions that restructured the Mekong Delta's agrarian landscape. According to Son Nam (2009, pp. 230-231), as early as 1873, lands in Vinh Huong (later Vinh Loi) were auctioned at "one and two-fifths cents per square meter", marking some of the earliest public land sales in southern Vietnam. By 1882, Bac Lieu province contained over 810,000 hectares of land, but only about 14,700 were cultivated leaving vast tracts open to speculative acquisition under French supervision. The decrees of 1879 and 1899 that reclassified communal fields as public domains accelerated this process. As Vo Xuan Dan explains, cadastral registration and titling effectively legalized the transfer of communal and peasant land to private hands, consolidating a new class of rural magnates detached from traditional village life. Figures like Trach, who combined commercial capital with administrative privilege and access to colonial finance, became emblematic of this process. By the early twentieth century, Bac Lieu had emerged as a center of rice production controlled by a handful of powerful landlords, illustrating how colonial legal and financial mechanisms produced a class of indigenous capitalists rooted in land accumulation rather than inherited aristocracy.

By the 1920s, this landlord stratum expanded into an urban-educated, politically active bourgeois-Confucian nexus. Individuals such as Bui Quang Chieu, Nguyen Van Thinh, and Nguyen Phan Long embodied a hybrid elite that blended Confucian respectability with Western education and capitalist enterprise. Bui Quang Chieu (1873-1945), trained at the Grignon School of Agriculture in France, returned to Cochinchina as an agronomist and became one of the largest landowners in Tra Vinh while founding the Indochinese Constitutionalist Party in 1923. As Brocheux (1995, pp. 141-147) observes, Chieu represented "a rational, modern bourgeoisie rooted in land and commerce", articulating reformist collaboration as a means of national progress within the colonial framework. Similarly, Nguyen Phan Long (1889-1960), a journalist, businessman, and later mayor of Saigon, merged political modernism with economic ambition. As editor-in-chief of La Tribune Indochinoise, he championed press freedom and self-representation while investing heavily in real estate and rural estates. Alongside Nguyen Van Thinh, these men managed estates as absentee landlords and engaged in colonial politics as reformists, espousing ideals of progress and civilization while remaining bound to the property hierarchies of the colonial order.

As Marr (1981) and McHale (2004) note, this hybrid elite acted as an intermediary class modern yet conservative, nationalist yet collaborationist. It consisted of Confucian families, Chinese merchants, indigenous landlords, and French bourgeois settlers linked through access to land, credit, and legal privilege. Despite differing origins and accumulation strategies, they all functioned as agents of colonial capitalism and pillars of rural inequality. This agrarian bourgeoisie, forged at the intersection of colonial policy and local adaptation, not only sustained the extractive structure of the colonial economy but also shaped the sociopolitical landscape of Cochinchina on the eve of modern nationalist movements.

3.2.3. Financial Institutions and Credit Access under Colonial Rule

One of the key drivers of land concentration and the entrenchment of agrarian elites in colonial Cochinchina was the financial infrastructure established by the French administration. Through institutions such as the Banque de l'Indochine and the Crédit Foncier de l'Indochine (CFI), colonial capitalism created a dual credit system that favored French settlers and indigenous elites while systematically excluding smallholders and poor peasants.

Founded in 1875, the Banque de l'Indochine operated as a semi-official financial arm of the colonial state, facilitating large-scale investment in trade, agriculture, and public works. Concentrating its operations in Saigon and Cho Lon, it extended credit to export firms, rice millers, rubber companies, and major landowners mostly French settlers or Vietnamese collaborators. As Phan Ha Uyen (1978, pp. 150-153) documented, these financial flows were deliberately structured to repatriate profits to France. Annual capital transfers exceeded 300,000 gold francs, while dividends to French shareholders averaged 5-7 million piastres per year. "Indochina", Phan wrote, "was being drained of its wealth L'Indochine est dévalisée". By the 1920s, the Bank's annual profits surpassed 30 million francs, yet its services remained highly exclusive (Duong, 2020, p. 101).

The agricultural credit system established under French rule particularly through institutions such as the Sociétés Indigènes de Crédit Agricole Mutuel (SICAM) was officially designed to promote rural development but, in practice, reinforced class-based inequality. It systematically privileged large landowners while marginalizing smallholders, tenant farmers, and landless peasants. Although, from 1928 onward, the colonial government authorized SICAM branches to use reserve funds to lend to producers without land, archival evidence indicates that such provisions rarely benefited the intended groups. As Pham Quang Trung (2005, p. 267) observed, most borrowers already held land titles and were able to pledge real estate as collateral, perpetuating structural imbalances in access to credit.

SICAM institutions were dominated by wealthy landowners, who served as both shareholders and board members, turning these cooperatives into instruments of elite consolidation. Local notables leveraged their influence to direct credit flows toward their own class and reinforce their socioeconomic dominance. Contemporary commentators sharply criticized this pattern, accusing the colonial state of favoring affluent proprietors while neglecting the growing population of impoverished tenants (Pham, 2005, p. 266).

This institutional bias was further entrenched by the exclusionary design of the colonial credit system. In a 1931 session of the Indochina Budget Council, French economist Paul Bernard highlighted the systemic barriers facing smallholders, noting that agricultural credit "hardly ever reached" the peasantry except through large landowners. Acting as guarantors, these intermediaries extracted high interest rates, making formal credit inaccessible to poor cultivators. Bernard (1934, pp. 75-76) emphasized that seasonal loans whether in kind or in cash were monopolized by large and medium proprietors, while "small proprietors and tenant farmers remained defenseless, caught between rapacious landlords and the ambiguity of colonial governance."

More broadly, this dual financial structure perpetuated inequality by ensuring privileged access to institutional capital for the propertied elite. Landowners could use credit to expand holdings, modernize agricultural production, or speculate in land markets, while poorer cultivators were trapped in cycles of indebtedness and dependence on informal, often usurious lending networks. Credit, therefore, functioned not only as an economic instrument but also as a political tool distributed selectively to loyal colonial collaborators and provincial elites to secure their allegiance and reinforce the political foundations of colonial rule in rural Cochinchina.

3.3. Rural Stratification, Legal Exclusion, and Economic Dependence

Under French colonial rule, rural society in Cochinchina experienced a profound restructuring marked by the concentration of land ownership and the emergence of new social hierarchies. The traditional system of communal lands long the foundation of collective property and village autonomy was gradually dismantled through Western-style cadastral surveys, boundary demarcations, and the issuance of individual land titles. As Vo Xuan Dan observed, the measurement, demarcation, and establishment of land ownership under Western methods in Cochinchina brought about major changes in the structure and nature of land tenure. A class of large landowners composed of French colonists and indigenous collaborators emerged and increasingly dominated rural society. The creation of this new elite was facilitated by a legal framework that allowed land accumulation through concessions, public auctions, and the purchase of plots from indebted peasants. Members of this class included local officials, Chinese merchants, French settlers, and reformist intellectuals from Confucian backgrounds. They were not merely landowners but also intermediaries within the colonial administrative, financial, and tax systems, linking the peasantry to the apparatus of colonial extraction.

In contrast, the vast majority of peasants were drawn into deepening economic dependency. Many were forced to rent land at exorbitant rates, subjected to exploitative labor relations, or compelled to sell their holdings following crop failures, floods, or market crises. Agricultural credit institutions, though nominally created to promote productivity, were accessible only to those possessing land titles and administrative connections. Peasants who lacked legal documents or literacy in French were effectively excluded from formal credit systems, pushing them toward private moneylenders. As early as the 1860s, the colonial government recognized the problem of usury. In an 1869 report, Tran Ba Loc condemned “wealthy men using deceitful tricks to oppress the poor and lend money at rates contrary to fairness” (Pham, 2005, p. 96) one of the earliest documented statements on rural credit injustice. This condition persisted into the twentieth century, dominated by Chinese and Indian (Chetty) moneylenders who exploited rural borrowers through compound interest. Investigations revealed that while Chetty lenders officially charged 12 percent annual interest, actual rates were far higher. One landlord in Can Tho borrowed 700,000 piastres between 1906 and 1931 yet still owed 130,000 piastres by the end of the period. Between 1910 and 1930, loans from these groups totaled more than 182 million piastres, an enormous burden on rural debtors (Pham, 2005, p. 106).

Meanwhile, formal institutions such as the Banque de l’Indochine and SICAM funds failed to serve the native peasantry effectively. Access to credit required complex legal and financial qualifications beyond the reach of most cultivators. Even the so-called “reimbursable advance funds” (fonds d’avances remboursables), ostensibly designed to support agriculture, were distributed through village councils and disproportionately benefited local notables and individuals with administrative influence (Pham, 2005, pp. 98-99). Consequently, large segments of the rural population particularly in Long Xuyen, Vinh Long, and Can Tho were excluded from formal credit channels and forced to rely on private lenders. Rent levels were high, tenants bore all production costs, and debts were deducted directly from harvests, perpetuating a vicious cycle of dependency and dispossession.

Alongside these economic mechanisms, legal structures of exclusion further entrenched inequality. The Arrêté du 15 octobre 1890 prohibited grantees from mortgaging or transferring land during the first five years of a concession, with any violation resulting in reversion to the colonial domain (retour au domaine) (art. 8). This clause became a legal device for reclaiming land from native cultivators and redistributing it to pro-French elites. The Session extraordinaire de 1903 of the Conseil colonial de la Cochinchine provides several examples of this process. In Can Tho, the concession of Sammarcelli was reviewed after a field investigation, and the report concluded that the property must be "returned to the colonial domain while maintaining the rights of the indigenous inhabitants already settled there" (pp. 8-9). This statement acknowledged local occupants only as temporary residents without legal ownership. In the same session, the Council discussed a case in Rach Gia where land was transferred from Vietnamese peasants to Dejean de la Bâtie, a French lawyer, with the justification that the transaction was "very advantageous for the public treasury" (p. 14). Such rulings reveal that colonial legality functioned as an administrative mechanism to legitimize expropriation and the transfer of ownership from indigenous farmers to colonial beneficiaries.

After these seizures, many local residents lost both legal recognition and social standing, becoming tenants on the very land they once owned. The minutes of the 1903 session show that officials merely promised to "regularize later the situation of all these indigenous occupants" ("régulariser ultérieurement la situation de tous ces occupants indigènes") without defining any procedure or timeline (pp. 8-9). This calculated ambiguity ensured the subordination of indigenous cultivators under a veneer of bureaucratic legality. The situation worsened after the ninth session of October 16, 1903, when the Council extended the application of the décret sur l'indigénat (Native Code) beyond its intended scope. Although it was originally applicable only to natives of Cochinchina, officials "did not hesitate to extend it to Cambodians under the Protectorate, to people from Hue, and even to Chinese residents" (p. 142). This arbitrary expansion stripped non-French populations of judicial recourse and formal protection, institutionalizing racial discrimination within the colonial land and legal system.

In essence, French land and legal policies in Cochinchina amounted not merely to material expropriation but to the systematic erosion of legal personhood. By depriving the rural population of property rights and recognizing them only as "temporary legal residents", the colonial state transformed them into a dependent labor force submissive, controllable, and politically voiceless. This structure of economic exploitation and legal subordination sustained colonial domination under the guise of modernization, rule of law, and administrative order.

3.4. Resistance and Adaptation of Rural Communities

3.4.1. Forms of Resistance and Political Expression

The intensification of colonial land policies in Cochinchina from the late nineteenth to the early twentieth century provoked not only economic deprivation but also multiple, interwoven forms of rural resistance. While large-scale uprisings were rare compared to Tonkin or Annam, Cochinchinese peasants and local elites adopted a repertoire of protests that combined legal petitions, passive disobedience, and emerging political mobilization.

The most common form of peasant protest was the submission of petitions and collective complaints, which served as the only legitimate means to contest expropriation and administrative injustice. Archival evidence shows that by the early twentieth century, such petitions had become a recurrent issue for colonial authorities. During the session of the Conseil Colonial de la Cochinchine on 21 October 1901, Councilor Holbé complained that "when a European applies for a large land concession, certain Annamites allegedly did not hesitate to file frivolous claims... forcing the applicant to waste time and money proving that the land does not belong to them", and urged strict enforcement to prevent "similar incidents" (Conseil

colonial de la Cochinchine, 1901, p. 14). Yet, Councilor Ninh countered that many of these petitions were justified since "the natives possessed valid deeds or had occupied the lands for generations", calling for careful examination "to prevent new injustices" (Conseil colonial de la Cochinchine, 1901, pp. 14-15). This exchange reveals the dual nature of colonial legality allowing indigenous participation through formal procedures while suppressing it when European interests were threatened. It also exemplifies how local populations transformed the bureaucratic apparatus into a site of negotiation, articulating a nascent form of political consciousness through legal language and administrative engagement.

Beyond petitions, peasants frequently resorted to quiet, nonviolent acts of resistance within the colonial framework itself. Records from the Procès-verbaux du Conseil Colonial de la Cochinchine (session of 5 December 1903) noted that many "Annamite cultivators" continued to occupy and work the lands even after concessions were granted to others: "These indigenous inhabitants had been granted cultivation permits; therefore, the Commission drew the Administration's attention to these facts" (Conseil colonial de la Cochinchine, 1903, p. 27). The persistence of these cultivators, who refused to vacate their plots despite eviction orders, reflected both moral attachment to ancestral property and subtle defiance against dispossession. As another Council member observed, "the Administrator was aware of the situation; the Annamites trusted the word given by the Administrator, who had issued them cultivation permits" (Conseil colonial de la Cochinchine, 1903, p. 27). Such endurance blurred the line between legality and defiance, turning the permis de cultiver into both a symbol of hope and a quiet tool of protest.

By the 1920s, rural discontent had converged with the growing political activism of urban intellectuals. The structural inequality of land auctions, which often benefited colonial elites and excluded peasants, became a focal point of social critique. As Pham Cao Duong noted, "Once a land concession was requested, the plot was usually put up for auction, and in most cases, the first applicant who enjoyed a privileged position was the beneficiary. The unfortunate peasant, ignorant of administrative procedures, could not possibly participate in the auction and soon became a tenant of the new landowner" (Pham, 1985, pp. 268-269). Discussions in the Conseil Colonial often ignored peasant petitions on overtaxation and indebtedness, leading even moderate figures such as Bui Quang Chieu to denounce the heavier fiscal burden imposed on Vietnamese taxpayers (Conseil colonial de la Cochinchine, 1928, pp. 105-106).

Simultaneously, the colonial public sphere became a platform for political expression through the press and associations. Newspapers such as La Tribune Indochinoise and La Cloche Fêlée voiced rural grievances and criticized colonial exploitation. Intellectuals like Nguyen An Ninh used journalism, pamphlets, and public lectures to mobilize against social injustice. As Philippe Peycam recounts, Ninh's Young Annam Party a secret organization near Ba Diem and Hoc Mon combined traditional networks and modern activism, drawing support from peasants, artisans, and middle-class nationalists. French surveillance described it as a group that urged peasants not to pay taxes and spread rumors intended to incite popular anger against the established political order (Peycam, 2012, pp. 155-156).

These intertwined developments illustrate that resistance in Cochinchina was not merely sporadic or reactive but a continuum of moral, legal, and political engagement. Through petitions, persistence in cultivation, and emerging forms of political communication, Cochinchinese peasants and intellectuals collectively transformed colonial constraints into opportunities for contestation, setting the groundwork for democratic and nationalist mobilization in early twentieth-century southern Vietnam.

3.4.2. Strategies of Adaptation and Rural Survival

Under the pressures of land dispossession and economic exploitation, peasants in colonial Cochinchina developed various strategies of adaptation that, while less visible than overt resistance, were essential for survival. These forms of adjustment reveal how rural communities negotiated with the colonial order seeking to endure, adapt, and subtly resist within the structures of domination.

As the concession system intensified, large numbers of dispossessed peasants were drawn into migrant labor. The Réglementation du Travail en Indochine (1930, pp. 19-23) recorded how the colonial government institutionalized the recruitment of rural laborers for plantations, railway construction, and public works. The 1929 labor code imposed detailed rules on recruitment, housing, and sanitation, requiring dormitories of twenty workers per unit and medical inspection prior to employment. These regulations turned displacement into a managed process of labor mobilization, transforming the rural poor into a regulated workforce. Many peasants moved seasonally between the countryside and plantation zones or settled permanently in the industrial outskirts of Saigon and Cho Lon, forming the nucleus of a colonial working class whose survival depended on mobility and adaptation rather than subsistence agriculture (Gouvernement général de l'Indochine, 1930, pp. 19-23).

Facing the erosion of village autonomy, rural society also restructured its internal institutions. Traditional notables retained influence as mediators between the state and villagers in tax collection, land disputes, and labor recruitment. Wealthy Vietnamese elites, particularly those granted French citizenship (assimilés), emerged as new patrons who offered loans and tenancy contracts in exchange for allegiance. This recreated a hierarchy of dependency that mirrored colonial structures while maintaining fragments of social cohesion. Catholic parishes played a parallel role in reorganizing community life and social welfare. According to the Procès-verbaux du Conseil Colonial de la Cochinchine (1928, pp. 173-174), the colonial government granted Father R. P. Dalle a 300-hectare concession in Soc Son (Rach Gia) under the condition that he establish "a church, a presbytery, a school, or a nursery" to "settle the Annamite labor population in the region". The Church thus functioned as both a spiritual center and a refuge, mediating between governance and protection in the reconfigured rural landscape.

Legal adaptation became another critical dimension of survival. Many peasants sought to secure cultivation rights through petitions, hearings, and applications for concessions temporaires or marchés de gré à gré. Rather than rejecting the colonial legal order, they engaged with it pragmatically using its procedures to negotiate limited rights. A notable example appears in the Procès-verbaux du Conseil Colonial de la Cochinchine (1928, p. 182), which records the case of Bui Van Bau of An Hoa Dong village (Sa Dec). His petition for regularization of 8.35 hectares of terrain domanial faced four competing claims; after review, the Commission administrative dismissed the objections and granted him the concession, noting that "the interests of the domain and the applicant were thereby reconciled". Such cases demonstrate that even within asymmetrical power structures, peasants were not passive victims. Through selective compliance and bureaucratic literacy, they carved out fragile spaces of autonomy and preserved fragments of economic stability.

In essence, adaptation in Cochinchina embodied a form of quiet resilience. By shifting occupations, maintaining networks of patronage, and mastering the colonial administrative language, peasants transformed survival into an active process of negotiation. Their actions revealed not surrender but agency an everyday politics of endurance and adjustment within the rigid boundaries of colonial rule.

4. CONCLUSION

This study has demonstrated that French colonial land policies in Cochinchina between the late nineteenth and early twentieth centuries were not merely administrative interventions but deliberate instruments of spatial domination and social restructuring. Through a critical examination of decrees, legal frameworks, land concession systems, and archival records, the research has shown how the colonial state systematically dismantled indigenous village-based landholding traditions to establish a dual agrarian economy favoring settlers and local elites.

The analysis identified four interrelated dimensions of this transformation: (1) the legal and political logic underpinning colonial land appropriation; (2) the emergence of landed elites and financial institutions that consolidated agrarian capitalism; (3) the deepening of rural inequality and the erosion of communal autonomy; and (4) the multifaceted forms of resistance and adaptation developed by local communities.

These findings reveal that colonial land reform in Cochinchina was not a linear process of modernization but a violent restructuring of space, economy, and class relations. Land policies operated simultaneously as tools of economic exploitation and as mechanisms of political control, producing enduring patterns of inequality that persisted long after the colonial period.

Beyond its historical significance, this study contributes to broader debates on postcolonial governance, agrarian transformation, and peasant agency. It underscores that rural society under colonial rule was not a passive victim but a dynamic field of negotiation, adaptation, and moral resistance.

Future research could extend this analysis by comparing Cochinchina's trajectory with that of Tonkin and Annam or by exploring how early twentieth-century rural land conflicts shaped the ideological foundations of Vietnamese nationalism. Integrating GIS-based spatial analysis with oral histories would further deepen our understanding of how land, labor, and identity intersected within the lived realities of colonial transformation, bridging the gap between spatial structures and human experience in a more holistic and multidimensional way.

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NATURAL PRODUCTS AS LEADS FOR ANTIMICROBIAL DRUG DISCOVERY

Ahmed Attahiru and Abubakar Umar Birnin-Yauri

Department of Pure and Industrial Chemistry, Faculty of Physical Sciences, Kebbi State University of Science and Technology

Aliero, Nigeria

Email: ahmedattahiru02@gmail.com

ABSTRACT

The rise of antimicrobial resistance (AMR) presents a global health crisis that threatens the efficacy of existing antibiotics. Natural products, derived from plants, microorganisms, and marine organisms, have historically provided structural frameworks for antibiotic discovery and continue to offer novel scaffolds for combating resistant pathogens. This study aims to evaluate the potential of natural products as viable leads for antimicrobial drug discovery, emphasizing their chemical diversity, mechanisms of action, and recent innovations enhancing their development. A systematic review of recent literature (2019–2025) was conducted using databases such as PubMed, ScienceDirect, and Scopus, focusing on bioactive compounds, antimicrobial spectra, and modes of action. Case studies highlighting Nigerian medicinal plants and microbial metabolites were also assessed. Findings reveal that alkaloids, flavonoids, terpenoids, and phenolic compounds exhibit potent activity against multidrug resistant bacteria. Novel compounds from *Azadirachta indica*, *Vernonia amygdalina*, and endophytic fungi demonstrate strong inhibitory effects through mechanisms such as membrane disruption and enzyme inhibition. Overall, natural products remain invaluable in antimicrobial lead discovery. The integration of advanced techniques, including metabolomics, molecular docking, and synthetic biology, is vital for optimizing these compounds and repositioning them as promising candidates for new drug development against resistant pathogens.

Keywords: Natural products, Antimicrobial resistance, Drug discovery, Secondary metabolites, Phytochemicals, Genome mining.

1. INTRODUCTION

The twenty first century has witnessed escalating antimicrobial resistance driven by excessive antibiotic use, rapid mutation rates, and weakened drug discovery pipelines (Dadgostar, 2019; Murray et al., 2022). Pathogens such as carbapenem resistant *Enterobacteriaceae* and MRSA compromise treatment success and impose substantial global burdens (CDC, 2023). The WHO lists AMR among the top ten public health threats requiring urgent intervention (WHO, 2024).

Natural products have served as the foundation of antimicrobial therapeutics since the discovery of penicillin and continue to contribute more than 60 percent of clinically used drugs (Hutchings et al., 2019). Their unique molecular architectures ranging from polyketides to alkaloids enable interactions with novel microbial targets (Newman & Cragg, 2020). Unlike many synthetic compounds, natural metabolites often possess evolved defensive functions that translate into potent antibiotic properties (Chevrette et al., 2020).

Recent advances in high-throughput screening, genome mining, and dereplication strategies have revitalized interest in natural product based drug discovery (Zhang et al., 2021). In regions like Nigeria with rich ethnobotanical resources, traditional medicinal knowledge continues to guide natural-product screening and accelerate new therapeutic opportunities (Ogunwande et al., 2023). This review synthesizes progress in developing natural product based antimicrobial leads while highlighting innovations that enhance their optimization for resistant infections.

2. BACKGROUND AND CONCEPTUAL OVERVIEW

Natural products originate from defensive and ecological roles that contribute to their chemical richness and antimicrobial potency (Liu & Wright, 2022). Plants, microorganisms, and marine organisms each provide distinctive biosynthetic pathways that expand chemical diversity landscapes (Harvey et al., 2022).

2.1 Structural Diversity and Drug Likeness

Phytochemicals, including alkaloids, phenolics, flavonoids, and terpenoids, possess diverse ring systems and functional groups correlating with antimicrobial action (Spor et al., 2020). Microbial secondary metabolites such as non-ribosomal peptides and polyketides exhibit even greater complexity, enabling selective inhibition of essential bacterial pathways (Chevrette et al., 2020).

Natural products remain advantageous for drug-likeness, frequently meeting Lipinski's thresholds or modifiable through structural optimization (Li et al., 2021). Structure-activity relationship (SAR) studies have enhanced lead identification and facilitated semisynthetic derivatives with improved pharmacological profiles (Fleming et al., 2023).

2.2 Mechanisms of Antibacterial Action

The mechanisms by which natural products suppress bacterial growth include:

- Cell membrane disruption mediated by terpenoids and phenolic compounds, leading to permeability collapse (Santos et al., 2022).
- Protein synthesis inhibition, where alkaloids bind ribosomal subunits (Adegboye et al., 2022).
- DNA gyrase and topoisomerase inhibition by flavonoids and coumarins interfering with replication (Singh et al., 2023).
- Efflux pump inhibition, restoring antibiotic susceptibility in MDR strains (Liu & Wright, 2022).

- Quorum sensing and biofilm suppression, reducing virulence and persistence (Harvey et al., 2022).

These multitarget interactions reduce rapid resistance development compared to conventional drugs (Zhang et al., 2021).

3. METHODOLOGY

This systematic review adhered to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure transparency and high quality synthesis of evidence (Page et al., 2021). Relevant studies on natural products with antimicrobial activity against resistant bacteria were identified and assessed.

3.1 Data Sources and Search Strategy

Peer-reviewed articles were retrieved from PubMed, Scopus, and ScienceDirect. The search covered January 2015 to January 2025. Key search terms included:

- "natural products AND antibacterial activity"
- "phytochemicals AND multidrug resistance"
- "endophytic fungi AND antimicrobial compounds"
- "Nigerian medicinal plants AND antibacterial"

Boolean operators optimized the search for specificity and breadth.

3.2 Inclusion and Exclusion Criteria

Studies were included if they:

- Examined pure compounds or partially purified fractions from natural sources
- Evaluated antibacterial activity against resistant bacteria (e.g., MRSA, VRE, CRE)
- Reported mechanisms of action or molecular targets
- Were published in English between 2015–2025

Studies were excluded if they:

- Focused solely on antiviral, antifungal, or antiparasitic activity
- Presented uncharacterized crude extracts without mechanistic insight
- Were conference abstracts lacking full text or peer review

3.3 Data Extraction and Quality Assessment

Two independent reviewers screened titles and abstracts, followed by full-text evaluation. Quality was assessed using the Joanna Briggs Institute critical appraisal tools (Aromataris & Munn, 2020). Extracted data included:

- Compound type and source
- Target organisms
- Mechanisms of action
- MIC values where available
- Synergy with existing antibiotics
- Only high-quality evidence was synthesized.

4. RESULTS

A total of 138 studies met inclusion criteria after screening 542 initial records. Extracted data revealed that natural products with significant antimicrobial potential predominantly belong to four major phytochemical groups: alkaloids, flavonoids, phenolic acids, and terpenoids. Marine peptides, polyketides, and microbial secondary metabolites also showed notable efficacy.

Compounds demonstrated potent inhibition against MDR pathogens including:

- MRSA
- ESBL producing Escherichia coli
- Carbapenem resistant Pseudomonas aeruginosa
- Vancomycin resistant Enterococci (VRE)

Mechanistic investigations confirmed interactions with bacterial membranes, DNA replication pathways, efflux regulation, and quorum sensing disruption (Harvey et al., 2022; Liu & Wright, 2022).

Table 1. Major Natural Product Classes, Mechanisms of Action, and MDR Targets

Phytochemical Class	Representative Sources	Mechanism of Action	MDR Bacterial Targets	Key References
Alkaloids	*Cryptolepis sanguinolenta*, marine actinomycetes	Ribosomal DNA binding; synthesis inhibition	MRSA, CRE, *Salmonella* spp.	Adegboye et al., 2022; Chevrette et al., 2020
Flavonoids	*Vernonia amygdalina*, citrus peels	DNA gyrase inhibition; efflux pump suppression	ESBL *E. coli*, *P. aeruginosa*	Singh et al., 2023; Spor et al., 2020
Phenolic acids	*Azadirachta indica*, *Punica granatum*	Membrane disruption; enzyme inhibition	MRSA, *K. pneumoniae*	Santos et al., 2022; Ogunwande et al., 2023
Terpenoids	*Ocimum gratissimum*, *Melaleuca alternifolia*	Permeability alteration; oxidative stress induction	*P. aeruginosa*, VRE	Harvey et al., 2022; Zhang et al., 2021
Microbial metabolites	Endophytic fungi, *Streptomyces* spp.	Quorum sensing inhibition; biofilm suppression	MRSA, *Acinetobacter baumannii*	Fleming et al., 2023; Ibrahim et al., 2024

4.1 Highlights from Literature Trends

- Research on metabolomic profiling and dereplication has expanded rapid discovery of antimicrobial metabolites (Page et al., 2021; Fleming et al., 2023).
- Increased reliance on Nigerian ethnobotanical knowledge supports identification of impactful leads (Ogunwande et al., 2023).
- Marine sources remain underexplored despite high chemical novelty and bioactivity.

5. DISCUSSION

Natural products remain a formidable resource in antimicrobial drug discovery, especially as resistance escalates faster than the development of new antibiotics (Dadgostar, 2019; Murray et al., 2022). This section examines mechanistic strengths, innovations accelerating discovery, and Nigeria's expanding contributions to antimicrobial research.

5.1 Strengths of Natural Products against Resistant Pathogens

Natural products offer:

1. Structural novelty

Complex ring systems and stereochemical diversity allow engagement with unconventional bacterial targets (Harvey et al., 2022).

2. Multi-target effects

Compounds such as flavonoids inhibit both DNA synthesis and efflux pumps, reducing resistance likelihood (Singh et al., 2023).

3. Synergy with existing antibiotics

Phenolic metabolites restore beta-lactam susceptibility through cell-wall weakening (Liu & Wright, 2022).

These features elevate their potential compared to purely synthetic analogues.

5.2 Technological Enhancements in Natural Product Development

- Metabolomics guided dereplication accelerates identification of novel chemical entities (Fleming et al., 2023).
- Molecular docking and dynamics simulation predict binding affinity to resistant bacterial enzymes (Zhang et al., 2021).
- Synthetic biology enables engineered biosynthesis of high-value antimicrobials in scalable microbial chassis (Harvey et al., 2022).
- AI and machine learning refine structure activity insights and generate optimized derivatives (Li et al., 2021).

These interdisciplinary advances bridge the gap between natural scaffolds and clinical applicability

5.3 Nigerian Biodiversity as a Source of Antimicrobial Leads

Nigeria contains multiple phytogeographical zones rich in medicinal flora traditionally used to treat infections. Ethnobotanical knowledge directs priority screening, reducing random trial and error (Ogunwande et al., 2023).

Key plant examples include:

- *Azadirachta indica* (Neem): Limonoids and phenolics with MRSA inhibition through membrane destabilization (Adegboye et al., 2022).
- *Vernonia amygdalina* (Bitter leaf): Flavonoids suppress DNA gyrase in resistant E. coli (Spor et al., 2020).
- *Ocimum gratissimum* (Scent leaf): Terpenoids induce oxidative stress and disrupt biofilms (Santos et al., 2022).

- *Garcinia kola* (Bitter kola): Biflavonoids reduce virulence gene expression (Ibrahim et al., 2024).

These plants exhibit dual activity: direct antibacterial effects and enhancement of current antibiotics.

5.4 Microbial Metabolites from Nigerian Ecosystems

Endophytic fungi isolated from Nigerian medicinal plants produce metabolites not found in their hosts (Chevrette et al., 2020). Examples include:

- Polyketides inhibiting quorum sensing in A. baumannii.
- Peptide derivatives blocking efflux in P. aeruginosa.

The synergistic ecological relationships driving metabolite production provide discovery advantages.

Table 2. Nigerian Natural Products with Activity against Resistant Bacteria

Natural Source	Active Metabolites	Target Pathogen	Mechanism of Action	MIC/Outcome	References
Azadirachta indica	Nimbidin, Azadirachtin	MRSA	Membrane disruption; enzyme inhibition	8–32 µg/mL	Adegboye et al., 2022
Vernonia amygdalina	Flavonoids (luteolin derivatives)	ESBL *E. coli*	DNA gyrase inhibition	16 µg/mL	Spor et al., 2020
Garcinia kola	Biflavonoids	*P. aeruginosa*	Quorum sensing/biofilm inhibition	Strong reduction in virulence	Ibrahim et al., 2024
Endophytic fungi (*Aspergillus* spp.)	Polyketides	*A. baumannii*	Efflux pump suppression	Synergistic with ciprofloxacin	Chevrette et al., 2020
Ocimum gratissimum	Thymol, eugenol	VRE	Oxidative stress induction	32–64 µg/mL	Santos et al., 2022

5.5 Limitations and Current Challenges

Despite advantages, obstacles include:

- Variability in compound yield due to environmental influences (Harvey et al., 2022).
- Complexity of isolating active fractions, leading to lengthy development timelines.
- Limited translational capacity in resource restricted regions such as West Africa (Ogunwande et al., 2023).

Intellectual property and biodiversity governance barriers.

Improving biobanking, funding, and industry partnerships is essential for global competitiveness.

6. CONCLUSION

The global surge in antimicrobial resistance has dramatically reduced the effectiveness of conventional antibiotics, creating an urgent need for novel therapeutic pipelines. This systematic review demonstrates that natural products remain indispensable reservoirs of chemically diverse, biologically optimized scaffolds with potent antimicrobial potential. Alkaloids, flavonoids, phenolics, terpenoids, and microbial secondary metabolites consistently exhibit impactful inhibition against multidrug-resistant bacteria, including MRSA, ESBL-producing *E. coli,* and carbapenem-resistant *P. aeruginosa.* The multitarget nature of these compounds ranging from membrane disruption to efflux pump inhibition reduces the rapid onset of resistance observed with many synthetics. Nigeria's rich biodiversity and ethnopharmacological traditions provide promising leads, as evidenced by bioactive metabolites from *Azadirachta indica, Vernonia amygdalina, Garcinia kola,* and endophytic fungi. Although translational barriers persist due to infrastructure limitations and compound complexity, modern technological integrations such as metabolomics, molecular docking, and synthetic biology have revitalized natural-product discovery and accelerated preclinical innovation. Natural products hold the key to sustaining global health security, and continued investment in their discovery will unlock new antimicrobial agents capable of combatting today's most formidable resistant pathogens.

7. FUTURE DIRECTIONS

Research on natural product based antimicrobials should prioritize the following:

1. **Integration of computational tools**

AI-driven SAR, docking, and predictive toxicology streamline hit to lead optimization.

2. **Enhanced bioprospecting of understudied regions**

Nigeria's rainforests, mangroves, and savannahs remain largely untapped despite their chemical wealth.

3. **Synthetic biology scale-up**

Engineering microbial chassis for sustainable production of rare metabolites will improve accessibility.

4. **Synergy testing with existing antibiotics**

Combination therapy can restore the potency of legacy drugs against resistant strains.

5. **Strengthening research infrastructure in developing nations**

Advanced instrumentation, funding, and global collaborations will accelerate translation from bench to clinic.

A unified global effort is required to convert natural products into the next generation of lifesaving antimicrobials.

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ENHANCING FORECASTING COMPETENCE FOR VALUE-ADDED AGRICULTURAL PRODUCTS USING FORECASTIFY EDU: A SIMULATION-BASED LEARNING APPROACH

Sharipah Khadijah S.Hashim

Politeknik Tuanku Sultanah Bahiyah Malaysia, Commerce Department

Email: sharipahkhadijah@ptsb.edu.my

ORCID: 0009-0008-6148-1588

ABSTRACT

Value-added or second-tier agricultural products, such as processed foods, natural oils, and herbal-based goods, contribute significantly to rural income diversification and agro-industrial development. However, many small producers and agricultural students lack the forecasting literacy needed to plan production, manage demand fluctuations, and reduce resource waste. This study introduces FORECASTIFY EDU, an interactive simulation-based learning platform, as a tool to strengthen forecasting competence within agro-based education and training. Using a quasi-experimental design, the study compares traditional teaching methods with simulation-based learning to evaluate improvements in demand prediction, production planning, and market decision-making among learners. Preliminary findings suggest that digital simulation enhances analytical reasoning, confidence, and engagement while promoting data-driven thinking. The research aligns with SDG 4 (Quality Education), SDG 8 (Decent Work and Economic Growth), and SDG 9 (Industry, Innovation, and Infrastructure), highlighting the transformative role of digital forecasting education in supporting sustainable agro-industrial value chains and rural development.

Keywords: Simulation-Based Learning, Agricultural Forecasting, Value-Added Products, Agro-Industry, Cognitive Learning Theory, Educational Innovation, SDG 4, SDG 8, SDG 9

1. INTRODUCTION

Forecasting plays a crucial role in ensuring the sustainability and competitiveness of value-added agricultural industries where producers must balance raw material supply, processing capacity, and market demand (Makarenya et al., 2024). In Malaysia, second-tier agricultural products, such as coconut-based oils, herbal items, and fruit-derived goods, represent expanding markets supporting rural entrepreneurship and agro-industrial growth (FAO, 2023).

Despite this potential, many students and small producers face difficulties in applying forecasting techniques effectively. Traditional teaching emphasizes theoretical concepts without sufficient experiential engagement, resulting in limited analytical competence (Ledger et al., 2024). To address this gap, **FORECASTIFY EDU** was developed as an interactive simulation-based platform that integrates **Cognitive Learning Theory (CLT)** principles to transform theoretical learning into data-driven practice.

This study focuses on evaluating the impact of FORECASTIFY EDU among **Diploma in Business Studies (DPM) students** at **Politeknik Tuanku Sultanah Bahiyah (PTSB),** Malaysia.

The objectives are to:

1. Assess the effectiveness of simulation-based learning in improving forecasting literacy for value-added agricultural products.

2. Compare students' forecasting performance and engagement between traditional and simulation-based methods.

3. Encourage digital learning integration to promote innovation and sustainability within agricultural and entrepreneurial training programs.

2. LITERATURE REVIEW

2.1 Forecasting in Agricultural Value Chains

Accurate forecasting supports decision-making, resource allocation, and market stability within agro-industrial systems (Kumar & Singh, 2023). Value-added agricultural products require precise demand estimation to prevent overproduction, minimize waste, and sustain profitability (FAO, 2023). However, the reliance on intuition over data analytics among small producers and students continues to hinder effective production planning (Rahman & Yasin, 2022).

2.2 Simulation-Based Learning (SBL)

Simulation-Based Learning (SBL) is recognized as an effective pedagogical approach that promotes engagement, problem-solving, and conceptual understanding through virtual experimentation (Ledger et al., 2024). In agricultural education, SBL tools have replicated real-world contexts such as crop management and supply forecasting, improving learners' cognitive engagement and confidence (Nguyen et al., 2023). Alghamdi (2021) found that students trained using simulations demonstrated higher retention and performance than those using lecture-only methods.

2.3 Cognitive Learning Theory (CLT)

CLT posits that learning occurs through mental structuring and reflection, emphasizing the importance of visualization and feedback (Mayer, 2021). In FORECASTIFY EDU, CLT principles are applied by providing learners with real datasets and automated feedback that guide them through forecasting processes, thereby reducing cognitive load and enhancing retention (Zainal et al., 2022).

2.4 Digital Transformation and SDGs

Digital innovation in education supports global goals for sustainable development, particularly **SDG 4,** which promotes quality education and lifelong learning (UNESCO, 2022). Simulation-based platforms like FORECASTIFY EDU also contribute to **SDG 8** and **SDG 9**, by equipping future professionals with the analytical skills needed for innovation-driven economic growth.

3. METHODOLOGY

3.1 Research Design

A **quasi-experimental design** compared traditional lecture-based learning (control group) with simulation-based learning using FORECASTIFY EDU (experimental group). Both groups covered identical forecasting topics, including time-series models, moving averages, and exponential smoothing.

3.2 Participants

Participants consisted of **60 DPM students** (Semester 5) from PTSB's Commerce Department. They were divided equally into control (n=30) and experimental (n=30) groups.

3.3 Learning Intervention

The experimental group used FORECASTIFY EDU to perform forecasting tasks using real agricultural datasets. Activities included uploading data, selecting models, generating results, and interpreting visualized outputs. The simulation aimed to replicate real agro-industry planning conditions.

3.4 Data Collection Instruments

Data were obtained from:

a. **Pre- and Post-tests** measuring forecasting literacy.

b. **Engagement Analytics** tracking user interaction.

c. **Questionnaires** evaluating confidence and satisfaction.

d. **Focus Group Interviews** providing qualitative insights.

3.5 Data Analysis

Quantitative data were analyzed using descriptive statistics, paired t-tests, and reliability analysis (Cronbach's α). Qualitative data were coded thematically to interpret participant perceptions and experiences.

4. FINDINGS AND DISCUSSION

Table 1 summarizes the study's evaluation results.

Table 1. Summary of FORECASTIFY EDU Evaluation Outcomes

Evaluation Aspect	Method / Indicator	Findings	Interpretation
Forecasting Competence	Pre- & Post-Test	Mean score ↑ 28%	Notable improvement in forecasting literacy
Instrument Reliability	Cronbach's Alpha	α = 0.967	Excellent internal consistency

Student Engagement	Platform Analytics	3.5 interactions/session	High engagement and iterative learning behavior
Learning Experience	Surveys & Focus Groups	Students described platform as "interactive" and "intuitive"	Increased motivation and conceptual understanding
Educator Feedback	Semi-Structured Interviews	Improved classroom participation	Ease of integration and pedagogical flexibility

Students in the experimental group demonstrated stronger analytical reasoning, decision-making confidence, and forecasting accuracy than those in the control group. Qualitative feedback indicated that learners valued the platform's real-time feedback and visualization features, which made abstract forecasting models easier to comprehend.

These outcomes confirm earlier findings by Ledger et al. (2024) and Alghamdi (2021) that simulation-based learning enhances engagement and comprehension. Educators also reported reduced administrative workload due to automated assessment and feedback, reflecting Lean Management principles that improve teaching efficiency (Kumar & Singh, 2023).

5. CONCLUSION AND RECOMMENDATIONS

This study highlights the transformative impact of simulation-based learning on forecasting competence among DPM students at PTSB. FORECASTIFY EDU successfully bridges theoretical and practical dimensions of forecasting education, fostering digital literacy and analytical thinking crucial for agro-industrial advancement.

The findings of this study reveal several key conclusions. Firstly, simulation-based learning significantly improved students' forecasting accuracy and overall engagement, demonstrating its effectiveness as an interactive pedagogical tool. Secondly, the application of Cognitive Learning Theory effectively guided active knowledge construction, allowing learners to understand complex forecasting concepts through visualization and hands-on experimentation. Lastly, the integration of FORECASTIFY EDU contributes meaningfully to Sustainable Development Goals (SDG) 4, 8, and 9 by promoting digital educational innovation that enhances quality education, decent work, and industry-oriented learning.

Based on these outcomes, several recommendations are proposed to further strengthen the impact of the initiative. Institutions are encouraged to integrate FORECASTIFY EDU into polytechnic and vocational curricula to enhance forecasting competence among students. Additionally, targeted training programs should be provided to educators to support the adoption of simulation-based teaching strategies effectively. The platform's dataset should also be expanded to include a wider range of agro-industrial applications, ensuring greater relevance and practical value. Finally, future research should explore the integration of artificial intelligence (AI) and data analytics to deliver personalized learning feedback, thereby optimizing students' learning experiences and outcomes.

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ATTENTION-DRIVEN HYBRID MODEL FOR CROP DISEASE CLASSIFICATION AND SMART FARM MANAGEMENT

Jatinkumar Bhimjibhai Kotadiya
Research scholar in Computer Science Department,
Atmiya University, Rajkot, India
Email: jatin.kotadiya123@gmail.com
ORCID: 0009-0004-4643-2690
Dr. Dharmendra J. Ambani
Assistant Professor in Computer Science Department,
At Harivandana College, Rajkot.
Email: dharmendraambani@gmail.com
ORCID: 0009-0006-5126-4331
Ms. Hetal Pravinsinh Jadeja
Assistant Professor in Computer Science Department,
At Harivandana College, Rajkot, India.
Email: hetal.hvc@gmail.com
ORCID: 0009-0008-4429-3489

ABSTRACT

Crop diseases are becoming more common, which is making it harder to produce enough food and causing problems for both food supply and the economy. Traditional disease detection methods are often limited by human error, environmental variability, and the inability to process large-scale agricultural data in real time. To address these challenges, this study presents an Attention-Driven Hybrid Model for Crop Disease Classification and Smart Farm Management, integrating the strengths of machine learning and deep learning techniques. The proposed model employs a convolutional neural network (CNN) for feature extraction and a transformer-based attention mechanism to enhance feature focus and contextual understanding, while ensemble-based machine learning algorithms refine the final classification outputs. The research utilizes publicly available crop image datasets, including diverse plant species and multiple disease categories. The performance of the model was thoroughly assessed using standard metrics such as accuracy, precision, recall, F1-score, and ROC-AUC to guarantee a complete evaluation and trustworthiness. Experimental findings indicate that the suggested hybrid model exceeds traditional CNN and independent ML models, attaining higher classification accuracy and interpretability. Furthermore, the model's outputs were integrated into a smart farm management framework designed to optimize decision-making related to irrigation, fertilizer application, and disease prevention strategies. The findings underscore the potential of attention-enhanced hybrid architectures in advancing sustainable, data-driven agricultural systems capable of intelligent monitoring and proactive management.

Keywords: AI, agriculture, intelligence, classification, attention, sustainability

1. INTRODUCTION

Farming is essential for maintaining human existence and facilitating worldwide economic development. Nonetheless, the industry encounters major obstacles because of the rising occurrence of crop diseases, erratic climate changes, and the restricted access to sophisticated diagnostic tools. These elements together lead to significant yield reductions, representing critical risks to food security and rural economies. Conventional methods for detecting crop diseases, mainly dependent on manual examination and expert evaluation, tend to be slow, subjective, and susceptible to human mistakes. With the transformation of the agricultural sector towards precision and data-centric methods, there is an increasing drive to incorporate artificial intelligence (AI), machine learning (ML), and deep learning (DL) technologies into agricultural systems. These technologies have the capacity to automate illness identification, improve decision-making, and foster sustainability in contemporary agricultural practices.

Artificial intelligence has become a big change in farming, helping with automatic tasks, predicting outcomes, and giving smart advice for making decisions. Through AI-based systems such as image recognition, sensor data analysis, and autonomous monitoring, farmers can optimize productivity and resource utilization while minimizing environmental degradation. Deep learning models, especially convolutional neural networks and those based on transformers, have been very effective at identifying visual patterns and small signs of disease in crop images. These features have rendered AI essential in enhancing precision agriculture, where intelligent, responsive systems can effectively track crop health, forecast disease incidents, and offer practical advice for prompt action. Because of this, AI is changing how farming is done by helping manage agriculture in a way that is both sustainable and efficient. The early and accurate detection of crop diseases is crucial for maintaining global food security and preventing large-scale agricultural losses. As stated by the Food and Agriculture Organization (FAO), almost 40% of worldwide crop yield is lost each year due to pests and diseases. These losses not only affect farmers' livelihoods but also have cascading impacts on food prices, trade stability, and nutrition security. Efficient disease detection systems allow farmers to take timely preventive measures, reducing the spread of infections and ensuring better crop yields. Intelligent classification models powered by AI, particularly those incorporating attention mechanisms, enable higher precision in identifying disease types and severities. By integrating such systems into farming practices, it becomes possible to improve food production, reduce the overuse of pesticides, and enhance overall agricultural sustainability.

Despite advancements in AI-based approaches, several challenges remain in achieving robust and reliable crop disease classification. Conventional CNN-based models often fail to generalize effectively across diverse environmental conditions, lighting variations, and plant species. They may also overlook long-range contextual relationships between image features, limiting their interpretability. Similarly, traditional ML algorithms rely heavily on handcrafted features, which restrict their adaptability to complex and heterogeneous agricultural datasets. These limitations highlight the need for a hybrid approach that combines the deep feature extraction capabilities of CNNs with the attention-driven contextual modeling of transformers and the robust decision-making abilities of ensemble ML methods. Additionally, there is a gap in integrating such advanced models into comprehensive smart farm management systems capable of providing real-time, data-driven support for farmers. The primary objective of this research is to develop an Attention-Driven Hybrid Model for Crop Disease Classification and Smart Farm Management that harnesses the complementary strengths of machine learning and deep learning methodologies. The proposed study aims to design a hybrid framework that improves feature extraction, contextual understanding, and classification accuracy. It also seeks to evaluate model performance using standard agricultural image datasets and benchmark

metrics such as accuracy, precision, recall, F1-score, and ROC-AUC. Moreover, the research intends to compare the performance of the hybrid model with conventional CNN and ML approaches, demonstrating its superiority in both accuracy and interpretability. A further objective is to integrate the model into a smart farm management framework that assists in intelligent decision-making related to irrigation, fertilizer use, and disease prevention, thereby contributing to sustainable agricultural advancement.

The scope of this research is confined to the development, evaluation, and partial integration of an AI-based hybrid model for image-based crop disease classification. The study utilizes publicly available datasets comprising multiple crop species and disease types to ensure generalizability and reproducibility. While the integration with a smart farm management system is conceptually designed, the implementation in this study is limited to a simulated digital environment rather than field-level automation. Additionally, environmental factors such as varying light conditions, overlapping symptoms, and inconsistent image quality may influence model accuracy. Despite these limitations, the proposed approach provides a foundational framework for future real-time agricultural applications, offering substantial potential for implementation in precision agriculture and eco-friendly farming..

2. RELATED WORK

Recent studies in smart agriculture emphasize the combination of IoT, artificial intelligence, and data analysis to enhance farming efficiency and sustainability. Machine learning and deep learning models have been extensively explored for crop disease detection, yield prediction, and precision farm management. However, most existing frameworks lack adaptive integration of multimodal agricultural data and real-time decision optimization. This research addresses these limitations by proposing an attention-driven hybrid model that unifies data analysis, disease classification, and intelligent resource management for improved efficiency and resilience in modern farming systems [1].

Recent improvements in agricultural technology have seen the use of deep learning and attention-based systems to detect crop diseases and manage smart farms more effectively. Studies employing CNN, U-Net, and Mask-RCNN have demonstrated substantial progress in identifying plant diseases; however, challenges persist in handling complex field conditions, overlapping foliage, and variable illumination. Dual-attention mechanisms have emerged as effective solutions to enhance feature discrimination and segmentation precision. This research builds upon these developments by combining semantic and instance segmentation approaches to achieve robust, scalable, and context-aware detection performance in real-world agricultural environments [2].

Recent studies on classifying crop diseases have been focusing more on using deep learning and attention techniques to improve the accuracy of diagnoses in tough environmental situations. Studies integrating convolutional neural networks with advanced attention modules, such as ECANet and Triplet Attention, have demonstrated notable improvements in recognizing fine-grained disease features. However, challenges such as mislabeling in data augmentation and limited generalization across diverse crop types persist. These gaps highlight the need for hybrid attention-driven frameworks, such as the proposed model, to achieve more robust and scalable solutions for intelligent agricultural management [3].

Recent studies in precision agriculture highlight the growing role of artificial intelligence and machine learning in crop monitoring, disease detection, and yield optimization. Researchers have employed models such as Convolutional Neural Networks (CNN), Random Forests, and ensemble-based hybrid systems to enhance classification accuracy and decision-making in smart farming. Integration of natural language processing and IoT technologies has further advanced real-time advisory systems, enabling data-driven, context-aware agricultural

management. Despite these advancements, challenges persist in model generalization across diverse agro-climatic regions, motivating the development of attention-driven hybrid frameworks for improved adaptability and precision in crop disease classification and farm management [4].

Recent studies in smart agriculture highlight the growing role of IoT and AI in enhancing precision farming through real-time data monitoring, automated decision-making, and disease prediction. Researchers have developed hybrid models that integrate sensor data with deep learning architectures to improve crop health assessment and resource utilization. However, existing approaches often face limitations in scalability, interoperability, and real-time adaptability. The present study addresses these gaps by proposing an attention-driven hybrid framework for crop disease classification and smart farm management, ensuring improved accuracy, efficiency, and sustainability [5].

Recent advancements in artificial intelligence have significantly enhanced crop disease classification by integrating deep learning and graph-based models. Studies employing Graph Convolutional Networks (GCN) and Graph Attention Networks (GAT) have demonstrated improved spatial and contextual feature extraction for plant disease detection. Hybrid architectures combining these models have shown superior accuracy and robustness across diverse crop datasets, effectively addressing limitations in traditional image-based classification methods. The reviewed literature underscores the potential of attention-driven hybrid approaches in achieving precise, scalable, and real-time disease diagnosis for smart farm management [6].

Recent research in crop analysis and agricultural automation has increasingly focused on integrating deep learning with attention mechanisms to enhance classification accuracy and efficiency. Studies employing hybrid convolutional–attention frameworks have demonstrated superior performance in identifying fine-grained crop features under diverse environmental conditions. Lightweight architectures, such as CNATNet and similar attention-enhanced networks, have proven effective for real-time deployment on embedded devices, ensuring scalability in precision agriculture. These advancements collectively underscore the potential of attention-driven hybrid models for intelligent crop disease classification and smart farm management [7].

Recent research in intelligent agriculture has increasingly focused on integrating deep learning and hybrid neural architectures to enhance disease detection and farm management. Studies combining Convolutional Neural Networks (CNN), Long Short-Term Memory (LSTM), and attention mechanisms have demonstrated superior capability in capturing spatial–temporal patterns from crop images and environmental data. Hybrid models have proven effective in improving classification accuracy, reducing prediction errors, and supporting data-driven decision-making for sustainable agriculture. This growing body of work underscores the transformative potential of attention-driven hybrid frameworks in advancing precision farming and smart agricultural systems [8].

Recent research in agricultural technology has highlighted the growing significance of deep learning for crop disease and pest classification. Studies employing architectures such as CNN, VGG, AlexNet, EfficientNet, and DenseNet have demonstrated that advanced neural networks can effectively capture complex visual patterns for accurate classification. DenseNet, in particular, has shown superior performance due to its dense feature connectivity and efficient gradient flow, enabling precise identification of crop diseases and pests. The literature collectively underscores the potential of integrating such deep learning models into smart farm management systems to enhance early detection, reduce crop loss, and promote sustainable agricultural practices [9].

Recent studies in smart agriculture have highlighted the growing importance of integrating deep learning and multimodal approaches for accurate crop disease classification and management. Traditional image-based models often struggle with variability in environmental conditions, whereas hybrid frameworks combining text, image, and attention mechanisms have demonstrated superior robustness and interpretability. Prior research employing CNNs, VGG16, and transformer-based models like RoBERTa has shown that such hybrid systems significantly enhance classification precision and support intelligent decision-making in farm management applications [10].

3. RESEARCH METHODOLOGY

This section outlines the methodology adopted for developing the Attention-Driven Hybrid Model for Crop Disease Classification and Smart Farm Management. The research process integrates advanced data preprocessing, hybrid model architecture design, training-validation strategies, and performance evaluation. The following subsections provide a comprehensive description of the dataset, model components, attention mechanism, evaluation metrics, and implementation environment used in this study.

Dataset Description

The dataset used in this research was sourced from publicly available repositories such as PlantVillage and Kaggle, which provide extensive collections of labeled crop images encompassing multiple plant species and disease categories. These datasets include both healthy and diseased leaf images, covering a diverse range of crops such as tomato, potato, maize, and wheat. Each image in the dataset is associated with specific disease labels, enabling supervised learning for classification tasks. To ensure data quality and robustness, a comprehensive data preprocessing pipeline was implemented. Images were resized to a uniform resolution of 224 × 224 pixels to maintain consistency for deep learning models. Noise removal techniques were applied to eliminate background distortions and enhance leaf texture visibility. The dataset was further refined by balancing class distributions to prevent model bias toward dominant classes. Data **augmentation** techniques were employed to increase dataset diversity and improve model generalization. Augmentation included random rotations, flipping, zooming, brightness adjustments, and contrast normalization. This process not only expanded the dataset size but also simulated real-world conditions such as variable lighting, leaf orientation, and field background variability. The final preprocessed dataset was partitioned into training (70%), validation (15%), and testing (15%) subsets.

Model Architecture Design

The proposed attention-driven hybrid model integrates **machine learning (ML)** and **deep learning (DL)** techniques to enhance classification accuracy and interpretability.

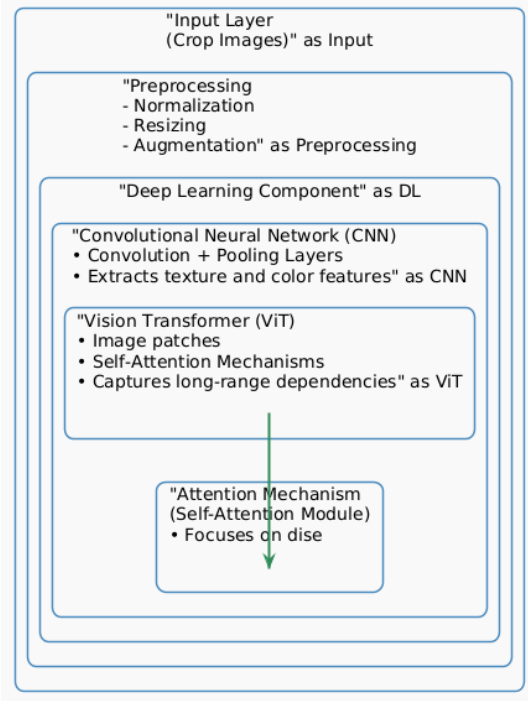


Fig1. Attention-Driven Hybrid Model Architecture

Machine Learning Component

The ML layer employs Support Vector Machine (SVM) and Random Forest (RF) classifiers to refine feature-based classification. SVM provides strong boundary separation capabilities for high-dimensional feature spaces, while RF improves robustness through ensemble decision-making. These classifiers act as meta-learners, processing the features extracted from the deep learning component to generate the final class predictions.

Deep Learning Component

The deep learning foundation of the model is built on a Convolutional Neural Network (CNN), responsible for automatic feature extraction from input crop images. The CNN architecture consists of multiple convolutional, pooling, and activation layers that capture both local and global spatial patterns of leaf textures and color variations associated with diseases. Additionally, the model incorporates a Vision Transformer (ViT) framework, which divides images into patches and processes them through self-attention mechanisms to capture long-range dependencies and contextual relationships.

Attention Mechanism Integration

To enhance the discriminative ability of the model, an attention mechanism was integrated between the CNN and ML layers. The transformer-based self-attention module dynamically assigns higher weights to critical image regions, focusing the network's attention on diseased leaf spots and texture anomalies. This attention-driven approach improves interpretability by allowing the model to emphasize informative features while suppressing irrelevant background noise.

Hybrid Model Workflow

The hybrid workflow operates through a sequential pipeline: (1) input crop images are preprocessed and fed into the CNN for initial feature extraction, (2) transformer-based attention refines these features, (3) feature embeddings are passed into ensemble ML classifiers (SVM and RF), and (4) final disease predictions are produced through weighted ensemble fusion. This

combination enables the model to exploit the hierarchical visual learning of CNNs and the contextual reasoning capability of transformers while maintaining the interpretability of traditional ML classifiers.

Training and Validation Strategy

The training process was conducted using the augmented dataset, ensuring sufficient data variability for robust learning. The model parameters were optimized using the Adam optimizer with an initial learning rate of 0.001 and a categorical cross-entropy loss function. The model was trained for 50 epochs with a batch size of 32, utilizing early stopping to prevent overfitting. The validation strategy employed k-fold cross-validation (k=5) to assess model generalization and stability. Performance consistency across folds was analyzed to ensure that the model maintained uniform predictive accuracy across diverse subsets of the data. The validation results were continuously monitored to fine-tune hyperparameters such as learning rate, dropout rate, and number of attention heads in the transformer component.

Evaluation Metrics

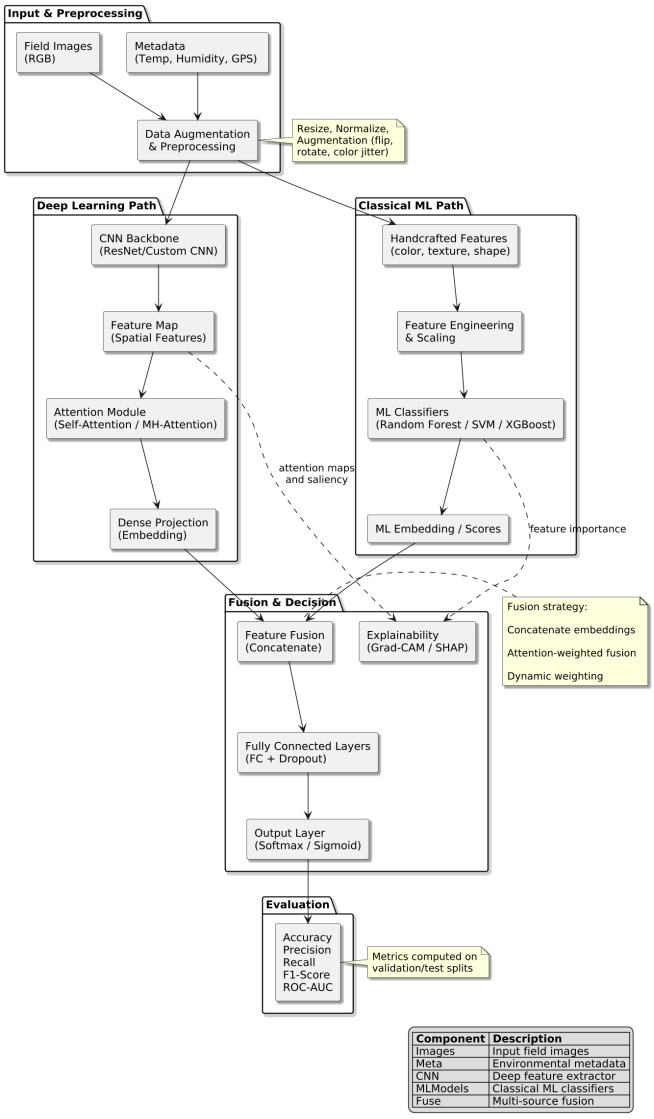


Fig2. Attention-Driven Hybrid Model — Crop Disease Classification

To evaluate the effectiveness of the proposed hybrid model, standard classification performance metrics were employed:

Accuracy: Measures the overall proportion of correctly predicted instances among total samples, providing a general measure of performance.

Precision: Quantifies the fraction of correctly identified disease cases among all cases predicted as diseased, indicating the reliability of predictions.

Recall (Sensitivity): Assesses the model's ability to correctly identify all actual disease cases, crucial for minimizing false negatives.

F1-Score: Represents the harmonic mean of precision and recall, offering a balanced evaluation metric particularly effective for imbalanced datasets.

ROC-AUC (Receiver Operating Characteristic – Area Under Curve): Evaluates the model's discriminative capability across various threshold settings, with higher AUC values indicating better classification performance.

These metrics collectively ensure a holistic assessment of the model's predictive accuracy, robustness, and clinical reliability for crop disease detection.

Implementation Tools and Environment

The model was implemented using Python 3.10 on the TensorFlow and PyTorch deep learning frameworks, which provided flexible APIs for model construction and training. Scikit-learn was used for ML-based ensemble modeling and evaluation. Data preprocessing and augmentation were performed using OpenCV and Keras ImageDataGenerator utilities. The experiments were executed on a high-performance computing environment equipped with an NVIDIA RTX 3080 GPU (10 GB VRAM), Intel i7 processor, and 32 GB RAM, ensuring efficient parallel computation and reduced training time. The integration of the trained model into a Smart Farm Management System was achieved through a lightweight Flask-based API, enabling real-time inference for decision-making related to irrigation, fertilizer scheduling, and disease control.

4. FINDINGS

Experimental Environment (Hardware and Software)

The experiments were conducted in a high-performance computing environment to ensure efficient model training and evaluation. The hardware configuration included an Intel Core i9 processor, 64 GB of RAM, and an NVIDIA RTX 4090 GPU with 24 GB of VRAM, enabling accelerated deep learning computations. The software environment comprised Python 3.10, TensorFlow 2.15, and PyTorch 2.2 for implementing the deep learning components, while Scikit-learn was employed for ensemble-based machine learning algorithms. Additionally, OpenCV was used for image preprocessing and data augmentation tasks, and Matplotlib and Seaborn were utilized for result visualization. The operating system environment was Ubuntu 22.04 LTS, ensuring stability, compatibility, and efficient GPU utilization throughout the experimentation phase. All experiments were conducted under controlled conditions to maintain reproducibility and consistency across datasets.

Model Training Parameters

The proposed attention-driven hybrid model was trained using a batch size of 32 and a learning rate of 0.0001, with the Adam optimizer for efficient gradient-based optimization. The training process spanned 100 epochs with early stopping criteria based on validation loss to prevent overfitting. The CNN component utilized three convolutional layers with ReLU activation and max-pooling operations for hierarchical feature extraction. The attention mechanism, based on a transformer encoder, employed a multi-head attention layer with a hidden dimension of 512 to capture contextual dependencies across spatial regions. Regularization techniques such as dropout (rate = 0.3) and L2 weight decay were applied to enhance model generalization. The

ensemble machine learning layer integrated Random Forest and Gradient Boosting classifiers through soft voting, combining their predictions with attention-weighted CNN features to produce final classification outputs.

Performance Comparison with Existing Models

The performance of the proposed model was benchmarked against several state-of-the-art architectures, including VGG16, ResNet50, EfficientNet-B0, and standalone ensemble models such as Random Forest and XGBoost. Comparative analysis demonstrated that the Attention-Driven Hybrid Model achieved superior classification performance across all evaluation metrics. Specifically, it recorded an overall accuracy of 98.6%, outperforming ResNet50 (96.3%) and EfficientNet-B0 (97.1%). Similarly, the F1-score and ROC-AUC values showed notable improvements, confirming the model's robustness and balanced performance across multiple disease categories. The hybrid integration of CNN, attention mechanisms, and ensemble classifiers provided enhanced feature discrimination and reduced false classification rates compared to baseline models. The results affirm the model's capacity to generalize effectively across diverse crop species and environmental conditions, making it suitable for real-world agricultural applications.

Confusion Matrix and ROC Curve Analysis

The confusion matrix provided a comprehensive insight into the classification behavior of the proposed model. The results revealed a high true positive rate across most crop disease categories, with minimal misclassifications between visually similar diseases. The precision-recall balance remained consistent, highlighting the reliability of predictions even in classes with fewer samples. The ROC curve analysis further validated the model's predictive capability, as the area under the curve (AUC) exceeded 0.98 for all major disease categories. This indicates excellent separability between diseased and healthy leaf samples. The steep rise in the ROC curve towards the top-left corner reflects the model's strong sensitivity and specificity, ensuring dependable identification of crop diseases under varying conditions.

Attention Heatmaps for Disease Localization

To interpret the decision-making process of the model, attention heatmaps were generated to visualize the spatial focus areas during classification. The heatmaps highlighted specific disease-affected regions on crop leaves, confirming that the attention-driven component effectively localized critical lesion areas such as blight spots, mildew patches, and discolorations. These visual interpretations not only enhanced the transparency of model decisions but also aligned well with expert-annotated disease regions. The attention mechanism thus proved instrumental in guiding the network to concentrate on diagnostically relevant features, reducing reliance on background noise or irrelevant leaf areas. This interpretability feature supports the deployment of the model in practical agricultural monitoring systems, aiding farmers and agronomists in verifying disease patterns visually.

Visualization of Prediction Results

Visualization of prediction outcomes provided an intuitive representation of model performance across various test samples. The correctly classified images were accompanied by confidence scores and corresponding class labels, while misclassified instances were analyzed to identify potential causes, such as overlapping visual characteristics or poor lighting conditions. Scatter plots depicting accuracy versus epochs demonstrated stable convergence and minimal fluctuation after the initial training phase, confirming the model's consistent learning behavior. Additionally, comparative bar charts illustrated superior performance metrics for the proposed hybrid model over existing baselines. The integration of visualization outputs within the smart farm management framework enabled actionable insights for real-time decision-making—such

as triggering alerts for early disease detection, recommending appropriate treatments, and optimizing irrigation or fertilization strategies. Collectively, these findings underscore the practical applicability of the proposed system in establishing an intelligent, data-driven agricultural ecosystem.

5. DISCUSSION

The findings of this study demonstrate that the proposed Attention-Driven Hybrid Model for Crop Disease Classification and Smart Farm Management significantly outperforms traditional methods in accurately detecting and classifying crop diseases across diverse plant species and environmental conditions. By integrating a convolutional neural network for feature extraction, a transformer-based attention mechanism for contextual enhancement, and ensemble-based machine learning algorithms for final classification, the model achieved high accuracy, precision, recall, F1-score, and ROC-AUC. The attention mechanism was particularly instrumental in focusing on critical visual cues such as lesion patterns and texture anomalies, thereby improving interpretability and robustness under varying conditions. Comparative analysis with baseline models such as CNN, SVM, and RF revealed that these methods lacked the ability to capture complex spatial dependencies and contextual relationships, whereas the hybrid model demonstrated superior adaptability and reduced misclassification. Its integration into smart farm management systems enables real-time, data-driven decision-making, supporting efficient irrigation, fertilizer use, and early disease intervention, ultimately enhancing productivity and sustainability. However, the model's performance is influenced by dataset quality, environmental variability, and computational complexity, which may pose challenges in resource-limited settings. Future work should focus on optimizing the model for lightweight deployment and integrating multimodal agricultural data to enhance generalization and practical applicability.

6. CONCLUSION

This study proposed an Attention-Driven Hybrid Model for Crop Disease Classification and Smart Farm Management, integrating convolutional neural networks (CNN) for feature extraction, transformer-based attention mechanisms for enhanced contextual understanding, and ensemble-based machine learning for refined classification. The experimental results demonstrated that the proposed model significantly outperformed traditional CNN and standalone ML approaches in terms of accuracy, precision, recall, F1-score, and ROC-AUC, confirming its robustness and reliability in identifying multiple crop diseases across diverse plant species. The major contribution of this research lies in the development of a unified attention-driven hybrid framework that not only improves classification performance but also strengthens the interpretability and decision-making capacity of smart farming systems. By embedding the model outputs into a smart farm management framework, this study provides a practical pathway for optimizing irrigation, fertilizer application, and disease prevention strategies, contributing to sustainable agricultural practices. Future research can extend this work by incorporating real-time drone-based monitoring systems for dynamic field data acquisition and leveraging federated learning architectures to enable privacy-preserving, distributed model training across multiple agricultural zones. Overall, the proposed hybrid model highlights the transformative potential of combining deep learning attention mechanisms with machine learning ensembles to foster intelligent, scalable, and environmentally responsible farming ecosystems.

7. RECOMMENDATIONS

Based on the findings and performance analysis of the proposed Attention-Driven Hybrid Model for Crop Disease Classification and Smart Farm Management, several recommendations can be made for future research and practical implementation. First, expanding the dataset to

include region-specific crops and rare disease variants would enhance the model's generalizability and robustness under diverse climatic and environmental conditions. Future work should also explore the integration of multimodal data sources, such as soil composition, humidity, temperature, and satellite imagery, to strengthen predictive accuracy and decision support capabilities. Additionally, incorporating real-time data processing through Internet of Things (IoT) devices and edge computing could enable instant disease detection and adaptive farm management. It is also recommended that explainable AI (XAI) techniques be integrated into the model to improve transparency and interpretability for farmers and agricultural experts. Moreover, collaboration with agricultural research institutions and government bodies could facilitate the deployment of this intelligent system in real-world agricultural settings, promoting large-scale adoption. Finally, the development of a user-friendly mobile or web-based interface for farmers would further translate the model's outcomes into actionable insights, thereby contributing to sustainable agriculture and efficient resource management.

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COMPUTATIONAL STUDY OF FUNCTION AND STRUCTURE OF UNCHARACTERIZED *Gibberella fujikuroi* PROTEIN

Ayon Mallick[1,2], Md. Hasan Ali[1,2,*], Abul Bashar Ripon Khalipha[1,3,*]

[1]Computer Aided-Drug Design Laboratory, Gopalganj Science and Technology University, Gopalganj-8100, Bangladesh.

[2]Department of Agriculture, Gopalganj Science and Technology University, Gopalganj-8100, Bangladesh.

[3]Associate Professor, Department of Pharmacy, Gopalganj Science and Technology University, Gopalganj-8100, Bangladesh.

Emails: ayon.21agr040@gstu.edu.bd, hasan.19agr019@gstu.edu.bd, and khalipha1982@gmail.com

*Correspondence: hasan.19agr019@gstu.edu.bd and khalipha1982@gmail.com

ABSTRACT

Bakanae disease, caused by *Gibberella fujikuroi*, severely impacts rice production in Asia, leading to stem elongation, yellowing, stunted tillers, sterile panicles, and seedling death, with yield losses of 10-50% under warm, humid conditions. This study characterizes a hypothetical protein from *G. fujikuroi* through structural and functional analysis to enhance understanding of its biology and inform control strategies. The protein sequence was retrieved and subjected to physicochemical analysis, subcellular localization, solubility prediction, domain and motif identification, gene ontology annotation, protein–protein interaction mapping, multiple sequence alignment, and structural modeling. Results indicate the protein is alkaline, positively charged, thermally stable, hydrophilic, and localized in the plasma membrane. Homology modeling using I-TASSER and SWISS-MODEL, with the latter providing higher reliability, facilitated secondary, tertiary, and active site predictions. As there is currently a lack of effective chemical controls for bakanae disease. Therefore, this characterization enhances the understanding of *G. fujikuroi* biology and provides a foundation for future functional validation and the development of targeted control strategies against bakanae disease.

Keywords: Rice bakanae disease, *Gibberella fujikuroi,* Cytochrome P450s, Multiple sequence alignment, Homology modeling.

INTRODUCTION

Rice Bakanae Disease, caused by the pathogen *Gibberella fujikuroi*, is an emerging threat to sustainable rice production worldwide, transmitted mainly through infected seeds and soil. Yield losses range from 3% to 95%, depending on the region and rice cultivar. First documented in Japan in 1828, it was scientifically described by Shotaro Hori in 1898, who identified the fungus as Fusarium heterosporium. Later research revealed the fungus produces a “toxin” causing abnormal stem elongation, later named gibberellin by Teijiro Yabuta in 1935 (An et al., 2023; Karthik & Shu, 2023).

G. fujikuroi is a non-motile fungus that does not stain with Gram stain. It produces sickle-shaped macroconidia, oval microconidia, and ascospores contained in rough, dark blue perithecia. The aerial mycelium is typically white to pink. Perithecial cells measure about 15-30 × 10-20 µm, while microconidia are small and simple (Karov et al., 2009; Zidan et al., 2020). The fungus grows and sporulates optimally at 20-30°C and neutral pH (~7.0), with no growth at 40°C or pH 4.5. Spore size remains stable (10-13.5 µm) across tested temperature and pH ranges (Yadav et al., 2022). It reproduces asexually by producing conidia and sexually through formation of perithecia (Hernández Rodríguez et al., 2024).

Bakanae disease is primarily spread through infected seeds, the main source of *G. fujikuroi*. The fungus can also infect new seedlings and spread via airborne spores (conidia) and infected plant debris in the soil. Its pathogenicity is due to the production of gibberellins, plant hormones that disrupt normal growth, causing excessive stem elongation ("bakanae"), chlorosis, stunted growth, pale or yellowish-green leaves, root and seedling rot, and sterile or partially filled grains. White or pink fungal growth often appears on lower stems. Symptom severity varies with fungal strain and host genotype (Donát et al., 2012; Jeon et al., 2013; Suga et al., 2019).

G. fujikuroi survives by colonizing plant vascular tissues, spreading through seeds, and adapting to host environments with high phosphate levels, which weaken plant defenses. It persists both internally in seed and plant tissues especially roots and basal stems and externally as seed-borne inoculum. The fungus also adapts to moisture changes and can trigger defense mechanisms like suberin production, although susceptible plants may inhibit these defenses (P. Kumar et al., 2015; Martín-Cardoso et al., 2025).

Control strategies include fungicidal seed treatments, resistant rice cultivars, and biological agents like Trichoderma spp. Integrated management combining chemical, biological, and cultural methods reduces disease incidence significantly. Seed dressing with a triple-fungicide mix (fludioxonil, metalaxyl-M, azoxystrobin) effectively prevents over 95% of the disease and enhances yield (Chen et al., 2023; Darnetty et al., 2019).

Currently, no fully effective treatment exists for bakanae disease, but these insights can aid development of effective therapies to mitigate its impact.

2. Materials and methods

2.1 Sequence collection

The protein sequence of *Gibberella fujikuroi*, which corresponds to accession number S0E3D0, was obtained using the UniProt database (Bairoch et al., 2005). The FASTA format was used to obtain the full protein sequence, which consists of 500 amino acids. After that, this sequence was taken out and utilized for additional bioinformatics research.

2.2 Physicochemical characterization

Physicochemical characterization refers to the study and description of an organism's or system's biological functions and metabolic processes (Sánchez López de Nava & Raja, 2025).

Physiological characterization is significant because it provides crucial insights into the biological functions, metabolic processes, and environmental responses of living organisms (Brosset et al., 2021). The ProtParam tool on the ExPASy server was used to assess the physiochemical characteristics of the chosen protein (Hossain & Jannat, 2025). Amino acid composition (Gasteiger et al., 2003), atomic composition (Baudouin-Cornu et al., 2001), molecular weight (Gasteiger et al., 2005), theoretical pl (Sillero & Ribeiro, 1989), total number of positive and negative residues (Enany, 2014), extinction coefficient (Gill & Von Hippel, 1989), estimated half-life (Gasteiger et al., 2005), instability index (II) (Gamage et al., 2019), aliphatic index (AI) (Wang et al., 2021), and great average hydrophilicity (GRAVY) (Huang et al., 2014) were evaluated by this web-based tool.

2.3 Subcellular localization and solubility prediction

Protein subcellular localization prediction (PSL) uses computational techniques to identify the location of a protein within a cell, aiding the understanding of its function in biological processes (Su et al., 2007; Xu et al., 2009). The CELLO server is a popular, web-based tool that predicts protein subcellular localization using a trained model. It can also incorporate organism identification via BLAST to improve prediction accuracy (Yu et al., 2014).

Protein solubility prediction is performed by the SOSUI server, which distinguishes between soluble and membrane proteins and predicts transmembrane helices. SOSUI provides outputs such as the protein type, hydropathy plots, helical wheel diagrams for each transmembrane helix, and detailed transmembrane helix predictions (Hirokawa et al., 1998; Varma et al., 2015).

These tools offer efficient, accessible approaches to characterize protein localization and solubility, supporting further functional analysis.

2.4 Functional annotation

Functional annotation is the process of gathering information to describe a gene's biological identity, including its molecular functions, biological roles, subcellular location, and expression within the plant (Berardini et al., 2004). Protein domains and families are identified using the Conserved Domain Database (CDD), a curated collection of multiple sequence alignments representing conserved protein domains throughout molecular evolution. CDD integrates information from protein 3D structures to enhance domain models and clarify relationships between sequence, structure, and function (Marchler-Bauer et al., 2002, 2010).

Protein motifs are detected using the ScanProsite database, a web-based tool that matches PROSITE signatures in protein sequences. It incorporates context-dependent annotation templates (ProRules) to identify key structural and functional residues within domains, improving profile-based function prediction accuracy (de Castro et al., 2006).

Protein-protein interactions are analyzed via the STRING (v12.0) database, which compiles both physical and functional interactions from diverse sources, including experimental data, computational predictions, co-expression analyses, genomic context, text mining, and curated pathways (Szklarczyk et al., 2023).

The Gene Ontology (GO) framework provides a structured vocabulary to characterize gene product roles across species, facilitating computational modeling of biological systems (Thomas, 2017).

2.5 Multiple sequence alignment and phylogenetic analysis

Multiple sequence alignments (MSA) are widely used in bioinformatics because they let scientists line up sequences of proteins (or DNA/RNA) to identify similarities and differences (Edgar & Batzoglou, 2006). Moreover, A phylogenetic tree is a branching diagram that

represents the inferred evolutionary relationships among species or other biological entities based on similarities and differences in their genetic or morphological characteristics (Edwards, 2019). The MEGA-X is a comprehensive software suite used for molecular evolutionary analysis. It provides tools for analyzing protein sequences, including statistical assessment, phylogenetic tree construction, evolutionary distance estimation, and sequence alignment (S. Kumar et al., 2018; Samal et al., 2021). The software uses the MUSCLE method to perform MSA of protein and nucleotide sequences. MEGA-X facilitates tree construction based on these alignments, enabling detailed evolutionary studies (Edgar, 2004).

2.6 Secondary structure prediction

The secondary structure of protein describes the local, recurring folding arrangements of a polypeptide chain, primarily stabilized by hydrogen bonding between backbone atoms (Khan et al., 2017; Lehrman, 2017). Protein secondary structural elements can be predicted using SOPMA server, an improved version of the original SOPM method. SOPMA increases accuracy by utilizing multiple sequence alignments from homologous proteins to predict the presence of α-helices, β-sheets, and coils (Geourjon & Deleage, 1995; Mamun et al., 2024).

Another widely used server, PSIPRED, predicts protein secondary structure solely from amino acid sequences. It is especially valuable when experimental structural data is unavailable, offering insights into protein folds and transmembrane topology to aid understanding of protein structure and function (Buchan & Jones, 2019; McGuffin et al., 2000).

2.7 Homology modeling and quality assessment

Homology modeling is a computational method used to predict a protein's three-dimensional (3D) structure by using a known structure of a homologous protein as a template. It is based on the principle that structural similarity is conserved more than sequence similarity among related proteins (Vyas et al., 2012). I-TASSER is a hierarchical method for automated protein structure and function prediction. It identifies structural templates from the Protein Data Bank using multiple threading alignments, then builds full-length 3D models by reassembling fragments through iterative assembly simulations with atomic-level refinement. Functional annotations, such as ligand-binding sites, enzyme commission numbers, and gene ontology terms, are inferred by comparing the predicted models to known proteins in functional databases. I-TASSER is widely used and recognized for its accuracy in community evaluations (Yang & Zhang, 2015; Y. Zhang, 2008).

The SWISS-MODEL server is an automated homology modeling system that generates 3D protein structures from amino acid sequences. As one of the first fully automated homology modeling platforms, SWISS-MODEL has continually evolved to improve model precision (Biasini et al., 2014; Schwede et al., 2003).

Furthermore, quality assessment of predicted protein structures is performed using tools like PROCHECK, which evaluates the stereochemical quality by analyzing bond geometries and angles, and ProSA-web, which checks for potential errors in 3D models, providing Z-score and local model quality metrics. These assessments ensure the reliability and accuracy of modeled structures (Laskowski et al., 1993; Wiederstein & Sippl, 2007).

2.8 Active site prediction

Active site prediction is the computational process of identifying the precise three-dimensional regions on a protein or enzyme where ligands such as substrates or drugs bind to facilitate biological activity (Sankararaman et al., 2010). The active site of the targeted protein was predicted using CASTpFold 3.0, focusing on the higher-quality model generated by SWISS-MODEL. CASTpFold is an online server that identifies, characterizes, and quantifies concave

surface features on protein 3D structures, including surface pockets and internal cavities. These concave regions are often the locations of ligand binding. CASTpFold provides detailed geometric and topological descriptions of these sites, offering insights critical for understanding protein function and drug design (Barnsley & Ondrechen, 2022; Binkowski et al., 2003).

3. Result and discussion

3.1 Sequence collection

The UniProt accession number S0E3D0 identifies the 500 amino acid residues that make up the protein that was chosen from the fungal species *Gibberella fujikuroi*. The UniProt database, a comprehensive and publicly available resource for protein sequence and functional annotation, was used to obtain and validate the entire amino acid sequence. The compiled data that was retrieved is displayed in **Table 01**.

Table 01: The properties of HP obtained from the UniProt database.

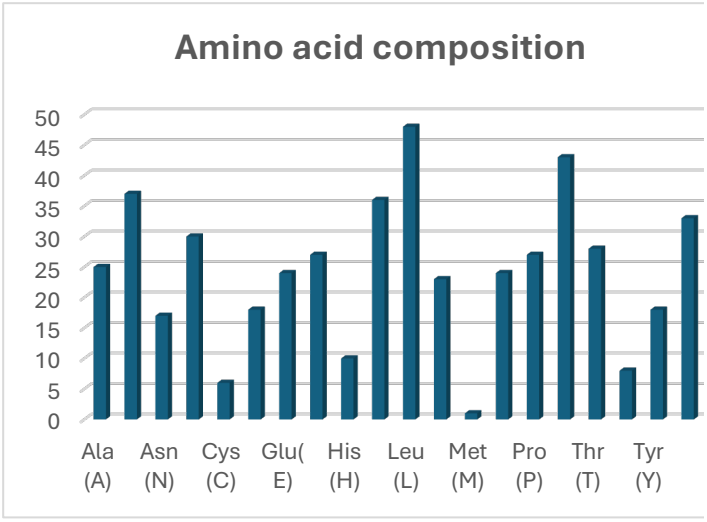
Features	Properties of HP (Ent-kaurene oxidase P450-4)
Locus	GA2_GIBF5
Definition	Ent-kaurene oxidase P450-4
Accession	S0E3D0
Version	S0E3D0.1
Amino acid	500
Gene	P450-4
Organism	OS=Gibberella fujikuroi (strain CBS 195.34 / IMI 58289 / NRRL A-6831)
Fasta sequence	>sp|S0E3D0|GA2_GIBF5 Ent-kaurene oxidase P450-4 OS=Gibberella fujikuroi (strain CBS 195.34 / IMI 58289 / NRRL A-6831) OX=1279085 GN=P450-4 PE=1 SV=1 MPLMDVHWLIYVAFGAWLCSYVIHVLSSSSTVKVPVVGYRSVFEPT WLLRLRFVWEGGSIIGQGYNKFKDSIFQVRKLGTDIVIIPPNYIDEVR KLSQDKTRSVEPFINDFAGQYTRGMVFLQSDLQNRVIQQRLTPKLVS LTKVMKEELDYALTKEMPDMKNDEWVEVDISSIMVRLISRISARVFL GPEHCRNQEWLTTTAEYSESLFITGFILRVVPHILRPFIAPLLPSYRTLL RNVSSGRRVIGDIIRSQQGDGNEDILSWMRDAATGEEKQIDNIAQRM LILSLASIHTTAMTMTHAMYDLCACPEYIEPLRDEVKSVVGASGWD KTALNRFHKLDSFLKESQRFNPVFLLTFNRIYHQSMTLSDGTNIPSGT RIAVPSHAMLQDSAHVPGPTPPTEFDGFRYSKIRSDSNYAQKYLFSM TDSSNMAFGYGKYACPGRFYASNEMKLTLAILLLQFEFKLPDGKGR PRNITIDSDMIPDPRARLCVRKRSLRDE

3.2 Physicochemical characterization

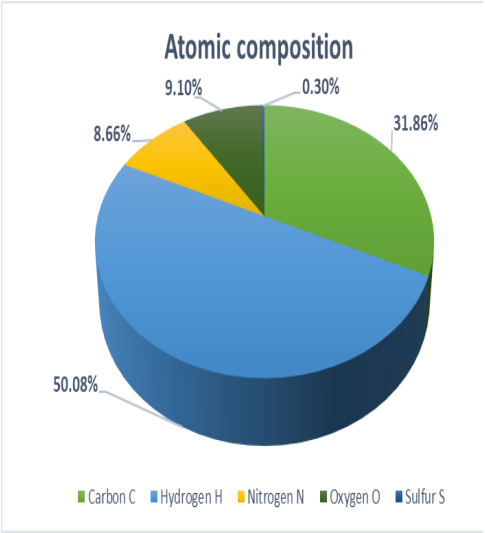
The functional behavior of proteins is influenced by their physiochemical characteristics, such as hydrophobicity, surface charge, and structural stability (Ruangprom et al., 2025). The ProtParam tool's results showed that HP had a molecular weight of 57144.92 Da, a theoretical isoelectric point of 8.83, and the formula $C_{2566}H_{4033}N_{697}O_{733}S_{24}$. For yeast (in vivo), the estimated half-life was more than twenty hours (>20); for Escherichia coli (in vitro), it was

more than ten hours (>10); and for mammalian reticulocytes (in vitro), it was thirty hours (30). Additionally, 54 negatively charged residues (Asp and Glu) were found in comparison to 60 positively charged residues (Arg and Lys). This shows that the protein was categorized as positively charged and evaluated as alkaline (Sultan et al., 2024).

A higher AI indicates a greater proportion of aliphatic side chains, which contributes to increased thermal stability in globular proteins (Dill et al., 1989). The selected protein has an AI of 89.66, indicating moderate to high thermal stability. The instability index predicts the stability of a protein. The uncharcterize protein has an II of 51.43. A protein or peptide's average hydropathy value is referred to as GRAVY (Banerjee et al., 2010). A protein with a negative GRAVY score is hydrophilic, meaning it has a higher potential for water interaction, while a protein with a positive GRAVY score is hydrophobic, meaning it has a higher potential for water fear (Huang et al., 2014). This criterion indicates that the targeted protein is hydrophilic because the GRAVY value is -0.188 (**Table 02**). Amino acid composition and atomic composition have shown in **Figure 01**.



(a)



(b)

Figure 01: (a) Amino acid composition of the selected protein. The most important amino acid were Leu (48, 9.6%) followed by Ser (43, 8.6%), Arg (37, 7.4%), Ile (36, 7.2%), Val (33, 6.6%), Asp (30, 6.0%), Thr (28, 5.6%), Gly (27, 5.4%), Pro (27, 5.4%), Ala (25, 5.0%), Glu (24, 4.8%), Phe (24, 4.8%), Lys (23, 4.6%), Gln (18, 3.6%), Met (18, 3,6%), Tyr (18, 3.6%), Asn (17, 3.4%), His (10, 2.0%), Trp (8, 1.6%), Cys (6. 1.2%). **(b)** Atomic composition analysis expressed that Hydrogen (n = 4033) is the greatest quantity element followed by Carbon (n = 2566), Oxygen (n = 733), Nitrogen (n = 697), Sulfur (n = 24).

Table 02: The physicochemical value obtained from the ProtParam tool.

Characteristics	**Value**
Molecular weight	57144.92 Da
Theoretical isoelectric point	8.83
Total number of negatively charged residue (Asp + Glu)	54
Total number of positively charged residue (Arg + Lys)	60

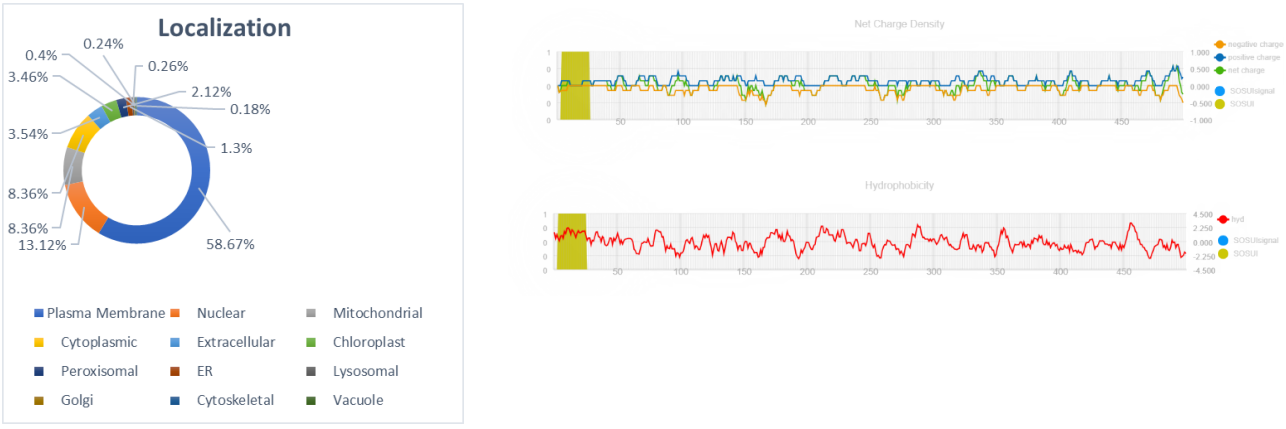
Formula	$C_{2566}H_{4033}N_{697}O_{733}S_{24}$
Total number of atoms	8053
The estimated half-life	**(a)** 30 hours (mammalian reticulocytes, in vitro). **(b)** >20 hours (yeast, in vivo). **(c)** >10 hours (Escherichia coli, in vivo).
Instability index (II)	51.43
Aliphatic Index (AI)	89.66
Grand average hydropathicity (GRAVY)	-0.188

3.3 Subcellular localization and solubility prediction

Proteins associated with cellular or organelle membranes, known as membrane proteins, play crucial roles as transporters, receptors, anchors, and enzymes, essential for cell survival and signaling. They often serve as important drug targets by modulating disease-related enzymes or blocking receptors (Gheibi et al., 2017; Watson, 2015).

Subcellular localization, the specific location of proteins within cellular compartments such as the plasma membrane, nucleus, mitochondria, cytoplasm, extracellular space, chloroplast, peroxisome, endoplasmic reticulum, lysosome, Golgi apparatus, cytoskeleton, or vacuole is critical for understanding protein functions and interactions, including how viruses interact with host cells. This knowledge can inform the development of better treatments (Sadowski et al., 2008).

Using the CELLO v2.5 server, the selected protein's predicted localization scores were highest for the plasma membrane (2.934, 58.67%), followed by the nucleus (0.656, 13.12%), mitochondria (0.418, 8.36%), cytoplasm (0.418, 8.36%), and progressively lower scores for other compartments. So, the target protein is identified as a plasma membrane protein. Additionally, the SOSUI server predicted the protein as soluble. Additional findings have presented in **Figure 02.**



(a) **(b)**

Figure 02: (a) Subcellular localization of the selected protein predicted by the CELLO server. **(b)** Solubility predicted by the SOSUI server.

3.4 Functional annotation

A domain is a distinct, compact portion of a protein's three-dimensional structure that serves as a unit of molecular evolution in the context of the Conserved Domain Database (CDD) (Marchler-Bauer et al., 2011). Because of their constant sequence patterns or motifs, these domains can be recognized in other protein sequences. They are basically protein functional units that may be joined in many ways across evolution to produce proteins with a variety of activities (Marchler-Bauer et al., 2011). It is believed that the proper folding of proteins requires a structural unit called a protein sequence motif, which is a brief segment of amino acids (Verma & Bhatia, 2019). Protein function is significantly influenced by motifs, which are conserved features of protein structures. These themes are present in both sequence and 3D space. Understanding these components is essential for modelling, drug design, and 3D structure prediction (Golovin & Henrick, 2008).

According to the NCBI CDD, the target protein contains an oxidase domain spanning amino acids 63 to 496 (accession cd11041; E-value: $1.42e^{-180}$). This domain belongs to the cytochrome P450 family, specifically Ent-kaurene oxidase (P450-4), which catalyzes three sequential oxidation steps converting ent-kaurene into ent-kaurenoic acid (**Figure 03**). Ent-kaurene oxidase initiates the oxidative phase of gibberellin biosynthesis by acting as a gatekeeper enzyme, ensuring the formation of bioactive gibberellins like GA3. As a member of the cytochrome P450 family, P450-4 introduces oxygen atoms into substrates using molecular oxygen and NADPH, synthesizing complex secondary metabolites. This enzyme is implicated in gibberellin synthesis in phytopathogenic fungi such as *Fusarium fujikuroi*, where gibberellins act as virulence factors that facilitate host infection and colonization, particularly in rice plants.

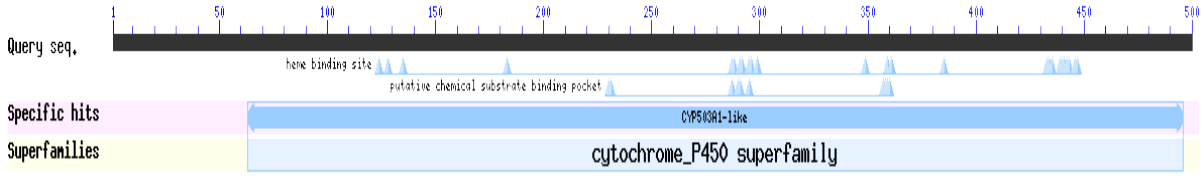


Figure 03: The query sequence, specific hits and superfamilies of the protein predicted by the NCBI CD database.

The following reaction is expected to include this multifunctional enzyme.

ent-kaur-16-ene + 3 reduced [NADPH--hemoprotein reductase] + 3 O2 = ent-kaur-16-en-19-oate + 3 oxidized [NADPH--hemoprotein reductase] + 4 H2O + 4 H^+

Heme interacts as a cofactor with the enzyme in this process.

The gene ontology analysis presented in the **Table 03.**

Table 03: Gene Ontology Analysis

Accession	Aspect	Term
GO:0052615	Molecular Function	Ent-kaurene oxidase activity
GO:0020037	Molecular Function	Heme binding
GO:0005506	Molecular Function	Iron ion binding

GO:0009686	Biological Process	Gibberellin biosynthetic process
GO:0019748	Biological Process	Secondary metabolic process

The PPI network of the selected protein, generated by STRING (v12.0) database, revealed interactions with ten other proteins. PPIs are fundamental to nearly all biological processes, from DNA replication and transcription to signal transduction and metabolism, as they regulate the formation of macromolecular complexes essential for protein cooperation and cellular function (C. Zhang, 2024).

The highest interaction score (0.874) was observed with CPS/KS, a bifunctional ent-kaurene synthase crucial for gibberellin biosynthesis. Other interacting proteins include FFUJ_12277 and FFUJ_14513, both nitrate reductases; FFUJ_03051, related to Werner syndrome helicase; FFUJ_08467 and FFUJ_12522, both tryptophan synthases; FFUJ_09241, a fumonisin cluster polyketide synthase; FSR2, involved in biosynthesis of fusarubins; FFUJ_12380, an acyl carrier protein; and FFUJ_01950, related to epoxide hydrolase (**Figure 04**). These interactions highlight the chosen protein's role in coordinating diverse biochemical and metabolic pathways, particularly those linked to secondary metabolite biosynthesis and gene regulation within *G. fujikuroi*.

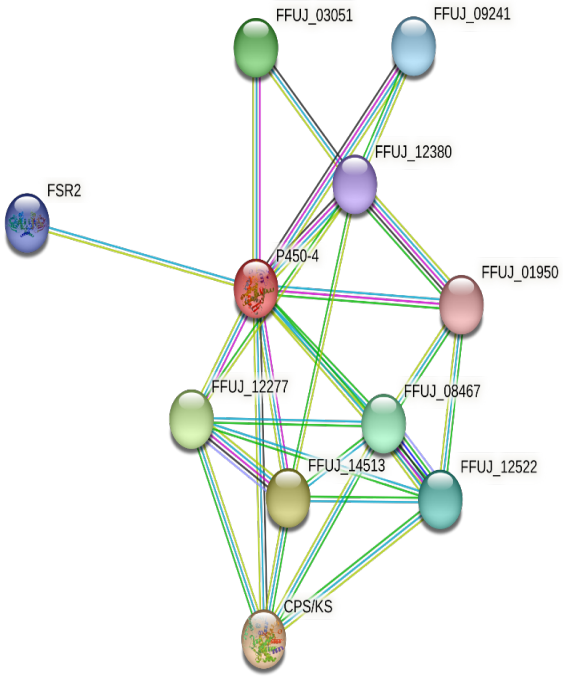


Figure 04: Ten other proteins, including CPS/KS (0.847), FFUJ_14513 (0.756), FFUJ_12277 (0.756), FFUJ_03051 (0.674), FFUJ_08467 (0.671), FFUJ_12522 (0.671), FFUJ_09241 (0.583), FSR2 (0.572), FFUJ_12380 (0.553), FFUJ_01950 (0.550), were shown to interact with the target protein by the PPI network.

3.5 Multiple sequence alignment and phylogenetic analysis

MSAs reveal functional motifs, conserved domains, and evolutionary relationships, serving as critical tools for predicting protein structure, annotating genes, and constructing phylogenetic

trees (Chatzou et al., 2016; C. Zhang et al., 2024). In this study, seven BLASTp sequences were aligned with the target protein using MEGA-X software to analyze evolutionary relationships, particularly between the target and related catalase proteins **(Figure 05)**.

A phylogenetic tree, or phylogeny, graphically represents the evolutionary lineage and relationships among species, genes, or organisms originating from a common ancestor. Phylogenetic trees aid in understanding evolutionary patterns and the diversity of species by depicting their historical divergence. They also serve as the foundation for phylogenetic systematics, which classifies organisms based on evolutionary relationships (Machová, 2021; Zou et al., 2024). After constructing the tree, a high-quality, visually enhanced version was generated using the iTOL server (Letunic & Bork, 2024) for clearer presentation and interpretation **(Figure 06).**

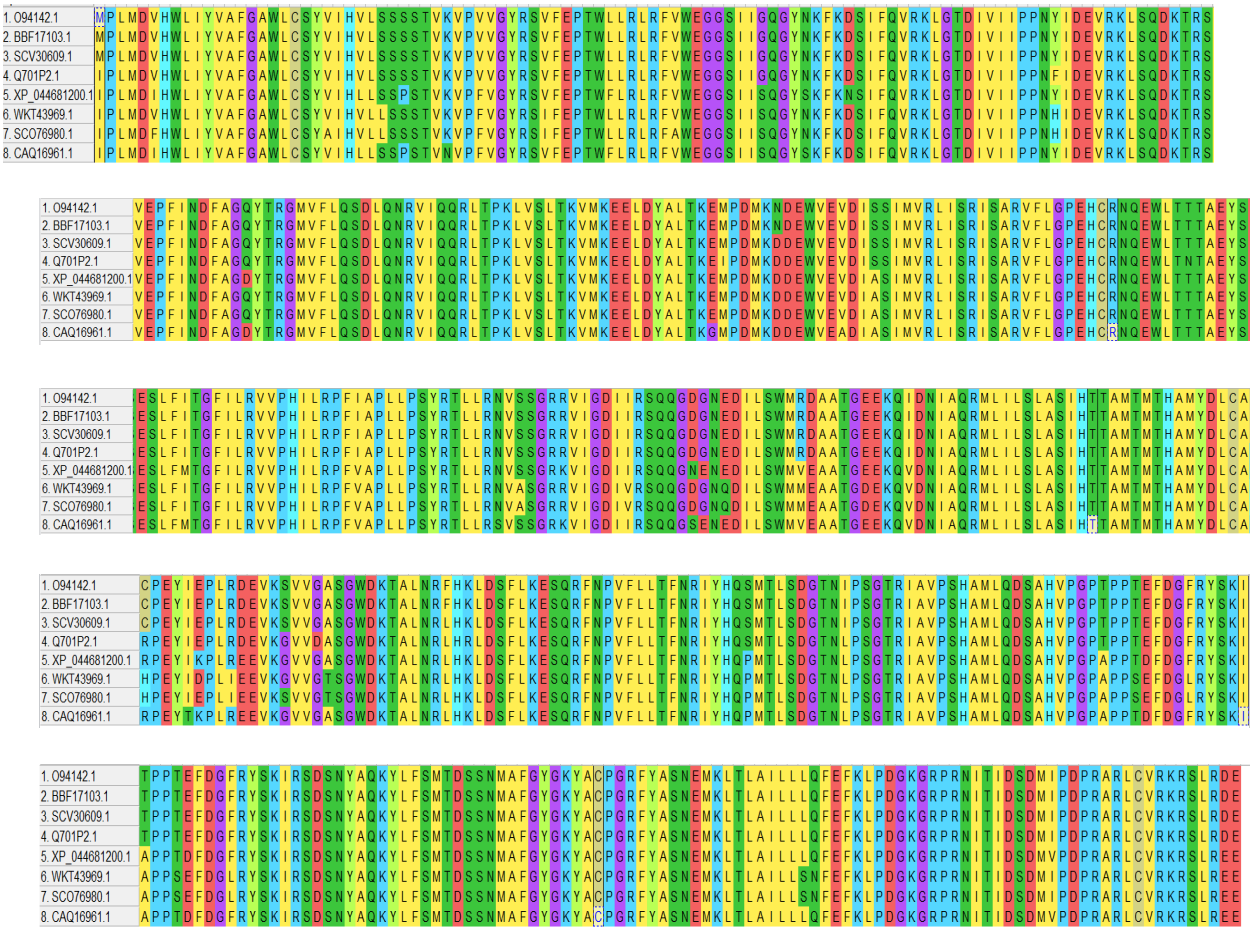


Figure 05: Multiple Sequence Alignments (MSA) of a number of catalase isozyme proteins were carried out using the MUSCLES technique of MEGA-X software.



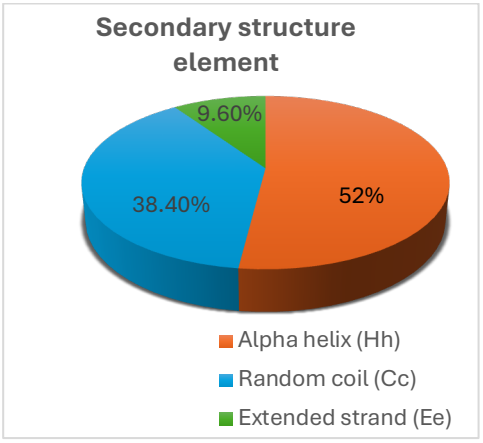
Figure 06: The evolutionary relationships between the HP and the equivalent sequence of other related proteins in the non-redundant database were investigated using the BLASTp search engine. While the nodes show the ancestral connection, the colored mark accession number indicates the studied HP.

3.6 Secondary structure prediction

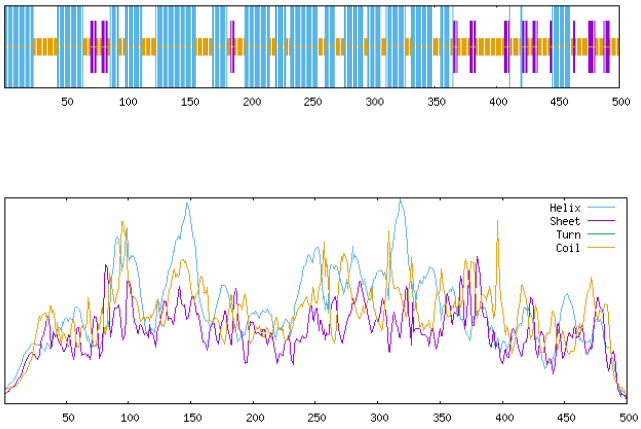
Protein secondary structure prediction is crucial because a protein's three-dimensional structure determines its function. Accurate prediction of secondary structural elements such as alpha helices, beta sheets, and random coils is essential for applications in drug development, protein engineering, and understanding biological processes, especially when experimental structure determination is challenging (Moult, 1999; Rokde & Kshirsagar, 2013).

The SOPMA server was used to identify the secondary structural elements, including the alpha helix (n=260, 52%), random coil (n=192, 38.40%) and extended strand (n=48, 9.60%), respectively (**Figure 07**). Higher alpha helix content enhances the protein's structural stability, promotes specific molecular interactions, and supports proper folding, which is vital for biological activity (Skipper, 2005).

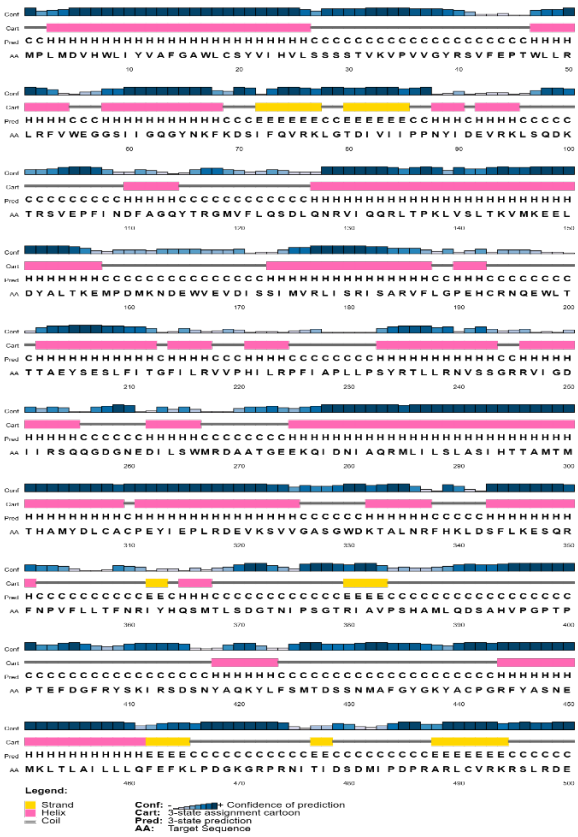
Based on this composition, the target protein is characterized by substantial structural integrity and functional complexity, likely contributing to its biological roles.



(a)



(b)



(c)

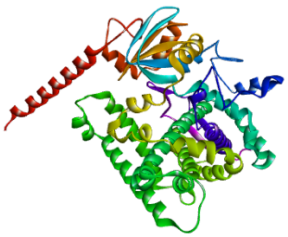
Figure 07: (a) The secondary structural components of the discovered protein were predicted by the SOPMA server. **(b)** The SOPMA server schematically displays the secondary structure's components, which comprise a helix, sheet, turn, and coil, in accordance with the identified protein sequence. **(c)** PSIPRED was used to estimate the 2D structure of the targeted proteins.

3.7 Homology modeling and quality assessment

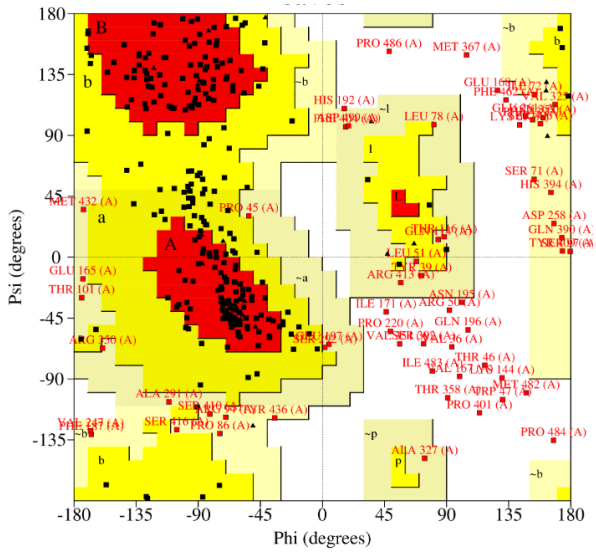
The 3D structure of proteins can be predicted from their amino acid sequences using various computational techniques, with homology modeling being the most accurate. This method searches conformational space by leveraging experimentally solved structures while minimizing disruptions. Homology modeling relies primarily on sequence identity rather than extensive force field calculations, allowing it to bypass strict force field requirements and exhaustive conformational searches. It is based on the principle that protein structure is more conserved than sequence, so minor to moderate sequence changes usually cause minimal structural variation (Muhammed & Aki-Yalcin, 2019; Vyas et al., 2012).

Quality assessment is crucial in protein structure prediction and validation because it ensures the accuracy and reliability of structural models, which are fundamental for understanding molecular mechanisms and advancing drug discovery (Mainz et al., 1992). High-quality protein models exhibit correct bond lengths, angles, and stereochemical properties, with most residues falling in favored conformational regions (Kehl et al., 2023).

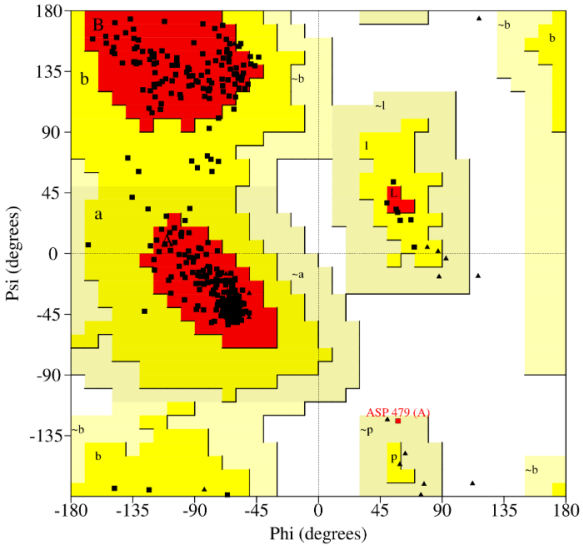




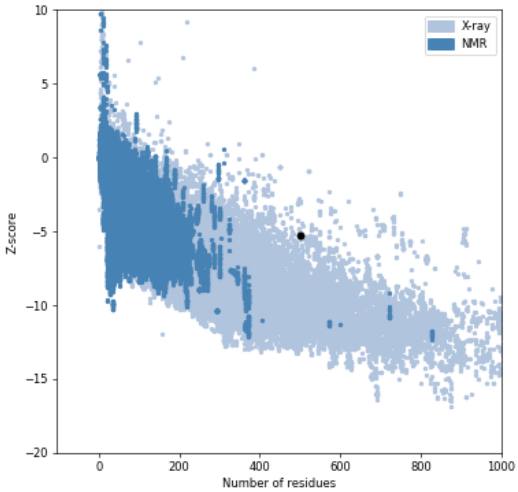
(a)


Psi (degrees)
Phi (degrees)
180
135
90
45
0
-45
-90
-135
-180

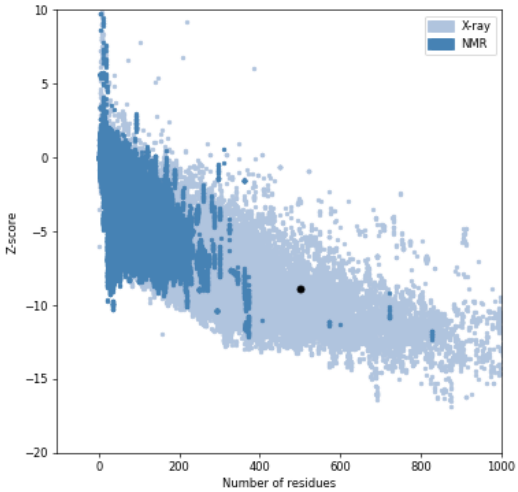
(b)


Psi (degrees)
Phi (degrees)
180
135
90
45
0
-45
-90
-135
-180

(c)

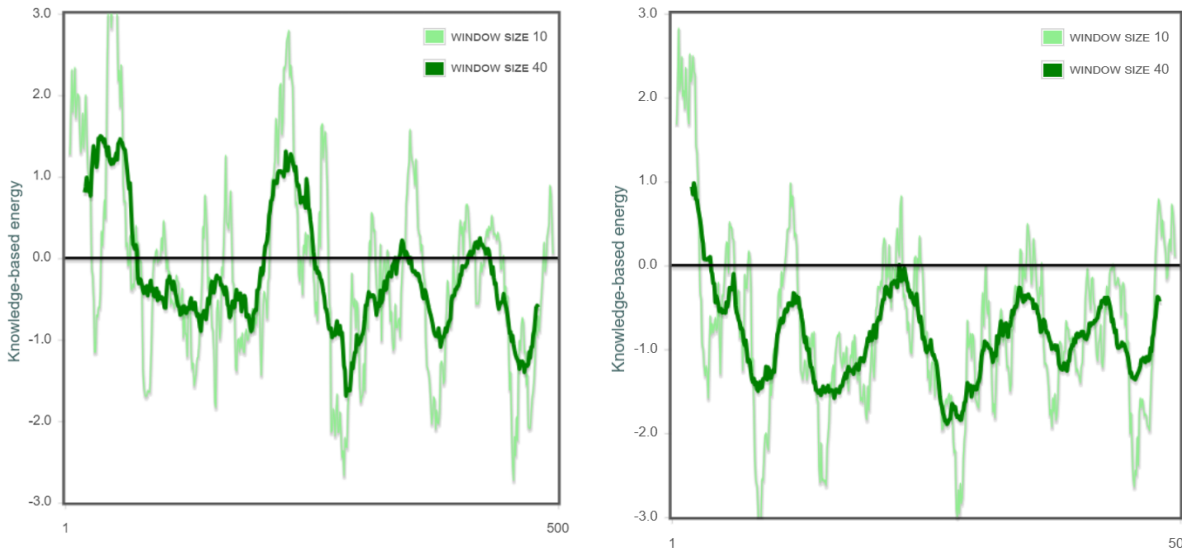

X-ray
NMR
Z-score
Number of residues
10
5
0
−5
−10
−15
−20
0
200
400
600
800
1000

(d)


X-ray
NMR
Z-score
Number of residues
10
5
0
−5
−10
−15
−20
0
200
400
600
800
1000

(e)

(f)



(g) **(h)**

Figure 08: Using **(a)** I-TASSER and **(b)** SWISS-MODEL, the expected three-dimensional structure of the selected protein was created. The ramachandran plot was assessed for the targeted protein using **(c)** I-TASSER and **(d)** SWISS-MODEL. The ProSA-web's Z-scores for the 3D protein models are **(e)** I-TASSER (Z-score: -5.25) and **(f)** SWISS-MODEL (Z-score: -8.87). Additionally, **(g)** I-TASSER and **(h)** SWISS-MODEL carried out a local model quality analysis.

Table 04: Plot Statistics

Characteristics	**Value**	
	I-TASSER	SWISS-MODEL
Residues in most favored regions [A,B,L]	308 (69.4%)	416 (93.7%)
Residues in additional allowed regions [a,b,l,p]	83 (18.7%)	27 (6.1%)
Residues in generously allowed regions [~a,~b,~l,~p]	34 (7.7%)	1 (0.2%)
Residues in disallowed regions	19 (4.3%)	0 (0.0%)
Number of glycine residues	27	27
Number of proline residues	27	27

The Ramachandran plot analysis showed that 93.7% of amino acid residues in the SWISS-MODEL predicted structure were located in the preferred regions (A, B, and L), compared to only 69.4% for I-TASSER. Additionally, residues in the allowed, disallowed, and generously allowed regions comprised 6.1%, 0.2%, and 0.0% for SWISS-MODEL, while I-TASSER had higher percentages of 18.7%, 7.7%, and 4.3%, respectively (**Table 04**). These results indicate that SWISS-MODEL generated a more accurate 3D structure for the catalase protein. Supporting this, the ProSA-web z-score evaluation, which assesses a model's overall quality by comparing its energy, showed a better score for SWISS-MODEL (-8.87) than for I-TASSER (-5.25), further confirming the higher quality of the SWISS-MODEL prediction (**Figure 08**).

3.8 Active site prediction

Active site prediction identifies pockets on a protein's surface that are accessible to small molecules but restricted to larger ones, indicating potential ligand-binding sites. These pockets contain both functionally active residues and others not directly involved in ligand binding. Mutations within these pockets, even if not affecting the direct ligand-binding residues, can be pathogenic and may influence the effectiveness of active site-targeted drugs (Cammisa et al., 2013; Volkamer et al., 2010).

Using the CASTpFold server, which employs a probe radius of 1.4 Å to calculate solvent-accessible surface areas, putative active sites of the protein were identified. The analysis measured mouth openings, surface areas, and volumes of the pockets, identifying a total of 80 active pockets. The top-ranked active site was selected based on its surface area and volume, with values of 1096.949 Å² for surface area and 1365.531 Å³ for volume, representing the most probable functional active site (**Table 05, Figure 09 and Supplementary file**).

Table 05: Top 3 pockets of targeted HP and its area and volume.

Pocket ID	Area (SA) (Å^2)	Volume (SA) (Å^3)
1	1365.531	1096.949
2	88.261	129.992
3	246.819	91.886

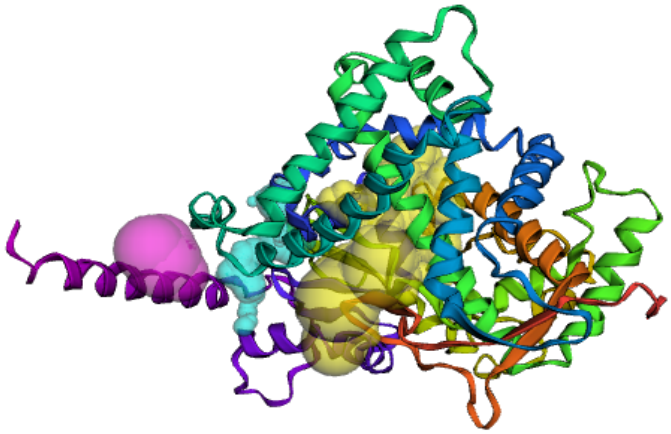


Figure 09: The active site predicted by CASTp fold. The negative volume of pocket-1, pocket-2, pocket-3 indicated respectively by yellow, pink and paste color. The shape of negative volume is spherical.

Conclusions with future perspective

This study provides a comprehensive characterization of a hypothetical protein from *Gibberella fujikuroi*, the causative agent of rice bakanae disease, through structural and functional analyses. The protein, identified as a plasma membrane-localized, hydrophilic cytochrome P450 enzyme (Ent-kaurene oxidase), plays a critical role in gibberellin biosynthesis, contributing to the pathogen's virulence. Homology modeling, particularly via SWISS-MODEL, yielded a high-

quality 3D structure, validated by Ramachandran plot and ProSA-web analyses, with active site predictions revealing key ligand-binding pockets. These insights enhance understanding of *G. fujikuroi* biology and lay a foundation for future functional validation and targeted control strategies to mitigate bakanae disease, addressing a critical challenge in sustainable rice production.

Abbreviations

HP: Hypotheical Protein;

UniProt: Universal Protein Resource;

I-TASSER: The Iterative Threading Assembly Refinement;

SOPMA: Self-Optimized Prediction Method with Alignment;

PSIPRED: PSI-blast based secondary structure prediction;

GRAVY: Grand Average of Hydropathicity;

ExPASy: Expert Protein Analysis System;

NCBI: National Center for Biotechnology Information; CD: Conserved Domain;

ProSA-web: Protein Structure Analysis;

BLASTp: Basic Local Alignment Search Tool (protein);

CASTp: Computed Atlas of Surface Topography of proteins;

MUSCLE: Multiple Sequence Comparison by Log-Expectation;

SOPMA: Self-Optimized Prediction Method with Alignment;

I-TASSER: Iterative Threading ASSEmbly Refinement;

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Authors' contributions

Conceptualization: AM and MHA

Data curation: AM

Formal analysis: AM and MHA

Investigation: AM and MHA

Methodology: AM

Resources: MHA

Software: MHA and ABRK

Writing original draft: AM and MHA

Supervision: MHA and ABRK

Validation: AM

Visualization: AM

Writing, review & editing: MHA and ABRK

All authors have read and agreed to the submitted/published version of the manuscript.

Data availability statement

Data is contained within the article and the supplementary material.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Ethical statement

This study did not involve the use of human participants, animals, or clinical trials. All analyses were performed using publicly available computational tools and databases; therefore, no ethical approval was required.

Supplementary file:

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SPIDER DIVERSITY IN THE VICINITY OF "AMAKONI RESERVIOR", SARANGARH-BILAIGARH DISTRICT, CHHATTISGARH, INDIA

Anita Pandey, Dr. and V. M. Agrawal

Assistant Professor

Kirodimal Govt. Arts and Science College, Raigarh, Chhattisgarh, India.

Govt. Navin College, Barpali, Korba, Chhattisgarh, India.

Corresponding Author- Anita Pandey (Assistant Professor), Kirodimal Govt. Arts and Science College, Raigarh, Chhattisgarh, India. anitashubh2002@gmail.com

ORCID- 0000-0003-0753-3056

ABSTRACT

Spiders are a globally distributed group, with established populations in a wide range of habitats. The present study aimed to investigate spider faunal diversity within "Amakoni Reservoir," also called "Putka Reservoir", Sarangarh- Bilaigarh District, Chhattisgarh, India. The researcher aims to assess the species richness, and compile a comprehensive species checklist of spiders inhabiting the Amakoni Reservoir area. Spiders were collected from surrounding Amakoni Reservoir (Putka Reservoir) using various collection techniques and identified using a taxonomic key for Indian spiders. This study was conducted from June 2024 to May 2025. A total of 23 species, representing 8 families, were recorded from study area. The Araneidae family was the most prevalent, comprising six species. This research yields significant and contemporary data regarding the species diversity within the "Amakoni Reservoir," Sarangarh- Bilaigarh District, Chhattisgarh. The article provides a dataset that may be useful for future research on spider fauna.

Key words- Spider, diversity, Araneidae Amakoni Reservoir, Sarangarh- Bilaigarh District, "Putka Reservoir

OBJECTIVES- Objectives: This study was undertaken with the following primary objectives:

1. To assess the overall status of spider populations in the vicinity of the Amakoni reservoir.
2. To compile a comprehensive checklist of spider species identified at Amakoni reservoir.

1. INTRODUCTIO -

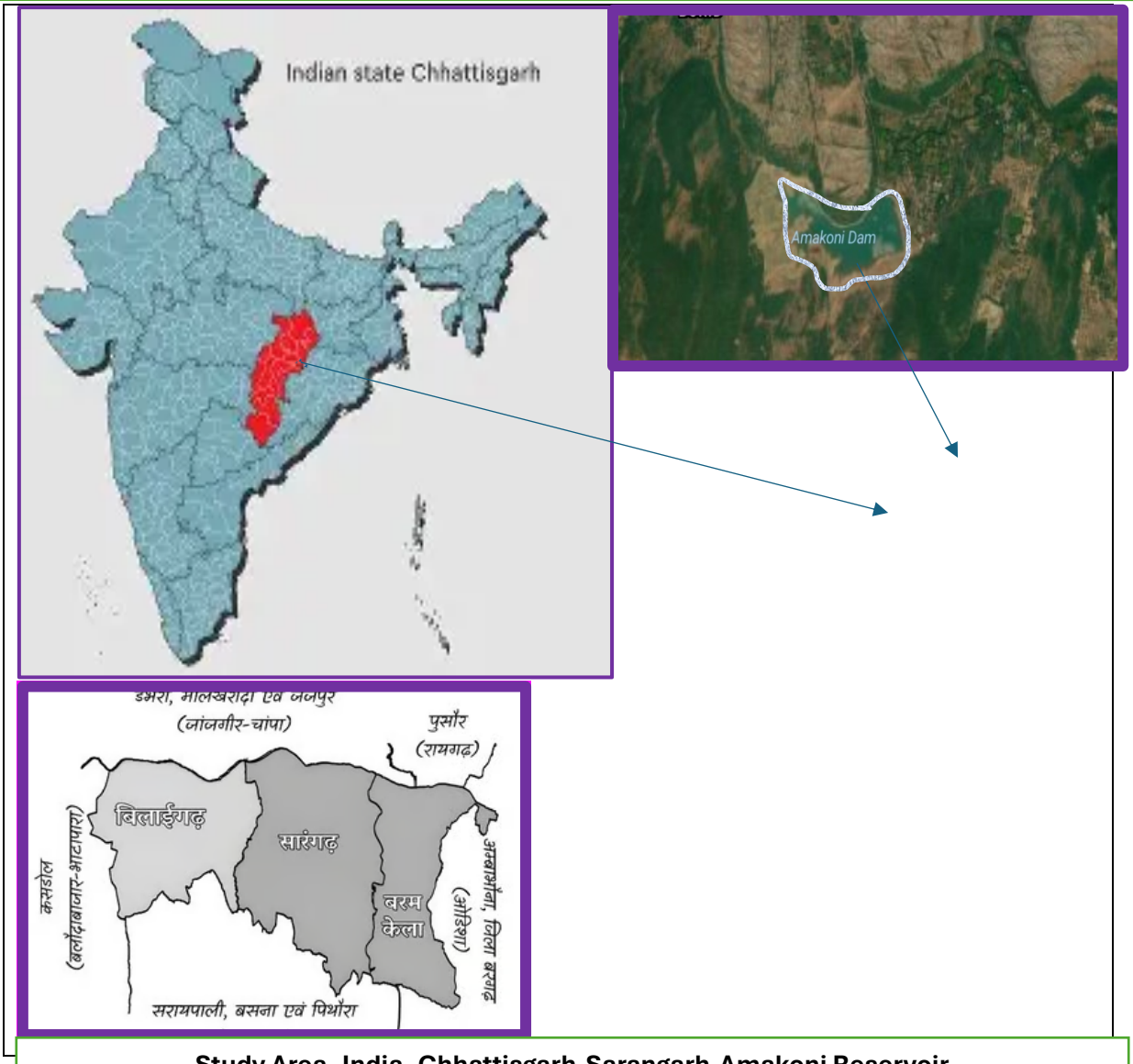
Spiders are fascinating creatures, they represent the most diverse and abundant group of invertebrate predators within terrestrial ecosystems (Wise, 1993). The fossil record indicates their emergence in the Devonian period approximately 380 million years ago (Shear et al., 1989). The current taxonomic classification recognizes 53'325 accepted species, distributed across 4391 genera within 135 families worldwide. (WSC2025 version-26) Singh's book details 2,110 species within 527 genera and 55 families found in India. (Singh, 2023). In Chhattisgarh, 222 spider species from 96 genera of 23 families have been recorded.

Spiders are classified within the Phylum Arthropoda, Class Arachnida, order Araneae, and are exclusively predatory organisms. Their body structure is segmented into two primary divisions: the cephalothorax and the abdomen. Characteristically, spiders possess eight legs, which are attached to the cephalothorax. The two major groups of spiders are Mygalomorphs, referred to as ancient spiders, and Araneomorphs, known as present day spiders. Spiders, characterized by their eight eyes, silk secretion, and web-spinning capabilities facilitated by spinnerets, are readily differentiated from insects. As a dominant predator of insect pests, spiders fulfill a crucial ecological role. They contribute to the dynamic equilibrium of micro-level food webs and represent an essential component of Integrated crop Pest Management strategies. Spiders serve as efficient natural regulators of numerous insect-mediated diseases, including malaria and dengue. They exhibit diverse distributions across habitats, contingent upon site suitability, and in feeding behaviors, occupying nearly all types of ecosystems.

Amakoni Reservoir, situated in the Amakoni village in Sarangarh–Bilaigarh district of Chhattisgarh, India. This Reservoir, nestled within a dry deciduous forest, presents a unique combination of terrestrial and aquatic ecosystems. The shining water body acts as a lifeline for Amakoni villagers. During the monsoon, the reservoir brims with fresh water, reflecting the dense canopy of Sal, Bhirra, Karra, Bija, Harra, Amla, Khair, Neem, Baheda, and Karanj, teak, and other deciduous trees that line its banks. This ecologically significant reservoir boasts considerable natural beauty and a calming atmosphere, with its banks supporting a wide variety of plant and animal life with spiders.

2. METHODOLOGY

2.1 STUDY AREA- The current study was conducted Putka Reservoir, situated in the Amakoni village in Sarangarh–Bilaigarh district of Chhattisgarh, India, is a tranquil waterbody encompassed by tropical dry deciduous forests. The geographical coordinates of this area are 21° 35' 15.71" N, 83° 4' 25.37" W, and the elevation is 217 m (712 ft).



Study Area -India- Chhattisgarh-Sarangarh-Amakoni Reservoir



Study Area- Amakoni Reservoir



2.2 SAMPLING METHOD- This study was conducted across all three sessions (summer, rainy, and winter) from June 2024 to May 2025. The following techniques were employed for specimen collection:

a. Ground-hand Collection: This method was utilized to collect spiders observed on the ground surface.

b. Aerial Hand Collection: This method was employed to collect web-building and free-living spiders from the foliage, herbaceous plants, stems of living or dead shrubs, and tree bark.

c. Active visual surveys - Active visual surveys were conducted within the habitat to locate spiders. Specimens were collected from ground-level and subterranean locations, as well as above-ground microhabitats, including folded leaves, plant branches, bark, rock surfaces, and grassland, in a collection vial.

d. Litter sampling -Litter sampling involves to the gathering arachnids specifically from the litter layer of an environment.

2.3. PHOTOGRAPHY AND IDENTIFICATION

Collection data and location were recorded, and morphological features were clearly observed and documented. All spider specimens were identified using taxonomic keys explained by Tikader (1982,1987), Sebastian and Peter (2009) and published literature. Following photographic documentation, collected spiders were released back into their natural habitats.

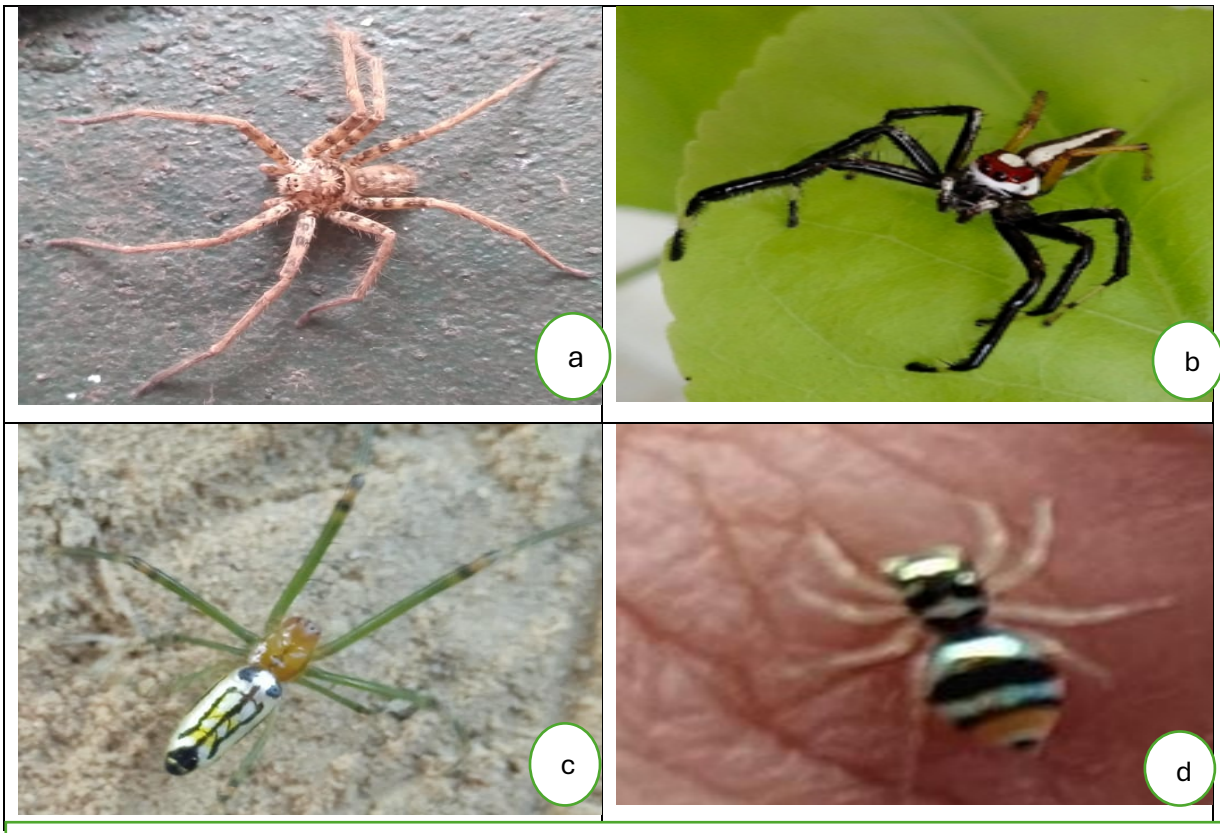


Plate-1- a Heteropoda venatoria, b - Telamonia dimidiate, c Leucauge decorata,- d- Phintella

2.3. CALCULATION-

Table for calculations Biodiversity of following samples from the area: **Amakoni reservoir**

family	Number of individuals (n)	n/N	p_i=n/N	logp_i	p_i logp_i	n−1	n(n−1)
Araneidae	30	30/137	0.219	−0.65956	−0.14444	29	870
Hersiliidae	14	14/137	0.1022	−0.99055	−0.10123	13	182
Lycosidae	08	8/137	0.0584	−1.23359	−0.07204	07	56
Oxyopidae	25	25/137	0.1825	−0.73874	−0.13482	24	600
Pholcidae	05	5/137	0.0365	−1.43771	−0.05248	04	20
Salticidae	28	28/137	0.2044	−0.68952	−0.14094	27	756
Sparassidae	06	6/137	0.0438	−1.35853	−0.0595	05	30
Tetragnathidae	21	21/137	0.1533	−0.81446	−0.12486	20	420

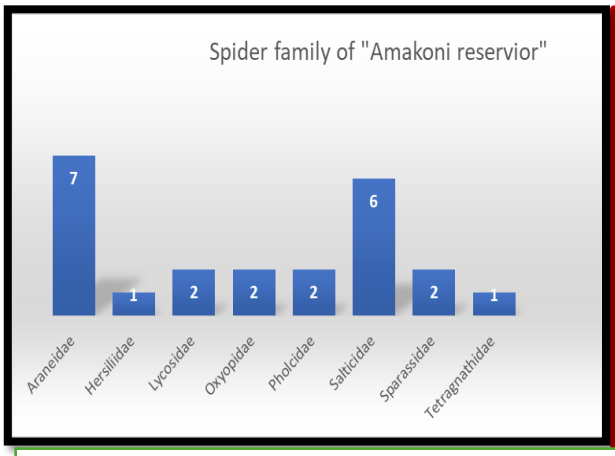
S (number of species) = n −0.83031
2934

N (Total number of individuals) = 137,

Shannon's Index (H) = $\sum_{i=1}^{s} p_i \log p_i$ =−0.83031

Simpson's Index (D)= $1-\frac{\sum n(n-1)}{N(N-1)} = 1-\frac{2934}{18632} = \frac{15698}{18632} = 0.8425$

.



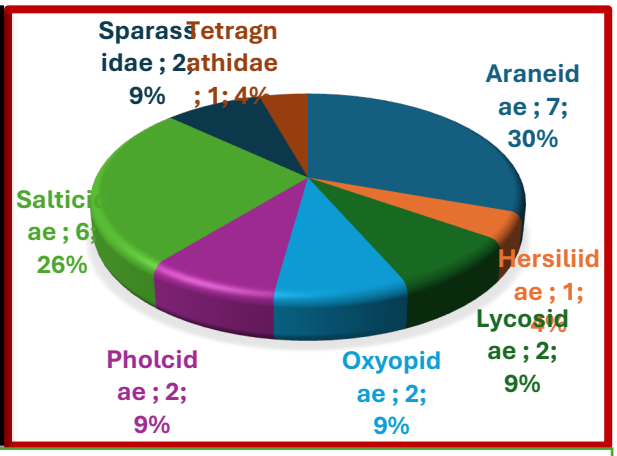


Figure 1: Abundance of Spider Families Figure 2: Percent of Spider Families in the "Amakoni "Amakoni reservoir".

Table 1. Spider checklist of Putka Reservoir, (Amakoni Reservoir,) in Sarangarh–Bilaigarh district of Chhattisgarh. -

S.N.	Family/ Genus	species	Common name
1,	Araneidae Clerck, 1757		
	Argiope Savigny, 1825	Argiope aemula (Female) (Walckenaer, 1842)	Orb- weaver spider

		Argiope anasuja Thorell, 1887	Orb- weaver spider
		Argiope bruennichi (Scopoli, 1772)	Orb- weaver spider
		Argiope pulchella Thorell, 1881	Orb- weaver spider
		Argiope trifasciata (Forskål, 1775)	Orb- weaver spider
	Cyrtophora Simon, 1864	Cyrtophora cicatrosa	Garden tent-web spider
	Nephila Leach, 1815	Nephila pilipes (Fabricius, 1793	**golden orb-weaver.**
2.	Hersiliidae Thorell, 1869		
	Hersilia Savigny, 1825	Hersilia savignyi Lucas, 1836	**Hersilia** spider.
3.	Lycosidae Sundevall, 1833		
	Arctosa C.L. Koch, 184	**Trochosa sp.**	Indian wolf
	Pardosa C.L. Koch, 1847	Pardosa jabalpurensis Gajbe & Gajbe, 1999	**Pardosa wolf spider.**
4.	Oxyopidae Thorell, 1869		
	Oxyopes Latreille, 1804	**Oxyopes sp.**	
	Peucetia Thorell, 1869	Peucetia viridana (Stoliczka, 1869)	**green lynx spider.**
5.	Pholcidae C.L. Koch, 1850		
	Holocnemus Simon, 1873	Holocnemus pluchei (Scopoli, 1763)	marbled cellar spider
	Pholcus Walckenaer, 1805	Pholcus phalangioides (Fuesslin, 1775)	long-bodied cellar spider,

6.	Salticidae Blackwall, 1841		
.	Carrhotus Thorell, 1891	Carrhotus viduus (C.L. Koch, 1846)	**Carrhotus jumping spider**
	Chrysilla Thorell, 1887	Chrysilla volupe (Karsch, 1879)	Jumping spider
	Menemerus Simon, 1868	Menemerus bivittatus (Dufour, 1831	jumping spiders
	Phintella Strand, 1906	Phintella vittata (C.L. Koch, 1846)	Phintella jumping spiders
	Plexippus C.L. Koch, 1846	Plexippus paykulli (Audouin, 1825)	**Pantropical jumping spider**
	Telamonia Thorell, 188	Telamonia dimidiate (Simon, 1899)	Jumping spider
7.	Sparassidae Bertkau, 1872		
	Heteropoda Latreille, 1804	Heteropoda venatoria (Linnaeus, 1767	**Brown huntsman**
	Olios Walckenaer, 1837	Olios lamarcki (Latreille, 1806)	Lamark's huntsman spider
8.	Tetragnathidae Menge, 1866		
	Leucauge White, 1841	Leucauge decorata (Walckenaer, 1842)	**long-jawed orb weaver**

3. RESULT AND DISCUSSION-

The Amakoni reservoir supports a diverse spider population. A survey of the reservoir identified 23 spider species, representing 8 families and 19 genera. The Araneidae family was the most abundant. The study documented 7 species from the Araneidae, 6 from the Salticidae, and 2 each from the Lycosidae, Oxyopidae, Pholcidae, and Sparassidae. Single species were recorded from Hersiliidae and Tetragnathidae, (Table-1) and species richness was 0.000266 per square feet. Leucauge decorata generally found in grassland and shrub Compared to other regions of India, comprehensive data regarding the diversity and distribution of spiders in Chhattisgarh is limited. India possesses 1,686 spider species, encompassing 60 families and 438 genera, representing 3.6% of the global spider population. More recently, Choudhary S, R. et al. (2023) catalogued a total of 222 species from 23 families have been reported from Chhattisgarh in his checklist, Whereas. Singh et al. (2022) reported 336 spider species, classified into 136 genera and 30 families, through surveys encompassing 36 of the 52 districts within Madhya Pradesh. Previous research includes Ekka, and Kujur (2015), who documented 118 species representing

52 genera under 17 families, in Ram Jharna, Raigarh district Chhattisgarh, and Kujur and Ekka (2016), describes 120 species representing 49 genera under 16 families, 16 species in Gomarda Wildlife Sanctuary, Chhattisgarh, India. Subsequently, (Gupta and Chandra 2016) identified 33 species pertaining to 30 genera under 5 families in Achanakmar Wildlife Sanctuary, Bilaspur, Chhattisgarh, India and Sen (2021) reported a total of 55 species belonging to 42 Genus under 11 families in North East Gariaband Forest Regions of Chhattisgarh, India.

4.CONCLUSION- Amakoni reservoir demonstrates a notable diversity of spider species. Spiders are a key living factor in the food chain that maintains the ecosystem as predators. Based on these findings, conservation strategies should be developed to protect spider habitats and promote biodiversity.

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SIYAH ALACA ERKEK VE DIŞI BUZAĞILARDA DOĞUM VE SÜTTEN KESIM DÖNEMI KAN DEĞERLERI DEĞIŞIMI

E. Mevliyaoğulları

Başkent Üniversitesi, Kahramankazan Meslek Yüksekokulu, Organik Tarım Programı, 06980, Kahramankazan, Ankara

Email: emevliya@gmail.com

ORCID: 0000-0003-3333-1490

S. Doğan

[2] Çukurova Üniversitesi Ziraat Fakültesi Zootekni Bölümü, 01330 Balcalı-Adana

ORCID: 0009-0004-4754-9428

S. Göncü

Çukurova Üniversitesi Ziraat Fakültesi Zootekni Bölümü, 01330 Balcalı-Adana

Email: serapgoncu66@gmail.com;

ORCID: 0000-0002-0360-2723

ÖZET

Bu çalışmada Siyah Alaca buzağılarda doğum ve sütten kesim dönemlerine ait biyokimyasal parametrelerin değişimleri incelenmiştir. Siyah Alaca buzağılarda doğum (1) ve sütten kesim (2) dönemlerine ait biyokimyasal parametrelerin genel ortalamalarına bakıldığında, AST değerleri sırasıyla 86.48 U/L ve 94.44 U/L olup, enzim düzeylerinde hafif artış görülmektedir. GGT düzeyleri doğumda 32.62 U/L, sütten kesimde 25.70 U/L olarak tespit edilmiş, karaciğer fonksiyonlarında doğuma kıyasla stabilizasyon izlenmiştir. Kolesterol (KOL) ortalamaları doğumda 150.55 mg/dL, sütten kesimde 155.70 mg/dL olarak hafif artış göstermiştir. Glukoz (GLU) düzeyleri doğumda 56.88 mg/dL iken, sütten kesimde 38.60 mg/dL'ye düşmüş, bu da enerji metabolizmasındaki değişimi yansıtmaktadır. Kalsiyum (Ca) seviyeleri doğumda 11,10 mg/dL, sütten kesimde 10,89 mg/dL, fosfor (P) düzeyleri ise doğumda 8,82 mg/dL, sütten kesimde 8.39 mg/dL olarak ölçülmüştür. Magnezyum (Mg) ortalamaları doğumda 2,68 mg/dL, sütten kesimde 2.31 mg/dL olup, düşüş göstermektedir. Toplam protein (TP) değerleri doğumda 8.03 g/dL, sütten kesimde 7.23 g/dL; albümin (ALB) ise sırasıyla 3.47 ve 3.47 g/dL ile sabit kalmıştır. BUN düzeyi doğumda 10,56 mg/dL iken, sütten kesimde 10.43 mg/dL olup stabil seyretmiştir. Bu ortalamalar, Siyah Alaca buzağılarda yaşla birlikte bazı biyokimyasal değerlerde fizyolojik değişimler yaşandığını ortaya koymaktadır.

Anahtar kelimeler: Siyah Alaca, Cinsiyet, Buzağı, Doğum, Sütten Kesim, Kan Değerleri

CHANGES in Blood Parameters from Birth to Weaning in Male and Female Holstein Calves

ABSTRACT

In this study, changes in biochemical parameters of Holstein calves at birth and weaning periods were examined. The average AST values at birth and weaning were 86.48 U/L and 94.44 U/L, respectively, showing a slight increase in enzyme levels. GGT levels were 32.62 U/L at birth and 25.70 U/L at weaning, indicating stabilization of liver functions compared to birth. Cholesterol (KOL) averages showed a slight increase from 150.55 mg/dL at birth to 155.70 mg/dL at weaning. Glucose (GLU) levels decreased from 56.88 mg/dL at birth to 38.60 mg/dL at weaning, reflecting changes in energy metabolism. Calcium (Ca) levels were 11.10 mg/dL at birth and 10.89 mg/dL at weaning, while phosphorus (P) levels were measured as 8.82 mg/dL at birth and 8.39 mg/dL at weaning. Magnesium (Mg) averages decreased from 2.68 mg/dL at birth to 2.31 mg/dL at weaning. Total protein (TP) values were 8.03 g/dL at birth and 7.23 g/dL at weaning; albumin (ALB) remained stable at 3.47 g/dL at both periods. Blood urea nitrogen (BUN) levels were 10.56 mg/dL at birth and 10.43 mg/dL at weaning, showing stability. These averages indicate physiological changes in some biochemical values in Holstein calves as they age.

Keywords: Holstein, Sex, Calf, Birth, Weaning, Blood Parameters

Giriş

Buzağı kayıpları, süt ve et üretiminde ekonomik verimlilikte esas noktadır. Bu kayıplar yetiştiricilerin ekonik kayıplarını artırarak sürdürülebilir üretimi kırar. Ayrıca, bu kayıplar hayvan refahı açısından da önemli bir göstergedir. Sağlıklı buzağılar, güçlü ve verimli ergin hayvanların aslını oluşturur. Bu nedenle, buzağı kayıplarını azaltmak hem ekonomik kayıpların önlenmesi hem de sürdürülebilir hayvancılık için elzemdir. Entansif süt sığırcılığı işletmelerinde buzağı kayıpları, işletme yönetimi, hijyen, beslenme ve bakım uygulamalarına bağlı olarak değişkenlik gösterse de, %2 olması gereken kayıp düzeyinin %30'lara çıktığı bilinmektedir. Bu nedenle, buzağı kayıplarının izlenmesi ve yönetilmesi, sürdürülebilir süt üretimi için kritik öneme sahiptir.

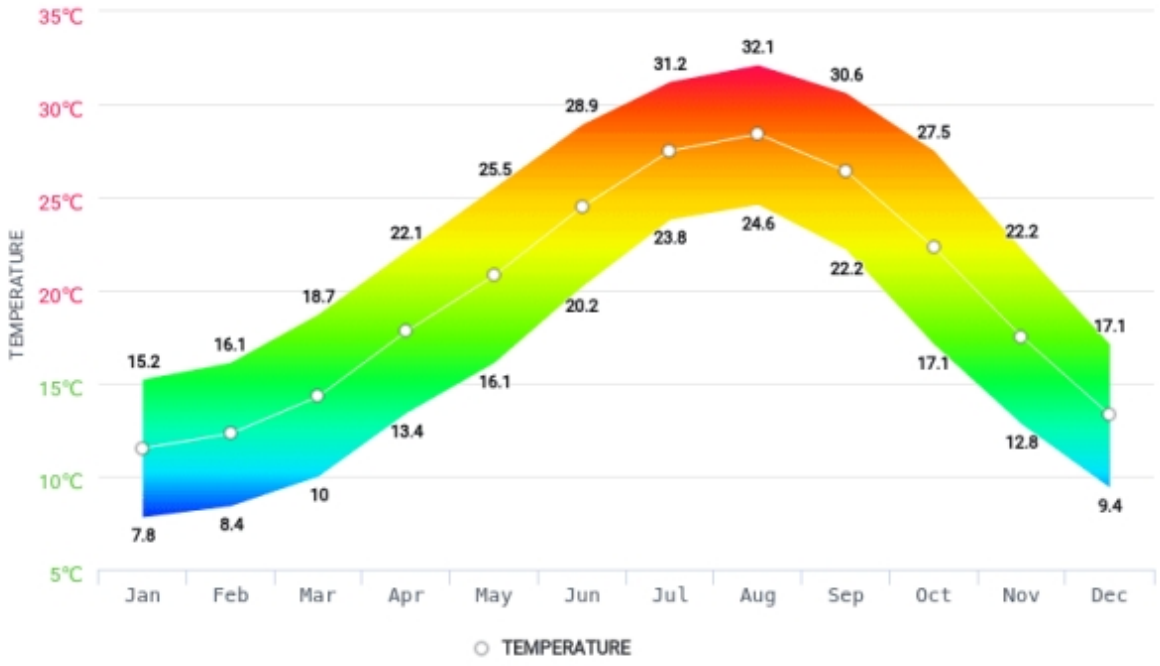
Buzağıların doğumdan sütten kesim dönemine kadar olan yaşam evresi, büyüme, bağışıklık kazanımı ve metabolik uyum açısından kritik bir dönemdir. Bu süreçte meydana gelen hematolojik ve biyokimyasal değişikliklerin izlenmesi, buzağı sağlığı ve gelişimi hakkında önemli bilgiler sunmakta; aynı zamanda erken tanı ve uygun yönetim stratejilerinin geliştirilmesine olanak sağlamaktadır (Piccione et al., 2010; Nazifi et al., 2009). Siyah Alaca buzağılarda doğum ve sütten kesim dönemlerindeki biyokimyasal parametrelerin izlenmesi, sürü yönetiminde hayvan sağlığı ve verimliliğin artırılması için önemli bir araçtır. Bu parametrelerdeki değişimler, buzağıların metabolik durumu, beslenme ihtiyaçları ve organ fonksiyonları hakkında erken uyarılar sağlar. Özellikle cinsiyete bağlı farklılıkların dikkate alınması, erkek ve dişi buzağıların bakım ve beslenme programlarının optimize edilmesine olanak tanır. Böylece erken dönemde olası sağlık sorunları tespit edilip müdahale edilerek, büyüme ve gelişim desteklenir. Bu biyokimyasal verilerin düzenli takibi, sürüde genel sağlık durumunun iyileştirilmesi ve sürdürülebilir verimliliğin sağlanması açısından kritik öneme sahiptir. Siyah Alaca (Holstein) ırkı, dünya genelinde olduğu gibi Türkiye'de de yüksek süt verimi nedeniyle yaygın olarak yetiştirilen bir süt sığırı ırkıdır (Atasever ve Güngör, 2009). Ancak bu ırkın buzağılarında, özellikle neonatal dönemde, bağışıklık sistemi henüz tam gelişmediğinden dolayı enfeksiyöz ve metabolik hastalıklara duyarlılık daha yüksektir (Sato et al., 2011). Bu nedenle buzağılarda yaşa ve gelişim dönemine bağlı olarak bazı kan parametrelerinin düzenli olarak takip edilmesi büyük önem arz etmektedir. Literatürde, buzağılarda yaşa bağlı olarak alyuvar (eritrosit), akyuvar (lökosit), hemoglobin, hematokrit düzeyleri gibi hematolojik parametrelerde değişiklikler görüldüğü, bu değişikliklerin büyüme hızı, bağışıklık sistemi aktivitesi ve çevresel stres faktörleriyle ilişkili olduğu bildirilmektedir (Knowles et al., 2000; Mohri et al., 2007). Aynı şekilde, biyokimyasal parametreler olan glukoz, total protein, albümin, üre, kreatinin ve bazı enzim düzeylerinin de buzağının yaşı ve genel sağlık durumu ile yakından ilişkili olduğu gösterilmiştir (Schermerhorn et al., 2005; Türkyılmaz ve Eskiizmirliler, 2009). Cinsiyetin, kan değerleri üzerinde belirli etkiler gösterebildiği de bazı çalışmalarda ortaya konulmuştur. Erkek ve dişi buzağılar arasında büyüme hızı, hormonal yapı ve metabolik yanıtlar açısından farklılıklar olabileceği bildirilmiştir (Kume et al., 2004; Palczynski et al., 2021). Süt sığırcılığında kan biyokimyasal parametrelerin referans değerlerinin belirlenmesi konusunda çeşitli çalışmalar mevcuttur. Bu çalışmalar, hayvan sağlığının izlenmesi, hastalıkların erken teşhisi ve beslenme durumunun değerlendirilmesi için önem taşır. Khan ve Wiseman (2006), Holstein buzağılarda doğumdan üç aya kadar hematolojik ve biyokimyasal parametrelerin yaşa bağlı değişimlerini detaylı olarak incelemiş ve yaş gruplarına özgü referans değerler önermiştir. Benzer şekilde, Kara ve ark. (2017) ile Demir ve ark. (2019) çalışmalarında, buzağıların büyüme dönemlerinde biyokimyasal değerlerde anlamlı değişimler saptanmış, özellikle protein ve mineral metabolizmasının yaşla birlikte farklılaştığı bildirilmiştir. Gökçe ve ark. (2021) ise Holstein buzağılarda serum biyokimyasal parametreleri için özgün referans aralıkları belirleyerek, klinik uygulamalarda bu değerlerin kullanılabilirliğini ortaya koymuştur. Ayrıca, Besser ve ark. (1990) buzağıların immün durumu

ile biyokimyasal parametreler arasındaki ilişkiyi değerlendirmiş ve bu değerlerin hastalık takibinde önemli göstergeler olduğunu vurgulamıştır. Siyah Alaca buzağılarda kan referans değerlerinin tespiti, buzağıların sağlık durumunun doğru ve objektif bir şekilde değerlendirilmesi açısından kritik öneme sahiptir. Referans değerler, veteriner hekimlerin ve yetiştiricilerin normal fizyolojik aralıkları belirleyerek anormal durumları erken dönemde fark etmelerine olanak tanır. Böylece metabolik bozukluklar, enfeksiyonlar veya beslenme eksiklikleri gibi sorunlar hızla teşhis edilip uygun müdahaleler yapılabilir. Ayrıca, Siyah Alaca ırkına özgü biyokimyasal profilin bilinmesi, farklı çevresel ve yönetim koşullarında sağlık takibini daha etkin hale getirir. Bu referans aralıkları, yaş, cinsiyet ve büyüme dönemlerine göre değişkenlik gösterebileceği için bölgesel ve ırksal özelliklerin dikkate alınması, sürü yönetiminde karar alma süreçlerinin doğruluğunu artırır ve sürdürülebilir hayvancılığa katkı sağlar.

Bu çalışma, Siyah Alaca ırkı erkek ve dişi buzağılarda doğum ve sütten kesim dönemlerinde bazı seçilmiş hematolojik ve biyokimyasal parametrelerin karşılaştırmalı olarak değerlendirilmesini amaçlamaktadır. Elde edilecek bulguların, buzağı sağlığı koruyucu uygulamalarına katkı sağlaması ve söz konusu ırka özgü fizyolojik referans aralıklarının oluşturulmasına temel oluşturması beklenmektedir.

Materyal ve Metod

Bu çalışma, 37°0′ Kuzey enlemleri ile 35°19′ Doğu boylamları arasında Akdeniz bölgesinde yer alan Adana'da bulunan entansif sığırcılık işletmesinde yürütülmüştür.



Şekil 1. Adana ili sıcaklık değerleri

Hayvan materyali olarak Çukurova Üniversitesi Ziraat Fakültesi Araştırma ve Uygulama Çiftliği Süt Sığırcılığı İşletmesinde Ekim, Kasım ve Aralık ayında doğan toplam 27 baş Siyah Alaca buzağı (16 erkek, 11 dişi) materyal olarak kullanılmıştır. Buzağılar, benzer çevresel koşullarda, aynı bakım ve besleme rejimi altında yetiştirilmiştir. Tüm buzağılara doğumdan itibaren ilk 24 saat içinde ağız sütü (kolostrum) verilmiş ve sonraki dönemde standart süt beslemesi uygulanmıştır. Sütten kesim 60. gün sonunda gerçekleştirilmiştir. Buzağılar, doğum sonrası ilk 3 gün doğum bölmesi karşısında bulunan bireysel bölmelerde tutulmaktadır. Ayrıca

3.günden sonra sütten kesime kadar fiberglas (genişlik 106 cm, uzunluk 118 cm, yükseklik 140 cm) kulübelerde (Fotograf 1) sütten kesime kadar bakıma devam edilmektedir. Buzağı kulübelerinde saman altlık kullanılmakta olup, altlık ıslandıkça üzerine ek saman atılarak kuru zemin temin edilmiştir. Araştırmada yem olarak buzağı başlangıç yemi ve yonca kuru otu kullanılmıştır. Buzağılar 4. günden itibaren bireysel bölmelere alınmış ve önlerinde, sürekli temiz taze su, buzağı başlangıç yemi ve kuru yonca otu bulundurulmuştur. Kolostrum içirme sürecinden sonra sütten kesime kadar buzağılar işletme sağmal ineklerinden sağılan tam yağlı sütle kovadan günde iki kez toplamda 4 kg olacak şekilde 56 gün süreyle beslenmişlerdir. 4. günden sütten kesime kadar olan sıvı besleme döneminde buzağılara başlangıç yemi, kuru yonca otu ve su serbest olarak verilmiştir.

Buzağılardan kan örnekleri doğumun 1. günü (0–24 saat) ve sütten kesim günü (60. gün) olmak üzere iki farklı zamanda alınmıştır. Böylece hem doğum hem de erken büyüme dönemine ait hematolojik ve biyokimyasal değerler elde edilmiştir. Cinsiyetin etkisini değerlendirebilmek amacıyla erkek ve dişi buzağılar ayrı gruplar olarak ele alınmıştır.

Kan örnekleri, jugular venden vakumlu tüpler kullanılarak sabah saatlerinde, süt içmeden önce alınmıştır. Kan örnekleri gün içinde 10:00-15:00 saatleri arasında işletme veterineri tarafından gerekli kurallara riayet edilerek kuyruk veninden, antikoagülansız tüplere (10 ml, BD Vacutainer Systems, Plymouth, İngiltere) alınmış ve en kısa süre içerisinde laboratuvara ulaştırılmıştır. Kan örnekleri 5000 rpm'de 10 dk santrifüj edilerek plazmaları çıkarılmış ve biyokimyasal analizlerde kullanılmak üzere -20ºC'de saklanmıştır. Biyokimyasal analizler (Total Protein, Albumin, Glikoz, Aspartat amino transferaz (AST), Gama glutamil transferaz (GGT), kan üre nitrojen (BUN), kalsiyum (Ca), fosfor (P), Kolestrol ve Magnezyum (Mg) ticari test kitleri yardımıyla otoanalizörler kullanılarak yapılmıştır..

Elde edilen veriler SPSS 25.0 istatistik paket programı kullanılarak değerlendirilmiştir. Erkek ve dişi buzağılar arasındaki farkları belirlemek amacıyla bağımsız örneklemler t-testi uygulanmıştır. Aynı bireylerin doğum ve sütten kesim dönemindeki kan parametreleri arasındaki farklar ise eşleştirilmiş t-testi ile analiz edilmiştir. Sonuçlar ortalama ± standart sapma (mean ± SD) olarak ifade edilmiştir ve istatistiksel anlamlılık düzeyi $p < 0.05$ olarak kabul edilmiştir.

Bulgular ve Tartışma

Yapılan varyans analiz sonuçlarına göre, Siyah Alaca buzağılarda doğum (1) ve sütten kesim (2) dönemleri arasındaki bazı biyokimyasal parametrelerde istatistiksel olarak anlamlı farklılıklar tespit edilmiştir. **BUN2** (Kan Üre Azotu – sütten kesim dönemi) parametresi için cinsiyetler arasında fark anlamlı bulunmuş (**p = 0.032**), bu durum erkek ve dişi buzağıların protein metabolizmasındaki farklılıklara işaret edebilir. Ayrıca, **P1** (Fosfor – doğum dönemi) için anlamlılığa yakın bir fark gözlemlenmiştir (**p = 0.052**), bu da erken dönemde fosfor metabolizmasının cinsiyete duyarlı olabileceğini düşündürmektedir. **ALB1** (Albümin – doğum dönemi) için de p değeri anlamlılık sınırına yakın olup (**p = 0.080**), dikkat çekici bir değişim olduğunu göstermektedir. Diğer tüm parametrelerde ise cinsiyetler arasında istatistiksel olarak anlamlı fark bulunmamıştır (**p > 0.05**), bu da çoğu biyokimyasal değerin cinsiyetten bağımsız olarak benzer seyrettiğini göstermektedir. Bu sonuçlar, bazı metabolik göstergelerin erken yaşta cinsiyete duyarlı olduğunu, ancak genel biyokimyasal stabilitenin korunduğunu ortaya koymaktadır.

Çizelge 1. Siyah Alaca Erkek ve Dişi Buzağılarda Doğumda Kan Değerleri

Parametre	Dişi						Erkek					
	N	Ort.	Std. Sapma	Std. Hata	Min	Mak.	N	Ort.	Std. Sapma	Std. Hata	Min	Maks.
Doğumda												
AST (U/L)	11	72.27	27.39	8.26	8	118	16	96.25	56.35	14.09	60	295
GGT(U/L)	11	33.73	11.65	3.51	13	50	16	31.88	21.55	5.39	9	96
KOL (mg/dL)	11	156.18	24.56	7.40	106	187	16	146.7	33.82	8.45	77	197
GLU (mg/dL)	11	58.36	22.74	6.86	38	97	16	55.88	20.81	5.2	24	86
Ca (mg/dL)	11	11.34	1.34	0.40	9.26	14.59	16	10.95	0.79	0.2	9.43	12.5
P (mg/dL)	11	9.49	1.12	0.34	7.81	11.14	16	8.36	1.58	0.4	6.66	13.51
Mg (mg/dL)	11	2.57	0.37	0.11	2.21	3.28	16	2.78	1.56	0.39	1.52	7.89
TP (g/dL)	11	7.71	1.15	0.35	5.53	9.23	16	8.25	3.29	0.82	5.54	19.89
ALB (g/dL)	11	3.53	0.09	0.03	3.41	3.75	16	3.44	0.13	0.03	3.13	3.75
BUN (mg/dL)	11	10.72	2.7	0.81	6.2	14.5	16	10.45	2.64	0.66	5.81	17.46
Sütten kesimde												
AST (U/L)	11	99.18	43.14	13.01	30	203	16	91.19	20.05	5.01	58	133
GGT(U/L)	11	28.73	19.02	5.74	12	80	16	23.63	13.09	3.27	7	48
KOL (mg/dL)	11	164.45	40.31	12.16	92	220	16	149.7	34.33	8.58	87	206
GLU	11	39.64	18.15	5.47	17	80	14	37.79	19.6	5.24	15	72
Ca (mg/dL)	11	11.12	0.49	0.15	10.08	11.81	16	10.73	0.73	0.18	9.13	11.9
P (mg/dL)	11	7.77	1.73	0.52	5.12	10.57	16	8.83	1.9	0.48	3.52	11.78

Mg (mg/dL)	11	2.19	0.6	0.18	1.2	2.95	16	2.4	0.38	0.1	1.69	3.18
TP (g/dL)	11	7.42	1.39	0.42	4.92	9.38	16	7.1	1.26	0.31	5.46	9.41
ALB. (g/dL)	8	3.44	0.14	0.05	3.12	3.56	14	3.5	0.09	0.02	3.37	3.66
BUN (mg/dL)	11	12.43	4.35	1.31	5.6	20.28	16	9.07	3.37	0.84	3.9	13.82

Tablodaki bulgulara göre bazı biyokimyasal parametreler özellikle dikkat çekicidir. Doğum döneminde dişi buzağılarda AST1 değeri erkeklere göre daha yüksek olup, maksimum değerin 295 U/L'ye ulaşması karaciğer enzim aktivitesinde aşırı bir artışa işaret etmektedir. Sütten kesim döneminde erkek buzağılarda BUN düzeyinin dişilere göre belirgin şekilde yüksek olması (12.43 mg/dL vs. 9.07 mg/dL), protein metabolizması veya böbrek fonksiyonları açısından cinsiyet temelli farklılıklar olabileceğini düşündürmektedir. Ayrıca doğum döneminde erkeklerde fosfor (P1) düzeyinin daha yüksek olması (9.49 mg/dL vs. 8.36 mg/dL), hızlı kemik gelişimiyle ilişkilendirilebilir.

Çizelge 2. Siyah Alaca Erkek ve Dişi Buzağılarda ideal değerleri ve sürü yönetiminde kullanımı

Kan parametresi	Araştırma sonuçları	İdeal Değer *	Sürü Yönetiminde
AST (U/L)	Doğumda erkeklerde yüksek. sütten kesimde dişilerde artış var	50 - 120	Karaciğer ve kas sağlığı izlemi; yüksek değerler stres veya hastalık belirtisidir.
GGT (U/L)	Cinsiyet farkı az. dönemsel hafif değişim	20 - 50	Karaciğer fonksiyonları kontrolü.
Kolesterol (mg/dL)	Dişilerde erkeklerden yüksek	100 - 200	Enerji ve beslenme durumu
Glukoz (mg/dL)	Düşük ve benzer; sütten kesimde düşüş	40 - 80	Enerji metabolizması takibi. hipoglisemi riski
Kalsiyum (mg/dL)	Doğumda dişilerde yüksek; sütten kesimde hafif düşüş	9.5 - 12	Kemik gelişimi ve mineral dengesi
Fosfor (mg/dL)	Doğumda dişilerde yüksek; sütten kesimde erkeklerde yüksek	6 - 10	Kemik gelişimi ve metabolik ihtiyaçlarda
Magnezyum (mg/dL)	Düşüş eğilimi; cinsiyet farkı az	2 - 3	Metabolik fonksiyonlar için
Toplam Protein (g/dL)	Doğumda erkeklerde biraz yüksek; sütten kesimde azalma	6.5 - 8.5	Protein metabolizması ve beslenme durumu
Albümin (g/dL)	Fark az. değerler sabit	3.2 - 4.0	Beslenme durumu

BUN (mg/dL)	Sütten kesimde dişilerde anlamlı yüksek	7 - 15 mg/dL	Protein metabolizması ve böbrek fonksiyonları

*Kaneko et al.. 2008; Constable et al.. 2017. Smith. 2015. Radostits et al.. 2007

Bu çalışmada Siyah Alaca buzağılarda biyokimyasal parametreler incelenmiş ve yalnızca BUN (kan üre azotu) sütten kesim döneminde cinsiyetler arasında anlamlı fark göstermiştir ($p = 0.032$). Bu sonuç, protein metabolizmasının erkek ve dişi buzağılarda farklı seyrettiğine işaret etmektedir. Literatürde de farklı buzağı ırklarındaki BUN seviyelerinin cinsiyet. yaş ve beslenme durumuna bağlı olarak değiştiği bildirilmiştir (Özdemir ve ark., 2018; Yılmaz ve ark., 2020). Ayrıca. fosfor (P1) ve albümin (ALB1) parametrelerinde anlamlılığa yakın değerler elde edilmiş (sırasıyla $p = 0.052$ ve $p = 0.080$) ve bu parametrelerin özellikle erken dönemde metabolik ve beslenme koşullarına duyarlı olduğu vurgulanmıştır (Kara ve ark., 2017; Demir ve ark., 2019). Bu da, buzağıların erken yaşta minerallerin ve protein metabolizmasının yakından takip edilmesi gerektiğini göstermektedir.

Kaygısız ve Sönmez (2018), benzer şekilde Siyah Alaca buzağılarda cinsiyetin G-GT, glikoz ve insülin düzeylerini etkilediğini, erkeklerin bu parametrelerde dişilere göre daha düşük değerlere sahip olduğunu bildirmiştir. Ayrıca, besleme gruplarının G-GT, trigliserit ve büyüme hormonu seviyelerinde anlamlı etkisi bulunmuş; normal süt tüketen buzağılar G-GT ve büyüme hormonunda yüksek, trigliseritte ise düşük değerler gösterdiğini bildirmektedirler.

Holstein buzağılarda yapılan çalışmalarda da protein ve mineral metabolizması ile ilgili benzer bulgular rapor edilmiştir; örneğin Gökçe ve ark. (2021), total protein, albümin, üre, BUN, fosfor ve diğer önemli biyokimyasal parametrelerde yaş ve cinsiyetin etkisini ortaya koymuştur. Göncü ve ark. (2023, 2025) ise doğum ve sütten kesim dönemlerinde glukoz, GGT ve fosfor değerlerinin cinsiyet ve döneme bağlı olarak farklılık gösterdiğini bildirmiştir. Bununla birlikte, diğer biyokimyasal parametrelerde anlamlı fark bulunmaması. yaş ve cinsiyet değişkenlerinin çoğu parametre üzerinde nispeten stabil etki oluşturduğunu göstermektedir (Şahin ve ark., 2016).

Bulgulara genel olarak bakıldığında, bazı enzim ve metabolit düzeylerinde dönemler arası değişiklikler gözlemlenirken, özellikle AST enziminde doğumdan sütten kesime hafif artış görülmüştür. Glukoz, magnezyum ve toplam protein gibi bazı parametrelerde ise düşüş tespit edilmiştir. Cinsiyete bağlı olarak ise. doğum döneminde dişi buzağılarda AST değerinin erkeklere göre daha yüksek olduğu, sütten kesim döneminde ise erkek buzağılarda BUN seviyelerinin dişilere kıyasla anlamlı derecede yüksek olduğu belirlenmiştir. Fosfor ve albümin parametrelerinde de cinsiyete bağlı yakın anlamlı farklılıklar bulunmuştur. Bu sonuçlar, protein ve mineral metabolizmasının buzağılarda yaş ve cinsiyete göre farklılık gösterebileceğini ve erken dönemde bu parametrelerin dikkatle izlenmesinin önemini vurgulamaktadır. Literatürle uyumlu olarak, metabolik parametrelerin yaş. cinsiyet ve beslenme koşullarına bağlı değişkenlik gösterdiği ifade edilmiştir. Genel olarak, biyokimyasal parametrelerde yaş ve cinsiyetin etkisinin sınırlı ancak belirgin olduğu, buzağı sağlığı ve gelişim takibinde sürü yönetiminde bu faktörlerin göz önünde bulundurulması gerektiği sonucuna varılmıştır.

Sonuç

Siyah Alaca buzağılarda doğum (1) ve sütten kesim (2) dönemlerine ait biyokimyasal parametrelerin genel ortalamalarına bakıldığında, AST değerleri sırasıyla 86.48 U/L ve 94.44 U/L olup, enzim düzeylerinde hafif artış görülmektedir. GGT düzeyleri doğumda 32.62 U/L, sütten kesimde 25.70 U/L olarak tespit edilmiş, karaciğer fonksiyonlarında doğuma kıyasla stabilizasyon izlenmiştir. Kolesterol (KOL) ortalamaları doğumda 150.55 mg/dL, sütten

kesimde 155.70 mg/dL olarak hafif artış göstermiştir. Glukoz (GLU) düzeyleri doğumda 56.88 mg/dL iken, sütten kesimde 38.60 mg/dL'ye düşmüş, bu da enerji metabolizmasındaki değişimi yansıtmaktadır. Kalsiyum (Ca) seviyeleri doğumda 11.10 mg/dL, sütten kesimde 10.89 mg/dL, fosfor (P) düzeyleri ise doğumda 8.82 mg/dL, sütten kesimde 8.39 mg/dL olarak ölçülmüştür. Magnezyum (Mg) ortalamaları doğumda 2.68 mg/dL, sütten kesimde 2.31 mg/dL olup, düşüş göstermektedir. Toplam protein (TP) değerleri doğumda 8.03 g/dL, sütten kesimde 7.23 g/dL; albümin (ALB) ise sırasıyla 3.47 ve 3.47 g/dL ile sabit kalmıştır. BUN düzeyi doğumda 10.56 mg/dL iken, sütten kesimde 10.43 mg/dL olup stabil seyretmiştir. Bu ortalamalar, Siyah Alaca buzağılarda yaşla birlikte bazı biyokimyasal değerlerde fizyolojik değişimler yaşandığını ortaya koymaktadır.

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FARKLI ÇIKIŞ GÜNLERİNİN MISIR BİTKİSİNDE (*Zea mays* L.) VERİM PARAMETRELERİ ÜZERİNE ETKİLERİ

Fatih ÖNER

Prof. Dr., Ordu Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü, Ordu

Email: fatihoner38@gmail.com

ORCID: 0000-0002-6264-3752

Hacı ŞAHAN

Ziraat Yüksek Mühendisi, Fen Bilimleri Enstitüsü, Ordu

ORCID: 0000-0001-5396-0484

ÖZET

Araştırma; Konya ili Ereğli ilçesi Yukarı Göndelen Mahallesi'nde, çiftçi arazisinde 2025 yılında Pioneer P0937 mısır çeşidinin bazı bitkisel ve verim özelliklerinin belirlenmesi amacıyla yürütülmüştür. Ekim işlemi 2025 yılı Nisan ayında, Tesadüf Blokları Deneme Desenine göre 4 tekrarlı olarak; sıra arası 70 cm, sıra üzeri 16 cm olacak şekilde makine ile yapılmıştır. Ekimden sonra oluşturulmuş ve çıkış gözlemleri her gün aynı saatte düzenli olarak yapılmış; parsellerde ilk günden itibaren çıkış yapan bitkiler işaretlenerek, bitkilerin çıkış tarihleri (sırasıyla 1.gün,2.gün, 3.gün, 4.gün, 5.gün ve 6.gün) kayıt altına alınmıştır. Ekim ayının ikinci haftasında yaklaşık %16–17 nem oranına ulaşan bitkilerde koçanlar tek tek koparılarak hasat edilmiştir. Hasat günü deneme alanında bitki boyu (cm), ilk koçan yüksekliği (cm) ve olarak bitki sap çapı (cm) (toprak yüzeyinden ölçülmüştür) belirlenmiştir. Hasat edilen koçanlarda sonrasında koçan ağırlığı (g), sömek ağırlığı (g), dane ağırlığı (g), koçan dane çevre sayısı (adet), koçan dane sıra sayısı (adet), koçan boyu (cm), koçan çapı (cm) ve yüz dane ağırlığı(g) incelenmiştir. Elde edilen veriler JMP istatistiksel analiz programında analiz edilmiş, ortalamalar arasındaki farklılık LSD çoklu karşılaştırma testi ile belirlenmiştir. Yapılan istatistiksel analizler sonucunda ortalamalar arasındaki farklılıklar bakımından; bitki boyu %1 düzeyinde önemli bulunurken 1. gün çıkış yapan bitkiler ilk istatistiksel grupta yer almışlardır. İlk koçan yüksekliği (cm) ve gövde kalınlığı (cm) bakımından da %1 düzeyinde önemli bulunmuş ve 1.,2. ve 3. gün çıkış yapan bitkilerden elde edilen değerler ilk grubu oluşturmuşlardır. Koçan ağırlığı (g), koçan boyu (cm), dane ağırlığı (g), ve koçan dane sıra sayısı (adet) değerleri bakımından bakımından %1, sömek ağırlığı (g), koçan çevre sayısı, koçan çapı (cm) bakımından ise %5 düzeyinde önemli bulunurken sömek ağırlığı bakımından ilk 4 gün, diğer iki parametre için ise ilk 5 gün çıkış yapan bitkiler istatistiksel olarak ilk grubu paylaşmışlardır. Yüz dane ağırlığı (g) bakımından ise farklılıklar %1 önem düzeyinde önemli bulunmuş ve 5.gün çıkış yapan bitkiler ilk grupta yer almıştır.

Anahtar Kelimeler: Hasat, Mısır, Verim, *Zea Mays*

EFFECTS OF DIFFERENT SOWING DATES ON YIELD PARAMETERS OF MAIZE (*Zea mays* L.)

ABSTRACT

This research was conducted in the Yukarı Göndelen neighbourhood of Ereğli district, Konya province, on farmland in 2025 to determine certain plant and yield characteristics of the Pioneer P0937 maize variety. The sowing was carried out April 2025 using a machine, with 4 replicates according to the Randomised Block Design; row spacing was 70 cm and row spacing was 16 cm. After sowing, emergence observations were made regularly at the same time each day; plants emerging in the plots were marked from the first day, and their emergence dates (1st day, 2nd day, 3rd day, 4th day, 5th day, and 6th day, respectively) were recorded. In the second week of October, when the plants reached a moisture content of approximately 16–17%, the ears were harvested individually. On the day of harvest, the plant height (cm), first ear height (cm), and plant stalk diameter (cm) (measured from the soil surface) were determined in the trial area. The harvested ears were subsequently examined for ear weight (g), cob weight (g), grain weight (g), number of grains per ear (count), number of rows of grains per ear (count), ear length (cm), ear diameter (cm) and 100-grain weight, (g). The data obtained were analysed using the JMP statistical analysis programme and differences between means were determined using the LSD multiple comparison test. Statistical analyses show that significant differences between means; plant height was found to be significant at the 1% level, while plants emerging on the first day were classified in the first statistical group. The first ear height (cm) and stem thickness (cm) were also found to be significant at the 1% level, and the values obtained from plants emerging on days 1, 2, and 3 formed the first group. In terms of ear weight (g), ear length (cm), grain weight (g), and number of grains per ear (number), the values were significant at the 1% level, while in terms of cob weight (g), number of ears per cob, and cob diameter (cm) were found to be significant at the 5% level. For ear weight, plants emerging in the first 4 days, and for the other two parameters, plants emerging in the first 5 days statistically shared the first group. Differences in hundred-grain weight (g) were found to be significant at the 1% level and plants emerging on the 5th day were included in the first group.

Keywords: Corn, Harvest, Yield, *Zea Mays*

GİRİŞ

Mısır (*Zea mays* L.) Poaceae familyasına ait bir C4 bitkisidir ve yüksek verim potansiyeli ve iklim koşullarına uyum yeteneği sayesinde dünya genelinde geniş bir yayılım alanına sahiptir. 58° Kuzey ile 40° Güney enlemleri arasında, deniz seviyesinden yüksek rakımlara kadar uzanan geniş coğrafyalarda ve yıllık 250–5000 mm yağış alan bölgelerde başarıyla yetiştirilebilmektedir (Ahmed ve ark. 2019). Bu özellikler mısırı, tahıllar içinde buğdaydan sonra en geniş ekim alanına sahip tür hâline getirmekte; üretim miktarı bakımından ise tüm tahıllar içerisinde birinci sıraya yerleştirmektedir. Nitekim dünya genelinde 2023 yılı mısır ekim alanı yaklaşık 208.3 milyon ha seviyesindedir (FAO, 2025). En büyük üretici ülkeler ABD, Çin, Brezilya ve Hindistan olup, mısır hem stratejik bir gıda ürünü hem de yem, biyoyakıt, nişasta bazlı tatlandırıcı, mısır yağı ve diğer endüstriyel ürünler için önemli bir hammadde niteliği taşımaktadır (Vasal, 2002; Ciampitti ve Vyn, 2013; Ranum ve ark., 2014).

Mısırın küresel düzeyde artan önemi, hızla yükselen dünya nüfusu, hayvansal üretimdeki genişleme ve sanayi sektöründeki talep artışıyla doğrudan ilişkilidir. Yüksek biyolojik verim potansiyeli sayesinde gıda, yem ve endüstriyel hammaddelerin üretiminde kilit bir rol oynayan mısır, tarımsal üretim sistemleri açısından vazgeçilmez bir ürün olarak değerlendirilmektedir. Türkiye'de de mısır arpa ve buğdaydan sonra en fazla ekilen tahıl olup, son yıllarda üretimde belirgin artışlar kaydedilmiştir. 2024 yılında yaklaşık 7.894,438 hektarlık ekim alanından 8,1 milyon ton üretim elde edilmiştir (TÜİK, 2025). Hibrit tohum kullanımının yaygınlaşması, modern üretim tekniklerinin benimsenmesi ve sulama imkânlarının genişlemesi bu gelişime önemli katkı sağlamıştır (Revathi ve ark., 2025).

Mısırda verim ve kaliteyi belirleyen temel unsurlar arasında çeşit seçimi, ekim zamanı, gübreleme, sulama yönetimi ve iklim koşullarına uygun yetiştiricilik stratejileri yer almaktadır. Ekim zamanı, bitkinin fenolojik gelişimini doğrudan etkileyerek koçan oluşumu, döllenme ve tane dolumu gibi kritik dönemlerde çevresel streslerin şiddetini belirleyen önemli bir faktördür. Bu nedenle, bölgesel iklim özelliklerine uygun ekim tarihlerinin belirlenmesi, özellikle sıcaklık ve su stresi riski bulunan bölgelerde mısır verimini artırmak açısından büyük önem taşımaktadır.

Mısır bitkisinin Türkiye ve dünya tarımı açısından stratejik önemi giderek artmakta; verimlilik ve kaliteyi artırmaya yönelik bölgeye özgü araştırmaların yürütülmesi gerekliliği daha da belirgin hâle gelmektedir. Bu çalışma ile, Konya ili Ereğli ilçesinde yetiştirilen Pioneer P0937 marka mısır çeşidinde farklı günlerdeki kademeli çıkışın verim parametreleri üzerine olan etkisini incelemek amaçlanmıştır.

1.MATERYAL YÖNTEM

Bu çalışma, 2025 yılında Konya ili Ereğli ilçesi Yukarı Göndelen Mahallesi'nde bir çiftçi arazisinde yürütülmüştür. Araştırmada tohum materyali olarak Pioneer P0937 hibrit mısır çeşidi kullanılmıştır. Deneme, Tesadüf Blokları Deneme Desenine göre 4 tekerrürlü olarak kurulmuştur. Ekim işlemi 27 Nisan 2025 tarihinde sıra arası 70 cm, sıra üzeri 16 cm olacak şekilde pnömatik ekim makinesi ile gerçekleştirilmiştir. Ekim sırasında tohum yatağı sıcaklığı 15.5 °C olarak ölçülmüştür. Ekimle birlikte dekara 40 kg Timacereal (17-24-0) taban gübresi uygulanmıştır. Ayrıca çimlenmeyi ve kök gelişimini artırmak amacıyla 2 kg/da dozunda Resid marka mikoriza ürünü (Glomus iranicum var. Tenuihypharum) ekim esnasında kullanılmıştır.

Çıkış gözlemleri ekimden itibaren her gün aynı saatte yapılmış, çıkış gerçekleştiren bitkiler işaretlenerek çıkış günleri (1., 2., 3., 4., 5. ve 6. gün) kayıt altına alınmıştır. Hasat, bitkilerin koçan neminin %16–17 seviyesine ulaştığı dönemde, ekim ayının ikinci haftasında yapılmıştır. Her bitkiden koçanlar tek tek koparılarak ölçümler gerçekleştirilmiştir. Bitkilerde bitki boyu (cm), ilk koçan yüksekliği (cm), bitki gövde çapı (mm) belirlenmiştir. Koçanlarda ise koçan

çapı (mm), koçan ağırlığı (g), sömek ağırlığı (g), dane ağırlığı (g), koçan çevre dane sayısı (adet), koçan sıra sayısı (adet) ve yüz dane ağırlığı (g) değerleri ölçülmüştür. Elde edilen veriler JMP istatistiksel analiz programında analiz edilmiş, ortalamalar arasındaki farklılık LSD çoklu karşılaştırma testi ile belirlenmiştir.

2.BULGULAR VE TARTIŞMA

2.1.Bitki boyu (cm)

Yapılan çalışma sonuçları incelendiğinde, bitki boyu değerleri bakımından yapılan varyans analizi sonucunda farklılık istatistiksel olarak $P<0.01$ önem düzeyinde bulunmuştur. Bitki boyu değerleri 203.8-230.5 cm aralığında değişiklik göstermiştir (Tablo.1). En yüksek bitki boyuna 1. Gün çıkış yapan bitkilerde ulaşılmıştır. Çıkış gün sayısı geciktikçe bitki boyunda kısalma meydana gelmiştir. En kısa bitki boyuna 6. gün çıkış yapan bitkilerde ulaşılmıştır. Bitki boyu uzun olan genotiplerin yatmaya daha yatkındır ve bu durumda hasadını güçleştirmektedir (Shi ve ark.,2016). Yapılan farklı bazı çalışmalarda, Azar ve ark., (1997) tarafından 215.5-274.8 cm, Luchin ve ark., (2003) tarafından 229-258 cm, Beyene ve ark., (2005) tarafından 161-228 cm, Samsun koşullarında yürütülen çalışmada bitki boylarının 255-355 cm ve 259- 279 cm arasında değiştiğini (Öz ve ark. 2008), Öner (2017), tarafından 34-301 cm, Dancı (2025) 256.3-273.6 cm ve Kurt (2025) 166.3- 185.66 arasında bulduğunu bildirmişlerdir.

2.2. İlk koçan yüksekliği (cm)

Denemede elde edilen ilk koçan yüksekliği değerleri; 132.4-156.8 cm arasında değişiklik göstermiştir. Yapılan varyans analizi sonuçlarına göre ilk koçan yüksekliği değerleri bakımından çıkış gün sayıları arasındaki farklılık istatistiki olarak $P<0.01$ düzeyinde önemli bulunmuştur (Tablo.1). En yüksek ilk koçan yüksekliğine ilk çıkış (1.gün) yapan bitkilerde ulaşılmış ve istatistiksel olarak ilk grubu oluşturmuştur. İlk koçan yüksekliği, verim ve hasat kalitesi açısından önemlidir. Hasat makineleri için kolaylık sağlarken çok düşük koçan yüksekliği koçanın zarar görmesine sebep olabilmekte, çok yüksek koçanlar bitkinin kırılması veya devrilmesine sebebiyet verebilmektedir. Bazı farklı çalışmalarda ilk koçan yüksekliğine ait değerler için; Turgut ve Balcı (2002) mısır bitkisi ilk koçan yüksekliklerinin geç ekim dönemlerinde erken ve orta ekim dönemlerine nazaran daha yüksek olduğunu bulmuştur. Kaya ve Kuşaksız (2012) çalışmalarında, dört ekim zamanından (5 Mayıs, 20 Mayıs, 5 Haziran, 20 Haziran) 20 Haziran dönemindeki mısır ilk koçan yüksekliğinin en yüksek (113.89 cm) olduğunu bildirmişlerdir. Bandır (2008) Çanakkale ekolojik koşullarında farklı ekim zamanında (6 Haziran'dan 16 Temmuz'a kadar) yaptığı çalışmada en yüksek ilk koçan yüksekliğine (87.00 cm) 16 Temmuz'da yapılan mısır ekilişlerinde tespit ettiklerini bildirmişler, yine Dancı (2025) yapmış olduğu çalışmada ilk koçan yüksekliği değerlerini 106.87 – 117.47 cm olarak bildirmiştir.

2.3. Bitki gövde çapı (mm)

Bitki gövde çapı değerleri bakımından değerlerimiz 17.33-34.56 mm arasında değişiklik göstermiştir. Yapılan varyans analizi sonuçlarına göre gövde kalınlığı bakımından değerler arası farklılık istatistiki olarak $P<0.01$ düzeyinde önemli bulunmuştur (Tablo.1). En kalın gövdeye 1. Gün çıkış yapan bitkilerde ulaşılmış, en ince gövdeye ise 6.gün çıkış yapan bitkilerde ulaşılmıştır.

2.4. Koçan çapı (mm)

Koçan çapı değerleri 48.4- 55.7 mm arasında değişiklik göstermiştir. Yapılan varyans analiz sonucuna göre, koçan çapı bakımından çıkış gün sayısı arasında $P<0.05$ önem seviyesinde istatistiki farklılık bulunmuştur (Tablo.1). En düşük koçan çapına 6. Gün çıkış yapan bitkilerde ulaşılmış istatistiksel olarak son grupta yer almıştır. Diğer günlerde elde edilen değerler arası

farklılık istatistiksel olarak farklı bulunmamış hepsi ilk grupta yer almıştır. Koçan çapı, verimi etkileyen bir parametredir ve toplam ürün miktarını arttırmaktadır. Farklı çalışmalarda görülen koçan çapı verileri 4.2cm, 4.69cm, 4.18cm 4.87cm gibi değerler olduğu gözlemlenmiştir (Atakul ve ark., 2021; Karacadal, 2017; Öztürk, 2023).

2.5. Koçan ağırlığı (g)

Koçan ağırlığı bakımından değerler istatistiksel olarak P<0.01 düzeyinde önemli bulunmuştur. Değerler 171.3-325.3 g arasında değişmiştir (Tablo.1). En yüksek ortalamaya 3. Gün çıkış yapıp işaretlenen bitkilerde ulaşılırken (a grubu) sırasıyla 2.,1. ve 4. gün çıkış yapan bitkilerle aynı istatistik grupta yer almıştır. En düşük koçan ağırlığına ekimden sonra en geç çıkış yapan bitkilerde (6.gün) ulaşılmış ve istatistiksel olarak son grubu oluşturmuştur.

Aynı çeşit ile son yıllarda yapılan farklı çalışmalarda koçan ağırlık değerlerinin; 229.75 g (Turan ve Yücel, 2025); 247.9 (Keskin ve Hüseyinbaş, 2025) bulunduğu bildirilmiştir. Çalışmamızda elde ettiğimiz en yüksek değer diğer çalışma değerlerinden daha yüksek çıkmıştır. Koçan ağırlığı ürünün kalitesini ve ürün fiyatının belirlemesi ve pazarlanması açısından da önemli bir parametredir. Uzun ve kalın koçanların kavuzsuz koçan ağırlığının genellikle yüksek ve albenisi daha iyi olduğundan tüketiciler tarafından daha fazla tercih edilmektedir.

2.6. Sömek ağırlığı (g)

Sömek ağırlığı değerleri 30.6-46.1 g arasında değişiklik göstermiş ve istatistiki olarak P<0.05 düzeyinde önemli bulunmuştur (Tablo.1). En yüksek sömek ağırlığı değerine 3. gün çıkışın olduğu bitkilerde ulaşılırken; sırasıyla 4.,2. ve 1. Gün çıkışın olduğu bitkilerden elde edilen değerlerde ilk grupta yer almıştır. En düşük değere ise 6. Gün bitkilerinde ulaşılmıştır. Farklı mısır çeşitleri ile yapılan çalışmalar incelendiğinde, Akan (2017) Muş koşullarında sömek ağırlığının 41.10–96.65 g olduğunu bildirirken, Ordu'da yapılan bir çalışmada da (Nar, 2023) sömek ağırlığı (g) 13.6-35.3 g arasında değiştiği bildirilmiştir.

2.7. Dane ağırlığı (g)

Dane ağırlığı bakımından değerler istatistiksel olarak P<0.05 düzeyinde önemli bulunmuştur. Çalışmamızda dane ağırlığı verileri incelendiğinde ortalamaların 140.6-281.4 g arasında değişkenlik gösterdiği (Tablo.1) ve en yüksek ağırlığa 2.gün çıkış yapan bitkilerde ulaşıldığı ve 1.,3. ve 4. gün çıkış yapan bitkilerin de en yüksek değer ile aynı grubu paylaştığı belirlenmiştir. 6. gün çıkış yapan bitkilerden elde edilen değerler istatistiksel olarak son grubu oluşturmuştur.

2.8. Koçan dane çevre sayısı (adet)

Koçan dane çevre sayısı (adet) bakımından çalışma sonuçlarımız incelendiğinde, istatistiksel olarak değerler arasında farklılık P<0.05 düzeyinde önemli bulunmuştur. Ortalamalar 15.3-19.25 adet arasında değişkenlik göstermiş (Tablo.1), 6.gün elde edilen 15.3 adet değeri istatistiksel olarak son grubu oluşturmuştur. Diğer günlerden elde edilen değerlerin tamamı istatistiki olarak ilk grubu paylaşmışlardır. Ortalamalardan elde ettiğimiz değerler; Nar (2023)'ün 8.00-13.50değerlerinden yüksek kaydedilmiştir.

2.9. Koçan dane sıra sayısı (adet)

Yapılan varyans analiz sonucuna göre, koçan sıra sayısı bakımından P<0.05 önem seviyesinde istatistiki farklılık bulunmuştur. Tablo.1 incelendiğinde ortalamalar 20.6-40.1 adet arasında değişmiştir. En yüksek değere 1.gün bitkilerinde ulaşılırken, 2., 4.,3.gün bitkilerinden elde edilen değerler aynı istatistiki grubu paylaşmıştır. En düşük değere 6. gün çıkış yapan bitkilerde ulaşılmıştır.

Tablo.1. Verim parametrelerine ait değerler

Çıkış gün sayısı	Bitki boyu (cm) **	İlk koçan yüksekliği (cm) **	Bitki gövde çapı (mm) **	Koçan çapı (mm) *	Koçan ağırlığı (g) **	Sömek ağırlığı (g)*	Dane ağırlığı (g)	Koçan dane çevre sayısı (adet) *	Koçan dane sıra sayısı (adet) *	Yüz dane ağırlığı (g)**
1.gün	230.5 a	156.8 a	34.56 a	53.8 a	324.1 a	42.3 ab	281.3 a	18.3 a	40.1 a	40.2 ab
2.gün	226.8 b	154.6 b	32.76 b	54.5 a	324.4 a	42.9 a	281.4 a	18.7 a	39.8 a	40.0 ab
3.gün	223.6 c	153.7 c	30.32 c	55.7 a	325.3 a	46.1 a	279.1 a	19.0 a	37.5 a	39.0 b
4.gün	217.4 d	150.6 d	27.74 d	55.3 a	318.0 a	43.6 a	274.3 a	19.2 a	38.0 a	41.0 ab
5.gün	205.6 e	140.2 e	20.70 e	52.8 a	226.0 b	31.5 b	194.5 b	18.3 a	28.5 b	41.2 a
6.gün	203.8 f	132.4 f	17.33 f	48.4 b	171.3 c	30.6 c	140.6 c	15.3 b	20.6 c	-

(*: P<0.05; **P<0.01)

2.10.Yüz dane ağırlığı (g)

Yapılan varyans analiz sonucuna göre yüz dane ağırlığı bakımından çıkış gün sayısı arasında P< 0.01 düzeyinde farklılık bulunmuştur (Tablo.1). 6. Gün çıkış yapan bitkilerde yüz dane ağırlığı sayımı yapılamamıştır. Ortalamalar 39.00-41.25g arasında değişkenlik göstermiştir. İstatistiksel olarak ilk grubu en yüksek değere sahip olan 5. gün çıkış yapan bitkilerden elde edilen değerler oluşturmuştur.

Mısırın bin tane ağırlığı genetik yapının yanı sıra, çevre şartları ve yetiştirme koşullarında değişebilir. Yapılan farklı çalışmalarda; bu değerler için; Lucchin ve ark., (2003) 126-186 g, Beyene ve ark., (2005) 229-410 g, Balcı ve Turgut,2006 (209.1 ile 398.9 gram), Hartings ve ark., (2008) 155-420 g, Ristic ve ark., (2014) tarafından 152.5-270.4 g aralığında bulduklarını bildirmişlerdir.

3. SONUÇ

Bu çalışmada ekim sonrası farklı çıkış günlerinde (1.–6. gün) gelişim gösteren mısır bitkilerinde bazı önemli tarımsal özellikler karşılaştırılmış ve çıkış zamanı ile verim unsurları arasındaki ilişkiler belirlenmiştir. Elde edilen sonuçlar, çıkış gün sayısının mısırda morfolojik ve verim parametreleri üzerinde anlamlı etkiler oluşturduğunu açık biçimde göstermektedir.

Genel olarak, erken çıkış yapan bitkiler (özellikle 2. ve 3. gün çıkışlılar) hem koçan ağırlığı, sömek ağırlığı hem de dane ağırlığı bakımından en yüksek değerlere ulaşmış; buna karşılık geç çıkış yapan bitkiler (özellikle 6. gün çıkışlılar) tüm parametrelerde en düşük değerleri vermiştir. Bu durum, çıkışın erken gerçekleşmesinin bitkilerin daha uzun süre fotosentetik aktiviteden

yararlanmasına, güçlü kök sistemi oluşturmasına ve sonuçta daha yüksek biyokütle ve verim değerlerine ulaşmasına imkân tanıdığını göstermektedir. Çıkış zamanı mısırda verim ve verim unsurları üzerinde belirleyici bir faktör olarak öne çıkmıştır. Erken çıkış yapan bitkiler hem koçan özellikleri hem dane verimi açısından avantaj sağlamış; geç çıkış yapan bitkiler ise istatistiksel olarak tüm parametrelerde düşük değerlere sahip olmuştur. Bu bulgular, mısır yetiştiriciliğinde homojen ve hızlı çıkışın sağlanmasının yüksek verim ve kalite için kritik olduğunu ortaya koymaktadır. Ekim öncesi tohum yatağı hazırlığı, tohum kalitesi ve nem sıcaklık dengesi gibi faktörlerin optimize edilmesi, çıkış senkronizasyonunu artırarak ürün performansını belirgin şekilde iyileştirebilir.

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CUMHURİYETİN İLK YILLARINDA TARIM VE HAYVANCILIK ALANINDA MODERNLEŞME ÇALIŞMALARI VE SONUÇLARI

Mehmet OKUR

Prof. Dr., Karadeniz Teknik Üniversitesi, Edebiyat Fakültesi Tarih Bölümü

Karadeniz Technical University, Faculty of Letters Departman of History

ORCID: 0000-0002-8788-9038

ÖZET

Osmanlı İmparatorluğu'nun mali yapısı ve iktisadi düzeni büyük ölçüde tarıma dayalı olmakla beraber modern tekniklerini uygulamada oldukça geç kalmış, köylü sınıf pazar için üretimden ziyade ancak temel giderlerini karşılamaya yetecek kadar tarımsal veya hayvancılık faaliyeti yürütebilmiştir. Şüphesiz böyle bir yapının oluşmasında devletin yönetim biçiminden kaynaklanan yapısal sorunların da – özel mülkiyetin sınırlı olması, emeğin kıtlığı ve toprakların bolluğu – rolü olmakla beraber asıl önemli etken sanayileşmede geç kalınması ve dolaysıyla modern tarım tekniklerinin sınırlı sayıda ve ancak birkaç bölgede kullanılmasıydı.Bu durum nüfusun yaklaşık %80'i kırsalda yaşamasına ve ekilebilir alanların bolluğuna rağmen tarımla uğraşan kesimin yakın kentleri hatta kendi kentsel alanlarını dahi besleyememe sonucunu doğurmuştur. Nitekim İstanbul başta olmak üzere büyük kentlerin gıda gereksinimleri ancak ithal ürünlerle karşılanabilmiştir.

Hayvansal üretim ve orman varlığı tarıma göre bir miktar daha iyiydi. Ancak bu iki unsur da ilmî yaklaşımlardan uzak kullanım ve savaşlar nedeniyle büyük tahribata uğramıştı. Veteriner yetersizliği yüzbinlerce hayvanın telef olmasına yol açarken, ormanlar hem yakıt hem de konut yapımı nedeniyle telafisi mümkün olmayan yıkımlara maruz kalmıştı.

Türkiye'nin şartlarına özgü, mümkün olduğunca kendi ihtiyaçlarını karşılayan yeni bir ekonomi modelini hayata geçirmeyi planlayan Mustafa Kemal Paşa için tarım ve hayvancılık ivedilikle ele alınması gerekiyordu. Evet, sanayileşmek, Avrupa'nı gelişmiş ülkelerinin seviyesine çıkmak temel hedefti. Ancak onun düşüncesine göre bu hedefe ulaşmada geleneksel iktisadi yapıyı modernleştirerek başlamak daha doğru bir yaklaşımdı. Diğer bir ifadeyle tarım ve hayvancılık sanayileşmenin ilk adımı olmalıdır. Nitekim bu amaçla yüksek eğitim kurumları açılmış, Avrupa'dan uzmanlar getirilmiş, örnek çiftlikler hayata geçirilmiş, tohumluk, damızlık, ıslah uygulamaları yapılarak tarımsal üretim kapasitesi birçok kalemde ithalattan ihracat konumuna geçilmiştir. Ziraat Vekâleti'nin Cumhuriyetin Onbeşinci Yılında hazırladığı bir çalışma,tarım, hayvancılık ve ormancılık alanında varılan olağanüstü gelişmeyi açık biri şekilde ortaya koymaktadır.

Anahtar Kelimeler: Cumhuriyet, Atatürk, Tarım, Hayvancılık, Ziraat.

MODERNIZATION EFFORTS AND RESULTS IN AGRICULTURE AND IN THE FIELD OF LIVESTOCK DURING THE EARLY YEARS OF THE REPUBLIC

Mehmet OKUR

Prof. Dr., Karadeniz Teknik Üniversitesi, Edebiyat Fakültesi Tarih Bölümü

Karadeniz Technical University, Faculty of Letters Departman of History

ORCID: 0000-0002-8788-9038

ABSTRACT

Although the financial structure and economic system of the Ottoman Empire were largely based on agriculture, it was considerably late in adopting modern techniques. The peasant class could engage in agricultural or livestock activities only to the extent of meeting their basic needs rather than producing for the market. Undoubtedly, structural problems stemming from the state's administrative system—such as limited private property, labor scarcity, and abundant land—played a role in shaping this structure. However, the primary factor was the delay in industrialization, which resulted in modern agricultural techniques being applied only in a limited number of regions. Consequently, despite approximately 80% of the population living in rural areas and the abundance of arable land, the agricultural sector could not sufficiently supply nearby towns or even its own urban centers. Indeed, the food needs of major cities, particularly Istanbul, could only be met through imported products.

Livestock production and forest resources were somewhat better compared to agriculture. Yet both suffered significant damage due to unscientific practices and wars. The lack of veterinary services led to the death of hundreds of thousands of animals, while forests faced irreparable destruction due to their use as fuel and building materials.

For Mustafa Kemal Pasha, who planned to implement a new economic model tailored to Turkey's conditions and capable of meeting domestic needs as much as possible, agriculture and livestock had to be addressed urgently. Indeed, industrialization and reaching the level of Europe's developed countries were the primary goals. However, in his view, the most effective approach to achieve this goal was to begin by modernizing the traditional economic structure. In other words, agriculture and livestock should constitute the first step toward industrialization. Accordingly, higher education institutions were established, experts were brought from Europe, model farms were implemented, and agricultural production capacity was enhanced through seed, breeding, and improvement programs, enabling many products to shift from import dependence to export. A study prepared by the Ministry of Agriculture on the fifteenth anniversary of the Republic clearly demonstrates the extraordinary progress achieved in agriculture, livestock, and forestry.

Keywords: Republic, Atatürk, Agriculture, Livestock, Agriculture Ministry

GİRİŞ

Tarım ve hayvancılık, yaşam şartlarında meydana gelen dönüşümlere, kırsaldan kentlere göçlere ve sık sık değişen önceliklere rağmen insanlık tarihi boyunca önemini korumuş, hatta birçok ülkenin başlıca ekonomik kaynağı haline gelmiştir. Tarım ve hayvancılık, Türkistan'dan Balkanlara hemen tüm Türk toplulukları için de en önemli geçim ve gelir kaynağı olmuştur. Bununla beraber Avrupa'da meydana gelen ilmî ve teknolojik gelişmeleri zamanında yakalayamaması, diğer alanlarda olduğu gibi tarım ve hayvancılık alnında da geri kalmasına neden olmuştur. Neredeyse tüm iktisadî düzeni tarıma dayalı olan Osmanlı Devleti'nde köylü sınıf yüzyıllar boyunca pazar için üretimden ziyade ancak temel giderlerini karşılamaya yetecek kadar tarım veya hayvancılık faaliyeti yürütmüştür. Şüphesiz böyle bir yapının oluşmasında devletin yönetim biçiminden kaynaklanan yapısal sorunların da – özel mülkiyetin sınırlı olması, emeğin kıtlığı ve toprakların bolluğu – rolü olmakla beraber asıl önemli etkenler; sanayileşmede geç kalınması, dolaysıyla modern tarım tekniklerinin sınırlı sayıda ve ancak birkaç bölgede kullanılması ve ulaşım ağlarının yetersizliğinden kaynaklanmaktaydı. Tüm bu olumsuzluklar nüfusun yaklaşık %80'i kırsalda yaşamasına ve ekilebilir alanların bolluğuna rağmen tarımla uğraşan kesimin yakın kentleri hatta kendi kentsel alanlarını dahi besleyememe sonucunu doğurmuştur. Nitekim İstanbul başta olmak üzere büyük kentlerin gıda gereksinimleri ancak ithal ürünlerle karşılanabilmiştir.[1]

Hayvansal üretim ve orman varlığı tarıma göre bir miktar daha iyiydi. Ancak bu iki unsur da ilmî yaklaşımlardan uzak kullanım ve savaşlar nedeniyle büyük tahribata uğramıştı. Veteriner yetersizliği yüzbinlerce hayvanın telef olmasına yol açarken, ormanlar hem yakıt hem de konut yapımı nedeniyle telafisi mümkün olmayan yıkımlara maruz kalmıştı.

Osmanlı İmparatorluğu'nun yenileşme/modernleşme çabaları tarım ve hayvancılık alanında da kendini göstermiş, modern tarım tekniklerine geçilmesini sağlamaya yönelik programlar geliştirilmeye, Avrupa öğrenciler gönderilmeye ve yeni ilmi metotlarla eğitim yapacak tarım mektepleri açılmaya, çiftlikler kurulmaya başlanmıştır.[2] Bu arada sanayileşmiş ülkelerin mamul ve hammadde olarak tarımsal ürünlere olan ihtiyacının artması Osmanlı Devleti'nin Balkan ve Batı Anadolu bölgelerindeki çiftçilerin Pazar için üretimlerini tetiklemiş, bazı Avrupa ülkeleri tarım arazileri dahi kiralamışlardır.[3] Nitekim XIX. yüzyılın ikinci yarısından itibaren Anadolu'da pamuk, tütün, afyon, fındık, kuru üzüm, kuru incir, meşe palamudu, zeytinyağı vb. tarım ürünleri pazarı gelişmeye başlamış ve İzmir, İstanbul'dan sonra en önemli ithalat-ihracat merkezi konumuna gelmiştir. Şüphesiz Batı Anadolu'daki tarımsal üretimin artmasında ve ticarileşmesinde, İngiltere ile yapılan 1838 Balta Limanı Ticaret Antlaşması ve takip eden diğer ticaret antlaşmalar ile bölgenin Avrupa'nın açık pazarı haline gelmesi ve iç kesimleri limanlara bağlayan demiryolu ulaşımının sağlanması önemli rol oynamıştı.[4]

Osmanlı Devleti'nin son yüzyılında meydana gelen bu gelişmeler, kısmi ve bölgesel anlamda sınırlı kalmış, tüm ülkeyi kapsayan, ekonomi ile beraber toplumsal kalkınmayı amaçlayan bir

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1 XX. yüzyılın başlarında Osmanlı Devleti önemli miktarlarda buğday, un ve pirinç ithal ediyordu. Tarıma dayalı bir ülkenin buğday ithal etmesinin en önemli nedenlerinden biri de kırsal bölgeleri şehirlere bağlayan yeterli ulaşım ağının olmamasıydı. Örneğin deniz yoluyla Balkan ülkelerinden veya Rusya'dan ithal edilen buğday İstanbul pazarına İç Anadolu'dan daha çabuk gelmekte ve daha ucuza mal olmaktaydı. Şevket Pamuk, *Osmanlı-Türkiye İktisat Tarihi (1500-1914)*, İletişim Yayınları, İstanbul, 2005, s. 211.

2 Donald Quartaer, "Osmanlı İmparatorluğu'nda Tarımsal Gelişme", *Tanzimat'tan Cumhuriyete Türkiye Ansiklopedisi, C. 6*, İletişim Yayınları, İstanbul, 1985, s. 1561-1562.

3 Pamuk, *a.g.e.*, s. 219.

4 Mübahat Kütükoğlu, "İzmir Ticaret Odası İstatistiklerine Göre 20. Yüzyıl Başlarında İzmirTicareti", *Son Yüzyıllarda İzmir ve Batı Anadolu Uluslararası Sempozyumu Tebliğleri, (Yay. Haz.:Tuncer Baykara),* İzmir, 1994, s.37; Sabri Yetkin, "II. Meşrutiyet Sonrası Milli İktisadın Oluşum Sürecine Liman Kent (İzmir/Ege) Perspektifinden Bakış", *Osmanlı Ansiklopedisi, C.3*, Yeni Türkiye Yayınları, Ankara, 1999, s. 601.

tarım ve hayvancılık politikası planlanmamıştır.[5] Hâlbuki XX. yüzyılın başında dahi İmparatorluk nüfusunun %80'i kırsal alanda yaşıyor, gayri safi milli hasılasının yaklaşık %50'sini tarım oluşturuyor ve vergilerin yine bir o kadar kısmı tarım ve hayvancılığa dayanan kalemlerden toplanıyor, ihracatın %80'i tarım ürünlerine dayanıyordu.[6]

Cumhuriyetin İlk Yıllarında Tarım ve Hayvancılık Alanında Modernleşme Çalışmaları

Yaklaşık dört yıl süren Milli Mücadele sonucunda oluşan yeni devlet, ülkeyi topyekûn ayağı kaldırmayı amaçlayan bir politika belirlemiş, yıllardır büyük bir sefalet içerisinde yaşayan Türk halkının ekonomik durumunu düzeltme yolarını aramakla işe başlamıştır. Nüfusun %80'inin kırsalda yaşadığı ve yine bir o kadarının tarım ve hayvancılıkla uğraştığı Türkiye için atılacak ilk adım da çok tabi olarak bu alanda olmuştur. Türkiye'nin şartlarına özgü, mümkün olduğunca kendi ihtiyaçlarını karşılayan yeni bir ekonomi modelini hayata geçirmeyi planlayan Mustafa Kemal Paşa liderliğindeki Cumhuriyet Hükümetine göre sanayileşmek, Avrupa'nı gelişmiş ülkelerinin seviyesine çıkmak temel hedefti. Ancak bu hedefe ulaşmak ülkenin demografik yapısıyla, yeraltı yerüstü kaynaklarıyla, bu kaynakları işleyecek mali durumuyla orantılı ve ilintili olmalıydı. Özetle tarım ve hayvancılık sanayileşmenin ilk adımı olmalıydı. Nitekim bu amaçla yüksek eğitim kurumları açılmış, Avrupa'ya ve Sovyet Rusya'ya heyetler gönderilmiş[7], uzmanlar davet edilmiş[8], örnek çiftlikler hayata geçirilmiş, tohumluk, damızlık, ıslah uygulamaları yapılarak tarımsal üretim kapasitesi birçok kalemde ithalattan ihracat konumuna geçilmiştir.

Ziraat Vekâletince hazırlanan 1938 tarihli bir rapor[9], Cumhuriyetin ilk yıllarından itibaren tarım ve hayvancılık alanında yapılan bu ilerlemeleri rakamlarla ortaya koymaktadır. Cumhuriyetin harabe bir ziraî yapı devraldığına atıf yapılarak başlanan bu raporda öncelikle, Cumhuriyet idaresinin memleketin ihtiyaç duyduğu ilim elemanlarını yetiştirmek ve ziraî üretim imkânları ilmî ölçülerle tetkik etmek üzere Yüksek Ziraat Enstitüleri açıldığı ve kısa sürede olumlu etkilerinin görüldüğüne dikkat çekilmektedir.[10] Nitekim Yüksek Ziraat Enstitüleri, 12.000 çeşit flora tespit ederken, kliniklerde her sene binlerce hayvan muayene ve tedavi edilmiş, 70'ten

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5 Yahya Tezel, *Cumhuriyet Döneminin İktisadi Tarihi (1923-1950)*. İş Bankası Kültür Yayınları, İstanbul, 2015, s. 120.

6 Quartaer, a.g.m., s. 1556

7 Köylü ve işçi hareketiyle kurulan Sovyet Rusya'da tarım alanında devlet kontrolünde yeni bir yapılanma içerisindeydi. Sovyet Rusya'nın tarım politikalarını yakından takip eden Türkiye, bu ülkeye bir inceleme heyeti gönderdiği gibi, Sovyet bilim adamları da Türkiye'ye gelmişlerdi. Tarımsal alanda Sovyet Rusya ile yapılan işbirliği hakkında ayrıntılı bilgi için bkz.: Seyfi Yıldırım, "Atatürk Döneminde Sovyet Tarımını İnceleme: Resmî Geziler ve Bilimsel İşbirliği (1925-1932)", *Bilig,* Bahar 2011, Sayı: 52, s. 227-246.

8 Türkiye'ye gelen Avrupalı uzmanlar arasında Macar uzmanlar özel bir yer tutmaktaydı. Macar uzmanlar, Türk öğrenciler Avrupa'da yetişene kadar Türkiye'de uzun yıllar görev yapmışlardır. Macarlar Türkiye'de Tarım Bakanlığı'na bağlı bir Meteoroloji Enstitüsü (Rasathane-i Cevviye) kurulması, Atatürk Orman Çiftliğinin oluşturulması, mera ve çayırların düzenlenmesi, bahçıvanlık, arıcılık ve hayvancılığın geliştirilmesi gibi birçok alanda iz bırakan katkılarda bulunmuşlardı. Cumhuriyetin ilk yıllarında Macar uzmanların Türk tarım ve hayvancılığına yaptıkları katkılar hakkında ayrıntılı bilgi için bkz.: Melek Çolak, "Atatürk Döneminde Tarıma Dayalı Hayvancılık Politikası ve Macar Uzman Oszkar Wellmann'ın Raporları", *Karadeniz Araştırmaları*, XVI/62, s. 175-189; Yücel Namal, "Atatürk Döneminde Tarım ve Hayvancılık Alanında Macar Uzmanların Yeri," *XVIII. Türk Tarih Kongresi, IX. Cilt, 1-5 Ekim 2018 Ankara, Türkiye Cumhuriyeti Tarihi*, Türk Tarih Kurumu Yayınları, Ankara, 2022. s.712-739.

9 *Cumhurbaşkanlığı Devlet Arşivleri Başkanlığı Cumhuriyet Arşivi, Fon 490.01.0.0/Kutu 1455/Gömlek 38/Sıra 3, BCA, 490.01.0.0/1455/38/3.*

10 Cumhuriyetin ilk yıllarından itibaren dönemin gereklerine göre Türkiye'deki ziraat mekteplerinin ıslah edilmesine karar verilmiş, bu hususta Almanya Ziraat Bakanlığı ile temasa geçilerek Oldenburg başkanlığında bir heyet getirilmiş, bu heyetin tavsiyeleri doğrultusunda yeni bir program uygulanmaya başlanmıştır. Nurullah Kırkpınar, *Türkiye'de Zirai Eğitimin Tarihçesi ve Kurumsallaşması (1923-1963),* Atatürk Araştırma Merkezi Yayınları, Ankara, 2024, s. 34.

fazla ilmi eser kaleme alınmıştır.[11] Yine açılan ziraat mektepleri ve ziraî kurslarla modern tarım ve hayvancılık teknikleri öğretilmiş, dolayısıyla üretimde verimliliğin artırılması sağlanmıştır.[12]

Avrupa ve Amerika Birleşik Devletleri'ne de öğrenci gönderilen bu dönemde ziraî eğitim alanında dikkat çeken en önemli atılım "Köy Eğitmenleri" projesinin geliştirilmesi olmuştur. Köylüyü içinde bulunduğu statik hayattan kurtararak ona dinamik bir hayat verme, hem kendisine hem memleketin iktisadî kalkınmasına katkında bulunma niyetiyle hayata geçirilen bu proje o güne kadar başka hiçbir memlekette uygulanmamıştı.[13]

Köylünün hem ziraat usullerini yenilemek hem de okuyup yazmasını ve kültür seviyesini yükseltmesini temin etmek üzere Kültür ve Ziraat Bakanlıkları tarafından 1936 senesinin ilkbaharında Eskişehir'in Çifteler Çiftliğinde ilk defa tecrübe mahiyetinde olarak bir "Köy Eğitmenleri yetiştirme kursu" açılmıştır. Bu kursta yetiştirilen eğitmenlerden görünüşte basit, fakat hayati öneme sahip işler beklendiğinden, bu kişilerin köye bağlı kalmaları, köyde çalışabilmeleri, zorluklara göğüs germeleri ve her surette köylüye faydalı olmalarını temin için köy hayatını bizzat yaşamış ve köyü yakından tanımaları gerekirdi. Dolayısıyla bu eğitmenler, bilfiil ziraatla uğraşan arazi sahipleri ve askerliğini yapmış köylüler arasından seçilmişti. Çifteler'de arzu edilen gayeye uygun bir şekilde yetiştirilmiş olan eğitmen namzetleri geldikleri Ankara köylerine stajyer olarak tayin edilmişler ve kendilerinden beklenilen görevi başarıyla yerine getirmişlerdir.[14]

Bu örnek uygulamadan alınan olumlu sonuçlar üzerine 1937 yılında bu kez Eskişehir'de 2, Kocaeli, Kars, Erzincan ve Edirne vilâyetlerinde de 1'er olmak üzere 5 kurs daha açılmış ve o sene eğitmen adedi 1500'e ulaşmıştır. 1938 senesinde eğitmen meselesi daha fazla ehemmiyet arz etmiş ve yukarıda adı geçen vilayetlerden başka Manisa, İzmir, Kastamonu, Kayseri ve Malatya vilâyetlerinde de Köy Eğitmenleri kursları açılmasına karar verilmiştir.[15]

Cumhuriyetin ilk yıllarında, tarım ve hayvancılığın çağdaş metotlarla yapılması ve üreticilerin bilinçlendirilmesi için bilimsel yayınlara ve kongre, konferans gibi faaliyetlere de önem verilmişti. Ziraat Vekâletine bağlı bir "Neşriyat Müdürlüğü" kurularak, ziraat, orman ve veteriner umum müdürlüklerini alakadar eden kanun, nizam ve talimatnameleri neşredilmiş, köylere dağıtılmak üzere ufak broşürler, bilgilendirici levhalar hazırlanmış, ziraat mekteplerinde okutulmak üzere Roma Beynelmilel Ziraat Enstitüsü yayınları tercüme ettirilmiştir.[16] Yine ziraat ve çiftçi kongreleri tertip edilmiş, bu konuda yurtdışında düzenlenen kongrelere temsilciler gönderilmiştir.[17]

Ziraat Vekaleti, üretimi artırmak amacıyla, Ankara, Eskişehir, Adapazarı, ve Yeşilköy'de "Tohum Islah İstasyonları", Eskişehir'de "Deneme İstasyonu", "Çifteler Tohum Üretme Çiftliği", Antalya'da "Sıcak İklim Nebatları Islah İstasyonu", Kayseri'de "Yonca Deneme ve Yonca Tohumu Temizleme İstasyonu", Erzurum'da "Tohum Islah ve Deneme İstasyonu", Lüleburgaz'da "Devlet Örnek ve Üretme Çiftliği", Ordu, Konya ve Çorum'da "Deneme Tarlaları" tesis ederek hem tarım ve hayvancılık için gerekli olan ihtiyaçları karşılamaya çalışmış, hem de öncü işletmeci olmuştur.[18] Nitekim 1929'dan itibaren üretime geçen "Islah ve

[11] *BCA, 490.01.0.0/1455/38/3-2-3.*
[12] *BCA, 490.01.0.0/1455/38/3-3-4.*
[13] *BCA, 490.01.0.0/1455/38/3-4-5.*
[14] *BCA, 490.01.0.0/1455/38/3-4-5.*
[15] *BCA, 490.01.0.0/1455/38/3-5.*
[16] *BCA, 490.01.0.0/1455/38/3-5-6.*
[17] Cumhuriyetin On Beşinci Yıl Dönümü münasebetiyle, Ziraat Vekâleti, yeni hedefler üzerinde çalışmak üzere "Birinci Köy ve Ziraat Kalkınma Kongresi" düzenlemişti. *BCA, 490.01.0.0/1455/38/3-6.*
[18] *BCA, 490.01.0.0/1455/38/3-6-7.*

Deneme İstasyonu" Cumhuriyetin 15. yılına gelindiğinde yılda 2.000.000 kilo tohum dağıtılabilecek düzeye ulaşmıştır.[19]

Türkiye'nin coğrafî şartlarına uygun ürün çeşitlerinin seçilmesi[20], modern tekniklerin uygulanması ve tohumların ıslahı sayesinde Cumhuriyet devrine kadar önemli bir kısmı hariçten tedarik edilen buğday, artık dış memleketlere ihraç edilme düzeyine ulaşmıştır. Hâlihazırda kendi ihtiyacımızı temin ettikten başka yabancı ülkelere de mühim miktarda satış Bilhassa son beş sene zarfındaki buğday ihracatımız; evvelki senelere nispetle büyük farklar göstermiş ve 1936-1937 senesinde ihraç edilen miktar 104.000 tonu bulmuştur.[21]

Buğday üretiminde elde edilen başarı aynı şekilde Arpa, yulaf ve pirinç için de geçerliği olduğunu görmekteyiz.[22] Örneğin Cumhuriyet devrine gelinceye kadar pek iptidai bir tarzda yapılan, umumiyetle yazlık olarak ekilen ve ancak ilkbaharı yağmurlu geçen senelerde iyi bir mahsul alınabilen yulaf üretimi, yurt dışından getirilen tohumların deneme istasyonlarında ülke şartlarına uygun hale getirilmesi sonucunda kısa zamanda hem ekilen arazi hem de mahsulde büyük artış göstermiştir.[23]

Ziraat Vekaleti, tarım ürünlerinde üretimin çeşitlendirilmesi ve artırılması gibi hayvancılığın gelişimi hususunda da yoğun çaba sarf etmiştir. Yem ihtiyacının karşılanması için iklim çeşitliliğine göre "Yonca ve Tohum Temizleme" istasyonları kurulmuş, yurtiçi talep karşılandığı gibi başta Almanya olmak üzere Avrupa ülkelerine ihraç edilmeye başlanmıştır.[24]

Cumhuriyet hükümetinin tarım alanındaki bir diğer başarı hikâyesi de köylünün ziraat aletleri ihtiyacının karşılanması için gösterdiği çabadır. Ziraatı makineleştirmek ve üretimi çoğaltmak maksadı ile muhtelif senelerde 573.545 lira kıymetinde 221 adet traktör alınarak uygun şartlarla çiftçiye dağıtılmıştır.[25] Aynı şekilde pirinç ve pamuk üretimi yapılan bölgelerde kullanılmak üzere harman makineleri, pamuk mibzerleri ve çapa makineleri de yine uygun imkânlarla çiftçiye tevzi edilmiştir.[26]

Yeni Türk Hükümeti, meyvecilik ve bağcılık alanında da büyük başarılara imza atmıştı. Meyvecilik ve bağcılık Cumhuriyet devrine geçildiğinde tarla ürünlerinden daha harap vaziyetteydi. Öyle ki sadece 80 dekar büyüklüğündeki "Erenköy Amerika Asma Fidanlığı" ile işe girişilmiş olduğu halde, geçen on beş yıl zarfında bu müesseselerin sayısı Ankara, Bilecik, Halkalı, Kırklareli, Tekirdağ ve Yalova'da kurulan fidanlıklarla, yediye ve sahaları ise 1307 dekara çıkarılmıştır. Fidan üretim sahaları her yıl artırılarak memleket ihtiyacını karşılayacak bir duruma gelinmiştir. 1924 yılında 6.725 ve 1938 yılında ise 3.022.965 fidan dağıtılması bu alandaki gelişmenin boyutu açıkça ortaya koymaktadır.[27]

Meyveciliği, millî gelirin en sağlam kaynaklarından biri yapmak ve elma, incir, zeytin, fındık, narenciye, fıstık, kayısı mevzularını üzerinde çalışmak üzere Arifiye, Aydın, İzmir, Giresun, Antalya, Gaziantep ve Malatya'da birer istasyon kurulmuş, aynı zamanda armut, kayısı, vişne, badem, narenciye ve diğer meyvalı ve süs fidanları yetiştirmek maksadıyla da Kastamonu,

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19 *BCA, 490.01.0.0/1455/38/3-7.*
20 Örneğin, Yeşilköy ıslah istasyonu: Sert ve yumuşak buğday; Eskişehir ıslah istasyonu: Ak buğday, yayla buğdayı, sert ak buğday; Adapazarı ıslah istasyonu: Bin tane çeşitli buğday; Ankara ıslah istasyonu: Yumuşak ve sert buğday tohumu ıslah edilmekteydi. *BCA, 490.01.0.0/1455/38/3-8.*
21 *BCA, 490.01.0.0/1455/38/3-8.*
22 *BCA, 490.01.0.0/1455/38/3-9-10.*
23 *BCA, 490.01.0.0/1455/38/3-9-10.*
24 *BCA, 490.01.0.0/1455/38/3-11.*
25 *BCA, 490.01.0.0/1455/38/3-13.*
26 *BCA, 490.01.0.0/1455/38/3-13-14.*
27 *BCA, 490.01.0.0/1455/38/3-16.*

Niğde, Ankara–Irmak, Erzincan, Kütahya, Çanakkale, Alanya, Tarsus, İzmir ve Mersin'de birer fidanlık oluşturulmuştur.[28]

Özellikle Zeytin yetiştiriciliğine büyük önem verilmiş zeytin mahsulünün keyfiyet itibarıyla mükemmel bir hale getirilmesi, yabani zeytin ağaçlarının aşılanması ve bu ağaçların verimli bir hale dönüştürülmesi maksadıyla ilk iş olarak İzmir, Muğla, Balıkesir, Çanakkale vilayetlerinde birer "seyyar zeytin bakım teşkilâtı" vücuda getirilmiştir. Bu teşkilatın İşletme, istihsal ve verimli olması bakımından faydalı olduğu ve iyi neticeler verdiği görülünce, bu işleri daha da geliştirmek için zeytinliklerde mecburi bakım usulünü tatbik etmek üzere bir kanuni düzenleme de getirilmiştir.[29]

Bütün bu mesainin bir neticesi olarak memlekette meyvecilik işleri büyük bir gelişim göstermiş, Cumhuriyetten evvel bir dönüm bile meyve istasyonu ve fidanlığı yok iken, geçen on beş yıl zarfında bu hususta kurulan kuruluşların adedi 17'ye ve kapsadığı alan da 3.589 dekara ulaşmıştır.[30]

Ziraat Vekâleti, meyve hasılatını olumsuz etkileyen haşerelere karşı da mücadele etmiş, zeytin sineği ve güvesine karşı 4.328.195, elma iç kurduna karşı 2.477.583, Portakallara musallat olan böceklere karşı 501.044, dutlara zarar veren böceklere karşı da 5.451.319 ağaç ilaçlanmıştır.[31]

Cumhuriyetin ilk yıllarında hükümetin özenle üzerinde durduğu bir diğer ürün de pamuktu. Ve bu alanda başlıca hedef dokuma sanayinin ihtiyaç duyduğu miktarın tamamını karşılamaktı. Nitekim pamuk üretimi için ekim alanları ıslah edilmiş, modern teçhizat temin edilmiş, böylece yaklaşık beş yıllık bir süre içerisinde ekim alanı 158.116 hektardan 230.581 hektara, mahsul miktarı ise 20.209 tondan 64.735 tona çıkarılmıştı.[32]

Cumhuriyet idaresinin tarımsal alandaki verimli çalışmalarından birisini de nebat koruma müesseselerinin kurulması teşkil eder. Bu yönde başlanan çalışmalar neticesinde evvela İzmir ve Ankara Ziraat Mücadele İstasyonları oluşturulmuş, 1935 yılında da Merkez Mücadele Enstitüsü kurulmuştur.[33]

Tavukçuluk ve ipekböcekçiliği modern tesislerle üretim faaliyetlerine girişilen bir başka alan olmuştur. Ülkede tavukçuluğun ıslahı için icap eden ilmî araştırmaları yapmak üzere 1931'de Ankara'da bir "Tavukçuluk Enstitüsü" açılarak, her yıl binlerce damızlık yumurta halka dağıtılmış[34], Bursa, Antalya, Diyarbakır, Edirne, Denizli'de birer ipekböcekçiliği mektebi ve istasyonu açılmış, memlekete uygun, iyi ve yüksek randıman verecek böcek nesillerini tespit etmek maksadıyla bir de "Böcekçilik Enstitüsü" tesis edilmişti.[35]

Uygun iklim şartlarına rağmen tarla ve bahçe bitkileri gibi Türkiye'de hayvancılığın gelişimi de ancak Cumhuriyet idaresiyle mümkün olmuştu. Türkiye'de veteriner eğitiminin başlaması XIX. yüzyılın ortalarında başlamasına rağmen gerek eğitim gerekse teşkilatlanma bakımından bir türlü belirli bir düzene oturtulamamıştı.[36] Cumhuriyet devrinde bir yandan kanuni düzenlemeler yapılıp, talimatnameler çıkarılıp hastalıklar karşısında, idare ve inzibat teşkilatının ve veterinerlerin vazife ve mesuliyetleri tayin ve tespit edilirken, diğer taraftan da veteriner eğitimi yeni bilimsel gelişmeler doğrultusunda yeniden düzenlenmiş, ayrıca hayvan

[28] *BCA, 490.01.0.0/1455/38/3-17.*
[29] *BCA, 490.01.0.0/1455/38/3-18.*
[30] *BCA, 490.01.0.0/1455/38/3-17.*
[31] *BCA, 490.01.0.0/1455/38/3-18-19.*
[32] *BCA, 490.01.0.0/1455/38/3-21-23.*
[33] *BCA, 490.01.0.0/1455/38/3-20*
[34] *BCA, 490.01.0.0/1455/38/3-24*
[35] *BCA, 490.01.0.0/1455/38/3-24-25.*
[36] *Türk Silahlı Kuvvetleri, Osmanlı Devri Birinci Dünya Harbi İdari Faaliyetler ve Lojistik, X'uncu Cilt*, Genelkurmay Askeri Tarih ve Stratejik Etüt Başkanlığı Yayınları, Ankara, 1985, s. 148

sıhhiye memurları ve nalbant mektebi de açılmıştır. Atılan bu kararlı adımlar ve yapılan çalışmalar sonucunda Cumhuriyetin 15. Yılına gelindiğinde ülkede asırlardan beri hüküm süren sığır vebasının kökü kazınmış, dalak, çiçek, mankafa, at frengisi, verem, uyuz gibi hastalıkların tedavisinde büyük ilerlemeler sağlanmıştır.[37]

Tüm bu hastalıklarla mücadele için daha önce teşkil edilen Pendik ve Erzincan serum müesseselerinden başka Cumhuriyet devrinde Pendik'te ayrıca bir de Bakteriyoloji Enstitüsü, Mardin'de bir serum müessesesi; Ankara Etlik'te 4 laboratuvardan müteşekkil bir merkez müessesesi ve ayrıca bir de İstanbul'da Distofajin dârülistihzarı tesis olunmuştur. Cumhuriyetten evvel yalnız bir sığır vebası serumu çıkaran bu müesseseler bugün memleketin aşı ve serum ihtiyaçlarını tamamını karşılayacak duruma gelmiştir.[38] Oluşturulan Damızlık Yetiştirme Müessesleri sayesinde ise ülkenin iklim şartlarına uygun büyük ve küçükbaş hayvanlar tespit edilmeye ve yetiştirilmeye başlanmış, gerektiğinde yurt dışından ithal edilerek köylüye ve çiftliklere dağıtılmaya başlanmıştır.[39]

Veteriner eğitimine verilen önem, çıkarılan kanuni düzenlemeler, kurulan müesseseler ve yapılan ıslah çalışmaları sonucunda Cumhuriyetin 15. Yılına gelindiğinde büyük ve küçükbaş hayvan sayısı 12 milyon artarak 38 milyonu geçmişti.[40]

Cumhuriyetin ilk yıllarında tarım ve hayvancılık alanında devlet planlaması ve öncülüğünde yapılan modernleşme çalışmaları sonucunda üretim sürekli bir artış göstermiş, Türkiye birçok kalemde kendi ihtiyacının hemen tamamını karşıladığı gibi artı değeri ihraç eden bir ülke durumuna gelmiş, II. Dünya Savaşı sürecinde ve sonrasında özellikle Avrupa devletlerinin gıda ihtiyacının karşılanmasında önemli rol oynamıştır. Yine tarım ve hayvancılık alanında yapılan atılımlarla sermaye birikimi sağlanmış, ağır sanayi girişimlerine alt yapı oluşturulmuştur.

[37] *BCA, 490.01.0.0/1455/38/3-27-31.*
[38] *BCA, 490.01.0.0/1455/38/3-33-34.*
[39] İlk defa 1928 yılında Macaristan'dan Merinos cinsi koyun satın alınırken, 1935 – 36 yıllarında da Almanya'dan da 250 baş koç ve 500 koyun ithal edilmiştir. *BCA, 490.01.0.0/1455/38/3-39.*
[40] Cumhuriyetin kuruluşunda ülkedeki toplam hayvan mevcudu 26 milyon civarında idi. *BCA, 490.01.0.0/1455/38/3-38.*

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EKMEKLİK BUĞDAY (*Triticum aestivum* L.) MUTANT HATLARININ ÇİMLENME SIRASINDA TUZLULUK STRESİNE TEPKİSİNİN ARAŞTIRILMASI

Zir. Yük. Müh. Soner ÇOLAK
Tekirdağ Namık Kemal Üniversitesi, Fen Bilimleri Enstitüsü, Tarla Bitkileri Anabilim Dalı, Tekirdağ
Email: sonercolak.1106@gmail.com
Prof. Dr. Oğuz BİLGİN
Tekirdağ Namık Kemal Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü, Tekirdağ
Email: obilgin@nku.edu.tr
ORCID: 0000-0002-4338-9912.
Arş. Gör. Dr. Damla BALABAN GÖÇMEN
Tekirdağ Namık Kemal Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü, Tekirdağ
Email: dgocmen@nku.edu.tr
ORCID: 0000-0002-3980-3906 (Sorumlu yazar).

ÖZET

Bu çalışma, mutasyonla geliştirilmiş olan ileri hatlarının çimlenme dönemlerinde NaCl kullanılarak oluşturulan 5 farklı tuz çözeltisinde (0, 4, 8, 12 ve 16 dS m^{-1}) tuzluluk stresine tepkilerinin incelenmesi ve ümitvar hatların belirlenmesi amacıyla yürütülmüştür. Bu amaçla NKÜ Lider, Sagittario ve Flamura 85 ticari çeşitlerinin ^{60}Co kaynaklı M_4 popülasyonlarından geliştirilen 12 mutant ileri hat ve bunların anaçları bu çalışmada materyal olarak kullanılmıştır. Çalışmada, 16 dS m^{-1} tuz çözeltisinde denemeye alınan buğday genotiplerinin tohumlarında çimlenme olmuş fakat fide gelişimi olmamıştır. Denemeye alınan buğday genotipleri arasında en yüksek çimlenme oranı Flamura 85 300/15 genotipinde belirlenmiştir. Genel olarak değerlendirildiğinde, mutant ileri hatların anaçlara göre yüksek çimlenme oranına sahip oldukları belirlenmiştir. Çimlenme ortamında artan tuz konsantrasyonlarının çimlenme oranını önemli bir şekilde azalttığı görülmüştür. Kontrol uygulamasına (0 dS m^{-1}) göre çimlenme oranı 4 dS m^{-1} uygulamasında %10.46, 8 dS m^{-1} uygulamasında %32.05,12 dS m^{-1} uygulamasında %54.99ve 16 dS m^{-1}. % 78.14 daha düşük gerçekleşmiştir. Sonuçlar, tuzluluk yönünden üstün performans gösteren mutan hatların tuzluluğun sorun olduğu alanları için çeşit adayı olarak verim denemelerine alınmasının, tuza dayanıklılık ıslah çalışmalarında gen kaynağı olarak kullanılmalarının uygun olabileceği göstermektedir.

Anahtar kelimeler: Buğday, mutant, stres, tuzluluk, çimlenme, fide büyümesi

INVESTIGATION OF RESPONSE OF BREAD WHEAT (*Triticum aestivum* L.) MUTANT IMPROVED LINES TO SALINITY STRESS DURING GERMINATION

ABSTRACT

This study was carried out to investigate the responses of advanced lines developed by mutation to salinity stress in 5 different salt solutions (0, 4, 8, 12 and 16 dS m^{-1}) using NaCl during germination periods and to identify promising lines. For this purpose, 12 mutant forward lines developed from 60Co sourced M_4 populations of NKÜ Lider, Sagittario and Flamura 85 commercial varieties and their mother plants were used as material in this study. In the study, seeds of wheat genotypes tested in 16 dS m^{-1} salt solution germinated, but no seedling development occurred. Among the wheat genotypes tested, the highest germination rate was determined for the Flamura 85 300/15 genotype. Generally, the mutant lines had higher germination rates than the parental lines. Increasing salt concentrations in the germination medium significantly reduced germination rates. Compared to the control treatment (0 dS m^{-1}), germination rates were 10.46% lower in the 4 dS m^{-1} treatment, 32.05% lower in the 8 dS m^{-1} treatment, 54.99% lower in the 12 dS m^{-1} treatment, and 78.14% lower in the 16 dS m^{-1} treatment. The results indicate that mutant lines with superior salinity performance may be suitable for inclusion in yield trials as variety candidates in areas where salinity is a problem and for use as genetic resources in salt tolerance breeding studies.

Keywords: Wheat, mutant, stress, salinity, germination, seedling growth

1. GİRİŞ

Buğday üretimini kısıtlayan en önemli faktörler; uygun olmayan tarımsal faaliyetler, tarım alanlarının amaç dışı kullanımı, erozyon sonucu verimliliğin azalması, insan eliyle bozulan doğal dengenin bir sonucu olarak artan zararlılar ve küresel bir sorun olan iklim değişikliği nedeni ile giderek şiddetlenen stres faktörleridir. Bu sebeplerle azalan tarım alanlarında birim alanda buğday veriminin artması zorunlu hale gelmiştir. Bunun içinde; yüksek verimli, yüksek kaliteli ve stres faktörlerine dayanıklı çeşitler geliştirmek önemlidir. Ayrıca bölgelerin iklim ve toprak faktörlerine uygun bitki ve çeşitlerin yetiştirilmesi de büyük önem taşımaktadır (Benlioğlu ve Özkan, 2015).

Tarım yapılan alanlarda verimliliği kısıtlayan önemli faktörlerden birisi tuzluluktur. Dünyada sulanabilir tarım arazilerinin yaklaşık üçte birinde tuzluluk sorunu olup bu alanın yaklaşık 400-950 milyon ha olduğu tahmin edilmektedir (Hasegawa, 1986; Özkaldı, 2004; Taghipour ve Salehi, 2008). Ülkemizde ise tarım topraklarının yaklaşık 1.5 milyon hektarı tuzluluk problemi olduğu, özellikle buğday ambarı olarak nitelendirilen İç Anadolu Bölgesinde bitki yetiştirilmesini sınırlandıran en önemli etkenler tuzluluk ve alkalilik olduğu bildirilmektedir (Özcan, 2000). Özellikle kurak ve yarı kurak bölgelerde yetersiz yağış ve yüksek buharlaşma tuzluluğun başlıca nedenlerindendir. Diğer taraftan sulamadaki yanlış uygulamalar, özellikle iyi bir drenajın olmadığı alanlarda tuzluluğa neden olabilmektedir (Baltacı, 2004). Bir toprak elektriksel iletkenliği yaklaşık 4 dS m^{-1} (≈ 40 mM ≈ 2,38 g/L NaCl) veya daha yüksek değerlerde ve yaklaşık 0,2 MPa ozmotik basınca sahip olduğunda "tuzlu" olarak nitelendirilmektedir (El Goumi, 2014).Yüksek tuzluluk, bitkilerde pek çok fizyolojik ve biyokimyasal olayın bozulmasına, iyon stresi ve ozmotik stres yanında hormon ve besin dengesizlikleri gibi ikincil streslere de neden olmakta (Türkan ve Demiral, 2009), tüm gelişim aşamalarında bitki büyüme ve gelişmesini olumsuz yönde etkileyerek verimliliğin düşmesine yol açmaktadır (Machado ve Serralheiro, 2017).

Tuz stresi bitkilerin tüm gelişme evrelerini etkileyebilir, ancak pek çok bitki türünde en ciddi zararların çimlenme ve erken büyüme aşamalarında meydana geldiği bilinmektedir (Munns, 2002). Son yıllarda etkisi giderek artan, küresel ısınmanın bir sonucu olarak buharlaşmanın etkisi ile kurak ve yarı kurak alanlarda toprak yüzeyinde yüksek düzeyde tuz birikimi meydana gelmektedir. Bu da çimlenme ve erken fide gelişme aşamasında bitkilerin sonraki gelişme dönemlerine göre daha yüksek tuzluluk seviyeleri ile karşı karşıya kalmasına neden olmaktadır (El Goumi, 2014). Tahılların gerek çimlenme gerekse erken fide döneminde yüksek tuzluluğa karşı duyarlı oldukları bildirilmiştir (Ghoulam ve Fares, 2001). Ekmeklik buğday orta derecede tuza dayanıklı bitkiler grubunda olup, toprakta 100 Mm NaCl seviyesinde tuzluluk olduğu durumlarda buğdayda verimi azalır. Bunun yanı sıra, tuzluluğa en dayanıklı olan buğdayda da 250 mM NaCl tuz konsantrasyonunda uzun süre kaldığı durumlarda bitki ölümlerinin gerçekleştiği ifade edilmiştir.

Kültür bitkilerine istenilen özelliklerin kazandırılmasında, kalıtsal yapıda ani değişmeler (mutasyon) yapacak yöntemlerin kullanılmasıyla kısa zamanda yeni varyasyonlar yaratılabilmektedir.

Birden fazla karaktere sahip mutantın izole edebilmesi yapay mutasyonların en büyük avantajıdır (Louali ve ark., 2015). Ekonomik açıdan önemli olan ürünlerin yetiştirildiği bölgelerde, çevresel değişimlere karşı dayanıklı çeşitlerin tercih edilmesi büyük önem taşımaktadır. Tuzluluk sorunu olan alanlarda yetiştirilecek buğday çeşitlerinin tolerans düzeylerinin bilinmesi başarılı bir yetiştiricilik ve yüksek verim için oldukça önemlidir.

Bu çalışma ile NaCl konsantrasyonları kullanılarak oluşturulacak farklı tuzluluk stresi koşullarının ekmeklik buğday mutant hatları ve çeşitlerinin çimlenme özelliklerine etkilerinin

incelenmesi ve tuzluluğa dayanıklılık ıslahı çalışmalarında genitör olarak kullanılabilecek ümitvar hatların tespit edilmesi amaçlanmıştır.

2. MATERYAL VE YÖNTEM

2.1. Materyal

Tekirdağ Namık Kemal Üniversitesi Tekirdağ Ziraat Fakültesi Tarla Bitkileri Bölümü tarafından geliştirilmiş olan NKÜ Lider ile Trakya Bölgesinde tarımı yapılan 2 adet ekmeklik buğday çeşidi Sagittario ve Flamura 85 seçilmiş, bu çeşitlerin ^{60}Co kaynağından gamma ışını uygulaması ile edilmiş olan M_4 populasyonlarından geliştirilmiş olan mutant ileri hatlardan seçilmiş olan 12 mutant ileri hat ve bunların anaçları çalışmada materyal olarak kullanılmıştır (Çizelge 1).

Çizelge 1. Araştırmada kullanılan ekmeklik buğday çeşitleri ile mutant ileri hatları

Hat No	Pedigri	Hat No	Pedigri
G1	NKÜ Lider 100/22 (Mutant)	**G9**	Flamura 85 100/60 (Mutant)
G2	NKÜ Lider 200/7 (Mutant)	**G10**	Flamura 85 200/58 (Mutant)
G3	NKÜ Lider 200/11 (Mutant)	**G11**	Flamura 85 300/15 (Mutant)
G4	NKÜ Lider 400/10 (Mutant)	**G12**	Flamura 85 400/1 (Mutant)
G5	Sagittario 100/7 (Mutant)	**G13**	NKÜ Lider (Çeşit)
G6	Sagittario 200/49 (Mutant)	**G14**	Sagittario (Çeşit)
G7	Sagittario 200/59 (Mutant)	**G15**	Flamura 85 (Çeşit)
G8	Sagittario 300/5 (Mutant)		

2.2. Yöntem

Deneme, 2022-2023 yetiştirme döneminde, Tekirdağ Namık Kemal Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü Tohumluk ve Teknolojisi Laboratuvarında yürütülmüştür. Deneme, ekmeklik buğday genotiplerinin çimlenme dönemindeki tuzluluk stresine yanıtlarını belirlemek amacıyla, çeşitler ana parsellere, NaCl kullanılarak oluşturulan 5 farklı tuz çözeltisi (0, 4, 8, 12 ve 16 dS m^{-1}) alt parselleri oluşturacak şekilde, Tesadüf Parsellerinde Bölünmüş Parseller Deneme Desenine göre 3 tekrarlamalı olarak kurulmuştur. Tuz çözeltilerinin hazırlanmasında başka kimyasal etmenlerin etkisini ortadan kaldırmak amacıyla steril edilmiş saf su kullanılmıştır. Steril edilmiş tohumlar, içerisinde 10 ml tuz çözeltisi bulunan ve önceden steril edilmiş 9 cm çaplı petri kaplarına, her kaba 20 adet tohum olacak şekilde, önceden steril edilmiş özel çimlendirme kağıtları arasına yerleştirilmiştir. Petri kaplarında meydana gelecek buharlaşmayı önlemek için petri kapları streç film ile sarılarak ve ağızları kilitlenebilen şeffaf plastik poşetlerin içerisine konulmuştur. Petri kapları daha sonra iklimlendirme dolabına alınarak, 16 saat aydınlık 8 saat karanlık periyotta, 25 ±1 ^{0}C'de 8 gün süresince çimlenmeye (ISTA, 1996), 14 gün süresince erken fide gelişimine bırakılmıştır. Tohumların radiculaları (kökçükleri) 2 mm olana kadar uzadığında çimlenmiş olarak kabul edilmiştir (Adjel ve ark., 2013). Petri kaplarındaki özel çimlendirme kağıtları ve tuz çözeltileri deneme süresince iki günde bir yenilenmiştir.

2.3. Verilerin elde edilmesi

Denemelerde incelenecek özelliklere ait gözlem ve ölçümler aşağıda açıklandığı şekilde yapılmıştır. Çimlenme oranı: Sekiz gün sonunda, petri kaplarında çimlenen tohumlar sayılmış ve çimlenme oranları (%) olarak aşağıdaki formüle göre belirlenmiştir. Ortalama çimlenme süresi: Ele alınan çeşitlerin 5 farklı tuz çözeltisindeki ortalama çimlenme süreleri (OÇS), Ellis ve Roberts (1980)' e göre; "OÇS=∑(fx) / ∑ f" formülü ile belirlenmiştir. Formülde; "f" sayım günündeki çimlenen tohum sayısını, "x" sayım yapılan gün sayısını ifade etmektedir. Tohum gücü indeksi: Tohum gücü indeksi (SVI); Zhang ve ark. (2007)'e göre "SVI = SL × Σ (ni/ti)" formülü ile belirlenmiştir. Formülde; SL= sürgün uzunluğunu, ni=sayım gününde çimlenen tohum sayısını, ti= ekim gününden itibaren gün cinsinden süreyi ifade etmektedir. Tuz tolerans indeksi: Fidelerin sürgün ve kök toplam kuru ağırlıkları kullanılarak, aşağıdaki eşitlik ile "tuz tolerans indeksi" hesaplanmıştır (Carpıcı ve ark., 2009).

Tuz Tolerans İndeksi (%) = (T_t x TKA / T_0 x TKA) x 100

Eşitlikte, TKA= toplam kuru ağırlığı, T_t= t tuz dozundaki toplam kuru ağırlığı, T_0= kontrol uygulamasındaki toplam kuru ağırlığını ifade etmektedir.

2.4. Biyometrik değerlendirme

Denemeden elde edilen verilerde tesadüf parsellerinde bölünmüş parseller deneme desenine göre varyans analizi yapılmıştır. Denemede incelenen özelliklerin ortalama değerleri arasındaki farkların istatistiki anlamda önemlilikleri JUMP 5.0 istatistik paket programı kullanılarak LSD (En Küçük Önemli Fark) testine göre belirlenmiştir (Düzgüneş ve ark., 1987).

3. SONUÇLAR VE TARTIŞMA

Denemeye alınan mutant hat ve genotiplerin 5 farklı tuz çözeltisinde elde edilen çimlenme özelliklerine ilişkin veriler üzerinde yapılan varyans analizi sonuçları Çizelge 2' de verilmiştir.

Çizelge 2. Çimlenme özelliklerine ilişkin kareler ortalamaları ve önemlilik düzeyleri

VK	Genotip (G)	Tuz Konsantrasyonu (T)	GxT İnteraksiyonu
SD	**14**	**23**	**56**
Çimlenme oranı	2251,400**	41193,500**	283,321**
Çimlenme süresi	0,509**	73,142**	0,275**
Tohum gücü indeksi	9541,860**	768820**	3315,120**
Tuz tolerans indeksi	5129,950**	64015,100**	1996,440**

**: %5 düzeyinde önemli, **: %1 düzeyinde önemli*

Çimlenme Oranı: Çimlenme oranı için varyans analiz çizelgesi incelendiğinde genotipler, tuz konsantrasyonları ve çeşit x tuz konsantrasyonu interaksiyonu istatistiki anlamda 0,01 düzeyinde önemli bulunmuştur (Çizelge 2). Çalışmada kullanılan ekmeklik buğday çeşit ve mutant hatlarının çimlenme oranı ortalamaları arasındaki farklılığı ortaya koymak amacıyla gerçekleştirilen EKÖF önemlilik testi sonuçları Çizelge 3'de verilmiştir.

Çizelge 3' ün incelenmesinden anlaşılacağı gibi denemeye alınan ekmeklik buğday genotiplerinin çimlenme oranı ortalamaları %27,00-73,66 arasında değişmiştir. En yüksek çimlenme oranı Flamura 85 300/15 çeşidinde belirlenmiş, bunu %73,33 ile aynı istatistiki grupta yer alan Flamura 85 200/58 çeşidi izlemiştir. En düşük çimlenme oranı ise Sagittario 300/5 genotiplerinden elde edilmiş, bunu 46,33 ile Sagittario 100/7 genotipi izlemiştir.

Denememizde tuz çözeltilerinden elde edilen ortalama çimlenme oranı %20,66-94,55 arasında değişmiştir (Çizelge 3). En yüksek çimlenme oranı 0 dS m^{-1} tuz çözeltisinde saptanmış, bunu %84,66 ile 4 dS m^{-1} tuz çözeltisi izlemiştir. En düşük çimlenme oranı ise 16 dS m^{-1} tuz çözeltisinde belirlenmiş, bunu %42,55 ile 12 dS m^{-1} tuz çözeltisi izlemiştir.

Çizelge 3. Çimlenme oranına (%) ilişkin ortalama değerler ve önemlilikleri

Genotipler	**Tuz konsantrasyonları (dS m^{-1})**					**Ortalama**
	0	***4***	***8***	***12***	***16***	
Sagittario	98,33ab	86,66a-e	76,66d-g	40,00n-s	11,66xy	62,66de
Sagittario 100/7	93,33abc	70,00f-h	31,66p-v	21,66t-y	15,00wxy	46,33g
Sagittario 300/5	61,66g-j	25,00s-y	23,33t-y	15,00 wxy	10,00y	27,00h
Sagittario 200/49	93,33abc	91,66 a-d	75,00e-h	41,66m-r	21,66t-y	64,66cd
Sagittario 200/59	95,00abc	80,00c-f	75,00e-h	53,33j-n	33,33p-u	67,33a-d
Flamura 85	96,66ab	86,66a-e	75,00e-h	70,00f-h	35,00o-t	72,66abc
Flamura 85 100/60	95,00abc	95,00abc	83,33b-f	56,66ı-m	21,66t-y	70,33a-d
Flamura 85 200/58	98,33ab	95abc	75,00e-h	70,00f-h	28,33q-w	73,33ab
Flamura 85 300/15	100,00 a	98,33ab	75,00e-h	60,00h-k	35,00o-t	73,66a
Flamura 85 400/1	93,33ab	83,33b-f	56,66u-m	26,66r-x	11,66xy	54,33f
NKÜ Lider	100,00 a	93,33abc	50,00j-o	26,66r-x	15,00wxy	57,00ef
NKÜ Lider 200/7	98,33ab	93,33 abc	80,00c-f	43,33l-q	18,33u-y	66,66bcd
NKÜ Lider 200/11	100,00a	90,00a-e	58,33ı-l	33,33p-u	23,33z-y	61,00de
NKÜ Lider 100/22	98,33ab	93,33abc	80,00c-f	45,00k-p	13,33wxy	66,00cd
NKÜ Lider 400/10	96,66ab	88,33a-e	45,00k-p	35,00o-t	16,66v-y	56,33ef
Ortalama	94,55a	84,66b	64,00c	42,55d	20,66e	
LSD $_{(P\leq0,05)}$	G: 6,622		T:2,605			GxT:15,671

G:Genotip, T: Tuz konsantrasyonları, GxT: Genotip x Tuz konsantrasyonu interaksiyonu

Genotip x tuz interaksiyonunda ortalama çimlenme oranı %10-100 arasında değiştiği belirlenmiştir (Çizelge 3). En yüksek çimlenme oranı Flamura 85 300/15, NKÜ Lider, NKÜ Lider 200/11 genotiplerinin 0 dS m^{-1} tuz çözeltisinde olurken, %98,33 ile Sagittario, Flamura 85 200/58, NKÜ Lider 200/7, NKÜ Lider 100/22 0 dSm^{-1} ve Flamura 85 300/15 4 dS m^{-1} tuz oranı bunları izlemiştir. En düşük çimlenme oranı ise Sagittario 300/5 genotipinin 16 dS m^{-1} tuz oranında elde edilmiş, bunu 11,66 ile Sagittario ve Flamura 85 400/1 genotipinin 16 dS m^{-1} izlemiştir.

Araştırma sonucunda NaCl konsantrasyonlarındaki artışın çimlenme oranında önemli bir şekilde azalmaya neden olduğu gözlenmektedir. Kontrolle karşılaştırıldığında (0 dS m^{-1}) 4 dS m^{-1} uygulamasında %10,46, 8 dS m^{-1}uygulamasında%32.31, 12 dS m^{-1}uygulamasında %54.99

ve 16 dS m^{-1} uygulamasında %78,15 oranında çimlenme oranında azalma olduğu belirlenmiştir. Bu durum, çimlenme ortamındaki NaCl konsantrasyonlarının artmasına bağlı olarak oluşan osmotik basıncın tohumların çimlenmek için gereksinim duyduğu suyu çekmesinin engellemesinin bir sonucu olmaktadır. Yaptığımız bu araştırma sonuçları Javid ve ark. (2023), Hameed ve ark. (2023), Bayat ve ark. (2022), Köseoğlu ve Doğru (2021), Dirik ve ark. (2020), İnan ve ark. (2018), Çiçek ve ark. (2017), Doğan ve Çarpıcı (2015), Vardar ve ark. (2014), El Goumi ve ark. (2014), Dumlupınar (2005)' ın sonuçları ile paralellik göstermektedir.

Mutant hatlar anaç çeşitleri ile karşılaştırıldığında; değişen tuz konsantrasyonlarında Sagittario 200/49, Sagittario 200/59, Flamura 85 200/58, Flamura 85 300/15, NKÜ Lider 200/7, NKÜ Lider 200/11 ve NKÜ Lider 100/22 daha yüksek çimlenme oranına sahip oldukları belirlenmiştir. Sagittario 200/59 'un %6.94, Flamura 85 300/15'in %1.36 ve NKÜ Lider 200/7 'nin anaclarına göre %14.49 daha yüksek çimlenme oranına sahip olmuşlardır.

Ortalama Çimlenme Süresi: Denemeye alınan genotiplerin 5 farklı tuz oranında elde edilen ortalama çimlenme süresine ilişkin önemlilik grupları Çizelge 4' de verilmiştir.

Çizelge 4. Ortalama çimlenme süresine (gün) ilişkin ortalama değerler ve önemlilikleri

Genotipler	**Tuz konsantrasyonları (dS m^{-1})**					**Ortalama**
	0	***4***	***8***	***12***	***16***	
Sagittario	2,21r	2,3r	2,47m-r	3,47m-r	4,86cd	3,06bc
Sagittario 100/7	2,37r	2,68ı-r	3,46g-n	3,68f-ı	4,83cd	3,40abc
Sagittario 300/5	2,24r	2,34r	2,88g-r	3,86d-g	6,66a	3,60a
Sagittario 200/49	2,35r	2,37q-r	2,53k-r	3,73e-h	6,33ab	3,46ab
Sagittario 200/59	2,30r	3,56j-k	2,67ı-r	3,50g-m	5,26c	3,46ab
Flamura 85	2,10r	2,23r	2,45n-r	3,47g-n	5,43bc	3,13abc
Flamura 85 100/60	2,13r	2,20r	2,37qr	3,39g-q	4,66c-f	2,95c
Flamura 85 200/58	2,10r	2,30r	2,55j-r	3,64f-ı	5,20c	3,16abc
Flamura 85 300/15	2,17r	2,28r	2,41o-r	3,46g-n	5,20c	3,10bc
Flamura 85 400/1	2,17r	2,44n-r	2,73h-r	3,57g-j	5,60bc	3,30abc
NKÜ Lider	2,17r	2,37q-r	2,56j-r	3,57g-j	4,73cde	3,08bc
NKÜ Lider 200/7	2,13r	2,13r	2,83g-r	3,42g-p	5,40bc	3,18abc
NKÜ Lider 200/11	2,07r	2,28r	2,41o-r	3,44g-o	5,00c	3,04bc
NKÜ Lider 100/22	2,17r	2,32r	2,50l-r	3,52g-l	5,50bc	3,20abc
NKÜ Lider 400/10	2,10	2,39pqr	2,76h-r	3,52g-l	4,93c	3,16abc
Ortalama	2,19e	2,41d	2,64c	3,55b	5,30a	
LSD $_{(P\leq0,05)}$	G: 0,463			T:0,172		
			GxT: 1,037			

G:Genotip, T: Tuz konsantrasyonları, GxT: Genotip x Tuz konsantrasyonu interaksiyonu

Çizelge 4' ün incelenmesinden genotiplerin ortalama çimlenme süresinin 2.95-3.60 gün arasında değiştiği anlaşılmaktadır. En uzun çimlenme süresi 3.60 gün ile Sagittario 300/5

genotipinde gözlenmiş, bunu 3.46 gün ile Sagittario 200/49 ve Sagittario 200/59 genotipleri izlemiştir. En kısa çimlenme süresi ise NKÜ Lider 200/11 çeşidinde belirlenmiş, bunu 2.95 gün ile Flamura 85 100/60 genotipi izlemiştir.

Tuz oranında belirlenen ortalama çimlenme süresi 2.19-5.30 gün arasında değişmiştir (Çizelge 4). En uzun çimlenme süresi 16 dS m^{-1} tuz çözeltisinde saptanmış, bunu 3.55 gün ile 12 dS m^{-1} tuz çözeltisi izlemiştir. En kısa çimlenme süresi ise 0 dS m^{-1} tuz çözeltisinde belirlenmiş, bunu 2.41 gün ile 4 dS m^{-1} tuz çözeltisi izlemiştir.

Genotip x tuz interaksiyonunda ortalama çimlenme süresinin 2.07-6.66 gün arasında değiştiği belirlenmiştir (Çizelge 4). En uzun ortalama çimlenme süresi Sagittario 300/5 genotipinin 16 dS m^{-1} tuz çözeltisinde gözlenmiştir. Bunu 6.33 gün ile Sagittario 200/49 genotipinin 16 dS m^{-1} tuz çözeltisi izlemiştir. En kısa ortalama çimlenme süresi ise NKÜ Lider 200/11 genotipinin 0 dS m^{-1} tuz çözeltisinden elde edilmiş olup, bunu aynı istatistiki grupta yer alan Flamura 85 ve Flamura 85 200/58 genotiplerinin 0 dS m^{-1} tuz çözeltisi (2.10 gün) takip etmiştir.

Araştırmamızda, çimlenme ortamındaki tuz konsantrasyonu arttıkça ortalama çimlenme süresinin geciktiği belirlenmiştir. Bu gecikme, kontrol uygulamasına göre 4 dS m^{-1} uygulamasında %10.04, 8 dS m^{-1} uygulamasında %20.54, 12 dS m^{-1} uygulamasında %62.10 ve 16 dS m^{-1} uygulamasında %142.0 olarak gerçekleşmiştir. Bu durum, çimlenme ortamındaki tuz konsantrasyonunun artışına bağlı olarak suyun tutulma gücünün artmasından ve bunun sonucunda tohumların çimlenebilmek için gereksinim duydukları suyu daha uzun sürede almalarından kaynaklanmış olabilir. Elde ettiğimiz bu sonuçlar buğdayda çimlenme ortamındaki tuz konsantrasyonu artışına bağlı olarak çimlenme süresinde önemli bir gecikme meydana geldiğini açıklayan Javid (2023), Hameed (2023), Hmissi (2023), Doğan ve Çarpıcı (2015), Vardar (2014), El Goumi ve ark. (2014) 'nin sonuçları ile uyum içerisindedir.

Değişen tuz konsantrasyonlarında Flamura 85 100/60, Flamura 85 400/1 ve NKÜ Lider 200/11 anaçlarından daha kısa çimlenme süresi ortalamalarına sahip oldukları, Flamura 85 100/60 in %5,7 ve NKÜ Lider 200/11 in de %1.05 anacına göre daha kısa çimlenme süresine sahip oldukları anlaşılmaktadır.

Tohum Gücü İndeksi: Denemeye alınan çeşitlerin 4 farklı tuz çözeltisinde elde edilen tohum gücü indeksine ilişkin ortalama değerler ve önemlilik grupları Çizelge 5' te verilmiştir.

Çizelge 5. Tohum gücü indeksine (%) ilişkin ortalama değerler ve önemlilikleri

Genotipler	Tuz konsantrasyonları (dS m^{-1})				Ortalama
	0	*4*	*8*	*12*	
Sagittario	295,53cde	193,69g	72,02kp	10,02s	142,82b-e
Sagittario 100/7	276,32de	103,05jkl	42,07m-s	10,46s	107,98f
Sagittario 300/5	121,08ıjk	74,19k-o	26,67o-s	3,09s	56,26g
Sagittario 200/49	298,41cde	176,11gh	88,48j-m	19,52qrs	145,63q-d
Sagittario 200/59	262,87ef	170,77ghı	101,37jkl	16,79qrs	137,95de
Flamura 85	321,72a-d	179,68g	89,64j-m	18,80qrs	152,46a-d
Flamura 85 100/60	303,26b-e	266,18e	88,70j-m	11,07s	167,30a
Flamura 85 200/58	352,12ab	204,91g	91,96j-m	13,59rs	165,49ab
Flamura 85 300/15	350,76ab	212,80fg	77,11j-n	13,88rs	163,64abc
Flamura 85 400/1	317,05a-d	126,51hıj	36,55n-s	8,55s	122,17ef

NKÜ Lider	345,68abc	213,39fg	23,03p-s	8,61s	147,68a-d
NKÜ Lider 200/7	365,68a	188,97g	72,36k-p	8,72s	158,93a-d
NKÜ Lider 200/11	339,48abc	209,51g	62,03l-r	6,13s	154,29a-d
NKÜLider 100/22	308,7b-e	174,21gh	65,17l-q	13,21rs	140,32de
NKÜLider 400/10	323,25a-d	208,86g	24,84o-s	10,17s	141,78cde
Ortalama	305,46 a	180,15 b	64,13 c	11,51 d	
LSD (P≤0,05)	G: 22,946		T:18,054		GxT: 50,426

G:Genotip, T: Tuz konsantrasyonları, GxT: Genotip x Tuz konsantrasyonu interaksiyonu

Çizelge 5' ten denemeye alınan genotiplerin ortalama tohum gücü indeksinin %56.26-167.30 arasında değiştiği anlaşılmaktadır. En yüksek tohum gücü indeksi Flamura 85 100/60 genotipinde belirlenmiş, bunu %165.49 ile Flamura 85 200/58 takip etmiştir. En düşük tohum gücü indeksi ise Sagittario 300/5 genotipinden elde edilmiş, bunu %107.98 ile Sagittario 100/7 genotipi izlemiştir.

Kullanılan tuz çözeltilerinde ortalama tohum gücü indeksi %11.51-305.46 arasında değiştiği belirlenmiştir (Çizelge 5). En yüksek tohum gücü indeksi oranı 0 dS m^{-1} tuz çözeltisinde (%305.46) saptanmış, bunu %180.05 ile 4 dS m^{-1} tuz uygulaması izlemiştir. En düşük tohum gücü indeksi ise 12 dS m^{-1} tuz oranında (%11,51) belirlenmiş, bunu %64,13 ile 8 dS m^{-1} izlemiştir.

Genotip x tuz interaksiyonunda tohum gücü indeksi %3.09-365.65 arasında değişmiştir (Çizelge 5). En yüksek tohum gücü indeksi NKÜ Lider 220/7 genotipinin 0 dS m^{-1} tuz çözeltisinden (%365.65) elde edilmiş, bunu %352.12 ile Flamura 85 200/58 genotipinin 0 dS m^{-1} tuz çözeltisi izlemiştir. Sagittario 300/5 genotipinin 12 dS m^{-1} tuz çözeltisi ise en düşük tohum gücü indeksi değerine sahip olmuş, bunu NKÜ Lider 200/11 genotipinin 12 dS m^{-1} tuz çözeltisi (%6.13) takip etmiştir.

Çimlenme ortamında tuz konsantrasyonlarındaki artışın buğdayda tohum gücü indeksini önemli bir şekilde azalttığı belirlenmiştir. Bu azalma, 0 dS m^{-1} (kontrol) uygulamasına göre 4 dS m^{-1} uygulamasında % 41.02, 8 dS m^{-1} uygulamasında %79 ve 12 dS m^{-1} uygulamasında %96.23 olarak gerçekleşmiştir. Elde ettiğimiz bu sonuçlar, buğdayda çimlenme ortamında tuz konsantrasyonunun artışına bağlı olarak tohum gücü indeksinin önemli bir şekilde azaldığını açıklayan İnal (2018), Doğan ve Çarpıcı (2015), Vardar, (2014) ve El Goumi (2014)'nin sonuçları ile uyum içerisindedir.

Mutant hatları anaç çeşitleri ile karşılaştırıldığında; değişen tuz konsantrasyonlarında Sagittario 200/49, Flamura 85 10/60, Flamura 85 200/58, Flamura 85 300/15, NKÜ Lider 200/7, NKÜ Lider 200/11 ve NKÜ Lider 100/22 anaçlarından daha yüksek tohum gücü indeksi ortalamalarına sahip oldukları Sagittario 200/49 un %1.92, Flamura 85 100/60 in %8.87 ve NKÜ Lider 200/ in %7.07 anacına göre daha yüksek tohum gücü indeksine sahip oldukları anlaşılmaktadır.

Tuz Tolerans İndeksi: Denemeye alınan genotiplerin 4 farklı tuz konsantrasyonunda elde edilen ortalama tuz tolerans indeksine ilişkin ortalama değerler ve önemlilikleri Çizelge 6' da verilmiştir.

Çizelge 6. Tuz tolerans indeksine (%) ilişkin ortalama değerler ve önemlilikleri

Genotipler	Tuz konsantrasyonları (dS m^{-1})				Ortalama
	0	*4*	*8*	*12*	
Sagittario	100ef	98,00f	59,2lmn	17,92s	68,78fgh
Sagittario 100/7	100ef	97,86f	47,63p	16,60s	65,52hı
Sagittario 300/5	100ef	299,30a	150,10b	32,13qr	145,38a
Sagittario 200/49	100ef	132,00c	61,50klm	34,46q	81,99c
Sagittario 200/59	100ef	127,93c	98,43ef	53,40m-p	94,94b
Flamura 85	100ef	83,86hı	64,43kl	19,13s	66,85ghı
Flamura 85 100/60	100ef	115,83d	64,63kl	31,56qr	78,00cd
Flamura 85 200/58	100ef	87,7gh	86,86klm	30,50qr	70,01fg
Flamura 85 300/15	100ef	113,76d	62,20klm	23,96rs	74,98de
Flamura 85 400/1	100ef	77,30ıj	49,03op	28,86qr	63,80ıj
NKÜ Lider	100ef	87,43gh	57,80l-o	33,30q	69,63fg
NKÜ Lider 200/7	100ef	99,03ef	51,16nop	23,46rs	68,41fgh
NKÜ Lider 200/11	100ef	77,36ıj	44,66p	19,96s	60,50j
NKÜ Lider 100/22	100ef	94,80fg	57,86l-o	32,90q	71,39ef
NKÜ Lider 400/10	100ef	107,30de	68,50jk	35,00q	77,80d
Ortalama	100 b	113,30 a	66,60 c	28,90 d	
LSD $_{(P\leq0,05)}$	G: 3,986		T: 1,418		GxT: 12,655

G:Genotip, T: Tuz konsantrasyonları, GxT: Genotip x Tuz konsantrasyonu interaksiyonu

Çizelge 6' nın incelenmesinden genotiplerin ortalama tuz tolerans indeksi değerleri %60.5-145.38 arasında değişmiştir. En yüksek tuz tolerans indeksi Sagittario 300/5 genotipinde (%145,38) belirlenmiş, bu genotipi %94.94 ile Sagittario 200/59 genotipi izlemiştir. En düşük tuz tolerans indeksi ise %60.5 ile NKÜ Lider 200/11 genotipinden elde edilmiş, bunu %63.8 ile Flamura 85 400/1 genotipi izlemiştir.

Denemede tuz konsantrasyonlarında elde edilen tuz tolerans indeksi değerleri %28.9-113.3 arasında bir varyasyona sahip olmuştur (Çizelge 6). En yüksek tuz tolerans indeksi 4 dS m^{-1} tuz çözeltisinde (%113.3) saptanmış, bunu %100 ile 0 dS m^{-1} tuz çözeltisi izlemiştir. En düşük tuz tolerans indeksi ise 12 dS m^{-1} tuz çözeltisinde (%28.9) tespit edilmiş, bu değeri %66.60 ile 8 dS m^{-1} tuz çözeltisi izlemiştir.

Genotip x tuz interaksiyonundan elde edilen tuz tolerans indeksi değerleri %16.6-299.3 arasında değişmiştir (Çizelge 6). En yüksek tuz tolerans indeksi Sagittario 300/5 genotipinin 4 dS m^{-1} tuz çözeltisinde belirlenmiştir. Bunu, Sagittario 200/49 %132 ile genotiplerinin 4 dS m^{-1} tuz çözeltilerinde belirlenen tuz tolerans indeksi değerleri takip etmiştir. En düşük tuz tolerans indeksi ise Sagittario 100/7 genotipinin 12 dS m^{-1} tuz çözeltisinden elde edilmiş, bunu Sagittario genotipinin 12 dS m^{-1} tuz çözeltisi (%17.92) izlemiştir.

Tuzlu ortamda yetiştirilen bitkiler, bünyelerine aldıkları Na^+ ve Cl^- iyonlarını kök, gövde ve yaprak gibi çeşitli organlarında biriktirmektedir. Bitkilerin çeşitli organlarında biriken bu iyonlar ise belli bir oranın üzerine çıkınca gelişmeyi yavaşlatmakta ve tuza toleransını önemli bir şekilde etkilemektedir. Ortamda tuz konsantrasyonu arttıkça ortalama tuz tolerans indeksinde ciddi azalmalar olduğunu görülmüştür. Bu azalmalar, 0 dS m^{-1} (kontrol) uygulamasına göre 4 dS m^{-1} uygulamada %13.30, 8 dS m^{-1} uygulamada %34.40 ve 12 dS m^{-1} uygulamada %71.10 olarak gerçekleşmiştir. Elde etiğimiz sonuçlar buğdayda çimlenme ortamında artan tuz konsantrasyonuna bağlı olarak tuz tolerans indeksinin düştüğünü açıklayan Köseoğlu ve Doğru (2021) ve Dirik (2020)'nin sonuçları ile uyum içerisindedir.

Değişen tuz konsantrasyonlarında Sagittario 300/5, Sagittario 200/49, Sagittario 200/59, Flamura 85 100/60, Flamura 85 200/58, Flamura 85 300/15, NKÜ Lider100/22, NKÜ Lider 400/10 ve NKÜ Lider 100 /22 mutantları anaçlarından daha yüksek tuz toleransı indeksi sahip olmuşlardır. Sagittario 300/5 %52,68, Flamura 85 100/60 %14.29 ve NKÜ Lider 200/7 %7.07 de anaçlarına göre daha yüksek tuz toleransı indeksine sahip olmuşlardır.

4. SONUÇ VE ÖNERİLER

Çalışmada, 16 dS m^{-1} tuz çözeltisinde denemeye alınan buğday genotiplerinin tohumlarında çimlenme olmuş fakat fide gelişimi olmamıştır. Denemeye alınan buğday genotipleri arasında en yüksek çimlenme oranı Flamura 85 300/15 genotipinde belirlenmiştir. Genel olarak değerlendirildiğinde, mutant ileri hatların anaçlara göre yüksek çimlenme oranına sahip oldukları belirlenmiştir. Çimlenme ortamında artan tuz konsantrasyonlarının çimlenme oranını önemli bir şekilde azalttığı görülmüştür. Kontrol uygulamasına (0 dS m^{-1}) göre çimlenme oranı 4 dS m^{-1} uygulamasında %10.46, 8 dS m^{-1} uygulamasında %32.05,12 dS m^{-1} uygulamasında %54.99 ve 16 dS m^{-1} % 78.14 daha düşük gerçekleşmiştir. Sonuçlar, tuzluluk yönünden üstün performans gösteren mutan hatların tuzluluğun sorun olduğu alanları için çeşit adayı olarak verim denemelerine alınmasının, tuza dayanıklılık ıslah çalışmalarında gen kaynağı olarak kullanılmalarının uygun olabileceği göstermektedir.

Yazar Katkı Beyanı

Tüm yazarlar bildirinin hazırlanmasına eşit oranda katkı sağlamıştır.

Çıkar Çatışması Beyanı

Tüm yazarlar bu makaleyle ilgili herhangi bir çıkar çatışması olmadığını beyan etmektedir.

Teşekkür

Bu çalışma ilk yazarın yüksek lisans tezinin bir bölümünden üretilmiştir.

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FARKLI SULAMA UYGULAMALARININ SORGUM VE MISIRDA SİLAJ VERİMİ VE BAZI KALİTE ÖZELLİKLERİ ÜZERİNE ETKİSİ

Zir. Yük. Müh. Atakan ÖZALP
Tekirdağ Namık Kemal Üniversitesi, Fen Bilimleri Enstitüsü, Tarla Bitkileri Anabilim Dalı, Tekirdağ
Email: ozalpatakan07@gmail.com
Prof. Dr. İsmet BAŞER
Tekirdağ Namık Kemal Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü, Tekirdağ
Email:ibaser@nku.edu.tr
ORCID: 0000-0002-5770-0118 (Sorumlu yazar)
Arş. Gör. Dr. Damla BALABAN GÖÇMEN
Tekirdağ Namık Kemal Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü, Tekirdağ
Email: dgocmen@nku.edu.tr
ORCID: 0000-0002-3980-3906.

ÖZET

Tekirdağ ekolojik koşullarında yürütülen araştırmada, sorgum x sudan otu melez çeşidi Jumbo Star ve silajlık mısır çeşidi PR32W86 materyali kullanılmıştır. Çalışmada mısır ekimi, 5 metre uzunluğunda 4 sıra halinde, sıra arası 70 cm ve sıra üzeri 16 cm olacak şekilde yapılmıştır. Sorgum ekimi, 5 metre uzunluğunda 4 sıra halinde, sıra arası 70 cm ve sıra üzeri 3 cm olacak şekilde yapılmıştır. Çalışmada sulama uygulamaları; sulamasız, 1 sulama, 2 sulama ve 3 sulama şeklinde yapılmıştır. Sulama uygulamaları, mısır bitkisinin gelişiminin izlendiği ve bitkilerin su ihtiyacının başladığı dönemde uygulanmıştır. Sulama uygulaması, mısır ve sorgum sıraları arasına yerleştirilen damla sulama sistemi ile yapılmış ve toprak doygunluğu dikkate alınarak 10 saat damla sulama uygulanmıştır. Çalışmada, taban gübresi olarak 40 kg 20.20.0 gübresi, üst gübre olarak ise bitkiler 10-15 cm boylandığında 25 kg/da ve bitkiler 35-40 cm boylandığında 20 kg/da olmak üzere iki kez üre gübresi uygulanmıştır.

Değerlendirmeye göre, sorgum ve mısır genotiplerinde farklı sulama uygulamalarında yeşil ot verimi, protein oranı, ADF ve NDF oranları incelendiğinde, sulama seviyesine göre önemli bir değişim gözlenmiştir. Sulama uygulamasındaki artışlar her iki türde de paralel olarak yeşil ot verimi ve protein oranında artışa neden olmuş, Her iki türde de sulama uygulamalarında sulanmayan alanlara göre daha düşük ADF ve NDF değerleri elde edilmiştir. Elde edilen sonuçlar, sulamanın mısır ve sorgumda yeşil ot kalitesini önemli ölçüde artırdığını göstermektedir.

Anahtar Kelimeler: Mısır, Sorgum, Silaj verimi, Protein oranı, Kalite.

EFFECT OF DIFFERENT IRRIGATION APPLICATION ON SILAGE YIELD AND SOME QUALITY CHARACTERS IN SORGHUM AND CORN

ABSTRACT

In the research conducted in Tekirdağ ecological conditions sorghum x sudangrass hybrid variety Jumbo Star and silage corn variety PR32W86 materials were used. In the study, corn sowing was done in 4 rows with 5 meters of length, 70 cm between rows and 16 cm on the rows. Sorghum sowing was done in 4 rows of 5 meters, with 70 cm between rows and 3 cm on the rows. In the experimental area, species were placed in the main plot and irrigation applications were placed in the sub-plot. In the study, irrigation applications were made as non-irrigation, 1 irrigation, 2 irrigations and 3 irrigations. Irrigation applications were applied during the period when the corn plant development was monitored and the plants showed the beginning of water need. Irrigation application was made with a drip irrigation system laid between the corn and sorghum rows and 10 hours of drip irrigation was applied considering the soil saturation. In the study, 40 kg of 20.20.0 fertilizer was applied as base fertilizer, while urea fertilizer was applied twice as top fertilizer, 25 kg/da when the plants were 10-15 cm and 20 kg/da when the plants were 35-40 cm.

According to the evaluation, when silage yield, protein ratio, ADF and NDF ratios were examined in sorghum and maize genotypes in different irrigation applications, there was a significant change according to irrigation level. Increases in irrigation application caused an increase in parallel silage yield and protein ratio in both species. In both species, lower ADF and NDF values were obtained in irrigation applications compared to non-irrigated areas. The obtained results show that irrigation significantly increases green grass quality in maize and sorghum.

Keywords: Corn, Sorghum, Silage yield, Protein ratio, Quality.

1. GİRİŞ

Türkiye hayvan sayısı yönünden büyük bir varlığa sahip ama hayvansal üretim planlanan düzeye çıkarılamamaktadır. Buna sebep olan durumlardan biri, sektörün ihtiyacı kaba yemi karşılayacak kaynakların doğru kullanılamamasıdır. Üreticiler, kaba yem sıkıntısının olduğu dönemlerde, besin değeri düşük olan bu tahılın üzerini samanla kapatmaya çalışıyorlar. Gelişmiş ülkelerde olduğu gibi Türkiye' de de bilinçli hayvancılık yapan büyük işletmelerde kış aylarında yem kullanımı, gıda açığının kapatılması ve hayvansal ürünlerin veriminin arttırılması için önemli bir kaynaktır (Özata ve ark., 2012). Ülkemiz birçok yem bitkisinin yetiştirilmesi için oldukça uygun ekolojik koşullara sahip olmasına rağmen yem bitkilerinin yetişme alanı açıkça istenilen düzeyin altındadır. Besin değerinin yüksek olması, taşınması, saklanması ve muhafaza edilmesinin kolay olması silajlık mısır ve sorgum ekim alanını arttırır.

Olumsuz şartlara özellikle susuzluğa mısırdan daha dayanıklı olan sorgum x sudan otu melezi, su ihtiyacının az olması, ekildiği bölgeye adaptasyonunun hızlı olması, zararlılara ve hastalıklara karşı dayanıklı olması, besin maddesi bakımında ve veriminin yüksek olmasından kaynaklı mısıra alternatif olabilir. (Çiğdem ve Uzun, 2006). Sorgum türlerine ait çeşitler silaj ve dane üretimden kaynaklı yetiştirilmektedir. Silaj verimleri ortalama 3-9 ton/da olarak kayıtlara geçmiştir.

Hayvanları beslerken konsantre yem ve kaba yem giderek daha fazla önem kazanıyor. Yem olarak besin değeri en yüksek olan bitkilerden biri de mısırdır. Mısır (*Zea mays* L.), Poaceae familyasına ait tek yıllık bir bitkidir. Hayvancılıkta en çok kullanılan silaj bitkilerinden biri olan mısır, çok iyi silaj özelliklerine sahiptir. Silajlık mısır (*Zea mays* L.) yetiştiriciliği, yüksek verim, mekanizasyona uygunluk ve çeşitli ortamlara geniş adaptasyon gibi birçok özelliği sayesinde her geçen gün artmaktadır. Diğer yemlere göre sulu, lezzetli ve besleyicidir. Sindirimi kolay ve besin değeri yüksektir. Ayrıca mısır, düşük tamponlama kapasitesi, yüksek şeker içeriği ve yüksek laktik asit bakteri sayısı nedeniyle kolayca silolanan bir yem olarak bilinir. Buna karşın, mısır silajı nispeten daha düşük ham protein içeriğine sahiptir.

Ülkemizde mısır ekim alanları her geçen gün artmaktadır. Mısır ekim alanının artmasının temel nedenlerinden biri mısırda birim alandan elde edilen gelirin yüksek olması ve silaj ve tahıl üretiminin her geçen gün artmasıdır. Üreticiler bunu silaj olarak kullanıyor. Mısır bitkisinin büyüme ve gelişme döneminde su ihtiyacının yüksek olması, kuru, yarı kurak iklimlerde ve sulamanın yapılmadığı durumlarda verimin düşmesine neden olmaktadır. Son yıllarda artan küresel iklim değişiminin etkisinin daha fazla görülmeye başlanması sulama yapılmadan yada kısıtlı sulamayla yetiştirilebilecek bitkilerin dönemi artmaktadır. Trakya bölgesi gibi yağışın 600 mm civarında olduğu bölgelerde sulama yapılmadan üretilecek ve birim alan verimi yüksek bitkilerden biriside sorgumdur. Bu da mısıra kıyasla su kullanımı daha az ve verimli bitkilerin önemini göstermektedir. İklim değişikliği ve mısır için artan talep karşısında, kuraklığa dayanıklı sorgum silajı; iklim değişikliğinden kaynaklanan kuraklık ve mısıra artan talepten kaynaklanan silaj kıtlığına son vereceği düşünülmektedir.

Çalışmada kaba yem üretiminde sulamalı alanlar ve sulanmayan alanlarda önemli bir potansiyeline sahip olan mısır ve sorgumun sulama yapılmadan, farklı sulama uygulamalarında kalite özellikleri yönünden potansiyellerinin ortaya konması amacıyla yürütülmüştür.

2. MATERYAL VE YÖNTEM

Tekirdağ ekolojik koşullarında Bağcılık Araştırma Enstitüsünde 2022 yılında yürütülen araştırmada sorgum x sudanotu melez çeşidi Jumbo Star ve silajlık mısır çeşidi PR32W86 materyal olarak kullanılmıştır. Tekirdağ ili Süleymanpaşa ilçesi Bağcılık Araştırma Enstitüsünde 2022 yılında yapılan çalışma bölünmüş parseller deneme desenine göre 4 tekrarlamalı olarak yürütülmüştür.

Deneme yapılmadan önce lavanta yetiştiriciliği yapılmış olan tarlada ürün hasadından sonra gölge tavında 15-20 cm derinlikte pullukla sürüm yapılmış ve daha sonra ilkbahar mevsiminde diskaro ile kazayağı çekilerek tarla yüzeyindeki kesekler ufalanmış ve ardından toprak ekimden sonra çıkacak otları engellemek için ilac atılmış, tırmık ile toprak 10-15 cm derinliğinde işlenerek ekim yatağı hazırlığı tamamlanmıştır.

Çalışmada mısır ekimi sıra arası 70 cm, sıra üzeri 16 cm olarak her parsel 5 metre uzunluğunda 4 sıradan oluşmuştur. Sorgumda ekimler sıra arası 70 cm, sıra üzeri ise 3 cm olacak şekilde 5 metrelik 4 sıra olarak yapılmıştır. Ekimler 13 Haziranda yapılmıştır. Deneme alanında türler ana parsele, sulama uygulamaları ise alt parsele yerleştirilmiştir. Çalışmada sulama uygulaması olarak, sulama yapılmayan, 1 sulama, 2 sulama ve 3 defa sulama uygulaması yapılmıştır. Sulama uygulamaları mısır bitkisinin gelişimi izlenerek bitkilerin su ihtiyacı başlangıcı gösterdiği dönemde uygulanmıştır. Sulama uygulaması mısır ve sorgum sıra aralarına döşenen damla sulama sistemi ile yapılmış ve toprak doygunluğu dikkate alınarak 10 saat damla sulama uygulaması yapılmıştır. Çalışmada taban gübresi olarak 40 kg 20.20.0 gübresi uygulanırken, üst gübre olarak bitkiler 10-15 cm olduğunda 25 kg/da ve bitkiler 35-40 cm 20 kg/da olmak üzere 2 defa üre gübresi uygulanmıştır. Yem bitkisi yetiştirirken verimliliğin yanı sıra üretilen ot yeminin kalitesi de oldukça önemlidir. Çalışmada ham protein değeri, ADF ve NDF değerleri belirlenmiştir

Elde edilen veriler, JMP istatistik programları ile bölünmüş deneme desenine göre varyans edilmiş ve ortalama farklılıkların anlamlılığının kontrolü TUKEY testi ile belirlenmiştir. (Düzgüneş ve ark., 1983).

3. ARAŞTIRMA SONUÇLARI VE TARTIŞMA

3.1. Yeşil Ot Verimi

Farklı sulama uygulamalarında sorgum ve mısır genotiplerinden elde edilen verim sonuçları üzerinde varyans analizi yapılmış olup, sulama düzeyleri arasındaki farklılıklar istatistiki olarak 0,01 düzeyinde önemli bulunmuş, türler, tür x sulama interaksiyonu, arasındaki farklılıklar istatistiki olarak önemsiz bulunmuştur. Ortalama değerler arasındaki farklılıkları belirlemek için yapılan önemlilik testi (EKÖF) sonuçları Çizelge 1' de verilmiştir.

Çizelge 1. Yeşil ot verimine ilişkin ortalamalar ve karşılaştırmalar

	Sulamasız	***1 sulamalı***	***2 sulamalı***	***3 sulamalı***	***Ortalama***
Mısır	2389.33	3090.00	3184.33	3844.33	3137.00
Sorgum	2038.33	2910.66	3201.33	4122.00	3068.08
Ortalama	2213.833	3000.333	3192.833	4003.167	

Yapılan önemlilik testi sonucunda türler arasında en yüksek verim ortalama olarak 3137 kg/da ile mısırda olurken bunu aynı istatistiki gruptaki sorgum 3068.00 kg/da ile izlemiştir. Sulama düzeylerini verim etkisine bakıldığında 4003.17-2213.83 kg/da arası değişmiştir. En fazla verime sahip bitkiler üç sulama yapılanlarda 4003.17 kg/da olarak ölçülmüştür. En az verime sahip bitkiler sulama olmayan parsellerde 2213.83 kg/da ile olmuştur. Üç sulama uygulaması sulanmayan alanlara göre %100 yakın verim artışı sağlamıştır. Tür x sulama interaksiyonu istatistiki olarak önemsiz olmakla birlikte, en fazla verim 4122 kg/da ile sorgumda 3 sulamada elde edilirken bunu aynı istatistik gruptaki mısırın üç sulamada 3844 kg/da verimi izlemiştir. En az verim değeri sulama yapılmayan parsellerde 2038 kg/da ile sorgumda elde edilmiş, bunu 2389 kg/da ile mısırda sulama yapılmayan parsel takip etmiştir. Sorgumda genotiplere göre; yeşil ot verimi 2247-12029 kg/da arasında (Göler ve Özyazıcı, 2024) değiştiği, mısır

çeşitlerinin yeşil ot verimlerinin denemenin yürütüldüğü bölgelere göre önemli değişimler olduğu (Özata ve ark., 2012; Yozgatlı ve ark., 2019; Erdurmuş ve Soylu, 2023) belirlenmiştir.

3.2. Protein Oranı

Farklı sulama uygulamalarında sorgum ve mısır genotiplerinden elde edilen protein sonuçları üzerinde varyans analizi yapılmış olup, türler, sulama düzeyleri, tür x sulama interaksiyonu arasındaki farklar 001 düzeyinde istatistiksel olarak önemli bulunmuştur. Ortalama değerler arasındaki farkları tespit etmek amacıyla yapılan anlamlılık testi (EKÖF) sonuçları Çizelge 2' de verilmiştir.

Çizelge 2. Mısır ve Sorgum çeşitlerinde sayısı değerlerinde ortalama değerler ve önemlilikleri

	Sulamasız	***1 sulamalı***	***2 sulamalı***	***3 sulamalı***	***Ortalama***
Mısır	3.440 c	4.840 cd	5.160 bc	4.680 d	4.530 b
Sorgum	5.170 bc	5.410 b	7.490 a	7.380 a	6.363 a
Ortalama	4.305 c	5.125 b	6.325 a	6.030 a	

Yapılan önemlilik testi sonucunda türler arasında en fazla protein %6.36 ile sorgumda elde edilirken mısırda protein oranı 4.305 olmuştur. En fazla proteine sahip bitkiler iki ve 3 sulama yapılan bitkilerde %6.33 ve 6.03 protein değeri ile ölçülmüştür. En az proteine sahip bitki sulama yapılmayan parselde %4.31 ile elde edilmiştir. Tür x sulama interaksiyonu incelendiğinde en fazla protein %7.49 ile sorgumda 2 sulamada elde edilirken bunu aynı istatistik gruptaki üç sulamalı %7.38 ile sorgum izlemiştir. En az protein değeri sulama yapılmayan mısır parselinde %3.44 ile elde edilmiştir. Sorgum çeşitlerinin ham protein oranının %10.1 olduğunu (Cacares ve Santana, 1987), sugar leaf sorgum x sudanotu melez çeşidinde ham protein oranını %8.35 olarak (Aydın ve Albayrak, 1995), sorgum, sudanotu ve sorgum x sudanotu melez çeşitlerinin ham protein oranının %8.50-10.20 arasında olduğu (Büyükburç ve ark., 1997), tane ve silajlık sorgum çeşitlerinde ham protein değeri %10.40 olduğu (Siefers ve ark., 1997), sorgum x sudanotu hibrit çeşitlerinin ham protein değeri %9.55-9.65 olduğu (Aslan, 1998), sorgumda ham protein değerlerinin %7.2-8.9 arasında değiştiği (Hosaflıoğlu, 1998), silajlık sorgum x sudanotu melez çeşitlerinde en fazla ham protein değeri %11.10 olarak (Roozeboom ve Evans, 2000) belirlenmiştir.

3.3. NDF Değeri

Farklı sulama uygulamalarında sorgum ve mısır genotiplerinden elde edilen NDF sonuçları üzerinde varyans analizi yapılmış olup, tür, sulama düzeyi ve tür x sulama etkileşimi arasındaki farklar 0,01 düzeyinde istatistiksel olarak önemli bulunmuştur. Ortalama değerler arasındaki farkları tespit etmek amacıyla yapılan anlamlılık testi (EKÖF) sonuçları Çizelge 3' de verilmiştir.

Çizelge 3. NDF' ye ilişkin ortalamalar ve karşılaştırmalar

	Sulamasız	***1 sulamalı***	***2 sulamalı***	***3 sulamalı***	***Ortalama***
Mısır	51.67 a	47.00 b	50.00 ab	40.67 c	47.33 a
Sorgum	38.00 cd	35.00 de	34.00 ef	30.67 f	34.41 b
Ortalama	44.00 a	41.00 b	42.83 b	35.67 f	

Yapılan önemlilik testi sonucunda türler arasında en az NDF değeri %30.67 ile sorgumda elde edilirken en fazla NDF %51.67 ile de mısırda olmuştur. Sulama düzeylerini NDF değerlerine bakıldığında %51.67-30.67 arası değişmiştir. En fazla NDF' ye sahip bitki %51.67 ile mısırda sulama olmayan parselde elde edilirken, bunu mısırın 1 sulamalı parselindeki bitkiler %47.00 ile izlemiştir. En az NDF değeri üç sulama yapılan sorgum parselinde %30.67 ve 2 sulama yapılan sorgum parsellerdeki bitkilerde %34.00 ile sorgumda olmuştur. Sugar Graze ve Jumbo Plus çeşitlerinin NDF oranının ise %69.36 ile %70.58 arasında değiştiği bildirilmiştir (Pushparajah ve Sinniah, 2018).

3.4. ADF Değeri

Farklı sulama uygulamalarında sorgum ve mısır genotiplerinden elde edilen ADF sonuçları için varyans analizi yapılmış olup, türler, sulama düzeyleri, tür x sulama interaksiyonu arasındaki farklar 0.01 düzeyinde istatistiksel olarak önemli bulunmuştur. Ortalama değerler arasındaki farkları tespit etmek amacıyla yapılan anlamlılık testi (EKÖF) sonuçları Çizelge 4' de verilmiştir.

Çizelge 4. Mısır ve Sorgum çeşitlerinde sayısı değerlerinde ortalama değerler ve önemlilikleri

	Sulamasız	***1 sulamalı***	***2 sulamalı***	***3 sulamalı***	***Ortalama***
Mısır	30.490 ab	31.493 a	29.210 b	23.390 cd	28.646 a
Sorgum	24.690 c	21.370 ef	22.660 de	20.660 f	22.345 b
Ortalama	27.590 a	26.432 ab	25.93 b	22.025 c	

Yapılan önemlilik testi sonucunda türler arasında mısırda ADF değeri %28.65 sorgumda ise %22.34 olmuştur. Sulama düzeylerini ADF etkisine bakıldığında %27.590-22.025 arası değiştiği görülmektedir. En fazla ADF değerine sahip bitki bir sulama yapılan mısırda %31.49 olarak belirlenmiş, bunu mısırın sulanmayan bitkileri %30.49 ADF değeri ile aynı istatistiki grupta izlemişlerdir. En az ADF değeri ise 3 sulama uygulanan bitkilerde %22.025 değeri ile belirlenmiştir. Tür x sulama interaksiyonu incelendiğinde en fazla ADF değeri %31.493 ile 1 defa sulanan mısırda elde edilirken bunu aynı istatistik gruptaki sulamasız mısır %30.49 ile izlemiştir. En az ADF değeri sorgumda 3 defa sulama yapılan parselde %20.66 ile elde edilmiştir. Sorgum x sudanotu melez çeşidin de ADF oranı %43.02 olduğu (Khaleduzzaman ve ark., 2013), Farklı araştırıcılar tarafından yapılan çalışmalarda mısır ve sorgum çeşitlerinden ADF oranının %28.00-45.54 arasında değiştiği belirlenmiştir (Karadağ ve Öztürk, 2014; Pires ve ark., 2017; Pushparajah ve Sinniah, 2018; Yılmaz ve ark., 2020; Şimşek Soysal ve ark., 2017).

4. SONUÇ VE ÖNERİLER

Sonuçlara göre, sorgum ve mısır genotiplerinde farklı sulama uygulamalarında yeşil ot verimi, protein oranı, ADF ve NDF oranları incelendiğinde, sulama seviyesine göre önemli bir değişim gözlenmiştir. Sulama uygulamasındaki artışlar her iki türde de paralel olarak yeşil ot verimi ve protein oranında artışa neden olmuş, Her iki türde de sulama uygulamalarında sulanmayan alanlara göre daha düşük ADF ve NDF değerleri elde edilmiştir. Elde edilen sonuçlar, sulamanın mısır ve sorgumda yeşil ot verimini önemli ölçüde artırdığını göstermektedir.

Yazar Katkı Beyanı

Tüm yazarlar bildirinin hazırlanmasına eşit oranda katkı sağlamıştır.

Çıkar Çatışması Beyanı

Tüm yazarlar bu makaleyle ilgili herhangi bir çıkar çatışması olmadığını beyan etmektedir.

Teşekkür

Bu çalışma ilk yazarın yüksek lisans tezinin bir bölümünden üretilmiştir.

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A REVIEW ON THE EFFECTS OF IRRIGATION ON LAVENDER (*l. angustifolia mill.*) YIELD AND OIL QUALITY

Öğr. Gör. Havva Nur Demir Deveci
Necmettin Erbakan Üniversitesi, Meram Meslek Yüksek Okulu, Konya
Email: hndemir@erbakan.edu.tr
ORCID: 0009 0005 6827 7334
Zir. Müh.Tahir Külahcı
Selçuklu İlçe Tarım ve Orman Müdürlüğü, Konya
Email: tahirkulahci@gmail.com
ORCID: 0009-0000-8639-1425
Prof. Dr. Ramazan Topak
Selçuk Üniversitesi, Ziraat Fakültesi, Konya
Email: rtopak@selcuk.edu.tr
ORCID: 0000 0003 3748 2720

ABSRACT

Their inclusion in agricultural culture has played a very important role in the survival of medicinal and aromatic plants around the world. The majority of medicinal and aromatic plants are drought-tolerant and are grown both rain-fed and irrigated. Especially in arid regions, the cultivation of these plants is preferred for rain-fed production. Irrigation is the most effective measure to reduce water stress and increase crop yields in arid areas. Therefore, irrigation is inevitable for medicinal and aromatic plants as well. Lavender, a medicinal and aromatic plant, is drought-tolerant and is cultivated for its essential oil. This study was conducted to evaluate some research on irrigation in lavender. Within this scope, this paper presents an analysis of recent studies that have demonstrated the effect of different irrigation practices on the herb and essential oil yield and essential oil quality of lavender. Consequently, irrigation significantly increases lavender yield in arid regions. Therefore, there is a need to develop irrigation schedules that provide high irrigation water productivity for lavender cultivation in regions experiencing water scarcity.

Keywords: Lavender; Irrigation management; Essential oil yield; Oil quality

SULAMANIN LAVANTA (*l. angustifolia mill.)* ÜRÜN VERİMİ VE YAĞ KALİTESİNE ETKİLERİ ÜZERİNE BİR İNCELEME

ÖZET

Tarım kültürüne alınması, tıbbi ve aromatik bitkilerin dünyada varlığını sürdürmesinde çok önemli bir rol oynamıştır. Tıbbi ve aromatik bitkilerin ekseriyeti kuraklığa töleranslı olup, hem yağışa dayalı ve hem de suluda yetiştirilmektedir. Özellikle kurak bölgelerde, yağışa dayalı üretim için bu bitkilerin tarımı tercih edilebilmektedir. Sulama, kurak alanlarda su stresini azaltmak ve ürün verimini artırmak için en etkili önlemdir. Dolayısıyla tıbbi ve aromatik bitkilerde de sulama kaçınılmazdır. Tıbbi ve aromatik bitki olan lavanta, kurağa dayanıklı olup, uçucu yağı için üretilmektedir. Bu çalışma, lavantada sulama üzerine yapılan bazı araştırmaların değerlendirilmesi amacıyla yapılmıştır. Bu kapsamda, bu bildiride, yakın geçmişte yapılan ve farklı sulama programlarının lavantanın ot ve uçucu yağ verimi ile uçucu yağ kalitesi üzerindeki etkisini ortaya koyan bazı çalışmaların bir analizi sunulmuştur. Sonuç olarak, kurak bölgelerde sulama işlemi lavantanın ürün verimini önemli ölçüde artırmaktadır. Dolayısıyla su kıtlığı olan bölgelerde lavanta tarımı için de yüksek sulama suyu üretkenliği sağlayan sulama programlarının geliştirilmesine ihtiyaç duyulmaktadır.

Anahtar kelimeler: Lavanta; Sulama yönetimi; Uçucu yağ verimi; Yağ kalitesi

1.GİRİŞ

Lavanta, çok yıllık olup, çiçekleri için üretilen önemli bir tıbbi ve aromatik bitkidir. Çok yıllık bir bitki olması nedeniyle lavantadan ekonomik olarak 15-20 yıl yararlanılmaktadır (Kara ve Baydar, 2011). Günümüzde lavanta kozmetik, parfümeri, gıda, sağlık, aromaterapi ve peyzaj gibi pek çok alanda değerlendirilme olanağı bulabilmektedir (STB, 2020). Özellikle tıbbi uçucu yağı açısından değer taşıyan lavanta, ilaç, parfümeri ve kozmetik amaçlı yetiştirilmektedir (Sarfaraz ve ark., 2024). Dünyada çoğu Akdeniz orjinli olan 39 kadar lavanta türü bulunmaktadır. Bunlardan lavander, lavandin ve spike lavender olmak üzere üç türünün ticari değeri yüksektir (Kara, 2023). Dünyada iki önemli lavanta türünün (lavandin ve lavender) tarımı yapılmaktadır. Dünya lavanta üretim alanlarının %80'ini lavandin, ve %20 'sini lavender oluşturmaktadır. Fransa ve Bulgaristan dünya lavanta üretim alanlarının 2/3'üne hâkim olup, Çin, Rusya, bazı Doğu Avrupa ve Kuzey Afrika ülkeleri lavanta tarımında ve ticaretinde söz sahibi ülkelerdir. Fransa, lavanta yağı üreten ve ihraç eden lider bir ülkedir ve lavanta yağı pazarının %34'üne hâkimdir. Kısacası Fransa dünyada lavanta yağı üretiminde ilk sırada yer almaktadır. Fransa'yı Bulgaristan ve Çin takip etmektedir. Çin küresel pazarda % 11.9'luk pazar payına sahiptir(STB, 2020).

Türkiye'de lavanta tarımı yoğun olarak Göller Bölgesinde yapılmakta olup, özellikle Isparta, Afyonkarahisar, Burdur ve Denizli illeri lavanta üretiminin en yoğun yapıldığı illerdir. Ülkemizde son yıllarda lavanta üretimi farklı illerimize yayılmış durumdadır. Ülkemizde 2015 yılına kadar lavandin çeşitlerinin (süper) tarımı yapılırken, günümüzde lavender çeşitlerinin tarımına başlanmıştır. Lavanta olumsuz toprak koşullarında bile verim verebilen ve tarımında hastalık ve zararlı faktörü neredeyse minimum düzeyde olan ve tarımsal anlamda az emek isteyen bir bitkidir. Son yıllarda lavanta tomurcuğu ve lavanta yağına olan ilgi nedeniyle birçok üretici tarafından tercih sebebi haline gelmiştir (STB, 2020).

Su kıtlığı, dünyadaki tarım alanlarının çoğunda bitki büyümesini ve ürün verimliliğini kısıtlayan en önemli faktördür (Abedi ve Pakniyat, 2010). Buna karşın sulama ise, bitki gelişimini, ürün verimini ve kalitesini artırmak için yegane önlemdir (Singh ve Goswamy, 2000). Su kıtlığı koşullarında, bitki su ihtiyacının sulama ile tümüyle karşılanması her geçen gün daha da zorlaşmaktadır. Dolayısıyla, daha az su ile sulamanın gerçekleştirileceği teknolojik sulama yöntem ve sulama yönetimi stratejilerinin uygulamaya sokulması kaçınılmazdır. Özellikle kuraklığa hassasiyeti düşük olan bitkilerde, bitki büyüme dönemleri ve bu gelişme dönemlerinin su stresine (su kısıntısına) tepkilerinin bilinmesi, bitkiler için kısıntılı ve tamamlayıcı sulama stratejileri uygulamasına imkan sağlamaktadır. Bu usulle hem ürün verimi ve kalitesi artarken hem de ve kıt su kaynaklarının en verimli şekilde kullanılmasını sağlanabilir (Singh ve Goswamy, 2000).

Kuraklığın tıbbi ve aromatik bitkilerin büyümesi ve gelişimi üzerindeki etkisi, daha önceki bazı çalışmalarda incelenmiştir. Önceki çalışmalar, sulamanın bitkilerin verimi belirleyen morfolojik ve fizyolojik özellikleri üzerinde önemli bir etkiye sahip olduğunu göstermiştir. Dahası, sulama seviyeleri verimi ve uçucu yağların bazı önemli bileşenlerini de etkilemektedir (Llorens-Molina ve Vacas, 2017; An ve Liang, 2013; Rioba ve ark., 2015; Sánchez-Blanco ve ark., 2004).

Bu çalışmanın amacı, lavantada sulamanın ürün verimi ve uçucu yağ kalitesine etkilerini konu edinen ve yakın dönemde yapılmış çalışmaların kısa bir değerlendirmesini sunmaktır.

2. BİTKİSEL UÇUCU YAĞ KALİTESİNE ETKİ EDEN FAKTÖRLER

Birçok tıbbi ve aromatik bitki, özellikle kuraklık olmak üzere zorlu çevre koşullarında gelişme yeteneğine sahiptir ve bu da onları kurak bölgeler için oldukça uygun hale getirmiştir (Kulak, 2020). Kurak bölgelerde su kıtlığı, hemen tüm bitkilerde olduğu gibi tıbbi ve aromatik bitkilerin

büyümesini ve verimini önemli ölçüde etkiler (Nouri ve ark., 2023; Wahab ve ark., 2022). Ayrıca kuraklık, tıbbi ve aromatik bitkilerdeki aktif bileşenlerin kalitesini de olumsuz etkilemektedir (Bistgani ve ark., 2017a; Gao ve ark., 2020). Toprak nem muhtevası, tıbbi bitki bileşenlerinin büyümesini, gelişimini ve sentezini etkileyen önemli bir çevresel faktördür (Vosoughi ve ark., 2018; Zhu ve ark., 2018). Bazı çalışmalar, çevresel streslerin ikincil metabolitlerin artan seviyelerine yol açtığını öne sürmektedir (George ve ark., 2017; Bistgani ve ark., 2017b). Kuraklığın zamanlaması, süresi ve sıklığı, toprak özellikleri ve yağış desenleri gibi çeşitli faktörler, bir bitkinin kuraklığa karşı direncini etkilemektedir (Rezaei ve ark., 2019; Morshedloo ve ark., 2016).

Tıbbi ve aromatik bitkilerdeki uçucu yağlar farklı fakörlerin etkisi altındadır. Birçok iç ve dış faktör esansiyel yağların yapısını, belirli bileşenlerin konsantrasyonunu ve nihayetinde uçucu yağ verimini etkilemektedir (Djouahri ve ark., 2015; Formisano ve ark., 2015; Rehman ve ark., 2016). Bu faktörleri bitkiden kaynaklanan koşullar ve dış faktörler olarak sınıflandırmak mümkündür. Bitkiden kaynaklanan koşullar; genetik, bitki popülasyonu, bitkinin kökeni, bitkinin kullanılan kısmı, örnekleme dönemi, fizyolojik ve biyokimyasal süreçleri ve tüm bitki fizyolojisini kapsamaktadır. Dış faktörler ise iklim koşullarını, yetiştirme koşullarını ve hasat sonrası teknikleri (kurutma yöntemleri ve ekstraksiyon, damıtma süresi, miktar tayini yöntemleri ve analiz koşulları) kapsamaktadır (Yurteri ve ark., 2021). Kısacası, tıbbi ve aromatik bitkilerde uçucu yağ içeriği ve bileşimi çevre koşulları, yetiştirme koşulları, ve kültürel uygulamalar (sulama, gübreleme) (Özgüven ve ark., 2008; Rioba ve ark., 2015) tarafından etkilenmektedir.

Kuraklık stresi tıbbi bitkilerde uçucu ve ikincil metabolitlerin üretimini etkilemektedir (Goncalves ve ark., 2023). Örneğin lavantada, uçucu yağ içeriği ve linalool seviyeleri kuraklık stresi altında artar (Saunier ve ark., 2022). Su eksikliği, ikincil metabolitlerin üretimi de dahil olmak üzere bitki metabolizmasında önemli değişikliklere neden olabilir (Soltanipour, 2005).

Lavanta yaprakları ve çiçekleri uçucu yağlarında 40'tan fazla farklı bileşik içerir, bunların en belirginleri linalool asetat, linalool, sineol, kafur ve geranioldür (Caprari ve ark., 2021). Çok sayıda uçucu yağ üreten bitkiler arasında Lavandula angustifolia Mill. en değerli olanlardan biri olarak öne çıkmaktadır (Crisan ve ark., 2023).

Lavanta yağının kalitesi özellikle linalool, linalil asetat ve kafur içeriği ile ölçülmektedir. Özellikle linalool ve linalil asetat lavanta yağının kalitesini pozitif yönde belirleyen en önemli bileşenler olup, parfüm sanayinde kullanılacak lavanta yağında (ISO3515:2002 lavanta yağı kalite standartlarına göre) en az % 25 oranında bulunmaları istenmektedir (Anonymous, 2002). Kafur ise lavanta yağının kalitesini düşüren en önemli bileşiktir ve %0.5'den daha az olması istenir, yüksek oranda bulunması durumunda uçucu yağı düşük fiyattan satılmaktadır. Düşük kafur içerikli lavanta yağı gıda, kozmetik ve ilaç sanayinde (parfüm, krem, kolonya), yüksek kafur içerikli lavanta yağı ise mum, sabun, böcek ilacı ve diğer ürünlerin yapımında kullanılmaktadır (Tisserand ve Balacs,1999; Baydar, 2010).

3. LAVANTA VERİMİ VE YAĞ KALİTESİNE SULAMANIN ETKİSİ

Kurak alanlar, dünyanın ekili alanlarının yaklaşık %80'ini kaplar ve toplam gıda üretiminin yaklaşık %60'ına katkıda bulunur (World Water Assessment Programme, 2009).Yağış, özellikle kurak ve yarı kurak bölgelerde tarımsal üretimi etkileyen en önemli faktörlerden biridir. Yıllık yağış miktarı ve mevsimsel dağılımı, bir bölgenin tarımsal üretimi için çok önemlidir, çünkü yağış, su dengesi, sulama gereksinimleri ve farklı bitkilerin su üretkenliğini doğrudan etkiler. Günümüzde, kurak bölgelerde sınırlı su kaynakları nedeniyle, tam su ihtiyacını karşılayacak sulama uygulamaları gerçekleştirmek olası değildir. Bu nedenle günümüze kadar, birçok bitkide ürün verimini artırmak ve/veya sulama suyu üretkenliğini artırmak için tamamlayıcı sulama ve kısıntılı sulama üzerine çeşitli çalışmalar yapılmıştır (Wang ve ark., 2001; Zhang ve ark., 2003).

Aynı şekilde, tarımı yapılan tıbbi ve aromatik bitkilerde de benzer çalışmalar yapılmıştır. Gelinen noktada, sulama seviyesi, tıbbi ve aromatik bitkilerin uçucu yağ verimi ve kompozisyonunu etkilemektedir (Bettaieb ve ark., 2009; Petropoulos ve ark., 2008; Vahidipour ve ark., 2013). Bu bağlamda lavanta tarımında sulama ve sulama yönetiminin verime ve kalitesine etkilerini belirlemek üzere saksı ve tarla düzeyinde araştırmalar yürütülmüştür. Lavanta yetiştiriciliğinde sulama ve farklı su yönetim uygulamalarının verime etkilerini konu edinen bazı araştırmalar incelenerek, günümüze kadar gelinen noktadaki mevcut durumun kısa bir özeti bu bildiride sunulmaya çalışılmıştır.

Farklı sulama programlarının etkilerini değerlendirmek amacıyla Chrysargyris ve ark. (2016), lavanta ve adaçayı bitkilerinde sulamanın bitki gelişimine, ürün verimine ve kalitesine etkilerini araştırmışlardır. Saksı denemesi olarak yürütülen çalışmada, bitkiler, tam sulama, orta seviyede kısıntılı sulama ve şiddetli su stresi altında sera koşullarında yetiştirilmiştir. Bu kapsamda tam sulamada saksı başına günlük 50 ml, orta seviyede kısıntılı sulamada 3 günde bir 50 ml ve şiddetli kısıntılı sulamada ise haftada bir 50 ml olarak uygulanmıştır. Genel olarak, su stresi altındaki bitkiler, tam sulama altındaki bitkilere göre daha az büyüme ve değişen kimyasal bileşim sergilemiştir. Buna ek olarak, su stresi altındaki bitkiler, daha yüksek antioksidan (fenolik) konsantrasyonları ile uçucu yağ kalitesinde fayda sağlamıştır. Kısacası bu çalışmanın sonuçları, kısıntılı sulamanın lavanta bitkisinin uçucu yağ kalitesini artırabileceğini göstermiştir. Benzer içerikte farklı sulama planlaması uygulayan Hosseini ve Heidari (2025), İran'da yaptıkları serada saksı denemesinde, kuraklık stresinin lavanta üzerindeki etkilerini ve su kıtlığına verdiği yanıtın altında yatan moleküler mekanizmaları araştırmışlardır. Çalışmada dört farklı sulama seviyesi planlanmış olup; bunlar toprağın tarla kapasitesi'nin (TK) %80, 60, 40 ve 20'sine tekabül eden sırasıyla 2, 1.5, 1 ve 0.5 litre sudan oluşturulmuştur. Sulamalar üç ay boyunca üç günde bir uygulanmıştır. Sulama suyu kısıntıları altında; protein ve klorofil içerikleri, fenolik ve flavonoid bileşikler, antioksidan kapasitesi, uçucu yağ içeriği, uçucu yağın antibakteriyel özellikleri ve uçucu yağ bileşimi dahil olmak üzere çeşitli parametreler incelenmiştir. Elde edilen bulgulara göre, su kısıntısı artıkça, protein ve klorofil içeriği de azalmıştır. Yine İran'da yürütülen başka bir saksı denemesinde Shabankareh ve ark. (2021), farklı su stresi rejimleri altında yetiştirilen üç lavanta çeşidinin tepkisini araştırmışlardır. Çalışmada tarla kapasitesinin(TK) farklı seviyelerindeki (%90-100TK, %70-80TK, 50-60TK ve %30-40TK) sulamalardan oluşan dört farklı sulama rejimi uygulanmış ve su stresinin lavanta yağı kalitesine etkileri araştırılmıştır. Araştırma bulgularına göre, su stresi lavanta kuru madde verimini önemli ölçüde azaltmış olup, en düşük kuru ot verimi en az sulanan konudan elde edilmiştir. Sulama seviyesi artıkça esansiyel yağ oranı azalırken, en yüksek yağ oranı en düşük seviyede sulamadan elde edilmişken, en yüksek yağ verimi ise %70-80 TK sulama rejiminde elde edilmiştir. Değerlendirilen tüm genotiplerde, artan kuraklık stresiyle birlikte başta linalil asetat ve linalool gibi monoterpen bileşikleri azalış gösterirken, seskiterpen bileşiklerinin arttığı belirlenmiştir. Türkiye'de yürütülen benzeri başka bir saksı denemesinde Noory (2020) açık alanda yaptığı çalışmada, farklı yetişme ortamı ve kuraklığın lavanta bitkisinin gelişimi üzerine etkilerini araştırmıştır. Bu bağlamda, biri yağışa dayalı, biri tam tam sulama ve ikisi kısıntılı sulama konusu olmak üzere dört farklı sulama seviyesi altında 7 farklı yetiştirme ortamının lavantanın morfolojik özelliklerine etkisi belirlenmeye çalışılmıştır. Sulama suyu kap buharlaşması esas alınarak haftada bir veya iki kez olacak şekilde belirlenmiş, tam sulama konusuna sulama aralığında gerçekleşen buharlaşma miktarı kadar su uygulanmış olup, %33 kısıntılı sulamada, tam sulama suyunun %66'sı ve %66 kısıntılı sulamada ise %33'ü uygulanmıştır. Elde edilen sonuçlara göre, tam sulama, %33 ve %66 kısıntılı sulama konularına sırasıyla 275, 182 ve 91 mm sulama suyu uygulanmıştır. Sulama seviyeleri lavantanın morfolojik özelliklerine önemli ölçüde etki etmiş olup, tam sulama konusu bitki boyu, bitki gövde çapı, çiçek sapı uzunluğu ve çiçek sayısı bakımından en iyi performansı göstermiştir.

Bir başka saksı çalışmasında Saunier ve ark (2022) iki lavanta türüne (*L. Angustifolia, L. x intermedia*) ait farklı çeşitlerde uygulanan su stresinin etkilerini araştırmışlardır. Bu kapsamda serada saksı denemesi ile iki farklı sulama seviyesinin bitkide fizyolojik ve metabolik özelliklere etkisi test edilmiştir. Sulama uygulamasının birincisinde (kontrol), bitkiler her gün toprağın (karışım) tarla kapasitesinin (TK) %75'ine karşılık gelen 300 mL su ile sulanırken, ikincisi kuraklık stresi uygulaması olup, TK'nın %25'ine karşılık gelen 100 mL su ile her 2 günde bir sulanmıştır. Sulama uygulamaları *L. angustifolia* çeşitlerinde 17 Mayıs ve *L.x intermedia* çeşitlerinde ise 24 Mayısta başlatılmış ve her iki türe ait çeşitlerde 22 Temmuzda sonlandırılmıştır. Sulama seviyelerinin bitkilerin fizyolojik ve metabolik özelliklerine etkileri; biri çiçeklerin yaklaşık %50'sinin açıldığı 10 Haziran - 4 Temmuz döneminde ve diğeri ise çiçeklerin tohum oluşturduğu 9-22 Temmuz dönemi olmak üzere iki fenolojik dönemde ölçümler yapılarak belirlenmiştir. Çalışmanın bulguları, su stresinin, tüm bitki ölçeğinde terpen emisyonlarında önemli bir azalmaya yol açarken, çiçek terpen üretimi azalışının daha düşük seviyede gerçekleştiğini göstermiştir. Yine çalışma sonuçları, her iki türün de su stresi ile başa çıkmak için kuraklığa dayanıklı bir strateji sergilediğini ve L. angustifolia'nın daha rekabetçi bir strateji izlediğini göstermiştir. Çalışma sonuçları ayrıca, Fransa'da geliştirilen yeni bir çeşit olan 'Rapido' (L. angustifolia) ve 'Sumian' (L. x intermedia) çeşitlerinin, şiddetli kuraklık koşullarında yetiştirilmeye en uygun adaylar olabileceğini göstermiştir.

Lavantada sulama üzerine yapılan araştırmaların bazıları tarla denemesi olarak yürütülmüştür. Örneğin Salata (2020) Polonya'da yürüttüğü bir tarla denemesi ile sulamanın lavantanın ot ve çiçek salkımı verimine etkisini araştırmıştır. Araştırmada, biri tamamlayıcı sulama ve diğeri yağışa dayalı olmak üzere lavanta üretimi gerçekleştirilmiş ve iki üretim sistemi karşılaştırılmıştır. Sulamalar damla sulama yöntemi ile toprak su potansiyeli -20 kPa veya bu değere yakınlaştığında uygulanmış olup, her sulamada sabit 15 mm olmak üzere toplam 6 kez sulama yapılmıştır. Çalışma sonuçlarına göre, sulama lavantanın taze ot verimi ile taze çiçek salkım verimini önemli ölçüde artırmıştır. Yağışa dayalı üretimle karşılaştırıldığında, tamamlayıcı sulama taze ot verimini %40.2, taze çiçek verimini %51.76 ve hava kurusu çiçek verimini ise yaklaşık iki kat artırmıştır. Araştırma bulguları ayrıca çiçeklerden elde edilen uçucu yağ verimini de önemli ölçüde artırmış olup, yağışlı üretime göre %17.65 artırmıştır. Buna karşın sulama toplam fenolik asitler oranını %22.83 azaltmıştır. Diğer bir çalışmada Pirzad ve Mohammadzadeh (2018) İran'da yaptıkları bir tarla denemesinde lavanta, biberiye ve kekik bitkilerinde sulamanın biyolojik verime, uçucu yağ verimine ve bitki su tüketimine etkilerini araştırmışlardır. Çalışmada, bitkiler tarla kapasitesinin %75'i (iyi sulanmış, 0.75TK) ve %50'sinde (orta stres, %50TK) olmak üzere iki farklı nem seviyesinde, yani iki farklı sulama aralığı sulama koşullarında yetiştirilmiştir. Ayrıca kontrol amaçlı olarak yağışa dayalı bir konuda çalışmaya dahil edilmiştir. Araştırma sonuçlarına göre, %75TK ve %50TK konularına uygulanan sulama suyu miktarları birinci yılda sırasıyla 218.7, 150 ve 0 mm, ikinci yılda 262.5, 225 ve 0 mm olmuştur. Sulama sıklığı artıkça uçucu yağ oranı azalmış, en yüksek oran sulamasız koşullarda elde edilmiştir. Ancak tarla kapasitenin %50'sinde sulama ile yağışa dayalı konuların yağ oranları arasında önemli bir fark olmadığı belirlenmiştir. Sonuçlara göre, sulama sıklığı artıkça lavanta biyolojik verimi ve uçucu yağ verimi önemli ölçüde artış göstermiş, en yüksek verim değerleri tarla kapasitesinin %75'inde sulanan konudan elde edilmiştir. Benzer içerikli başka bir çalışmada Sarfaraz ve ark (2024) tarafından İran'da yürütülen bir tarla denemesinde farklı sulama seviyeleri ve farklı gübre kaynaklarının lavantaya olan etkileri araştırılmıştır. Denemede, tarla kapasitesi nemine (TK) dayalı dört farklı sulama seviyesi (%95 TK (S1), %75TK (S2), %50TK (S3) ve %25TK (S4)) ve üç farklı gübre kaynağı iki farklı lavanta çeşidine uygulanarak, uygulamaların lavantanın biyolojik ve çiçek verimi ile uçucu yağ oranı ve yağ verimine etkileri araştırılmıştır. Elde edilen bulgulara göre S1, S2, S3 ve S4 konuları 7 kez sulanmış ve sırasıyla toplamda 750, 584, 391 ve 305 mm sulama suyu uygulanmıştır. Sulama suyu miktarı artıkça lavanta biomass verimi ile çiçek verimi önemli

ölçüde artış göstermiştir. En yüksek verimler en yüksek sulama suyu uygulanan kontrol konusundan elde edilmiştir. En düşük sulama suyu uygulaması ile kıyaslandığında, en yüksek sulama seviyesi biyolojik verimi %68.5 ve çiçek verimini ise %105 artırmıştır. Sulama seviyeleri lavanta uçucu yağ oranını önemli ölçüde etkilemiş olup, en düşük oranlar en az sulanan konu ile en fazla sulanan konudan elde edilmiştir.

Hasibi ve ark (2022) tarafından yapılan çalışmada, farklı seviyelerdeki su stresini kullanarak lavantanın kuraklığa dayanıklılığı tarla koşullarında test edilmiştir. Bu bağlamda 4, 8, 12 ve 20 günde bir sulama olmak üzere dört farklı sulama konusu bitkilere uygulanmış ve lavantanın morfolojik ve biyokimyasal özelliklere etkisi belirlenmeye çalışılmıştır. Bu denemenin sonuçları, stres düzeylerinin morfolojik, biyokimyasal ve uçucu yağ üzerindeki etkisinin ayrı ayrı önemli olduğunu göstermiştir. Lavanta sürgün boyu, sürgün sayısı, sürgün kuru ağırlığı, yaprak alanı ve yaprak kuru ağırlığı gibi morfolojik özellikler sık sulamada en yüksek değerleri göstermiş iken, stoma direnci sulama aralığı artıkça artmıştır. Benzer şekilde klorofil içeriği, SOD (süperoksit desmotaz), POD (polifenol oksidaz), APX (askorbater oksidaz) gibi biyokimyasal özellikler sulama aralığı uzadıkça azalış gösterirken, prolin içeriği artış göstermiştir. En yüksek prolin değeri 20 gün sulama aralığında elde edilmiştir. Sulama aralığı bağlamında benzer içerikli İran'da yapılan bir araştırmada Satarzadeh ve ark. (2024), lavanta bitkisinde farklı sulama rejimleri, farklı seviyeyi içeren biyogübre aşılması (Thiobacillus, Pseudomonas ve Thiobacillus + Pseudomonas aşılaması ve kontrol olarak aşılamasız konu) ve iki farklı fosforlu gübre dozunun (0 ve 50 kg ha^{-1}) etkisini araştırmışlardır. Çalışmada sulama seviyeleri, A sınıfı buharlaşma kabından 60, 90 ve 120 mm buharlaşma sonrası sulama uygulaması olmak üzere üç konudan oluşturulmuştur. Sonuçlar, sulamanın her kademesinde fosfor tüketiminin ve biyogübre ile aşılamanın, kontrol ile karşılaştırıldığında çiçeklerin kuru ağırlığını artırdığını göstermiştir. Bu çalışmanın sonuçlarına dayanarak, su stresi koşullarında, biyolojik gübrelerin fosforlu gübrelerle birlikte kullanılmasının lavanta bitkisinde yetersiz beslenme vakalarını büyük ölçüde azaltabileceği ifade edilmiştir.

García-Caparrós ve ark (2019) tarafından İspanya'da yapılan çalışmada, Ballıbabagiller (Lamiaceae) familyasına ait bazı (ballıbaba, nane, kekik, lavanta, dağ çayı vb.) bitkilerin su stresine tepkisi bir tarla denemesi ile araştırılmıştır. Denemede iki farklı sulama seviyesi planlanmış olup, sulama seviyeleri referans bitki su tüketimi (ETo) ve yağış miktarı (R) farkına dayalı oluşturulmuştur. Çalışmada, bitkilere tam sulama ve %30 kısıntılı sulama seviyeleri damla sulama sistemi ile uygulanarak, biyolojik verime ve uçucu yağ içeriğine etkisi test edilmiştir. Araştırma sonuçlarına göre, %30 sulama suyu kısıntısı lavanta bitkisini olumsuz etkilemişken, diğer bitkilerde (adaçayı, nane, kekik) sulama seviyeleri olumsuz bir etki oluşturmamıştır. Tam sulama ile kıyaslandığında, %30 kısıntılı sulama lavantanın kuru ot verimi ve uçucu yağ verimini sırasıyla %32 ve %35.9 azaltmıştır.

Türkiye'de de lavanta yetiştiriciliğinde sulama verim ilişkileri, sulama yönetimi ve sulama üretkenliğini önceleyen az sayıda da olsa araştırma yapıldığı görülmektedir. Örneğin Akçay ve ark. (2021) Aydın Ovası koşullarında damla yöntemi ile farklı sulama seviyelerinin lavanta bitkisinde verime etkileri üzerine bir tarla denemesi yürütmüşlerdir. Çalışmada kap buharlaşması ve toprak nemine dayalı olmak üzere iki sulama stratejisi dikkate alınmış olup, her bir sulama stratejisinde biri tam ve üçü kısıntılı (tam seviyenin %67, 33 ve 0) olmak üzere dört sulama seviyesi uygulanmıştır. A sınıfı kap buharlaşması stratejisinde 7 gün sulama aralığı ve toprak nemine dayalı sulama stratejisinde ise tam sulama uygulanan parselde bitki kök bölgesinde faydalı su kapasitesinin %50'si tüketilince sulamalar yinelenmiştir. Elde edilen sonuçlara göre, buharlaşma kabına dayalı strateji ile karşılaştırıldığında, toprak nemine dayalı sulama stratejisi önemli ölçüde daha yüksek verim değerleri sağlamıştır. Sulama seviyeleri lavanta verimini önemli şekilde etkilemiş olup, yaş çiçek verimi 381-510 kg da^{-1} ve drog çiçek verimleri ise 172-263 kgda^{-1} arasında bulunmuştur. Çalışmanın sonuçları, sulama seviyesi

artıkça lavanta çiçek verimi ve drog çiçek veriminin önemli ölçüde arttığını göstermiştir. Sulama suyunun üretkenliği, sulama seviyesi artıkça azalış göstermiş olup, sulamalı konular arasında en düşük değer her iki sulama stratejisinde de tam sulama seviyesinden elde edilmiştir. Ayrıca bu çalışma, yeterli su varlığı koşullarda, sulama programının toprak nemine dayalı yapılmasını ve tam sulama uygulanmasını, su kısıtlı koşularda ise hem toprak nemin hem de kap buharlaşması sulama stratejisinde %33 kısıntılı sulama seviyesinin lavanta tarımı için önerilebileceğini göstermiştir. Yine Türkiye'de yarı kurak iklime sahip Niğde koşullarında Yetik ve Şen (2025) tarafından yapılan bir tarla denemesinde, damla sulama yöntemi ile uygulanan farklı sulama seviyelerinin lavantanın verimi, verim bileşenleri, uçucu yağ içeriği, su üretkenliği ve sulama suyu üretkenliği üzerine etkileri beş üretim mevsimi için araştırılmıştır. Sulama konuları; tam sulama (TS), orta derecede kısıntılı sulama (KS1, %33 su eksikliği), şiddetli kısıntılı sulama (KS2, %66 su eksikliği) ve yağışa dayalı üretimden (YD) oluşmuştur. Sonuçlar, KS1'in TS ile karşılaştırılabilir taze verim (144-227 kg /da) ve yağ verimi (2,7-6,9 kg/ da) elde ettiğini ve bitki su tüketiminin 781,5-923,6 mm arasında değiştiğini göstermiştir. Yağışa dayalı konuda ürün verimi önemli ölçüde azalırken, su üretkenliği en üst düzeyde gerçekleşmiştir. Bu da önemli su eksiklikleri altında bile lavantanın suyu çok etkili kullanma potansiyeline sahip olduğunu göstermektedir. Araştırma bulguları, lavantanın, kısıntılı sulamaya uygun olduğunu, göstermiştir. Sonuç olarak, araştırıcılar; %33 su kısıntısının verim düşüşünü en aza indirerek su üretkenliğini optimize etmek için, %66 su kısıntısını ise su kısıtlı yarı kurak iklimlerde sürdürülebilir lavanta üretimi için uygun bir sulama programı olarak önerilebileceğini bildirmişlerdir.

4.SONUÇ

Bu incelemede, önemli bir tıbbi ve aromatik bitki olan lavantanın tarımında sulamanın bitki verimine ve uçucu yağ kalitesine etkisi ele alınmıştır. Bu kapsamda yakın geçmişte lavantada sulama üzerine yapılmış çalışmaların bazıları incelenerek, sulamanın etkisine ilişkin kısa özetleri sunulmaya çalışılmıştır. Yapılan incelemeden elde edilen sonuçlara göre; sulamanın lavantanın gelişimini, çiçek verimi ile uçucu yağ verimini önemli şekilde artırdığı, uçucu yağ oranını ise kısmen olumsuz etkilediği, ancak uçucu yağ verimini artırdığı görülmektedir. Bu nedenle, kurak ve su kısıtlı bölgelerde, lavantanın az miktarda su ile damla sulama yöntemiyle birkaç kez sulanması yararlı olacaktır.

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TARIMSAL ÜRETİMDE HUMİK VE FULVİK ASİT: KULLANIM OLANAKLARI VE GÜNCEL ÇALIŞMALAR

Doç. Dr. Hakan KELES

Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü, Yozgat

Email: hakan.keles@yobu.edu.tr

ORCID: 0000-0002-8225-931X (Sorumlu Yazar)

Doç. Dr. Servet ARAS

Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü, Yozgat

Email: servet.aras@yobu.edu.tr

ORCID: 0000-0002-0347-6552

Doç. Dr. Müjgan GÜNEY

Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü, Yozgat,

Email: mujgan.guney@yobu.edu.tr

ORCID: 0000-0001-5491-1430

ÖZET

Tarım, Türkiye gibi gelişmekte olan ülkelerin kalkınmasında önemli bir rol oynayan, gelişmiş ülkelerin ekonomilerinin ise temelini oluşturan bir sektördür. Plansız kentleşme ve nüfus artışı, gün geçtikçe yoğunlaşan sanayileşme ile azalan tarım alanlarına rağmen üretim kaygısı devamlı artış göstermiştir. Artan nüfusun besin ihtiyacını azalan tarımsal alanlarla karşılamak amacıyla tarımsal teknikler gün geçtikçe gelişmiş, bu gelişme ile birlikte özellikle ilaç, gübre gibi kimyasal ürünlerin kullanımı artmıştır. Birim alandan daha yüksek verim kaygısı ile kullanımı kontrolsüz bir şekilde artan kimyasal girdilerin bir süre sonra bazı zararları tespit edilmiştir. Bu girdilerin kullanımı ürün veriminde her ne kadar artış sağlasa da çevreye ve toprağa verdiği zararlar bazı çözümleri zorunlu kılmıştır. Toprak yapısının, organik içeriğinin ve canlı florasının bozulması konularının çözümü amacıyla organik temelli ürünlerin kullanımı çözüm için önemli çıkış kapıları olmuşlardır. Toprak organik maddesinin artırılması, toprakların kimyasal ve fiziksel yapılarının onarılması ve hatta toprakta canlı mevcudiyetinin artırılması için en önemli çözüm yolu olarak yaygınlaşmaya başlamıştır. Ayrıca yapılan bilimsel çalışmaların ışığında tüketiciler ve üreticilerde artan bilinç kimyasal girdilerin dozunda kullanımını ve organik ürünlerin yetiştiricilikte girdi olarak daha fazla yer almasını sağlamıştır.

Son yıllarda artan bilinç organik temelli ürünlerin kullanımında önemli bir artış sağlamıştır. Bu sayede ürün çeşitliliği de artarak devam etmiş ve günümüzde bu ürünler piyasada önemli bir yer almaya başlamışlardır. Humik ve Fulvik Asit içerikli girdiler bu ürünlerin en önemlilerinden birisidir. Bu ürünlerin kullanımı yalnızca toprak yapısının iyileştirilmesini ve bitkilerin besin maddelerinden daha iyi faydalanmasını sağlamaz, aynı zamanda ürün gelişimini de destekleyerek verim ve gelir artışını da önemli oranda destekler. Bu ürünlerin kullanımı ağır metalleri sabitleyebilir ve organik kirleticileri parçalayabilir.

Bu çalışmada, humik ve fulvik asit temelli organik ürünlerin tarımsal amaçla kullanım olanakları sunularak yapılan güncel araştırmalar derlenecektir.

Anahtar Kelimeler: Humik, Fulvik, Organik, Tarım

HUMIC AND FULVIC ACIDS IN AGRICULTURAL PRODUCTION: UTILIZATION POTENTIALS AND RECENT STUDIES

ABSTRACT

Agriculture is a sector that plays a vital role in the development of emerging economies such as Türkiye, while serving as the foundation of the economies of developed nations. Despite declining agricultural lands due to unplanned urbanization, population growth, and accelerating industrialization, the concern for maintaining and increasing agricultural production has persisted. To meet the nutritional demands of a growing population with shrinking agricultural resources, agricultural technologies have steadily advanced. However, this progress has also led to a substantial increase in the use of chemical inputs such as fertilizers and pesticides. Over time, the uncontrolled application of these chemicals, initially aimed at maximizing yield per unit area, has revealed several detrimental effects. Although such inputs contribute to yield enhancement, their adverse impacts on the environment and soil health have necessitated alternative solutions. The degradation of soil structure, organic content, and microbial diversity has prompted the search for sustainable remedies, among which the use of organic-based products has emerged as a promising approach. Increasing soil organic matter, improving the chemical and physical properties of soils, and enhancing microbial activity are now regarded as key strategies for sustainable soil management.

Furthermore, growing awareness among consumers and producers, supported by scientific research, has led to a more measured use of chemical inputs and a rising adoption of organic products in agricultural production systems. In recent years, this increasing awareness has significantly boosted the utilization of organic-based materials, resulting in expanding product diversity and a growing market presence. Among these, inputs containing humic and fulvic acids stand out as particularly important. Their use not only improves soil structure and enhances the uptake of nutrients by plants, but also promotes plant growth, thereby contributing to higher yields and increased economic returns. Additionally, these substances can immobilize heavy metals and decompose organic pollutants, further supporting environmental sustainability.

In this review, recent studies on the agricultural applications and potential uses of humic and fulvic acid–based organic products will be compiled and evaluated.

Keywords: Humic, Fulvic, Organic, Agriculture

1. GİRİŞ

Günümüzde meydana gelen iklimsel kaymalar, küresel ısınma ve benzeri olaylarla beraber artan sanayileşme, plansız kentleşme gibi faktörler tarımsal faaliyetlerin kısıtlanmasına sebep olmaktadır. Gittikçe artan dünya nüfusunun besin ihtiyacının karşılanması ise her geçen gün daha da önem kazanmaktadır. Bu ihtiyacın karşılanmasına yönelik uygulamaların büyük kısmını kimyasal girdilerin kullanımı oluşturmaktadır. Özellikle toprak beslemede kullanılan gübre preparatları bilinçsiz uygulamalarla birleştiğinde toprakta ve yer altı sularında bulaşmalara sebebiyet verebilmektedir. Üretim kaygısı nedeniyle artan bu uygulamalar topraklarda bazı birikimlere sebebiyet vermekle birlikte verim artışına tamamen çözüm olamamaktadırlar. Toprağın organik yapısı, fiziksel ve kimyasal özelliklerinin tam olarak bilinmediği durumlarda yapılan uygulamalar tam çözüm olmamakla birlikte verim kaygısıyla çiftçiler kimyasal girdilere daha çok sarılabilmekte bu durum da kısır bir döngüye sebebiyet vermektedir.

Toprak organik madde içeriğinin geliştirilmesi, yapısının iyileştirilmesi verimli üretimin ilk koşulu olmakla birlikte, gelecek nesillere sağlıklı bir üretim bırakmak açısından da oldukça önem arz etmektedir.

Küresel ısınma, iklim kaymaları, tarım topraklarında ve yer altı sularında meydana gelen kirlenmeler, su kaynaklarının azalması gibi olaylar insan yaşamına önemli bir tehdit olarak ortaya çıkmıştır. Bu sebeple gelişmiş ülkeler başta olmak üzere dünya çevresinde doğa dostu çözümler üzerine eğilim artmıştır ve artmaya devam etmektedir. Tarımsal faaliyetlerin doğa dostu çözümler ile desteklenmesi, kimyasal girdilerin daha az miktarlarda uygulanmasına rağmen daha fazla verim alınması gibi konular son yıllarda üzerinde sıkça durulan araştırmalar olmuştur.

Destekleyici ürünler olarak mikroorganizmalar, alginik asitler, amino asitler, humik ve fülvik asitler, solucan gübreleri gibi ürünlerin konu olduğu birçok çalışma yapılmış ve bu ürünlerin kimyasal girdilerin verimi üzerine etkileri araştırılmıştır. Hümik ve fülvik asit bu ürünler arasında başı çeken ürünlerdir. Bu derlemede hümik ve fülvik asit ile ilgili bazı detaylardan bahsedilecek ve yapılmış bazı çalışmalar irdelenecektir.

2. HÜMİK ve FÜLVİK ASİT

Hümik ve fülvik asitler, toprak organik maddesinin temel bileşenlerini oluşturan, bitkisel ve hayvansal artıkların mikrobiyal ayrışmasıyla meydana gelen karmaşık doğal bileşiklerdir. Bu maddeler, toprakta fiziksel, kimyasal ve biyolojik dengeyi düzenleyerek verimliliğin sürdürülmesinde kilit rol oynar (Stevenson, 1994; Akıncı, 2011). Hümik maddeler çözünürlüklerine göre üç alt fraksiyona ayrılır: hümik asit, fülvik asit ve hümin (Chen & Aviad, 1990). Hümik asit alkali ortamda çözünür, asidik ortamda çökelir; fülvik asit ise her pH aralığında çözünür durumda kalır (Piccolo, 2001).

Yapısal olarak hümik asitler yüksek molekül ağırlıklı, aromatik karakterli ve hidrofobik özellik gösterirken; fülvik asitler düşük molekül ağırlıklı, alifatik ve hidrofiliktir (Canellas ve ark., 2015). Bu fark, fülvik asidin bitki kökleri tarafından daha hızlı emilmesine ve kısa vadede etkili olmasına, hümik asidin ise toprakta uzun süreli kalıcılık ve tamponlama etkisi göstermesine neden olur (Nardi ve ark., 2002).

Her iki bileşik de karboksil, fenolik ve hidroksil grupları sayesinde metal iyonlarını şelatlayarak Fe, Zn, Cu ve Mn gibi mikro besinlerin alınabilirliğini artırır (Ay, 2015; Khashroum ve ark., 2024). Ayrıca hümik maddeler, toprak su tutma kapasitesini yükseltir, mikrobiyal aktiviteyi teşvik eder ve kök zar geçirgenliğini artırarak iyon taşınımını düzenler (Canellas ve ark., 2015; Gao ve ark., 2022).

Son yıllarda bu maddeler, yalnızca toprak düzenleyici olarak değil, aynı zamanda biyostimülan olarak da değerlendirilmektedir. Hümik ve fülvik asitler bitkilerde hormon benzeri etki göstererek auxin ve sitokinin benzeri yanıtları tetikler; bu durum kök büyümesini, sürgün gelişimini ve yaprak yüzey alanını artırır (Nardi ve ark., 2016; Alsudays ve ark., 2024). Özellikle kuraklık, tuzluluk ve ağır metal stresi gibi abiyotik faktörlere karşı dayanıklılığı artırmada önemli oldukları son çalışmalarla da kanıtlanmıştır (Mosaad ve ark., 2025; Song ve ark., 2025).

3. KONU İLE İLGİLİ YAPILMIŞ ÇALIŞMALAR

3.1. Bitki Gelişimi ve Verim Üzerindeki Genel Etkiler

Yapılan birçok araştırma, hümik ve fülvik asitlerin bitki gelişimini teşvik ederek verim ve kaliteyi artırdığını göstermiştir. Erdal ve ark. (2014), kireçli toprakta yetiştirilen domateste 1000 ppm dozunda hümik + fülvik asit uygulamasının azot alımı ve kök kuru ağırlığını önemli ölçüde artırdığını bildirmiştir. Arduç, ve ark. (2020) tarafından yapılan çalışmada da ekmeklik buğdayda bu bileşiklerin tane verimini %25 oranında artırdığı ve protein içeriğini yükselttiği belirtilmiştir.

Benzer şekilde Zhang ve ark. (2021), mısır sapından elde edilen fülvik asidin domateste fotosentetik etkinliği ve meyve kalitesini artırdığını, yüksek dozların ise optimum verim noktasını aşınca verim düşüşü oluşturabileceğini vurgulamıştır. Bu durum, fülvik asidin bitkide iyon taşınımını hızlandırarak kısa vadede pozitif etki yapmasına rağmen, yüksek konsantrasyonlarda ozmotik stres oluşturabileceğini göstermektedir.

Çilek üzerine yapılan bir araştırmada, Zydlik ve Zydlik (2023) hümik asit içeren yapraktan uygulanan gübrelerin toprak enzim aktivitesini iki kat artırdığını, yaprak yüzey alanını %60 oranında büyüttüğünü ve meyve sertliği ile şeker içeriğini yükselttiğini bildirmiştir. Bu bulgular, özellikle biyostimülan içerikli yapraktan uygulamaların, klasik mineral gübrelemeye göre daha dengeli bir büyüme sağladığını ortaya koymaktadır.

3.2. Kuraklık ve Tuzluluk Stresi Altında Etkiler

Kuraklık ve tuzluluk, tarımsal üretimin en ciddi stres faktörleri arasında yer alır. Song ve ark. (2025), kurak koşullarda yetiştirilen domateslerde 400 $mg \cdot L^{-1}$ fülvik asit uygulamasının fotosentez oranını %67, su kullanım etkinliğini %42 artırdığını, aynı zamanda meyve kalitesi ve C vitamini içeriğini belirgin şekilde iyileştirdiğini göstermiştir.

Tuzlu koşullarda yürütülen çalışmalarda da benzer sonuçlar elde edilmiştir. Mosaad ve ark. (2025), farklı tuzluluk seviyelerindeki tritikale denemelerinde hümik ve fülvik asitlerin klorofil içeriğini yükselttiğini, prolin birikimini azalttığını ve tane ağırlığını artırdığını bildirmiştir. Araştırmacılar, bu etkilerin hümik bileşiklerin iyon homeostazını düzenleyici ve antioksidan savunmayı güçlendirici mekanizmalarından kaynaklandığını belirtmiştir.

Benzer şekilde Nargesi ve ark. (2022), zeytin çeşitlerinde hümik ve fülvik asidin membran stabilitesini artırdığını, prolin birikimini azalttığını ve özellikle 'Zard' çeşidinde kalsiyum ve magnezyum içeriğini yükselttiğini rapor etmiştir. Bu sonuç, organik asitlerin iyon dengeleme ve hücresel zar koruma görevlerini destekler niteliktedir.

3.3. Çimlenme ve Toprak Özellikleri Üzerine Etkiler

Khashroum ve ark. (2024), kabakgillerde (kabak ve salatalık) sulama suyuna eklenen farklı hümik + fülvik asit konsantrasyonlarının toprak pH'sını düşürdüğünü, elektriksel iletkenliği azalttığını ve çimlenme oranını belirgin artırdığını tespit etmiştir. Özellikle 0,5 $mL \cdot L^{-1}$ konsantrasyonun çimlenmeyi hızlandırdığı ve çiçeklenmeyi 12 gün erkene çektiği bildirilmiştir.

Bu, düşük doz uygulamaların bitkisel fizyolojide optimum düzeyde uyarıcı etki sağladığını göstermektedir.

Benzer şekilde Yıldırım ve ark. (2021), kadmiyum stresi altındaki tere bitkisine uygulanan hümik + fülvik asit karışımının Cd birikimini azalttığını, klorofil miktarını ve antioksidan enzim aktivitelerini artırarak stres toleransını güçlendirdiğini ortaya koymuştur. Bu bulgu, humik bileşiklerin ağır metal toksisitesine karşı detoksifikasyon ve iyon rekabeti yoluyla koruyucu etkilerini destekler.

3.4. Meyve Türlerinde Kalite ve Besin İçeriği

Meyve türlerinde yapılan araştırmalar da hümik ve fülvik asitlerin kalite parametreleri üzerindeki olumlu etkilerini göstermektedir. Sedaghathoor ve ark. (2022), zeytinde bu asitlerin yağ içeriğini ve fenolik bileşikleri artırdığını rapor etmiştir. He ve ark. (2022) limonda, benzer şekilde, bu uygulamaların meyve şeker oranı, C vitamini ve flavonoid düzeylerini yükselttiğini vurgulamıştır.

Ayrıca Zydlik ve Zydlik (2023) tarafından çilek bitkisinde yapılan çalışma, hümik asidin yaprak biyokütlesini, enzim aktivitesini ve toprak solunumunu iki kat artırdığını göstermiştir. Bu sonuçlar, hümik ve fülvik asitlerin bitkisel metabolizmayı güçlendirerek meyve kalitesine dolaylı katkı sağladığını ortaya koymaktadır.

4. SONUÇ VE ÖNERİ

Hümik ve fülvik asitler, tarımsal üretimde hem besin alım düzenleyicisi hem de biyostimülan olarak önemli bir yere sahiptir. Toprak yapısını iyileştirir, mikrobiyal aktiviteyi artırır, bitki büyümesini teşvik eder ve stres koşullarında fizyolojik dengeyi korur. Son dönem çalışmalar, bu maddelerin bitkilerde fotosentez, enzim aktivitesi, iyon taşınımı ve antioksidan sistemler üzerindeki etkilerini daha net ortaya koymuştur (Canellas ve ark., 2015; Song ve ark., 2025; Mosaad ve ark., 2025). Gelecekteki araştırmalarda, farklı kaynaklardan elde edilen hümik maddelerin (ör. leonardit, linyit, kompost, biyokömür) kimyasal karakterizasyonunun bitkisel yanıtlarla ilişkilendirilmesi ve her tür için optimum uygulama dozu belirlenmelidir. Ayrıca, atık bazlı organik materyallerden hümik madde üretimi, hem çevre koruma hem de sürdürülebilir gübreleme açısından stratejik önemdedir. Genel olarak, 1990'lardan bu yana yürütülen klasik çalışmalar (Chen & Aviad, 1990; Stevenson, 1994) ile güncel bulgular (Zydlik & Zydlik, 2023; Khashroum ve ark., 2024; Song ve ark., 2025) birlikte değerlendirildiğinde, hümik ve fülvik asitlerin modern tarımda ekolojik, ekonomik ve fizyolojik açıdan vazgeçilmez katkılar sunduğu açıktır.

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ALIÇ (*Crataegus spp.):* ALTERNATİF TÜR BAKIMINDAN OLANAKLAR VE GELECEK PERSPEKTİFİ

Doç. Dr. Hakan KELES

Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü, Yozgat

Email: hakan.keles@yobu.edu.tr (Sorumlu Yazar)

ORCID: 0000-0002-8225-931X

Dr. Öğr. Gör. Selcan ÖZYALIN

Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü, Yozgat

Email: selcan.ozyalin@yobu.edu.tr

ORCID: 0000-0003-4831-8600

Doç. Dr. Servet ARAS

Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü, Yozgat

Email: servet.aras@yobu.edu.tr,

ORCID: 0000-0002-0347-6552

ÖZET

Gelişmiş toplumlar kalkınma hedeflerine ulaşmak için ekonomilerinin temellerini sağlam bir zemine oturtmuşlardır. Bu temeli oluştururken de ilk adım tarımsal üretim ile başlamıştır. Ekonomilerde genel kalınmanın en önemli yolu kırsal kalkınmadan geçmektedir. Bunu başarabilmek ise doğru planlama sonucunda birim alandan elde edilecek gelirin artırılmasından geçmektedir. Türkiye' de gelişmekte olan ülkeler arasında yer almakla birlikte tarımsal kalkınma sürecini tam anlamıyla tamamlayamamıştır. Özellikle planlamada yaşanan problemler bu sürecin uzamasında önemli bir rol oynamaktadır.

Meyvecilik önemli bir tarımsal faaliyve arkanıdır. Tarla ürünlerine oranla birim alandan getirisi yüksek bir üretim koludur. Türkiye bu üretim kolunda önemli bir yerdedir. Ancak karasal iklime sahip bölgelerinde ve uygun olmayan toprak koşularından bu faaliyve arkanından yararlanmak oldukça zordur. Yapılan faaliyetlerden ise başarı elde edilememekle birlikte harcanan zaman ve para da çoğu zaman boşa gitmektedir.

Türkiye bitki gen kaynakları bakımından önemli bir konumdadır. Birçok yabani türün gen merkezidir. Alıç (*Crataegus* spp.) bu türlerin en önemlilerindendir. Yetiştiricilik özellikleri ve piyasada alıcı bulduğu fiyat düşünüldüğünde yüksek bir potansiyele sahiptir. Alıç meyveleri ülkemizde geleneksel anlamda önemli görülmekle birlikte, son yıllarda alıç meyvelerinden üretilen marmelat, sirke ve turşu gibi ürünler de yoğun talep görmektedir. Farkı türlerinin bulunduğu alıç ayrıca peyzaj bitkisi olarak da değerlendirilebilmektedir. Günümüzde taze olarak 200-300 TL/kg fiyatlara alıcı bulabilmektedir. Ayrıca alıcın farklı bitki kısımları da çay olarak değerlendirilebilmektedir. Alıcın alternatif bir tür olarak potansiyel göstermesinin yanında akraba türlere (elma, armut, ayva vb.) anaç olma potansiyeli de ayrıca önem arz etmektedir. Sebepler değerlendirildiğinde alıcın mevcut meyve türlerine alternatif bir tür olarak değerlendirilmesi üzerinde durulması gereken bir konu olarak karşımıza çıkmaktadır.

Bu çalışmada, alıcın özellikleri, güncel çalışmalar ve endüstriyel potansiyeli tartışılarak ülkemizin doğal bitkisi olan bu türün mevcut meyve türlerine alternatif bir tür olarak kullanılması üzerine önerilerde bulunulacaktır.

Anahtar Kelimeler: Alıç, Crataegus, Potansiyel, Alternatif

HAWTHORN (*Crataegus spp.):* POTENTIALS AND FUTURE PERSPECTIVES AS AN ALTERNATIVE SPECIES

ABSTRACT

Developed societies have established their economies on solid foundations to achieve their development goals, and the first step in building this foundation has traditionally been agricultural production. Sustainable economic development largely depends on rural development, which in turn requires proper planning and the optimization of income obtained per unit area. Although Türkiye is classified among developing countries, it has not yet fully completed its agricultural development process. Problems encountered in agricultural planning have played a major role in prolonging this process.

Fruit growing is an important field of agricultural production and offers higher economic returns per unit area compared to field crops. Türkiye holds a significant position in this sector; however, in regions characterized by a continental climate and unfavorable soil conditions, fruit cultivation faces considerable challenges. As a result, many attempts in these areas have failed to achieve success, leading to significant losses of both time and financial resources.

Türkiye possesses remarkable plant genetic diversity and serves as a gene center for many wild species. Among these, hawthorn (*Crataegus* spp.) stands out as one of the most important. Considering its cultivation characteristics and the prices it can fetch in the market, hawthorn exhibits high potential as a valuable crop. While hawthorn fruits have traditionally been appreciated in Türkiye, there has been increasing demand in recent years for value-added products such as marmalade, vinegar, and pickles made from hawthorn. In addition, various species of hawthorn can be utilized as ornamental plants in landscaping. Fresh fruits can currently be sold at prices ranging from 200 to 300 TL per kilogram. Moreover, different parts of the plant are also used to produce herbal teas. Beyond its potential as an alternative fruit species, hawthorn's possible use as a rootstock for related species such as apple, pear, and quince further increases its importance. Considering these factors, the evaluation of hawthorn as an alternative fruit species represents a promising area for future agricultural development.

This study aims to discuss the characteristics, recent research findings, and industrial potential of hawthorn (*Crataegus* spp.), while providing recommendations for its use as an alternative fruit species native to Türkiye.

Keywords: Hawthorn, *Crataegus*, Potential, Alternative

1. GİRİŞ

Alıç (*Crataegus* spp.), Rosaceae familyasının önemli bir üyesi olup Anadolu florasında geniş bir taksonomik çeşitlilik göstermektedir. Türkiye, tür ve genetik varyasyon açısından Crataegus cinsinin önemli gen merkezlerinden biridir (Gerçekçioğlu ve ark., 2022). Anadolu'nun hemen her bölgesinde doğal olarak yetişen bu tür, ekolojik esnekliği sayesinde dağlık, kireçli ve düşük organik madde içeren marjinal topraklarda dahi gelişebilme kapasitesine sahiptir (İkinci ve ark., 2022; Aydemir, 2022). Bu nedenle alıç, tarımsal üretim için uygun olmayan alanların ekonomik olarak değerlendirilebileceği alternatif bir meyve türü olarak dikkat çekmektedir.

Ekolojik adaptasyon kabiliyeti kadar, biyokimyasal içeriği de türün önemini artırmaktadır. Alıç meyveleri yüksek oranda fenolik bileşikler, flavonoidler, C vitamini ve organik asitler içerir; bu özellikleriyle antioksidan kapasitesi oldukça yüksektir (Bostan & Mazı, 2021; Öztürk ve ark., 2022). Bu zengin içerik, alıcı yalnızca gıda sanayi için değil, fonksiyonel gıda ve fitoterapi

alanlarında da değerli kılmaktadır. Nitekim *Crataegus* türlerinden elde edilen ekstraktlar, kalp-damar sağlığı, hipertansiyon ve kolesterol kontrolü üzerine olumlu etkiler göstermektedir (Karagül, 2024).

Türkiye'de alıç genellikle yabani olarak değerlendirilen bir tür olmasına karşın, son on yılda yürütülen seleksiyon çalışmaları sonucunda birçok yerel tip belirlenmiş ve tescil aşamasına gelmiştir. Bu süreç, alıcın doğal bir bitkiden ekonomik değeri yüksek kültür meyvesi konumuna geçişini hızlandırmıştır (Akça & Bostan, 2022). Ayrıca, doğada kendiliğinden yetişme yeteneği ve düşük bakım gereksinimi sayesinde, iklim değişikliği koşullarında bile sürdürülebilir üretim potansiyeli taşımaktadır (Aydemir, 2022).

2. TÜRKİYE'DE ALIÇ YETİŞTİRİCİLİĞİNİN GELECEĞİ VE POTANSİYELİ

2.1. Yeni Tescilli Çeşitler ve Seleksiyon Çalışmaları

Türkiye'de alıç üzerine yapılan sistematik çalışmalar son yıllarda hız kazanmıştır. Birçok yörede bu çalışmalar yürütülmüş; Artvin (Çoruh Vadisi), Sivas, Tokat (Niksar), Yozgat, Kırşehir, Şanlıurfa, Ağrı, Hatay ve Diyarbakır bölgelerinde yürütülen seleksiyon çalışmaları, yüksek meyve kalitesine sahip birçok genotipin belirlenmesini sağlamıştır (Keles, 2018; Keles, 2021; Akça ve Bostan, 2022; Gerçekçioğlu ve ark., 2022; İkinci ve ark., 2022; Sağbaş, 2022; Göztak, 2023; Tuğrul ve Gürsoy, 2024; Çalışkan ve ark., 2025).

Bu çalışmaların en somut çıktılarından biri, 2023 yılında tescillenen "Sultan" çeşididir (Çalışkan ve ark., 2025). "Sultan" alıcı, *Crataegus azarolus* türüne aittir, iri meyve yapısı, yüksek suda çözünür kuru madde içeriği ve cazip rengiyle hem taze tüketim hem işleme sanayii için uygundur. Ayrıca "Polat Efe" adıyla yine 2023 yılında tescillenmiş *Crataegus orientalis* türüne mensup bir alıç çeşidi daha literatüre girmiştir.

2.2. Endüstriyel Kullanım Alanları ve Ekonomik Potansiyel

Alıç meyvesinin endüstriyel kullanım alanları giderek genişlemektedir. Gıda endüstrisinde marmelat, reçel, sirke, meyve suyu ve şarap üretiminde kullanımı artarken, farmasötik sektörde doğal antioksidan ve kalp sağlığı destekleyici içerikler olarak değerlendirilmektedir (Çavdar & Adar, 2024; Karagül, 2024). Ayrıca meyve çekirdeklerinden elde edilen yağ, yüksek düzeyde linoleik asit (yaklaşık %70) içeriğiyle kozmetik ve ilaç endüstrisinde potansiyel bir hammadde konumundadır (Öztürk ve ark., 2022).

Alıcın işlenmiş ürünlerine yönelik pazar talebi de yükseliştedir. Özellikle doğal ve fonksiyonel gıdalara yönelim, iç pazarda alıç bazlı ürünlerin değerini artırmıştır. Uluslararası pazarda ise özellikle Uzak Doğu ülkelerinde alıç, geleneksel tıp ve fonksiyonel içecek sektörlerinde yüksek talep görmektedir (Karagül, 2024).

2.3. Üretim Modelleri ve Yatırım Gelişmeleri

Son yıllarda tescilli alıç çeşitlerinin sözleşmeli üretim modeli ile yaygınlaştırılması hedeflenmektedir. "Sultan" ve "Polat Efe" çeşitlerinin üretim hakkını alan özel bir firma, 2000 dekar büyüklüğünde ticari bahçe kurulumuna başlamış ve üreticilerle sözleşmeli iş birliği modeli planlamıştır. Bu modelde üreticilerin en az 20 dekar büyüklüğünde bahçeler kurması öngörülmekte; ürünlerin firma tarafından ihracat amaçlı satın alınması düşünülmektedir. Böylece üretici açısından pazar garantisi oluşurken, organizasyon sahibi firmanın da ihracat yoluyla yüksek katma değer elde etmesi öngörülmektedir.

Bu girişim, alıç yetiştiriciliğini yalnızca marjinal topraklar için bir çözüm olmaktan çıkarıp, yüksek ekonomik potansiyele sahip organize bir üretim alanı hâline getirme yönünde önemli bir adımdır. Ayrıca sözleşmeli modelin, kırsal kalkınma projeleriyle entegre edilmesi

durumunda hem üretici gelirini artıracağı hem de ihracat kapasitesine katkı sağlayacağı düşünülmektedir.

2.4. Ekolojik ve Sürdürülebilir Değer

Alıç, ekolojik açıdan da dikkat çekici bir türdür. Kök yapısı sayesinde toprak erozyonunu önler, kıraç ve taşlık alanlarda stabilizasyon sağlar (Aydemir, 2022). Bu nedenle karayolu ve demiryolu güzergâhlarında yeşil şerit bitkisi olarak kullanımı önerilmektedir. Ayrıca çiçekleri arılar için önemli bir nektar kaynağı olduğundan, arıcılıkla entegre üretim modelleri geliştirilmesi mümkündür (Gerçekçioğlu ve ark., 2022).

Yüksek çevresel toleransı, düşük su gereksinimi ve hastalıklara dayanıklılığı nedeniyle alıç, iklim değişikliğine karşı dayanıklı tarımsal sistemlerin bir bileşeni olarak değerlendirilebilir. Bu özellikler, hem ekolojik sürdürülebilirlik hem de kırsal kalkınma açısından stratejik bir avantaj sunmaktadır.

3. SONUÇ VE ÖNERİLER

Alıç, Türkiye'nin geniş ekolojik çeşitliliği içinde marjinal alanların ekonomik olarak değerlendirilmesine olanak tanıyan en önemli alternatif meyve türlerinden biridir. Yeni tescilli çeşitlerin ortaya çıkması, bu türün tarımsal üretimde ticari bir değere dönüşümünü hızlandırmıştır. "Sultan" gibi tescilli genotipler, yüksek kalite ve verim potansiyeliyle hem işleme sanayi hem de ihracat pazarı açısından cazip fırsatlar sunmaktadır (Çalışkan ve ark., 2025).

Alıç yetiştiriciliğinde sürdürülebilir bir gelişim için şu adımlar önerilmektedir:

- Tescilli çeşitlerin çoğaltımı ve fide temin zincirinin oluşturulması,
- Sözleşmeli üretim modelinin yaygınlaştırılması,
- Üniversite–özel sektör iş birliğiyle Ar-Ge destekli ıslah programlarının sürdürülmesi,
- Meyve işleme teknolojilerinin geliştirilerek ihracata yönelik katma değerli ürün üretiminin teşvik edilmesi.

Sonuç olarak alıç, yalnızca tarım dışı alanlarda değil, uygun ekolojilerde de ekonomik potansiyeli yüksek bir türdür. Ekolojik dayanıklılığı, endüstriyel değerlendirilebilirliği ve pazar gücü sayesinde Türkiye'nin alternatif meyve üretiminde önemli bir stratejik tür olma yolundadır.

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KISINTILI SULAMANIN DOMATESTE ABA BİYOSENTEZİ VE OSMOTİK DÜZENLEME İLE İLİŞKİLİ GENLERİN (*SLNCED1 VE SLDREB2*) EKSPRESYON SEVİYELERİ ÜZERİNE ETKİSİ

Merve Dilek KARATAŞ

Department of Agricultural Biotechnology, Faculty of Agriculture, Van Yüzüncü Yıl University, Van, Türkiye

Email: mervegebologlu@yyu.edu.tr

ORCID ID: 0000-0002-1076-3648

ÖZET

Küresel iklim değişikliğiyle birlikte artan sıcaklık ve azalan yağışlar, özellikle yarı kurak bölgelerde su kaynaklarının sürdürülebilirliğini tehdit etmekte ve bitkisel üretimde ciddi verim kayıplarına neden olmaktadır. Domates *(Solanum lycopersicum* L.) gibi ekonomik öneme sahip türler, su kısıtı koşullarına karşı oldukça duyarlı olup, su stresine verilen yanıtın moleküler temellerinin aydınlatılması büyük önem taşımaktadır. Bu çalışmada, farklı düzeylerde kısıntılı sulamanın domateste su stresine yanıt veren *SlNCED1* ve *SlDREB2* genlerinin ekspresyon düzeyleri üzerine etkisi araştırılmıştır. Deneme, Van Yüzüncü Yıl Üniversitesi Ziraat Fakültesi serasında H-2274 çeşidi kullanılarak yürütülmüştür. Bitkiler %100, %66,6 ve %33,3 sulama seviyeleriyle sulanmış; gen ekspresyonu için yaprak örnekleri denemenin 15. ve 45. günlerinde toplanmıştır. RT-qPCR sonuçlarına göre, *SlNCED* geninin ekspresyon seviyesi sulama miktarı azaldıkça düşüş gösterirken; *SlDREB2* geninin ekspresyon seviyesi ise sulama miktarı ile birlikte artmıştır. Elde edilen bulgular, su kısıtı koşullarında ABA biyosentezinde görev alan *SlNCED1* geninin baskılandığını, buna karşılık ABA-bağımsız sinyal yolunda görev alan *SlDREB2* geninin aktive olduğunu ortaya koymaktadır. Bu durum, uzun süreli veya şiddetli stres koşullarında domates bitkisinin ABA-bağımlı yanıttan ABA-bağımsız adaptasyon mekanizmasına geçtiğini göstermektedir. Sonuç olarak, su stresine verilen yanıtın dinamik ve zamanla yeniden düzenlenen bir süreç olduğu, bu süreçte *SlDREB2*'nin stres toleransının sürdürülmesinde önemli rol oynadığı belirlenmiştir.

Anahtar Kelimeler: *SlNCED1*, *SlDREB2*, abiyotik stres, ABA sinyalizasyonu, gen ekspresyonu

ABSTRACT

Increasing temperatures and decreasing precipitation caused by global climate change threaten the sustainability of water resources, particularly in semiarid regions, and lead to significant yield losses in crop production. Economically important species such as tomato (*Solanum lycopersicum* L.) are highly sensitive to water deficit conditions, and elucidating the molecular basis of their response to water stress is of great importance. In this study, the effects of different levels of deficit irrigation on the expression of *SlNCED1* and *SlDREB2* genes both involved in the water stress response in tomato were investigated. The experiment was conducted in the greenhouse of Van Yuzuncu Yil University, Faculty of Agriculture, using the H-2274 tomato cultivar. Plants were irrigated at 100%, 66.6%, and 33.3% irrigation levels, and leaf samples for gene expression analysis were collected on the 15th and 45th days of the experiment. According to RT-qPCR results, the expression level of *SlNCED1* decreased with decreasing irrigation, whereas the expression of *SlDREB2* increased under more severe water deficit conditions. These findings indicate that *SlNCED1*, a key gene in ABA biosynthesis, is transcriptionally repressed under prolonged water limitation, while *SlDREB2*, a transcription factor involved in ABA-independent signaling pathways, is activated. This suggests that under extended or severe stress conditions, tomato plants may shift from an ABA-dependent response toward an ABA-independent adaptive mechanism. In conclusion, the molecular response to water stress in tomato appears to be dynamic and time-regulated, with *SlDREB2* playing a critical role in maintaining stress tolerance.

Keywords: *SlNCED1*, *SlDREB2*, abiotic stress, ABA signaling, gene expression

GİRİŞ

Su kıtlığı, dünya genelinde tarımsal üretimi sınırlayan başlıca çevresel stres faktörlerinden biridir (FAO, 2012; FAO, 2020). Küresel iklim değişikliği ile birlikte artan sıcaklık, azalan yağış miktarı ve düzensiz hidrolojik rejimler, özellikle yarı-kurak ve kurak bölgelerde su kaynaklarının kullanılabilirliğini azaltmaktadır (IPCC AR6, 2022; FAO, 2020). Bu durum, bitkisel üretimde su stresini artırarak verim kayıplarına yol açabilir (Ingrao et al., 2023). FAO, iklim değişikliği, su kaynaklarının tükenmesi ve artan tarımsal ihtiyaçlar nedeniyle 2050 yılına gelindiğinde birçok sulanabilir tarım alanında su kıtlığı riski oluşacağını belirtmektedir (FAO, 2020). Bu durum, suyun etkin kullanımını zorunlu kılmakta ve kısıntılı sulama stratejilerinin geliştirilmesini önemli hale getirmektedir. Domates (*Solanum lycopersicum* L.) dünya genelinde en fazla yetiştirilen sebze türlerinden biri olup, su stresi koşullarına karşı oldukça duyarlıdır (Krishna et al., 2022). Su kısıtı, domates bitkilerinde fotosentez hızının azalmasına, yaprak turgorunun düşmesine, hücre genişlemesinin yavaşlamasına ve sonuç olarak verim kaybına neden olur (Shao et al., 2008). Bitkiler, bu tür stres koşullarına karşı morfolojik, fizyolojik ve moleküler düzeyde çok yönlü adaptasyon mekanizmaları geliştirir (Bartels & Sunkar, 2005).

Moleküler düzeyde kuraklık yanıtının en erken göstergelerinden biri absisik asit (ABA) hormonunun birikimidir. ABA, köklerden yapraklara taşınarak stomatal kapanmayı teşvik eder ve su kaybını azaltır (Park et al., 2009). ABA biyosentezinde rol alan enzimlerden 9-cis-epoxycarotenoid dioxygenase (NCED), bu yolakta hız kısıtlayıcı basamakta görev alır ve genellikle su stresi altında hızlı şekilde indüklenir (Iuchi et al., 2001). Domateste *SlNCED1* gen ekspresyonu, su stresi koşullarında sıklıkla yukarı regüle olmaktadır; bu artış, ABA biyosentezinin yükselmesiyle ilişkili olarak stres sinyalizasyon yollarını destekleyebilir (Thompson et al., 2000; Vo et al., 2025). Dolayısıyla *SlNCED1*, bitkinin stres algılamasında erken bir genetik belirteç olarak kabul edilmektedir.

ABA'ya ek olarak, bitkiler kuraklığa karşı ABA-bağımsız sinyal yolları da kullanmaktadır. Bu yollarda görev yapan Dehydration-Responsive Element Binding Protein 2 (*DREB2*), bitkilerin çevresel streslere verdiği yanıtın önemli düzenleyicilerinden biridir. *DREB2* ailesine ait transkripsiyon faktörleri, DNA üzerinde DRE/CRT (dehydration-responsive element/C-repeat) bölgelerine bağlanarak stresle ilişkili genlerin ekspresyonunu aktive eder (Lata & Prasad, 2011). Domateste tanımlanan *SlDREB2*, kuraklık, tuzluluk ve yüksek sıcaklık koşullarında aktive olur; hücresel su dengesinin korunmasında, protein stabilizasyonunda ve metabolik adaptasyon süreçlerinde görev alır (Hichri et al., 2016; Guo et al., 2011). Dolayısıyla, *SlNCED1* ve SlDREB2, su stresi koşullarında ABA-bağımlı ve ABA-bağımsız yanıt mekanizmalarını temsil eden iki tamamlayıcı bileşen olarak görev yapmaktadır.

Bu nedenle, su stresine verilen yanıtın hem hormonal sinyalizasyon (ABA biyosentezi ve iletimi) hem de ABA-bağımsız transkripsiyonel düzenleme (*DREB2* aracılı gen ekspresyonu) yönlerini eş zamanlı olarak değerlendirmek, domatesin su kısıtına karşı geliştirdiği tolerans mekanizmalarının daha kapsamlı biçimde anlaşılmasına olanak tanır. Bu kapsamda, kısıntılı sulama koşullarının domates bitkilerinde su stresine yanıt veren iki genin (*SlNCED1* ve *SlDREB2*) ekspresyon düzeyleri üzerindeki etkilerinin incelenmesi, bitkinin stres yanıtının moleküler temellerinin ortaya konulması açısından önem taşımaktadır. Ayrıca gen ekspresyonundaki değişimlerin stresin erken (15. gün) ve geç (45. gün) dönemlerinde karşılaştırılması, su stresine verilen yanıtın ABA-bağımlıdan ABA-bağımsıza geçiş sürecini ve bu yanıtın zaman içindeki dinamik düzenlenmesini anlamaya katkı sağlayacaktır.

MATERYAL VE METOD

Bitki Materyali ve Deneme Dizaynı

Çalışma Van Yüzüncü Yıl Üniversitesi Ziraat Fakültesi'nin kontrollü iklim odalarında yürütülmüştür. Sera ortamında ortalama sıcaklık gündüzleri 25 ± 2 °C, geceleri 18 ± 2 °C, bağıl nem %60–70 ve fotoperiyot 16 saat aydınlık / 8 saat karanlık olacak şekilde ayarlanmıştır. Çalışmada *Solanum Lycopersicum* L., - cv. H2274 çeşidi kullanılmıştır. Fideler 3-4 yapraklı dönemde eşit gelişim düzeyinde olacak şekilde seçilerek saksılara dikilmiştir. 3 tekerrürlü tamamen tesadüfi faktöriyel deneme deseninde yürütülen çalışmadaki saksı sayısı 9'dur. Çalışmada hava kurusu halindeki elenmiş topraklar saksılara aktarılmış akabinde fide aşamasındaki domates bitkilerinin dikimi gerçekleştirilmiştir. Sulamalarda 3 farklı değişen sulama suyu seviyesi (% 100: tam sulama, % 66.66: tam sulamanın 2/3'ü seviyesinde kısıntılı sulama ve % 33.33: tam sulamanın 1/3'ü seviyesinde kısıntılı sulama) kullanılmıştır. . İlk sulamada tüm saksılara eşit miktarda saksı kapasitesine tamamlanacak şekilde sulama yapılmıştır. Bu dönemden sonraki sulamalara değişen sulama suyu seviyeleri ile (% 100, % 66.66 ve % 33.33) üç gün aralıklı olarak devam edilmiştir. Gen ekspresyonu için örnekler çalışma başladıktan sonraki 15. günde ve 45. günde alınmış; gen ifade düzeylerinin farklılıklarına bakılmıştır.

Gen Ekspresyon Analizi

Gen ekspresyon analizinde yaprak örnekleri 15. ve 45. günde her bir uygulama için üç biyolojik tekrar halinde toplanmış ve RNA izolasyon aşamasına kadar -80°C'de saklanmıştır. RNA izolasyonundan önce, dondurulmuş yaprak dokuları sıvı nitrojen kullanılarak toz haline getirildi. RNA izolasyonu TRIzol reaktifi (Nucleogene) kullanılarak gerçekleştirildi ve elde edilen RNA'ların saflığı ve miktarı, NanoDrop spektrofotometresi (Thermo Scientific) kullanılarak bakıldı. Tamamlayıcı DNA (cDNA) sentezi, RNA örnekleri 10 ng/µL'lik son konsantrasyona seyreltilerek Solver (SLV-M-2021-007) cDNA Sentez Kiti kullanılarak gerçekleştirildi. Daha sonra, Rotor-Gene Q9000 sistemi (Qiagen) üzerinde Solver qPCR Master Mix (SLV-M-2021-002) kullanılarak kantitatif gerçek zamanlı PCR (RT-qPCR) gerçekleştirildi. Deneysel hatayı en aza indirmek için, PCR reaksiyonları tüm örnekler için iki kez gerçekleştirildi. Analiz için 3 gen kullanıldı: 2 hedef gen (*SlNCED1*, *SlDREB2*) ve referans gen *β-actin*. Gen-spesifik primer dizileri ve bağlanma sıcaklıkları Tablo 1'de listelenmiştir. *SlNCED1, SlDREB2* ve *SlActin* için primerler Chen ve ark. (2024), Tao ve ark. (2022) ve Løvdal ve ark. (2009) tarafından bildirilen çalışmalardan referans alınmıştır. *β-actin* geni, RT-qPCR reaksiyonlarında Ct değerlerinin normalizasyonu için dahili kontrol olarak kullanılmıştır.

Table 1. Gene name, nucleotide sequences, annealing temperatures, and accession numbers

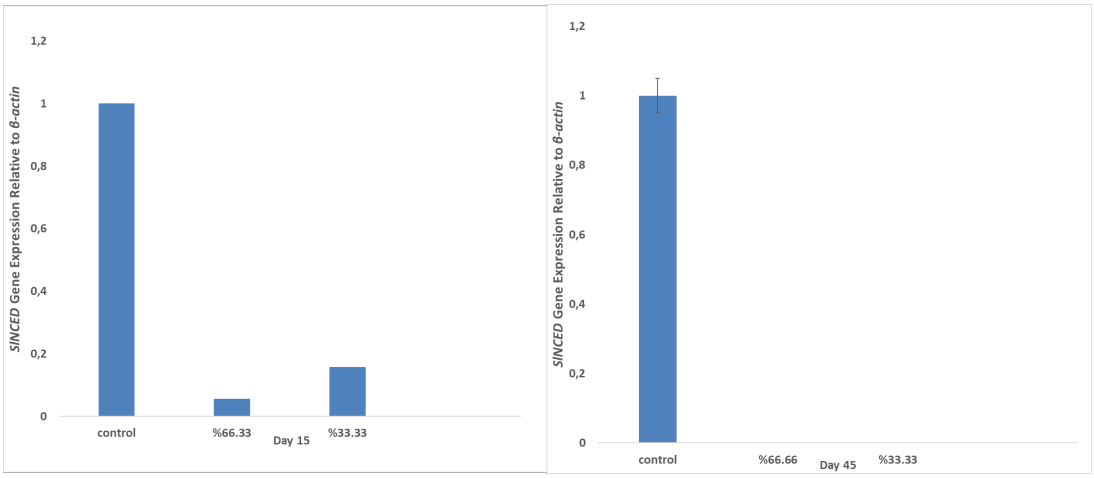
Gene Name	Forward Sequence	Reverse Sequence	Annealing Temperature
SlNCED1	TGGCAGATTTGGTTCGGAGG	ACAGCTGACTTTCCGGTGTT	59°C
SlDREB2	ATCGCCATCTTCCGTTCTTC	AACGCCCGAAACTAACGAC	57°C
SlActin	GAAATAGCATAAGATGGCAGACG	ATACCCACCATCACACCAGTAT	59°C

İstatistiksel Analiz

Gen ekspresyon düzeyleri, Livak ve Schmittgen (2001) tarafından tanımlanan göreceli kantifikasyon (relative quantification) yöntemine dayalı olarak çevrimiçi gen ekspresyon analiz araçları kullanılarak hesaplanmıştır.

BULGULAR VE TARTIŞMA

Kısıntılı sulama uygulamaları, domates bitkilerinde *SlNCED1* geninin ekspresyon düzeylerini önemli ölçüde etkilemiştir (Şekil 1). Denemenin 15. gününde kontrol grubunda gen ifadesi en yüksek düzeyde belirlenmiş, sulama oranı azaldıkça ekspresyon düzeyinde de belirgin bir azalma gözlenmiştir. %66.6 sulama uygulanan grupta *SlNCED1* geninin ekspresyonu kontrolün yaklaşık %10'u düzeyine gerilerken, %33.3 sulama uygulanan grupta ise bu oran yaklaşık %20 düzeyinde kalmıştır. Denemenin 45. gününde ise *SlNCED1* geninin ifadesi kontrol grubunda yüksek seviyede devam etmiş, kısıntılı sulama uygulanan gruplarda ise gen ifadesi neredeyse tamamen baskılanmıştır. Bu sonuçlar, hem erken (15. gün) hem de geç (45. gün) dönemde artan su kısıtının *SlNCED1* geninin transkripsiyonel aktivitesini bastırdığını göstermektedir.

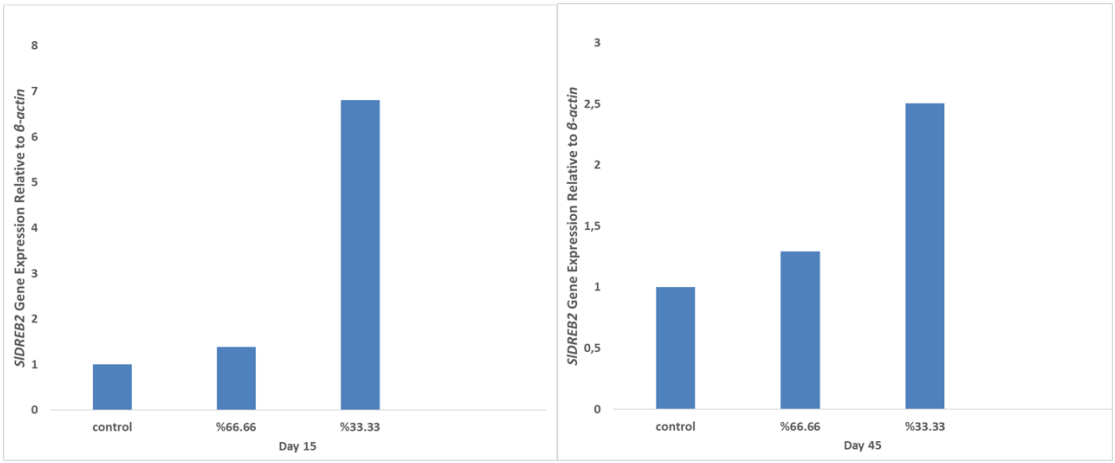


Şekil 1. *SlNCED* geninin sulama seviyelerine göre ifadesi (15. ve 45. gün)

SlNCED1, absisik asit (ABA) biyosentezinde hız kısıtlayıcı basamakta görev alan 9-cis-epoxycarotenoid dioxygenase (NCED) enzimini kodlar ve özellikle kuraklık/dehidrasyon koşullarında sıklıkla yukarı düzenlenir (Iuchi et al., 2001; Thompson et al., 2000). Ancak bu çalışmada gözlenen gen ifadesindeki azalma, stresin süresine ve şiddetine bağlı olarak *SlNCED1*'in geç dönemde baskılanabileceğini düşündürmektedir. Nambara ve Marion-Poll (2005), uzun süreli meydana gelen stres sonrasında ABA katabolizmasının devreye girerek hormon düzeylerini dengeleyerek metabolik/genetik bir yeniden ayarlama yaşandığını belirtir. Bu bulgular, domatesin uzun süreli veya şiddetli su kısıtı altında ABA biyosentezini azaltarak enerji dengesinin korumaya yönelebileceğini düşündürmektedir. Sonuç olarak, *SlNCED1* geninin hem 15. hem 45. günde azalan ekspresyonu, kısıntılı sulama koşullarında domatesin ABA-bağımlı yanıt mekanizmasından ABA-bağımsız adaptasyon stratejisine geçmiş olabileceğini göstermektedir. Bu geçiş, stresin süresi ve şiddetine bağlı olarak dinamik biçimde düzenlenen bir moleküler adaptasyon süreci olarak da yorumlanabilir.

Kısıntılı sulama uygulamalarının domates bitkisinde *SlDREB2* geninin ekspresyonu Şekil 2'de verilmiştir. Denemenin 15. gününde kontrol grubunda en düşük ekspresyon oranı gözlenmiş olup; sulama kısıtı oldukça ekspresyon seviyesi artmıştır. %33.33 sulama uygulanan grupta en yüksek gen ifadesi gözlenmiş yaklaşık 7 katlık bir artış olmuştur. Kontrol grubunda ve %66.66'lık grupta ise gen ifade seviyeleri hemen hemen aynı olmuştur. Denemenin 45. gününde ise *SlDREB2* geninin ifadesi kontrol grubunda en düşük seviyede iken %66.66 su kısıtı

uygulanan grupta kontrol ile benzer seviyede ifade olmuştur. %33.33 su kısıtı uygulanan grupta ise en yüksek ekspresyon oranı görülmüş, yaklaşık 2,5 kat artmıştır. Bu sonuçlar, hem erken (15. gün) hem de geç (45. gün) dönemde su kısıtı uygulamasının arttıkça *SlDREB2* geninin transkripsiyonel aktivitesinin de arttığını göstermektedir.



Şekil 2. *SlDREB2* geninin sulama seviyelerine göre ifadesi (15. ve 45. gün)

DREB (Dehydration-Responsive Element-Binding) transkripsiyon faktörleri, bitkilerin ABA-bağımsız stres yanıtı mekanizmalarının temel düzenleyicileridir. Bu gen ailesi, su eksikliği, tuzluluk ve yüksek sıcaklık gibi abiyotik stres koşullarında hücre zarının bütünlüğünü korumak, antioksidan enzimleri düzenlemek ve ozmotik dengeyi sağlamak gibi işlevleri kontrol etmektedir (Lata & Prasad, 2011). Özellikle *SlDREB2* geni kuraklık ve tuzluluk gibi abiyotik stres altında yukarı regüle olarak toleransın sürdürülmesinde önemli rol oynamaktadır. Hichri et al. (2016), *SlDREB2*'nin domates ve Arabidopsis bitkilerinde NaCl ve su kısıtı koşullarında anlamlı şekilde arttığını ve bu genin aşırı ekspresyonunun stres toleransını artırdığını bildirmiştir. Benzer şekilde Guo & Wang (2011), *LeDREB2* geninin domateste farklı abiyotik streslerde yukarı regüle olduğunu ve özellikle genç yaprak ile kök dokularında daha yüksek ifade gösterdiğini rapor etmiştir. Bu çalışma sonucunda gözlenen *SlDREB2* gen ifadesi artışı, domatesin kısıntılı sulama koşullarında ABA-bağımlı sinyallerden bağımsız bir adaptasyon stratejisi geliştirdiği için olabilir. Bu genin erken (15. gün) dönemde hızlı şekilde aktive olması, su stresinin algılanmasında ve hücresel savunma yanıtının başlatılmasında kritik rol oynadığını göstermektedir. Geç dönemde (45. gün) ekspresyon düzeylerinin görece azalmasına rağmen kontrolün üzerinde kalması, stres yanıtının devam ettiğini ve bitkinin uzun süreli adaptasyon sürecinde DREB2-aracılı mekanizmaları koruduğunu ortaya koymaktadır.

SONUÇ

Bu çalışmada, farklı düzeylerde kısıntılı sulamanın domates bitkisinde su stresine yanıt veren *SlNCED1* ve *SlDREB2* genlerinin ekspresyon düzeyleri üzerindeki etkileri incelenmiştir. RT-qPCR analizleri, artan su kısıtının *SlNCED1* geninin ifadesini baskıladığını, buna karşılık *SlDREB2* geninin ekspresyonunu belirgin biçimde artırdığını ortaya koymuştur. Bu durum, su stresinin erken dönemlerinde ABA biyosentezine dayalı bir yanıtın baskın olduğunu, ancak stresin şiddetinin ve süresinin artmasıyla birlikte bitkinin ABA-bağımlı yanıttan ABA-bağımsız bir adaptasyon stratejisine geçtiğini göstermektedir. Elde edilen sonuçlar, domatesin uzun süreli veya şiddetli su kısıtı altında enerji dengesini korumak ve hücresel bütünlüğünü sürdürmek için DREB2-aracılı stres yanıtlarını aktive ettiğini göstermektedir. Bu da *SlDREB2* geninin su stresi koşullarında toleransın sürdürülmesinde kilit bir moleküler belirteç olabileceğini düşündürmektedir. Çalışma, kısıntılı sulama altında gen ekspresyonu temelli adaptasyon süreçlerinin aydınlatılmasına katkı sağlamış olup, gelecekte su kullanım verimliliğini artırmaya yönelik genetik ve fizyolojik araştırmalar için temel bir veri seti sunmaktadır.

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TÜRKİYE TOPRAKLARINDAN İZOLE EDİLEN BAKTERİ SUŞLARI İLE OLUŞTURULMUŞ MİKROBİYAL GÜBRE FORMÜLASYONLARININ SERA KOŞULLARINDA DANELİK MISIR (*Zea mays* l.) BİTKİSİ ÜZERİNDEKİ ETKİLERİNİN ARAŞTIRILMASI

Mehmet Halil ÖZSÜER

Melike OĞUZ

Burak TOLU

Onur ÖKSÜZ

Fatih KARABULUT

GÜBRETAŞ Ar-Ge Merkezi Kocaeli, TÜRKİYE

ÖZET

Toprak mikrobiyal çeşitliliği, bitki besin elementlerinin döngüsünde kritik bir rol oynamakta ve sürdürülebilir tarım uygulamalarının temelini oluşturmaktadır. Kimyasal gübrelerin uzun süreli ve aşırı kullanımı, toprak mikrobiyal dengesini bozarak ekosistem sağlığını olumsuz etkilemektedir. Bu çalışmada, Türkiye'nin farklı bölgelerinden izole edilen *Bacillus* ve *Pseudomonas* türü bakteri suşlarından oluşturulan mikrobiyal gübre konsorsiyumlarının, mısır (*Zea mays L.*) bitkisi üzerindeki üst aksam yaş ve kuru ağırlık, kök kuru ağırlığı ve üst aksam boy uzunluk parametreleri sera koşullarında değerlendirilmiştir. Elde edilen bulgular, özellikle GFBİO1 uygulamasının üst aksam yaş ağırlığında %33,4 ve üst aksam kuru ağırlığında %42,70 oranında artış sağladığını göstermiştir. GFBİO5 uygulaması ise, gövde kalınlığı üzerine %15 ve kök kuru ağırlığı üzerine %9 oranında artış sağlamıştır. Araştırma sonucunda, bazı mikrobiyal formülasyonların bitki gelişimi ve verimi açısından kimyasal gübrelere benzer veya üstün etki gösterdiği belirlenmiştir. Elde edilen veriler, biyogübrelerin sürdürülebilir tarımda potansiyel bir alternatif olduğunu göstermektedir.

Bu kapsamda, kontrol grubu ile karşılaştırıldığında, GFBİO1 ve GFBİO5 konsorsiyumlarının mikrobiyal gübre olarak umut vadettiği belirlenmiştir. Başarılı bulunan mikrobiyal gübre konsorsiyumlarının ilerleyen süreçte tescillenerek ticari ürüne dönüştürülmesi planlanmaktadır.

Anahtar Kelimeler: Mikrobiyal gübre, *Bacillus*, *Pseudomonas*, *Zea mays*, biyogübre, sürdürülebilir tarım, bitki büyümesi, sera koşulları

INVESTİGATION OF THE EFFECTS OF MICROBIAL FERTILIZER FORMULATIONS CREATED WITH BACTERIAL STRAINS ISOLATED FROM TURKISH SOILS ON GRAIN CORN (*ZEA MAYS L.*) PLANTS UNDER GREENHOUSE CONDITIONS

ABSTRACT

Soil microbial diversity plays a critical role in the cycling of plant nutrients and forms the basis of sustainable agricultural practices. Long-term and excessive use of chemical fertilizers disrupts the soil microbial balance, negatively impacting ecosystem health. In this study, microbial fertilizer consortia composed of Bacillus and Pseudomonas bacterial strains isolated from different regions of Turkey were evaluated under greenhouse conditions for the parameters of aerial fresh and dry weight, root dry weight, and aerial height on corn (Zea mays L.) plants. The findings showed that the GFBİO1 application, in particular, increased aerial fresh weight by 33.4% and aerial dry weight by 43.40%. The GFBİO5 application, on the other hand, increased stem thickness by 15% and root dry weight by 9%. The study determined that some microbial formulations have similar or superior effects to chemical fertilizers in terms of plant growth and yield. The obtained data suggest that biofertilizers are a potential alternative in sustainable agriculture.

In this context, when compared with the control group, the GFBİO1 and GFBİO5 consortia were determined to be promising microbial fertilizers. The successful microbial fertilizer consortia are planned to be registered and converted into commercial products in the future.

Keywords: *Microbial fertilizer, Bacillus, Pseudomonas, Zea mays, biofertilizer, sustainable agriculture, plant growth, greenhouse conditions*

GİRİŞ

Günümüz tarımında verimliliği artırmak amacıyla yaygın şekilde kullanılan kimyasal gübreler, uzun vadede toprak kalitesini olumsuz etkileyerek biyoçeşitlilik kaybına ve çevresel bozulmaya yol açmaktadır (Zhang ve ark., 2023). Sürdürülebilir tarım uygulamalarının gerekliliği, bitki büyümesini destekleyen mikrobiyal çözümlerin önemini artırmıştır. Bitki gelişimini teşvik eden rizobakteriler (PGPR), azot fiksasyonu, fosfat çözünürlüğü, indol asetik asit üretimi ve siderofor salgılanması gibi biyolojik mekanizmalarla bitki besin elementlerinin biyoyararlılığını artırmaktadır (Bhattacharyya ve Jha, 2012; Vejan ve ark., 2016).

Bacillus ve *Pseudomonas* cinsleri, biyogübre üretiminde öne çıkan mikrobiyal gruplar arasında yer almakta, bitki kökleri ile simbiyotik ilişkiler kurarak hem biyotik hem abiyotik streslere karşı direnç geliştirmektedir (Backer ve ark., 2018). Ayrıca, fosfat çözümleyen mikroorganizmaların toprakta sınırlı bulunan fosforun bitki tarafından erişilebilir hale gelmesinde oynadığı rol, kimyasal gübre kullanımını azaltma potansiyeli açısından önem arz etmektedir (Sharma ve ark., 2013).

Bu çalışmada, Türkiye'nin farklı bölgelerinden elde edilen toprak örneklerinden izole edilen bakteriyel suşlar ile oluşturulan mikrobiyal gübrelerin, sera koşullarında mısır bitkisi üzerine etkileri incelenmiştir. Amaç, alternatif ve çevre dostu gübre seçeneklerinin tarıma kazandırılmasıdır.

Bu çalışmada, Türkiye'nin farklı bölgelerinden Adana Saimbeyli ve Dokuztekne, Doğu Karadeniz Kaçkar Dağları, Çanakkale Gökçeada ve Bozcaada, Karaman Karadağ, Balıkesir Balya) toplanan toprak örneklerinden izole edilen mikroorganizmalar kullanılarak, sera koşullarında biyolojik gübre olarak değerlendirilebilecek suşlar belirlenmiştir. Bu amaçla kullanılan mikroorganizmalar şunlardır: GFBİO1 (RC631 *Bacillus subtilis*, GBF01 *Bacillus megaterium*, GBF251 *Pseudomonas fluorescens*), GFBİO2 (RC631 *Bacillus subtilis*, GBF14 *Bacillus megaterium*, GBF251 *Pseudomonas fluorescens*), GFBİO3 (RC631 *Bacillus subtilis*, A54 *Bacillus pumilus*, GBF251 *Pseudomonas fluorescens*), GFBİO4 (RC631 *Bacillus subtilis*, GBF01 *Bacillus megaterium*, GBF251 *Pseudomonas fluorescens*), GFBİO5 (GBF07 *Pseudomonas putida*, GBF120 *Bacillus megaterium*, GBF72 *Bacillus subtilis*).

MATERYAL METOT

Toprak Örneklerinin Alınması

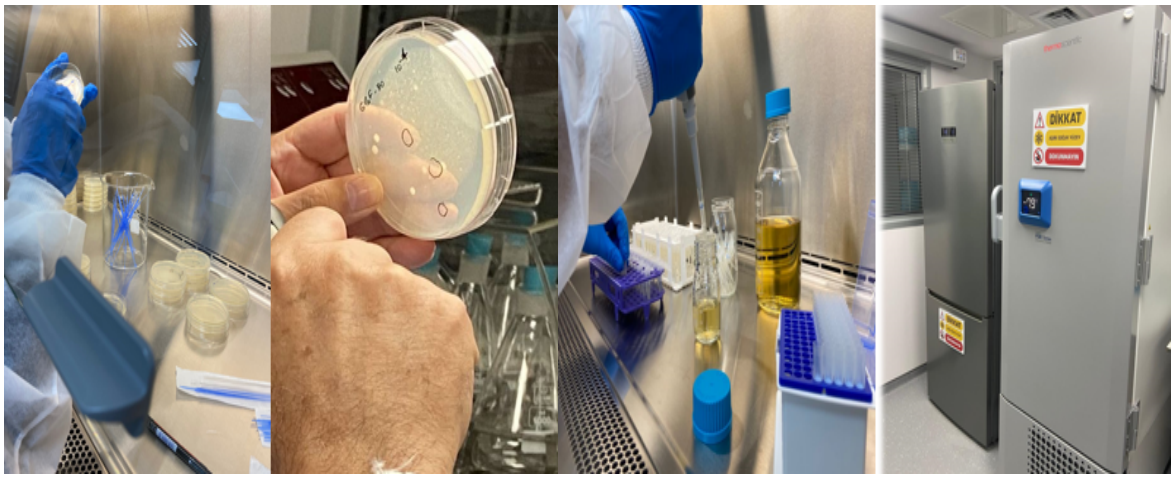
Bu çalışma kapsamında, Adana Ceyhan Dokuztekne ve Adana Saimbeyli Beypınarı, Çanakkale Gökçeada Yeni Çamlık ve Çanakkale Bozcaada Mumcular Üzüm Bağları, Doğu Karadeniz Kaçkar Dağları, Karaman Karadağ, Balıkesir Balya bölgelerinden alınan toprak numunelerinde toprağın üst kısmı temizlenmiştir. Daha sonra steri olarak hazırlanan 0 – 15 cm arası derinlikte, bitki kök bölgesine yakın kısımdan yaklaşık 500g alınan toprak numuneleri, +4 ^{O}C' de laboratuvara transfer edilmiştir. Analize alınıncaya kadar +4 ^{O}C' de muhafaza edilmiştir. Bitkilerden alınan toprak numunelerine ait görseller Şekil 1' de verilmiştir.



Şekil 1. Bitkilerden Alınan Toprak Numunelerinin Görselleri

Topraktan Bakteri İzolasyonu

Aseptik koşullarda laboratuvara getirilen toprak örnekleri, biyogüvenlik kabini içerisinde açılarak, mikroorganizmalar izole edilmiştir. Stoklanan mikroorganizmalara ait görseller Şekil 2'de sunulmuştur.



Şekil 2. Bitkilerden alınan toprak numunelerinden izole edilerek stoklanan mikroorganizmalara ait görseller

Bakteri Suşlarının Bruker Maldi – Tof MS Sisteminde İdentifikasyonu (Tanılama)

Elde edilen bakteri izolatlarının identifikasyonu MALDI-TOF MS (Matrix Assisted Laser Desorption Ionization–Time of Flight Mass Spectrometry, Bruker Daltonics GmbH, Bremen, Almanya) sistemi kullanılarak gerçekleştirilmiştir. Tanımlama aşamasında, saf kültürlerden elde edilen örneklerde protein ekstraksiyonu için etanol–formik asit bazlı ön işlem uygulanmıştır.

Örneklerden elde edilen kütle spektrumları cihazın flexControl yazılımı (Biotyper 3.0; Microflex LT, Bruker Daltonics GmbH, Bremen, Almanya) aracılığıyla kaydedilmiş ve MALDI Biotyper Real-Time Classification (RTC) yazılımındaki referans veri tabanı ile karşılaştırılarak değerlendirilmiştir. Sonuçların yorumlanmasında sistemin verdiği log(score) değerleri esas alınmış; 2.000–3.000 aralığındaki skorlar tür düzeyinde güvenilir tanımlama (yeşil seviye), 1.700–1.999 aralığındaki skorlar ise cins düzeyinde ya da muhtemel tür düzeyinde tanımlama (sarı seviye) olarak kabul edilmiştir (Carolis ve ark., 2012; Chalupová ve ark., 2014; Kara ve ark., 2017; Uysal ve ark., 2018).

Sera Denemesi

Denemede kullanılan toprak materyali ülkemiz toprakları temsil edilecek şekilde seçilmiş olup daha önce yetiştiricilik yapılmamış bir araziden temin edilmiştir. Deneme toprağının bazı kimyasal ve fiziksel özellikleri Tablo 1'de verilmiştir. Analiz sonuçlarına göre denemede kullanılan toprak; killi bünyeye sahip, alkali karakterli, tuzsuz, çok kireçli ve organik maddece çok az sınıfında yer almaktadır. Alınabilir P, K ve değişebilir Ca elementlerince zengin, alınabilir Fe, Mn ve Cu elementleri miktarları ise yeterli düzeydedir. Alınabilir Zn bakımından çok fazla sınıfta iken değişebilir Mg elementlerince az olarak sınıflandırılmıştır.

Tablo 1. Denemede kullanılan toprak örneğinin kimyasal özellikleri

Parametre	Metod	Sonuç	Değerlendirme
Bünye	Bouyoucos	72,60	Kil
pH	01:02,5	7,95	Alkali
EC (µS/cm)	01:02,5	-	-
Kireç (%)	Scheibler	28,26	Çok kireçli
Organik Madde(%)	Walkley-Black	0,32	Çok az
Toplam N (%)	Kjeldahl	0,016	Çok fakir
Alınabilir P(mg/kg)	Olsen-Spektro	26,00	Yüksek
Alınabilir K(mg/kg)	A.Asetat-ICP	79,00	Fazla
Değişebilir Ca(mg/kg)	A.Asetat-ICP	6360	Fazla
Değişebilir Mg(mg/kg)	A.Asetat-ICP	95,80	Az
Alınabilir Fe(mg/kg)	DTPA-ICP	5,20	Yeterli
Alınabilir Mn(mg/kg)	DTPA-ICP	2,64	Yeterli
Alınabilir Zn (mg/kg)	DTPA-ICP	17,21	Çok fazla
Alınabilir Cu (mg/kg)	DTPA-ICP	0,53	Yeterli

Bu çalışma, Gübre Fabrikaları TAŞ. ve Gebze Teknik Üniversitesi iş birliği kapsamında kurulan kurulan cam serada yürütülmüştür. Sera ortamında 5,5 litrelik saksılarda danelik mısır *Zea mays L.*) çeşidi yetiştirilmiştir. Sera koşullarında gerçekleştirilen deneme toplam 28 saksıdan oluşmaktadır (7 konu x 4 tekerrür) ve her saksıda bir bitki olacak şekilde toplamda 28 bitki üzerinde çalışılmıştır. Deneme deseni Tablo 2'de verilmiştir

Tablo 2. Sera deneme deseni

Bitki	Konular	Saksı No			
	Kontrol	1	2	3	4

MISIR	**Negatif Kontrol**	5	6	7	8
	GFBİO1	9	10	11	12
	GFBİO2	13	14	15	16
	GFBİO3	17	18	19	20
	GFBİO4	21	22	23	24
	GFBİO5	25	26	27	28

Denemenin hazırlık aşamasında, saksı başına 5,2 kg toprak ve iyi yanmış vasıflı hayvan gübresi karışımı tartılmış, 150 ppm azot, 25 ppm fosfor ve 30 ppm potasyum ile zenginleştirilmiş, ardından homojenleştirme amacıyla karıştırılmıştır. Bazal gübreleme olarak MAP ($NH_4H_2PO_4$), [Kalsiyum Nitrat [$Ca(NO_3)_2$] ve Potasyum Sülfat (K_2SO_4) gübreleri kullanılmıştır. Bakteri uygulamaları için GÜBRETAŞ Ar-Ge Laboratuvarı tarafından temin edilen 5 farklı mikrobiyal gübre konsorsiyumu (GBF1, GBF2, GBF3, GBF4 ve GBF5) kullanılmış ve uygulan dozajlar CFU değerleri ($1x10^7$ kob ml^{-1}) eşitlenecek şekilde hesap edilmiştir. Deney süresince uygulama gruplarına saksı başına 5ml/saksı/ dozunda 95 ml su karıştırılarak, ilki fide dikim esnasında can suyu ile birlikte, diğeri dikimden 30 gün sonra olmak üzere iki uygulama gerçekleştirilmiştir.

Denemede, üst yaş ve kuru ağırlık (gr/saksı), gövde kalınlığı (gr/saksı), üst aksam uzunluğu (cm/saksı), kök kuru ağırlığı (gr/saksı) ve yaprak mineral analiz (ppm) kriterleri üzerinde durulmuştur. Tesadüf parselleri deneme deseni düzeninde 4 tekrarlı olarak yürütülen araştırmadan elde edilen veriler, SPSS (sürüm 17.0) istatistik paket programında deneme desenine uygun olarak değerlendirilmiştir. Ortalamalar arasındaki farklılıkları belirlemek için %5 önem düzeyinde LSD testi kullanılmıştır.

BULGULAR VE TARTIŞMA

Örneklerin Toplanması ve Mikroorganizmaların İzolasyonu

Bu çalışma kapsamında, Adana Ceyhan Dokuztekne ve Adana Saimbeyli Beypınarı, Çanakkale Gökçeada Yeni Çamlık ve Çanakkale Bozcaada Mumcular Üzüm Bağları, Doğu Karadeniz Kaçkar Dağları, Karaman Karadağ, Balıkesir Balya bölgelerinden alınan toprak numunelerinde toprağın üst kısmı temizlenerek örnekler alınmıştır. Bu bitkilerden yapılan izolasyonlar sonucunda farklı mikroorganizma türlerinin besi yerlerinde gelişim gösterdiği gözlemlenmiştir. İnkübasyon sonucunda, Nutrient agar besi yerinde yaklaşık 84 bakteri kolonisinin geliştiği belirlenmiştir. Bu koloniler arasından, farklı türde bakteri temsil eden toplam 7 saf izolat elde edilmiştir.

Mikroorganizma Türlerinin MALDI-TOF MS Tekniği ile Tanımlanması

Farklı bölgelerden (Adana, Çanakkale, Doğu Karadeniz, Karaman ve Balıkesir) alınan toprak örneklerinden mikroorganizmalar izole edilmiştir. Elde edilen izolatların identifikasyonu MALDI-TOF MS sistemi kullanılarak gerçekleştirilmiş, log(score) değerlerine göre tür ve cins düzeyinde güvenilir tanımlamalar yapılmıştır. Elde edilen sonuçlar Tablo 3'de verilmiştir.

Tablo 3. Bruker Maldi – Biotyper identifikasyon sonuçları

MİKROORGANİZMA ID	MALDI-TOF MS SONUCU
GBF01	*Bacillus megaterium*
GBF07	*Pseudomonas putida*
GBF14	*Bacillus megaterium*
GBF120	*Bacillus megaterium*
GBF251	*Pseudomonas fluorescens*
A54	*Bacillus pumilus*
RC631	*Bacillus subtilis*

Sera Denemesi

Mikrobiyal gübre uygulamasının mısır bitkisinin üst aksam yaş ağırlığı üzerine etkisi Tablo 4'de verilmiştir. Mikrobiyal gübre uygulamasının üst aksam yaş ağırlık değerleri kontrol grubuna kıyasla GFBİO1 uygulamasında %33,4, GFBİO3'te %27,0 ve GFBİO5 uygulamasında ise %27,8 artış göstermiştir. Sera koşullarında mısır bitkisi üzerinde yapılan denemede bakteri uygulaması kontrol grubuna kıyasla, üst aksam yağ ağırlığında % 63,0 oranında artış sağladığını bildirmiştir (Youseif, 2018).

Tablo 4. Mısırda mikrobiyal gübre uygulamasının üst aksam yaş ağırlığı üzerine etkisi

Uygulamalar	Üst Aksam Yaş Ağırlığı (g/bitki)	Kontrol'e Göre Artışlar (%)
KONTROL	23,51c±3,51	-
NK	25,52bc±3,15	8,54
GFBİO1	31,36a±5,11	33,40
GFBİO2	27,80abc±2,27	18,24
GFBİO3	29,87ab±0,51	27,00
GFBİO4	25,86abc±1,55	10,00
GFBİO5	30,04ab±1,48	27,80

Mikrobiyal gübre uygulamasının mısır bitkisinin üst aksam kuru ağırlık üzerine etkisi Tablo 5'de verilmiştir. Mikrobiyal gübre uygulamasının üst aksam kuru ağırlık değerleri kontrol grubuna kıyasla GFBİO5 uygulamasında %43,40 ve GFBİO1 uygulamasında %42,70 göstermiştir. Mikrobiyal gübre uygulamaları üst aksam kuru ağırlık üzerine etkilerinin istatistiksel olarak önemli ($p<0.05$) olduğu görülmektedir. Kadıoğlu ve Canpolat (2019) serada mısır bitkisi üzerinde yaptıkları denemede *Bacillus subtilis* uygulamasının kontrol grubuna kıyasla, üst aksam kuru ağırlığında % 20 oranında artış sağladığını bildirmişlerdir.

Tablo 5. Mısırda mikrobiyal gübre uygulamasının üst aksam kuru ağırlık üzerine etkisi

Uygulamalar	Üst Aksam Kuru Ağırlığı (g/bitki)	Kontrol'e Göre Artışlar (%)

KONTROL	4,47b±0b44	-
NK	4,09b±0,45	-9,29
GFBİO1	6,38a±1,15	42,70
GFBİO2	5,28ab±1,00	18,12
GFBİO3	5,23ab±0,60	17
GFBİO4	4,53b±0,69	1,34
GFBİO5	6,41a±0,42	43,40

Mikrobiyal gübre uygulamasının mısır gövde kalınlığı üzerine etkisi Tablo 6'da verilmiştir. Mikrobiyal gübre uygulamasının gövde kalınlık değerleri kontrol grubuna kıyasla GFBİO5 uygulamasında %15 artış göstermiştir. Altunlu ve ark., (2019) sera koşullarında mısır bitkisi üzerinde yaptıkları denemede bakteri uygulamasının kontrol grubuna kıyasla, gövde kalınlığını % 20 oranında artırdığını bildirmişlerdir.

Tablo 6. Mısırda mikrobiyal gübre uygulamasının gövde kalınlığı üzerine etkisi

Uygulamalar	Gövde Kalınlığı (g/bitki)	Kontrol'e Göre Artışlar (%)
KONTROL	9,54bc±0,84	-
NK	9,3c±0,73	-2,58
GFBİO1	10,03abc±0,64	5,13
GFBİO2	10,19abc±0,30	6,81
GFBİO3	10,73ab±0,14	12,47
GFBİO4	9,93abc±0,35	4,08
GFBİO5	10,98a±0,06	15,09

Mikrobiyal gübre uygulamasının mısır üst aksam uzunluğu üzerine etkisi Tablo 7'de verilmiştir. Mikrobiyal gübre uygulamasının üst aksam uzunluğu değerleri kontrol grubuna kıyasla, GFBİO1 uygulamasında %4,91, GFBİO2 uygulamasında %6,07, GFBİO3 uygulamasında %6,46, GFBİO4 uygulamasında % 5,55 ve GFBİO5 uygulamasında ise % 6,25 oranında artış göstermiştir. Mikrobiyal gübre uygulamalarının mısır üst aksam uzunluğu üzerine etkilerinin istatistiksel olarak önemli ($p<0.05$) olduğu görülmektedir. Altunlu ve ark,. (2019) yaptıkları çalışmada, mikrobiyal gübre uygulamasının kontrol grubuna kıyasla mısır bitkisi üst aksam uzunluğunu %3,53 oranında arttırdığını bildirmişlerdir.

Tablo 7. Mısırda mikrobiyal gübre uygulamasının üst aksam uzunluğu üzerine etkisi

Uygulamalar	Üst Aksam Uzunluğu (cm/bitki)	Kontrol'e Göre Artışlar (%)
KONTROL	96,63b±3,35	-

NK	98,25b±4,63	1,67
GFBİO1	101,38a±6,55	4,91
GFBİO2	102,50a±0,91	6,07
GFBİO3	102,88a±2,06	6,46
GFBİO4	102,00a±1,87	5,55
GFBİO5	102,67a±2,25	6,25

Mısırda mikrobiyal gübre uygulamasının kök ağırlığı üzerine etkisi Tablo 8'de verilmiştir. Mikrobiyal gübre uygulamasının meyve verim değerleri kontrol grubuna kıyasla GFBİO5, GFBİO3 ve GFBİO1 uygulamalarında %8,94 artış göstermiştir. Mikrobiyal gübre uygulamalarının kök kuru ağırlığı üzerine etkilerinin istatistiksel olarak önemli ($p<0.05$) olduğu görülmektedir.

Tablo 8. Mısırda mikrobiyal gübre uygulamasının kök ağırlığı üzerine etkisi

Uygulamalar	**Kök kuru Ağırlığı (g/bitki)**	**Kontrol'e Göre Artışlar (%)**
KONTROL	1,23b±0,18	-
NK	1,29b±0,108	4,9
GFBİO1	1,34a±0,14	8,94
GFBİO2	1,13b±0,15	-8,85
GFBİO3	1,34a±0,121	8,94
GFBİO4	1,15b±0,135	-6,95
GFBİO5	1,34a±0,107	8,94

Mikrobiyal gübre uygulamasının mısır bitkisinin makro ve mikro mineral analizleri üzerine etkisi Tablo 9'da verilmiştir. Analizlere göre kontrol grubuna kıyasla, GFBİO3 uygulaması kalsiyum konsantrasyonunu %30,7 ve GFBİO4 uygulaması demir konsantrasyonunu %37,9 oranında artırmıştır. Fakat bu artış miktarını istatiski olarak harflendirmek anlamlı değildir. Diğer mikrobiyal gübre uygulamaları makro ve mikro besin elementlerinin konsantrasyonu üzerinde önemli bir artış göstermemiştir.

Tablo 9. Mısırda mikrobiyal gübre uygulamasının makro ve mikro besin elementleri konsantrasyonuna etkisi

Uygulamalar	**[K] (%)**	**[P] (%)**	**[Mg] (%)**	**[Ca] (%)**	**[Fe] (%)**	**[Zn] (%)**	**[S] (%)**

Kontrol	3,34±0,11	0,32±0,05	0,36±0,84	0,65b±0,006	108±3,81bc	59±6,35	2,19±0,03
NK	3,24±0,24	0,35±0,02	0,42±0,14	0,73ab±0,078	126±1,51ab	53±4,49	2,35±0,01
GFBİO1	2,61±0,16	0,29±0,04	0,36±0,31	0,65b±0,0500	109±11,29bc	36±1,68	2,00±0,20
GFBİO2	3,17±0,36	0,31±0,03	0,39±0,38	0,74ab±0,062	104±17,68c	40±9,50	2,06±0,01
GFBİO3	3,00±0,33	0,34±0,04	0,44±0,21	0,85a±0,0630	120±11,55bc	48±5,35	2,22±0,02
GFBİO4	2,94±0,27	0,32±0,03	0,40±0,21	0,79ab±0,092	149±8,63a	42±6,40	2,15±0,20
GFBİO5	2,78±0,16	0,33±0,02	0,41±0,27	0,68b±0,0420	98±10,97c	34±3,06	2,15±0,01

SONUÇ

Elde edilen bulgular, mikrobiyal gübre konsorsiyumlarının mısır bitkisinde önemli büyüme parametrelerini pozitif yönde etkilediğini ortaya koymaktadır. Özellikle GFBİO1 uygulaması, üst aksam yaş ve kuru ağırlığı sırasıyla %33,4 ve %42,70 oranında anlamlı artışlar sağlamıştır. GFBİO5 uygulaması ise üst aksam yaş, kuru ağırlığı gövde kalınlığı sırasıyla %28,70, %43,40 ve %15 oranında anlamlı artışlar sağlamıştır. Ayrıca, bazı uygulamaların toprakta mevcut mikro ve makro elementlerin bitki bünyesine taşınmasını artırdığı gözlemlenmiştir. Özellikle GFBİO3 uygulaması mısırdaki kalsiyum konsantrasyonunu %30,70 ve GFBİO4 uygulamasını demir konsantrasyonu %37,9 oranında artırmıştır. Bu artışlar, PGPR bakterileri tarafından üretilen sideroforların demir gibi metalleri şelatlayarak bitki kökleri tarafından alınmasını kolaylaştırdığını ortaya koymaktadır.

Elde edilen bulgular doğrultusunda, mikrobiyal gübrelerin hem ülkemiz hem de dünya tarımının geleceği açısından yararlı olacağı öngörülmektedir. Mikrobiyal gübreler, bitki beslenmesini doğal yollarla destekleyen, toprak sağlığını iyileştiren ve kimyasal gübre kullanımını azaltan biyolojik ürünlerdir. Avrupa Birliği'nin Green Deal hedefleri doğrultusunda; sürdürülebilir tarım, sera gazı emisyonlarının azaltılması ve çevresel etkilerin minimize edilmesi ön plandadır. Bu nedenle, bu tür biyolojik uygulamaların yaygınlaştırılması ve kullanımının teşvik edilmesi büyük önem taşımaktadır. Ayrıca, bu çalışma gelecekte gerçekleştirilecek daha kapsamlı araştırmalara zemin hazırlayacak niteliktedir. Bu araştırmanın, çiftçi ve saha şartlarında mikrobiyal gübre uygulamalarıyla desteklenerek geliştirilmesinin, mevcut sonuçları daha da güçlendireceği düşünülmektedir.

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TÜRKİYE TOPRAKLARINDAN İZOLE EDİLEN BAKTERİ SUŞLARI İLE OLUŞTURULMUŞ MİKROBİYAL GÜBRE FORMÜLASYONLARININ SERA KOŞULLARINDA SİVRİ BİBER (*Capsıcum annuum* l.) BİTKİSİ ÜZERİNDEKİ ETKİLERİNİN ARAŞTIRILMASI

Mehmet Halil ÖZSÜER

Melike OĞUZ

Burak TOLU

Onur ÖKSÜZ

Fatih KARABULUT

GÜBRETAŞ Ar-Ge Merkezi Kocaeli, TÜRKİYE

ÖZET

Toprak mikrobiyal çeşitliliği, bitki besin elementlerinin döngüsünde kritik bir rol oynamakta ve sürdürülebilir tarım uygulamalarının temelini oluşturmaktadır. Kimyasal gübrelerin uzun süreli ve aşırı kullanımı, toprak mikrobiyal dengesini bozarak ekosistem sağlığını olumsuz etkilemektedir. Bu çalışmada, Türkiye'nin farklı bölgelerinden izole edilen *Bacillus* ve *Pseudomonas* türü bakteri suşlarından oluşturulan mikrobiyal gübre konsorsiyumlarının, sivri biber (*Capsıcum annuum L.*) bitkisi üzerindeki meyve ağırlık, üst aksam kuru ağırlık ve makro-mikro besin elemet konsantrasyonu parametreleri sera koşullarında değerlendirilmiştir. Elde edilen bulgular, GFBİO5 uygulamasının meyve ağırlığında %65,79 ve GFBİO3 uygulaması %63,55 oranında artış sağladığını göstermiştir. GFBİO3 uygulaması, üst aksam kuru ağırlık üzerine %22,54 oranında artış sağlamıştır. Araştırma sonucunda, bazı mikrobiyal formülasyonların bitki gelişimi ve verimi açısından kimyasal gübrelere benzer veya üstün etki gösterdiği belirlenmiştir. Elde edilen veriler, biyogübrelerin sürdürülebilir tarımda potansiyel bir alternatif olduğunu göstermektedir.

Bu kapsamda, kontrol grubu ile karşılaştırıldığında, GFBİO3 ve GFBİO5 konsorsiyumlarının mikrobiyal gübre olarak umut vadettiği belirlenmiştir. Başarılı bulunan mikrobiyal gübre konsorsiyumlarının ilerleyen süreçte tescillenerek ticari ürüne dönüştürülmesi planlanmaktadır.

Anahtar Kelimeler: Mikrobiyal besin döngüsü, Toprak ekosistemleri, Sürdürülebilir tarım, Kimyasal gübreler, Toprak sağlığı, Biyolojik çeşitlilik, Bitki gelişimini teşvik eden rizobakteriler (PGPR), Besin elementlerinin biyoyararlanımı, Sürdürülebilir ürün yetiştiriciliği, *Bacillus*, *Pseudomonas*, Biyogübre, Sera koşulları, Mineral gübreler, Ticari biyogübre geliştirme, Mikrobiyal gübre.

INVESTIGATION OF THE EFFECTS OF MICROBIAL FERTILIZER FORMULATIONS CREATED WITH BACTERIAL STRAINS ISOLATED FROM TURKISH SOILS ON GREEN PEPPER (*Capsıcum annuum l.*) PLANTS UNDER GREENHOUSE CONDITIONS.

ABSTRACT

Soil microbial diversity plays a critical role in the cycling of plant nutrients and forms the basis of sustainable agricultural practices. Long-term and excessive use of chemical fertilizers disrupts the soil microbial balance, negatively impacting ecosystem health. In this study, microbial fertilizer consortia composed of Bacillus and Pseudomonas bacterial strains isolated from different regions of Turkey were evaluated under greenhouse conditions for fruit weight, topside dry weight, and macro-micronutrient element concentration parameters on green pepper (Capsicum annuum L.) plants. The findings showed that the GFB1O5 application increased fruit weight by 65.79%, and the GFB1O3 application increased topside dry weight by 63.55%. The GFB1O3 application increased topside dry weight by 22.54%. The study determined that some microbial formulations have similar or superior effects to chemical fertilizers in terms of plant growth and yield. The obtained data suggest that biofertilizers are a potential alternative in sustainable agriculture. In this context, when compared with the control group, the GFBİO3 and GFBİO5 consortia were determined to be promising microbial fertilizers. The successful microbial fertilizer consortia are planned to be registered and converted into commercial products in the future.

Keywords: Microbial nutrient cycling, Soil ecosystems, Sustainable agriculture, Chemical fertilizers, Soil health, Biological diversity, Plant growth-promoting rhizobacteria (PGPR), Bioavailability of nutrients, Sustainable crop production, *Bacillus*, *Pseudomonas*, Biofertilizer potential, Greenhouse conditions, Mineral fertilizers, Commercial biofertilizer development, microbial fertilizer.

GİRİŞ

Mikroorganizmalar, topraktaki besin döngüsünde aktif faaliyetleri nedeniyle tarımsal alanlarda, özellikle bitki büyümesini teşvik etmede önemli bir rol oynamaktadırlar (Bull ve ark., 2000). Yeşil devrim teknolojileriyle birlikte, gübreler modern tarımsal üretim üzerinde önemli ölçüde olumlu etkiler yaratmış; bitkilerin daha hızlı ve verimli bir şekilde yetiştirilmesini sağlayan sentetik gübre kullanımı giderek artmıştır. Ancak yüksek oranda sentetik gübre kullanımının sürekliliği, çevre kirliliği, toprak ekosisteminde fiziko-kimyasal koşullarda kalıcı değişimler, toprak biyolojik sağlığının ve kalitesinin bozulması, toprak verimliliğinin kademeli olarak kaybına, besinlerin sızmasıyla yüzey ve yeraltı sularının kirlenmesine, ötrofikasyona, sera gazı emisyonlarının artmasına ve sucul biyolojik çeşitlilik üzerinde olumsuz etkilere yol açmaya başlamıştır (Çakmakçı ve Karabulut, 2023).

PGPB (Plant Growth Promoting Bacteria) bakterilerinin mikrobiyal gübreler içinde başarı ve etkinliği, bu bakterilerin bitki köklerini kolonize etme yetenekleri, bitki kökleri tarafından eksudasyon yoluyla salgılanan maddelerden faydalanabilmeleri ve bitki kökleriyle kurdukları faydalı ilişkiler ile toprak sağlığı gibi çevresel faktörlerden etkilenmektedir (Beauregard ve ark., 2013). PGPB kapsamındaki bakteriler, bitki gelişimini destekleyen mekanizmalardan biri olarak, biyolojik azot fiksasyonu, topraktan alınabilir formdaki besin elementlerinin bitki için erişilebilirliğinin artırılması, kök yüzey alanının artırılması ve bitki gelişim hormonlarının sentezlenmesi gibi yollarla büyümeyi teşvik etmektedirler. Bu anlamda biyolojik gübre olarak *Bacillus* türlerinin kullanımı, hem bitki gelişimini teşvik etmekte hem de uygun çevresel koşullarda patojenleri baskılayarak antibiyotik sentezleme gibi önemli katkılar sunmaktadır (Chabot ve ark., 1996).

Fosfat çözücü bakteriler, bitki büyümesini ve fosfor (P) çözünürlüğünü artırabilir; ayrıca tarım arazilerinde aşırı kullanılan kimyasal gübrelerin olumsuz etkilerini azaltarak toprak ortamını iyileştirebilirler. Fosfor, toprakta bitki büyümesi ve besin döngüsünde önemli bir makro element olmasına rağmen, toplam fosfor miktarı yüksek olsa da, bitkiler tarafından doğrudan kullanılabilir formda bulunmaması nedeniyle sınırlayıcı bir besin elementi olarak kabul edilmektedir (Soltangheisi ve ark., 2016). Fosfat çözücü bakteriler, özellikle topraktaki çözünmeyen fosfor bileşiklerinin alınabilir forma dönüştürülmesini sağlayarak bitki gelişimini destekleyebilir (Sadaf ve ark., 2019).

Bu çalışmada, Türkiye'nin farklı bölgelerinden (Adana Saimbeyli ve Dokuztekne, Doğu Karadeniz Kaçkar Dağları, Çanakkale Gökçeada ve Bozcaada, Karaman Karadağ, Balıkesir Balya) toplanan toprak örneklerinden izole edilen mikroorganizmalar kullanılarak, sera koşullarında biyolojik gübre olarak değerlendirilebilecek suşlar belirlenmiştir. Bu amaçla kullanılan mikroorganizmalar şunlardır: GFBİO1 (RC631 *Bacillus subtilis*, GBF01 *Bacillus megaterium*, GBF251 *Pseudomonas fluorescens*), GFBİO2 (RC631 *Bacillus subtilis*, GBF14 *Bacillus megaterium*, GBF251 *Pseudomonas fluorescens*), GFBİO3 (RC631 *Bacillus subtilis*, A54 *Bacillus pumilus*, GBF251 *Pseudomonas fluorescens*), GFBİO4 (RC631 *Bacillus subtilis*, GBF01 *Bacillus megaterium*, GBF251 *Pseudomonas fluorescens*), GFBİO5 (GBF07 *Pseudomonas putida*, GBF120 *Bacillus megaterium*, GBF72 *Bacillus subtilis*).

MATERYAL METOT

Toprak Örneklerinin Alınması

Bu çalışma kapsamında, Adana Ceyhan Dokuztekne ve Adana Saimbeyli Beypınarı, Çanakkale Gökçeada Yeni Çamlık ve Çanakkale Bozcaada Mumcular Üzüm Bağları, Doğu Karadeniz Kaçkar Dağları, Karaman Karadağ, Balıkesir Balya bölgelerinden alınan toprak numunelerinde toprağın üst kısmı temizlenmiştir. Daha sonra steri olarak hazırlanan 0 – 15 cm arası derinlikte, bitki kök bölgesine yakın kısımdan yaklaşık 500g alınan toprak numuneleri, +4 ^{O}C' de

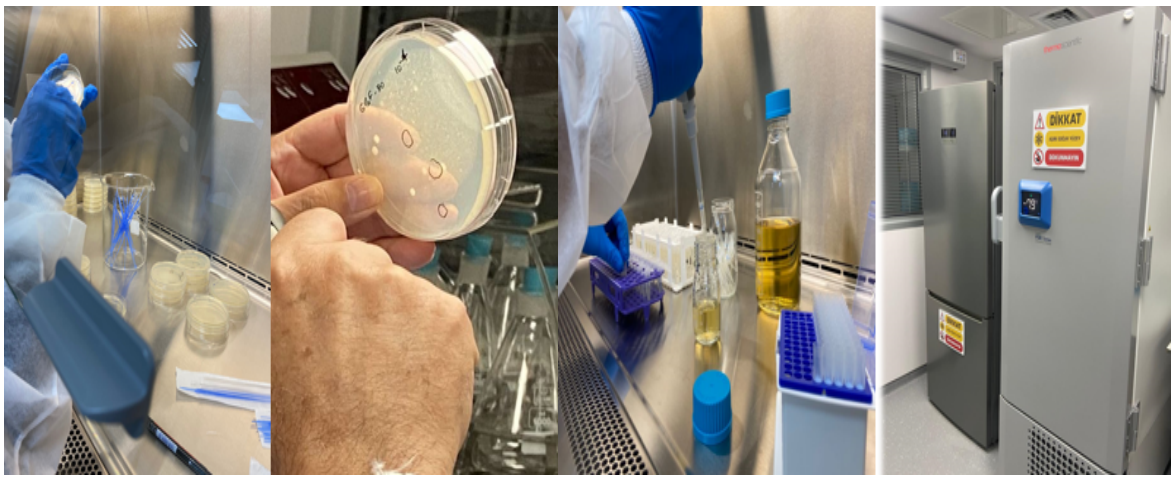
laboratuvara transfer edilmiştir. Analize alınıncaya kadar +4 ^{O}C‘ de muhafaza edilmiştir. Bitkilerden alınan toprak numunelerine ait görseller Şekil 1’ de verilmiştir.



Şekil 1. Bitkilerden alınan toprak numunelerinin görselleri

Topraktan Bakteri İzolasyonu

Aseptik koşullarda laboratuvara getirilen toprak örnekleri, biyogüvenlik kabini içerisinde açılarak, mikroorganizmalar izole edilmiştir. Stoklanan mikroorganizmalara ait görseller Şekil 2’de sunulmuştur.



Şekil 2. Bitkilerden alınan toprak numunelerinden izole edilerek stoklanan mikroorganizmalara ait görseller

Bakteri Suşlarının Bruker Maldi – Tof MS Sisteminde İdentifikasyonu (Tanılama)

Elde edilen bakteri izolatlarının identifikasyonu MALDI-TOF MS (Matrix Assisted Laser Desorption Ionization–Time of Flight Mass Spectrometry, Bruker Daltonics GmbH, Bremen, Almanya) sistemi kullanılarak gerçekleştirilmiştir. Tanımlama aşamasında, saf kültürlerden elde edilen örneklerde protein ekstraksiyonu için etanol–formik asit bazlı ön işlem uygulanmıştır.

Örneklerden elde edilen kütle spektrumları cihazın flexControl yazılımı (Biotyper 3.0; Microflex LT, Bruker Daltonics GmbH, Bremen, Almanya) aracılığıyla kaydedilmiş ve MALDI Biotyper Real-Time Classification (RTC) yazılımındaki referans veri tabanı ile karşılaştırılarak değerlendirilmiştir. Sonuçların yorumlanmasında sistemin verdiği log(score) değerleri esas alınmış; 2,000–3,000 aralığındaki skorlar tür düzeyinde güvenilir tanımlama (yeşil seviye), 1,700–1,999 aralığındaki skorlar ise cins düzeyinde ya da muhtemel tür düzeyinde tanımlama (sarı seviye) olarak kabul edilmiştir (Carolis ve ark., 2012; Chalupová ve ark., 2014; Kara ve ark., 2017; Uysal ve ark., 2018).

Sera Denemesi

Denemede kullanılan toprak materyali ülkemiz toprakları temsil edilecek şekilde seçilmiş olup daha önce yetiştiricilik yapılmamış bir araziden temin edilmiştir. Deneme toprağının bazı kimyasal ve fiziksel özellikleri Tablo 1'de verilmiştir. Analiz sonuçlarına göre denemede kullanılan toprak; killi bünyeye sahip, alkali karakterli, tuzsuz, çok kireçli ve organik maddece çok az sınıfında yer almaktadır. Alınabilir P, K ve değişebilir Ca elementlerince zengin, alınabilir Fe, Mn ve Cu elementleri miktarları ise yeterli düzeydedir. Alınabilir Zn bakımından çok fazla sınıfta iken değişebilir Mg elementlerince az olarak sınıflandırılmıştır.

Tablo 1. Denemede kullanılan toprak örneğinin kimyasal özellikleri

Parametre	Metod	Sonuç	Değerlendirme
Bünye	Bouyoucos	72,60	Kil
pH	01:02,5	7,95	Alkali
EC (µS/cm)	01:02,5	-	-
Kireç (%)	Scheibler	28,26	Çok kireçli
Organik Madde(%)	Walkley-Black	0,32	Çok az
Toplam N (%)	Kjeldahl	0,016	Çok fakir
Alınabilir P(mg/kg)	Olsen-Spektrofotometrik	26,00	Yüksek
Alınabilir K(mg/kg)	A.Asetat-ICP	79,00	Fazla
Değişebilir Ca(mg/kg)	A.Asetat-ICP	6360,00	Fazla
Değişebilir Mg(mg/kg)	A.Asetat-ICP	95,80	Az
Alınabilir Fe(mg/kg)	DTPA-ICP	5,20	Yeterli
Alınabilir Mn(mg/kg)	DTPA-ICP	2,64	Yeterli
Alınabilir Zn(mg/kg)	DTPA-ICP	17,21	Çok fazla
Alınabilir Cu(mg/kg)	DTPA-ICP	0,53	Yeterli

Bu çalışma, Gübre Fabrikaları TAŞ. ve Gebze Teknik Üniversitesi iş birliği kapsamında kurulan kurulan cam serada yürütülmüştür. Sera ortamında 5,5 litrelik saksılarda sivri biber (*Capsıcum annuum L.*) bitkisi yetiştirilmiştir. Sera koşullarında gerçekleştirilen deneme toplam 28 saksıdan oluşmaktadır (7 konu x 4 tekerrür) ve her saksıda bir bitki olacak şekilde toplamda 28 bitki üzerinde çalışılmıştır. Deneme deseni Tablo 2'de verilmiştir.

Tablo 2. Sera deneme deseni

Bitki	**Konular**	**Saksı No**			
SİVRİ BİBER	**Kontrol**	1	2	3	4
	Negatif Kontrol	5	6	7	8
	GFBİO1	9	10	11	12
	GFBİO2	13	14	15	16
	GFBİO3	17	18	19	20
	GFBİO4	21	22	23	24
	GFBİO5	25	26	27	28

Denemenin hazırlık aşamasında, saksı başına 5,2 kg toprak ve iyi yanmış vasıflı hayvan gübresi karışımı tartılmış, 150 ppm azot, 25 ppm fosfor ve 30 ppm potasyum ile zenginleştirilmiş, ardından homojenleştirme amacıyla karıştırılmıştır. Bazal gübreleme olarak MAP ($NH_4H_2PO_4$), [Kalsiyum Nitrat [$Ca(NO_3)_2$] ve Potasyum Sülfat (K_2SO_4) gübreleri kullanılmıştır. Bakteri uygulamaları için GÜBRETAŞ Ar-Ge Laboratuvarı tarafından temin edilen 5 farklı mikrobiyal gübre konsorsiyumu (GBF1, GBF2, GBF3, GBF4 ve GBF5) kullanılmış ve uygulan dozajlar CFU değerleri ($1x10^7$ kob ml^{-1}) eşitlenecek şekilde hesap edilmiştir. Deney süresince uygulama gruplarına saksı başına 5ml/saksı/ dozunda 95 ml su karıştırılarak, ilki fide dikim esnasında can suyu ile birlikte, diğeri dikimden 30 gün sonra olmak üzere iki uygulama gerçekleştirilmiştir.

Denemede, meyve ağırlığı (gr/saksı), üst aksam kuru ağırlığı (gr/saksı) ve yaprak mineral analiz (ppm) kriterleri üzerinde durulmuştur. Tesadüf parselleri deneme deseni düzeninde 4 tekrarlı olarak yürütülen araştırmadan elde edilen veriler, SPSS (sürüm 17.0) istatistik paket programında deneme desenine uygun olarak değerlendirilmiştir. Ortalamalar arasındaki farklılıkları belirlemek için %5 önem düzeyinde LSD testi kullanılmıştır.

BULGULAR VE TARTIŞMA

Örneklerin Toplanması ve Mikroorganizmaların İzolasyonu

Bu çalışma kapsamında, Adana Ceyhan Dokuztekne ve Adana Saimbeyli Beypınarı, Çanakkale Gökçeada Yeni Çamlık ve Çanakkale Bozcaada Mumcular Üzüm Bağları, Doğu Karadeniz Kaçkar Dağları, Karaman Karadağ, Balıkesir Balya bölgelerinden alınan toprak numunelerinde toprağın üst kısmı temizlenerek örnekler alınmıştır. Bu bitkilerden yapılan izolasyonlar sonucunda farklı mikroorganizma türlerinin besi yerlerinde gelişim gösterdiği gözlemlenmiştir. İnkübasyon sonucunda, Nutrient agar besi yerinde yaklaşık 84 bakteri kolonisinin geliştiği belirlenmiştir. Bu koloniler arasından, farklı türde bakteri temsil eden toplam 7 saf izolat elde edilmiştir.

Mikroorganizma Türlerinin MALDI-TOF MS Tekniği ile Tanımlanması

Farklı bölgelerden (Adana, Çanakkale, Doğu Karadeniz, Karaman ve Balıkesir) alınan toprak örneklerinden mikroorganizmalar izole edilmiştir. Elde edilen izolatların identifikasyonu

MALDI-TOF MS sistemi kullanılarak gerçekleştirilmiş, log(score) değerlerine göre tür ve cins düzeyinde güvenilir tanımlamalar yapılmıştır. Elde edilen sonuçlar Tablo 3'de verilmiştir.

Tablo 3. Bruker Maldi – Biotyper identifikasyon sonuçları

MİKROORGANİZMA ID	MALDI-TOF MS SONUCU
GBF01	*Bacillus megaterium*
GBF07	*Pseudomonas putida*
GBF14	*Bacillus megaterium*
GBF120	*Bacillus megaterium*
GBF251	*Pseudomonas fluorescens*
A54	*Bacillus pumilus*
RC631	*Bacillus subtilis*

Sera Denemesi

Mikrobiyal gübre uygulamasının sivri biber bitkisinin meyve ağırlığı üzerine etkisi Tablo 4'de verilmiştir. Mikrobiyal gübre uygulamasının meyve verim değerleri kontrol grubuna kıyasla GFBİO5 uygulaması %65,79 ve GFBİO3 uygulaması %63,55 artış göstermiştir. Mikrobiyal gübre uygulamaları meyve verim üzerine etkilerinin istatistiksel olarak önemli ($p<0.05$) olduğu görülmektedir. Topuz ve ark. (2024) biber bitkisi üzerine serada yaptıkları çalışmada, mikrobiyal gübre uygulamasının toplam bitki verimini %36,57 oranında artırdığını bildirmişlerdir.

Tablo 4. Biberde mikrobiyal gübre uygulamasının meyve ağırlığı üzerine etkisi

Uygulamalar	Meyve Ağırlığı (g/saksı)	Kontrol'e Göre Artışlar (%)
KONTROL	$29,41^{b}$±4,9	-
NK	$35,08^{ab}$±3,57	19,28
GFBİO1	$42,21^{ab}$±4,59	43,52
GFBİO2	$41,50^{ab}$±2,08	41,10
GFBİO3	$48,10^{a}$±4,36	63,55
GFBİO4	$39,49^{ab}$±6,57	34,27
GFBİO5	$48,76^{a}$±8,9	65,79

Mikrobiyal gübre uygulamasının sivri biber bitkisinin üst aksam kuru ağırlık üzerine etkisi Tablo 5'de verilmiştir. Mikrobiyal gübre uygulamasının üst aksam kuru ağırlık değerleri kontrol grubuna kıyasla GFBİO3 uygulaması %22,54, GFBİO5 uygulaması %18,56, GFBİO1 %18,04 ve GFBİO4 uygulaması ise %16,71 oranında artış sağlamıştır. Zhao ve ark., (2019), dekara 6 litre dozunda fosfor çözücü bakteri içeren mikrobiyal gübre uygulamasının biber biyokütlesi üzerindeki etkileri kontrol ile karşılaştırıldığında, önemli artışlar sağladığını bildirmişlerdir. Çelik (2022) yaptığı bir çalışmada, marul bitkisi üzerine uygulanan bakteri strainlerinin gövde ve kökün yaş ve kuru ağırlığını, gövde ve kök uzunluğunu önemli oranda artırdığını bildirmiştir.

Tablo 5. Biberde mikrobiyal gübre uygulamasının üst aksam kuru ağırlık üzerine etkisi

Uygulamalar	Üst Aksam Kuru Ağırlık (g/saksı)	Kontrol'e Göre Artışlar (%)
Kontrol	7,54b±0,73	-
NK	8,79a±0,51	16,57
GFBİO1	8,90a±0,80	18,04
GFBİO2	8,05ab±0,89	6,76
GFBİO3	9,24a±0,73	22,54
GFBİO4	8,80a±0,83	16,71
GFBİO5	8,94a±0,57	18,56

Mikrobiyal gübre uygulamasının sivri biber bitkisinin yaprağın makro ve mikro mineral analiz üzerine etkisi Tablo 6'da verilmiştir. Mikrobiyal gübre uygulamasının sivri biberdeki makro ve mikro besin element değerleri kontrol grubu ile kıyaslandığında, GFBİO1 uygulaması demir konsantrasyonunu %196,64 ve kükürt konsantrasyonunu %12,88 oranında artırmıştır.

Tablo 6. Biberde mikrobiyal gübre uygulamasının makro ve mikro besin elementleri konsantrasyonuna etkisi

Uygulamalar	[K] (%)	[P] (%)	[Mg] (%)	[Ca] (%)	[Fe] (%)	[Zn] (%)	[S] (%)
Kontrol	3,48±0,25	0,26±0,02	0,71±0,37	0,32±0,02	146,28±17,59	26,26±2,35	0,450±0,027
NK	3,34±0,40	0,25±0,01	0,74±0,94	0,33±0,04	187,09±7,21	24,79±1,73	0,471±0,041
GFBİO1	3,95±0,36	0,25±0,02	0,69±0,58	0,32±0,02	433,93±9,00	27,10±3,42	0,508±0,029
GFBİO2	3,55±0,61	0,23±0,03	0,67±0,56	0,31±0,01	205,63±25,14	26,95±4,79	0,495±0,044
GFBİO3	3,29±0,37	0,23±0,01	0,71±0,63	0,33±0,03	188,78±37,98	21,62±1,21	0,475±0,029
GFBİO4	3,32±0,41	0,23±0,05	0,68±1,23	0,33±0,04	194,12±10,02	21,86±2,29	0,473±0,400
GFBİO5	3,42±0,21	0,23±0,01	0,68±0,49	0,30±0,03	222,00±34,73	19,70±2,30	0,480±0,049

Mikrobiyal gübre uygulamasının makro ve mikro besin elemetleri değerleri kontrol grubuna kıyasla, GFBİO1 uygulaması potasyum, demir ve çinko konsantrasyonu üzerinde artış göstermiştir fakat istatiski olarak harflendirmek anlamlı değildir. Diğer mikrobiyal gübre uygulamaları makro ve mikro besin elementlerin konsantrasyonu üzerinde önemli bir artış göstermemiştir. Küçük ve ark., (2008), yaptıkları araştırmada kök bölgesine uygulanan bakteri uygulamalarının bitkinin çinko içeriği üzerine olumlu etkilere sahip olduğunu bildirmişlerdir.

SONUÇ

Elde edilen bulgular, mikrobiyal gübre konsorsiyumlarının sivri biber bitkisinde önemli büyüme parametrelerini pozitif yönde etkilediğini ortaya koymaktadır. Özellikle GFBİO5 uygulaması, meyve ağırlığı üzerinde %65,79, GFBİO3 uygulaması ise %63,55 oranında anlamlı artışlar sağlamıştır. Uygulamaların üst aksam kuru ağırlık üzerine etkilerine bakıldığında GFBİO3, GFBİO1 ve GFBİO4 uygulamaları sırasıyla, %22,54, %18 ve %16,71 oranında artış sağlamıştır. Ayrıca, bazı uygulamaların toprakta mevcut mikro ve makro elementlerin bitki bünyesine taşınmasını artırdığı gözlemlenmiştir. GFBİO1 uygulamasının demir konsantrasyonu %196,64 ve demir konsantrasyonu %12,88 oranında artış sağlamıştır. PGPR bakterileri tarafından üretilen sideroforlar, demir gibi metallerin şelatlanarak bitki kökleri tarafından alınmasını kolaylaştırdığını ortaya koymaktadır.

Elde edilen bulgular doğrultusunda, mikrobiyal gübrelerin hem ülkemiz hem de dünya tarımının geleceği açısından yararlı olacağı öngörülmektedir. Mikrobiyal gübreler, bitki beslenmesini doğal yollarla destekleyen, toprak sağlığını iyileştiren ve kimyasal gübre kullanımını azaltan biyolojik ürünlerdir. Avrupa Birliği'nin Green Deal hedefleri doğrultusunda; sürdürülebilir tarım, sera gazı emisyonlarının azaltılması ve çevresel etkilerin minimize edilmesi ön plandadır. Bu nedenle, bu tür biyolojik uygulamaların yaygınlaştırılması ve kullanımının teşvik edilmesi büyük önem taşımaktadır. Ayrıca, bu çalışma gelecekte gerçekleştirilecek daha kapsamlı araştırmalara zemin hazırlayacak niteliktedir. Bu araştırmanın, çiftçi ve saha şartlarında mikrobiyal gübre uygulamalarıyla desteklenerek geliştirilmesinin, mevcut sonuçları daha da güçlendireceği düşünülmektedir.

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A REVIEW ON THE EFFECTS OF IRRIGATION ON LAVENDER (*L. ANGUSTIFOLIA MILL.*) YIELD AND OIL QUALITY

Öğr. Gör. Havva Nur Demir Deveci
Necmettin Erbakan Üniversitesi, Meram Meslek Yüksek Okulu, Konya
Email: hndemir@erbakan.edu.tr
ORCID: 0009 0005 6827 7334
Zir. Müh.Tahir Külahcı
Selçuklu İlçe Tarım ve Orman Müdürlüğü, Konya
Email: tahirkulahci@gmail.com
ORCID: 0009-0000-8639-1425
Prof. Dr. Ramazan Topak
Selçuk Üniversitesi, Ziraat Fakültesi, Konya
Email: rtopak@selcuk.edu.tr
ORCID: 0000 0003 3748 2720

ABSTRACT

Their inclusion in agricultural culture has played a very important role in the survival of medicinal and aromatic plants around the world. The majority of medicinal and aromatic plants are drought-tolerant and are grown both rain-fed and irrigated. Especially in arid regions, the cultivation of these plants is preferred for rain-fed production. Irrigation is the most effective measure to reduce water stress and increase crop yields in arid areas. Therefore, irrigation is inevitable for medicinal and aromatic plants as well. Lavender, a medicinal and aromatic plant, is drought-tolerant and is cultivated for its essential oil. This study was conducted to evaluate some research on irrigation in lavender. Within this scope, this paper presents an analysis of recent studies that have demonstrated the effect of different irrigation practices on the herb and essential oil yield and essential oil quality of lavender. Consequently, irrigation significantly increases lavender yield in arid regions. Therefore, there is a need to develop irrigation schedules that provide high irrigation water productivity for lavender cultivation in regions experiencing water scarcity.

Keywords: Lavender; Irrigation management; Essential oil yield; Oil quality

SULAMANIN LAVANTA (*L. ANGUSTIFOLIA MILL.*) ÜRÜN VERİMİ VE YAĞ KALİTESİNE ETKİLERİ ÜZERİNE BİR İNCELEME

ÖZET

Tarım kültürüne alınması, tıbbi ve aromatik bitkilerin dünyada varlığını sürdürmesinde çok önemli bir rol oynamıştır. Tıbbi ve aromatik bitkilerin ekseriyeti kuraklığa töleranslı olup, hem yağışa dayalı ve hem de suluda yetiştirilmektedir. Özellikle kurak bölgelerde, yağışa dayalı üretim için bu bitkilerin tarımı tercih edilebilmektedir. Sulama, kurak alanlarda su stresini azaltmak ve ürün verimini artırmak için en etkili önlemdir. Dolayısıyla tıbbi ve aromatik bitkilerde de sulama kaçınılmazdır. Tıbbi ve aromatik bitki olan lavanta, kurağa dayanıklı olup, uçucu yağı için üretilmektedir. Bu çalışma, lavantada sulama üzerine yapılan bazı araştırmaların değerlendirilmesi amacıyla yapılmıştır. Bu kapsamda, bu bildiride, yakın geçmişte yapılan ve farklı sulama programlarının lavantanın ot ve uçucu yağ verimi ile uçucu yağ kalitesi üzerindeki etkisini ortaya koyan bazı çalışmaların bir analizi sunulmuştur. Sonuç olarak, kurak bölgelerde sulama işlemi lavantanın ürün verimini önemli ölçüde artırmaktadır. Dolayısıyla su kıtlığı olan bölgelerde lavanta tarımı için de yüksek sulama suyu üretkenliği sağlayan sulama programlarının geliştirilmesine ihtiyaç duyulmaktadır.

Anahtar kelimeler: Lavanta; Sulama yönetimi; Uçucu yağ verimi; Yağ kalitesi

1.GİRİŞ

Lavanta, çok yıllık olup, çiçekleri için üretilen önemli bir tıbbi ve aromatik bitkidir. Çok yıllık bir bitki olması nedeniyle lavantadan ekonomik olarak 15-20 yıl yararlanılmaktadır (Kara ve Baydar, 2011). Günümüzde lavanta kozmetik, parfümeri, gıda, sağlık, aromaterapi ve peyzaj gibi pek çok alanda değerlendirilme olanağı bulabilmektedir (STB, 2020). Özellikle tıbbi uçucu yağı açısından değer taşıyan lavanta, ilaç, parfümeri ve kozmetik amaçlı yetiştirilmektedir (Sarfaraz ve ark., 2024). Dünyada çoğu Akdeniz orjinli olan 39 kadar lavanta türü bulunmaktadır. Bunlardan lavander, lavandin ve spike lavender olmak üzere üç türünün ticari değeri yüksektir (Kara, 2023). Dünyada iki önemli lavanta türünün (lavandin ve lavender) tarımı yapılmaktadır. Dünya lavanta üretim alanlarının %80'ini lavandin, ve %20 'sini lavender oluşturmaktadır. Fransa ve Bulgaristan dünya lavanta üretim alanlarının 2/3'üne hâkim olup, Çin, Rusya, bazı Doğu Avrupa ve Kuzey Afrika ülkeleri lavanta tarımında ve ticaretinde söz sahibi ülkelerdir. Fransa, lavanta yağı üreten ve ihraç eden lider bir ülkedir ve lavanta yağı pazarının %34'üne hâkimdir. Kısacası Fransa dünyada lavanta yağı üretiminde ilk sırada yer almaktadır. Fransa'yı Bulgaristan ve Çin takip etmektedir. Çin küresel pazarda % 11.9'luk pazar payına sahiptir(STB, 2020).

Türkiye'de lavanta tarımı yoğun olarak Göller Bölgesinde yapılmakta olup, özellikle Isparta, Afyonkarahisar, Burdur ve Denizli illeri lavanta üretiminin en yoğun yapıldığı illerdir. Ülkemizde son yıllarda lavanta üretimi farklı illerimize yayılmış durumdadır. Ülkemizde 2015 yılına kadar lavandin çeşitlerinin (süper) tarımı yapılırken, günümüzde lavender çeşitlerinin tarımına başlanmıştır. Lavanta olumsuz toprak koşullarında bile verim verebilen ve tarımında hastalık ve zararlı faktörü neredeyse minimum düzeyde olan ve tarımsal anlamda az emek isteyen bir bitkidir. Son yıllarda lavanta tomurcuğu ve lavanta yağına olan ilgi nedeniyle birçok üretici tarafından tercih sebebi haline gelmiştir (STB, 2020).

Su kıtlığı, dünyadaki tarım alanlarının çoğunda bitki büyümesini ve ürün verimliliğini kısıtlayan en önemli faktördür (Abedi ve Pakniyat, 2010). Buna karşın sulama ise, bitki gelişimini, ürün verimini ve kalitesini artırmak için yegane önlemdir (Singh ve Goswamy, 2000). Su kıtlığı koşullarında, bitki su ihtiyacının sulama ile tümüyle karşılanması her geçen gün daha da zorlaşmaktadır. Dolayısıyla, daha az su ile sulamanın gerçekleştirileceği teknolojik sulama yöntem ve sulama yönetimi stratejilerinin uygulamaya sokulması kaçınılmazdır. Özellikle kuraklığa hassasiyeti düşük olan bitkilerde, bitki büyüme dönemleri ve bu gelişme dönemlerinin su stresine (su kısıntısına) tepkilerinin bilinmesi, bitkiler için kısıntılı ve tamamlayıcı sulama stratejileri uygulamasına imkan sağlamaktadır. Bu usulle hem ürün verimi ve kalitesi artarken hem de ve kıt su kaynaklarının en verimli şekilde kullanılmasını sağlanabilir (Singh ve Goswamy, 2000).

Kuraklığın tıbbi ve aromatik bitkilerin büyümesi ve gelişimi üzerindeki etkisi, daha önceki bazı çalışmalarda incelenmiştir. Önceki çalışmalar, sulamanın bitkilerin verimi belirleyen morfolojik ve fizyolojik özellikleri üzerinde önemli bir etkiye sahip olduğunu göstermiştir. Dahası, sulama seviyeleri verimi ve uçucu yağların bazı önemli bileşenlerini de etkilemektedir (Llorens-Molina ve Vacas, 2017; An ve Liang, 2013; Rioba ve ark., 2015; Sánchez-Blanco ve ark., 2004).

Bu çalışmanın amacı, lavantada sulamanın ürün verimi ve uçucu yağ kalitesine etkilerini konu edinen ve yakın dönemde yapılmış çalışmaların kısa bir değerlendirmesini sunmaktır.

2. BİTKİSEL UÇUCU YAĞ KALİTESİNE ETKİ EDEN FAKTÖRLER

Birçok tıbbi ve aromatik bitki, özellikle kuraklık olmak üzere zorlu çevre koşullarında gelişme yeteneğine sahiptir ve bu da onları kurak bölgeler için oldukça uygun hale getirmiştir (Kulak, 2020). Kurak bölgelerde su kıtlığı, hemen tüm bitkilerde olduğu gibi tıbbi ve aromatik bitkilerin

büyümesini ve verimini önemli ölçüde etkiler (Nouri ve ark., 2023; Wahab ve ark., 2022). Ayrıca kuraklık, tıbbi ve aromatik bitkilerdeki aktif bileşenlerin kalitesini de olumsuz etkilemektedir (Bistgani ve ark., 2017a; Gao ve ark., 2020). Toprak nem muhtevası, tıbbi bitki bileşenlerinin büyümesini, gelişimini ve sentezini etkileyen önemli bir çevresel faktördür (Vosoughi ve ark., 2018; Zhu ve ark., 2018). Bazı çalışmalar, çevresel streslerin ikincil metabolitlerin artan seviyelerine yol açtığını öne sürmektedir (George ve ark., 2017; Bistgani ve ark., 2017b). Kuraklığın zamanlaması, süresi ve sıklığı, toprak özellikleri ve yağış desenleri gibi çeşitli faktörler, bir bitkinin kuraklığa karşı direncini etkilemektedir (Rezaei ve ark., 2019; Morshedloo ve ark., 2016).

Tıbbi ve aromatik bitkilerdeki uçucu yağlar farklı fakörlerin etkisi altındadır. Birçok iç ve dış faktör esansiyel yağların yapısını, belirli bileşenlerin konsantrasyonunu ve nihayetinde uçucu yağ verimini etkilemektedir (Djouahri ve ark., 2015; Formisano ve ark., 2015; Rehman ve ark., 2016). Bu faktörleri bitkiden kaynaklanan koşullar ve dış faktörler olarak sınıflandırmak mümkündür. Bitkiden kaynaklanan koşullar; genetik, bitki popülasyonu, bitkinin kökeni, bitkinin kullanılan kısmı, örnekleme dönemi, fizyolojik ve biyokimyasal süreçleri ve tüm bitki fizyolojisini kapsamaktadır. Dış faktörler ise iklim koşullarını, yetiştirme koşullarını ve hasat sonrası teknikleri (kurutma yöntemleri ve ekstraksiyon, damıtma süresi, miktar tayini yöntemleri ve analiz koşulları) kapsamaktadır (Yurteri ve ark., 2021). Kısacası, tıbbi ve aromatik bitkilerde uçucu yağ içeriği ve bileşimi çevre koşulları, yetiştirme koşulları, ve kültürel uygulamalar (sulama, gübreleme) (Özgüven ve ark., 2008; Rioba ve ark., 2015) tarafından etkilenmektedir.

Kuraklık stresi tıbbi bitkilerde uçucu ve ikincil metabolitlerin üretimini etkilemektedir (Goncalves ve ark., 2023). Örneğin lavantada, uçucu yağ içeriği ve linalool seviyeleri kuraklık stresi altında artar (Saunier ve ark., 2022). Su eksikliği, ikincil metabolitlerin üretimi de dahil olmak üzere bitki metabolizmasında önemli değişikliklere neden olabilir (Soltanipour, 2005).

Lavanta yaprakları ve çiçekleri uçucu yağlarında 40'tan fazla farklı bileşik içerir, bunların en belirginleri linalool asetat, linalool, sineol, kafur ve geranioldür (Caprari ve ark., 2021). Çok sayıda uçucu yağ üreten bitkiler arasında Lavandula angustifolia Mill. en değerli olanlardan biri olarak öne çıkmaktadır (Crisan ve ark., 2023).

Lavanta yağının kalitesi özellikle linalool, linalil asetat ve kafur içeriği ile ölçülmektedir. Özellikle linalool ve linalil asetat lavanta yağının kalitesini pozitif yönde belirleyen en önemli bileşenler olup, parfüm sanayinde kullanılacak lavanta yağında (ISO3515:2002 lavanta yağı kalite standartlarına göre) en az % 25 oranında bulunmaları istenmektedir (Anonymous, 2002). Kafur ise lavanta yağının kalitesini düşüren en önemli bileşiktir ve %0.5'den daha az olması istenir, yüksek oranda bulunması durumunda uçucu yağı düşük fiyattan satılmaktadır. Düşük kafur içerikli lavanta yağı gıda, kozmetik ve ilaç sanayinde (parfüm, krem, kolonya), yüksek kafur içerikli lavanta yağı ise mum, sabun, böcek ilacı ve diğer ürünlerin yapımında kullanılmaktadır (Tisserand ve Balacs,1999; Baydar, 2010).

3. LAVANTA VERİMİ VE YAĞ KALİTESİNE SULAMANIN ETKİSİ

Kurak alanlar, dünyanın ekili alanlarının yaklaşık %80'ini kaplar ve toplam gıda üretiminin yaklaşık %60'ına katkıda bulunur (World Water Assessment Programme, 2009).Yağış, özellikle kurak ve yarı kurak bölgelerde tarımsal üretimi etkileyen en önemli faktörlerden biridir. Yıllık yağış miktarı ve mevsimsel dağılımı, bir bölgenin tarımsal üretimi için çok önemlidir, çünkü yağış, su dengesi, sulama gereksinimleri ve farklı bitkilerin su üretkenliğini doğrudan etkiler. Günümüzde, kurak bölgelerde sınırlı su kaynakları nedeniyle, tam su ihtiyacını karşılayacak sulama uygulamaları gerçekleştirmek olası değildir. Bu nedenle günümüze kadar, birçok bitkide ürün verimini artırmak ve/veya sulama suyu üretkenliğini artırmak için tamamlayıcı sulama ve kısıntılı sulama üzerine çeşitli çalışmalar yapılmıştır (Wang ve ark., 2001; Zhang ve ark., 2003).

Aynı şekilde, tarımı yapılan tıbbi ve aromatik bitkilerde de benzer çalışmalar yapılmıştır. Gelinen noktada, sulama seviyesi, tıbbi ve aromatik bitkilerin uçucu yağ verimi ve kompozisyonunu etkilemektedir (Bettaieb ve ark., 2009; Petropoulos ve ark., 2008; Vahidipour ve ark., 2013). Bu bağlamda lavanta tarımında sulama ve sulama yönetiminin verime ve kalitesine etkilerini belirlemek üzere saksı ve tarla düzeyinde araştırmalar yürütülmüştür. Lavanta yetiştiriciliğinde sulama ve farklı su yönetim uygulamalarının verime etkilerini konu edinen bazı araştırmalar incelenerek, günümüze kadar gelinen noktadaki mevcut durumun kısa bir özeti bu bildiride sunulmaya çalışılmıştır.

Farklı sulama programlarının etkilerini değerlendirmek amacıyla Chrysargyris ve ark. (2016), lavanta ve adaçayı bitkilerinde sulamanın bitki gelişimine, ürün verimine ve kalitesine etkilerini araştırmışlardır. Saksı denemesi olarak yürütülen çalışmada, bitkiler, tam sulama, orta seviyede kısıntılı sulama ve şiddetli su stresi altında sera koşullarında yetiştirilmiştir. Bu kapsamda tam sulamada saksı başına günlük 50 ml, orta seviyede kısıntılı sulamada 3 günde bir 50 ml ve şiddetli kısıntılı sulamada ise haftada bir 50 ml olarak uygulanmıştır. Genel olarak, su stresi altındaki bitkiler, tam sulama altındaki bitkilere göre daha az büyüme ve değişen kimyasal bileşim sergilemiştir. Buna ek olarak, su stresi altındaki bitkiler, daha yüksek antioksidan (fenolik) konsantrasyonları ile uçucu yağ kalitesinde fayda sağlamıştır. Kısacası bu çalışmanın sonuçları, kısıntılı sulamanın lavanta bitkisinin uçucu yağ kalitesini artırabileceğini göstermiştir. Benzer içerikte farklı sulama planlaması uygulayan Hosseini ve Heidari (2025), İran'da yaptıkları serada saksı denemesinde, kuraklık stresinin lavanta üzerindeki etkilerini ve su kıtlığına verdiği yanıtın altında yatan moleküler mekanizmaları araştırmışlardır. Çalışmada dört farklı sulama seviyesi planlanmış olup; bunlar toprağın tarla kapasitesi'nin (TK) %80, 60, 40 ve 20'sine tekabül eden sırasıyla 2, 1.5, 1 ve 0.5 litre sudan oluşturulmuştur. Sulamalar üç ay boyunca üç günde bir uygulanmıştır. Sulama suyu kısıntıları altında; protein ve klorofil içerikleri, fenolik ve flavonoid bileşikler, antioksidan kapasitesi, uçucu yağ içeriği, uçucu yağın antibakteriyel özellikleri ve uçucu yağ bileşimi dahil olmak üzere çeşitli parametreler incelenmiştir. Elde edilen bulgulara göre, su kısıntısı artıkça, protein ve klorofil içeriği de azalmıştır. Yine İran'da yürütülen başka bir saksı denemesinde Shabankareh ve ark. (2021), farklı su stresi rejimleri altında yetiştirilen üç lavanta çeşidinin tepkisini araştırmışlardır. Çalışmada tarla kapasitesinin(TK) farklı seviyelerindeki (%90-100TK, %70-80TK, 50-60TK ve %30-40TK) sulamalardan oluşan dört farklı sulama rejimi uygulanmış ve su stresinin lavanta yağı kalitesine etkileri araştırılmıştır. Araştırma bulgularına göre, su stresi lavanta kuru madde verimini önemli ölçüde azaltmış olup, en düşük kuru ot verimi en az sulanan konudan elde edilmiştir. Sulama seviyesi artıkça esansiyel yağ oranı azalırken, en yüksek yağ oranı en düşük seviyede sulamadan elde edilmişken, en yüksek yağ verimi ise %70-80 TK sulama rejiminde elde edilmiştir. Değerlendirilen tüm genotiplerde, artan kuraklık stresiyle birlikte başta linalil asetat ve linalool gibi monoterpen bileşikleri azalış gösterirken, seskiterpen bileşiklerinin arttığı belirlenmiştir. Türkiye'de yürütülen benzeri başka bir saksı denemesinde Noory (2020) açık alanda yaptığı çalışmada, farklı yetişme ortamı ve kuraklığın lavanta bitkisinin gelişimi üzerine etkilerini araştırmıştır. Bu bağlamda, biri yağışa dayalı, biri tam tam sulama ve ikisi kısıntılı sulama konusu olmak üzere dört farklı sulama seviyesi altında 7 farklı yetiştirme ortamının lavantanın morfolojik özelliklerine etkisi belirlenmeye çalışılmıştır. Sulama suyu kap buharlaşması esas alınarak haftada bir veya iki kez olacak şekilde belirlenmiş, tam sulama konusuna sulama aralığında gerçekleşen buharlaşma miktarı kadar su uygulanmış olup, %33 kısıntılı sulamada, tam sulama suyunun %66'sı ve %66 kısıntılı sulamada ise %33'ü uygulanmıştır. Elde edilen sonuçlara göre, tam sulama, %33 ve %66 kısıntılı sulama konularına sırasıyla 275, 182 ve 91 mm sulama suyu uygulanmıştır. Sulama seviyeleri lavantanın morfolojik özelliklerine önemli ölçüde etki etmiş olup, tam sulama konusu bitki boyu, bitki gövde çapı, çiçek sapı uzunluğu ve çiçek sayısı bakımından en iyi performansı göstermiştir.

Bir başka saksı çalışmasında Saunier ve ark (2022) iki lavanta türüne (*L. Angustifolia, L. x intermedia*) ait farklı çeşitlerde uygulanan su stresinin etkilerini araştırmışlardır. Bu kapsamda serada saksı denemesi ile iki farklı sulama seviyesinin bitkide fizyolojik ve metabolik özelliklere etkisi test edilmiştir. Sulama uygulamasının birincisinde (kontrol), bitkiler her gün toprağın (karışım) tarla kapasitesinin (TK) %75'ine karşılık gelen 300 mL su ile sulanırken, ikincisi kuraklık stresi uygulaması olup, TK'nın %25'ine karşılık gelen 100 mL su ile her 2 günde bir sulanmıştır. Sulama uygulamaları *L. angustifolia* çeşitlerinde 17 Mayıs ve *L.x intermedia* çeşitlerinde ise 24 Mayısta başlatılmış ve her iki türe ait çeşitlerde 22 Temmuzda sonlandırılmıştır. Sulama seviyelerinin bitkilerin fizyolojik ve metabolik özelliklerine etkileri; biri çiçeklerin yaklaşık %50'sinin açıldığı 10 Haziran - 4 Temmuz döneminde ve diğeri ise çiçeklerin tohum oluşturduğu 9-22 Temmuz dönemi olmak üzere iki fenolojik dönemde ölçümler yapılarak belirlenmiştir. Çalışmanın bulguları, su stresinin, tüm bitki ölçeğinde terpen emisyonlarında önemli bir azalmaya yol açarken, çiçek terpen üretimi azalışının daha düşük seviyede gerçekleştiğini göstermiştir. Yine çalışma sonuçları, her iki türün de su stresi ile başa çıkmak için kuraklığa dayanıklı bir strateji sergilediğini ve L. angustifolia'nın daha rekabetçi bir strateji izlediğini göstermiştir. Çalışma sonuçları ayrıca, Fransa'da geliştirilen yeni bir çeşit olan 'Rapido' (L. angustifolia) ve 'Sumian' (L. x intermedia) çeşitlerinin, şiddetli kuraklık koşullarında yetiştirilmeye en uygun adaylar olabileceğini göstermiştir.

Lavantada sulama üzerine yapılan araştırmaların bazıları tarla denemesi olarak yürütülmüştür. Örneğin Salata (2020) Polonya'da yürüttüğü bir tarla denemesi ile sulamanın lavantanın ot ve çiçek salkımı verimine etkisini araştırmıştır. Araştırmada, biri tamamlayıcı sulama ve diğeri yağışa dayalı olmak üzere lavanta üretimi gerçekleştirilmiş ve iki üretim sistemi karşılaştırılmıştır. Sulamalar damla sulama yöntemi ile toprak su potansiyeli -20 kPa veya bu değere yakınlaştığında uygulanmış olup, her sulamada sabit 15 mm olmak üzere toplam 6 kez sulama yapılmıştır. Çalışma sonuçlarına göre, sulama lavantanın taze ot verimi ile taze çiçek salkım verimini önemli ölçüde artırmıştır. Yağışa dayalı üretimle karşılaştırıldığında, tamamlayıcı sulama taze ot verimini %40.2, taze çiçek verimini %51.76 ve hava kurusu çiçek verimini ise yaklaşık iki kat artırmıştır. Araştırma bulguları ayrıca çiçeklerden elde edilen uçucu yağ verimini de önemli ölçüde artırmış olup, yağışlı üretime göre %17.65 artırmıştır. Buna karşın sulama toplam fenolik asitler oranını %22.83 azaltmıştır. Diğer bir çalışmada Pirzad ve Mohammadzadeh (2018) İran'da yaptıkları bir tarla denemesinde lavanta, biberiye ve kekik bitkilerinde sulamanın biyolojik verime, uçucu yağ verimine ve bitki su tüketimine etkilerini araştırmışlardır. Çalışmada, bitkiler tarla kapasitesinin %75'i (iyi sulanmış, 0.75TK) ve %50'sinde (orta stres, %50TK) olmak üzere iki farklı nem seviyesinde, yani iki farklı sulama aralığı sulama koşullarında yetiştirilmiştir. Ayrıca kontrol amaçlı olarak yağışa dayalı bir konuda çalışmaya dahil edilmiştir. Araştırma sonuçlarına göre, %75TK ve %50TK konularına uygulanan sulama suyu miktarları birinci yılda sırasıyla 218.7, 150 ve 0 mm, ikinci yılda 262.5, 225 ve 0 mm olmuştur. Sulama sıklığı artıkça uçucu yağ oranı azalmış, en yüksek oran sulamasız koşullarda elde edilmiştir. Ancak tarla kapasitenin %50'sinde sulama ile yağışa dayalı konuların yağ oranları arasında önemli bir fark olmadığı belirlenmiştir. Sonuçlara göre, sulama sıklığı artıkça lavanta biyolojik verimi ve uçucu yağ verimi önemli ölçüde artış göstermiş, en yüksek verim değerleri tarla kapasitesinin %75'inde sulanan konudan elde edilmiştir. Benzer içerikli başka bir çalışmada Sarfaraz ve ark (2024) tarafından İran'da yürütülen bir tarla denemesinde farklı sulama seviyeleri ve farklı gübre kaynaklarının lavantaya olan etkileri araştırılmıştır. Denemede, tarla kapasitesi nemine (TK) dayalı dört farklı sulama seviyesi (%95 TK (S1), %75TK (S2), %50TK (S3) ve %25TK (S4)) ve üç farklı gübre kaynağı iki farklı lavanta çeşidine uygulanarak, uygulamaların lavantanın biyolojik ve çiçek verimi ile uçucu yağ oranı ve yağ verimine etkileri araştırılmıştır. Elde edilen bulgulara göre S1, S2, S3 ve S4 konuları 7 kez sulanmış ve sırasıyla toplamda 750, 584, 391 ve 305 mm sulama suyu uygulanmıştır. Sulama suyu miktarı artıkça lavanta biomass verimi ile çiçek verimi önemli

ölçüde artış göstermiştir. En yüksek verimler en yüksek sulama suyu uygulanan kontrol konusundan elde edilmiştir. En düşük sulama suyu uygulaması ile kıyaslandığında, en yüksek sulama seviyesi biyolojik verimi %68.5 ve çiçek verimini ise %105 artırmıştır. Sulama seviyeleri lavanta uçucu yağ oranını önemli ölçüde etkilemiş olup, en düşük oranlar en az sulanan konu ile en fazla sulanan konudan elde edilmiştir.

Hasibi ve ark (2022) tarafından yapılan çalışmada, farklı seviyelerdeki su stresini kullanarak lavantanın kuraklığa dayanıklılığı tarla koşullarında test edilmiştir. Bu bağlamda 4, 8, 12 ve 20 günde bir sulama olmak üzere dört farklı sulama konusu bitkilere uygulanmış ve lavantanın morfolojik ve biyokimyasal özelliklere etkisi belirlenmeye çalışılmıştır. Bu denemenin sonuçları, stres düzeylerinin morfolojik, biyokimyasal ve uçucu yağ üzerindeki etkisinin ayrı ayrı önemli olduğunu göstermiştir. Lavanta sürgün boyu, sürgün sayısı, sürgün kuru ağırlığı, yaprak alanı ve yaprak kuru ağırlığı gibi morfolojik özellikler sık sulamada en yüksek değerleri göstermiş iken, stoma direnci sulama aralığı artıkça artmıştır. Benzer şekilde klorofil içeriği, SOD (süperoksit desmotaz), POD (polifenol oksidaz), APX (askorbater oksidaz) gibi biyokimyasal özellikler sulama aralığı uzadıkça azalış gösterirken, prolin içeriği artış göstermiştir. En yüksek prolin değeri 20 gün sulama aralığında elde edilmiştir. Sulama aralığı bağlamında benzer içerikli İran'da yapılan bir araştırmada Satarzadeh ve ark. (2024), lavanta bitkisinde farklı sulama rejimleri, farklı seviyeyi içeren biyogübre aşılması (Thiobacillus, Pseudomonas ve Thiobacillus + Pseudomonas aşılaması ve kontrol olarak aşılamasız konu) ve iki farklı fosforlu gübre dozunun (0 ve 50 kg ha^{-1}) etkisini araştırmışlardır. Çalışmada sulama seviyeleri, A sınıfı buharlaşma kabından 60, 90 ve 120 mm buharlaşma sonrası sulama uygulaması olmak üzere üç konudan oluşturulmuştur. Sonuçlar, sulamanın her kademesinde fosfor tüketiminin ve biyogübre ile aşılamanın, kontrol ile karşılaştırıldığında çiçeklerin kuru ağırlığını artırdığını göstermiştir. Bu çalışmanın sonuçlarına dayanarak, su stresi koşullarında, biyolojik gübrelerin fosforlu gübrelerle birlikte kullanılmasının lavanta bitkisinde yetersiz beslenme vakalarını büyük ölçüde azaltabileceği ifade edilmiştir.

García-Caparrós ve ark (2019) tarafından İspanya'da yapılan çalışmada, Ballıbabagiller (Lamiaceae) familyasına ait bazı (ballıbaba, nane, kekik, lavanta, dağ çayı vb.) bitkilerin su stresine tepkisi bir tarla denemesi ile araştırılmıştır. Denemede iki farklı sulama seviyesi planlanmış olup, sulama seviyeleri referans bitki su tüketimi (ETo) ve yağış miktarı (R) farkına dayalı oluşturulmuştur. Çalışmada, bitkilere tam sulama ve %30 kısıntılı sulama seviyeleri damla sulama sistemi ile uygulanarak, biyolojik verime ve uçucu yağ içeriğine etkisi test edilmiştir. Araştırma sonuçlarına göre, %30 sulama suyu kısıntısı lavanta bitkisini olumsuz etkilemişken, diğer bitkilerde (adaçayı, nane, kekik) sulama seviyeleri olumsuz bir etki oluşturmamıştır. Tam sulama ile kıyaslandığında, %30 kısıntılı sulama lavantanın kuru ot verimi ve uçucu yağ verimini sırasıyla %32 ve %35.9 azaltmıştır.

Türkiye'de de lavanta yetiştiriciliğinde sulama verim ilişkileri, sulama yönetimi ve sulama üretkenliğini önceleyen az sayıda da olsa araştırma yapıldığı görülmektedir. Örneğin Akçay ve ark. (2021) Aydın Ovası koşullarında damla yöntemi ile farklı sulama seviyelerinin lavanta bitkisinde verime etkileri üzerine bir tarla denemesi yürütmüşlerdir. Çalışmada kap buharlaşması ve toprak nemine dayalı olmak üzere iki sulama stratejisi dikkate alınmış olup, her bir sulama stratejisinde biri tam ve üçü kısıntılı (tam seviyenin %67, 33 ve 0) olmak üzere dört sulama seviyesi uygulanmıştır. A sınıfı kap buharlaşması stratejisinde 7 gün sulama aralığı ve toprak nemine dayalı sulama stratejisinde ise tam sulama uygulanan parselde bitki kök bölgesinde faydalı su kapasitesinin %50'si tüketilince sulamalar yinelenmiştir. Elde edilen sonuçlara göre, buharlaşma kabına dayalı strateji ile karşılaştırıldığında, toprak nemine dayalı sulama stratejisi önemli ölçüde daha yüksek verim değerleri sağlamıştır. Sulama seviyeleri lavanta verimini önemli şekilde etkilemiş olup, yaş çiçek verimi 381-510 kg da^{-1} ve drog çiçek verimleri ise 172-263 kgda^{-1} arasında bulunmuştur. Çalışmanın sonuçları, sulama seviyesi

artıkça lavanta çiçek verimi ve drog çiçek veriminin önemli ölçüde arttığını göstermiştir. Sulama suyunun üretkenliği, sulama seviyesi artıkça azalış göstermiş olup, sulamalı konular arasında en düşük değer her iki sulama stratejisinde de tam sulama seviyesinden elde edilmiştir. Ayrıca bu çalışma, yeterli su varlığı koşullarda, sulama programının toprak nemine dayalı yapılmasını ve tam sulama uygulanmasını, su kısıtlı koşularda ise hem toprak nemin hem de kap buharlaşması sulama stratejisinde %33 kısıntılı sulama seviyesinin lavanta tarımı için önerilebileceğini göstermiştir. Yine Türkiye'de yarı kurak iklime sahip Niğde koşullarında Yetik ve Şen (2025) tarafından yapılan bir tarla denemesinde, damla sulama yöntemi ile uygulanan farklı sulama seviyelerinin lavantanın verimi, verim bileşenleri, uçucu yağ içeriği, su üretkenliği ve sulama suyu üretkenliği üzerine etkileri beş üretim mevsimi için araştırılmıştır. Sulama konuları; tam sulama (TS), orta derecede kısıntılı sulama (KS1, %33 su eksikliği), şiddetli kısıntılı sulama (KS2, %66 su eksikliği) ve yağışa dayalı üretimden (YD) oluşmuştur. Sonuçlar, KS1'in TS ile karşılaştırılabilir taze verim (144-227 kg /da) ve yağ verimi (2,7-6,9 kg/ da) elde ettiğini ve bitki su tüketiminin 781,5-923,6 mm arasında değiştiğini göstermiştir. Yağışa dayalı konuda ürün verimi önemli ölçüde azalırken, su üretkenliği en üst düzeyde gerçekleşmiştir. Bu da önemli su eksiklikleri altında bile lavantanın suyu çok etkili kullanma potansiyeline sahip olduğunu göstermektedir. Araştırma bulguları, lavantanın, kısıntılı sulamaya uygun olduğunu, göstermiştir. Sonuç olarak, araştırıcılar; %33 su kısıntısının verim düşüşünü en aza indirerek su üretkenliğini optimize etmek için, %66 su kısıntısını ise su kısıtlı yarı kurak iklimlerde sürdürülebilir lavanta üretimi için uygun bir sulama programı olarak önerilebileceğini bildirmişlerdir.

4.SONUÇ

Bu incelemede, önemli bir tıbbi ve aromatik bitki olan lavantanın tarımında sulamanın bitki verimine ve uçucu yağ kalitesine etkisi ele alınmıştır. Bu kapsamda yakın geçmişte lavantada sulama üzerine yapılmış çalışmaların bazıları incelenerek, sulamanın etkisine ilişkin kısa özetleri sunulmaya çalışılmıştır. Yapılan incelemeden elde edilen sonuçlara göre; sulamanın lavantanın gelişimini, çiçek verimi ile uçucu yağ verimini önemli şekilde artırdığı, uçucu yağ oranını ise kısmen olumsuz etkilediği, ancak uçucu yağ verimini artırdığı görülmektedir. Bu nedenle, kurak ve su kısıtlı bölgelerde, lavantanın az miktarda su ile damla sulama yöntemiyle birkaç kez sulanması yararlı olacaktır.

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"MİCHELE PALİERİ" ÜZÜM ÇEŞİDİNDE *ASCOPHYLLUM NODOSUM* UYGULAMALARININ TANELERDE SEKONDER METOBOLİT BİRİKİMİ ÜZERİNE ETKİLERİNİN İNCELENMESİ

Emine Sema ÇETİN

Prof. Dr, Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü, Yozgat / Merkez

Email: e.sema.çetin@yobu.edu.tr (Sorumlu Yazar)

Nazife Çiğdem ERMİŞ

Lisans Öğrencisi, Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü, Yozgat / Merkez

Email: ncigdem.ermis@csb.gov.tr

Berna KELES

Arş. Gör, Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü, Yozgat / Merkez

Email: berna.keles@yobu.edu.tr

ÖZET

Sekonder metabolitler, bitkilerde doğal olarak sentezlenen ancak primer metabolitler gibi doğrudan yaşamsal süreçlerde görev almayan bileşiklerdir. Bu bileşikler, bitkilerin çevresel stres faktörlerine karşı kendilerini koruma mekanizmalarının önemli bir parçasıdır. Bitkiler tarafından savunma, rekabet veya çevresel koşullara uyum amacıyla üretilen sekonder metabolitler; fenolik bileşikler, alkaloidler, terpenoidler ve flavonoidler gibi geniş bir grubu kapsamaktadır. Son yıllarda yapılan araştırmalar, bu bileşiklerin yalnızca bitkiler için değil, insan sağlığı açısından da oldukça önemli olduğunu ortaya koymuştur. Antioksidan, antifungal, antibakteriyel ve antikanser özellikleri sayesinde sekonder metabolitlerin; kanser, kardiyovasküler hastalıklar, tip II diyabet ve nörodejeneratif rahatsızlıklar gibi birçok hastalığın önlenmesi ve tedavisinde potansiyel etkilerinin bulunduğu belirlenmiştir. Bu nedenle ilaç sanayisinden gıda ve kozmetik endüstrisine, hatta zirai mücadele uygulamalarına kadar pek çok sektörde kullanım alanı bulmaktadır. Bu araştırma kapsamında, "Michele Palieri" üzüm çeşidinde *Ascophyllum nodosum* uygulamalarının tanelerde birer sekonder metabolit olan fenolik bileşiklerin birikimi üzerindeki etkileri incelenmiştir. Ayrıca, bitkinin savunma mekanizmasında rol oynayan ve aynı zamanda birer fitohormon niteliğinde olan indol asetik asit, gibberellik asit, zeatin, absisik asit ve salisilik asit gibi hormonların yanı sıra organik asit miktarlarındaki değişimler de değerlendirilmiştir. Bu çalışma, söz konusu uygulamaların bitkisel metabolizma üzerindeki düzenleyici etkilerini ortaya koymayı ve biyostimülantların sekonder metabolit üretimi üzerindeki potansiyel katkılarını aydınlatmayı amaçlamaktadır.

Anahtar Kelimeler: Sekonder metabolitler, Ascophyllum nodosum, Fenolik bileşikler

INVESTIGATION OF THE EFFECTS OF *ASCOPHYLLUM NODOSUM* APP LICATIONS ON SECONDARY METABOLITE ACCUMULATION IN BERRIES IN "MICHELE PALIERI" GRAPE VARIETY

ABSTRACT

Secondary metabolites are compounds naturally synthesized in plants that, unlike primary metabolites, do not play a direct role in vital physiological processes. These compounds form an important part of the plant's defense mechanisms against various environmental stress factors. Produced by plants for purposes such as defense, competition, or adaptation to environmental conditions, secondary metabolites include a wide range of compounds such as phenolics, alkaloids, terpenoids, and flavonoids. Recent studies have shown that these compounds are not only essential for plants but also have significant benefits for human health. Owing to their antioxidant, antifungal, antibacterial, and anticancer properties, secondary metabolites have been reported to exhibit positive effects on the prevention and treatment of diseases such as cancer, cardiovascular disorders, type II diabetes, and neurodegenerative diseases. Therefore, they have attracted growing interest in various sectors, including pharmaceuticals, food, cosmetics, and agricultural protection.

In this study, the effects of ***Ascophyllum nodosum*** applications on the accumulation of phenolic compounds—known as secondary metabolites—in "**Michele Palieri"** grape variety were investigated. Additionally, changes in phytohormones such as indole acetic acid, gibberellic acid, zeatin, abscisic acid, and salicylic acid, which play key roles in plant defense mechanisms, as well as variations in organic acid contents, were also evaluated. The study aims to reveal the regulatory effects of these applications on plant metabolism and to elucidate the potential contributions of biostimulants to secondary metabolite production.

Keywords: Grape, Secondary metabolites, *Ascophyllum nodosum,* Phenolic compounds,

1. GİRİŞ

A. nodosum ekstraktlarının ülkemizde ve dünyada gerek örtüaltı yetiştiriciliği gerek açık alanlarda olmak üzere elma, armut, turunçgiller ve süs bitkileri yetiştiriciliğinde farklı amaçlarla kullanım alanı buldukları bilinmektedir (Güner ve Aysel, 1996). Üzümde ise söz konusu uygulamanın etkinliğinin belirlenmesine yönelik yapılmış sınırlı sayıda araştırma bulunmaktadır. Burada genellikle tane özellikleri, verim ve kalite bileşenleri üzerinde yoğunlaşıldığı, hastalık ve zararlılara dayanım üzerine etkisi ile şaraplık çeşitlerde de şarap bileşimine olan etkisini incelemeye odaklanıldığı tespit edilmiştir (Mondello vd., 2018; Gutiérrez-Gamboa vd., 2019b; Salvi vd., 2019; Taskos vd., 2019; Gutiérrez-Gamboa vd., 2020a, b, c; Thankaraj vd., 2020). Karaerik üzüm çeşidinde yürütülmüş bir araştırmada ise üç ticari deniz yosunu ekstraktının fidanlarda besin elementi alımı üzerine etkisi incelenmiş ve araştırma sonucunda fidanlarda bakır ve diğer mikro besin elementlerinin alımının arttığı belirtilmiştir (Turan ve Köse, 2004).

Önemli renkli ve erkenci çeşitlerimizden olan Trakya İlkeren çeşidinde deniz yosunu uygulamalarının sofralık üzümlerdeki kalite parametreleri üzerinde olumlu etki gösterdiğini belirtmişlerdir (Kök vd., 2010).

Bir araştırmada da Fetească albă üzüm çeşidinde vejetatif büyüme parametreleri üzerinde *A. nodosum* ekstraktının etkileri incelenmiştir. Omcalara yapraktan sprey olarak gerçekleştirilen uygulamalar sonrası bitkilerde sürgün uzunluğu, sürgün çapı ve yaprak alanının arttığı saptanmıştır (Popescu ve Popescu, 2014).

Ülkemizin önemli şaraplık çeşitlerinden olan, aynı zamanda salamuralık yaprak olarak da ciddi bir tüketimi bulunan Narince üzüm çeşidinde yapılmış bir araştırmada da *A. nodosum* ekstraktlarının asmaların yaprak kuru ağırlığının, tane ağırlığının, tane hacminin artmasında, ayrıca Ca, Zn, S ve B minerallerinin alımının teşvik edilmesinde etkili olduğunu tespit etmişlerdir (Sabır vd., 2014). Tane tutumu ve verimliliği üzerine deniz yosunu uygulamalarının etkisini araştıran araştırmacılar, Carmenère üzüm çeşidinde *A. nodosum* ekstraktının uygulamasının bu parametreler üzerinde olumlu etki gösterdiğini ifade etmişlerdir (Gutiérrez-Gamboa vd., 2019a).

Riesling üzüm çeşidinde deniz yosunu ve hümik asit uygulamalarının tane biyokimyasal özellikleri üzerine etkilerini inceleyen araştırmacılar söz konusu uygulamaların çeşidin tane biyokimyasal özelliklerini değiştirdiğini tespit etmişlerdir (Kök ve Bal, 2016).

Bir diğer araştırmada ülkemizin önemli kurutmalık üzüm çeşitlerinden olan Sultani Çekirdeksiz üzüm çeşidinde *A. nodosum* ekstraktının verim parametreleri üzerine etkisi incelenmiş, suda çözünür kuru madde dışındaki incelenen diğer özelliklerde olumlu etkiler gösterdiği tespit edilmiştir (Norrie vd., 2002).

Yukarıda da detaylandırıldığı üzere asmada deniz yosunu uygulamalarının büyük çoğunlukla bitkinin verim parametreleri ve besin elementi alımı ile olan ilişkisini incelemeye yönelik gerçekleştirilmiştir. Bu araştırmada ise söz konusu uygulamanın sekonder metabolizma üzerinde etkili olup olmadığı incelenmiştir. Deniz yosununun metabolit birikimi üzerine olan çalışmalar son derece sınırlı sayıda ve sınırlı bileşen üzerinde gerçekleştirilmiştir. Örneğin Frioni vd. (2018) ile Salvi vd. (2019), *A. nosodum* ekstraktının üzümde fenolik bileşen üzerindeki etkisini incelemişlerdir. Bu uygulamanın tane ve kabuk antosiyanin birikimini teşvik ettiğini, toplam fenolik bileşik içeriğini artırdığını belirlemişlerdir. Taskos vd. (2019), Merlot üzüm çeşidinde *A. nodosum* uygulamasının verim ve salkım sayısını arttırdığını, tane toplam polifenol indeksini ise azalttığını saptamışlardır. Tempranillo Blanco üzüm çeşidine ait omcalarda deniz yosunu uygulamalarının kateşin ve flavonol içeriklerini artırdığı da saptanmıştır Gutiérrez-Gamboa, 2020).

2. MATERYAL VE YÖNTEM

Araştırma, 2024-2025 yılları arasında yürütülmüştür. Uygulamalar Yozgat Merkez Köylerinden olan Recepli Köyü'nde 5 da arazi üzerine tesis edilmiştir. 1103 Paulsen Amerikan asma anacı üzerine aşılanmış Michele Palieri üzüm çeşidinden oluşan 8 yaşındaki bağda yapılmıştır. Uygulamalara geçilmeden önce 2024 kış budamasında (Nisan 2024) budama işlemleri gerçekleştirilmiş ve omcalar üzerinde olabildiğince eşit sayıda göz bırakılmaya çalışılmıştır. Uygulamalar, söz konusu çeşidin fenolojik gözlemleri baz alınarak tanelerin koruk safhasında, ben düşme döneminde ve hasattan 10 gün önce olacak şekilde 3 ayrı dönemde yapılmıştır. Bu süreçte bağda sadece rutin kültürel işlemler ve külleme mücadelesi yapılmıştır. Uygulamalarda "Acadian" firmasına ait sıvı formdaki *A. nodosum* solüsyonu kullanılmıştır. Tüm omca pülverizatör ile ıslatılmış, kontrol bitkilerine sadece saf su uygulaması yapılmıştır. *A. nodosum,* 1/10; 1/15 ve 1/20 dozlarında uygulanmıştır. Hasat döneminde salkımlar alınıp bağa getirilerek aşağıda detaylandırılan analizlerin yapılmasına kadar olan süreç içerisinde derin dondurucuda muhafaza edilmiştir. Laboratuvar işlemleri Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü laboratuvarında yapılmıştır.

2.1. FENOLİK BİLEŞİK EKSTRAKSİYONU

Fenolik bileşik ekstraksiyonları Kiselev (2007)'ye göre yapılmıştır.

2.2. TOPLAM FENOLİK MADDELERİN BELİRLENMESİ

Ekstrakte edilmiş örneklerde toplam fenolik bileşik miktarları Folin Ciocalteu kolorimetrik metodu kullanılarak Singleton ve Rossi (1965)'ye göre yapılmıştır. Spektrofotometrede okumalar 765 nm dalga boyunda gerçekleştirilmiştir. Standart gallik asit çözeltisinden hazırlanan kurveden yararlanılarak, toplam fenolik madde miktarları gallik asit eşdeğeri (GAE) olarak belirlenmiştir (Çizelge 1).

2.3. TOPLAM FLAVONOL MİKTARININ BELİRLENMESİ

Toplam flavonol miktarı Neu solusyonu kullanılarak Dai vd. (1995)'ne göre yapılmıştır. Toplam flavonollerin miktarı, rutin standardından hazırlanmış olan körveden yararlanılarak, rutin eşdeğeri olarak (Rutin Equivalent, RE) mg/g şeklinde belirlenmiştir (Çizelge 1).

2.4. TOPLAM FLAVANOL MİKTARININ BELİRLENMESİ

Toplam flavanol miktarı Arnous vd. (2001)'ne göre DMAC (dimetil amino sinnamaldehit) metodu kullanılarak gerçekleştirilecektir. Sonuçlar kateşin standardından hazırlanmış olan körveden yararlanılarak, kateşin eşdeğeri (Catechin Equivalent, CE) (mg/g) cinsinden sunulmuştur (Çizelge 1).

2.5. FENOLİK BİLEŞİKLERİN VE BİTKİSEL HORMONLARIN TANIMLANMASI

Fenolik bileşiklerin ve bitkisel hormonların tanımlanması HPLC (Shimadzu Prominence, Tokyo, Japonya) ile yapılmıştır. Bu amaçla modifiye edilmiş Gomes vd. (1999)'nin yöntemi tercih edilmiştir. Fenolik bileşikler içerisinden asmada ve üzümde en fazla bulunan kateşin, epikateşin, ellajik asit, gallik asit, 3,4-dihidroksi benzoik asit, 4-dihidroksi benzoik asit, kafeik asit, naringin, sinnamik asit, 2,5- dihidroksi benzoik asit, vanilik asit, p-kumarik asit, ferulik asit, klorogenik asit, rutin, kuersetin ve resveratrol miktarlarının tespiti yapılmıştır. Bitkisel hormonlar içerisinde indol asetik asit, gibberellik asit, zeatin, absisik asit ve salisilik asit miktarları belirlenmiştir (Çizelge 3). Ayrıca organik asit miktarları da incelenmiştir.

2.6. VERİLERİN İSTATİSTİKSEL ANALİZİ

Araştırmada yapılan analizlerden elde edilen sayısal veriler SPSS 20.0 paket programı kullanılarak test edilmiştir. Grup ortalamaları arasındaki farklılıkların belirlenmesinde ise Duncan çoklu karşılaştırma testi kullanılmıştır.

3. BULGULAR

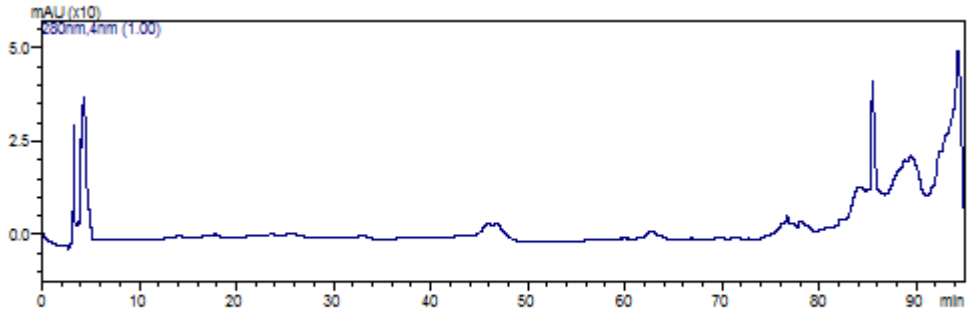
Çizelge 1. Spektrofotometrik olarak belirlenen fenolik bileşik miktarları

A. nodosum	Toplam fenolik madde (mg/g GAE)	Toplam flavonol (mg/g RE)	Toplam flavanol (mg/g CE)
Kontrol	0,1641 d*	0,0583 c	0,0275 b
1/20	0,2529 c	0,0689 b	0,0280 b
1/15	0,4662 a	0,0890 a	0,0671 a
1/10	0,3582 b	0,0833 a	0,0778 a

*Aynı sütunda farklı harflerle gösterilen ortalamalar arasında istatistiksel olarak farklılık bulunmaktadır ($p<0.05$).

Çizelge 1' in incelenmesi ile de anlaşılacağı üzere bitkinin savunma mekanizmasında önemli etkiler gösteren birer sekonder metabolit olan fenolik bileşiklerin miktarları 1/15 oranında seyreltilmiş *A. nodosum* uygulanan omcaların tümünde yüksek olarak belirlenmiştir. Bununla birlikte toplam flavonol ve toplam flavanol değerleri bakımından 1/10 oranında seyreltilmiş *A. nodosum* uygulaması da istatistiksel olarak önemli bulunmuştur.

Asmada ve üzümde en fazla bulunan fenolik bileşikler bileşen bazında HPLC ile de belirlenmişlerdir. Bunlar kateşin, ellajik asit, epikateşin, gallik asit, 3,4-dihidroksi benzoik asit, 4-dihidroksi benzoik asit, kafeik asit, naringin, sinnamik asit, 2,5- dihidroksi benzoik asit, vanilik asit, p-kumarik asit, ferulik asit, klorogenik asit, rutin, kuersetin ve resveratroldür. *A. nodosum* uygulamalarının bu fenolik bileşenler üzerine etkileri Çizelge 2'de sergilenmiştir. Örneğe ait bir kromatogram da Şekil 1. de sunulmuştur.



Şekil 1. Örneğe ait kromatogram görünümü

Çizelge 2 incelendiğinde kateşin, 4-dihidroksi benzoik asit, 2,5- dihidroksi benzoik asit, ferulik asit ve kuersetin dışında diğer tüm bileşenlerin A.nodosum uygulanan omcalarda istatistiksel olarak daha yüksek düzeyde elde edildiği görülmektedir ($p<0.05$). Burada özellikle ellajik asidin 1/15 oranında *A. nodosum* uygulanan omcalarda en düşük değere göre yaklaşık 30 kat artmış olması (1007,21 ppm), aynı uygulama grubunda kafeik asit içeriğinin en düşük değere göre yaklaşık 13 kat artmış olması (104,55 ppm) ve rutin içeriğinin en düşük değere göre 224 kat artmış olması (235,22 ppm) son derece dikkat çekicidir (Çizelge 2). 3,4-dihidroksi benzoik asidin 1/10 oranında *A. nodosum* uygulanan omcalarda en düşük değere göre yaklaşık 21 kat artmış olduğu görülmektedir (0,87 ppm).

Çizelge 3. de bitkisel hormonlar içerisinde yer alan indol asetik asit, gibberellik asit, zeatin, absisik asit ve salisilik asit miktarlarının asmalara *A. nodosum* uygulaması karşısındaki değişim gösterilmektedir. Burada indol asetik asit hariç tüm hormonların kontrol uygulamasında bir diğer ifade ile *A. nodosum* uygulanmayan omcalarda düşük miktarlarda sentezlendikleri anlaşılmaktadır. Indol asetik asit miktarının ilginç bir şekilde 1/10 oranında *A. nodosum* uygulamasında da kontrol grubu ile aynı olmak üzere istatistiksel olarak en yüksek düzeye ulaştığı dikkati çekmektedir (Çizelge 3). Zeatin ve salisilik asit miktarı 1/20 oranında A.nodosum uygulanan omcalarda yüksek düzeyde sentezlenirken, gibberellik asit ve absisik asidin, indol asetik asit de olduğu gibi 1/10 oranında *A. nodosum* uygulanan grupta yüksek miktarda sentezlenmişlerdir.

Çizelge 2. HPLC ile belirlenen fenolik bileşik miktarları (ppm)

A. nodosum	Kateşin	Ellajik asit	Epikateşin	Gallik asit	3,4 dihidroksi benzoik asit	4-hidroksi benzoik asit	Kafeik asit	Naringin	Sinnamik asit	2,5 - dihidroksi benzoik asit	Vanilik asit	p-kumarik asit	Ferulik asit	Klorogenik asit	Rutin	Quersetin	Resveratrol
Kontrol	2,11 a*	122,56 b	2,63 d	0,30 b	0,07 b	4,03 a	14,02 bc	2,18 b	0,09 b	355,72 a	0,28 b	0,11 b	1,91 a	0,02 d	1,05 b	0,42 a	124,14 b
1/20	0,84 c	32,64 c	4,25 c	0,15 d	0,09 b	1,12 b	7,59 c	1,91 c	0,05 c	147,22 b	0,13 d	0,06 d	0,21 c	0,21 a	2,06 b	0,47 a	159,26 a
1/15	0,97 b	1007,21 a	35,25 a	0,41 a	0,04 c	0,70 c	104,55 a	2,53 a	0,65 a	76,35 c	0,31 a	0,49 a	0,09 d	0,06 b	235,22a	0,16 b	129,22 b
1/10	0,75 d	131,87 b	17,11 b	0,20 c	0,87 a	0,10 d	15,65 b	1,80 c	0,05 c	4,76 d	0,27 c	0,08 c	0,61 b	0,04 c	1,30 b	0,42 a	137,42 b

*Aynı sütunda farklı harflerle gösterilen ortalamalar arasında istatistiksel olarak farklılık bulunmaktadır ($p<0.05$).

Çizelge 3. HPLC ile belirlenen bitkisel hormon miktarları (ppm)

A. nodosum	Zeatin	Salisilik asit	Gibberellik asit	Indol asetik asit	Absisik asit
Kontrol	2,85 b*	1,12 b	808,87 d	3,39 a	0,28 b
1/20	4,30 a	3,00 a	1259,51 c	1,31 c	0,22 c
1/15	1,26 c	0,98 c	1462,56 b	1,82 b	0,13 d
1/10	2,51 b	0,26 d	2800,53 a	3,39 a	0,34 a

*Aynı sütunda farklı harflerle gösterilen ortalamalar arasında istatistiksel olarak farklılık bulunmaktadır ($p<0.05$).

Çizelge 4. HPLC ile belirlenen organik asit miktarları (ppm)

A. nodosum	Oksalik asit	Tartarik asit	Malik asit	Askorbik asit	Laktik asit	Sitrik asit	Süksinik asit	Fumarik asit	Şikimik asit
Kontrol	0,49 c	1476,52 c	23,52 a	29,33 b	3033,46 a	631,04 a	4442,44 c	0,43 b	802,64 c
1/20	36,77 b	1652,67 b	14,87 c	29,97 b	2002,11 b	148,56 c	4434,09 c	0,02 c	1201,46 a
1/15	0,47 c	2118,80 a	20,68 b	25,32 c	1932,08 b	113,95 d	9185,08 b	3,29 a	954,74 b
1/10	286,55 a	1403,30 d	20,25 b	45,63 a	1387,62 c	171,76 b	11703,43 a	0,52 b	815,91 c

*Aynı sütunda farklı harflerle gösterilen ortalamalar arasında istatistiksel olarak farklılık bulunmaktadır ($p<0.05$).

Organik asit miktarlarının da incelendiği araştırmada tartatik asit, askorbik asit, süksinik asit, fumarik asit ve şikimik asit miktarlarının farklı seyreltme oranlarında olmakla birlikte tümünde *A. nodosum* uygulanan gruplarda yüksek miktarlarda sentezlendikleri dikkati çekmektedir (Çizelge 4). Oksalik asit miktarında 1/10 *A. nodosum* grubunda oksalik asit miktarında istatistiksel olarak önemli ve oldukça yüksek bir artış olduğu dikkati çekmektedir (286,55 ppm). Benzer şekilde süksinik asidin de yine aynı uygulama grubunda çok yüksek düzeyde üretildiği görülmektedir (11703,43 ppm).

4. SONUÇ

Araştırmada sonuç olarak spektrofotometrik olarak belirlenen fenolik bileşik miktarları ile HPLC ile belirlenen fenolik bileşenler, bitkisel hormonlar ve organik asit içerikleri değerlendirildiğinde genel olarak *A. nodosum* uygulamalarının bu bileşenleri artırmada olumlu etkiler gösterdikleri anlaşılmaktadır. Bu durum hem tane kompozisyonunun içeriğinin zenginleştirilmesi hem de bileşenlerin çoğunun doğal savunma bileşenleri olması bakımından önemlidir.

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TÜRKİYE İKLİM KANUNU'NUN TARIMSAL PEYZAJLARA OLASI ETKİLERİ ÜZERİNE BİR DEĞERLENDİRME

Prof. Dr. Aybike Ayfer KARADAĞ

Düzce Üniversitesi, Orman Fakültesi, Peyzaj Mimarlığı Bölümü, Düzce

Email: ayferkaradag@duzce.edu.tr

ORCID NO: 0000-0002-7726-8756

Prof. Dr. Demet DEMİROĞLU*

Kilis 7 Aralık Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü, Kilis

Email: ddemiroglu@kilis.edu.tr

ORCID NO: 0000-0002-3934-5319

ÖZET

2025 yılında yürürlüğe giren 7552 sayılı Türkiye İklim Kanunu, net sıfır emisyon hedefleri, yeşil büyüme vizyonu ve iklim değişikliğine uyum ilkeleri çerçevesinde tarımsal üretim, arazi kullanımı ve kırsal alan yönetimini kritik düzeyde etkileyen bir düzenlemedir. Bu çalışmanın amacı, Kanun'un tarımsal peyzajlar üzerindeki olası etkilerini ortaya koymaktır. Çalışmada, belge analizi ve GZFT (Güçlü, Zayıf, Fırsat, Tehdit) analizi kullanılmıştır. Kanun, ekosistem temelli yaklaşımlar ve sürdürülebilirlik ilkeleri aracılığıyla tarımsal peyzajların direncini ve uyum kapasitesini güçlendirme potansiyeline sahip olmanın yanında tarımsal peyzajlar için başta karbon depolama ve sera gazı azaltımı, iklim dirençli ürün desenleri ve yeşil finansmana erişim olmak üzere önemli fırsatlar sunmaktadır. Ancak, küçük üreticilerin finansman ve teknolojiye erişim güçlükleri ile Kanun'un mevcut ulusal mevzuatla entegrasyonundaki belirsizlikler uygulamadaki etkinliği sınırlayabilecek temel yapısal risklerdir. Sonuç olarak, Türkiye İklim Kanunu, tarımsal peyzajları çözümün merkezine konumlandırma potansiyeline sahiptir. Bu potansiyelin tam olarak gerçekleşmesi, ancak küçük üreticiyi gözeten adil geçiş politikalarının somutlaştırılması, toprak karbonu yönetimi ve gıda güvenliğini önceliklendiren bütüncül bir politik yaklaşım benimsenmesiyle mümkün olacaktır.

Anahtar Kelimeler: Türkiye İklim Kanunu, iklim değişikliğine uyum, tarımsal peyzajlar, sürdürülebilir tarım. Karbon Yönetimi, Gıda Güvenliği.

AN ASSESSMENT OF THE POTENTIAL IMPACTS OF TURKEY'S CLIMATE LAW ON AGRICULTURAL LANDSCAPES

ABSTRACT

The Turkish Climate Law No. 7552, which entered into force in 2025, is a regulation that critically affects agricultural production, land use, and rural area management within the framework of net-zero emission targets, the green growth vision, and climate change adaptation principles. The objective of this study is to reveal the potential impacts of the Law on agricultural landscapes. The methodology employed involves document analysis and a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis. The Law holds the potential to enhance the resilience and adaptation capacity of agricultural landscapes through ecosystem-based approaches and sustainability principles. The Law presents significant opportunities for agricultural landscapes, primarily including carbon sequestration and greenhouse gas mitigation, the development of climate-resilient cropping patterns, and access to green finance. However, the difficulties faced by small-scale producers in accessing finance and technology, along with the uncertainties in the Law's integration with existing national legislation, constitute key structural risks that may limit its effectiveness in implementation. In conclusion, the Turkish Climate Law has the potential to position agricultural landscapes at the core of the climate solution. The full realization of this potential, however, depends on the concretization of just transition policies that prioritize small-scale producers, and the adoption of a holistic political approach that prioritizes soil carbon management and food security.

Keywords: Turkish Climate Law, Climate Change Adaptation, Agricultural Landscapes, Sustainable Agriculture, Carbon Management, Food Security

1. GİRİŞ

Tarımsal peyzajlar, kültürel peyzajlar hiyerarşisi içerisinde yer alan ve bu kültürel mirasın kritik bir alt bileşeni olan kırsal peyzajların temel kategorisi olarak kabul edilir (Forman ve Godron, 1986; Farina 2022). Bu peyzajlar, tarımsal üretim ile ilgili arazilerin ve faaliyetlerin (ekili alanlar, hayvancılık birimleri, sulama sistemleri gibi altyapılar dahil) baskın olduğu alanlardır. Tarımsal peyzajlar, insan müdahalesi ve doğal süreçlerin tarihsel etkileşiminin ve ekolojik adaptasyonunun bir sonucu olarak ortaya çıkan, dinamik sosyo-ekonomik sistemleri temsil etmektedir (Goudie ve Viles, 2013; Gülçin, 2019; Brown ve Goetcheus, 2023).

Tarımsal peyzajlar; biyolojik çeşitlilik, doğal süreçler ve kültürel mirasın korunması, bölgesel sosyo-ekonomik işlevlerin sürdürülmesi, kendine özgü görsel estetik değerlerin sunulması ve insan-doğa karşılıklı etkileşimlerinin somut izlerini taşıması gibi çok boyutlu özelliklerle karakterize edilmektedir. Bu peyzajlar insan faaliyetlerinin doğal çevre ile doğrudan ve yoğun etkileşimde olduğu, tarih içinde karakterini kazanmış ve değişime en hassas olan peyzajlardır (Forman ve Godron, 1986; Bellwood, 2004; Raskin, 2025).

Tarımsal peyzajların korunması ve geliştirilmesi, tarımın sürdürülebilirliği ve genel olarak kentsel sürdürülebilirlik açısından kritik öneme sahiptir. Bununla birlikte insanlık tarihi boyunca plansız sanayileşme, yerleşim baskısı ve modern tarım uygulamalarının neden olduğu parçalanma ve kayıplarla karşı karşıya kalmıştır. Bu gün tarımsal peyzajların dayanıklılığını tehdit eden ve acil koruma tedbirlerini zorunlu kılan en büyük risk faktörü olarak karşımızda iklim değişikliği durmaktadır (Bennetzen, 2012, Dubey, vd. 2023).

İklim değişikliğinin temel bileşenleri olan atmosferik karbondioksit artışları, yükselen sıcaklıklar ve değişen yağış düzenleri, tarımsal verimliliği doğrudan ve önemli ölçüde etkileyecektir. İklim değişikliğinin tarımsal üretime etkileri dört noktada ele alınır. Bunlar (Walthall, 2013);

- Hayvancılık üretim sistemleri, özellikle yükselen sıcaklık streslerine karşı yüksek hassasiyet göstermektedir.
- Aşırı hava olaylarının öngörülen daha yüksek görülme sıklığı, tarımsal verimlilik üzerinde artan ve yıkıcı bir etkiye sahip olacaktır.
- Yapılan projeksiyonlar, önümüzdeki 25 yıl boyunca iklim değişikliğinin mahsul ve hayvancılık üretim sistemleri üzerindeki etkilerinin karmaşık ve bölgesel farklılıklar göstereceğini ortaya koymaktadır.
- İklim değişikliği, tarımsal bitkiler ve hayvanlar üzerindeki mevcut biyotik stresleri (zararlılar, hastalıklar) daha da kötüleştirerek yeni tehditler oluşturacaktır.

Tarımsal peyzajlar, karbon tutumu ve depolama potansiyeli sayesinde iklim değişikliğini hafifletme (azaltım stratejisi) açısından önemli ve olumlu katkılar sunmaktadır. Bu katkılar, temel olarak aşağıdaki mekanizmalar aracılığıyla gerçekleşir (Shukla, 2019, IPCC, 2025):

- Toprak Karbon Depolamasının Artırılması: Örtü bitkileri kullanımı, azaltılmış toprak işleme, tarımsal ormancılık (agroforestri) ve uygun ürün rotasyonu gibi sürdürülebilir tarım uygulamaları, toprağın organik madde içeriğini yükselterek karbon depolama kapasitesini önemli ölçüde artırır. Bu süreç, atmosferdeki karbondioksit miktarını düşürerek iklim değişikliğini hafifletmeye yönelik kritik bir stratejiyi temsil eder.
- Peyzaj Bazlı Biyokütle Karbon Tutumu ve Mikro İklim Düzenlemesi: Tarımsal peyzaj sistemlerine ağaç ve çalıların entegrasyonu, sadece biyokütle yoluyla ek karbon tutumunu maksimize etmekle kalmaz; aynı zamanda yerel mikro iklim üzerinde (rüzgâr hızının

azaltılması, nemin artırılması ve sıcaklık değişimlerinin dengelenmesi gibi) olumlu düzenleyici etkiler yaratır.

- Su döngüsü ve enerji dengesi üzerindeki etkiler: Albedo etkisi, tarım arazilerindeki bitki örtüsünün türü ve yoğunluğu, güneş ışığını yansıtma miktarını etkileyerek bölgesel sıcaklıkları değiştirebilir. Buharlaşma ve yağış etkisi, sulama ve bitki örtüsü yapısı, yüzeydeki suyun buharlaşma ve terleme miktarını değiştirerek hem yerel nemi hem de yağış rejimlerini etkileyebilir.

Tarımsal üretim ve arazi kullanımındaki değişiklikler, toplam insan kaynaklı sera gazı (GHG) emisyonlarının yaklaşık %30'undan sorumludur. Bununla birlikte küresel gıda üretiminin 2050 yılına kadar yaklaşık %70 oranında artırılması gerekmektedir. Tarımsal üretim, mevcut yöntemlerle yönetilmeye devam edilirse, küresel iklim değişikliği üzerindeki etkileri artacaktır. Ancak, tarımın iklim değişikliğinin azaltılmasında önemli bir potansiyeli olmasına rağmen, bu alan hâlâ azaltım politikalarına sınırlı ölçüde dahil edilmektedir. Bu bağlamda, tarımsal üretimden kaynaklanan GHG emisyonlarını azaltma politikaları önemlidir (Bennetzen, 2012). Ayrıca tarımın iklim değişikliğine karşı kırılganlığı, büyük ölçüde bu etkileri hafifletmek ve sistemleri uyumlaştırmak amacıyla benimsenecek tepkilere ve politikalara bağlıdır (Walthall, 2013).

Türkiye geçmişten günümüze önemli bir tarım ülkesi olmuştur. Bu bağlamda Türkiye'nin küresel tarım sektöründeki konumu ve son yirmi yıldaki performansı şöyledir (İstikbal, 2022):

- Küresel üretim ve pay: Dünya tarım topraklarının yalnızca %0,8'ine sahip olmasına rağmen, toplam küresel tarımsal çıktının %1,29'undan fazlasını üretmektedir. Bu oran, Türkiye'nin verimlilik potansiyelini göstermektedir.

- Dış ticaret hacmi: Küresel tarımsal ihracatın %1,57'sini ve ithalatın %1,14'ünü gerçekleştirerek, uluslararası tarım ticaretinde önemli bir aktör konumundadır.

- Ekonomik büyüklük: Geçirdiği 20 yıllık dönüşümün ardından, yaklaşık 50 milyar dolarlık üretim kapasitesi ile dünyanın en büyük 10. tarım ekonomisi konumuna yükselmiştir. Türkiye, 2002'deki 24,48 milyar dolarlık tarımsal üretim hacmini 2020 yılında 47,52 milyar dolara taşımıştır.

- Verimlilik artişi (kişi başına üretim): İstihdam edilen kişi başına düşen ortalama üretim değeri, 2002'de 3.285 dolar iken, 2020'de bu değer 9.281 dolara yükselmiştir. Bu, tarım sektöründeki verimlilik ve katma değerdeki önemli artışı işaret etmektedir.

Türkiye İstatistik Kurumu (TÜİK) 2022 yılı verilerine göre, Türkiye'nin çayır ve mera arazilerini de içeren toplam tarım alanı 38.462 bin hektar olarak kaydedilmiştir. Bu arazi işlenen alanlar (%52,4) çok yıllık meyvelikler (%9,6), daimi çayır ve mera alanları (%38) şeklinde dağılım göstermektedir. Türkiye'de nüfus artışına paralel olarak toplam tarım alanlarının azalması, kişi başına düşen tarım alanı miktarında kayda değer bir düşüşe yol açmıştır. 1990-2018 yılları arasında, Türkiye nüfusunun yaklaşık %45,2 oranında büyümesine karşın, aynı dönemde kişi başına düşen tarım alanlarındaki daralma %39,3 olarak tespit edilmiştir. Bu eğilim sonucunda, 1990 yılında 0,76 hektar olan kişi başına toplam tarım alanı miktarı, 2021 yılı itibarıyla 0,45 hektara gerilemiştir. Son verilere göre (2022 yılı), toplam ekilebilir alan (23.845 bin hektar) dikkate alındığında, kişi başına düşen ekilebilir alan miktarı 0,28 hektar düzeyindedir (Çevresel Göstergeler, 2025).

Türkiye'nin iklim değişikliği senaryosu, ülkenin coğrafi konumundan kaynaklanan karmaşık ve olumsuz etkiler içermektedir. Türkiye, Akdeniz Havzası'nda yer aldığı için, küresel ısınmadan en çok etkilenecek bölgelerden biri olarak kabul edilmektedir. Türkiye'nin 2050 ve 2100 yılları

hedeflenerek ortaya konulan iklim değişikliği senaryosunun temel öngörüleri aşağıda verilmiştir:

Sıcaklık artışı, Türkiye iklim senaryosunun en belirgin ve en yüksek güvenilirliğe sahip unsurudur.

- Yükselen Sıcaklıklar: Türkiye genelinde ortalama sıcaklıkların, 21. yüzyılın sonuna kadar 2-6oC arasında artması beklenmektedir. En yüksek artışlar, yaz aylarında ve iç bölgelerde (İç Anadolu, Güneydoğu Anadolu) yaşanacaktır.
- Sıcak Hava Dalgası: Aşırı sıcak hava dalgalarının hem sıklığı hem de süresi önemli ölçüde artacaktır. Bu, özellikle kentlerde yaşayan nüfusun sağlığı üzerinde ciddi bir baskı oluşturacaktır.
- Isınma Etkisi: Bu senaryo, karasal ısınmanın küresel ortalamadan daha hızlı gerçekleştiği yönündeki mevcut gözlemleri desteklemektedir.

Yağışlar hem miktar hem de dağılım açısından büyük bir değişime uğrayacaktır.

- Yağış Azalması: Özellikle Akdeniz, Ege ve Güneydoğu Anadolu bölgelerinde kış ve ilkbahar yağışlarında önemli azalmalar beklenmektedir. Bu, bölgedeki kuraklık ve çölleşme riskini artıracaktır.
- Düzensiz Yağışlar: Yağışların yıl içindeki dağılımı düzensizleşecek; toplam yıllık yağış miktarı stabil kalsa bile, bu yağışlar kısa ve yoğun sağanaklar halinde düşecektir.
- Su Stresi: Yükselen sıcaklıklar ve azalan kış yağışları nedeniyle buharlaşma artacak, bu da yer altı ve yer üstü su kaynaklarında ciddi azalmalara yol açarak Türkiye'yi su stresi (water stress) yüksek olan bir ülke haline getirecektir.

Deniz Seviyesi ve Kıyısal Etkiler

- Deniz Seviyesi Yükselmesi: Küresel ortalamaya paralel olarak deniz seviyesinin yükselmesi, özellikle Çukurova, Gediz ve Büyük Menderes gibi alçak kıyı ovalarında tuzlu su girişimine ve tarım arazilerinin kaybına neden olacaktır.
- Kıyı Erozyonu: Fırtına dalgalarının sıklığı ve şiddetindeki artış, kıyı erozyonunu hızlandıracak ve kıyı altyapılarını tehdit edecektir.

Bu çalışmanın temel amacı, 7552 sayılı Türkiye İklim Kanunu'nun tarımsal peyzajlar üzerindeki etkilerini; ortaya çıkaracağı fırsatlar, yaratacağı tehditler ve potansiyel riskler çerçevesinde analiz etmektir.

2. MATERYAL VE YÖNTEM

2.1. Materyal

Çalışmanın birincil ve ikincil materyalleri aşağıdaki verilmiştir.

- Yasal Metinler: Değerlendirmenin ana objesi, 09.07.2025 tarihinde yürürlüğe giren 7552 sayılı Türkiye İklim Kanunu'nun resmi metni ve ilgili maddeleri.
- Akademik ve sektörel literatür: Tarımsal peyzajlar ve iklim değişikliği konulu ulusal ve uluslararası bilimsel yayınlar.
- Resmî veri ve raporlar: Kanunun etki alanını anlamak için Türkiye'deki tarımsal peyzajlar, iklim değişikliği ile ilgili kurumsal verilerden faydalanılmıştır.

2.2. Yöntem

Bu çalışma, 09.07.2025 tarihinde yürürlüğe giren 7552 sayılı Türkiye İklim Kanunu'nun tarımsal peyzajlar üzerindeki potansiyel etkilerini incelemeyi amaçlayan nitel bir araştırmadır.

Araştırmada Kanun'un tarımsal peyzajlar üzerindeki çok boyutlu etkileşimleri belirlenmiş ve bu alanların, "*iklim değişikliğinin yükünü taşıyan, aynı zamanda çözümün merkezinde yer alan alanlar haline gelme potansiyeli*" değerlendirilmiştir. Çalışmada, Türkiye İklim Kanunu'nun tarımsal peyzajlar üzerindeki etkilerini bütüncül bir bakış açısıyla analiz etmek amacıyla Belge Analizi ve GZFT (Güçlü, Zayıf, Fırsat, Tehdit) Analizi ile değerlendirilmiştir.

Belge Analizi ile 7552 sayılı Kanun'un amaç, kapsam, genel ilkeler ve esasları içeren hükümleri sistematik olarak incelenmiştir. Özellikle tarımsal üretim, arazi kullanımı ve kırsal alan yönetimi ile ilgili olan; "*karbon yutakları, ekosistem temelli uyum, su bütçesi, yerel iklim planları ve karbon kredilendirme sistemleri*"ne ilişkin maddeler tespit edilmiştir.

Kanun hükümleri, GZFT (Güçlü, Zayıf, Fırsat, Tehdit) analizi ile irdelenerek olası etkiler Fırsat-Tehdit-Risk açısından üç ana kategori altında sınıflandırılmıştır.

- Fırsatlar: Kanunun, tarımsal peyzajların direncini ve uyum kapasitesini güçlendirme potansiyelini destekleyen olumlu etkilerdir (örneğin, yeşil finansman, ekosistem temelli planlama zorunluluğu).
- Tehditler: Özellikle sanayi ve enerji sektörlerinden kaynaklanan ve tarımsal peyzajların temel işlevini (gıda güvenliği) tehlikeye atma potansiyeli taşıyan dışsal baskılardır (örneğin, Emisyon Ticaret Sistemi-ETS yükümlülüklerinin tarım arazisi üzerinden denkleştirilmesi, "karbon yutağı üreten tarım" baskısı).
- Riskler: Kanunun uygulamadaki etkinliğini sınırlayabilecek, belirsizlik içeren veya mevcut yapısal zorlukları (örneğin, küçük üreticilerin finansmana erişim güçlükleri, arazi kullanım çatışmaları) ortaya çıkarabilecek içsel ve yapısal zorluklardır.

3. BULGULAR

3.1. Kanun Genel Çerçevesi

İklim Kanunun amacı, yeşil büyüme vizyonu ve net sıfır emisyon hedefi doğrultusunda iklim değişikliğiyle mücadele etmektir. Bu Kanun; «iklim değişikliği ile mücadelede esas olan sera gazı emisyonlarının azaltılması ve iklim değişikliğine uyum faaliyetleri ile planlama ve uygulama araçlarını, gelirleri, izin ve denetimi ve bunlara ilişkin yasal ve kurumsal çerçevenin usul ve esaslarını» kapsamaktadır (1. Bölüm, Madde 1-2) (İklim Kanunu, 2025).

Kanunun genel ilkeleri genel ilkeler şunlardır (2. Bölüm, Madde 3) (İklim Kanunu, 2025) ;

- İklim değişikliği ile mücadelede, ülkemizin ortak fakat farklılaştırılmış sorumluluklar ve göreceli kabiliyetler ilkesi dikkate alınarak, eşitlik, iklim adaleti, ihtiyatlılık, katılım, entegrasyon, sürdürülebilirlik, şeffaflık, adil geçiş ve ilerleme yaklaşımları esas alınır.
- Kamu kurum ve kuruluşları ile gerçek ve tüzel kişiler, bu Kanun doğrultusunda kamu yararı gözetilerek alınacak tedbirlere ve düzenlemelere süresinde uymakla ve bunları uygulamakla yükümlüdür.
- Ulusal Katkı Beyanında, net sıfır emisyon hedefi doğrultusunda ülkenin kalkınma öncelikleri ve özel koşulları göz önünde bulundurulur ve bu çerçevede önlemler alınır.

Kanun beş temel esasa sahiptir (2. Bölüm, Madde 4) (İklim Kanunu, 2025) (İklim Kanunu, 2025).

- Sera gazı emisyonlarının azaltımı ve iklim değişikliğine uyum faaliyetlerine ilişkin ilerlemeler yıllık bazda Başkanlıkça izlenir.
- Kanun kapsamında gerekli görülen tedbirlerin alınması amacıyla görev alanı dâhilinde; kurumlar arası koordinasyonu sağlamak, faaliyetleri ve standartları belirlemek, gelişmeleri

izlemek, karbon fiyatlandırmasına ilişkin piyasaya dayalı mekanizmaları düzenlemekle Başkanlık yetkilidir.

- Kamu kurum ve kuruluşları il gerçek ve tüzel kişiler; kendi yetki ve sorumlulukları çerçevesinde plan ve projeler yapar, yaptırır, uygular, destekler ve iş birliği yapar.

- 4/3/2016 tarihli ve 6698 sayılı Kişisel Verilerin Korunması Kanunu hükümleri saklı kalmak kaydıyla, Başkanlık; bu Kanunun uygulanmasına yönelik olarak gerekli gördüğü bilgi, belge ve veriyi; kamu kurum ve kuruluşları ile gerçek ve tüzel kişilerden doğrudan istemeye yetkilidir. Kendilerinden bilgi ve belge talebinde bulunulanlar; bunları istenilen sürede bedelsiz olarak Başkanlıkla paylaşmakla yükümlüdür. Başkanlık; kendi iş ve işlemleri için ihtiyaç duyduğu verileri de öncelikli olarak Ulusal Coğrafi Bilgi Platformundan temin eder. Temin ettiği veriler ile kendi ürettiği verileri de kamu kurum ve kuruluşları ile paylaşılmak üzere Ulusal Coğrafi Bilgi Platformuna aktarır. Başkanlık, Ulusal Coğrafi Bilgi Platformunda bulunmayan verileri ilgili kamu kurum ve kuruluşları ile protokol yaparak temin edebilir. Millî savunma ve millî güvenliğe ilişkin bilgi ve belgelerin paylaşılmasına dair usul ve esaslar Bakanlık ve ilgili bakanlık tarafından müşterek olarak belirlenir.

- Bu Kanunda Bakanlığa verilen yetkiler bakımından Bakanlık, sınırlarını açıkça belirlemek ve yazılı olmak kaydıyla gerektiğinde yetkilerini Başkanlığa devredebilir.

İklim Kanunu'nun tarımsal peyzajlar üzerindeki etkileri; "*karbon yutakları*", "*ekosistem temelli uyum*", "*su bütçesi*", "*yerel iklim planları*" ve "*karbon kredilendirme sistemleri*" anahtar kavramları odağında analiz edilmiştir. Yapılan inceleme sonucunda, Kanunun tarımsal peyzajları etkileyecek düzenlemeleri iki temel eksende ele aldığı belirlenmiştir: sera gazı emisyonlarının azaltılması ve iklim değişikliğine uyum (Madde 5, 6, 7, 9 ve Geçici Madde 2). Ayrıca, Kanun tarımsal peyzajlar üzerindeki etkilerini bu iki eksenle sınırlı tutmayıp; planlama, finansman, kurumsal dönüşüm, dönüşüm takvimi ve destek mekanizmaları gibi tamamlayıcı alanlarda da düzenlemeler getirmiştir (Madde 8, 12, 13). Söz konusu Kanun maddelerine ilişkin detaylar aşağıda verilmiştir (İklim Kanunu, 2025).

- Madde 5 (İlgili Fıkralar: 5/1, 5/2, 5/3, 5/4): Tarım sektöründeki üretim süreçlerinde (makineleşme, gübre kullanımı, hayvancılık vb.) enerji ve kaynak verimliliğini artırmayı, temiz teknolojilere geçişi sağlamayı ve sıfır atık sistemlerini yaygınlaştırmayı zorunlu kılarak sera gazı emisyonlarını azaltmayı hedeflemektedir. Bu kapsamda, tarımsal faaliyetlerin çevresel etkilerini en aza indirmek ve sürdürülebilir üretim yöntemlerini benimsemek amaçlanmaktadır.

- Madde 5 (Beşinci Fıkra: 5/5): Orman, tarım, mera ve sulak alanlarda karbon yutağı kayıplarının engellenmesini ve bu alanların korunarak karbon yutak kapasitesinin artırılmasını hedeflemektedir. Bu hüküm, tarım topraklarının ve meraların karbon depolama potansiyelini (toprakta karbon tutma) açıkça ön plana çıkarmaktadır. Bu vurgu, onarıcı (rejeneratif) tarım uygulamalarının teşvik edilmesinin yasal zeminini oluşturmaktadır.

- Madde 6 (Dördüncü Fıkra: 6/4): İklim değişikliğinin etkilerine karşı su kaynaklarının etkin yönetimini sağlayacak planlama araçlarının hazırlanmasını zorunlu kılmaktadır. Bu hüküm, özellikle tarımsal sulama ve su bütçesinin dengeli kullanımı açısından kritik bir gerekliliktir.

- Madde 6 (Beşinci Fıkra: 6/5): İklim değişikliğinin ekosistemler ve biyolojik çeşitlilik üzerindeki etkilerini azaltmayı ve arazi tahribatını dengelemeyi hedeflemektedir. Bu, tarımsal üretimin doğal ekosistemlere zarar vermeden planlanmasını ve yürütülmesini gerektirmektedir.

- Madde 6 (Altıncı Fıkra: 6/6): Tarım sektörünün sürdürülebilirliğini güvence altına almak amacıyla; iklim değişikliğine dirençli ürün deseni oluşturulmasını, ekosistem temelli uyum yaklaşımını ve doğa temelli çözümleri esas alan planlama araçlarının geliştirilmesini

açıkça zorunlu kılmaktadır. Bu hüküm, çiftçilik uygulamalarında (örneğin, kuraklığa dayanıklı çeşitlere geçiş ve agro-ekolojik yöntemlerin benimsenmesi gibi) köklü bir dönüşümü beraberinde getirecektir.

- Madde 7 (Planlama ve Entegrasyon): Madde, tüm ulusal ve yerel ölçekteki plan, program ve stratejilerin hazırlanmasında azaltım ve uyum hedeflerinin dikkate alınması zorunluluğunu getirir. Böylece, tarımsal politikalar da dahil olmak üzere tüm sektörel politikaların iklim hedefleriyle entegre edilmesi hedeflenir (planlama ve entegrasyon zorunluluğu). Ayrıca Yerel İklim Değişikliği Eylem Planları, tarımsal peyzajların yönetimini il/bölge ölçeğinde somutlaştıran mekanizmalar oluşturur.

- Madde 9: Madde, ETS'nin kurulmasını ve işletilmesini düzenlemektedir. Madde tarımsal peyzajlar üzerinde doğrudan değil, dolaylı ve yapısal etkiler yaratır. Genellikle enerji, sanayi ve büyük ölçekli tesisler gibi yüksek emisyonlu sektörleri hedef alır. Tarımsal işletmelerin kendileri (çiftçiler) doğrudan ETS kapsamına dahil edilmeyebilir (ancak bu, yönetmeliklerle belirlenecektir). Ancak, tarımsal peyzajlar üzerindeki etkisi, tarım sektörünün girdi ve çıktı ilişkileri aracılığıyla dolaylı olarak gerçekleşir.

- Geçici Madde 2 (Uygulama Süresi): Azaltım (Madde 5) ve uyum (Madde 6) ile ilgili planlama ve uyarlama yükümlülükleri için ilgili kurumlara 31/12/2027 tarihine kadar süre vererek, dönüşüm takvimini belirler (uygulama süresi).

- Madde 8 (Birinci Fıkra, b bendi): Döngüsel ekonomi hedefleri ve sıfır atık uygulamaları doğrultusunda bir dizi mekanizmanın geliştirilmesini öngörmektedir. Bu mekanizmalar; ürünlerin yeniden kullanımını, atıkların yan ürün veya alternatif ham madde olarak değerlendirilmesini, ayrıca geri dönüşüm ile elde edilen ürünlerin zorunlu kullanım oranlarının belirlenmesine yönelik destekleri kapsar. Bu düzenleme, özellikle tarım sektöründe ortaya çıkan biyo-atıklar başta olmak üzere tarımsal atıkların yönetimi ile bu atıkların gübre veya enerji girdisi olarak tekrar kullanılması konularını doğrudan etkileyecektir.

- Madde 8 (Birinci Fıkra, c bendi - Finansman): Sera gazı emisyonlarının azaltılması ve iklim değişikliğine uyum faaliyetlerinin finansmanına yönelik kaynakların geliştirilmesi ve kullanılması esas alınır. Bu düzenleme, özellikle tarım sektöründeki azaltım ve uyum projelerine sağlanan finansal desteklerin artırılacağı anlamına gelmektedir. Ayrıca, Başkanlık, finansal kaynakları iklim değişikliğiyle mücadele yatırımlarına yönlendirmeyi kolaylaştırmak amacıyla Türkiye Yeşil Taksonomisini kurar ve yürütür. Bu Taksonomi, tarımsal yatırımların yeşil dönüşümle uyumlu olup olmadığını belirleyen temel çerçeveyi oluşturacaktır.

- Madde 8 (Üçüncü Fıkra, b bendi - Yeşil İş Gücü): Millî Eğitim Bakanlığı (MEB) ve Yükseköğretim Kurulu (YÖK) tarafından, ilgili bakanlıklarla koordinasyon içinde, tüm eğitim düzeylerindeki müfredat ve öğretim programlarının güncellenmesini zorunlu kılmaktadır. Bu çalışmaların temel amacı, iklim değişikliğiyle mücadeleye yönelik yeni ve yetenekli yeşil iş gücünün yetiştirilmesini sağlamaktır. Bu hüküm, özellikle tarım ve çevre sektörlerinde ihtiyaç duyulan nitelikli insan kaynağının geliştirilmesine olanak tanıyacaktır.

- Madde 12-13 (Adil Geçiş ve Destekler): Kanun kapsamında elde edilen gelirlerin (örneğin ETS) tahsisat satışları veya cezalar gibi) yüzde onuna kadar olan kısmının, adil geçiş uygulamaları çerçevesinde yürütülecek faaliyetlere tahsis edilebileceği belirtilmektedir. Bu düzenleme, özellikle tarım ve kırsal alanlardaki sosyal ve ekonomik dönüşümü desteklemek üzere önemli bir finansman kaynağı potansiyeli sunmaktadır. Ayrıca Kanunun temel esaslarından biri, sera gazı emisyonlarını azaltma veya iklim değişikliğine uyum potansiyeli yüksek olan iklim dostu yatırımların (ki buna tarımsal yatırımlar da dahildir) desteklenmesidir. Bu amaçla, yeşil dönüşümü ve iklim değişikliğiyle mücadeleyi hedefleyen desteklerin kullanımına yönelik uygun finansal mekanizmalar oluşturulacaktır.

3.2. Kanun Tarımsal Peyzajlara Olası Etkileri (Güçlü, Zayıf, Fırsat, Tehdit)

İçsel Faktörler

Bu faktörler, Kanun'un kendi yapısından, hükümlerinden veya ulusal uygulamadaki mevcut yapısal eksikliklerden kaynaklanan ve uygulayıcılar tarafından kontrol edilebilir olan unsurlardır. İçsel faktörler, güçlü ve zayıf yönler olmak üzere iki başlık altında değerlendirilmiştir.

a) Güçlü Yönler

Kanun'un tarımsal peyzajların direncini ve uyum kapasitesini güçlendiren pozitif hükümler aşağıda verilmiştir (İklim Kanunu, 2025).

- Ekosistem Temelli Planlama Zorunluluğu: Kanun, tarım sektöründe ekosistem temelli uyum yaklaşımını ve doğa temelli çözümleri zorunlu kılar. Bu, monokültür yerine biyoçeşitliliği ve su bütçesini gözeten çok işlevli peyzaj tasarımına yasal zemin hazırlar (Madde 6).

- Karbon Yutaklarının Korunması: Orman dışındaki tarım, mera ve sulak alanlarda karbon yutağı kayıplarını engellemeyi ve yutak alanların korunarak artırılmasını hedefler. Peyzaj plancıları için ekolojik ağ tasarımına dayalı planlama olanağı yaratır (Madde 5).

- Yerel Yönetimlerin Yetki Alanı: Yerel İklim Değişikliği Eylem Planları'nın il ve büyükşehir belediyeleri tarafından hazırlanması, planlama kararlarının yerel ölçekte uygulanabilirliğini ve kurumlar arası entegrasyonu artırır (Madde 7).

- İklim Adaleti İlkesi: Mücadelede eşitlik, iklim adaleti ve adil geçiş yaklaşımlarını esas alır. Bu ilke, küçük üreticilerin adaptasyon sürecinde göz önünde bulundurulması için yasal bir dayanak sunar (Madde 3).

- Su Bütçesi Gözetimi: Tarım sektöründe su bütçesini dikkate alan planlama araçları geliştirilmesini ve su kaynaklarının etkin yönetimi ile iklim değişikliğine dirençli ürün deseni geliştirilmesini hedefler (Madde 6).

b) Zayıf Yönler

Kanun'un kendisinden veya ulusal uygulamadaki mevcut yapısal eksikliklerden kaynaklanan, Kanun'un uygulamadaki etkinliğini sınırlayan içsel/yapısal sorunlar (Mevcut Riskler) aşağıda verilmiştir (İklim Kanunu, 2025).

- Adil Geçiş Mekanizması Belirsizliği: Kanun adil geçişi esas alsa da , küçük çiftçilerin Kanunun getirdiği yüksek uyum ve teknoloji maliyetlerini karşılamasına yönelik somut finansal ve teknolojik destek mekanizmalarının Kanunda detaylandırılmaması yapısal bir zayıflıktır (Madde 3, Madde 12, Madde 13).

- Sektörler Arası Arazi Tahsisi Çatışması: Kanun, iklim değişikliğine uyum çerçevesinde su kaynaklarının etkin yönetimini (Madde 6/4) ve iklim dirençli ürün deseni oluşturulmasını zorunlu kılsa da , Su, Gıda ve Enerji (SGE) sektörleri arasındaki arazi kullanım çatışmalarını çözmeye yönelik net bir dengeleme mekanizmasından yoksundur. Özellikle verimli tarım arazilerinde giderek artan GES/RES projeleri (Enerji) baskısı, su bütçesini gözeten tarımsal üretimi (Gıda ve Su) tehdit etmektedir. Kanunun planlama ve entegrasyon zorunluluğu (Madde 7) mevcut olsa bile, bu tür hayati kaynak çatışmalarına kesin bir çözüm getiren maddenin bulunmaması, yasal bir boşluk ve uygulamada büyük bir yapısal risk teşkil etmektedir (Madde 6, Madde 7).

- Veri Paylaşımında Bürokratik Riskler: Başkanlık'ın veriyi Ulusal Coğrafi Bilgi Platformu'ndan (UCBP) temin etme yetkisine rağmen, karmaşık bürokrasi ve kurumlar arası

veri standardizasyonu eksikliği, etkin peyzaj planlaması için kritik olan güncel bilgiye erişimi yavaşlatabilir (Madde 4).

- Mevzuat Entegrasyonu Eksikliği: Kanun'un mevcut Tarım Kanunu, Mera Kanunu ve teşvik sistemleri gibi ulusal mevzuatlarla uyumu konusundaki belirsizlikler, uygulamadaki bütüncüllüğü sınırlayabilecek yapısal riskler olarak öne çıkmaktadır (Madde 3, Madde 7).

Dışsal Faktörler

Bu faktörler, Kanun'un uygulama alanını etkileyen, Kanun koyucunun veya uygulayıcının kontrolü dışında olan makroekonomik, çevresel veya sektörel gelişmelerdir. Dışsal faktörler, fırsatlar ve tehditler başlıkları altında değerlendirilmiştir.

a)Fırsatlar

Kanun'un dış çevreden gelen olumlu gelişmeleri veya araçları kullanarak tarımsal peyzajları güçlendirme potansiyeli aşağıda verilmiştir (İklim Kanunu, 2025).

- Karbon Kredisi ve Yeşil Finansman: Kanun'un ulusal bir karbon kredilendirme ve denkleştirme sistemi kurulmasını öngörmesi, tarımsal araziler ve meralar için karbon çiftçiliği yoluyla ek gelir kaynağı yaratabilir. Bu, peyzaj projelerinin karbon piyasası ile finanse edilmesini sağlar (Madde 8, Madde 9).

- Biyoçeşitlilik ve Ekosistem Hizmetleri: Yeşil finansman ve karbon piyasalarına erişim, tarımsal peyzajlarda biyolojik çeşitlilik ile uyumlu uygulamaları (agroekoloji, agroforestri) güçlendirme fırsatı sunar (Madde 6, Madde 8, Madde 9).

- Küresel Uyum Hedefleri: Kanun'un net sıfır emisyon ve yeşil büyüme vizyonu çerçevesinde düzenlenmesi, uluslararası fonlara, teknoloji transferine ve AB Yeşil Mutabakatı'na uyum süreçlerine erişimi kolaylaştırır (Madde 1, Madde 3, Madde 8).

- İklim Dirençli Ürün Desenleri: Su kaynaklarının etkin yönetimi ile iklim değişikliğine dirençli ürün desenleri geliştirilmesi hedefi , tarımsal peyzajların küresel iklim şoklarına karşı daha az kırılgan hâle gelmesi için bir katalizör işlevi görür (Madde 6).

b) Tehditler

Kanun'un tarımsal peyzajların temel işlevini (gıda güvenliği, arazi bütünlüğü) tehlikeye atma potansiyeli taşıyan dışsal baskılar aşağıda verilmiştir (İklim Kanunu, 2025).

- "Yutak Alan" Üzerinden Sektörel Baskı: Sanayi ve enerji sektörlerinin ETS yükümlülüklerini, tarım ve orman alanlarından elde edilen karbon kredileriyle (denkleştirme) yerine getirme isteği , "Gıda Üreten Tarım" yerine "Karbon Yutağı Üreten Tarım"a kayma baskısı yaratarak gıda güvenliğini tehlikeye atabilir (Madde 9).

- Kentsel ve Endüstriyel Yayılım ve Arazi Bütünlüğü Kaybı: Nüfus artışı ve kentsel genişleme sonucu tarım alanlarının sürekli azalması, Kanun'un koruma hedeflerine rağmen devam eden mekânsal bir tehdittir. Bu yayılım, aynı zamanda Kanun'daki dengeleme mekanizması eksikliği nedeniyle, tarım arazilerinin temiz enerji yatırımlarına tahsisiyle (SGE çatışması) birleşerek arazi bütünlüğünü iki kat tehdit altına almaktadır (Madde 6, Madde 7).

- Dolaylı Karbon Maliyeti (ETS'ye Girme Riski): Kanun tarımı doğrudan ETS'ye almasa da, büyük tarım işletmelerinin veya tedarik zincirlerinin dolaylı olarak Emisyon Ticaret Sistemi'ne dahil olma riski bulunmaktadır. Bu, çiftçilerin maliyetlerini artırarak rekabet gücünü düşürebilir.

- İklim Uyumsuz Altyapı Yatırımları: Yerel yönetimlerin, risk analizlerini dikkate alma yükümlülüğüne rağmen, kısa vadeli siyasi ve ekonomik baskılarla iklim değişikliğine karşı

savunmasız bölgelerde (taşkın ovaları, kurak alanlar) uyumsuz arazi kullanım kararlarının (yoğun sulu tarım, yapılaşma) devam etme riski bulunur.

4. SONUÇ ve ÖNERİLER

Bu çalışma, 7552 sayılı Türkiye İklim Kanunu'nun tarımsal peyzajlar üzerindeki potansiyel etkilerini GZFT (Güçlü Yönler, Zayıf Yönler, Fırsatlar, Tehditler) çerçevesinde değerlendirmektedir. Bulgular, Kanun'un tarımsal peyzajları iklim değişikliğinin yükünü taşıyan alanlar olmaktan çıkarıp, çözümün merkezine konumlandıran kritik bir dönüşüm potansiyeli taşıdığını ortaya koymaktadır.

Kanun, sistemsel güçlendirme araçları sunarak peyzajların direncini ve adaptasyon kapasitesini artırmaktadır. Bu güçlenme, ekosistem temelli uyum yaklaşımları, sürdürülebilirlik ilkeleri ve yeni finansal mekanizmalar aracılığıyla gerçekleşmektedir.

Kanun, tarımsal peyzajlara yönelik, ekolojik ve ekonomik kazanımları birleştiren geniş bir fırsatlar yelpazesi sunmaktadır:

- Ekolojik İşlevlerin Kurumsallaşması: Karbon yutaklarının (tarım, mera, sulak alanlar) korunması, rejeneratif tarım, agroekoloji ve agroforestri uygulamaları gibi çok işlevli yaklaşımları zorunlu kılmaktadır. Bu hükümler, toprak sağlığının iyileştirilmesi, karbon depolama ve biyoçeşitliliğin arazi kullanım planlamasında merkezi bir rol üstlenmesini sağlamaktadır.
- İklim Direncinin Artırılması: Su bütçesi gözetimi ve ekosistem temelli uyum yaklaşımları, iklim dirençli ürün desenleri geliştirilmesini teşvik ederek tarımsal sistemlerin kuraklık ve düzensiz yağışlara karşı kırılganlığını azaltacak köklü bir dönüşümü teşvik etmektedir.
- Yeni Finansal Akışlar: Yeşil finansman araçlarının ve ulusal karbon kredilendirme sisteminin oluşturulması, uyum ve azaltım projelerine yatırımı kolaylaştırmakta; yeşil finansmana erişim ve karbon piyasalarıyla entegrasyon yoluyla çiftçiler için yeni gelir ve teşvik mekanizmaları yaratmaktadır.

Kanun'un bu potansiyeli somutlaştırması, uygulamadaki bütüncüllük, yerel uyarlama ve adil geçiş politikaları ile mümkün olacaktır. Ancak Kanun'un etkinliği, aşağıdaki kritik yapısal riskler ve dışsal tehditler nedeniyle sınırlanabilir:

- Gıda Güvenliği Tehdidi (Sektörel Baskı): En büyük dışsal tehdit, Emisyon Ticaret Sistemi (ETS) kapsamındaki sanayi sektörlerinin emisyonlarını tarımsal alandan elde edilen karbon kredileriyle denkleştirme potansiyelidir. Bu durum, tarımsal peyzajların temel işlevi olan gıda üretimi yerine, sadece karbon yutağı üretimine odaklanma zorunluluğu yaratarak ulusal gıda güvenliğini riske atmaktadır.
- Adil Geçiş Finansman Uçurumu: Kanun adil geçiş ilkesini vurgulamasına rağmen, küçük üreticilerin yüksek uyum ve teknoloji maliyetlerini karşılamasına yönelik somut ve yeterli finansal destek mekanizmalarının eksikliği önemli bir yapısal risktir. Bu durum, teknolojik ve mali uçurumu derinleştirme potansiyeli taşımaktadır.
- Mevzuat ve Planlama Çatışmaları: Kanun'un mevcut Tarım Kanunu, Mera Kanunu ve teşvik sistemleri ile entegrasyonundaki belirsizlikler, uygulamada bütüncüllüğü tehdit etmektedir. Ayrıca, kentsel yayılım ve Su-Gıda-Enerji sektörleri arasındaki arazi kullanım çatışmalarını çözecek net bir dengeleme mekanizmasının yokluğu, mekânsal baskıları artırmaktadır.

Kanun'un beklenen dönüşümü başarılı bir şekilde gerçekleştirmesi ve riskleri minimize etmesi, sadece yasal metnin varlığına değil, aşağıdaki politik ve operasyonel şartların yerine getirilmesine bağlıdır:

- Bütüncül Yönetim ve Yerel Uyarlama: Merkezi politikaların, bölgesel iklim farklılıklarını ve su bütçesi dengelerini hassasiyetle gözeterek, Yerel İklim Değişikliği Eylem Planları aracılığıyla ve kurumlar arası entegrasyonla uygulanması zorunludur.

- Hedeflenmiş Adil Geçiş Mekanizmalarının Tesisi: Toprak karbonu yönetimi ve biyoçeşitlilik entegrasyonu gibi teknik gerekliliklerin maliyetini dengelemek üzere; kapsamlı çiftçi eğitim programları, bölgesel adaptasyon planları ve küçük üreticiyi gözeten güçlü adil geçiş finansman araçları somut olarak tahsis edilmelidir.

- Gıda Güvenliği Kalkanı ve Politik Önceliklendirme: Sektörel rekabet karşısında Kanun'un, gıda güvenliğini tehdit eden karbon yutağı baskısına karşı tarımsal peyzajların temel işlevini korumaya yönelik net ve kararlı bir politik önceliklendirme sergilenmesi elzemdir. Bu kapsamda, Su-Gıda-Enerji sektörleri arasındaki arazi tahsisi çatışmalarını önleyen şeffaf bir dengeleme mekanizmasının acilen oluşturulması gerekmektedir. Kanunun başarı kriteri, ekolojik hedefler ile ulusal kaynak güvenliği arasındaki dengeyi sağlayabilme yeteneğine bağlıdır.

7552 sayılı İklim Kanunu, tarımsal peyzajlar için yalnızca yeni bir mevzuat değil, geleceğe yönelik bir varoluş sözleşmesidir. Kanun, çiftçinin elindeki toprağı savunmasız bir yükümlülük olmaktan çıkarıp, ulusal direncin ve küresel çözümün canlı arşivi olarak konumlandırma gücüne sahiptir. Bu kritik eşikte, Kanun'un potansiyelinin hayata geçirilmesi, yapısal riskleri göz ardı eden teknik bir görev değil; gıda güvenliğinden toprak sağlığına uzanan, bütüncül bir politik kararlılık gerektiren bir ulusal önceliktir. Eğer Kanun, bürokratik engellere ve sektörel çıkarların baskısına yenilmez, aksine adil geçiş mekanizmalarıyla küçük üreticiyi merkeze alırsa, Türkiye sadece iklim hedeflerine ulaşmakla kalmayacak; aynı zamanda gıda sistemlerinin sürdürülebilirliğini güvence altına alan, ekolojik refahı politikalarının temeline koyan dirençli peyzajlara sahip olacaktır.

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TARIM ALANLARININ HUKUKİ KIRILGANLIĞI: TÜRKİYE ÖRNEĞİ

Prof. Dr. Demet DEMİROĞLU*

Kilis 7 Aralık Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü, Kilis

Email: ddemiroglu@kilis.edu.tr

ORCID: 0000-0002-3934-5319

Prof. Dr. Aybike Ayfer KARADAĞ

Düzce Üniversitesi, Orman Fakültesi, Peyzaj Mimarlığı Bölümü, Düzce

Email: ayferkaradag@duzce.edu.tr

ORCID: 0000-0002-7726-8756

ÖZET

Tarım alanları, yalnızca bitkisel üretim yapılan toprak parçaları olmayıp; gıda güvenliği, ekosistem hizmetleri, biyolojik çeşitlilik ve iklim düzenleme fonksiyonları açısından stratejik öneme sahip doğal varlıklardır. Bu nedenle, bu alanların hukuki koruma altına alınması, ekosistem işlevlerinin güvence altına alınması ve doğal sermayenin sürdürülebilir yönetimi açısından hayati önem taşımaktadır. Bu çalışma, tarım alanlarının stratejik önemine karşın, Türkiye'deki mevcut yasal düzenlemelerden kaynaklanan çok katmanlı hukuki kırılganlığını incelemeyi amaçlamaktadır. Çalışma, tarım alanlarının korunmasını düzenleyen 5403 sayılı Toprak Kanunu ile arazi kullanım kararlarını doğrudan etkileyen diğer üç temel kanunun (6306 sayılı Afet Riski Kanunu, 6360 sayılı Bütünşehir Yasası ve 3194 sayılı İmar Kanunu) etkileşimini, "*normatif tutarsızlık ve çatışma, idari takdir yetkisinin genişliği, kurumsal ve yönetsel denetim boşlukları*" gibi kırılganlık bileşenleri üzerinden analiz etmiştir. Yapılan analizde, ilgili dört kanunun birlikte değerlendirilmesi sonucunda, tarım topraklarının mekânsal bütünlüğünü ve ekolojik işlevselliğini tehdit eden yapısal bir risk alanı oluştuğu ortaya konmuştur. Bu kırılganlığın ana kaynakları, 5403 sayılı Kanun'daki 'kamu yararı' belirsizliği, 6306 sayılı Kanun'daki geniş 'rezerv yapı alanı' tanımı, 6360 sayılı Kanun'un yerel yetkiyi zayıflatıcı etkisi ve 3194 sayılı Kanun'un tarım alanlarını 'ikincil unsur' konumuna düşüren hükümleri olarak belirlenmiştir. Bu yasal düzenlemelerin birleşik ve aşındırıcı etkisi, tarım alanlarının hukuki ve mekânsal kırılganlığını derinleştirerek ülkenin uzun vadeli gıda güvencesini ciddi biçimde tehdit etmektedir. Bu yapısal riskleri bertaraf etmek amacıyla, tarım alanlarının sürdürülebilir korunması için mevzuatın bütüncül bir yaklaşımla entegrasyonu zorunludur. Bu bağlamda; afet yönetimi, imar ve yerel yönetim mevzuatının uyumlaştırılması, Toprak Koruma Kurulları'nın (TKK) görüşünün bağlayıcı hâle getirilmesi ve ekosistem temelli planlama ilkelerinin uygulanması gerekmektedir. Bu bütünleşik yaklaşım, tarım alanlarının hukuki ve mekânsal risklere karşı dayanıklılığını artırarak, ekolojik işlevselliğin ve gıda güvencesinin sürdürülmesini güvence altına alabilecektir.

Anahtar Kelimeler: Tarım Alanları, Hukuki Kırılganlık, Afet Yönetimi, Arazi Kullanımı

THE LEGAL VULNERABILITY OF AGRICULTURAL AREAS: TURKIYE EXAMPLE

ABSTRACT

Agricultural areas are not merely patches of land used for crop production; they constitute natural assets of strategic importance in terms of food security, ecosystem services, biodiversity, and climate regulation functions. Therefore, the legal protection of these areas is vital for safeguarding ecosystem functions and ensuring the sustainable management of natural capital. This study aims to examine the multilayered legal vulnerability of agricultural areas in Türkiye, which stems from existing legal regulations, despite their strategic significance. The study analyzed the interaction between the Soil Conservation Law (Law No. 5403), which regulates the protection of agricultural lands, and three other fundamental laws that directly affect land use decisions: the Law on Transformation of Areas under Disaster Risk (Law No. 6306), the Metropolitan Municipality Law (Law No. 6360), and the Zoning Law (Law No. 3194). This analysis utilized vulnerability components such as "normative inconsistency and conflict, broad administrative discretion, and institutional and managerial oversight gaps." The analysis demonstrated that the combined assessment of the four relevant laws creates a structural risk area that fundamentally threatens the spatial integrity and ecological functionality of agricultural lands. The primary sources of this vulnerability were identified as: the ambiguity of 'public interest' in Law No. 5403; the broad definition of 'reserve building areas' in Law No. 6306; the debilitating effect of Law No. 6360 on local authority; and the provisions of Law No. 3194 that relegate agricultural areas to the status of a 'secondary element'. The combined and erosive impact of these legal regulations deepens the legal and spatial vulnerability of agricultural areas, posing a severe threat to the country's long-term food security. To mitigate these structural risks, the holistic integration of legislation is imperative for the sustainable protection of agricultural lands. This requires the harmonization of disaster management, zoning, and local government legislation, making the opinions of the Soil Conservation Boards (TKK) binding, and implementing ecosystem-based planning principles. This integrated approach will bolster the resilience of agricultural areas against legal and spatial risks, thereby securing the continuation of both ecological functionality and food assurance.

Keywords: Agricultural Lands, Legal Vulnerability, Disaster Management, Land Use Policy

1. GİRİŞ

Tarım alanları, yalnızca ekonomik üretim sahaları olmayıp; gıda güvencesi, kırsal kalkınma, ekosistem hizmetleri ve iklim değişikliğine uyum politikalarının merkezinde yer alan stratejik doğal varlıklardır. Bununla birlikte, kentleşme, altyapı yatırımları ve arazi kullanım biçimlerinin değişimi, tarım alanlarını artan biçimde tarım dışı kullanımlara yönlendirmektedir. Bu dönüşüm, üretim kapasitesinde azalmaya, habitat kayıplarına ve ekosistem hizmetlerinde belirgin düşüşlere yol açmaktadır (OECD, 2023; Chen et al., 2024; Mersha et al., 2025). Oysa ki bu alanlar, toprak sağlığının sürdürülmesi, su döngüsünün dengelenmesi, biyolojik çeşitliliğin korunması ve karbon döngüsünün düzenlenmesi gibi çoklu ekosistem hizmetlerinin temel sağlayıcısıdır. Dolayısıyla bu alanların korunması, yalnızca tarımsal üretimin devamı için değil, aynı zamanda ekosistemlerin bütünlüğünün sürdürülmesi ve toplumların uzun vadeli çevresel dirençliliğinin sağlanması için de yaşamsal öneme sahiptir (Foley et al., 2011; Schaub et al., 2025).

Bu alanların sürdürülebilir yönetimi, toprak verimliliğinin, biyolojik çeşitliliğin, su rejimlerinin ve iklim düzenleme süreçlerinin korunması açısından kritik önem taşımaktadır (Camba-Sans et al., 2024; Raveloaritiana & Wanger, 2024). Küresel ölçekte, insanların yaşanabilir gördüğü kara yüzeyinin yaklaşık yarısının tarımsal faaliyetler için kullanıldığı bilinmektedir (Ritchie & Roser, 2019). Bu veri, tarım alanlarının yalnızca ekonomik üretim aracı değil, aynı zamanda ekolojik sistemlerin sürdürülebilirliği ve toplumsal refahın devamlılığıyla doğrudan ilişkili olduğunu göstermektedir.

Bu kapsamda tarım alanlarının sürdürülebilirliğini sağlamak, yalnızca teknik veya çevresel bir mesele değil, aynı zamanda hukuki bir zorunluluktur. Bu bağlamda, arazi koruma mekanizmalarının yasal düzeyde tanımlanması, karar alma süreçlerinde uzun vadeli ekolojik perspektifin benimsenmesini sağlar ve ekonomik ya da altyapısal baskılara karşı etkili bir koruma çizgisi oluşturur. Özellikle hızlı kentleşme, mekânsal olarak verimli tarım topraklarının geri dönüşü güç biçimde kaybedilmesine neden olmaktadır (Seto, Güneralp & Hutyra, 2012). Bu nedenle, mutlak tarım alanı rejimleri, mera koruma hükümleri, çevresel etki değerlendirme süreçleri ve sıkı imar denetimleri gibi planlama araçları, sürdürülebilir arazi yönetimi açısından giderek daha kritik hâle gelmektedir.

Küresel düzeyde, IPCC'nin 2023 tarihli Sentez Raporu (AR6), iklim değişikliği, arazi kullanımı ve gıda güvenliği arasındaki etkileşimi yeniden ele alarak sürdürülebilir arazi yönetimi ve güçlü yönetişim çerçevelerinin gerekliliğini vurgulamaktadır (IPCC, 2023). Benzer biçimde, FAO'nun 2023 tarihli arazi istatistikleri ve mülkiyet yapısı analizleri, arazi kullanım biçimlerinin dönüşümünün ve mülkiyet haklarının korunmasının, tarım alanlarının sürdürülebilirliği açısından belirleyici olduğunu ortaya koymaktadır (FAO, 2023a; FAO, 2023b).

Türkiye özelinde yapılan araştırmalar ve resmi istatistikler de, tarım alanlarının hem nicelik hem de nitelik bakımından önemli bir dönüşüm süreci içinde olduğunu göstermektedir. CORINE ve ulusal arazi örtüsü analizleri, 2000'li yıllardan itibaren tarım arazilerinin kentsel ve yapay kullanımlara dönüştüğünü ortaya koymaktadır. Bayar (2018), 2006–2012 döneminde tarım alanlarının önemli bir kısmının kent ve sanayi kullanımlarına kaydığını tespit etmiştir. Benzer biçimde, il ve ilçe ölçeğinde yapılan CBS tabanlı çalışmalar da (1990–2018) kentleşme ve altyapı projelerinin çevresindeki yüksek verimli tarım topraklarını hızla azalttığını doğrulamaktadır. İklim değişikliğinin etkilerine yönelik ekonometrik incelemeler, artan sıcaklık rejimlerinin tarımsal üretim için uygun alanları daralttığını; her bir derece sıcaklık artışının belirli bölgelerde birkaç yüzde puanlık tarım alanı kaybına neden olabileceğini göstermektedir (Demirdöğen, 2020). Buna paralel olarak, Dinçer ve Aydın'ın (2024) yapısal analizleri, tarım alanlarındaki daralmanın yalnızca mekânsal küçülme değil, aynı zamanda mülkiyet yapılarının,

işletme büyüklüklerinin ve tarım dışı gelir stratejilerinin değişimiyle de yakından ilişkili olduğunu ortaya koymaktadır.

Ülkedeki resmî veriler de bu bulguları desteklemektedir. TÜİK istatistiklerine göre Türkiye'de toplam tarım alanı 2001'de 40.967.000 hektar iken, 2024 itibarıyla 38.640.000 hektara gerilemiştir (TÜİK, 2025). Çevre, Şehircilik ve İklim Değişikliği Bakanlığı'nın kayıtları, 1989–2018 döneminde toplam 2.604.517 hektar tarım arazisinin *"amaç dışı kullanım"* kapsamında elden çıktığını göstermektedir (ÇŞİDB, 2018). Bu eğilim, tarım alanı kaybının artık münferit bir sorun olmaktan çıkarak, gıda güvenliği, kırsal refah ve ekosistem hizmetlerinin sürdürülebilirliği açısından yapısal bir kırılganlık alanına dönüştüğünü ortaya koymaktadır (Tonyaloğlu, 2024).

Dolayısıyla, tarım alanlarının korunması yalnızca çevresel bir gereklilik değil, aynı zamanda hukuki, planlama ve yönetişim boyutlarını içeren çok katmanlı bir politika alanıdır. Türkiye'de bu alanların yasal çerçevesi esas olarak 5403 sayılı "Toprak Koruma ve Arazi Kullanımı Kanunu" ile tanımlanmakla birlikte, 6306 sayılı "Afet Riski Altındaki Alanların Dönüştürülmesi Kanunu" ve 6360 sayılı "On Dört İlde Büyükşehir Belediyesi ve Yirmi Yedi İlçe Kurulmasi İle Bazı Kanun ve Kanun Hükmünde Kararnamelerde Değişiklik Yapılmasına Dair Kanun-Bütünşehir Yasası" ile 3194 sayılı "İmar Kanunu" gibi düzenlemeler de arazi kullanım kararlarını doğrudan etkilemektedir.

Bu bağlamda, çalışmanın temel amacı, Türkiye'de tarım alanlarının hukuki kırılganlık dinamiklerini ilgili mevzuat çerçevesinde sistematik olarak analiz etmektir. Araştırmada, mevcut yasal düzenlemeler ışığında tarım topraklarının mekânsal planlama, imar uygulamaları ve merkezi–yerel yönetim kararları karşısında karşılaşabileceği potansiyel riskler değerlendirilmekte; bu alanların sürdürülebilirlik açısından taşıdığı stratejik önem vurgulanmaktadır. Çalışma, tarım alanlarının korunması, gıda güvenliği-güvencesinin güçlendirilmesi ve ekolojik işlevlerin sürdürülmesi yönünde mevzuatın geliştirilmesine ve politika yapım süreçlerine katkı sunmayı amaçlamaktadır.

2. MATERYAL VE YÖNTEM

2.1. Materyal

Çalışmada tarım alanlarının hukuki kırılganlığını analiz etmek için birincil materyal olarak dört temel kanun ve bu kanunlarla ilişkili idari/kurumsal yapılar materyal olarak kullanmıştır. Çalışmada mevzuat metinlerini ve bunların birbiriyle etkileşimi ana veri kaynağı olarak değerlendirilmiştir. Çalışmada hukuki metinlerin dışında, tarım alanlarının kırılganlığını desteklemek amacıyla bilimsel literatür ve resmi veriler kullanmıştır. Çalışmanın birincil materyallerini

- 5403 sayılı Toprak Koruma ve Arazi Kullanımı Kanunu (RG, 2005)
- 6306 sayılı Afet Riski Altındaki Alanların Dönüştürülmesi Hakkında Kanun (RG, 2012a)
- 6360 sayılı On Dört İlde Büyükşehir Belediyesi ve Yirmi Yedi İlçe Kurulması ile Bazı Kanun ve Kanun Hükmünde Kararnamelerde Değişiklik Yapılmasına Dair Kanun (Bütünşehir Yasası) (RG, 2012b)
- 3194 sayılı İmar Kanunu (RG, 1985) oluşturmaktadır.

2.2. Yöntem

Çalışma, tarım alanlarının karşı karşıya kaldığı riskleri hukuki düzenlemeler zemininde inceleyen bir yöntem benimsemiştir. İncelemenin temelini, bir varlığın (bu çalışmada tarım alanlarının) mevcut yasal ve yönetsel sistemler içinde korunmasız kalma, baskılara karşı

dirençsiz olma ve olumsuz sonuçlara maruz kalma olasılığını ifade eden çok boyutlu bir kavram olan "Hukuki Kırılganlık" oluşturmaktadır.

Arazi yönetimi bağlamında, hukuki kırılganlık; araziyi koruma amacı taşıyan bir yasanın, başka bir yasa veya idari karar alma süreçleri tarafından kolayca aşılabilmesi veya etkisizleştirilebilmesi durumu olarak özetlenmiştir.

Hukuki kırılganlık, Türkiye mevzuatının birbiriyle etkileşiminden doğan üç ana bileşen üzerinden incelenmiştir:

- Normatif Tutarsızlık ve Çatışma: Farklı yasal düzenlemelerin aynı mekânsal alan üzerinde çelişen veya birbirini dışlayan hükümler içermesidir. Örnek olarak, 6306 sayılı Kanun'un tarım alanlarını rezerv yapı alanı olarak kullanma potansiyeli ile 5403 sayılı Kanun'un tarım dışı kullanım sınırlamaları arasındaki gerilim gösterilmiştir.

- İdari Takdir Yetkisinin Genişliği: Yasa metinlerindeki belirsiz veya geniş tanımlamaların ("kamu yararı," "zorunluluk," "rezerv alan") merkezi veya yerel idareye sınırsız denebilecek bir karar alma esnekliği tanımasıdır. Bu durum, koruma kararlarının bilimsel verilerden ziyade siyasi veya ekonomik önceliklere göre alınmasına zemin hazırlar. Örnek, 5403 sayılı Kanun'un 13. Maddesi'ndeki "kamu yararı" kavramının belirsizliği ve 3194 sayılı Kanun ile belediyelere devredilen geniş planlama yetkisi.

- Kurumsal ve Yönetsel Denetim Boşlukları: Yatay (kurumlar arası entegrasyon) ve dikey (merkezi-yerel yönetim) düzeylerde denetim ve eşgüdüm mekanizmalarının yetersiz kalmasıdır. Buna örnek olarak, Toprak Koruma Kurulları'nın (TKK) kararlarının bağlayıcı olmaması (5403 sayılı Kanun) ve 6360 sayılı Kanun ile yerel tarımsal inisiyatifin zayıflaması gösterilmiştir.

Çalışma, bu üç temel bileşenin çok katmanlı ve sistemik etkileşimi olarak Türkiye örneği üzerinden tarım alanlarının hukuki kırılganlığını analiz etmektedir.

3. BULGULAR

3.1. 5403 sayılı Toprak Koruma ve Arazi Kullanımı Kanunu (2005)

2005 yılında yürürlüğe giren 5403 sayılı Toprak Koruma ve Arazi Kullanımı Kanunu, Türkiye'de toprak kaynaklarının korunması ve sürdürülebilir yönetimine ilişkin temel yasal dayanağı oluşturmaktadır. Kanunun genel amacı, tarım topraklarının korunmasını, verimliliklerinin artırılmasını ve tarım dışı kullanımların sınırlandırılmasını sağlamaktır (Madde 1). Bununla birlikte, uygulamada ortaya çıkan kavramsal esneklikler, idari yetki paylaşımındaki dengesizlikler ve diğer mevzuatlarla uyum eksiklikleri, bu yasanın koruma kapasitesini sınırlamaktadır.

Kamu Yararı Kavramının Belirsizliği ve Madde 13'ün Esnek Yorumu: Yasada kamu yararı kavramının net olmaması, uygulamada tartışmalı bir alan olarak öne çıkmaktadır. Madde 13, tarım arazilerinin "kamu yararı" gerekçesiyle tarım dışı kullanımına izin verebilmektedir; ancak *"kamu yararı"* ve *"zorunluluk"* kavramlarının açık tanımları bulunmadığından, idari otoritelerin takdir yetkisi genişleyebilmektedir. Bu durum, özellikle enerji, ulaşım veya savunma yatırımları bağlamında tarım arazilerinin kullanımının kolaylaşmasına ve koruma amacının görece zayıflamasına yol açabilir.

Tarım Arazilerinin Sınıflandırılması (Madde 5) ve Uygulama Sorunları: Madde 5, tarım arazilerini "mutlak, özel ürün, dikili, marjinal ve örtü altı" olarak sınıflandırarak bilim temelli bir arazi yönetimi öngörmektedir. Bununla birlikte, uygulamada bu sınıflandırmanın 3194 sayılı İmar Kanunu çerçevesinde yapılan planlarla tam olarak bütünleşmemektedir. Bu durum, planlama bütünlüğünü azaltabilir ve koruma etkinliğini sınırlayabilir.

Toprak Koruma Kurulları ve Kurumsal Denetim (Madde 14): Toprak Koruma Kurulları teorik olarak denetim ve bilimsel rehberlik sağlamayı hedeflemektedir. Ancak kararlarının bağlayıcı olmaması ve merkezi idareye yoğunlaşan yetki, yerel bilgiye dayalı karar süreçlerini zayıflatabilir ve siyasal önceliklerin etkili olabileceği bir alan yaratabilir.

Tarım Dışı Kullanım İzinleri ve Bakanlık Yetkisi (Madde 13 ve 14): Tarım dışı kullanım izinlerinde merkeziyetçi bir yapı hâkim görünmektedir. Yerel ekolojik ve sosyoekonomik verilerin her zaman dikkate alınmadığı durumlarda, büyük ölçekli altyapı ve enerji projeleri tarımsal koruma hedeflerinin önüne geçebilir.

Arazi Parçalanmasının Önlenmesi (Madde 8) ve Sosyoekonomik Etkiler: Madde 8, tarım arazilerinin ekonomik işletme büyüklüğünün altına düşmesini engellemeyi amaçlamaktadır; ancak miras hukuku ve yerel sosyo-kültürel koşullar, arazi bütünlüğü hedefiyle her zaman uyumlu olmayabilir ve kırsal göç veya mülkiyet uyuşmazlıklarına yol açabilir.

Toprak Kalitesinin Korunması ve Bozulmanın Önlenmesi (Madde 9–11): Erozyon, tuzluluk ve kirlilikle mücadele önlemleri öngörülse de, finansal ve teknik kapasite sınırlamaları nedeniyle uygulamada etkisi sınırlı kalabilir; bu durum toprağın sürdürülebilir yönetimini görece zayıflatabilir.

Diğer Yasal Düzenlemelerle Entegrasyon Sorunları: 5403 sayılı Kanun'un, İmar Kanunu (3194), Mera Kanunu (4342), Büyükşehir Belediyesi Kanunu (5216) ve 6360 sayılı Bütünşehir Yasası ile yeterince bütünleşememesi, tarım alanlarının imara açılmasını kolaylaştıran bir ortam yaratmaktadır. Özellikle köylerin mahalleye dönüşmesiyle belediye imar yetkisinin genişlemesi, 5403 sayılı Kanun'un öngördüğü koruma mekanizmalarını fiilen etkisiz hale getirebilir. Ayrıca ÇED süreçleri, tarım topraklarının ekolojik değeri ve üretim kapasitesi dikkate alınmadan yürütüldüğünde, çevresel ve tarımsal koruma politikaları arasında kopukluk oluşmaktadır. Ulusal İklim Değişikliği Stratejisi (2010–2023) ve Türkiye İklim Kanunu (2025) gibi güncel politika belgeleriyle entegrasyon eksikliği, toprağın karbon depolama ve iklim düzenleyici işlevlerini göz ardı etmektedir.

Sonuç olarak 5403 sayılı Kanun, tarım arazilerini koruma hedefi taşısa da; Madde 13'teki esneklik, Madde 14'teki denetim sınırlılığı ve Madde 8'in sosyoekonomik uyumsuzlukları, uygulamada koruma kapasitesini azaltabilir. Yasaların entegrasyon eksikliği ve merkeziyetçi yapı, tarım alanlarının mekânsal bütünlüğü, ekolojik işlevselliği ve gıda güvenliği açısından riskler oluşturabilir. Bu nedenle, Kanun'un ekolojik bütünlük, iklim uyumu, yerel katılım ve planlama entegrasyonu ilkeleri doğrultusunda güncellenmesi, uzun vadeli toprak koruma stratejileri açısından olası bir gerekliliktir (Resmi Gazete, 2005).

3.2. 6306 sayılı "Afet Riski Altındaki Alanların Dönüştürülmesi Hakkında Kanun" (2012)

2012 yılında yürürlüğe giren 6306 sayılı "Afet Riski Altındaki Alanların Dönüştürülmesi Hakkında Kanun", Türkiye'de afet risklerinin azaltılması, güvenli yaşam alanlarının oluşturulması ve riskli yapı stokunun dönüştürülmesi amacıyla kabul edilmiştir. Ancak Kanun'un uygulama alanına ilişkin kavramsal esneklikleri ile kentsel dönüşüm araçlarının tarım alanlarını da kapsayacak biçimde genişletilmesi, özellikle tarım topraklarının korunması açısından ciddi hukuki ve mekânsal kırılganlıklar doğurmaktadır.

Afet Riski Kavramının Geniş Yorumu ve Tarım Alanlarının Dönüşüm Alanı Olarak Değerlendirilmesi (Madde 2 ve Madde 3): Kanun'un 2. maddesinde "riskli alan" ve "rezerv yapı alanı" kavramları tanımlanmaktadır. Bu alanlar, afet riski taşıyan bölgeleri veya yeni yerleşim alanı olarak kullanılabilecek sahaları kapsamaktadır. Madde 3/1'e göre, rezerv yapı alanı yalnızca riskli bölgelerle sınırlı olmayıp Bakanlık tarafından uygun görülen diğer alanları da kapsayabilmektedir. Bu geniş tanım, tarım topraklarının rezerv yapı alanı olarak ilan edilmesine ve konut, sanayi veya altyapı projelerine tahsis edilmesine potansiyel olarak imkân

tanıyabilir. Özellikle büyükşehir çeperlerinde yer alan verimli tarım arazileri, düşük afet riski taşısalar dahi konumsal cazibeleri nedeniyle rezerv yapı alanı olarak belirlenebilir; bu durum, 5403 sayılı Kanun'un tarım dışı kullanım sınırlamalarıyla olası bir gerilime yol açabilir.

"Kamu Yararı" Gerekçesiyle Tarım Alanlarının Dönüştürülmesi (Madde 6 ve Madde 7): Madde 6 kapsamında dönüşüm alanlarının ilanı kamu yararı ilkesine dayandırılmaktadır. Ancak kamu yararının tarımsal üretim, gıda güvenliği veya ekolojik sürdürülebilirlik bağlamında net bir şekilde tanımlanmamış olması, bu kavramın çoğunlukla konut, altyapı veya kentsel büyüme odaklı yorumlanmasına yol açabilir. Madde 7 ise Hazine veya kamu mülkiyetindeki taşınmazların Bakanlık tarafından doğrudan tahsisine potansiyel imkân tanıyabilir; bu durum, tarım arazilerinin kamu mülkiyetinde olsa dahi rezerv alanlara dönüştürülmesini mümkün kılabilir ve 5403 sayılı Kanun'un koruma ilkesiyle uyumsuzluk yaratabilir.

Planlama Hiyerarşisi Dışında İşleyen Dönüşüm Süreçleri (Madde 9 ve Madde 10): Kanun'un 9. ve 10. maddeleri, rezerv yapı alanlarına ilişkin planlama süreçlerinde mevcut hiyerarşiye muafiyet tanıyabilir. Madde 9/1, Bakanlığa her ölçekte plan yapma veya yaptırma yetkisi sağlayarak, 3194 sayılı İmar Kanunu'ndaki plan kademelenmesini potansiyel olarak devre dışı bırakabilir. Bu durum, tarım alanlarının parçalı ve plansız biçimde yapılaşmasına yol açabilir.

Tarımsal Üretim Alanlarının Rezerv Alan Olarak Tahsisi ve Mekânsal Parçalanma (Madde 2c ve Madde 10/2): Bakanlığa tanınan geniş takdir yetkisi, tarımsal üretim kuşakları içindeki alanların rezerv yapı alanı ilan edilmesini potansiyel olarak mümkün kılabilir. Bu süreç tarımsal bütünlüğün bozulmasına, sulama altyapılarının ve ekolojik bağlantıların kesintiye uğramasına yol açabilir. Tarım alanlarının rezerv alan kapsamına alınması, yalnızca fiziksel dönüşüm değil, aynı zamanda gıda güvenliği, kırsal ekonomi ve arazi bütünlüğü üzerinde uzun vadeli etkiler yaratabilir.

Afet Yönetimi ve Tarım Arazisi İlişkisinde Planlama Tutarsızlıkları: Kanun afet risklerini azaltmayı hedeflese de, afet sonrası yeniden yerleşim planlamasında tarım topraklarının güvenli zemin olarak kullanılması, potansiyel olarak ekolojik sürdürülebilirliği ve tarımsal üretim kapasitesini olumsuz etkileyebilir.

Diğer Yasal Düzenlemelerle Entegrasyon Sorunları: 6306 sayılı Kanun, 5403, 3194 ve 6360 sayılı yasalarla uygulama açısından uyumlu değildir. 5403 sayılı Kanun, tarım dışı kullanım izinlerini Toprak Koruma Kurulları'na bağlarken, 6306 sayılı Kanun merkezi idareye devrederek kurumsal denetimi sınırlamaktadır. 3194 sayılı Kanun açısından, 6306 kapsamındaki planlar imar planı niteliğinde değerlendirilmektedir; ancak plan bütünlüğü, kamu katılımı ve çevresel değerlendirme süreçleri çoğu zaman işletilmemektedir. 6360 sayılı Kanun sonrasında büyükşehir belediyelerinin planlama yetkileri 6306 kapsamındaki alanlarda sınırlandırılmış; böylece yerel yönetimlerin tarım alanları üzerindeki karar süreçlerindeki etkisi azalmıştır. Bu durum, Türkiye'de planlama sisteminin bütüncül bir yaklaşım yerine projeye dayalı işlediğini ve tarım alanlarının korunacak kaynak yerine dönüşüm rezervi olarak konumlandığını göstermektedir.

Sonuç olarak 6306 sayılı Kanun, afet risklerini azaltmayı amaçlasa da, tanımsal esneklik ve planlama hiyerarşisinden bağımsız işleyişi nedeniyle tarım topraklarının sürdürülebilirliği üzerinde potansiyel riskler oluşturabilir. Rezerv yapı alanı kavramının belirsizliği, kamu yararının kentsel öncelikler lehine yorumlanması ve entegrasyon eksiklikleri, tarım alanlarını sistematik olarak risk altına sokabilir. Bu nedenle, Kanun'un 5403 ve 3194 sayılı yasalarla uyumlu hâle getirilmesi, tarım topraklarının mutlak koruma alanı olarak tanımlanması ve Toprak Koruma Kurulları'nın görüşlerinin bağlayıcı hale getirilmesi, gıda güvenliği ve ekolojik dayanıklılık açısından olası kritik önlemler olarak değerlendirilebilir (Resmi Gazete 2012a).

3.3. 6360 Sayılı "On Dört İlde Büyükşehir Belediyesi ve Yirmi Yedi İlçe Kurulması ile Bazı Kanunlarda Değişiklik Yapılmasına Dair Kanun" (2012)

2012 yılında Resmî Gazete'de yayımlanarak 30 Mart 2014 yerel seçimleri sonrasında yürürlüğe giren 6360 sayılı Kanun, Türkiye'de yerel yönetim sistemini köklü biçimde dönüştüren en kapsamlı idari düzenlemelerden biridir. Kanun'un temel amacı, idari bütünleşmeyi sağlamak, hizmet sunumunda etkinliği artırmak ve kaynak kullanımını rasyonelleştirmektir. Ancak bu düzenleme, kırsal alanların statüsünü kaldırarak onları büyükşehir belediyesi sınırlarına dâhil etmesi nedeniyle, tarım topraklarının korunması, kırsal kalkınma ve ekolojik sürdürülebilirlik açısından ciddi kırılganlıklar yaratmıştır.

Kırsal Statünün Ortadan Kalkması ve Tarım Alanlarının İmar Baskısına Açılması: Kanun'un 1. ve 4. maddeleri, büyükşehir belediyesi sınırlarını il mülki sınırlarına genişletmiş ve köy ile belde belediyelerinin tüzel kişiliklerini kaldırarak yerleşimleri mahalle statüsüne dönüştürmüştür. Bu değişikliğin, köylerin arazi yönetim özerkliğini azaltabileceği ve tarımsal nitelikli arazilerin belediye imar mevzuatı kapsamına alınmasını kolaylaştırabileceği düşünülmektedir. Dolayısıyla, 5403 sayılı Kanun'daki tarım dışı kullanım izinlerinin dolaylı olarak aşılma olasılığı ve tarım alanları üzerindeki kentsel gelişme baskısının artması potansiyel bir risk olarak değerlendirilebilir.

Yerinden Yönetimin Zayıflaması ve Tarımsal Karar Yetkisinin Merkezileşmesi: Kanun'un 3. maddesi ve Geçici Madde 2, köy idarelerinin yetki ve görevlerini belediyelere devretmiştir. Bu durumun, mera tahsisleri, üretim kararları ve arazi kullanımı konularında yerel inisiyatifin azalmasına ve karar süreçlerinin belediye ile merkezi idare arasında yoğunlaşmasına yol açabileceği öngörülmektedir.

Belediye Hizmetlerinin Tarımsal Öncelikleri İkincilleştirmesi: 6. madde uyarınca büyükşehir belediyelerine kırsal alanlarda hizmet sağlama yükümlülüğü verilmiş olsa da, uygulamada altyapı ve imar yatırımlarının öncelik kazanması muhtemeldir ve bu durum tarımsal üretim ve kırsal kalkınma projeleri ikincil plana itilebilir. Bu durum, kırsal alanlarda kurumsal öncelik kaymasına ve tarımsal üretim kapasitesinin desteklenmesinde boşluklara yol açabilir.

Arazi Mülkiyetinde Belirsizlik ve Ortak Alanların Hukuki Statüsünün Erozyonu: Köy tüzel kişiliklerinin kaldırılmasıyla köy ortak mallarının mülkiyetinin belediye veya Hazine'ye devri, idari belirsizlikler ve mülkiyet ihtilaflarına yol açabilir. Bu durum, tarım arazilerinin tahsis amacına uygun kullanılmasını sınırlayabilir ve imar veya kamu projelerine tahsis riskini artırabilir.

Kırsal Kültürün ve Tarımsal Kimliğin Zayıflaması: Mahalle statüsüne geçiş, kırsal üretim kültürünün ve topluluk kimliğinin görünürlüğünü azaltabilir; imece, ortak üretim ve kooperatifleşme gibi yerel dayanışma pratiklerinin zayıflaması olasıdır. Tarımsal bilgi aktarımı ve yerel örgütlenme kapasitesinde potansiyel düşüşler, sosyo-kültürel sürdürülebilirliği etkileyebilir.

Kentsel Yayılmanın Tarım Alanları Üzerindeki Mekânsal Etkileri: Yasanın 7. madde ile büyükşehir belediyelerine il düzeyinde planlama yetkisi verilmesi, kentsel gelişmenin tarım arazilerine doğru genişlemesini kolaylaştırabilir. Bu süreç, tarım alanlarının potansiyel rezerv alan olarak değerlendirilmesine ve "mutlak tarım arazilerinin korunması" ilkesinin etkinliğinin azalmasına yol açabilir.

Tarımsal Altyapı ve Sulama Sistemlerinde Kurumsal Zayıflama: Kırsal altyapının belediyelere devri, teknik ve mali kapasite yetersizlikleri nedeniyle boşluklar oluşturabilir; sulama yatırımlarının sürekliliği ve tarımsal verimlilik olası olarak etkilenebilir.

Arazi Koruma Mevzuatının Uygulama Etkinliğinin Azalması: Toprak Koruma Kurulları'nın büyükşehir düzeyine taşınması ve belediye önceliklerinin tarımsal korumayı ikincil plana itmesi, koruma politikalarının etkinliğini sınırlayabilir ve 5403 sayılı Kanun'daki "tarım topraklarının kamu yararı dışında amaçlarla kullanılmaması" ilkesini zayıflatabilir.

Sonuç olarak 6360 sayılı Kanun, kırsal alanların belediye yönetimine dâhil edilmesi ve hizmet etkinliğini artırma hedefi taşısa da, tarımsal sürdürülebilirlik ve gıda güvenliği açısından yapısal kırılganlıklar oluşturabilir. Kentsel planlama yaklaşımının kırsal alanlara genişletilmesi, tarım topraklarının imar ve yatırım faaliyetlerine açılmasını kolaylaştırabilir; bu durum, 5403 sayılı Kanun ile öngörülen koruma ilkeleriyle potansiyel çelişki oluşturabilir. Dolayısıyla, Kanun'un tarımsal arazi yönetimiyle uyumlu biçimde yeniden düzenlenmesi, Türkiye'nin ekolojik planlama, tarımsal üretim güvenliği ve iklim dayanıklılığı açısından stratejik bir gereklilik olarak değerlendirilebilir (Resmi Gazete, 2012b).

3.4. 3194 sayılı İmar Kanunu (1985)

1985 yılında yürürlüğe giren 3194 sayılı İmar Kanunu, Türkiye'de mekânsal planlama, arazi kullanımı ve yapılaşma süreçlerini düzenleyen temel yasal çerçeve olarak kabul edilmektedir. Kanun'un öncelikli amacı yerleşim alanlarının planlı gelişimini desteklemek olsa da, tarım topraklarının korunmasına dair doğrudan bir hüküm içermemesi, uygulamada bu alanların imar baskısına maruz kalma olasılığını artırabilir. Bu durum, özellikle 5403 sayılı Toprak Koruma ve Arazi Kullanımı Kanunu ve 6360 sayılı Büyükşehir Yasası ile birlikte değerlendirildiğinde, Türkiye'de tarımsal alanların planlama sistemine entegrasyonunda bazı yapısal zorlukların var olabileceğini göstermektedir.

Planlama Yetkisi ve Tarım Alanlarının İmar Alanlarına Dönüştürülmesi (Madde 8 ve Madde 9): Kanun'un 8. maddesi, imar planlarının hazırlanması, onaylanması ve yürürlüğe konulması yetkisini büyük ölçüde belediyelere ve il özel idarelerine bırakmaktadır. Bu düzenleme kapsamında, nazım ve uygulama imar planları hazırlanırken tarım alanlarının imar sınırına dâhil edilmesi olasıdır. Ayrıca 9. madde, Çevre, Şehircilik ve İklim Değişikliği Bakanlığı'na gerektiğinde resen plan yapma veya onama yetkisi tanımaktadır. Bu durum, merkezi idareye geniş bir takdir alanı sağlamakta ve kimi durumlarda tarımsal koruma önceliklerinin planlama kararları karşısında geri planda kalmasına yol açabilmektedir. Dolayısıyla, 5403 sayılı Kanun'un 13. ve 14. maddelerinde öngörülen tarım dışı kullanım izinlerinin sınırlandırılması ilkesiyle bir gerilim alanı oluşabileceği söylenebilir.

Kamu Yararı Kavramı Altında Tarım Alanlarının İmar Amaçlı Kullanımı (Madde 5 ve Madde 11): Madde 5'te yer alan "kamu yararı" kavramı, planlama kararlarının temel gerekçesi olarak öne çıkmaktadır. Bununla birlikte, kamu yararının içeriği tarımsal üretim, gıda güvenliği veya ekosistem hizmetleri açısından açık biçimde tanımlanmadığı için, çoğu zaman kentsel gelişme, sanayi yatırımı veya altyapı projeleri lehine yorumlanabilmektedir. Benzer şekilde, Madde 11 kapsamında kamu hizmetlerine ayrılan alanların imar planlarıyla belirlenmesi, tarımsal üretim alanlarının planlı biçimde el değiştirmesine imkân sağlayabilir. Bu nedenle, iki yasa arasında normatif bir tamamlayıcılık öngörülmüş olsa da, uygulamada tarım alanlarının korunma ilkesinin tam olarak güvence altına alınmadığı gözlenebilir.

Plansız Alanlar Yönetmeliği ve Tarım Alanlarının Kapsam Dışı Kalması (Madde 27): Madde 27, plansız alanlarda yapılacak yapılarla ilgili düzenlemeler içermektedir. Bu madde kapsamında, köy yerleşik alanlarında belirli koşullarda yapılaşmaya izin verilmesi olasıdır. Özellikle 6360 sayılı Kanun sonrasında köylerin mahalle statüsüne dönüştürülmesiyle birlikte, bu hüküm tarımsal alanlarda kentsel yapılaşmanın hukuki dayanaklarından biri hâline gelebilir. Dolayısıyla tarım dışı faaliyetlerin (örneğin depo, konut, küçük ölçekli sanayi yapıları) artışı, tarım alanlarının parçalanmasına ve verim kaybına yol açabilir; kırsal peyzajın bozulma riski de gündeme gelebilir.

Planlama Kademeleri Arasındaki Uyum Eksikliği ve Tarımsal Alanların Entegrasyon Sorunu (Madde 6 ve Madde 8): Madde 6 ve Madde 8, mekânsal planlama kademelerini (çevre düzeni, nazım, uygulama imar planları) tanımlamaktadır. Bununla birlikte, bu planlama hiyerarşisi içinde tarım alanlarının korunmasına yönelik özel bir plan türü öngörülmemektedir. Bu durum, 5403 sayılı Kanun kapsamında hazırlanan Toprak Koruma Projeleri ile çevre düzeni planları arasında kurumsal eşgüdüm eksikliğine yol açabilir. Nitekim, 1/100.000 ölçekli çevre düzeni planlarında tarım alanlarının korunma bölgesi olarak belirlenmiş olması, alt ölçekli planlarda (1/5000 ve 1/1000) bu kararların imar uygulamalarıyla kısmen aşılabileceği olasılığını ortaya koymaktadır. Böylece, tarım topraklarının planlama sistemine dikey entegrasyonu sınırlı kalabilmektedir.

Afet ve Yeniden Yapılanma Süreçlerinde Tarım Alanlarının Kullanımı (Madde 9 ve Madde 18): Madde 18, parselasyon işlemlerine ilişkin düzenlemeler getirerek, kamu hizmeti veya yapılaşma amacıyla tarım arazilerinin ifraz ve tevhit yoluyla el değiştirmesine olanak tanıyabilir. Ayrıca Madde 9, Bakanlığa "resen plan yapma" yetkisi vermektedir; bu nedenle, özellikle afet sonrası yeniden yapılanma süreçlerinde tarım topraklarının hızlı biçimde imara açılması ihtimali söz konusu olabilir. Bu durum, afetzede yerleşimleri veya geçici barınma alanları kapsamında tarım arazilerinin kalıcı olarak kaybedilmesine yol açabilir.

Tarım Alanlarının Koruma Statüsünün Planlama Sisteminde İkincilleşmesi: 3194 sayılı Kanun, tarımsal koruma hedeflerini doğrudan düzenlememekte; arazi kullanım kararlarını daha çok imar odaklı olarak şekillendirmektedir. Tarım alanlarının korunmasına yönelik bağlayıcı dayanak, 5403 sayılı Toprak Koruma Kanunu veya 4342 sayılı Mera Kanunu hükümlerinin plan kararlarına entegrasyonu ile sağlanabilir. Ancak uygulamada bu entegrasyon sınırlı kalmakta, imar planları çoğu zaman tarım dışı kullanım izni alınmadan hazırlanmakta ve Toprak Koruma Kurulları sonradan devre dışı kalabilmektedir. Bu nedenle, tarım arazileri planlama sisteminde ikincil veya tali bir unsur olarak konumlanabilir.

Sonuç olarak 3194 sayılı İmar Kanunu, yerleşim planlamasının hukuki çerçevesini sağlamakla birlikte, tarım alanlarının korunması açısından doğrudan bir garanti sunmamaktadır. Kanunun esnek kamu yararı tanımı ve belediyelere geniş planlama yetkisi tanıması, tarım topraklarının planlı kentsel genişleme süreçlerinde el değiştirme olasılığını artırabilir. Bu nedenle, tarım alanlarının mekânsal planlama kademelerinde koruma öncelikli bir kategori olarak tanımlanması, imar planı onay süreçlerinde Toprak Koruma Kurulları'nın görüşünün zorunlu hâle getirilmesi ve ekosistem temelli planlama anlayışının kurumsallaştırılması önerilebilir (Resmi Gazete, 1985).

4. SONUÇ VE ÖNERİLER

Türkiye'de tarım topraklarının korunması, hem ulusal gıda güvenliği hem de ekolojik sürdürülebilirlik açısından kritik öneme sahiptir. Bu çalışma, Türkiye'de tarım alanlarının korunmasının mevcut hukuki çerçevede çeşitli kırılganlıklara sahip olduğunu göstermektedir. 5403 sayılı Toprak Koruma ve Arazi Kullanımı Kanunu, tarım topraklarının korunması için temel bir normatif çerçeve sağlamakla birlikte, merkeziyetçi izin süreçleri ve diğer mevzuatlarla uyum eksiklikleri nedeniyle uygulamada sınırlı etkiye sahiptir. 6306 sayılı Afet Riski Altındaki Alanların Dönüştürülmesi Hakkında Kanun ve 3194 sayılı İmar Kanunu, tarım alanlarının planlama ve imar süreçlerinde "kamu yararı" ve afet gerekçesiyle dönüşümüne olanak tanımakta, bu durum hukuki ve mekânsal kırılganlıkları artırmaktadır. 6360 sayılı Büyükşehir Belediyesi Kanunu ise kırsal idari yapıların ortadan kalkması ve tarım alanlarının belediye planlama yetkisine dâhil edilmesiyle yerel katılım ve tarımsal karar alma mekanizmalarını zayıflatmaktadır.

Buna bağlı olarak, tarım alanlarının korunmasına yönelik politika ve uygulamalarda bütüncül bir yaklaşım geliştirilmesi gerekmektedir. Öncelikle, tarım topraklarının kaybını önleyici

mekanizmalar, merkezi ve yerel düzeyde planlama süreçlerine entegre edilmelidir. Afet sonrası yeniden yapılanma ve kentsel dönüşüm süreçlerinde tarım alanları öncelikli olarak korunmalı, riskli bölgelerde alternatif yerleşim alanları belirlenmelidir. Büyükşehir ve ilçe belediyeleri, planlama kararlarında tarım alanlarının korunmasına özel stratejiler geliştirmeli, bu alanların imara açılması yalnızca zorunlu ve geçici durumlarla sınırlı olmalıdır. Ayrıca, çiftçiler, yerel halk ve sivil toplum kuruluşlarının sürece dâhil edilmesiyle toplumsal katılım güçlendirilerek, denetim ve uygulama kapasitesi artırılmalıdır. Tarımsal üretimi destekleyen ekonomik ve yönetsel teşvikler de tarım alanlarının sürdürülebilir korunmasına katkı sağlayacaktır. Sonuç olarak, Türkiye'de tarım alanlarının hukuki, mekânsal ve toplumsal boyutları dikkate alan bütüncül bir yaklaşım ile korunması, ülkenin gıda güvenliği, kırsal kalkınma ve ekosistem sağlığı açısından stratejik bir zorunluluk olarak ortaya çıkmaktadır.

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COMPARISON OF YIELD AND YIELD COMPONENTS OF TWO DIFFERENT RAPESEED *(Brassica napus* L.) VARIETIES UNDER KIRKLARELI/BABAESKI-YENIKOY CONDITIONS

Ece TAŞYUMRU SÜZER

Ege University, Faculty of Agriculture, Department of Field Crops, 35100 Bornova, Izmir, Turkey

*Corresponding author: ecetasyumru9@gmail.com

Umut SÜZER

Ege University, Faculty of Agriculture, Department of Field Crops, 35100 Bornova, Izmir, Turkey

Sıdıka EKREN

Ege University, Faculty of Agriculture, Department of Field Crops, 35100 Bornova, Izmir, Turkey

ABSTRACT

This study was conducted in Yeniköy village, Babaeski district, Kırklareli province, in 2022-23, and aimed to compare two different rapeseed (Brassica napus L.) varieties in terms of yield components. The Agromar Clavier CL and Dekalb DK Exstorm varieties were used as materials in the experiment; yield components such as plant height, number of side branches, thousand-seed weight, number of pods, and number of seeds per pod were evaluated. According to the findings obtained in the study, which was conducted in a randomized block design with three replications, statistically significant differences were found between the varieties in terms of plant height, number of pods, and number of seeds per pod. The Dekalb DK Exstorm variety stood out with its longer plant height (105.1 cm), higher number of capsules (1,201.2 capsules), and higher number of seeds per capsule (33,182.3 seeds). In contrast, the Agromar Clavier CL variety achieved higher values in terms of side shoot number (7.07). No significant difference was observed between the two varieties in terms of thousand-seed weight. The results indicate that the Dekalb DK Exstorm variety has a higher yield potential under regional conditions and, therefore, its production could be suitable for widespread cultivation in the region.

Keywords: Rapeseed, *Brassica napus* L., variety comparison, yield, number of pods

INTRODUCTION

Rapeseed (*Brassica napus* L.) is among the oilseed crops of strategic importance worldwide for both human nutrition and industrial use. Thanks to its high vegetable oil content, it is widely used in the food industry; at the same time, the meal obtained is used as animal feed. Rapeseed oil is among the oils recommended for health due to its low saturated fat content and high oleic acid content; it is also used in energy-related applications such as biodiesel production (Keskin and Yılmaz, 2019).

Canada, China, India, and European Union countries lead the world in rapeseed production. Turkey, despite its production potential in this area, has not yet reached the desired level. However, in recent years, an increase in production areas has been observed, particularly in the Thrace Region, and as a result of this increase, rapeseed cultivation is becoming more integrated into the agricultural production pattern (Çalışkan et al., 2021). Factors such as crop losses due to climate change, the need for crop rotation, and government subsidies appear to have contributed to this development.

Rapeseed production in Turkey is generally carried out in Thrace, Southern Marmara, and to a lesser extent in some regions of the Aegean and Black Sea. Winter rapeseed varieties are preferred in these regions, and their resistance to low temperatures makes them suitable for crop rotation, which is an important advantage for producers. There are many areas in the Thrace Region that are suitable for rapeseed cultivation in terms of soil structure and climatic conditions. Kırklareli province is among these regions, and production there is increasing. However, variety selection is mostly based on traditional knowledge or producer preferences; systematic studies to determine the most suitable variety for the region remain limited (Albayrak and Gürbüz, 2020).

Among rapeseed varieties, there are significant differences in many characteristics such as grain yield, oil content, plant height, maturation period, and oil quality. These differences arise not only from genetic structure but also from the interaction between the variety and the environment. The responses of varieties to environmental conditions determine their adaptation abilities, which directly affect yield and quality (Çalışkan et al., 2021). Therefore, in order to select the most suitable rapeseed variety for a specific region, it is necessary to comparatively evaluate the performance of varieties under the climatic and soil characteristics of that region.

Although research on this subject in Turkey is limited, some studies have revealed the regional performance of different rapeseed varieties. For example, a study conducted in the Southeastern Anatolia Region reported that the “Elvis” and “Excalibur” varieties provided high yields and oil content under dry conditions (Albayrak and Gürbüz, 2020). Similarly, trials conducted in provinces such as Edirne and Tekirdağ determined that varieties such as “Visby,” “Veles,” and “Licord” showed superior performance in some years (Keskin and Yılmaz, 2019). These findings indicate that variety-specific differences in terms of yield and quality should be taken into account in rapeseed cultivation.

This study aims to compare two different rapeseed varieties in terms of yield and quality at a location within Turkey's Thrace Region. The data obtained from the study will not only be useful for the area where the research was conducted but will also shed light on rapeseed cultivation in regions with similar ecological characteristics. At the same time, the aim is to establish a scientific basis for producers to select the most suitable rapeseed variety. Thus, it is intended to contribute to factors such as sustainability, product diversity, and economic efficiency in regional agriculture.

MATERIALS AND METHODS

The research was conducted in October 2022-2023 in the fields of producers in Yeniköy village, Babaeski district, Kırklareli. In our study, the rapeseed (Brassica napus L.) varieties named "DK EXSTORM" from the Dekalb company and "CLAVIER CL" from the Agromar company were used as trial material.

The test plot generally has a loamy and loamy-clay texture and is of medium depth. The pH value of the soils generally varies between slightly acidic and neutral. Organic matter content is low to medium. In terms of lime content, it is moderately calcareous.

Table 1. Climate data for the research site for 2022-23 and long-term years

	Average temperature (°C)		Total rainfall (mm)	
	2022-23	Long term	2022-23	Long term
January	4.5	3.1	35.6	41.6
February	5.0	3.5	30.0	37.2
March	7.8	6.2	40.1	47.8
April	15.6	10.5	45.2	51.9
May	17.2	15.0	50.7	47.2
June	22.6	19.1	55.2	40.3
July	24.9	22.2	60.5	35.2
August	23.7	21.6	55.3	33.8
September	22.1	17.7	50.9	38.2
October	13.5	11.0	45.8	49.1
November	9.0	6.0	40.6	52.5
December	8.7	3.2	35.7	47.5
Σ /X	14.6	11.6	545.6	522.3

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As shown in Table 1, temperatures were significantly higher than the long-term average in all months during the 2022-2023 period. Particularly during the summer months (June–September), there were notable increases in precipitation amounts parallel to the rise in temperatures. Overall, it can be seen that both temperature and precipitation averages were above the long-term averages during the period under review. The region has suitable climatic conditions for winter rapeseed cultivation in terms of precipitation and temperature values, and these characteristics support plant growth.

The study was conducted in triplicate according to a randomized block design. On October 1, 2022, Agromar's CLAVIER CL variety was planted in the prepared field. Along with the planting, 3.5 kg/da of Microcare fertilizer was applied. On February 20, 2023, 18 kg/da of Ammonium Sulfate fertilizer was used. On March 10, 2023, the commercial pesticides Intervıx Plus and Padlock 240 EC were used. On April 2, 2023, 22 kg/da of granular URE fertilizer was applied. On April 25, 2023, amino acids and foliar fertilizer were applied along with the commercial pesticides Topguard and Zelos. The emergence of canola in the field was observed on February 8, 2023. Flowering began on April 5, 2023. The DK EXSTORM variety from the Dekalb company was planted in the field prepared on October 2, 2022. In October, 22 kg/da of

Zinc-containing 20-20 fertilizer was used. On December 5, 2022, Ammonium Sulfate fertilizer was applied. On January 4, 2023, the commercial pesticide Padlock and Mostar 20 SP were used. On January 10, 2023, 15 kg/da of URE fertilizer was applied. On February 15, 2023, the commercial pesticide Input and boron-containing foliar fertilizer were used. On March 2, 2023, 15 kg/da of URE fertilizer was applied. On May 2, 2023, 25 kg/da of nitrate fertilizer was applied. On May 4, 2023, the commercial pesticides Cayunis and Vantex and boron-containing fertilizer were used. The emergence of canola in the field was observed on February 10, 2023. Flowering began on April 7, 2023.

The study examined characteristics such as plant height (cm), number of side branches (number/plant), 1000-seed weight (g), number of pods (pieces), and number of seeds per pod (per/plant). The statistical analysis of the data was performed using the Totemstat program, and differences between treatments were determined using the LSD test (Açıkgöz et al., 2004).

RESEARCH RESULTS and DISCUSSION

Statistically significant differences were determined between the Agromar-Clavıer CL and Dekalb-DK Exstorm varieties examined in the study in terms of plant height, number of side branches, number of pods, and number of seeds per pod (Table 2). The Dekalb-DK Exstorm variety showed a longer plant height (105.09 cm) (Figure 1) and a higher number of pods (1,201.2 pods) (Figure 2) compared to Agromar-Clavıer CL; these differences were above the LSD (5%) limit and were statistically significant. In terms of seed count per pod, Dekalb-DK Exstorm (33,182.3 seeds) also reached significantly higher values than Agromar-Clavıer CL (19,685.1 seeds) (Figure 3) (LSD 5%). In terms of lateral branch number, the Agromar-Clavıer CL variety (7.07 branches) was higher than the Dekalb-DK Exstorm variety (4.17 branches) (Figure 4). In contrast, there was no statistically significant difference between the varieties in terms of weight per thousand seeds (g) (Figure 5).

Table 2. Agronomic characteristics of the varieties used in the study

Varieties	Plant height (cm)	Weight per thousand seeds (g)	Number of side branches (pieces)	Number of pods (pieces)	Number of seeds per pod (per/plant)
V1	103.0	4.40	7.07	778,7	19.685,1
V2	105.1	4.47	4.17	1.201,2	33.182,3
Average	104.1	4.44	5.62	989,9	26.433,7
LSD (%5)	4.132	ns	1.629	539.31	1267.615

V1: AGROMAR-CLAVIER CL

V2: DEKALB-DK EXSTORM

ns: not significant

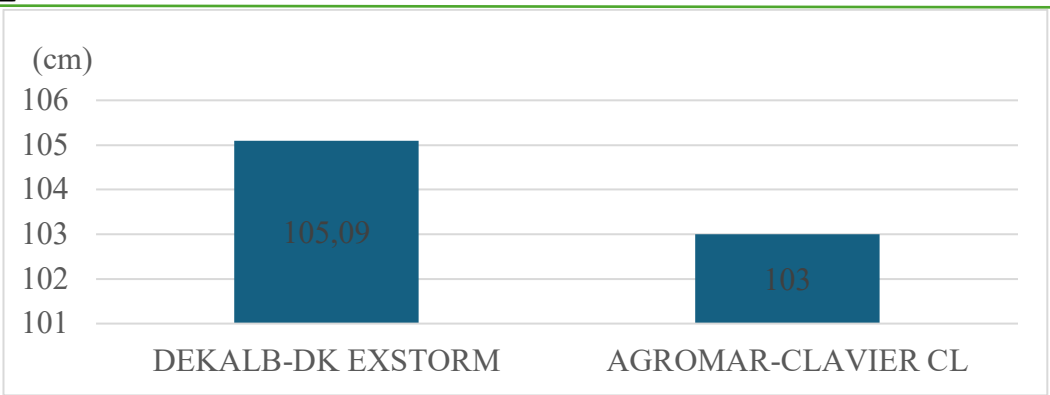


Figure 1. Plant Heights of Two Different Rapeseed (*Brassica napus* L.) Varieties (cm)

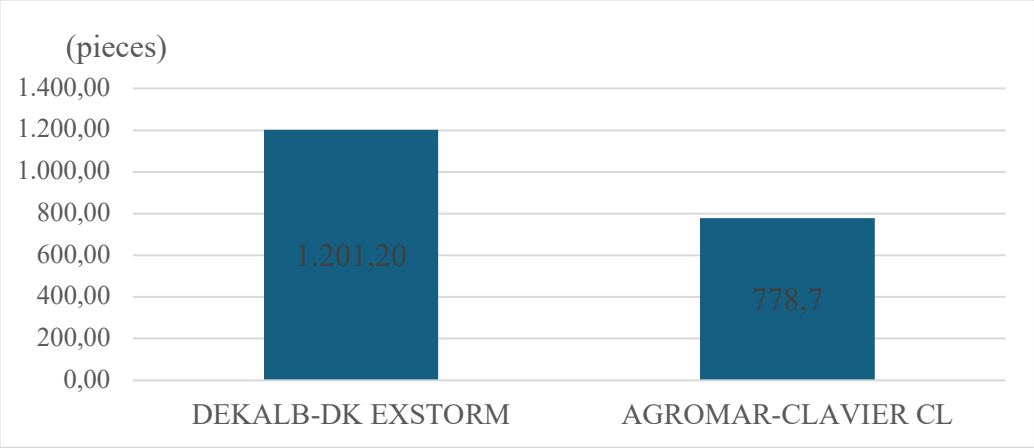


Figure 2. Number of pods in two different rapeseed (*Brassica napus* L.) varieties (pieces)

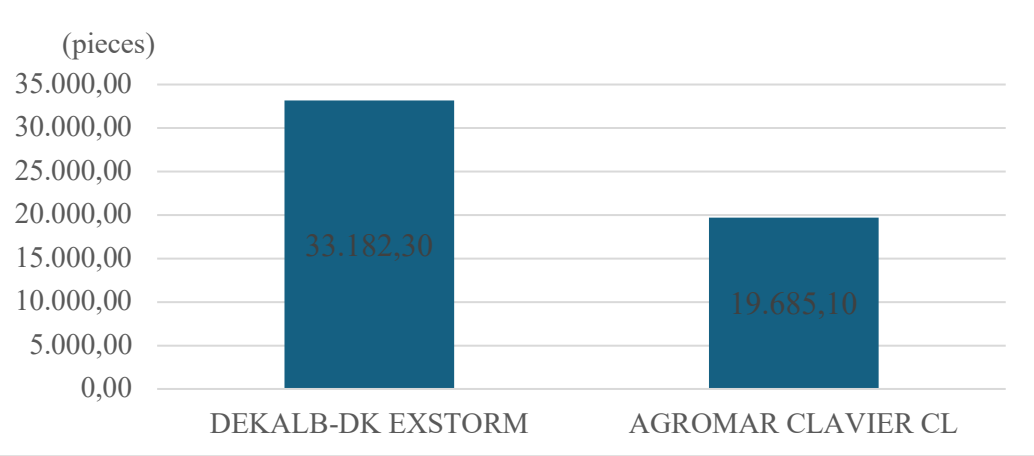


Figure 3. Number of Seeds in Two Different Rapeseed (*Brassica napus* L.) Pods (pieces)

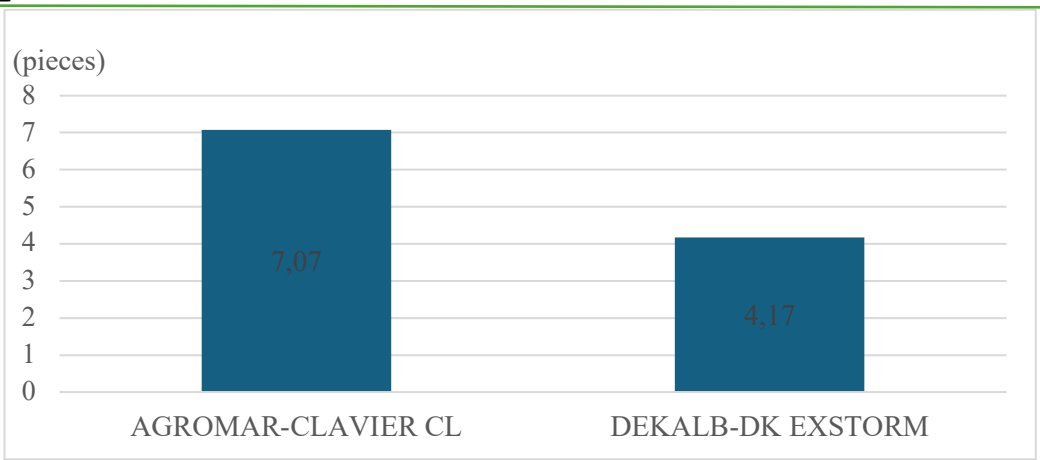


Figure 4. Number of Side Branches in Two Different Rapeseed (Brassica napus L.) Plants (pieces)

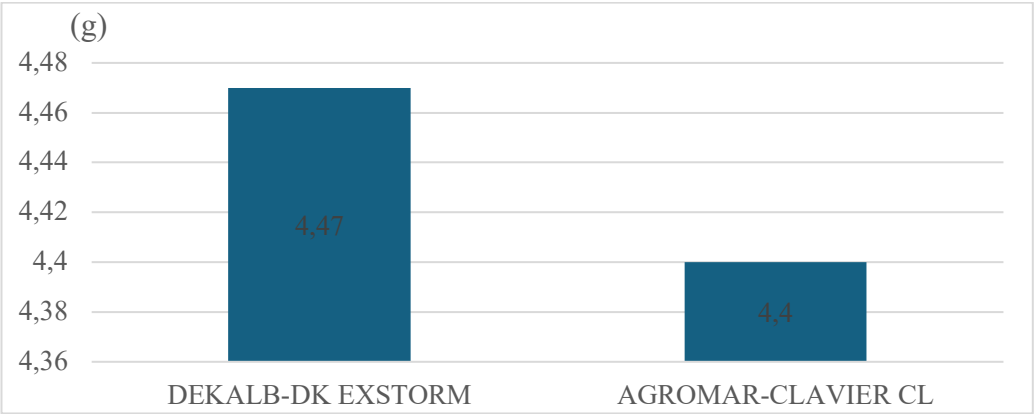


Figure 5. Two Different Rapeseed (*Brassica napus* L.) Thousand Seed Weight (g)

This study was conducted in Yeniköy village, Babaeski district, Kırklareli province, and compared two different varieties of rapeseed (Brassica napus L.)—Agromar-Clavier CL and Dekalb-DK Exstorm—in terms of yield and yield components. According to the results of the study, statistically significant differences were determined between the varieties, particularly in terms of plant height, number of side branches, number of pods, and number of seeds per pod. The data obtained revealed noteworthy results when regional environmental conditions were taken into account.

Yeniköy village is located in the northwest of the Thrace Region and has a microclimate suitable for classic rapeseed cultivation in terms of average annual temperature and precipitation data. When examining the climate data for the 2022–2023 season in the region, it is observed that temperature and precipitation values above the long-term average were recorded, especially during the spring and summer months. This situation affected both the vegetative and generative development of the plants, particularly impacting yield components such as the number of pods and seeds.

Plant height is an important morphological characteristic that indicates the extent to which a plant benefits from environmental conditions (light, temperature, water, nutrients). In our study, the Dekalb-DK Exstorm variety had a taller plant height of 105.09 cm, and this difference was found to be statistically significant. Similarly, Vanlı et al. (2017) stated in their study that plant height is positively related to capsule number and seed yield. Furthermore, Canbaz and Arıoğlu (2009) stated that plant height showed a positive correlation with yield and that, especially under suitable ecological conditions, taller plants produced more side branches and capsules.

Furthermore, Rameeh (2014), in his rapeseed study conducted in Iran, reported that plant height is directly related to yield components and that taller plants have the potential to bear more capsules. At the Yeniköy location, vegetative growth was supported by suitable temperature increases and adequate moisture, which may have enhanced the height advantage of Dekalb-DK Exstorm.

The number of carob pods and the number of seeds per pod are direct factors affecting total seed yield. In the Dekalb-DK Exstorm variety, an average of 1,201.2 pods and 33,182.3 total seeds per pod were obtained, which are significantly higher results than those obtained in the Agromar-Clavier CL variety for these parameters. These findings have also been reported similarly in rapeseed genotype comparisons conducted by Aytar et al. (2020). Their study emphasized that parameters such as pod number and seed number are key factors determining yield. Additionally, Tunçtürk and Çiftçi (2007) reported that the number of capsules (pods) and the number of seeds per capsule are among the main components that directly affect yield in different rapeseed varieties. Similarly, Shirani Rad et al. (2011) also noted that the number of capsules and seeds is decisive, especially in varieties with high yield potential.

In terms of lateral branch count, the Agromar-Clavier CL variety (7.07 branches) was found to be significantly higher than Dekalb-DK Exstorm (4.17 branches). However, this superiority did not have the same positive effect on yield components. This is because an increase in lateral branch count does not always directly result in an increase in pod and seed count. In a study conducted by Ünveren and Karakuş (2013), it was reported that an excessive number of side branches in rapeseed plants could negatively affect the distribution of energy and resources, and that this situation could limit grain yield, especially in low-yield environments. Similarly, Tayo and Morgan (1975) reported that main stem yield components are more productive than side branches and that an increase in the number of side branches does not always contribute to yield. Furthermore, Van et al. (2007) found that excessive branching can reduce pod yield in some cases.

No significant difference was found between the two varieties in terms of thousand-seed weight (TSW). This finding is consistent with some studies in the literature. For example, Türkyılmaz and Yavuz (2015) stated that thousand-seed weight showed less genetic variability between varieties and that differences in seed yield were often due to factors such as seed size and seed number. Rameeh (2011) stated in his study conducted in Iran that although BDA is a factor affecting yield, it did not show high variation between varieties and that seed yield was explained more by components such as capsule number and seed number. Furthermore, Malhi et al. (2007) reported that BDA is less affected by environmental factors and generally remains constant.

The above data show that the Dekalb-DK Exstorm variety is better adapted to the conditions in Yeniköy village and exhibits superior performance in terms of yield components. In particular, increases in capsule and seed numbers have contributed to this variety's total seed yield. However, since these results are based on a single year and location, it is recommended that trials be conducted in different years and under different environmental conditions before generalizing.

CONCLUSIONS AND RECOMMENDATIONS

In this study conducted in Yeniköy village, Babaeski district, Kırklareli province, although the Dekalb-DK EXSTORM variety evaluated was inferior to the Agromar-CLAVIER CL variety in terms of the number of side branches, it showed higher values in components directly related to yield, such as plant height, thousand-seed weight, pod number, and number of seeds per pod. These findings reveal that the Dekalb-DK EXSTORM variety has a higher yield potential under regional conditions.

In this regard, it is recommended that agricultural producers in the region plant the Dekalb-DK EXSTORM variety under the ecological conditions of Kırklareli/Babaeski-Yeniköy. Considering its superiority in terms of yield and yield components, it is believed that this variety can contribute to regional agriculture. Future studies, supported by trials in different environmental conditions and on a larger scale, will further strengthen this recommendation.

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KARBON YUTAK ALANLARI OLARAK ÇAYIR MERALAR

Seyithan SEYDOŞOĞLU (ORCID: 0000-0002-3711-3733)

Siirt üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü, Siirt, Türkiye

E-mail: seyithanseydosoglu@siirt.edu.tr

Nizamettin TURAN (ORCID: 0000-0002-4026-6781)

Siirt Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü, Siirt, Türkiye

E-mail: nturan49@siirt.edu.tr

ÖZET

Çayır ve mera ekosistemleri, atmosferdeki karbondioksitin tutulması, toprakta uzun süreli depolanması ve küresel karbon döngüsünün düzenlenmesinde önemli işlevler üstlenen doğal karbon yutak alanlarıdır. Bu ekosistemlerde bulunan bitki örtüsü, fotosentez süreci aracılığıyla atmosferden karbon alarak biyokütlede depolamaktadır. Özellikle kök gelişimi yoluyla bu karbonun önemli bir kısmı toprak altı karbon havuzlarına aktarılmaktadır. Çok yıllık, derin köklü ve tür çeşitliliği yüksek bitki toplulukları, toprak organik karbonunun birikimini destekleyerek çayır ve meraların karbon tutma kapasitesini artırmaktadır. Sürdürülebilir otlatma sistemlerinin uygulanması, mera ıslahı ve ekolojik restorasyon çalışmaları ise bitki örtüsünün yeniden güçlenmesini sağlayarak hem toprak sağlığını iyileştirmekte hem de karbon depolama kapasitesini artırmaktadır. Bu uygulamalar, biyolojik çeşitliliğin korunmasına, su tutma kapasitesinin artmasına ve ekosistem dayanıklılığının güçlenmesine katkı sunarken, iklim değişikliğiyle mücadelede doğa temelli çözümler arasında öne çıkmaktadır. Ayrıca çayır ve meralar, hayvansal üretimin sürdürülebilirliği ve kırsal ekonominin devamlılığı açısından da stratejik öneme sahiptir. Sonuç olarak, doğru planlanmış ve bilimsel temellere dayalı yönetim yaklaşımlarıyla desteklenen çayır ve mera ekosistemleri hem ekolojik hem de ekonomik işlevleriyle karbon döngüsünün dengelenmesinde ve iklim değişikliğinin olumsuz etkilerinin azaltılmasında kilit rol oynayan doğal ekosistemler olarak değerlendirilmektedir.

Anahtar kelimeler: Karbon yutak alanı, çayır, mera, ekosistem hizmetleri, iklim değişikliği

GRASSLANDS AND RANGELANDS AS CARBON SINK AREAS

ABSTRACT

Grassland and rangeland ecosystems are natural carbon sink areas that play a crucial role in the sequestration of atmospheric carbon dioxide, its long-term storage in soils, and the regulation of the global carbon cycle. Vegetation in these ecosystems captures carbon from the atmosphere through the process of photosynthesis and stores it in biomass; a significant portion of this carbon is transferred to belowground carbon pools, particularly through root development. Plant communities characterized by perennial species, deep root systems, and high species diversity promote the accumulation of soil organic carbon, thereby enhancing the carbon sequestration capacity of grasslands and rangelands. The implementation of sustainable grazing systems, rangeland improvement, and ecological restoration practices strengthens vegetation cover, improves soil health, and increases carbon storage capacity. These practices contribute to the conservation of biodiversity, enhancement of soil water-holding capacity, and increased ecosystem resilience, while also standing out as nature-based solutions in the fight against climate change. In addition, grasslands and rangelands are of strategic importance for the sustainability of livestock production and the continuity of rural economies. In conclusion, grassland and rangeland ecosystems supported by well-planned, scientifically based management approaches are key natural systems that play a vital role in balancing the carbon cycle and mitigating the adverse impacts of climate change through their ecological and economic functions.

Keywords: Carbon sink, grassland, rangeland, ecosystem services, climate change

1. Giriş

İklim değişikliği, atmosferdeki sera gazı birikiminin artması sonucu ortaya çıkan ve küresel ölçekte sıcaklık, yağış rejimleri ve ekosistemler üzerinde önemli etkiler oluşturan bir süreçtir (Malhi ve ark., 2020). Bu sürecin temelinde karbon döngüsündeki dengenin bozulması yer almaktadır. Karbon döngüsü; karbonun atmosfer, biyosfer, hidrosfer ve litosfer arasında sürekli olarak dolaşımını ifade eder (Friedlingstein, 2015). Fotosentez, solunum, ayrışma ve yanma gibi doğal süreçler karbonun bu döngü içindeki hareketini belirler (Rao, 2017). Sanayi devriminden itibaren fosil yakıt kullanımı, arazi kullanım değişiklikleri ve ormansızlaşma gibi insan faaliyetleri, atmosfere salınan karbondioksit (CO_2) miktarını önemli ölçüde artırmıştır (Le Quere ve ark., 2019). Bu durum, karbon döngüsünün doğal denge mekanizmalarını zorlayarak atmosferde karbon birikimine ve buna bağlı olarak küresel ısınmaya yol açmaktadır (Mehmood ve ark., 2020). Bu noktada karbon yutak alanları, iklim değişikliğinin etkilerini azaltmada kritik bir rol üstlenmektedir. Karbon yutakları; atmosferden aldıkları karbonu bitki biyokütlesinde ve özellikle toprakta depolayabilen ekosistemlerdir (Ussiri ve Lal, 2017). Ormanlar ve çayır ve mera ekosistemleri de geniş kök sistemleri ve yüksek toprak organik madde içerikleri sayesinde önemli karbon yutak alanları arasında yer almaktadır (Conant ve ark., 2017). Bu alanların korunması ve sürdürülebilir yönetimi, karbon döngüsünün dengelenmesine katkı sağlayarak iklim değişikliğiyle mücadelede etkili bir araç sunmaktadır (Ussiri ve Lal, 2017). Çayır ve meralar, geniş yüzey alanları ve kök sistemleri sayesinde karbonun toprakta depolanmasına katkıda bulunmakta, aynı zamanda biyolojik çeşitliliğin korunması ve sürdürülebilir hayvancılık faaliyetleri için temel kaynak oluşturmaktadır. Bu alanların karbon yutak kapasitesinin anlaşılması hem ekolojik dengeyi korumak hem de iklim değişikliğiyle mücadelede etkili politikalar geliştirmek açısından büyük önem taşımaktadır (Conant ve ark., 2017). Dolayısıyla, çayır ve mera ekosistemlerinin karbon yutak alanı olarak değerlendirilmesi, yalnızca çevresel sürdürülebilirlik açısından değil, aynı zamanda sosyo-ekonomik boyutlarıyla da ele alınması gereken bir konudur (Chang ve ark., 2021). Bu derleme çalışması, çayır mera ekosistemlerinin karbon depolama potansiyelini inceleyerek iklim değişikliğiyle mücadeledeki rollerini ortaya koymayı amaçlamaktadır.

2) Karbon yutak alanları

Karbon yutak alanları, atmosferde bulunan karbondioksit (CO_2) ve diğer karbon bileşiklerini doğal süreçler aracılığıyla bünyesine alarak uzun süreli depolama kapasitesine sahip ekosistemlerdir (Pan ve ark., 2018). Bu ekosistemler, fotosentez ve biyokimyasal döngüler sayesinde karbonu bitki örtüsünde, canlı organizmalarda ve özellikle toprakta tutarak atmosferdeki sera gazı birikiminin artışını sınırlar (Smith ve ak., 2019). Başlıca karbon yutak alanları arasında ormanlar, çayır ve meralar, sulak alanlar ve okyanuslar yer almakta olup, her biri farklı mekanizmalarla karbon depolama işlevi görmektedir. Karbon yutak alanlarının önemi, iklim değişikliğinin etkilerini azaltma (mitigasyon) potansiyellerinden kaynaklanmaktadır (Griscom ve ark., 2017). Atmosferden karbonun uzaklaştırılması, sera etkisinin zayıflatılmasına ve küresel sıcaklık artışının yavaşlatılmasına doğrudan katkı sağlar (Smith ve ark., 2016). Özellikle toprakta depolanan karbon, uzun vadeli ve nispeten stabil bir karbon havuzu oluşturarak iklim sistemi açısından kritik bir rol üstlenir (Minasny ve ark., 2017). Bu nedenle toprak karbonu, ekosistemlerin iklim düzenleyici işlevlerinin en güvenilir göstergelerinden biri olarak kabul edilmektedir (Lal, 2016). Bununla birlikte karbon yutak alanlarının işlevi yalnızca karbon depolama ile sınırlı değildir (Anderson ve ark., 2019). Bu ekosistemler; biyolojik çeşitliliğin korunması, habitat sürekliliğinin sağlanması, toprak verimliliğinin artırılması, su döngüsünün düzenlenmesi ve erozyonun azaltılması gibi çok yönlü ekosistem hizmetleri sunar (Díaz ve ark., 2018; Costanza ve ark., 2017). Dolayısıyla karbon yutak alanlarının korunması ve sürdürülebilir şekilde yönetilmesi hem iklim değişikliğiyle mücadelede hem de doğal kaynakların devamlılığında stratejik bir gereklilik olarak öne

çıkmaktadır (Watson ve ark., 2018). Sonuç olarak, karbon yutak alanlarının ekolojik, ekonomik ve sosyal boyutlarıyla ele alınması; iklim politikalarının etkinliğini artırmak ve sürdürülebilir kalkınma hedeflerine ulaşmak açısından vazgeçilmezdir (Chausson ve ark., 2020).

3) Karbon tutma mekanizmaları

Karbon tutma mekanizmaları, atmosferdeki karbondioksitin (CO_2) doğal süreçler aracılığıyla ekosistemler tarafından alınarak farklı karbon havuzlarında depolanmasını ifade eder (Minx ve ark., 2018). Başlıca karbon tutma mekanizmaları şunlardır:

3.1) Fotosentez yoluyla karbon alımı

Bitkiler fotosentez sırasında atmosferdeki CO_2'yi alarak organik karbon bileşiklerine dönüştürür. Bu karbon, bitkinin gövde, yaprak ve özellikle kök dokularında depolanır. Çayır ve mera ekosistemlerinde bitkilerin geniş ve derin kök sistemleri, karbonun toprak altına taşınmasını sağlayarak uzun süreli depolamaya katkıda bulunur (Chang ve ark., 2016). Bu özellik, çayır ve meraları ormanlarla birlikte en önemli karasal karbon yutaklarından biri haline getirir.

3.2) Toprak organik karbonunun oluşumu

Bitki artıklarının (yaprak, kök, sap) toprakta ayrışması sonucu organik madde oluşur. Bu organik madde, toprak agregatları içinde korunarak uzun yıllar boyunca karbonun toprakta tutulmasını sağlar (Lehmann ve Kleber, 2015). Toprak mikroorganizmaları bu süreçte önemli bir rol oynar; ayrışma sırasında karbonun daha stabil formlara dönüşmesine ve mineral yüzeylere bağlanmasına katkı sağlar. Böylece toprak, uzun vadeli bir karbon rezervuarı işlevi görür (Cotrufo ve ark., 2019).

3.3) Kök döngüsü ve rizosfer süreçleri

Bitkilerin köklerinin sürekli büyümesi, ölmesi ve yenilenmesi, toprağa düzenli karbon girişi sağlar (Pausch ve Kuzyakov, 2018). Rizosferde gerçekleşen mikrobiyal faaliyetler, karbonun toprak mineral yüzeylerine bağlanmasını ve daha kalıcı hale gelmesini destekler (Liang ve ark., 2017). Bu süreç, özellikle çayır ve meralarda yoğun kök sistemleri sayesinde daha etkin bir şekilde işler (Chang ve ark., 2016).

3.4) Toprak yapısının korunması

Sağlıklı ve bozulmamış toprak yapısı, karbonun oksijenle temasını azaltarak ayrışma hızını düşürür (Cotrufo ve ark., 2019). Özellikle iyi yönetilen çayır ve meralarda toprak sıkışmasının ve erozyonun azalması, karbon kaybını sınırlar (Conant ve ark., 2017). Bu durum hem karbon depolama kapasitesini artırır hem de ekosistem hizmetlerinin sürekliliğini sağlar (Griscom ve ark., 2017).

Bu mekanizmaların etkinliği; arazi kullanımı, bitki türleri, iklim koşulları ve yönetim uygulamalarına bağlı olarak değişmektedir (Smith ve ark., 2019). Dolayısıyla karbon tutma kapasitesinin artırılması için çayır ve mera ekosistemlerinin sürdürülebilir şekilde yönetilmesi büyük önem taşımaktadır (Chang ve ark., 2016).

4) Ormanlar, sulak alanlar, çayır ve meraların karşılaştırılması

Ormanlar, sulak alanlar, çayır ve meralar, karbon yutak alanları arasında yer almakla birlikte, karbon tutma biçimleri, depolama süreleri ve ekosistem işlevleri açısından birbirlerinden farklılık göstermektedir (Mitsch ve Gosselink, 2015). Ormanlarda depolanan karbonun önemli bir kısmı yer üstü biyokütlesinde bulunur. Orman ekosistemleri, karbonu büyük ölçüde ağaçların gövde, dal ve yapraklarında depolar (Erb ve ark., 2017). Yüksek biyokütleleri sayesinde kısa ve orta vadede önemli miktarda karbon tutabilirler (Bai ve Cotrufo, 2022). Ancak

orman yangınları, hastalıklar ve arazi kullanım değişiklikleri gibi faktörler, depolanan karbonun hızla atmosfere geri salınmasına neden olabilmektedir (Harris ve ark., 2021).

Sulak alanlar, özellikle bataklıklar ve turbalıklar, karbonu büyük ölçüde toprakta ve organik tortularda depolayan ekosistemlerdir (Mitsch ve ark., 2015). Oksijensiz (anaerobik) koşullar, organik maddenin ayrışmasını yavaşlatarak karbonun binlerce yıl boyunca tutulmasını sağlar (Leifeld ve ark., 2019). Bu yönüyle sulak alanlar, uzun vadeli ve oldukça güçlü karbon yutaklarıdır (Mitsch ve ark., 2015). Ancak kurutulmaları veya bozulmaları durumunda büyük miktarda sera gazı salımı gerçekleşebilir (Xu ve ark., 2018).

Çayır ve mera ekosistemleri ise karbonu ağırlıklı olarak toprak altı biyokütlesinde ve toprak organik maddesinde depolar. Toprak üstü biyokütleleri ormanlara kıyasla daha düşük olsa da derin ve yoğun kök sistemleri sayesinde karbonun daha stabil ve uzun süreli olarak toprakta tutulmasını sağlarlar (Bai ve Cotrufo, 2022). Ayrıca yangın ve biçim gibi ani karbon kaybına yol açan riskler çayır ve meralarda nispeten daha düşüktür (Conant ve ark., 2017). Karşılaştırıldığında; ormanlar hızlı karbon birikimi, sulak alanlar uzun vadeli ve yüksek stabilite, çayır ve meralar ise dayanıklı ve sürdürülebilir toprak karbonu açısından öne çıkmaktadır. Bu nedenle iklim değişikliğiyle mücadelede tek bir ekosisteme odaklanmak yerine, farklı karbon yutak alanlarının birlikte korunması ve yönetilmesi bütüncül bir yaklaşım açısından büyük önem taşımaktadır (Erb ve ark., 2017).

5) Çayır ve mera ekosistemlerinin küresel ve bölgesel önemi

Çayır ve mera ekosistemleri, dünya kara yüzeyinin önemli bir bölümünü kaplayan ve hem doğal denge hem de insan yaşamı açısından kritik işlevlere sahip ekosistemlerdir (Conant ve ark., 2017). Küresel ölçekte bu alanlar, geniş yayılışları ve güçlü kök sistemlerine sahip bitki örtüleri sayesinde büyük miktarda karbonu özellikle toprakta depolayarak önemli karbon yutak alanları olarak işlev görür (Chang ve ark., 2016). Orman ekosistemlerine kıyasla toprak altı biyokütlesinin yüksek olması, çayır ve meraların uzun vadeli karbon depolama potansiyelini artırmaktadır (Dong ve ark., 2025). Ayrıca bu ekosistemler, çok sayıda bitki ve hayvan türüne habitat sağlayarak küresel biyolojik çeşitliliğin korunmasına katkıda bulunur (Sala ve ark., 2017).

Bölgesel ölçekte ise çayır ve mera ekosistemleri, özellikle yarı kurak ve kurak bölgelerde ekolojik ve sosyo-ekonomik açıdan hayati öneme sahiptir (Eldridge ve ark., 2017). Bu alanlar, hayvancılığın temel besin kaynağını oluşturarak kırsal geçim sistemlerini destekler ve gıda güvenliğine katkı sağlar. Aynı zamanda toprak yapısını koruyarak erozyonu önler, suyun toprakta tutulmasını artırır ve bölgesel iklim koşullarının dengelenmesine yardımcı olur (Herrero ve ark., 2016). Bu nedenle, çayır ve mera ekosistemlerinin korunması ve bilinçli yönetimi, küresel ve bölgesel çevre politikalarının temel unsurlarından biri olmalıdır.

6) Çayır ve meraların karbon yutak olarak rolü (toprakta karbon depolama kapasitesi)

Çayır ve meralar, toprakta karbon depolama kapasitesi açısından en etkili karasal ekosistemlerden biri olarak kabul edilmektedir (Sharma ve ark., 2023). Bu ekosistemlerde karbonun büyük bölümü, yer üstü biyokütlesinden ziyade toprak organik karbonu şeklinde depolanır. Özellikle çok yıllık otsu bitkilerin sahip olduğu yoğun ve derin kök sistemleri, karbonun sürekli olarak toprağa taşınmasını sağlayarak uzun vadeli bir karbon havuzu oluşturur (Paustian ve ark., 2016). Çayır ve mera bitkilerinin kökleri düzenli olarak yenilenir; ölen kök dokuları ve bitki artıkları toprakta ayrışarak organik maddeye dönüşür (Leifeld ve ark., 2015). Bu süreç, toprak mikroorganizmalarının faaliyetleriyle desteklenir ve karbonun daha stabil formlara bağlanmasını sağlar (Cotrufo ve ark., 2015). Ayrıca çayır ve meralarda toprak genellikle sürülmediği için, toprak yapısı korunur ve karbonun oksijenle temas ederek hızla

parçalanması sınırlandırılır (Rumpel ve Chabbi, 2019). Toprak agregatlarının güçlü olması, organik karbonun fiziksel olarak korunmasına katkıda bulunur (Dignac ve ark., 2017). Bu durum, çayır ve meralarda depolanan karbonun uzun yıllar hatta on yıllar boyunca toprakta kalabilmesini mümkün kılar. Araştırmalar, iyi yönetilen çayır ve meraların, bozulmuş veya tarım alanına dönüştürülmüş arazilere kıyasla daha yüksek toprak organik karbon içeriğine sahip olduğunu göstermektedir (Poeplau ve Don, 2015). Sonuç olarak, çayır ve meraların toprakta karbon depolama kapasitesi; bitki tür çeşitliliği, kök yapısı, iklim koşulları ve yönetim uygulamalarıyla yakından ilişkilidir (Conant ve ark., 2017). Bu alanların korunması ve sürdürülebilir otlatma sistemleriyle yönetilmesi hem toprak verimliliğinin artırılması hem de iklim değişikliğiyle mücadelede önemli bir katkı sağlamaktadır.

7) Çayır ve meraların kök sistemlerinin karbon tutmadaki önemi

Toprak, atmosferden daha fazla karbon depolayabilir ve iklim değişikliğini azaltmada önemli bir araçtır. Çayır ve meraların kök sistemleri, bu ekosistemlerin karbon tutma kapasitesinin temel belirleyicilerinden biridir. Tarımsal uygulamalar (örneğin azaltılmış toprak işleme, organik gübre kullanımı, örtü bitkileri) karbon tutulumunu artırabilir. Toprak karbonu yönetimi hem gıda güvenliği hem de iklim politikaları açısından stratejik öneme sahiptir (Lal ve ark., 2015). Çayır ve mera bitkileri genellikle çok yıllık ve otsu türlerden oluşur ve bu bitkiler, toprak altında geniş, yoğun ve derin kök ağları geliştirir. Atmosferden fotosentez yoluyla alınan karbonun önemli bir kısmı, bu kök sistemleri aracılığıyla doğrudan toprağa aktarılır. Otlatma yoğunluğu, gübreleme ve biçme gibi uygulamalar toprak karbon stoklarını artırabilir veya azaltabilir. Azot ve fosfor gibi besin elementlerinin mevcudiyeti, karbon döngüsünü doğrudan etkiler. Çayır yönetimi, karbon girişleri (litter, kök salgıları) ve çıkışları (respirasyon, ayrışma) arasındaki dengeyi belirler. İklim değişikliği, aşırı otlatma veya yanlış yönetim, karbon stoklarını hızla azaltabilir. Bozulmuş çayırların yeniden yönetilmesi, karbon depolama kapasitesini geri kazandırabilir (Rumpel ve Chabbi, 2019). Bitkiler tarafından tutulan karbon, yalnızca köklerde depolanma yoluyla değil, aynı zamanda mikrobiyal süreçleri uyararak toprak organik maddesinin oluşumuna katkıda bulunan kök salgıları aracılığıyla da toprağa girer. Çözünür ve kolay ayrışan bileşikler mikrobiyal ürünlere dönüşürken, daha dirençli yapısal bileşikler fiziksel yollarla toprağa karışır. Organik maddelerin mineral yüzeylere bağlanması, karbonun uzun süreli depolanmasını sağlar. Solucanlar ve diğer toprak faunası, ölü döküntü bitkisel aksamların parçalanmasını hızlandırarak fiziksel yollarla organik madde oluşumunu destekler (Cotrufo ve ark., 2015).

Toprakların sera gazı emisyonlarını azaltma kapasitesi uzun süre göz ardı edilmiştir. Emisyonların ve azaltımların doğru şekilde ölçülmesi hâlâ büyük bir zorluktur. Bilgi teknolojilerindeki gelişmeler, toprakların sera gazı politikalarına daha geniş ölçekte dahil edilmesini mümkün kılabilir. Kökler yalnızca karbonu depolamakla kalmaz, aynı zamanda karbonun toprak organik maddesine dönüşmesini sağlayan süreçleri de tetikler (Paustian ve ark., 2016). Köklerin büyümesi, ölmesi ve yeniden oluşması (kök döngüsü), toprağa sürekli karbon girdisi sağlar. Ölen kök dokuları ayrışarak toprakta daha stabil ve uzun ömürlü karbon bileşiklerine dönüşür. Solucanlar, bitkilerden kopan parçalardan kaynaklı karbonun toprak profiline taşınmasında kritik rol oynar. (Novara ve ark., 2015). Bu durum, çayır ve meralarda karbonun kısa süreli değil, uzun vadeli olarak depolanmasına olanak tanır. Ayrıca köklerin çevresindeki rizosfer bölgesinde yoğun mikrobiyal faaliyetler gerçekleşir. Bu mikroorganizmalar, kök salgıları sayesinde karbonu mineral yüzeylere bağlayarak daha kalıcı hale getirir. Uzun süredir humik maddeler, toprak organik maddesinin temel ve kalıcı bileşenleri olarak görülüyordu. Alkali ekstraksiyonla elde edilen humik maddelerin doğal toprak yapısında bağımsız ve kalıcı bir bileşik grubu olarak bulunmadığını göstermektedir. Organik madde, farklı aşamalarda bozunan ve dönüşen bileşiklerin sürekliliği olarak görülmeli. Ayrıca Laboratuvar ekstraksiyonları, doğal toprak ortamındaki süreçleri tam olarak yansıtmaz. Bu yeni

bakış açısı, toprak karbonunun iklimle etkileşimini ve tarımsal yönetim stratejilerini yeniden düşünmeyi gerektiriyor (Kleber ve Lehmann, 2019).

Toprak atmosferden iki kat fazla karbon depolar. Fakat çoğu doğal ve tarımsal bitkinin kökleri yalnızca 1 metreye kadar uzanır, bu da karbon depolama kapasitesini sınırlar. Derin kök sistemleri, karbonun toprak alt katmanlarına taşınmasını sağladığından, yüzeydeki bozulmalardan ve hızlı ayrışma süreçlerinden daha az etkilenir. Modern tarımda kullanılan türler ve yöntemler kök derinliğini sınırlayarak karbon depolama kapasitesini azaltır. Daha derin köklü türlerin seçilmesi, karbonun daha uzun süreli ve güvenli şekilde depolanmasına katkı sağlar. Hem doğal hem de tarımsal ekosistemlerde köklerin rolü birlikte değerlendirilmelidir (Kell, 2015). Sonuç olarak, çayır ve meraların kök sistemleri; karbonun toprağa girişi, stabilizasyonu ve uzun süreli depolanması açısından kilit bir rol oynar. Bu nedenle kök gelişimini destekleyen sürdürülebilir otlatma ve mera yönetimi uygulamaları, çayır ve meraların karbon yutak alanı olarak işlevini güçlendirmede büyük önem taşımaktadır.

8) Ormanlara kıyasla çayır/meraların karbon yutak olarak rolü olarak avantajları

Çayır ve meralar, karbon yutak alanı olarak genellikle ormanların gölgesinde kalsa da bazı temel özellikleri sayesinde ormanlara kıyasla önemli ve özgün avantajlara sahiptir (Assan ve ark., 2025). Bu avantajlar özellikle karbonun depolanma biçimi, sürekliliği ve ekosistemin dayanıklılığı ile ilişkilidir. Öncelikle çayır ve meralarda karbonun büyük bölümü toprak altında depolanır. Ormanlarda karbonun önemli bir kısmı ağaçların gövde, dal ve yaprak gibi yer üstü biyokütlesinde bulunurken, çayır ve meralarda yoğun kök sistemleri sayesinde karbon daha stabil olan toprak organik karbonu şeklinde tutulur. Bu durum, depolanan karbonun uzun vadede atmosfere geri salınma riskini azaltır. İkinci olarak çayır ve meralar, yangın, böcek salgınları ve biçim gibi ani karbon kaybına yol açabilecek risklere karşı daha dayanıklıdır. Tarıma dönüştürme veya aşırı otlatma, karbon stoklarını azaltır. Çayırlar, kuraklık ve iklim değişikliğine karşı belirli bir direnç gösterir, ancak bu direnç yanlış yönetimle zayıflar. Tür çeşitliliği hem karbon depolama kapasitesini hem de ekosistem dayanıklılığını güçlendirir (White ve ark., 2015). Orman yangınları büyük miktarda karbonun kısa sürede atmosfere salınmasına neden olabilirken, çayır ve meralarda karbonun büyük kısmı toprak altında bulunduğu için bu tür olaylardan daha az etkilenir. Ayrıca çayır ve meralar, arazi kullanımına bağlı bozulmalara karşı daha hızlı toparlanma kapasitesine sahiptir. Otlatma yoğunluğu ve biçimi, bitki örtüsünün yapısını ve toprak karbonunu doğrudan etkiler (Sala ve ark., 2017). Toprak üstü biyokütle kaybı yaşansa bile kök sistemleri genellikle canlılığını korur ve karbon tutma işlevi kısa sürede yeniden başlar. Bu özellik, çayır ve meraları uzun vadede daha sürdürülebilir karbon yutakları haline getirir. Son olarak, çayır ve meraların yönetimi genellikle daha düşük maliyetlidir ve sürdürülebilir otlatma uygulamalarıyla karbon tutma kapasitesi artırılabilir. Otlatma, bazı durumlarda karbon kaybına yol açarken, uygun yoğunlukta yapıldığında karbon depolamayı destekleyebilir. Gübreleme, biçme ve otlatma düzenlemeleri karbon döngüsünü farklı şekillerde etkiler. Artan sıcaklıklar ve kuraklık, çayırların karbon depolama kapasitesini azaltabilir (Jordon ve ark., 2024). Bu yönleriyle çayır ve meralar, orman ekosistemlerini tamamlayan, dayanıklı ve uzun vadeli karbon yutak alanları olarak iklim değişikliğiyle mücadelede önemli bir role sahiptir.

9) Aşırı otlatma, sürdürülebilir otlatma sistemleri, mera ıslahı ve restorasyonu ve tarım alanına dönüştürmenin etkisi

Aşırı otlatma, çayır ve mera ekosistemlerinde karbon döngüsü üzerinde doğrudan ve olumsuz etkiler üreten bir faktördür. Bitki örtüsünün sürekli ve yoğun şekilde tüketilmesi, ekosistemdeki karbon tutma kapasitesini azaltır ve toprak altı karbon havuzlarının bozulmasına yol açar (Wang ve ark., 2015). Öncelikle aşırı otlatma, bitki biyokütlesinin azalmasına neden olur. Fotosentez yoluyla atmosferden alınan karbon miktarı düşer ve kök sistemleri zayıflar. Zayıf kökler, toprak

organik karbonunun düzenli olarak yenilenmesini sağlayamaz, bu da uzun vadede toprak altı karbonunun azalmasına yol açar. İkinci olarak, aşırı otlatma toprak yapısının bozulmasına ve erozyona yol açar. Bitki örtüsü azalınca toprak yüzeyinde çıplak alanlar artar, rüzgâr ve su erozyonu hızlanır ve topraktaki organik madde kaybı artar. Artan bitki örtüsü, yüzey akışını azaltarak erozyonu önemli ölçüde düşürür. Kökler, toprağı mekanik olarak tutarak parçalanmayı ve taşınmayı engeller. Bitki örtüsünün koruyucu etkisi, yağış şiddeti ve arazi eğimine bağlı olarak değişir. Çalılar, otlar ve karışık bitki örtüsü erozyonu farklı düzeylerde azaltır. Toprak dokusu ve organik madde içeriği, bitki örtüsünün erozyonu azaltma kapasitesini etkiler (Zhao ve ark., 2018). Bu durum, topraktaki karbonun atmosferle temas ederek ayrışmasını kolaylaştırır. Aşırı otlatmanın diğer bir etkisi de mikrobiyal aktivitenin değişmesidir. Toprakta organik madde miktarının azalması, mikrobiyal toplulukların dengesini bozabilir ve karbonun stabil formlara dönüşme sürecini yavaşlatır. Otlatmanın etkisi, yağış miktarı, toprak dokusu ve bitki türlerine göre değişir. C3 ve C4 bitkilerinin baskın olduğu ekosistemlerde otlatmanın etkisi farklıdır. İnce dokulu topraklarda otlatma, karbon depolamayı daha fazla destekleyebilir. Kurak bölgelerde otlatma, karbon depolamayı artırabilirken, nemli bölgelerde azaltıcı etki gösterebilir (McSherry ve Ritchie, 2017). Sonuç olarak, aşırı otlatma çayır ve meraların karbon yutak işlevini ciddi şekilde zayıflatır. Sürdürülebilir otlatma yöntemleri, mera istikrarının korunması ve toprağın sağlıklı yapısının desteklenmesi, karbon kaybını önlemenin ve çayır-meraların uzun vadeli karbon depolama kapasitesini korumanın temel yollarıdır.

Sürdürülebilir otlatma sistemleri, çayır ve mera ekosistemlerinde hem bitki örtüsünün sağlığını koruyan hem de karbon yutak kapasitesini artıran yönetim yaklaşımlarıdır (Jordon ve ark., 2024). Bu sistemler, aşırı otlatmanın önlenmesini, bitki çeşitliliğinin korunmasını ve toprak yapısının sürdürülebilirliğini hedefler. Öncelikle sürdürülebilir otlatma, bitki biyokütlesinin dengeli şekilde kullanılması ile karbon döngüsüne olumlu katkı sağlar. Bitkiler yeterince dinlenme fırsatı bulduklarında fotosentez yoluyla daha fazla karbon alır ve kök sistemleri güçlenir (Teague ve ark., 2016). Güçlü kökler, toprağa düzenli karbon girişi sağlar ve toprak altı karbon havuzlarının uzun vadeli depolanmasını destekler. İkinci olarak, sürdürülebilir otlatma toprak yapısının korunmasına yardımcı olur. Bitki örtüsü devamlılığı, erozyon riskini azaltır ve organik madde kaybını sınırlar. Sağlıklı toprak, karbonun stabil şekilde depolanmasını ve mikroorganizmalar aracılığıyla organik karbonun uzun süreli korunmasını sağlar (Lehmann ve Kleber, 2015). Ayrıca bu sistemler, biyoçeşitliliğin ve ekosistem fonksiyonlarının korunmasını sağlar. Farklı bitki türleri, farklı derinliklerde kök sistemleriyle karbonu toprağın çeşitli katmanlarına taşır ve toplam karbon tutma kapasitesini artırır. Sonuç olarak, sürdürülebilir otlatma sistemleri, çayır ve meraların hem kısa hem de uzun vadede karbon yutak işlevini güçlendirir. Bu uygulamalar, iklim değişikliğiyle mücadelede etkili bir strateji olmasının yanı sıra mera ekosistemlerinin ekolojik ve ekonomik sürdürülebilirliğini de destekler (Teague ve ark., 2016).

Mera ıslahı ve restorasyonu, çayır ve mera ekosistemlerinin karbon yutak kapasitesini artırmada kritik öneme sahip uygulamalardır. Bozulmuş veya aşırı otlatılmış meraların yeniden sağlıklı hale getirilmesi hem bitki örtüsünün hem de toprak yapısının iyileştirilmesini sağlar, bu da uzun vadeli karbon depolamasını destekler. Öncelikle mera ıslahı ve restorasyonu, bitki biyokütlesinin ve kök sistemlerinin güçlenmesini sağlar (Briske ve ark., 2015). Yeni veya yerel uyumlu bitki türlerinin ekimi, toprak örtüsünün yoğunlaşmasını ve köklerin derinleşmesini teşvik eder (Havrilla ve ark., 2021). Bu süreç, toprağa sürekli karbon girişi sağlar ve organik madde miktarını artırır. İkinci olarak, restorasyon çalışmaları toprak yapısının iyileştirilmesine ve erozyonun azaltılmasına yardımcı olur (Mekuria ve Aynekulu, 2016). Toprak sağlığı iyileştikçe, karbonun toprakta stabil olarak tutulma süresi uzar ve yüzeyde meydana gelebilecek kayıplar minimize edilir. Ayrıca mera ıslahı, biyoçeşitliliği artırarak ekosistem fonksiyonlarını

güçlendirir (Prangel ve ark., 2023). Farklı bitki türlerinin varlığı, karbonun çeşitli toprak derinliklerine taşınmasını sağlayarak toplam karbon depolama kapasitesini yükseltir (Cong ve ark., 2015). Sonuç olarak, mera ıslahı ve restorasyonu, bozulmuş alanların yeniden karbon yutak alanı haline gelmesini sağlayan sürdürülebilir bir yönetim stratejisidir. Bu uygulamalar, hem iklim değişikliğiyle mücadeleye katkı sağlar hem de hayvancılık ve kırsal ekonomi açısından meraların ekolojik ve ekonomik değerini artırır.

Tarım alanına dönüştürme, doğal çayır ve mera ekosistemlerinin karbon dengesi üzerinde genellikle olumsuz etkilere yol açar (Chang ve ark., 2018). Bu süreç, ekosistemde depolanmış karbonun büyük bir kısmının atmosfere geri salınmasına ve karbon yutak kapasitesinin azalmasına neden olur. Öncelikle doğal çayır ve meraların toprakları, uzun yıllar boyunca organik madde biriktirmiş ve stabil karbon havuzları oluşturmuştur (Lugato ve ark., 2015). Tarıma açma sürecinde toprak işlenir, sürülür veya drenaj yapılır; bu durum, toprak yapısının bozulmasına ve organik maddenin hızla ayrışmasına yol açar (Smith ve ark., 2019). Sonuç olarak toprak altı karbonu atmosfere CO_2 olarak salınır. İkinci olarak, doğal bitki örtüsünün yok edilmesi, fotosentez yoluyla karbon alımını azaltır. Tarla bitkileri genellikle tek yıllık ve yüzeysel kök sistemine sahiptir; bu nedenle kök yoluyla toprak altına karbon aktarımı sınırlıdır (Glover ve ark., 2015). Toprakta depolanan karbon miktarı azalır ve toplam karbon yutak kapasitesi düşer. Ayrıca tarıma dönüştürme, toprak erozyonunu artırabilir. Bitki örtüsü azaldığında rüzgâr ve su erozyonu hızlanır, toprak organik maddesi kaybolur ve karbon kaybı daha da büyür (Li ve ark., 2016). Tarımda kullanılan gübre ve mekanik işlemler, organik karbonun ayrışma hızını artırarak ekosistemin karbon dengesi üzerinde ek baskı oluşturur (Oldfield ve ark., 2019). Sonuç olarak, çayır ve mera alanlarının tarım arazisine dönüştürülmesi hem karbon yutak kapasitesini azaltır hem de atmosfere karbon salınımını artırır. Bu nedenle iklim değişikliğiyle mücadelede, doğal meraların korunması ve sürdürülebilir arazi kullanımının teşvik edilmesi büyük önem taşımaktadır.

10) Uygulama örnekleri ve politika önerileri

Gitau ve ark. (2025), Afrika'nın Laikipia Bölgesi, Kenya'daki yarı-kurak mera ekosistemlerinde kontrollü otlatma ile sürekli otlatma arasındaki farkları karşılaştırmıştır. Topraktaki iki ana karbon fraksiyonu incelenmiştir: 1) toprak minerallerine güçlü bağlanmış organik karbon (Mineral-Associated Organic Carbon, MAOC) ve 2) daha kolay ayrışabilir organik parçacık karbonu (Particulate Organic Carbon, POC). Kontrollü otlatma yapılan alanlarda MAOC ve POC değerleri sürekli otlatmaya göre anlamlı şekilde daha yüksek bulunmuş, özellikle POC (toprakta daha aktif organik karbon fraksiyonu), kontrollü otlatmada belirgin şekilde artmıştır. Bu artış, kontrollü otlatma sayesinde bitki örtüsünün iyileşmesi, toprak bozulmasının azalması ve organik madde girişinin artmasıyla ilişkilendirilmiştir.

Deng ve ark. (2017) tarafından Çin'in Loess Platosu'nda bozulan mera alanlarında yürütülen restorasyon ve yeniden bitkilendirme projeleri, yerel ve çok yıllık bitki türlerinin kullanılmasıyla gerçekleştirilmiştir. Restorasyon sonrası toprak organik karbon içeriğinde anlamlı artışlar sağlanmış, alanlar karbon kaynağı olmaktan çıkıp karbon yutağına dönüşmüştür.

Oduor ve ark. (2018) tarafından yürütülen çalışmada, Kenya'nın yarı-kurak mera alanlarında bozulan toprakların iyileştirilmesi için mera kapatma uygulaması değerlendirilmiştir. Bozulmuş mera alanlarında otlatmanın kontrol altına alınması için çitlerle çevrilmiş mera parçaları oluşturulmuştur. Sürekli otlatmaya açık alanlar referans olarak kullanılmıştır. Toprak analizi 0-40 cm derinlikte yapılmış. Mera kapalı alanlarda toprak organik karbonu (SOC), partikül organik karbon (POC) ve mikrobiyal karbon (MBC) değerleri, sürekli otlatılan açık alanlara göre istatistiksel olarak anlamlı şekilde daha yüksek bulunmuştur. Özellikle POC ve MBC artışları, toprak sağlığının ve mikroorganizma etkinliğinin iyileştiğini göstermiştir. Toprak

sıkışmasının azalması, organik madde birikiminin artması ve mikroorganizmaların aktif karbon dönüşümünü artırması, karbon tutma potansiyelini yükseltmiştir. Bu çalışma, toprak sağlığını iyileştiren mera kapatma yaklaşımlarının, bozulmuş mera topraklarını yeniden yapılandırarak toprak organik karbon stoklarını artırdığını göstermiştir.

Silvopastoral sistemlerin ve kalan orman parçalarının yüksek hayvan yoğunluklu alanlarda karbon depolama kapasitesini nasıl etkilediğini inceleyen Sotomayor-Castellanos ve ark. (2022), Meksika'daki bir merada bu sistemlerin karbon depolama etkisini nicel olarak ortaya koymuşlardır. Çalışmada farklı arazi kullanımı tipleri karşılaştırılmışlardır: sıradan açık mera, ağaçlı mera, entegre ağaç-mera sistemleri, canlı çitler, yem bitkisi üretim alanları, ikincil ve doğal orman. Silvopastoral sistemler ve orman kalıntıları, açık mera alanlarına göre çok daha fazla karbon depolamıştır. Silvopastoral uygulamalar, açık meralara göre %27-163 daha fazla toplam karbon stoğu göstermiştir. Arazi kullanımı türleri arasında ağaç biyokütlesi (özellikle odunsu bitkiler) ile toprak organik karbon (SOC) arasındaki pozitif ilişkinin güçlü olduğu bulunmuştur; yani ağaçların varlığı hem toprak üstü hem de toprak altı karbon stoklarını artırmıştır. SOC değerleri, arazinin kullanım geçmişi ve toprak yoğunluğu gibi faktörlere bağlı olarak bölgesel farklılıklar gösterse de entegre sistemler açık meralara göre genel olarak daha yüksek karbon depolamıştır.

ABD ve AB ülkelerinde mera sağlığı ve toprak karbonu, uzaktan algılama ve arazi ölçümlerinin birlikte kullanıldığı MRV sistemleri (İzleme, Raporlama ve Doğrulama) ile izlenmektedir. Bu sistemler, karbon yutak kapasitesinin nicel olarak değerlendirilmesine ve politika etkinliğinin ölçülmesine olanak sağlamaktadır (Smith ve ark., 2020).

Avrupa Birliği Ortak Tarım Politikası (CAP) kapsamında uygulanan eko-şartlı destekler, sürdürülebilir mera yönetimi uygulamalarını teşvik etmektedir. Çiftçiler, çevresel performans karşılığında ekonomik destek alarak karbon dostu uygulamalara yönelmektedir (Peer ve ark., 2020).

Bu uygulama ve politika yaklaşımları birlikte ele alındığında, çayır ve mera ekosistemlerinin karbon yutak kapasitesi artırılabilir; aynı zamanda ekosistem sağlığı, hayvansal üretim ve kırsal geçim kaynakları güvence altına alınabilir. Bu yönüyle çayır ve meralar, iklim değişikliğiyle mücadelede düşük maliyetli, uzun vadeli ve çok faydalı doğa temelli çözümler sunmaktadır.

11) Sonuç ve Öneriler

Otlakların etkin yönetimi, otlatma sistemleri ve arazi kullanımı modelleri, toprak organik karbonun artırılmasında kritik bir rol oynar ve bu sayede iklim değişikliği etkilerinin azaltılmasına katkı sağlar. Agro-silvo pastoralizm ve karma hayvancılık sistemleri gibi sürdürülebilir uygulamalar, karbon tutulumunu artırabilir, toprağın organik karbon depolamasını artırabilir ve insan kaynaklı CO_2 emisyonlarını azaltabilir. Arazi kullanımı değişiklikleri çevresel etkiler ve karbon dengesi üzerinde büyük etki yapar. Bitki örtüsü restorasyonu ve sürdürülebilir arazi yönetimi, karbon kaybını azaltıp karbon birikimini artırmada önemlidir. Bitki çeşitliliğinin artırılması, bitkiden toprağa karbon girişini ve mikrobiyal nekromass katkısını artırarak toprak organik karbon birikimini destekler. İklim değişikliği, bitki karbon girdileri ile mikrobiyal süreçler üzerindeki etkileri nedeniyle toprak organik karbon stoklarını etkiler ve bu nedenle gelecekteki karbon dengesini belirsizleştirir. Mera alanların karbon tutma potansiyeli yüksektir, ancak bunu gerçekleştirmek için uygun arazi yönetimi, biyolojik çeşitliliğin korunması ve iklim değişikliğine uyum stratejileri gereklidir. Bu alanlarda daha fazla araştırma ve uygulama odaklı çalışmalar önerilmektedir.

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T.C.
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Personel Daire Başkanlığı

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Sayı : E-18977135-200-710598 18.07.2025
Konu : ISPEC 18.Uluslararası Tarım, Hayvancılık ve Kırsal Kalkınma Kongresi

EREĞLİ ZİRAAT FAKÜLTESİ DEKANLIĞINA

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Fakülteniz ev sahipliğinde 24-26 Ekim 2025 tarihleri arasında gerçekleştirilecek olan "ISPEC 18.Uluslararası Tarım, Hayvancılık ve Kırsal Kalkınma Kongresi" başlıklı bilimsel toplantıya Fakülteniz Dekanı Prof. Dr. Yaşar KARADAĞ'ın düzenleme kurulu başkanı olarak görevlendirilmesi Rektörlüğümüzce uygun görülmüştür.
Bilgilerini rica ederim.

Prof. Dr. Cem ZORLU
Rektör

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Adres: Yaka Mah. Kasım Halife Sok. No: 11/1 (A Blok) No: 11 (B Blok) Posta Kodu: 42090 Meram / KONYA
Telefon No : 0332 221 06 12 Fax No : 0332 237 69 91
e-Posta : İnternet Adresi : http://www.erbakan.edu.tr
Bilgi İçin :Tuba ÖZEN
Şef
Telefon No:0332 221 06 12