CİLT / VOLUME:40 SAYI / NUMBER:3 YIL / YEAR: ARALIK / DECEMBER 2023

JAFAG

TOKAT GAZİOSMANPAŞA ÜNİVERSİTESİ ZİRAAT FAKÜLTESİ DERGİSİ

JAFAG

JOURNAL OF AGRICULTURAL FACULTY OF GAZIOSMANPASA UNIVERSITY

ISSN: 1300 - 2910
e-ISSN: 2147 - 8848

TOKAT GAZİOSMANPAŞA ÜNİVERSİTESİ ZİRAAT FAKÜLTESİ

Tokat Gaziosmanpasa University, Faculty of Agriculture
TOKAT, TÜRKİYE

GAZİOSMANPAŞA ÜNİVERSİTESİ ZİRAAT FAKÜLTESİ DERGİSİ

Journal of Agricultural Faculty of Gaziosmanpasa

University
(JAFAG)

ISSN: 1300 - 2910

E-ISSN: 2147 - 8848

Cilt/*Volume:40* **Sayı**/*Number:*3 **Yıl**/*Year:* **Aralık 2023**/*December 2023*

GAZİOSMANPAŞA ÜNİVERSİTESİ ZİRAAT FAKÜLTESİ DERGİSİ

Journal of Agricultural Faculty of Gaziosmanpasa University (JAFAG)

Sahibi/*Owner:*

Prof. Dr. Rüstem CANGİ (Dekan/*Dean*)

Tokat Gaziosmanpaşa Üniversitesi Ziraat Fakültesi
Tokat Gaziosmanpasa University Faculty of Agriculture

Yönetim Adresi/*Administration Adress:*

Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi Yayın Ofisi
Tokat Gaziosmanpaşa Üniversitesi, Ziraat Fakültesi, 60240 Taşlıçiftlik Yerleşkesi – TOKAT Telefon: (356) 252 16 16 / 2141 Faks: (356) 252 14 88

Gaziosmanpasa University Journal of Agricultural Faculty Publishing Unit Tokat Gaziosmanpasa University, Faculty of Agriculture, 60240 Tasliciftlik Campus-TOKAT Tel: (356) 252 16 16 / 2141 Fax: (356) 252 14 88

***E-Posta** /E-mail:*

ziraatdergi@gop.edu.tr

***Web adresi**/Web adress:*

https://dergipark.org.tr/tr/pub/gopzfd

***Sekreterya**/Secretary:*

Betül TARHANACI
Güzella YILMAZ
Müberra ERDOGAN
Şaziye DÖKÜLEN
Yağmur KAYA

***Kapak Tasarım**/Cover Design:*

M. Furkan ÇITAK

***Basım**/Publisher:*

Tokat Gaziosmanpaşa Üniversitesi Matbaası, 60240, Taşlıçiftlik, Tokat/TÜRKİYE
Tokat Gaziosmanpasa University Press, 60240, Taşlıçiftlik, Tokat/TURKEY

GAZİOSMANPAŞA ÜNİVERSİTESİ ZİRAAT FAKÜLTESİ DERGİSİ

Journal of Agricultural Faculty of Gaziosmanpasa University (JAFAG)

Ümran ÇİÇEK, Tokat Gaziosmanpaşa Üniversitesi, Mühendislik ve Mimarlık Fakültesi, Gıda Mühendisliği, Tokat, Türkiye /*Tokat Gaziosmanpasa University, Faculty of Engineering and Natural Sciences, Department of Food Engineering, Tokat, Turkey*
e-mail: umran.ensoy@gop.edu.tr

Yakut Gevrekçi, Ege Üniversitesi Ziraat Fakültesi, Zootekni Bölümü, İzmir, Türkiye /*Ege University, Agricultural Faculty, Animal Science, Izmir, Turkey*
e-mail:yakut.gevrekci@ege.edu.tr.

Yalçın Tahtalı, Tokat Gaziosmanpaşa Üniversitesi, Ziraat Fakültesi, Zootekni Bölümü, Tokat, Türkiye /*Tokat Gaziosmanpasa University, Agricultural Faculty, Animal Science, Tokat, Turkey*
e-mail:yalcin.tahtali@gop.edu.tr

GAZİOSMANPAŞA ÜNİVERSİTESİ ZİRAAT FAKÜLTESİ DERGİSİ

Journal of Agricultural Faculty of Gaziosmanpasa University (JAFAG)

Hakem Listesi / *Referee List*

Ahmet ÇELİK_Atatürk Üniversitesi
Ahmet KAZANKAYA_Kırşehir Ahi Evran Üniversitesi
Ali ENDES_Yozgat Bozok Üniversitesi
Duygu MERMER DOĞU_Zirai Mücadele Merkez Araştırma Enstitüsü Müdürlüğü, Ankara
Elçin YEŞİLOĞLU CEVHER_Ondokuz Mayıs Üniversitesi
Ergün ÇITIL _ Selçuk Üniversitesi
Gülden ÖZGÜNALTAY ERTUĞRUL _ Kırşehir Ahi Evran Üniversitesi
Halil Özcan ÖZDEMİR _ Kırşehir Ahi Evran Üniversitesi
Halil İbrahim OĞUZ _ Adıyaman Üniversitesi
Hasan Gökhan DOĞAN _ Kırşehir Ahi Evran Üniversitesi
Kübra ÖZDEMİR DİRİK _ Tokat Gaziosmanpaşa Üniversitesi
Muhammed TAŞOVA _ Tokat Gaziosmanpaşa Üniversitesi
Muhittin Murat TURGUT _ Dicle Üniversitesi
Mustafa ALKAN _ Yozgat Bozok Üniversitesi
Nuri ORHAN _ Selcuk Üniversitesi
Osman GÖKDOĞAN _ Isparta Uygulamalı Bilimler Üniversitesi
Ramazan DOGAN _ Bursa Uludağ Üniversitesi
Tarık BALKAN _ Tokat Gazıosmanpasa Unıversıty
Yasin Emre KİTİŞ _ Akdeniz Üniversitesi
Yusuf YANAR _ Gaziosmanpaşa Üniversitesi
Özer ÇALIŞ _ Akdeniz Üniversitesi

GAZİOSMANPAŞA ÜNİVERSİTESİ ZİRAAT FAKÜLTESİ DERGİSİ

Journal of Agricultural Faculty of Gaziosmanpasa University (JAFAG)

GAZİOSMANPAŞA ÜNİVERSİTESİ ZİRAAT FAKÜLTESİ DERGİSİ

Journal of Agricultural Faculty of Gaziosmanpasa University (JAFAG)

Tarandığı İndeksler / *Indexing*

TR DİZİN

NINDEX COPERNICUS

THE DIRECTORY OF OPEN ACCESS JOURNALS

GOOGLE SCHOLAR

CAB ABSTRACTS

DOAJ

WORLDCAT

FAO/AGRİS

ARASTIRMAX

AMAÇ VE KAPSAM

Gaziosmanpaşa Üniversitesi Ziraat Fakültesinin 1985 yılından beri hakemli v bilimse süreli yayınıdır.Tokat Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi, Tarım bilimleri (tarım ekonomisi, zootekni, biyosistem mühendisliği, tarla bitkileri, su ürünleri mühendisliği, bahçe bitkileri, bitki koruma, toprak bilimi ve bitki besleme) alanındaki uluslararası bilimsel makaleleri Türkçe ve İngilizce olarak yayınlamayı amaçlamaktadır. Dergi yılda en az iki kez basılır. 2014 yılı itibariyle senede 3 baskı yapmıştır.

YAYIN POLİTİKASI

Dergide yayınlanacak makaleler İngilizce yayınlanır. Makaleler incelenmek üzere dergiye sorumlu yazar tarafından sunulur. Sunulan makalelerin başka bir yerde yayınlanmamış olması gerekir. Telif Hakkı Devir Sözleşmesi Formu tüm yazarlar tarafından imzalanmış olmalıdır.

Dergimizde yayınlanacak makaleler araştırma ve yayın etiğine uygun olmak zorundadır. Etik kurul kararı gerektiren klinik ve deneysel hayvan çalışmaları için ayrı ayrı etik kurul onayı alınmış olmalı ve belgelendirilmelidir. Dergimize gönderilecek bilimsel yazılarda, ICMJE (International Committee of Medcial Journal Editors) tavsiyeleri ile COPE (Committee on Publication Ethics)'un "Editör ve Yazarlar için Uluslararası Standartlar"ı dikkate alınmaktadır.

Dergiye sunulan makale, Dergi Sekreteryası tarafından yazım kuralları ve içerik açısından ön değerlendirmeye alınır. Dergide basılacak nitelikte bulunmayan makale yazara iade edilebilir. Uygun bulunanlar ise bilimsel açıdan değerlendirilmek üzere konusunda uzman hakemlere (maksimum 1 5 gün süre için) gönderilir. Hakem incelenmesinden sonra basıma uygun olmayan makaleler yazara bildirilir, makaleler iade edilmez. Hakem onayından geçenler içinde düzeltme yapılması istenen makaleler gerekli dokümanlarla yazara iletilir. Yazar gerekli düzeltmeleri en kısa sürede (maksimum 15 gün) tamamlayarak dergi e-posta adresine gönderir. Editörler kurulu nihai kararını vererek makaleyi uygun bulursa basım ünitesine gönderir. Basımına karar verilen ve düzeltme için yazarına gönderilen eserde, ekleme veya çıkartma yapılamaz.

Bir yazarın derginin aynı sayısında ilk isim olarak, en fazla iki eseri basılabilir.

Yayınlanan makalelerin tüm sorumluluğu yazar(lar)ına aittir

AIMS AND SCOPE

Journal of Agricultural Faculty is scientific, peer reviewed journal and belonged to the Tokat Gaziosmanpasa University Faculty of Agriculture since 1985. Journal of Agricultural Faculty of Tokat Gaziosmanpasa University aims to publish the international scientific paper on agriculture sciences (agricultural economics, animal science, biosystems engineering, field crops, fisheries engineering, horticulture, plant protection, soil science and plant nutrition). The journal is published at least twice in a year. The journal was published three issues in a year at 2014 year.

PUBLISHING POLICY

Manuscripts are published in English. The manuscripts are submitted to the journal from Turkey and the other countries for review by corresponding author. The manuscript submitted should not have been submitted and published in another journal

Manuscripts published in our journal must be appropriate to the research and publication ethics. Separate ethical board resolutions are needed for each clinical and experimental study on animals which requires ethical board decision. International Committee on Publication

Ethics' (ICMJE) recommendations and Committee on Publication Ethics' (COPE) "International Standards for Editors and Auditors" should be taken into consideration for the scientific manuscripts sent to our Journal.

Submitted manuscript to the journal is considered to preliminary assessment by the Editorial Board of journal. The Editorial Board has the right to decline the manuscript in event the manuscript does not meet the journal publishing rules. Manuscripts that meet the basic requirements are numbered and sent to three referees, experts in particular field of science, to peer review process (for max. 15 days period). Then, if the referees do not find the manuscript for publication, the related manuscript are not returned to the author, manuscript are archived. After peer reviewing, if the referees find the manuscript for publication with requires revision and corrections, author is informed, and the referee's suggestions and the related documents are sent to the corresponding author. The author is sent the corrected and revised manuscript to the Editorial Board as soon as possible (max. 30 days). Then, Editorial Board takes the final decision (positive or negative) for publication of manuscript. For the content of the accepted manuscripts, no editing, changes, including addition or deletion, can be made.

Only two manuscripts of each author, as the first author for one of the manuscript, can be published in same issue of the journal.

The author(s) are responsible for the content of the published manuscripts

ETİK İLKELER VE YAYIN POLİTİKASI

YAYIN ETİĞİ İLKELERİ

Gaziosmanpaşa ÜniversitesiZiraat Fakültesi Dergisi, yayın politikasında akademik ilke ve etik değerlere bağlıdır. Etik ilke ve değerlere ilişkin ulusal ve uluslararası standartlara uygun olarak yayın hayatını sürdürmektedir. Bu kapsamda, COPE (Committee on Publication Ethics) tarafından belirlenen standartlar ve YÖK "Bilimsel Araştırma ve Yayın Etiği Yönergesi"nde belirlenen esaslar dikkate alınmaktadır (https://publicationethics.org/, https://www.yok.gov.tr/Sayfalar/Kurumsal/mevzuat/bilimsel-arastirma-ve-…). Makale değerlendirme sürecinde kabul edilen araştırma ve yayın etiği standartlarına aykırılığı tespit edilen eserlerin yayın talebi reddedilir. Eserin yayınlanmasından sonra söz konusu aykırılığın tespit edilmesi halinde eser yayından kaldırılır.

Hakemli dergide yayın ilkeleri ile ilgili tüm taraflardan (yazar, dergi editörü, hakem ve yayımcı kuruluşlar) beklenen genel etik davranışlar ve sorumluluklara ilişkin tanımlamalar aşağıda belirtilmektedir.

Yazar(lar)ın Sorumlulukları

• Kaynakça listesi eksiksiz olmalıdır.
• İntihal ve sahte veriye yer verilmemelidir.
• Aynı araştırmanın birden fazla dergide yayımlanmasına teşebbüs edilmemeli,
• Bilim araştırma ve yayın etiğine uymalıdır.
• Tüm yazarların araştırmaya katkısı bulunmalıdır.
• Makalede geçen tüm veriler gerçek ve orijinal olmalıdır.
• Tüm yazarlar hatalı makalenin geri çekilmesini ve hataların düzeltilmesini sağlamak zorundadır.

Bilim araştırma ve yayın etiğine aykırı eylemler şunlardır:

• İntihal: Başkalarının fikirlerini, metotlarını, verilerini, uygulamalarını, yazılarını, şekillerini veya eserlerini sahiplerine bilimsel kurallara uygun biçimde atıf yapmadan kısmen veya tamamen kendi eseriymiş gibi sunmak,
• Sahtecilik: Araştırmaya dayanmayan veriler üretmek, sunulan veya yayınlanan eseri gerçek olmayan verilere dayandırarak düzenlemek veya değiştirmek, bunları rapor etmek veya yayımlamak, yapılmamış bir araştırmayı yapılmış gibi göstermek,
• Çarpıtma: Araştırma kayıtları ve elde edilen verileri tahrif etmek, araştırmada kullanılmayan yöntem, cihaz ve materyalleri kullanılmış gibi göstermek, ilgili teori veya varsayımlara uydurmak için veriler ve/veya sonuçlarla oynamak, destek alınan kişi ve kuruluşların çıkarları doğrultusunda araştırma sonuçlarını tahrif etmek veya şekillendirmek,
• Tekrar yayım: Bir araştırmanın aynı sonuçlarını içeren birden fazla eseri ayrı eserler olarak sunmak,
• Dilimleme: Bir araştırmanın sonuçlarını araştırmanın bütünlüğünü bozacak şekilde, uygun olmayan biçimde parçalara ayırarak ve birbirine atıf yapmadan çok sayıda yayın yaparak ayrı eserler olarak sunmak,
• Haksız yazarlık: Aktif katkısı olmayan kişileri yazarlar arasına dâhil etmek, aktif katkısı olan kişileri yazarlar arasına dâhil etmemek, yazar sıralamasını gerekçesiz ve uygun olmayan bir biçimde değiştirmek, aktif katkısı olanların isimlerini yayım sırasında veya sonraki baskılarda eserden çıkarmak, aktif katkısı olmadığı halde

ETHICAL PRINCIPLES AND PUBLICATION POLICY

PRINCIPLES OF PUBLICATION ETHICS

Journal of Agricultural Faculty of Gaziosmanpasa University is committed to academic principles and ethical values in its editorial policy. It continues its publication life in accordance with national and international standards regarding ethical principles and values. In this context, the standards set by COPE (Committee on Publication Ethics) and the principles set in the Council of Higher Education "Scientific Research and Publication Ethics Directive" are taken into account (https://publicationethics.org/, https://www.yok.gov.tr/Sayfalar/Kurumsal/mevzuat/bilimsel-arastirma-ve-…). The publication request of the works that are found to be in violation of the research and publication ethics standards accepted in the manuscript evaluation process is rejected. If the said contradiction is detected after the publication of the work, the work is removed from the publication.

Author’s responsibilities:

The references list should be complete;
No plagiarism, no fraudulent data is allowed;
It is forbidden to publish same research in more than one journal;
Authors obliged to participate in peer review process;
All authors have significantly contributed to the research;
Statement that all data in manuscript are real and authentic;
All authors are obliged to provide retractions or corrections of mistakes,
Authors should ensure that any studies involving human or animal subjects conform to national, local and institutional laws and requirements.

The actions against science research and publication ethics include;

Plagiarism: Presenting others' ideas, methods, data, applications, writings, figures or works as if they were their own works, partly or completely, without referring to the scientific rules.
Fraud: to produce data that is not based on research, to organize or modify the work submitted or published on the basis of unreal data, to report or to publish them, to make a research that has not been done.
Distorting: Dealing with the records of research and the data obtained, showing the unused methods, devices and materials used in the research, playing with data and / or results to fit the relevant theory or assumptions, or falsifying or shaping the results of the research in the interests of the people and organizations supported.
Slicing: Presenting the results of a research as separate works by disrupting the uniqueness of the research, by dissecting it inappropriately and making a large number of publications without reference to each other.
Unfair writ•er: To include people who do not have active contribution among the authors, not to include the people who have active contribution among the writers, to change the ranking of the authors without any justification and in an inappropriate way, to remove the names of those who have active contributions from the

nüfuzunu kullanarak ismini yazarlar arasına dâhil ettirmek.
• Diğer etik ihlali türleri: Destek alınarak yürütülen araştırmaların yayınlarında destek veren kişi, kurum veya kuruluşlar ile onların araştırmadaki katkılarını açık bir biçimde belirtmemek, insan ve hayvanlar üzerinde yapılan araştırmalarda etik kurallara uymamak, yayınlarında hasta haklarına saygı göstermemek, hakem olarak incelemek üzere görevlendirildiği bir eserde yer alan bilgileri yayınlanmadan önce başkalarıyla paylaşmak, bilimsel araştırma için sağlanan veya ayrılan kaynakları, mekânları, imkânları ve cihazları amaç dışı kullanmak, tamamen dayanaksız, yersiz ve kasıtlı etik ihlali suçlamasında bulunmak (YÖK Bilimsel Araştırma ve Yayın Etiği Yönergesi, Madde 8).

Hakemlerin Sorumlulukları
•Hakemlik süreci, bilimsel akademik yayıncılığın başarısında önemli bir konumda bulunmaktadır. Hakemler bu sürecin sağlıklı yürütülebilmesi ve iyileştirilmesine gayret göstermelidir.
•Hakemler araştırmayla, yazarlarla ve/veya araştırma fon sağlayıcılar ile çıkar çatışması/çakışması içerisinde olmamalıdır.
•Değerlendirmeleri tarafsız olmalıdır.
•Değerlendirilen makaleler hakem tarafından gizli tutulmalıdır.

Editörün Sorumlulukları
•Editörler bir makaleyi kabul etmek ya da reddetmek için tüm sorumluluğa ve yetkiye sahiptir.
•Editörler kabul ettiği ya da reddettiği makaleler ile ilgili çıkar çatışması/çakışması içerisinde olmamalıdır.
•Sadece alana katkı sağlayacak makaleler kabul edilmelidir.
•Hakemlerin ismini değerlendirme tamamlanana kadar saklı tutmalıdır.
•Makalenin yayımlanmasından sonra herhangi bir araştırmacı tarafından bilimsel hata tespit edildiğinde ilgili düzeltme/düzeltmelerin yayımlanmasını ya da geri çekilmesini desteklemelidir.

Yayımcının Sorumlulukları
•Yayıncılık etiğinin yayın kurulu tarafından izlenmesi/korunması,
•Akademik kaydın bütünlüğünü korumak,
•Etik standartlardan ödün vermemek,
•Gerektiğinde düzeltmeleri, açıklamaları ve özürleri yayımlamak,
•Okuyucunun dergide yayımlanan bir makalede önemli bir bilimsel hata ya da intihal, yinelenen makaleler gibi konularda herhangi bir uyarısı olduğu zaman ziraatderdi@gop.edu.tr adresine mail atarak editör kuruluna bildirebilir. Derginin bilimsel ve teknik yönden gelişmesi için bir fırsat olacağı bilinci ile, yapacağınız uyarılar/eleştiriler, editör kurulu tarafından memnuniyetle karşılanarak hızlı ve yapıcı bir şekilde iyileştirmelerimiz gerçekleştirilmektedir.

Değerlendirme Süreci
Yayımlanması için gönderilen eser, yayın ilkeleri doğrultusunda editör tarafından ön incelemeye alınır. Editör, dergide yayımlanabilecek nitelikte bulmadığı makaleleri hakemlere göndermeden yazara/yazarlara iade

work during publication or in later editions, and to use their influence even if there is no active contribution.

Other types of ethical violations: Not expressing the contributions of the persons, institutions or organizations that support them in the research, and their contributions in the research, Not to obey the ethical rules in human and animal research, to respect the rights of patients in their publications, To share the information contained in a work that he is commissioned to examine as an arbitrator with others, To use the sources, facilities and devices provided for scientific research out of their use purposes. To blame for a completely irrelevant, unwarranted and intentional violation of ethics (YÖK Scientific Research and Publication Ethics Directive, Article 8).

Peer review/responsibility for the reviewers:
To contribute to the decision-making process, and to assist in improving the quality of the published paper by reviewing the manuscript objectively.
Reviewers should have no conflict of interest with respect to the research, the authors and/or the research funders;
Judgments should be objective;
Reviewed manuscripts should be treated confidentially.

Editorial responsibilities:
Editors have complete responsibility and authority to reject/accept an manuscript;
Editors should have no conflict of interest with respect to manuscripts they reject/accept;
Only accept a paper when reasonably certain;
Preserve anonymity of reviewers.
No plagiarism, no fraudulent data.
When errors are found, promote publication of correction or retraction;
To act in a balanced, objective and fair way while carrying out their expected duties, without discrimination on grounds of gender, sexual orientation, religious or political beliefs, ethnic or geographical origin of the authors.

Duties of the Publisher
Monitoring/safeguarding publishing ethics by editorial board;
Guidelines for retracting manuscripts;
Maintain the integrity of the academic record;
Preclude business needs from compromising intellectual and ethical standards;
Always be willing to publish corrections, clarifications, retractions, and apologies when needed.
In an manuscript published in the journal, the reader can send an e-mail to ziraatdergi@gop.edu.tr when he has any warnings about important scientific error or plagiarism, recurring manuscripts. With the awareness that the journal will be an opportunity for the scientific and technical development of the journal, your warnings / criticisms are welcomed by the editorial board and our improvements are made quickly and constructively.

Evaluation Process
The submitted manuscript for publication is taken into consideration by the editor in accordance with the principles of publication. In case of finding not qualified to publish it in the journal, the editor has the right to make

kararı verme hakkına sahiptir. Ayrıca yazım kurallarına uymayan veya anlatım dili yetersiz olan makaleler, düzeltilmek üzere yazara/yazarlara iade edilir. Değerlendirmeye alınan makaleler, incelenmek üzere en az 2 hakeme gönderilir. Değerlendirmede çift yönlü kör hakemlik uygulaması esastır. Hakem değerlendirmesinden geçen makalelere ait düzeltmeler en kısa sürede sisteme yüklenmelidir.
Editör, hakem raporlarını ve/veya istenilen düzeltmelerin yeterli olup olmamasını dikkate alarak makalenin yayımlanıp yayımlanmamasına yönelik nihai karar vericidir. Makalenin yayımlanmasından önce makalede sayfa düzeni yapılarak son kontrol için yazarına gönderilir. Yazar makalenin son kontrolünü yaptıktan sonra ziraatdergi@gop.edu.tr mail adresine gönderir. Kontrolün düzgün yapılmaması sonucunda oluşabilecek baskı hataları yazarların sorumluluğundadır. İşlemi tamamlanan eserler kabul tarihi dikkate alınarak derginin yayınlanacak sayısında bulunması gereken makale limitleri dahilinde yayımlanır.

Alıntılanma Yüzdesi
Dergiye başvurusu yapılan makalelerin, hakemlik sürecine alınmadan önce intihal programı ile (iThenticate Plagiarism Detection Software) (http://www.ithenticate.com) taratılmış olması gerekmektedir. Tarama sonucunda Kaynaklar bölümü haricinde, benzerlik oranı %20 ve aşağı değeri taşıyan makaleler başvuruya kabul edilmektedir. Makale sisteme yüklendikten sonra iThenticate raporunun da ziraatdergi@gop.edu.tr mail adresine gönderilmesi süreç için gereklidir

Etik Kurul Onayı
Yazarlar yayımlatmak istedikleri makale ile ilgili olarak gerekli olan etik kurul onayını aldıkları kurumu ve onay numarasını Materyal ve Yöntem bölümünde mutlaka belirtmelidirler. Yayın kurulu gerekli gördüğünde "Etik Kurul Onay Belgesini" ayrıca isteyebilir. Makalenin etik kurul onayı gerektirip gerektirmediği aşağıda bildirilen kısımdan yazarlar ve alan editörleri tarafından mutlaka sorgulanması gerekmektedir.

Etik Kurul izni gerektiren araştırmalar aşağıdaki gibidir.
•Anket, mülakat, odak grup çalışması, gözlem, deney, görüşme teknikleri kullanılarak katılımcılardan veri toplanmasını gerektiren nitel ya da nicel yaklaşımlarla yürütülen her türlü araştırmalar
•İnsan ve hayvanların (materyal/veriler dahil) deneysel ya da diğer bilimsel amaçlarla kullanılması,
•İnsanlar üzerinde yapılan klinik araştırmalar,
•Hayvanlar üzerinde yapılan araştırmalar,
•Kişisel verilerin korunması kanunu gereğince retrospektif çalışmalar,
Ayrıca;
•Olgu sunumlarında "Aydınlatılmış onam formu"nun alındığının belirtilmesi,
•Başkalarına ait ölçek, anket, fotoğrafların kullanımı için sahiplerinden izin alınması ve belirtilmesi,
•Kullanılan fikir ve sanat eserleri için telif hakları düzenlemelerine uyulduğunun belirtilmesi.

a decision to return the manuscripts to the author / authors without sending to the referees. Papers should be written with fluent English without any grammatical and typographical errors. Manuscripts with any of those errors will be rejected and sent to the authors for corrections before submission and review. The journal uses double-blind system for peer-review; both reviewers and authors' identities remain anonymous. The paper will be peer-reviewed at least by two reviewers and one editor from the journal. The authors should upload the corrected manuscript with correction form and answers to the reviewers' comments immediately after receiving the comments. After the author has made the final check of the manuscript, he sends it to the ziraatdergi@gop.edu.tr e-mail address.
The Editor is the ultimate decision-maker for the publication of the manuscript, taking into account the referee reports and / or the adequacy of the requested corrections. Before the publication of the manuscript, the manuscript is edited and sent to the author for the final check. Print errors as a result of incorrect control are the responsibility of the authors. The completed works are published within the manuscript limits that should be in the issue of the journal, considering the date of acceptance

Plagiarism Percentage
Manuscripts submitted to the journal are reviewed in the plagiarism program (iThenticate Plagiarism Detection Software) (http://www.ithenticate.com) before being submitted to the evaluation process. As a result of the screening, except the references section, manuscripts with similarity rate of 20% and lower are accepted for application. After the manuscript is uploaded to the system, it is necessary to send the iThenticate report to the e-mail address ziraatdergi@gop.edu.tr .

Ethics Committee Approval
Authors should indicate the name of institute approves the necessary ethical commission report and the serial number of the approval in the Material and Methods section. If necessary, editorial board may also request the official document of the ethical commission report. Whether the manuscript requires approval from the ethical committee should be questioned by the authors and editors from the section below.
Researches requiring the Ethics Committee's permission are as follows
Any research carried out with qualitative or quantitative approaches that require data collection from participants using survey, interview, focus group work, observation, experiment, interview techniques.
Use of humans and animals (including material / data) for experimental or other scientific purposes,
Clinical researches on humans
Researches on animals,
Retrospective studies in accordance with the law of protection of personal data,
Also;
In the case reports, it is stated that the "informed consent form" was taken
Obtaining and specifying the permission of the owners for the use of scales, surveys and photographs belonging to others,

YAYIN POLİTİKASI

Dergiye İngilizce araştırma makaleleri kabul edilmektedir. Makale başvuruları sorumlu yazar tarafından yapılmalıdır. Dergiye yayımlanması talebi ile gönderilen makalelerin diğer dergilerde yayımlanmamış ve/veya yayımlanması amacıyla gönderilmemiş olması gerekmektedir.

•Makale başvurusunda;
•Tam metin makale,
•Tam metin makalenin taratıldığını gösteren benzerlik raporu (Ithenticate) (% 20'nin altında olmalıdır),
•İmzalanmış ve taratılmış başvuru formu,
•Tüm yazarlar tarafından imzalanmış çıkar çatışması, yazarlık katkı beyan formu, Etik kurul onay raporu vb.
•Tüm yazarlar tarafından imzalanmış telif hakkı devir formunun taranmış kopyasının elektronik formatta dergipark sistemine http://dergipark.org.tr/login adresinden kayıt olunarak yüklenmesi gerekmektedir.
•Yayımlanan makalelerin tüm hakları Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisine aittir. Makalenin bilimsel sorumlulukları yazarlarına aittir. Yazarlara telif ücreti ödenmez. Bir yazarın aynı sayıda ilk isim olarak en fazla iki makalesine yer verilir. Dergimizde yayımlanan makalelerin bir kısmı veya tamamı dergimiz kaynak gösterilmeden kullanılamaz.

Stating that the copyright regulations are complied with for the ideas and works of art used.

PUBLICATION POLICY

English research manuscripts are accepted to the journal. Manuscript submissions should be made by the corresponding author. The manuscripts sent to the journal with a request for publication must not have been published in other journals and/or not sent for publication.

•In the manuscript application;
•Full text manuscript,
• Similarity report (Ithenticate) showing that the full-text manuscript has been scanned (must be below 20%),
• Signed and scanned application form,
• Conflict of interest, authorship contribution declaration form, Ethics committee approval report etc. signed by all authors.
• A scanned copy of the copyright transfer form signed by all authors must be uploaded to the Dergipark system by registering at http://dergipark.org.tr/login in electronic format.
•All rights of the published manuscripts belong to Journal of Agricultural Faculty of Gaziosmanpaşa University (JAFAG). Scientific responsibilities of the manuscript belong to the authors. No royalties are paid to authors. A maximum of two manuscripts by an author in the same number of first names are included. Some or all of the manuscripts published in our journal cannot be used without reference to our journal.

MAKALE HAZIRLAMA

1. Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi Nisan, Ağustos ve Aralık aylarında olmak üzere yılda üç sayı olarak yayımlanır.
2. Dergide Tarım Bilimleri alanında hazırlanan ve daha önce yayımlanmamış orijinal araştırma makaleleri ile kongre kitaplarında özet metni basılmış olan araştırma makaleler yayımlanır.
3. Aynı sayıda bir yazarın en fazla iki makalesine yer verilir.
4. Yazarlara telif ücreti ödenmez. Basıma kabul edilen makalelerden basım ücreti alınmaz.
5. Makalelerin bilimsel sorumlulukları yazarlarına aittir.
6. Araştırma makaleleri İngilizce olarak; Başlık, Abstract , Öz, İngilizce ve Türkçe Anahtar Kelimeler, Giriş, Materyal ve Yöntem, Araştırma Bulguları ve tartışma, Sonuç ve Kaynaklar ana başlıkları altında hazırlanmalıdır.
7. Makale düzeni;

a. A4 boyutunda 12 punto Times New Roman tipi harflerle ve 1,5 satır aralıklı yazılmalıdır. Sayfa kenar boşlukları 3'er cm olmalıdır.

b. Makalenin her sayfası ve satırları numaralandırılmalıdır. Makale toplam 15 sayfayı geçmemelidir.

c. Makalenin Türkçe ve İngilizce başlığı koyu, 14, ortalı ve ilk harfleri büyük olacak şekilde küçük harflerle yazılmalıdır.

d. En fazla 2. düzeyde bölüm başlıkları kullanılmalıdır. Birinci düzey başlıklar 0.5 cm girintili, iki yana yaslı, koyu ve her kelimenin ilk harfi büyük olmalıdır. İkinci düzey başlıklar koyu, 0.5 cm girintili, iki yana yaslı, ve yalnız ilk kelimenin ilk harfi büyük olmalıdır.

e. Metnin ana gövdesi 0,5 cm girintili yazılmalıdır. Tüm paragraflar sol kenardan başlamalıdır. Metin tümüyle iki yana yaslı hizalanmalıdır. Hiçbir heceleme olmamalıdır. Kalın veya altı çizili yazı kullanımı ile metin vurgulama önerilmez.

f. Yazar ad(lar)ı açık olarak yazılmalı (akademik unvan belirtilmemeli), tüm yazarların adres bilgileri,ORCID ID'leri ile yazışma yapılacak yazarın iletişim bilgileri (e-mail, telefon, faks vb.) belirtilmelidir. Adresler kelimelerin ilk harfi büyük olacak şekilde, yazar adlarının hemen altında açıkça yazılmalıdır

Başlık: Makale başlığı kısa ve açıklayıcı ve 15 kelimeyi geçmemelidir.

Öz: Hem Türkçe ve hem de İngilizce özet 200 kelimeyi geçmeyecek şekilde 12 punto ve 1,5 aralık ile yazılmalı, makalenin amacını, çalışmanın önemli veri ve sonuçlarını içermelidir. Yurtdışından gelen makalelerde özet sadece İngilizce yazılabilir.

Anahtar kelimeler: Alfabetik sıraya göre 5 kelimeyi geçmeyecek şekilde verilmelidir.

Giriş: Bu bölüm çalışmadaki problemi açıkça ifade etmeli, önceki ve özellikle son yıllardaki yapılan ve yayınlanan çalışmaları açıklamalı, çalışmanın amaçlarını açıkça vermelidir.

Materyal ve Metot: Bu bölüm, çalışmada kullanılan tüm materyalleri içermeli, yöntemler detaylı açıklanmalı, istatistiksel metotlar açıklanmalıdır.

Bulgular ve tartışma: Çalışmadaki elde edilen veriler ve bulgular tablo ve bilgi olarak verilmeli, önceki yapılan çalışma sonuçlarına göre yorumlanarak tartışılmalıdır.

MANUSCRIPT PREPARATION

1. The Journal of Gaziosmanpaşa University Faculty of Agriculture is published three issues in a year as in April, August and December.
2. The journal publishes original research articles in the field of Agricultural Sciences that have not been published previously and including original research articles published as an abstract in proceeding books.
3. If the authors are the same in the manuscripts, only two of them are accepted for the publication in the same issue.
4. There is no royalty payment to the authors. Also there is no publication fee for the accepted manuscript.
5. Authors are responsible for the scientific content of the manuscripts to be published.
6. The research articles should be prepared in English under the main headings; Title, Abstract, Öz, Keywords in Turkish and in English, Introduction, Material and Methods, Findings and Discussion, Results and References.
7. Article layout;

a. It should be written in A4 size, 12 point Times New Roman type letters and 1.5 line spacing. Page margins should be 3 cm each.

b. Each page and line of the article should be numbered. The article should not exceed 15 pages in total.

c. The Turkish and English title of the article should be written size 14 point, bold, centered and only the first letter of each words should be a capital and the rest in lower case letters.

d. A maximum two levels of headings are recommended. First-level heading should be indented 0.5 cm, justified, bold, and the first letter of each word should be capitalized. Second level heading should be bold, indented 0.5 cm, justified, and only the first letter of the first word should be capitalized.

e. The main body of the text should be indented 0.5 cm. All paragraphs should start from the left margin. The text should be completely justified. There should be no spelling. Highlighting text with the use of bold or underlined is not recommended.

f. The name(s) of the author should be written clearly (academic title should not be specified), the address information of all authors, their ORCID IDs and the contact information of correspondence author should be given (e-mail, telephone, fax, etc.). Addresses should be written clearly just below the authors' names with the first letter of the words capitalized.

Title: The title of the article should be short and descriptive and should not exceed 15 words.

Abstract: Both Turkish and English abstracts should not exceed 200 words, should be written in 12 points and 1.5 spacing, should include the purpose of the article, important data and results of the study. Only english abstract can be written for articles coming from abroad.

Keywords: Should not exceed 5 words in alphabetical order.

Introduction: This section should clearly express the problem in the study, explain previous and especially recent work, and clearly state the aims of the study.

Materials and Methods: This section should contain all the materials used in the study, the methods should be explained in detail, and statistical methods should be explained.

Sonuç: Elde edilen sonuçların bilime ve uygulamaya katkısı önerilerle birlikte vurgulanmalıdır

Teşekkür: Bu bölümde çalışmanın yapılmasına katkı veren kişi, kuruluş ve projelere yer verilebilir.

8. Makalede yer alan türlerin bilimsel isimleri italik karakterde olmalı ve ondalık sayılar nokta işareti ile ayrılmalıdır.

9. Grafik, harita, fotoğraf, resim ve benzeri sunuşlar "Şekil", sayısal değerlerin verilişi "Çizelge" olarak isimlendirilmelidir. Şekil ve Çizelgelere ait İngilizce isimlendirmelerin altında Türkçe isimlendirmeler de yer almalıdır. Verilen tüm çizelge ve şekillere metin içerisinde atıf yapılmalı ve makale içinde atıf yapılan yere en yakın yerde atıftan sonra verilmelidir.

Metin içi atıflar ve Kaynaklar:APA 7 yazım kuralına göre yapılmalıdır.
(https://dergipark.org.tr/tr/pub/gopzfd/writing-rules)

Web adresi: *https://dergipark.org.tr/tr/pub/gopzfd*
E-mail: *ziraatdergi@gop.edu.tr*

Findings and discussion: The data and findings obtained in the study should be given as tables and information, and should be interpreted and discussed according to the results of the previous studies.

Conclusion: The contribution of the findings to science and practice should be emphasized together with the recommendations.

Acknowledgments: In this section, people, organizations and projects that contributed to the work can be included.

Scientific names of the species in the article should be in italics and decimal numbers should be separated by a point.

9. Graphics, maps, photographs, pictures and similar presentations should be named as "Figure" and the presentation of numerical values should be named as "Table". Turkish nomenclature (For Turkish authors) should be placed under the English nomenclature of Figures and Tables. All given tables and pictures should be cited in the text and should be given after the reference in the article close to the cited place.

In-text citations and References: It should be made according to the APA 7 spelling rule.
(https://dergipark.org.tr/en/pub/gopzfd/writing-rules)

Web adress: *https://dergipark.org.tr/en/pub/gopzfd*
E-mail: *ziraatdergi@gop.edu.tr*

Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi
Journal of Agricultural Faculty of Gaziosmanpasa University
https://dergipark.org.tr/tr/pub/gopzfd

Araştırma Makalesi/*Research Article*

JAFAG
ISSN: 1300-2910
E-ISSN: 2147-8848
(2023) 40(3) 96-102
doi:10.55507/gopzfd.1280364

Effect of Feed Materials on Pellet Properties, Capacity and Energy Consumptions Values

Ergün ÇITIL[1]*, Tamer MARAKOĞLU[1]
[1]Selcuk University, Faculty of Agriculture, Department of Agricultural Machinery and Technologies Engineering, Konya
***Corresponding author's email:** ecitil@selcuk.edu.tr

Alındığı tarih (Received): 10.04.2023 Kabul tarihi (Accepted): 19.09.2023

Abstract: In this study, it was aimed to determine the power consumption, work capacity and some properties of the pellet feed of the pelletizing machine used in the pelleting of animal feeds consisting of small and granular mixtures.
A pellet machine with a die hole inlet diameter of 8 mm, an outlet diameter of 5 mm and a flat die with a diameter of 195 mm was used to pellet the feeds. In the experiments, two different feed materials consisting of mixed feed and barley only were used. The bulk weight of the pellets (kg m-3), durability (%), compression resistance (N mm-2), pellet moisture (%) were determined. In addition, hourly pelleting capacity (kg h -1), required energy consumption (kW), specific energy consumption (kW kg -1) of the pelletizing machine were determined.As a result of the trials, the capacity of the pellet feed making machine was 172.80 kg h-1 in the pelleting process from barley and 170 kg h-1 in the pelleting process from mixed feed. The required electrical energy consumption was 7.63 kW, in barley pelleting and 9.18 kW in mixed feed pelleting. Specific energy consumption 0.044 kW kg^{-1} in barley pelleting, 0.054 kW kg^{-1} in mixed feed pelleting

Keywords: Capacity, durability, mold, pellet, energy consumption

Pelet Yem Yapma Makinesi Bazi İşletme Özelliklerinin ve Pelet Özelliklerinin Belirlenmesi

Öz: Bu çalışmada, küçük ve granül karışımlardan oluşan hayvan yemlerinin peletlenmesinde kullanılan peletleme makinesinin güç tüketimi, iş kapasitesi ve pelet yeminin bazı özelliklerinin belirlenmesi amaçlanmıştır. Yemleri peletlemek için kalıp deliği giriş çapı 8 mm, çıkış çapı 5 mm ve çapı 195 mm olan düz kalıbı olan bir pelet makinesi kullanılmıştır. Denemelerde karma yem ve sadece arpadan oluşan iki farklı yem maddesi kullanılmıştır. Peletlerin yığın ağırlığı (kg m^{-3}), dayanıklılık (%), sıkıştırma direnci (N mm^{-2}), pelet nemi (%) belirlenmiştir. Ayrıca peletleme makinesinin saatlik peletleme kapasitesi (kg h^{-1}), gerekli elektrik motoru gücü (kW), özgül güç tüketimi (kW kg^{-1}) belirlenmiştir. Denemeler sonucunda pelet yem yapma makinesinin kapasitesi arpadan peletleme işleminde 172,8 kg h^{-1}, karma yem peletleme işleminde ise 170 kg h^{-1} olmuştur. Gerekli elektrik motoru gücü arpa peletlemede 7,63 kw, karma yem peletlemede 9,18 kw olarak bulunmuştur. Spesifik enerji tüketimi 0,044 kW kg^{-1} arpa peletlemede, karma yem peletlemede ise 0,054 kW kg^{-1} olarak bulunmuştur.

Anahtar Kelimeler: Dayanıklılık, kalıp, kapasite, pelet , enerji tüketimi

1.Introduction

Giving the feed raw materials in the form of a mixture because the deficiencies of each feed raw material are completed by the other raw materials in the mixture, giving the mixed feed to the animals has many nutritional benefits compared to giving a single raw material. (Ergül, 2005; Gül, 2007).

Feed costs have the largest share in production costs in the livestock sector. Due to the degradation of meadow-pasture areas and the decrease in agricultural lands, the livestock sector has turned to the search for alternative and cheap feed resources (Yılmaz, 2010).

High capacity animals require high quality feeds. Compound feeds allow animals to benefit from raw materials with different nutrients at the highest level. Raw materials that are not willingly consumed by animals are turned into compound feed and consumed by animals. In Turkey and in the world, factory feeds are produced in powder, pellet and granule forms. With the recent increase in animal production, there has been an increase in compound feed production. The balanced nutrition that animals need has an important role in preventing health problems and increasing the yield of animal products (Najwa et al., 2017).

Electricity consumption of compound feed varies according to the content of the prepared feed rate. The extension of the enclosures to the mix and their ratio effect the electricity consumption. So much so that less electricity is consumed (3.5-7 kWh t^{-1}) in the grinding of oily beans and more electricity is consumed during the grinding of meetings (7-15 kWh t^{-1}) (Gill, 1998; Boyar, 2006). The possible importance of the time-to-start-up durability of the pellets is of great importance. Pellets with high durability provide advantage in transportation, handling by hand or any vehicle and storage works (Lehtikangas, 2001). Pellets

with 80% or more durability are considered high quality, between 70-80% medium quality and 70% of pellets low quality (Tabil &Sokhansanj, 1996; Tabil &Sokhansanj, 1997).

With the positive physical effects of pellet feed better yields from animals consuming this feed has played an important role in popularizing its use (Dozier, 2001). Pellet durability index and pellet hardness physical measurement parameters are used to determine pellet strength or pellet quality (Yalcın et al. 2018).

Miranda et al. (2011) and Miranda et al. (2012) reported that the moisture content of pellet feed is effective in reducing the pellet durability index, and the durability rate is between 85.83% and 97.08% depending on the feed raw material ratio in the mixture, pellet moisture content and types.

The material that gives the pellet its shape is called mould.The die has an important and large home in the elements in the energy use and pellet care centers where they press. For consumers who use the right mold to improve pellet quality. Widening the matrix hole from which the pellet feed comes out provides the total thickness required to prevent the matrix from disintegrating and reduces the effective thickness of the matrix, ensuring the appropriate ratio between matrix thickness and matrix hole diameter. According to the diameter and thickness of the mold, the effective area of the mold increases. The large area of this area extends the residence time of the feed in the mold holes, reduces the energy consumption for each ton of pellet feed production and increases the production efficiency (Fairfield, 2003).

The physical quality of the pellet feed is very effective on the passage time through the digestive system and degradation in the feeding of animals. Pellet feeds with high physical quality can be better utilized by animals (Gürbüz et al., 2003)

While it is easy to pellet raw materials such as wheat, barley and canola, pelleting of feed raw materials such as corn is more difficult. Energy consumption will increase due to increased friction in the presses, as pellets made from ground feeds with more small particles than necessary are more durable. Good results were obtained in pelleting powdered feeds in the period when the pelleting process was started for the first time. While pelleting the feeds with very small particles was done at the beginning, the pelleting of the feed with larger particles decreased the level of meeting the desired expectations (Basmacıoglu, 2004).

It has been reported that the use of pellet feed improves live weight by 27% and feed conversion efficiency by up to 17% compared to powder feed in broiler breeding (Karabulut et al., 2000).

In this study, it was aimed to make feed pelleting of two different feed raw materials in the form of mixture and using only barley, without using any adhesive material. Determination of the volume weight of the pellets (kgm^{-3}), Pellet density ($kg.m^{-3}$), durability (%), compression resistance (Nmm^{-2}), pellet moisture (%), as well as the hourly pelleting capacity of the pelletizing machine (kgh^{-1}), the required electric energy consumption (kW) and specific energy consumption ($kW\ kg^{-1}$).

2. Material and Method

MEDYAMAK brand and MY200 model feed pelleting machine used in the trials turns small animal feeds into cylindrical shaped pellets. With the electric motor, the pellet mold, which is the reducer shaft line, is moved. The mold is in a shelter in a body and the three compression cylinders on the mold rotate around itself with the width of the mold. The material feed tank is located just above the mold and clamping cylinders to provide continuous material inflow. The material taken from the rollers and the mold inlet tank is compressed and comes out as cylindrical pellets from the holes on the mold and is sent to the machine from the pellet delivery port (Figure 1). The technical specifications of the pelletizing machine are given in Table 1, and the label information of the electric motor powering the machine is given in Table 2.

The mixed feed material used in pelleting has 16.2% moisture. Pellet has 16.20% moisture, 588 kg m^{-3} in weight contains 50.80% corn, 31.60% sunflower + alfalfa residues and 17.60% barley (Figure 2A). As the other feed material, barley with a volume weight of 570 kgm^{-3} thousand grain weight 65 g and a moisture content of 13.60% was used (Figure 2B).

Pellet compression resistance, pellet output values obtained by Aydın & Öğüt (1991) were measured by pressing the pellet extraction stationary platform on the mobile bottom platform of the biological material testing device (Figure 3). The hardness of the pellets was measured with a 2 mm high probe connected to the dynamometer. The experiments were carried out at a speed of 50 mm min^{-1}.

(A) **(B)** **(C)**

Figure 1. Pelletizing machine and parts: (A) Pellet making machine,(B) Compression rollers,(C) Pellet mold
Şekil 1. *Peletleme makinesi ve parçaları (A) Pelet yapma makinesi, (B) Sıkıştırma silindirleri, (C) pelet kalıbı*

(A) **(B)**

Figure 2. Peletting materials; (A) Mixed feed, (B)Barley
Şekil 2. *Pelet materyalleri; (A) Karma yem, (B) Arpa*

Table 1. Pelletizing machine technical specifications
Çizelge 1. Peletleme makinesi teknik özellikleri

	Compressors Cylinder	**Pellet Mold**
Diameter	95mm	195mm
Width	45mm	34mm
Number of holes	22x4 (88 pcs)	272
Hole diameter	6mm	Inlet diameter: 8 mm Output diameter: 5 mm
Mold working speed		196 minutes $^{-1}$
Die circumference speed		2 ms $^{-1}$

Table 2. Electric motor label information
Çizelge 2. Elektrik motoru etiket bilgileri

V	A	Hz.	cosω	Transfer	kW
400	21.0	50	0.83	1465	11th
690	12.1	50	0.83	1465	11th

Three replications were taken to determine the moisture content of the material. An oven with a temperature range of between 1° C and 200° C was used to weigh 0.5g precision and 15 kg precision scales. Pellet samples were dried in a drying oven at 105±2°C for 24 hours. After drying in the oven, they were weighed again. The moisture rate was calculated on the basis of wet weight with the following eg.1 (Toruk, 1997).

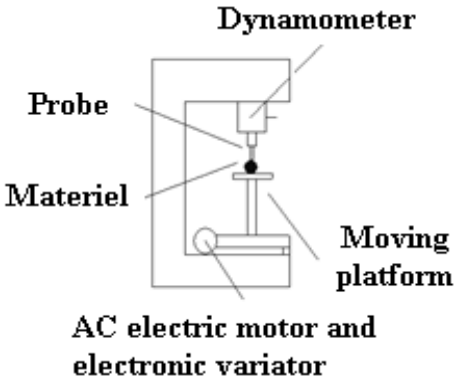

Figure 3. Biological material testing device (Aydın and Öğüt, 1991)
Şekil 3. *Biyolojik materyal test cihazı (Aydın ve Öğüt, 1991)*

Pelleting machine for both feed materials can be determined, the electrical energy consumption is measured. According to the machine capacity and its electrical energy consumption has been calculated. The hourly pellet making capacity of the pelletizing machine was determined as kg h^{-1} by collecting and weighing the pellets made in a certain time after the machine started to extract pellets and entered the regime. The electrical energy consumption of the pelletizing machine was used by a 3-phase electrical energy analyzer. By dividing the electrical energy consumption to the hourly pellet making capacity of the machine, the specific electrical energy consumption of the pellet making machine was calculated as kWh kg-1.

$$Ny = ((M\ y - M\ )/ M\ y) \times 100 \quad (1)$$

Here
Ny : Product moisture content (wb.) (%)
My : Initial weight of samples taken (g)
Mk : The weight of the samples taken after drying (g)

Pelleting machine for both feed materials can be determined, the electrical energy consumption is measured. According to the machine capacity and electrical energy consumption, its electrical energy consumption has been calculated. The hourly pellet making capacity of the pelletizing machine was determined as kg h^{-1} by collecting and weighing the pellets made in a certain time after the machine started to extract pellets and entered the regime. The electrical energy consumption of the pelletizing machine was used by a 3-phase electrical energy analyzer. The electrical energy consumption of the pellet- making machine was calculated as kWh kg^{-1} by proportioning the electrical energy consumption of the machine usage and pellet making uses.

Pellet particle density was designed by measuring the size of the resulting pellets. 15 randomly selected pellets from each pellet sample were weighed, their weights were recorded, and the pellet portion was used. Then, the diameter and length of 50 randomly selected pellets were measured with a digital caliper and the pellet volume was calculated (Eg.2). The pellet particle density was calculated as kg m^{-3} with the layers of the pellet weight to the pellet volume with the freedoms given below (Eg.3) (Adapa et al., 2006).

$$V_u = \frac{\prod d^2 \ell}{4} \quad (2)$$

$$P_u = \frac{M_u}{V_u} \quad (3)$$

In equations;
V_u : Single pellet volume (m^3)
d : Pellet diameter (m)
ℓ: Pellet length (m)
P_u : Pellet density (kg m^{-3})
M_u: Single pellet weight (kg)

Endurance resistance of the pellets is determined according to the EN 15210-1 (2009) standard. The resulting pellets completely fill the outside of a cone from a height of approximately 200-300 mm into the 5 liter container. Then, the excess pellets in the limited upper part were scraped with a flat material and the excess pellets were given as a container. The large gaps in the upper part of the container are filled. The pellet bulk density was calculated in kg m^3 with the following freedom (Eg.4).

$$Phy = \frac{M}{V} \quad (4)$$

In equality;
Phy: Pellet bulk density (kg m^{-3})
M: Pellet weight (kg)
V: Cabin net volume (m^3)

Of the pellets is determined according to the EN 15210-1 (2009) standard. The pellet samples in the body of 500 grams, which were sieved with a 4 mm round hole sieve and separated from the dust, were put into the pellet turning box and allowed to be rotated for 10 minutes. This process was repeated 3 times for each pellet sample. After the spinning process, all of the pellets were taken out and sieved again using a round perforated sieve with 4 mm diameter holes. The lifetimes of the pellets were calculated as percent (%) with the following (Eg.5)

$$Dt = \frac{M_{ilk}}{M_{son}} \quad (5)$$

In equality;
Dt : Endurance resistance (%)
M_{first} : Weight of sifted pellet before test (g)
M_{end} : Screened pellet weight after test (g)

3. Research Findings and Discussion

The lengths, diameter, weight and moisture values of the pellets obtained as a result of the trials are given in Table 3. Although the length, weight and moisture values of the pellets obtained from both feed materials reflect the patterns, the pellet diameter values were found to be the same.

Table 3. Pellet properties
Çizelge 3. *Pelet özellikleri*

Pellet properties	Mix feed	Barley
Length (mm)	21.800	22.2000
Diameter (mm)	5.000	5.000
Weight (g)	0.055	0.049
Pellet moisture (%)	13.200	13.600

As a result of the trials, the work capacity, required electrical energy consumption and spescific energy consumption values of both feed materials of the pellet making machine are given in Table 4. The work capacity of the pellet making machine in obtaining pellets from mixed feed material is less than obtaining pellets using barley.

Required electrical energy consumption and spescific energy consumption values in using barley production were also found to be higher in mixed feed pellet production. The reason for this is that the amount of corn in the mixed feed is higher and the corn has a harder structure than barley.

Table 4. Capacity and energy consumption values obtained as a result of the trials
Çizelge 4. *Denemeler sonucunda elde edilen kapasite ve güç değerleri*

Pellet properties	Mix feed	Barley
Hourly pellet making capacity (kg h^{-1})	170.000	172.800
Required electrical energy consumption (kW)	9.180	7.630
Specific energy consumption (kW kg^{-1})	0.054	0.044

As a result of the trials, the bulk density, durability, compression resistance, pellet particle density values of the pellets obtained from both feed materials are given in Table 5. The bulk density, durability, compression resistance, pellet particle density values of the pellets obtained from both feed materials as a result of the trials are given in Table 5. The bulk density and particle density of pellets obtained from barley are higher than pellets obtained from mixed feed. Larsson and Rudolfsson (2012) reached the lowest pellet moisture content and the highest pellet bulk density in the pellets they obtained from biomass materials with different moisture contents.

Durability and compression resistance in pellets obtained from mixed feed values are higher than in pellets obtained from barley. It has been concluded that the durability and compression resistance of pellets obtained from mixed feed raw materials is better than pellets made from a single raw material, due to the diversity of feed.

Abdollahi et al. (2013) found in a study that pellets of wheat-based feeds contain more crude protein because wheat proteins are of gliadin nature. and therefore more durable than corn-based ones.

Strength and compression resistance values were found to be higher in pellets obtained from mixed feed. It can be explained as the moisture value of the pellets obtained from barley is higher than the moisture value of the mixed feed pellets.

The pellets to be able to identify most of the parts obtained especially by mechanical or pneumatics , it is helpful to control the quality of the pellets by compression, and hence the quality of the pellets . Pellets with high durability in production are classified as high- quality pellets in terms of quality (Kaliyan & Morey 2009).

Table 5. Volume and particle density, durability and compression resistance values of pellets
Çizelge 5. Peletlerin hacim ve parça yoğunluğu ile dayanıklılık ve sıkıştırma direnci değerleri

Pellet properties	Mix feed	Barley
Bulk density (kg m^{-3})	505.00	507.00
Pellet particle density (kg m^{-3})	1279.00	1309.00
Durability (%)	92.30	86.00
Compression resistance (N mm^{-2})	8.57	7.47

Miranda et al. (2011) and Miranda et al. (2012) reported that pellet strength resistance decreases with greater than pellet moisture content, and the strength toughness remains between 85.83% and 97.08% depending on the type of materials used, mixing ratios, and pellet moisture content.

Çakmak (2019) reported that the durability index of pelleted feeds varied between 89.47% and 92.74%.

Gürbüz (2003) found that the durability of pellets obtained from pelletizing powdered compound feed with three different binders were 96.50%, 96.70% and 96.85%.

Pellet feeds obtained from mixed feed and barley are given in Figures 4, after trials with the pellet feed machine.

In pelleting with the pellet feed machine , it was concluded that the durability and resistance of the pellets obtained from the mixed feed raw materials (Figure 4a) compared to the pellets made from the barley raw material (Figure 4b), were better due to more feed consumption. The fact that feed storage is rich in some nutritional products increases the limitation of the pellet and increases its durability. Pellet bulk density and pellet particle density are not very different in both pellet feeds.

(A) **(B)**

Figure 4. Produced pellets; (A) Pellet from mixed feed, (B) Pellet from barley
Şekil 4. *Üretilen peletler ; (A) Karma yemden elde edilen pelet,(B) Arpadan elde edilen pelet*

The pelleting capacity is not determined in both feed raw materials, the electrical power required for the feed raw material in the mixture is 16% and the skilled power consumption is 20% higher.

4.Conclusion

The pelleting of feed materials such as barley and oats, which are found in the form of particles or powder mixtures, also allows the use of quality feeds in animal husbandry. Factors affecting the production of quality pellet feed can be explained as the physical properties of the mixed feed, the particle size of the feed raw material, the variety and proportions of the raw materials in the composition of the mixed feed, as well as the manufacturers' ignorance of the quality factor in order to provide economy. In addition to these, the pelleting technique is also one of the factors affecting the quality. Along with the raw materials to be pelleted, it is also important to choose the most suitable pellet mold for pellet feed production of the desired quality. Necessary studies should be carried out in order to produce quality pellets and to ensure the continuity of quality in an economical way.

References

Abdollahi, M. R., Ravindran, V., & Svihus, B. (2013). Pelleting of broiler diets: An overview with emphasis on pellet quality and nutritional value. *Animal feed science and technology*, *179*(1-4), 1-23. https://doi.org/10.1016/j.anifeedsci.2012.10.011

Adapa, P. K., Singh, A. K., Schoenau, G. J., & Tabil, L. G. (2006). Pellet hardness-pelleting characteristics of fractionated alfalfa grinds: Hardness models. *Powder Handling and Processing*, *18*(5), 294-299.

Aydın, C. & Ogut, H. (1991). Determination of some bio-logical properties Amaya apple and hazelnuts. *Selcuk University the Journal of Agricultural Faculty 1(1): 45-54.*

Basmacıoglu, H., (2004) Karma yem üretiminde pelet kalitesine etki eden etkenler. *Hayvansal Üretim*, *45(1):* 23-30

Boyar, S., (2006) *Karma yem sanayinde enerji verimliliğinin belirlenmesi ve iyileştirilme olanakları üzerine bir araştırma (iki fabrika örneğinde)*. (Doktora tezi, Ege Üniversitesi)

Çakmak, A., (2019) *Yem fabrikasinda üretilen pelet yemlerde pelet kalite faktörü (pkf) değerinin pelet kalitesi ve enerji tüketimine etkisinin incelenmesi.*(Yüksek Lisans Tezi, Afyon Kocatepe Üniversitesi)

Dozier, W.A. 2001. Cost-effective pellet quality for meat birds. *Feed Management,* 52 (2).

Ergül, M., (2005) Mixed feeds and mixed feed technology. *EU. Faculty of Agriculture Arrow. No: 384-İzmir*.

EN 15210-1. (2009) Solid biofuels mechanical determination durability of pellets and briquettes part 1: Pellets. https://standards.iteh.ai/catalog/standards/cen/17d0321a-8893-4e73-a941-e19e39deace9/en-15210-1-2009

Fairfield, D.A. 2003. Correct pellets die selection. *Feed International*, 6 (24): 26-30.

Gill, C. (1998). More power in pelleting: Maintaining energy efficiency despite more intensive processing. *Feed Industrial*, 24-30.

Gül, T. (2007) *Hammadde öğütme derecesi ve karıştırma müddetinin karma yem homojenitesine etkisi* (Yüksek Lisans tezi, Ege Üniversitesi)

Gürbüz, Y., Yazgan, O., & Kamalak, A. (2003). Karma Yemlerdeki Farklı Pelet Bağlayıcıların Pelet Kalitesine Etkileri. *KSÜ Fen ve Mühendislik Dergisi*, *6*(1), 160-167.

Kaliyan, N., & Morey, R. V. (2009). Factors affecting strength and durability of densified biomass products. *Biomass and Bioenergy*, *33*(3), 337-359.

Karabulut, A., Ergül, M., Ak, İ., Kutlu, H. R., & Alçiçek, A., (2000). Karma Yem Endüstrisi. *V. Türkiye Ziraat Mühendisliği Teknik Kongresi,* 17-21 Ocak, 2, 985-1008

Larsson, S. H., & Rudolfsson, M. (2012). Temperature control in energy grass pellet production–Effects on process stability and pellet quality. *Applied Energy*, *97*, 24-29. https://doi.org/10.1016/j.biombioe.2008.08.005

Lehtikangas, P. (2001). Quality properties of pelletised sawdust, logging residues and bark. *Biomass and bioenergy*, *20*(5), 351-360.

Miranda, M. T., Arranz, J. I., Román, S., Rojas, S., Montero, I., López, M., & Cruz, J. A. (2011). Characterization of grape pomace and pyrenean oak pellets. *Fuel processing technology*, *92*(2), 278-283. https://doi.org/10.1016/j.fuproc.2010.05.035

Miranda, T., Arranz, J. I., Montero, I., Román, S., Rojas, C. V., & Nogales, S. (2012). Characterization and combustion of olive pomace and forest residue pellets. *Fuel Processing*

Technology, *103*, 91-96. https://doi.org/10.1016/j.fuproc.2011.10.016

Haiba, O. N., Gümüş, E., & Küçükersen, S. (2017). Pelet yem kalitesini etkileyen faktörler. *Yem Magazin*, *25*, 80. *www.yem.org.tr/DosyaMerkezi/Dergi/yem%20magazin%20say%C4%B1%2080/80.pdf*

Tabil Jr, L., & Sokhansanj, S. (1996). Process conditions affecting the physical quality of alfalfa pellets. *Applied Engineering in Agriculture*, *12*(3), 345-350.

Tabil Jr, L. G., & Sokhansanj, S. (1997). Bulk properties of alfalfa grind in relation to its compaction characteristics. *Applied Engineering in Agriculture*, *13*(4), 499-505.

Tabil, L.G., & Sokhansanj, S. (1997). Bulk properties of alfalfa grind in relation to its compaction characteristics. *Applied Engineering in Agriculture*, 13: 499-505.

Toruk, F., (1997). *Yonca hasadında farklı hasat sistemlerinin otun kuruma olgusu ve kalitesi üzerine etkilerinin saptanması*. (Doktora Tezi, Trakya Üniversitesi)

Yalçin, S., Onbaşilar, İ., Escribano, F., Ramay, M. S., & Pirpanahi, M. (2018). Broyler büyütme yeminde sepiyolitin su ile birlikte kullanımının pelet kalitesi ve üretim parametreleri üzerine etkisi. *Veteriner Hekimler Derneği Dergisi*, *89*(1), 25-31.

Yılmaz, F.M. (2010) *Farklı seviyelerde kurutulmuş damıtık tahıl çözünürleri(ddgs) içeren rasyonların japon bıldırcınlarının (couturnixcoturn x japonico) performans özelliklerine etkisi* (Yüksek Lisans Tezi. Selçuk Üniversitesi)

Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi
Journal of Agricultural Faculty of Gaziosmanpasa University
https://dergipark.org.tr/tr/pub/gopzfd

Araştırma Makalesi/*Research Article*

JAFAG
ISSN: 1300-2910
E-ISSN: 2147-8848
(2023) 40(3) 103-114
doi:10.55507/gopzfd. 1331126

Agricultural Mechanization Level and Projection Estimation of Soil Tillage Equipment's, Drills -Fertilizer Distributors of TR22 Region

Hamide ERSOY[1*], Ebubekir ALTUNTAŞ[1]

[1]Department of Biosystems Engineering, Faculty of Agriculture, University of Tokat Gaziosmanpasa, Tokat
[*]**Corresponding author's email:** hamide.ersoy7421@gop.edu.tr:

Alındığı tarih (Received): 21.07.2023 Kabul tarihi (Accepted): 19.09.2023

Abstract: In this study, the change in agricultural mechanization level of Balıkesir and Çanakkale provinces (TR22 Region) for the last 10 years (2013-2022) was determined, and the projection estimation of soil tillage equipment, drills and fertilizer distributors was determined. The material of the study consisted of tillage equipment, drills-fertilizing machines, two-axle tractors, and total cultivated area data obtained from the Turkish Statistical Institute (TUIK). For Balıkesir and Çanakkale provinces, the level of agricultural mechanization tended to increase according to the measured parameters between the years 2013-2022, and increases were observed in the number of soil tillage equipment and drills-fertilizer distributors. According to the projection coefficient values, tractor power values are generally projected to increase between 2023-2032 in Balıkesir and Çanakkale provinces. While the number of tractors increased in both provinces, the tractor power per unit cultivated area (kW ha^{-1}) and the number of tractors per 1000 hectares (tractor 1000 ha^{-1}) increased over the years, while the cultivated area per unit tractor (ha $tractor^{-1}$) also decreased in value. These findings show that there is an improvement in agricultural mechanization level in Balıkesir and Çanakkale provinces.

Keywords: Tractor, Cultivated area, Mechanization level, Projection coefficient, Çanakkale, Balıkesir.

TR22 Bölgesinin Tarımsal Mekanizasyon Seviyesi ile Toprak İşleme ile Ekim ve Gübreleme Makinaları Projeksiyon Tahmini

Öz: Bu çalışmada, Balıkesir ve Çanakkale illerinin (TR22 Bölgesi) son 10 yıla ait (2013-2022) tarımsal mekanizasyon seviyesindeki değişimi belirlenmiş, toprak işleme ile ekim ve gübreleme makinaları projeksiyon tahmini belirlenmiştir. Çalışmanın materyalini Türkiye İstatistik Kurumu'ndan (TÜİK) alınan toprak işleme ile ekim ve gübreleme makinaları, iki akslı traktörler verileri ve toplam işlenen alan verileri oluşturmuştur. Balıkesir ve Çanakkale illerinde için, 2013-2022 yılları arasında tarımsal mekanizasyon seviyesi ise ölçülen parametrelere göre artış eğiliminde olup, toprak işleme ekipmanları ve ekim makinaları sayısında da artışlar görülmüştür. Projeksiyon katsayısı değerlerine göre, Balıkesir ve Çanakkale illerinde 2023-2032 yılları arasında traktör gücü değerlerinin genel olarak artacağı öngörülmektedir. Her iki ilde de traktör sayılarında artış görülürken, birim işlenen alana düşen traktör gücü (kW ha^{-1}) ve 1000 hektar alana düşen traktör sayısı (traktör 1000 ha^{-1}) değerleri yıllara göre artış gösterirken, birim traktöre düşen işlenen alan (ha $traktör^{-1}$) değerinde de azalışlar olmuştur. Bu bulgular, Balıkesir ve Çanakkale illerinde tarımsal mekanizasyon seviyesinde bir iyileşme olduğunu göstermektedir. Çalışma sonuçlarına göre, Çanakkale ve Balıkesir illerinde tarımsal mekanizasyonun artmasıyla, tarımsal faaliyetlerinin ve teknolojilerinin verimliliği artırma potansiyeline sahip olduğunu göstermiştir.

Anahtar Kelimeler: Traktör, İşlenen alan, Mekanizasyon seviyesi, Projeksiyon katsayısı, Çanakkale, Balıkesir

1. Introductıon

In line with the productivity and sustainability goals of the agricultural sector, the importance of agricultural mechanization is increasing day by day (Smith et al., 2020). Therefore, increasing the level of agricultural mechanization and the use of appropriate agricultural equipment provide an important transformation in modern agriculture. Agricultural mechanization aims to increase productivity through the use of technology in agricultural processes. In this way, it is possible to carry out agricultural activities more effectively and use resources more sustainably.

The selection and use of appropriate equipment and machinery influences important factors such as

productivity, production quality, and environmental sustainability in the agricultural sector. The impact of agricultural mechanization has the potential to shape future farming technologies as well as provide farmers with better practices. The projection of soil tillage equipment and drills -fertilizer distributors is an approach that aims to increase the use of technology and efficiency of agricultural operations (Johnson et al., 2018). Studies on this topic related to agricultural mechanization provide significant benefits in the agricultural sector (Chen et al., 2021).

Demir and Kuş (2016) reported that the projection on the use of agricultural technology in the Central Anatolia Region for the next 10 years was examined. They explained that these projections include the use of agricultural equipment such as combine drills, chemical fertilizer distributors, harrows, pneumatic drills, and disc ploughs. Malaslı et al. (2015) reported that estimating future mechanization projections is of great importance in terms of determining the use of machinery and creating future scenarios to guide the relevant policies. Altuntaş (2020) calculated projection coefficients for the period until 2030 based on the 11-year production and utilization amounts of agricultural tools and machinery commonly used in agricultural production in Turkey. For this purpose, the projection coefficients in 5 different groups, such as tillage, drills, fertilizer and maintenance equipment's, spraying, harvesting, and other agricultural machinery, were determined and estimated the future trends and usage amounts of agricultural mechanization in Turkey. Gül et al. (2022) examined the use of tillage and drills and the projection estimation of the agricultural mechanization level in agricultural farmers among Tokat province.

In this study, the change in the level of agricultural mechanization in Balıkesir and Çanakkale provinces (TR22 Region) for the last 10 years (2013-2022) was determined, and the projection of the use of tillage equipment, drills, and fertilizer distributors was tried to be determined. By knowing the level of mechanization in the agricultural sector, important steps will be taken to achieve productivity and sustainability targets. Determining the use and projection of mechanization in the agricultural sector has the potential to shape the future agricultural policies of farmers, agricultural machinery manufacturers, and the ministry of agricultural as stakeholders.

The TR22 Region has a special position in terms of agricultural production compared to other regions in Turkey. The TR22 Region covers the South Marmara Region of Turkey and is a region with high agricultural potential. This region is favorable for the cultivation of various agricultural products due to its climate and geographical characteristics. The TR22 region has an area of 2 426 504 hectares, which corresponds to 3.1% of Turkey's total surface area. It is seen that 75.7% of the cultivable land consists of arable land (including fallow), 6.1% of vegetable land (including under cover), 7% of fruit land, 1.4% of vineyard land, and 9.9% of olive groves (Anonymous, 2023).

As the agricultural sector, grain production, fruit and vegetable production, and animal husbandry play an important role in TR22 Region provinces, especially grain production, which is of great importance in Balıkesir and Çanakkale provinces (Anonymous, 2023). However, the TR22 Region may also face some challenges in agricultural production. Factors affecting agricultural production in the region include insufficient water resources, the need to improve irrigation infrastructure, and soil fertility problems in some regions. At the same time, soil fertility problems in some regions can also negatively affect agricultural production (ZMO, 2020). However, TR22 Region is a region with agricultural potential, and it is possible to develop more efficient and sustainable agricultural practices with the right strategies, technological developments, and investments (Anonymous, 2013).

Machinery used in agricultural production depends on many factors affecting crop yield. These include machine capacity, tractor or agricultural machinery compatibility, land conditions, parcel size, soil and climate characteristics, crop pattern, production techniques, and trained manpower (Yıldız and Erkmen, 2004). Studies to determine the projection of tillage machines, drills, and fertilizer distributors can contribute to the development of policies on agricultural productivity. And also, the correct use of mechanization in the agricultural sector, the development of new technologies with the selection of appropriate equipment, and the benefits of the use of precision drill systems in agricultural production.

In this study, the change in the level of agricultural mechanization in Balıkesir and Çanakkale provinces (TR22 Region) for the last 10 years (2013-2022) was determined, and the projection of the use of tillage, drills, and fertilization machines was tried to be determined.

2. Material and Method

This study was conducted using the data on agricultural machinery from the Turkish Statistical Institute for the last 10 years, 2013-2022. These data

were analyzed based on the production and usage amounts for the TR22 region. The percentage increase and decrease values of the numbers obtained were calculated, and the average coefficients of these percentage changes were found. The South Marmara Region consisting of Balıkesir (TR221) and Çanakkale (TR222) provinces, is called TR22 Level 2 Region (GMKA, 2023). Balıkesir Province is situated in the southeastern part of the Marmara Region. It has a coastline along the Aegean Sea. In contrast, Çanakkale Province is located in the southern part of the Marmara Region, with coastlines along both the Aegean and Marmara Seas. Both provinces are located within the Marmara Region and are influenced by the Mediterranean climate, they have highly fertile areas for agriculture. Balıkesir Province, being closer to the Aegean Region, it has the agricultural products typical of the Aegean area. On the other hand, Çanakkale Province has more characteristics of the Marmara Region in its agricultural practices. Çanakkale Province holds a strategic position due to its location along the route of the Dardanelles Strait, making it essential for transportation and trade. In contrast, Balıkesir Province is situated further inland and does not have the same maritime significance (Anonymous, 2023a).

Table 1. Soil cultivation, drills and fertilization machinery used in calculations.
Çizelge 1. *Hesaplamalarda kullanılan toprak işleme, ekim ve gübreleme makinaları.*

Mouldboard plough	Toothed harrow
Stubble plough	Lister
Cultivator	Roller
Combined harrows	Earth auger
Horizontal axis rotary cultivators	Chemical fertilizer distributors
Vertical axes Rotary cultivators	Direct seed drills
Subsoiler	Combined seed drills
Disc Harrow	Pneumatic precision drills
Disc Stubble Plough (One way)	Trailed seed drills
Disc plough	Universal drills (including beet drills)

The agricultural mechanization level of Balıkesir and Çanakkale provinces was determined by the chain index method using data for the period 2013-2022 (Gül et al., 2022). The projection coefficient expresses the change in the number of existing machine. A positive (+) projection coefficient indicates that the number of existing tools and machinery has increased, while a negative (-) projection coefficient indicates that the number of existing tools and machinery has decreased (Demir et al., 2013). In this study, the change in the agricultural mechanization level of Balıkesir and Çanakkale provinces for the last 10 years (2013-2022) was determined, and the projection of tillage equipment and drills and fertilizer distributor usage was determined.

In the projection calculations in this study, the machines listed in Table 1 were considered, while in Table 2, tractors are divided into six groups according to their power values, and the average power values given in the calculation of the total power value are given (Kuzu et al., 2021).

Table 2. Average power groups of two axle tractors*
Çizelge 2. *İki akslı traktörlerin ortalama güç grupları**

Tractor powers groups (HP)	Average power of groups (HP)
> 70	85.5
51-70	60.5
35-50	42.5
25-34	29.5
11-24	17.5
1-10	5.5

*(Kuzu et al., 2021)

To indicate the average power values of the tractor groups, HP unit is used. Each tractor group has a certain power range, and these power values are given as average in Table 2. The mechanization level in Balıkesir and Çanakkale provinces has been assessed according to certain criteria for each year from 2013 to 2022, including the last 10 years. This assessment is based on total cultivated area, total tractor power and number of tractors. The criteria used to determine the mechanization level of the region are as follows:

a) Average tractor power (kW),

b) Number of tractors per unit agricultural area (tractor 1000 ha^{-1}),

c) Agricultural area per tractor (ha $tractor^{-1}$),

d) Tractor power per cultivated area (kW ha^{-1}).

The level of mechanization in Balıkesir and Çanakkale provinces was determined for each year by using these criteria.

3. Results and Discussion

Table 3 presents the total cultivated area of Balıkesir and Çanakkale provinces, which include the TR22 region, and the change in the last 10 years (2013-2022) and the projection estimates for the next 10 years (2023-2032). In Table 3, based on the projection coefficients, it is seen that the total cultivated area of Balıkesir province decreased by 7.80% and that of Çanakkale province increased by 7.82% between 2013 and 2022. According to the same projection coefficients, Balıkesir province is assumed to decrease by 7.73% and Çanakkale province is assumed to increase by 7.86% by 2022.

The number of tractors in TR22 provinces for the years 2013-2022 and the estimated number of tractors for the years 2023-2032 are given in Tables 4 and 5. In 2013, the number of 1-10 HP tractors, the lowest power group, was 290, while the number of more than 70 HP tractors, the highest power group, was 2770. In 2022, the number of 1-10 HP tractors increased to 507 and the number of more than 70 HP tractors to 5706. According to projection coefficients, increases in tractor assets are expected in Balıkesir province in the 2023-2032 period. In this period, the increase in >70 HP tractors, which is the highest power group, was higher compared with other groups. In 2022, the number of 35-50 HP and 51-70 HP tractors is observed to be higher with 32564 and 17543, respectively. According to the projection estimation in 2032, the number of 1-10 HP tractors is expected to reach 1081 and the number of more than 70 HP tractors is expected to reach 14435.

For Çanakkale province, while there was a decrease in 1-10 HP power groups between 2013- 2022, there was an increase in 11-24 HP, 25-34 HP, 35-50 HP, 51-70 HP and more than 70 HP groups. In 2013, the number of tractors in the lowest power group of 1-10 HP was 94, while the number of tractors in the highest power group of more than 70 HP was recorded as 2060. In 2022, while the number of 1-10 HP tractors was 74, the number of more than 70 HP tractors increased to 3933.

According to the projection coefficients, increases are expected in tractor assets in Çanakkale province in the 2023-2032 period, except for 1-10 HP tractors. In this period, the rate of increase in more than 70 HP tractors, which is the highest power group, is estimated to be higher compared to other power groups. In 2032, according to the projection estimate, the number of 35-50 HP and 51-70 HP tractors is expected to reach 10566 and 13528, respectively, while the number of more than 70 HP tractors is expected to reach 8576. In general, according to the projection coefficient values, while an increase is expected in tractor power groups in Balıkesir in the 2023-2032 period, a decrease is expected in Çanakkale, especially in the 1-10 HP power group.

The mechanization level indicators calculated using the total number of tractors, tractor power, and area cultivated data in TR22 provinces, the values obtained for the years 2013-2022, and the estimated values for the years 2023-2032 are given in Tables 6 and 7.

According to the tractor power and mechanization level values of Balıkesir province for the period 2013-2022 and projection estimates covering the period 2023-2032, tractor power in the province has continuously increased. Mechanization level indicators such as kW ha^{-1}, tractor 1000 ha^{-1}, and ha/tractor values have changed throughout the period. In the period 2013-2022, total tractor power in Balıkesir increased from 1 450 094.80 kW in 2013 to 2 226 270.83 kW in 2022 due to an increase in total tractor power. Mechanization level indicators are expressed as average tractor power, kW ha^{-1}, tractor 1000 ha^{-1} and ha/tractor, and these values have varied throughout the period.

According to the projection coefficients, tractor power is projected to continue to increase in Balıkesir province in the 2023-2032 period. For example, tractor power is expected to reach 2 367 686.03 kW in 2023 and 4 121 346.68 kW in 2032. Mechanization level indicators also show an upward trend in general. Considering these data, it is seen that agricultural mechanization plays an important role in Balıkesir province and tractor power is continuously increasing. This can be considered as a positive development in terms of increasing technology use and productivity in the agricultural sector.

The tractor power and mechanization level indicators of Çanakkale province obtained between 2013 and 2022 and the values estimated for 2023-2032 are shown in Table 7.

Table 3. The cultivated areas according to the provinces of the TR22 region and the 2023-2032 projection.
Çizelge 3. *TR22 bölgesi illerine göre işlenen alanlar ve 2023-2032 projeksiyonu.*

Years	Balıkesir	Çanakkale
	Total cultivated area (ha)	**Total cultivated area (ha)**
2013	423 931.58	278 723.90
2014	420 758.56	284 373.00
2015	411 122.86	287 954.10
2016	413 125.27	290 747.90
2017	407 126.27	288 898.20
2018	393 635.57	291 553.20
2019	388 024.87	292 515.90
2020	390 253.55	297 206.20
2021	391 123.65	302 173.20
2022	390 873.25	300 520.40
Projection Coefficient	-0.007	0.008
2023	387 394.79	303 057.13
2024	383 947.28	305 615.27
2025	380 530.45	308 195.00
2026	377 144.03	310 796.51
2027	373 787.75	313 419.98
2028	370 461.33	316 065.60
2029	367 164.52	318 733.55
2030	363 897.05	321 424.01
2031	360 658.65	324 137.19
2032	357 449.08	326 873.27

Table 4. The tractor inventory and the change between 2013-2022, as well as the projected estimation for 2023-2032 based on the power groups in Balıkesir province.
Çizelge 4. *Balıkesir ilinin güç gruplarına göre traktör varlığı ve 2013-2022 değişimi, 2023-2032 projeksiyon tahmini.*

Years	Tractor power groups HP					
	1-10	11-24	25-34	35-50	51-70	>70
2013	290	814	1527	23468	11182	2770
2014	314	813	1501	22902	11344	2821
2015	320	793	1480	21896	11511	3047
2016	331	782	1508	21813	12005	3124
2017	329	778	1503	21714	12118	3173
2018	330	782	1488	21582	12222	3276
2019	327	777	1488	21446	12268	3327
2020	535	1260	2435	34744	20062	5472
2021	506	1253	2395	34104	19453	5436
2022	507	1235	2376	32564	17543	5706
Projection Coefficient	0.079	0.062	0.065	0.052	0.067	0.097
2023	547	1311	2531	34256	18714	6261
2024	590	1392	2696	36037	19963	6870
2025	636	1478	2872	37910	21295	7538
2026	686	1569	3059	39880	22716	8271
2027	740	1666	3258	41952	24232	9076
2028	799	1769	3471	44133	25850	9958
2029	861	1878	3697	46426	27575	10927
2030	929	1994	3938	48839	29415	11990
2031	1002	2117	4194	51377	31378	13156
2032	1081	2248	4468	54047	33472	14435

Table 5. The tractor inventory and the change between 2013-2022, as well as the projected estimation for 2023-2032 based on the power groups in Çanakkale province.
Çizelge 5. *Çanakkale ilinin güç gruplarına göre traktör varlığı ve 2013-2022 değişimi, 2023-2032 projeksiyon tahmini.*

Years	Tractor power groups HP					
	1-10	11-24	25-34	35-50	51-70	>70
2013	94	236	1591	9316	9441	2060
2014	76	248	1582	8966	9683	2939
2015	74	257	1589	9068	10219	3294
2016	74	257	1588	9094	10722	3495
2017	73	257	1588	9101	10874	3632
2018	66	261	1594	9450	10775	3522
2019	66	266	1609	9494	10696	3702
2020	70	282	1660	9679	10862	3794
2021	71	281	1638	9765	11005	3837
2022	74	279	1616	9880	11184	3933
Projection Coefficient	-0.023	0.019	0.002	0.007	0.019	0.081
2023	72	284	1619	9947	11399	4252
2024	71	290	1622	10013	11618	4597
2025	69	295	1625	10081	11841	4969
2026	67	301	1628	10149	12069	5372
2027	66	307	1631	10217	12300	5808
2028	64	312	1634	10286	12537	6279
2029	63	318	1637	10355	12778	6788
2030	61	324	1640	10425	13023	7338
2031	60	331	1643	10495	13273	7933
2032	58	337	1646	10566	13528	8576

According to Table 7, tractor power in Çanakkale province has increased over the years and reached 1 092 075.70 kW in 2022. Looking at the mechanization level indicators, kW ha^{-1}, tractor 1000 ha^{-1} values have increased between 2013 and 2017, and the mechanization level indicators in 2022 is calculated as 3.63 kW ha^{-1}, 89.73 tractor 1000 ha^{-1} and 11.14 tractors per ha.

According to the projection coefficient values, tractor power and mechanization level values are generally projected to increase between 2023 and 2032 in Çanakkale province. For example, in 2032, tractor power is estimated to be 1 393 201.86 kW, as an indicator of the mechanization level, tractor power per

unit cultivated area will be 4.26 kw/ha, the number of tractors per 1000 ha agricultural area will be 99.81, and the unit cultivated area per tractor will be 10.03 ha/tractor. Based on these data, it is predicted that the use of tractors will increase in Çanakkale province and there will be improvements in the level of mechanization.

Table 6. The projection estimates covering the period of 2023-2032 for Balıkesir province include the tractor power and mechanization level values from 2013-2022.
Çizelge 6. *Balıkesir ilinin 2013-2022 dönemindeki traktör gücü ve mekanizasyon seviyesi değerleri ile 2023-2032 dönemini kapsayan projeksiyon tahminleri.*

Years	**Total Tractor power (kW)**	**Mechanization level indicators**			
		Average Tractor power (kW)	**kW ha^{-1}**	**tractor 1000 ha^{-1}**	**ha tractor^{-1}**
2013	1 450 094.80	36.21	3.42	94.48	10.58
2014	1 442 314.18	36.33	3.43	94.34	10.60
2015	1 431 731.97	36.67	3.48	94.98	10.53
2016	1 456 460.46	36.81	3.53	95.77	10.44
2017	1 461 292.67	36.89	3.59	97.30	10.28
2018	1 467 968.19	37.00	3.73	100.80	9.92
2019	1 468 876.42	37.06	3.79	102.14	9.79
2020	2 393 704.58	37.11	6.13	165.30	6.05
2021	2 343 239.63	37.11	5.99	161.45	6.19
2022	2 226 270.83	37.15	5.70	153.33	6.52
Projection Coefficient	0.064	0.003	0.072	0.069	-0.042
2023	2 367 686.03	37.25	6.11	163.95	6.24
2024	2 518 084.08	37.36	6.55	175.31	5.98
2025	2 678 035.57	37.47	7.02	187.46	5.73
2026	2 848 147.37	37.57	7.53	200.45	5.48
2027	3 029 064.85	37.68	8.07	214.34	5.25
2028	3 221 474.42	37.79	8.66	229.19	5.03
2029	3 426 106.05	37.90	9.28	245.08	4.81
2030	3 643 736.12	38.01	9.95	262.06	4.61
2031	3 875 190.28	38.11	10.67	280.22	4.41
2032	4 121 346,68	38,22	11,44	299,63	4,23

Table 7. The projection estimates covering the period of 2023-2032 for Çanakkale province include the tractor power and mechanization level values from 2013-2022.
Çizelge 7. *Çanakkale ilinin 2013-2022 dönemindeki traktör gücü ve mekanizasyon seviyesi değerleri ile 2023-2032 dönemini kapsayan projeksiyon tahminleri.*

Years	Total Tractor power (kW)	Mechanization level indicators			
		Average Tractor power (kW)	kW ha^{-1}	tractor 1000 ha^{-1}	ha tractor^{-1}
2013	878 630.91	38.64	3.15	81.58	12.26
2014	933 335.22	39.73	3.28	82.62	12.10
2015	982 861.39	40.12	3.41	85.09	11.75
2016	1 018 625.10	40.37	3.50	86.78	11.52
2017	1 034 178.99	40.52	3.58	88.35	11.32
2018	1 033 959.30	40.28	3.55	88.04	11.36
2019	1 043 468.78	40.39	3.57	88.31	11.32
2020	1 063 732.34	40.37	3.58	88.65	11.28
2021	1 074 993.50	40.42	3.56	88.02	11.36
2022	1 092 075.70	40.50	3.63	89.73	11.14
Projection Coefficient	0.025	0.005	0.016	0.011	-0.010
2023	1 118 996.87	40.71	3.69	90.69	11.03
2024	1 146 581.69	40.93	3.75	91.66	10.91
2025	1 174 846.52	41.14	3.81	92.64	10.80
2026	1 203 808.11	41.36	3.87	93.64	10.69
2027	1 233 483.64	41.58	3.94	94.64	10.57
2028	1 263 890.72	41.80	4.00	95.65	10.46
2029	1 295 047.37	42.02	4.06	96.68	10.35
2030	1 326 972.08	42.24	4.13	97.71	10.25
2031	1 359 683.78	42.46	4.19	98.76	10.14
2032	1 393 201.86	42.68	4.26	99.81	10.03

Table 8. The numbers (quantities) of soil tillage machinery in Balıkesir province for the period of 2013-2022 and the projection for the years 2023-2032.

Çizelge 8. *Balıkesir ilinin 2013-2022 dönemindeki toprak işleme makinaları sayıları (adet) ve 2023-2032 yılları için projeksiyonu.*

Years	Lister	Subsoiler	Disc stubble Plough (One-way)	Disc Harrow	Disc plough	Toothed Harrow	Combined harrow
2013	1321	1472	370	3876	442	11135	555
2014	1326	1499	377	3764	459	11156	551
2015	1322	1561	378	3676	480	11093	553
2016	1371	1594	376	3753	499	11152	555
2017	1378	1608	379	3744	502	11187	558
2018	1387	1625	388	3780	520	11231	574
2019	1407	1628	388	3797	542	11226	569
2020	1420	1671	408	3787	549	11243	603
2021	1465	1725	406	3903	569	11268	635
2022	1466	1667	406	3928	579	11122	647
Projection Coefficient	0.012	0.014	0.011	0.002	0.031	0.000	0.017
2023	1483	1691	410	3934	597	11121	658
2024	1501	1714	415	3941	615	11119	670
2025	1518	1739	419	3947	634	11118	681
2026	1536	1763	423	3954	653	11117	693
2027	1554	1788	428	3960	673	11116	705
2028	1572	1813	432	3967	694	11114	718
2029	1591	1839	437	3973	715	11113	730
2030	1609	1865	441	3980	737	11112	743
2031	1628	1891	446	3986	759	11110	756
2032	1647	1918	451	3993	782	11109	769

Table 8 (Continue). The numbers (quantities) of soil tillage machinery in Balıkesir province for the period of 2013-2022 and the projection for the years 2023-2032.

Çizelge 8 (Devamı). *Balıkesir ilinin 2013-2022 dönemindeki toprak işleme makinaları sayıları (adet) ve 2023-2032 yılları için projeksiyonu.*

Years	Mouldboard Stubble plough	Mouldboard plough	Cultivator	Roller	Earth auger	Horizontal axis rotary cultivators	Vertical axis Rotary cultivators
2013	1074	37344	19611	477	89	175	993
2014	1082	36893	19672	462	89	178	1072
2015	1179	36264	19598	480	92	207	1130
2016	1175	36308	19820	494	92	286	1175
2017	1209	35597	19829	502	100	291	1232
2018	1213	35794	19949	519	103	302	1249
2019	1214	35968	20115	546	110	309	1276
2020	1623	36197	20187	559	117	329	1310
2021	1642	36974	20649	588	126	348	1396
2022	1545	37014	20893	616	148	354	1486
Projection Coefficient	0.046	-0.001	0.007	0.029	0.059	0.087	0.046
2023	1616	36980	21041	634	157	385	1554
2024	1691	36947	21190	652	166	418	1626
2025	1769	36913	21340	671	176	454	1701
2026	1851	36880	21492	691	186	494	1779
2027	1937	36846	21644	711	197	536	1861
2028	2027	36812	21797	732	209	583	1947
2029	2120	36779	21952	753	222	633	2036
2030	2218	36746	22107	775	235	688	2130
2031	2321	36712	22264	798	249	748	2228
2032	2428	36679	22422	821	263	813	2330

The current status of the number of tillage machines used in TR22 provinces for the years 2013- 2022 and the estimated values for the next 10 years for the years 2023-2032 are given in Tables 8 and 9. According to Table 8, the fact that the number of soil tillage machines in Balıkesir province increased slightly in 2022 (81871) compared to 2013 (78934) shows the efficiency of soil tillage activities in agricultural production. Among the tillage equipment used in the agricultural sector in Balıkesir, the ones with the highest rate of increase are disc plough, soil auger, mouldboard tractor plough, and horizontal axis rotary cultivators. These equipments cover the equipment used for primary tillage in agricultural lands. There are small decreases in the number of mouldboard ploughs, while there is a noticeable increase in other equipment in general.

Table 9 shows a significant increase in the number of tillage machines in Çanakkale province in 2022 (64043) compared with 2013 (62874). For Çanakkale province in general, among the increases in the use of many tillage equipment between 2013 and 2022, significant increases were recorded especially in equipment such as mouldboard plough, cultivator and disc harrow. Although the number of mouldboard ploughs is the highest in Çanakkale province according to 2022 data, when the change between 2013 and 2022 is analyzed, fluctuations and partial decreases are observed, while there is a large increase in equipment such as subsoilers, mouldboard stubble ploughs, and Horizontal axis rotary cultivators. The number of subsoilers increased from 421 in 2013 to 1064 in 2022, an increase of 152.02%. This shows that the use of subsoilers has increased in agricultural lands in order to prevent the formation of soil stones, increase soil fertility and ensure healthier development of plant roots. Mouldboard stubble plough increased by 400% from 32 units in 2013 to 160 units in 2022. Stubble plough increases organic matter content and improves the soil structure by mixing plant residues left in the field into the soil. The increasing number of mouldboard stubble ploughs is the result of the adoption of sustainable agricultural practices and efforts to increase soil fertility. Horizontal axis rotary cultivators increased by 584.75%, from 59 in 2013 to 403 in 2022. Horizontal axis rotary cultivators aerate the soil, help plant roots to develop better and facilitate the soil preparation process. These increases agree with the goals of increasing productivity in agricultural activities, improving soil fertility, and transition to sustainable agricultural methods. In the study by Malaslı et al. (2015), there was a significant increase in the number of second-class tillage implements, indicating that farmers in the region have an increasing awareness of soil conservation.

Table 9. The numbers (quantities) of soil tillage equipments in Çanakkale province for the period of 2013-2022 and the projection for the years 2023-2032.
Çizelge 9. *Çanakkale ilinin 2013-2022 dönemindeki toprak işleme ekipmanları sayıları (adet) ve 2023-2032 yılları için projeksiyonu.*

Years	Lister	Subsoiler	Disc stubble plough (One-way)	Disc Harrow	Disc Plough	Toothed Harrow	Combined harrow
2013	1033	421	571	8637	671	11009	87
2014	962	988	700	8368	709	10819	260
2015	970	1004	709	8455	707	10995	279
2016	1007	1021	723	8635	707	11146	285
2017	1013	1033	724	8701	715	11255	288
2018	1006	1032	736	8653	720	11394	284
2019	1008	1043	752	8660	693	11451	299
2020	1010	1034	758	8560	698	11453	306
2021	1012	1036	757	8479	711	11681	313
2022	1005	1064	772	8491	699	11682	326
Projection Coefficient	-0.003	0.158	0.036	-0.002	0.005	0.0067	0.247
2023	1002	1232	800	8476	702	11760	406
2024	1000	1427	829	8461	706	11838	507
2025	997	1652	859	8445	709	11917	632
2026	994	1913	890	8430	713	11997	788
2027	992	2215	922	8415	716	12077	982
2028	989	2565	955	8400	720	12157	1224
2029	986	2970	989	8385	723	12239	1526
2030	984	3440	1025	8370	727	12320	1903
2031	981	3983	1062	8355	730	12402	2372
2032	978	4612	1100	8340	734	12485	2957

Table 9 (Continue). The numbers (quantities) of soil tillage machinery in Çanakkale province for the period of 2013-2022 and the projection for the years 2023-2032.

Çizelge 9 (Devamı). *Çanakkale ilinin 2013-2022 dönemindeki toprak işleme makinaları sayıları (adet) ve 2023-2032 yılları için projeksiyonu.*

Years	Moulboard Stubble plough	Mouldboard plough	Cultivator	Roller	Earth auger	Horizontal axis rotary cultivators	Vertical axis Rotary cultivators
2013	32	29458	9497	850	130	59	419
2014	126	27865	9367	826	124	299	540
2015	130	27997	9486	841	129	321	572
2016	127	28113	9614	857	132	343	598
2017	126	28226	9676	846	141	375	651
2018	127	27947	9636	865	174	379	674
2019	132	27602	9739	891	189	380	721
2020	139	27587	9838	916	230	387	745
2021	142	27473	10182	936	240	394	771
2022	160	27275	10189	942	245	403	790
Projection Coefficient	0.354	-0.008	0.008	0.012	0.076	0.486	0.076
2023	217	27047	10270	953	264	599	850
2024	293	26821	10351	964	284	890	914
2025	397	26596	10433	975	306	1323	983
2026	538	26374	10516	987	329	1966	1057
2027	728	26153	10599	998	354	2922	1137
2028	986	25934	10683	1010	381	4343	1223
2029	1336	25717	10768	1022	410	6454	1315
2030	1809	25502	10853	1034	441	9593	1415
2031	2449	25289	10939	1046	475	14257	1522
2032	3316	25077	11026	1058	511	21188	1637

Table 10. The numbers (quantities) of drills and fertilizer distributors in Balıkesir province for the period of 2013-2022 and the projection for the years 2023-2032.

Çizelge 10. *Balıkesir ilinin 2013-2022 dönemindeki ekim makinaları ve gübre dağıtma sayıları (adet) ve 2023-2032 projeksiyonu.*

Years	Direct seed drills	Combined seed drills	Pneumatic precision drills	Trailed seed drills	Chemical fertilizer distributors	Universal seed drills (including beet drills)
2013	44	1945	350	2770	7744	1947
2014	44	1966	380	2797	7819	1953
2015	45	1971	402	2832	7989	1947
2016	46	2011	459	2825	9111	1649
2017	48	2023	469	2833	9178	1652
2018	55	2064	505	2838	9324	1654
2019	53	2092	524	2887	9395	1658
2020	54	2123	558	2929	9453	1683
2021	65	2151	633	2987	9453	1707
2022	86	2343	703	2815	9576	1685
Projection Coefficient	0.083	0.021	0.081	0.002	0.025	-0.015
2023	93	2393	760	2821	9812	1660
2024	101	2443	822	2827	10054	1636
2025	109	2495	889	2832	10302	1612
2026	118	2548	961	2838	10556	1589
2027	128	2602	1039	2844	10816	1566
2028	138	2657	1123	2850	11083	1543
2029	150	2713	1215	2856	11356	1520
2030	162	2771	1314	2861	11636	1498
2031	176	2830	1420	2867	11923	1476
2032	190	2890	1536	2873	12217	1455

It is observed that the number of drills and fertilizer distributors has increased over the years in Balıkesir province (Table 10). The number of stubble seeders increased from 44 to 86 between 2013 and 2022; the number of combined seed drills increased from 1945 to 2343; and the number of pneumatic precision drills increased from 350 to 703 between 2013 and trailed seed drills. This is an important indicator of productivity in agricultural areas and faster and more efficient sowing operations. According to 2023-2032 projection coefficients, the use of agricultural equipment in Balıkesir is expected to continue to increase in general.

Significant increases are expected, especially in the amount of equipment such as direct seed drills, combined seed drills, and pneumatic precision seedersTable 11 shows a certain increase and change in the use of drills and fertilizer distributors in Çanakkale province. A significant increase in the amount of equipment such as direct seed drills, combined seed drills, and pneumatic precision drills was observed. In particular, combined seed drills have great importance in grain sowing. In addition, pneumatic precision drills are preferred equipment due to their precise seed distribution. The increase in the number of this equipment reflects the trend toward more precise and effective seed sowing in agriculture.

Table 11. The numbers (quantities) of drills and fertilizer distributors in Çanakkale province for the period of 2013-2022 and the projection for the years 2023-2032.
Çizelge 11. *Çanakkale ilinin 2013-2022 dönemindeki ekim makinaları sayıları (adet) ve 2023-2032 projeksiyonu.*

Years	Direct seed drills	Combined seed drills	Pneumatic precision drills	Trailed seed drills	Chemical fertilizer distributors	Universal seed drills (including beet drills)
2013	1	3546	403	1897	9164	1675
2014	25	3669	460	1910	9541	1673
2015	26	3675	469	1913	9649	1677
2016	25	3690	496	1948	9824	1689
2017	25	3696	508	1969	9978	1693
2018	24	3722	530	1963	10060	1695
2019	23	3744	542	1976	10159	1694
2020	22	3771	555	1981	10145	1696
2021	20	3785	568	1981	10258	1688
2022	20	3863	571	1987	10248	1676
Projection Coefficient	2.643	0.010	0.040	0.005	0.013	0.0001
2023	73	3900	594	1997	10377	1676
2024	265	3938	618	2008	10507	1676
2025	967	3975	643	2018	10639	1676
2026	3 522	4014	668	2029	10773	1676
2027	12 830	4052	695	2039	10908	1677
2028	46 737	4091	723	2050	11046	1677
2029	170 256	4131	752	2060	11184	1677
2030	620 216	4170	782	2071	11325	1677
2031	2 259 341	4210	814	2082	11467	1677
2032	8 230 400	4251	846	2092	11611	1677

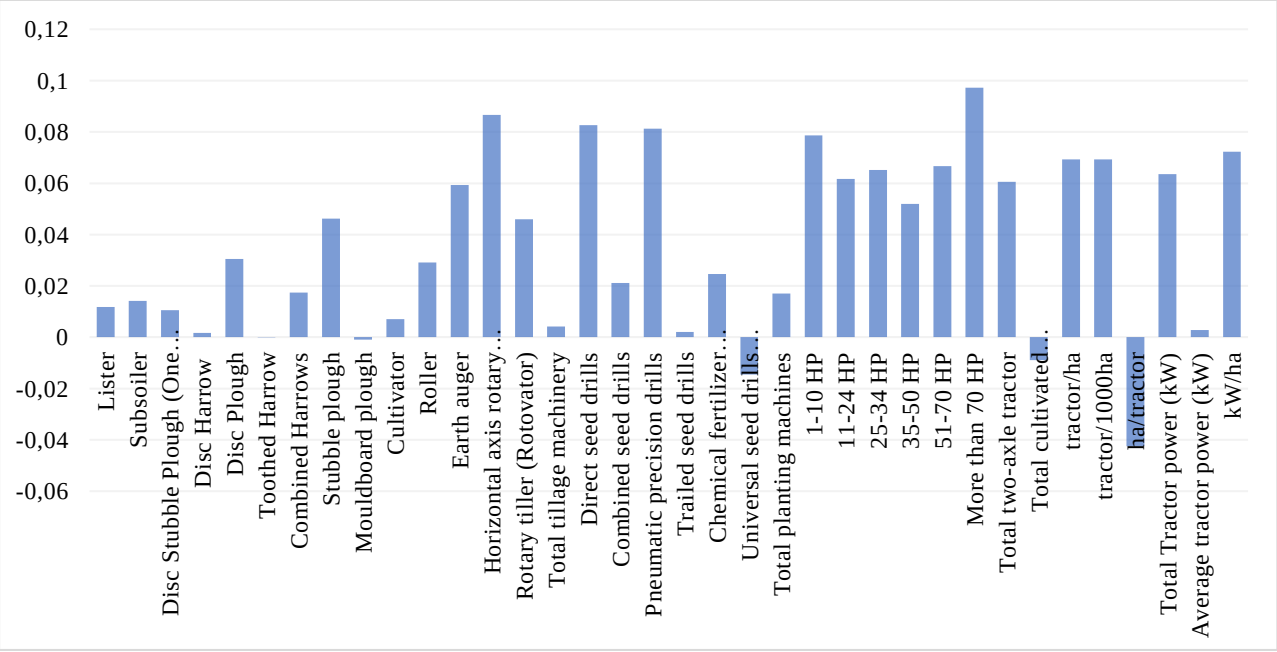

Figure 1. The change in the projection coefficients of two-axle tractors, indicators of agricultural mechanization level, and agricultural equipment machinery for Balıkesir province.
Şekil 1. *Balıkesir iline ait, iki akslı traktörler, tarımsal mekanizasyon düzeyi göstergeleri ile tarım alet makinalarının projeksiyon katsayıları değişimi.*

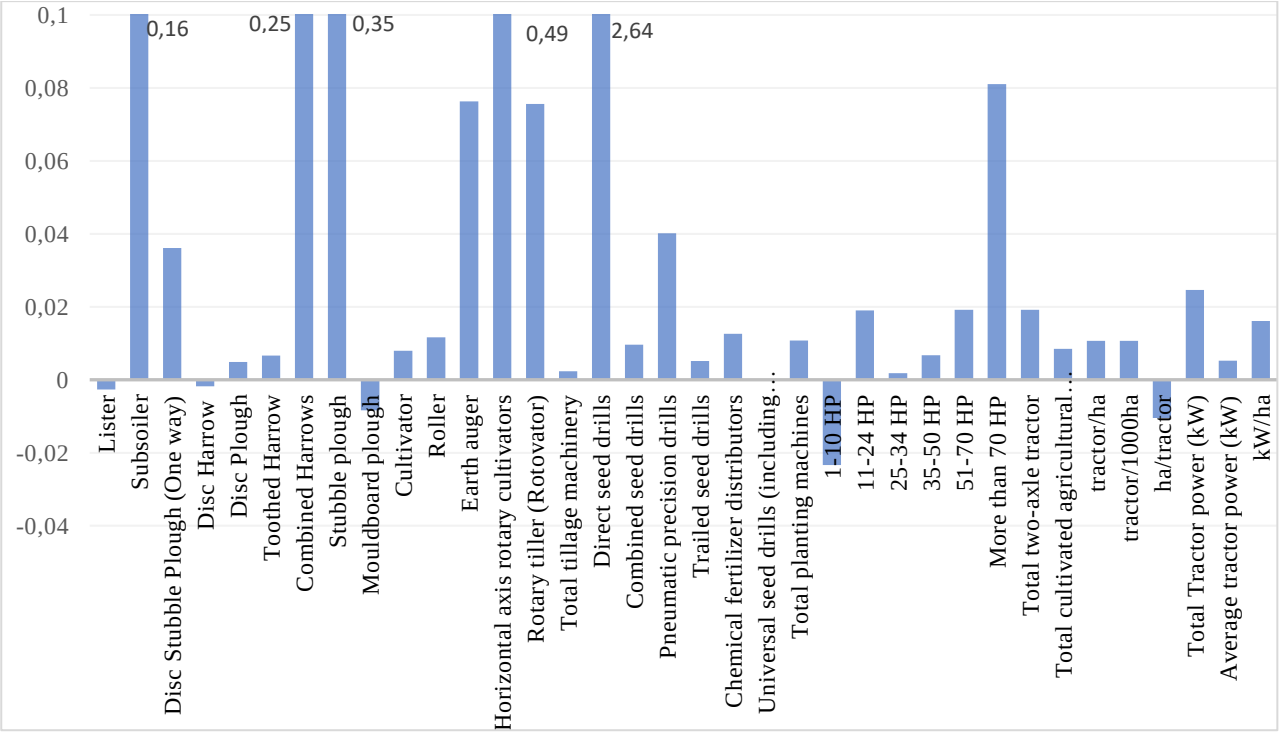

Figure 2. The change in the projection coefficients of two-axle tractors, indicators of agricultural mechanization level, and agricultural equipment machinery for Çanakkale province.
Şekil 2. *Çanakkale için iki akslı traktörlerin ve mekanizasyon düzeyi göstergeleri ile tarım alet makinalarının, projeksiyon katsayıları değişimi.*

In Çanakkale province, while the number of direct seed drills was 1 in 2013, it increased to 20 in 2022. In this period, an increase was observed in the use of broadcast seeding machines. The number of combined grain seeders increased from 3546 in 2013 to 3863 in 2022. This shows an increase in the amount of equipment used in grain cultivation. Increases were also observed in the number of pneumatic precision drills and trailed seed drills. In general, no significant change was observed in the number of universal seed drills, trailed seed drills.

For Çanakkale province, there is a general increase in the equipment used in agricultural practices such as sowing, fertilization, and other agricultural operations. These increases indicate that modern agricultural techniques and efficiency are being adopted and the agricultural sector is developing. This trend is expected to continue in the coming years.

In Figure 1 and Figure 2, the projection coefficients of two-axle tractors, mechanization level indicators, and agricultural machinery for Balıkesir and Çanakkale provinces are presented and compared together with their changes.

4. Conclusion

In this study, data obtained from the Turkish Statistical Institute (TUİK) were used to determine the agricultural mechanization level of Balıkesir and Çanakkale provinces. These data include important indicators such as the number of soil tillage equipment and drills-fertilizer distributors, cultivated area, and number of tractors.

In this study, we examined the change in the presence of tillage and drills and fertilizer distributors in Balıkesir and Çanakkale provinces during the last 10 years 2013-2022 and analyzed the number of tractors and agricultural mechanization level indicators.

The study made forecasts using projection coefficients for the next decade. These forecasts predict the expected change in the level of agricultural mechanization in Balıkesir and Çanakkale provinces. The results characterize the level of agricultural mechanization and its numerical change in the region. The use of tillage machinery, drills, and fertilizer distributors in the agricultural sector for TR22 provinces has a dynamic structure.

Analyses based on numerical data emphasize how equipment preferences in agricultural production have changed over time and the importance of supporting this change with agricultural policies. These data can be used as a guide in determining the future directions of the agricultural sector in Balıkesir and Çanakkale provinces. According to the findings of the study, agricultural mechanization in the TR22 region has made

significant progress between 2013 and 2022.

Moreover, increases were observed in indicators such as tractor power, average tractor power, and tractor power per hectare area. The increase in the number of soil tillage equipments, drills, and tractors indicates that agricultural mechanization in the region has improved technologically and productivity has increased. Future projections indicate that agricultural mechanization will further improve in the TR22 region.

The difference in the number of agricultural machinery between Balıkesir and Çanakkale provinces, in light of the economic difficulties that started in Turkey in 2018 and continued into 2019, can be attributed to several potential factors. Firstly, the types of crops grown in each region might differ, with Balıkesir possibly specializing in more resilient and diverse agricultural products, ensuring a continuous demand for machinery and thus maintaining stable numbers. Secondly, the size of agricultural operations could vary, with Balıkesir possibly hosting larger farms that tend to employ more mechanization, potentially preventing a decline in the number of agricultural machines. Additionally, differences in export opportunities, government policies and support, labor availability, and climate conditions might all play roles in influencing the resilience of the agricultural machinery sector in these two provinces. Further detailed analysis would be necessary to pinpoint the exact reasons for this disparity.

Estimates using the chain index method predict that the number of soil tillage equipment, drills, and tractors will continue to increase. This will make the agricultural production more efficient and sustainable. However, according to the results of the study, there are some challenges for further development of agricultural mechanization in the TR22 region.

Factors such as insufficient water resources, the improvement of irrigation infrastructure, and soil fertility problems may limit the effective use of agricultural mechanization. Therefore, strategic planning for the development of agricultural mechanization in the region requires technological investments and infrastructure development.

Finally, it has been shown that agricultural activities and technologies can increase productivity by increasing agricultural mechanization in Çanakkale and Balıkesir provinces. This will ensure the transition of farmers to more modern and effective agricultural equipment and methods and ensure sustainability.

References

Altuntas, E. (2020). Estimation of agricultural machinery utilization projection in Turkey. *International Journal of Agricultural and Wildlife Sciences*, 6(3), 506-516. https://doi.org/10.24180/ijaws.728023

Anonymous (2023). TR-22-Guney-Marmara-Bolgesi-2014-2023-Bolge-Plani.pdf (gmka.gov.tr)

Anonymous, (2013). TR22 Güney Marmara Bölgesi Tarım Araştırma Raporu. tarim-arastirma-raporu.pdf (kalkinmakutuphanesi.gov.tr)

Anonymous (2023a). Marmara Bölgesi - Vikipedi (wikipedia.org).

Chen, X., Johnson, A., Smith, J. (2021). Benefits of Agricultural Mechanization in the Agricultural Sector: Examples of Spraying, Harvesting and Other Agricultural Machinery. *Agricultural Machinery Research*, 202, 185-196.

Demir, B., Kuş, E. (2016). Projection of Technology Use in Agriculture in Central Anatolia Region. *Nevşehir Journal of Science and Technology*, 5, 89-95. https://doi.org/10.17100/nevbiltek.210970

Demir, B., Öztürk, İ., Sayıncı, B., Sakarya, A. (2013). Turkey's plant protection machinery projection. I. Plant Protection Products and Machinery Congress, April 2-5, 2013, Antalya

GMKA (2023). Güney Marmara Kalkınma Ajansı, https://www.gmka.gov.tr/

Gül, E.N., Özgöz, E., Altuntaş, E. (2022). Agricultural Mechanization Level of Tokat Province, Soil Tillage

Equipment and Machines and Sowing Machines Projection. *Gaziosmanpaşa Scientific Research Journal*, 11(2), 12-24.

Johnson, A., Smith, J., Chen, X. (2018). Projection of Tillage Implements and Machines and Seeding Machines: Automating Agricultural Operations and Increasing Productivity. Journal of Agricultural Technology, 110(3), 201-210.

Kuzu, H., Karadöl, H., Aybek, A. (2021). The changes of agricultural mechanization level in Southeastern Anatolia Region between 2010-2019 and determination of the trends for the next decade using trend analysis. *Mustafa Kemal University Journal of Agricultural Sciences*, 26(1), 41-62. https://doi.org/10.37908/mkutbd.767567

Malaslı, M.Z., Çelik, A., Çelik, Ş. (2015). Determination of tillage tools and machinery projection of Southeastern Anatolia Region by regression analysis method. *Turkish Journal of Agriculture and Natural Sciences*, 2 (1), 126-132.

Smith, J., Johnson, A., Chen, X. (2020). Agricultural Mechanization and Productivity: The Importance of Transformation in Modern Agriculture. *Journal of Agricultural Research*, 45(2), 123-136.

Yildiz, C., Erkmen, Y. (2004). Agricultural Structure and Mechanization Status of Pasinler District of Erzurum Province. *Journal of Atatürk University Faculty of Agriculture*, 35 (1-2), 59-63. 34445 (dergipark.org.tr)

ZMO Çanakkale Şubesi. (2020). Çanakkale'de Tarımsal Yapı, Sorunlar ve Çözüm Önerileri, 2020 Raporu. Yayın Kurulu: N. Oral, M. Türkeş, M. İ. Mutluay, T. Savaş, H. Nalbant, S. K. Sümer, O. S. Türkmen, M. Diler, U. Tunç, G. Özünel, E. Düzen. Ziraat Mühendisleri Odası (ZMO) Çanakkale Şubesi, 60 sayfa, Çanakkale. (PDF) Çanakkale'de Tarımsal Yapı, Sorunlar ve Çözüm Önerileri, 2020 Raporu (researchgate.net)

Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi
Journal of Agricultural Faculty of Gaziosmanpasa University
https://dergipark.org.tr/tr/pub/gopzfd

Araştırma Makalesi/*Research Article*

JAFAG
ISSN: 1300-2910
E-ISSN: 2147-8848
(2023) 40(3) 115-124
doi:10.55507/gopzfd.1339608

The Relationship between Spirodiclofen Resistance and *Wolbachia* Endosymbiont in *Tetranychus urticae* Koch (Acari: Tetranychidae)

Betül BAL[1], Sibel YORULMAZ[2*]

[1]Department of Plant Protection, Faculty of Agriculture, Isparta University of Applied Sciences, Isparta,
***Corresponding author's email:** sibelyorulmaz@isparta.edu.trt

Alındığı tarih (Received): 08.08.2023 Kabul tarihi (Accepted): 26.09.2023

Abstract:*Tetranychus urticae* Koch (Acari: Tetranychidae) is an important pest that causes economic losses in many varieties of cultivated plants around the world. In this study, it was aimed at determiningthe relationship between spirodiclofen resistance in *T. urticae* and the presence of *Wolbachia*. Therefore, simultaneous selection of spirodiclofen was performed in both *Wolbachia* infected (GSS) and uninfected (GSSN) populations of *T. urticae*. The dry residue method was used to determine lethal concentration (LC) values in *T. urticae*. Bioassay experiments were applied to the larval stage of the mite. The LC value studies were established as 7 doses +1 control and 3 replications. Dead-alive counts were made at the end of the 7th day and resistance ratios were determined. In the last selection of *T. urticae* with *Wolbachia* infection, 23-fold spirodiclofen resistance was determined, and in the last selection without *Wolbachia* infection, 103-fold resistance was determined. The presence of *Wolbachia* was found to be quite low in all *Wolbachia*-uninfected selection populations compared to *Wolbachia*-infected populations. As a result, it is thought that there may be a negative relationship between spirodiclofen resistance and *Wolbachia* endosymbiont in *T. urticae*, and that esterase enzyme may have an effect on the development of resistance within the scope of this relationship.

Keywords: esterase, LC, acaricide, *Tetranychus urticae, Wolbachia*

Tetranychus urticae Koch (Acari: Tetranychidae)'de *Wolbachia* Endosimbiyontu ve Spirodiclofen Direnci Arasındaki İlişki

Öz:*Tetranychus urticae* Koch (Acari: Tetranychidae), dünyada birçok kültür bitkisi çeşidinde ekonomik kayıplara neden olan önemli bir zararlıdır. Bu çalışmada, *T. urticae*' de spirodiclofen direnci ile *Wolbachia* varlığı arasındaki ilişkinin belirlenmesi amaçlanmıştır. Bu nedenle, *T. urticae'* nin hem *Wolbachia* ile enfekteli olan (GSS) hem de enfekteli olmayan (GSSN) popülasyonlarında eş zamanlı spirodiclofen seleksiyonu yapılmıştır. *T. urticae*' de lethal konsantrasyon (LC) değerlerini belirlemek için kuru rezidü yöntemi kullanılmıştır. Biyoassay denemelerde akarın larva dönemine uygulanmıştır. Lethal konsantrasyon çalışmaları 7 doz +1 kontrol ve 3 tekerrürlü olarak yapılmıştır. 7. gün sonunda ölü-canlı sayımı yapılarak direnç oranları belirlenmiştir. *T. urticae'*nin *Wolbachia* ile enfekteli olan son seleksiyonunda 23 kat spirodiclofen direnci belirlenirken, *Wolbachia* ile enfekteli olmayan son seleksiyonda 103 kat direnç belirlenmiştir. *Wolbachia* varlığının, Wolbachia ile enfekte olmayan tüm seleksiyon popülasyonlarında, *Wolbachia* ile enfekte olmuş seleksiyon popülasyonlarına kıyasla oldukça düşük olduğu belirlenmiştir. Sonuç olarak *T. urticae*'de spirodiclofen direnci ile *Wolbachia* endosymbiont arasında negatif bir ilişki olabileceği ve bu ilişki kapsamında esteraz enziminin direnç gelişiminde etkili olabileceği düşünülmektedir.

Anahtar sözcükler: esteraz, LC, akarisit, *Tetranychus urticae, Wolbachia*

1. Introduction

The two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) is a polyphagous pest that causes damage to many economically produced plants (Helle & Sabelis, 1985). The pest causes economic loss tomore than 150 important cultivated plants in the world (Zhang, 2003). In the control of *T. urticae*, chemical control is preferred by the producers in the first place (Van Leeuwen et al., 2005). The use of acaricide in the control of the pest is quite common, and it was reported that the world acaricide market value was 900 million euros in 2013 (Van Leeuwen et al., 2015). As a result, the pest has developed resistance to more than 80 acaricides in 60 countries (Miresmailli et al., 2006). It has been reported that *T. urticae* is the pest species that develops the most resistance to chemicals in the world (Dermauw et al., 2013).

Spirodiclofen has a specific mode of action and is located within the spirocyclic tetronic acaricide group.

Spirodiclofen is a selective, non-systemic acaricide, that is one of the tetronic acid derivatives and is widely used in recent times. Spirodiclofen; is effective in all developmental stages of important pest mite species such as *Tetranychus urticae*, *Panonychus ulmi* (Koch) (Acari: Tetranychidae) and *Panonychus citri* (McGregor) (Acari: Tetranychidae) (Wachendorff et al. 2002). Spirodiclofenis used worldwide in the control of phytophagous mites in many cases within integrated pest management programs. This acaricide acts by inhibiting lipid biosynthesis and inhibiting carboxylesterase enzyme activity in pests (Bretschneider et al., 2007).

Wolbachia was first identified in the reproductive tissues of mosquitoes by Herting and *Wolbachia* in 1924 (Hertig & Wolbach, 1924). *Wolbachia* is an endosymbiont proteobacterium that infects invertebrates such as spiders, mites, crustaceans and nematodes, especially insects, and can be transferred from mother to offspring (Stouthamer et al., 1999). In studies conducted, *Wolbachia* was detected in 48 of 63 arthropod species (Aracnida 2, Insecta 61), and in 18 of 20 nematode species (Stouthamer, 1999; Sinkins, 2000). *Wolbachia*, which is found in nearly 80% of arthropods; it causes some reproductive changes such as cytoplasmic incompatibility in its host, death of male individuals, and feminization (Breeuwer et al., 1992; Stouthamer et al., 1999).Although the relationship between mites and *Wolbachia* endosymbiont is still not clearly known, the presence of *Wolbachia* in some phytogaph mite species in the Tetranychidae family has been reported in studies (Vala et al., 2002; Gotoh et al., 2003; Zang et al., 2013; Zele et al., 2018; Pina et al., 2020).

The mechanism underlying the interactions between insecticide resistance and endosymbionts in pests is still not clearly understood. Considering the detoxification abilities and rapid evolution processes of symbionts, it is thought that they may contribute to insecticide resistance in their hosts (Su et al., 2013). It is speculated that endosymbionts may have important roles in modulating host states, detoxifying toxic compounds, and altering their hosts' gene expression. It is thought that detoxifying enzymes such as aromatic ester hydrolase, glucosidase, phosphatase and glutathione transferase can be activated by endosymbionts and this may play a role in insecticide resistance developed in the pest. For example, in *Riptortus pedestris* (Hemiptera: Alydidae), it has been determined that the symbiotic bacterium *Burkholderia* provides protection against organophosphorus pesticides. (Kikuchi et al., 2012). In another study, *Lymantria dispar* (Lepidoptera: Lymantriidae) larvae from *Bacillus thrungiensis* were isolated from the symbiont *Enterobacter* sp. It has been reported that it cannot kill without it (Broderick et al., 2006). Although much is unknown about the interactions between insecticide resistance and symbionts, studies have reported that facultative endosymbionts can cause conditional changes in insecticide resistance in pests. It is thought that there may be a positive, negative or neutral effect between endosymbionts and insecticide resistance developed in the pest, and this situation is also worth investigating.

It is extremely important to know the effect of the *Wolbachia* endosymbiont, which has been identified in the Tetranychidae family, on *T. urticae*, which has the ability to develop rapid resistance to chemicals, in terms of developing new approaches to the control of the pest. Therefore, the possible positive, negative or neutral effect relationship between spirodiclofen resistance and the *Wolbachia* endosymbiont in *T. urticae* was investigated in this study. The development of spirodiclofen resistance was determined in two populations of *T. urticae* with and without *Wolbachia* infection. The relationship between spirodiclofen resistance and the presence and density of *Wolbachia* endosymbionts and the amount of some detoxification enzymes was investigated in both populations.

2. Material and Method

2.1. Origin and reproduction of *Tetranychus urticae*

The susceptible (GSS) population of *T. urticae*, which has been produced in the climate chamber without any pesticide exposure since 2001, was used in the study. As a result of preliminary studies in the GSS population, it was determined that it was infected with *Wolbachia* endosymbiont. The *Wolbachia*-free population obtained as a result of the administration of antibiotics to the GSS population was named as GSSN. The GSS and GSSN populations were used as starting populations for spirodiclofen selections. The production of *T. urticae* populations was carried out on bean (*Phaseolus vulgaris* L. var. barbunia) in climate chambers with 26±2ºC temperature, 60±5% proportional humidity and 16 hours lighting conditions. The populations were produced in the Department of Plant Protection, Faculty of Agriculture, Isparta University of Applied Sciences.

2.2. Molecular identification of endosymbionts in *Tetranychus urticae*

In order to determine the endosymbiont presence in the GSS population of *T. urticae*, DNA isolation was performed collectively from 50 female adult mites. Total DNA isolation was performed with the Qiagen DNeasy Blood & Tissue Kit, following the company's instructions. *Wolbachia, Cardinium, Rickettsia* and *Spiroplasma* are endosymbionts identified in the Tetranychidae family (Zele et al. 2018*)*.Therefore, the presence of these endosymbionts in the GSS population was checked. Primers determined in previous studies were used to detect the presence of endosymbiont bacteria (Jeyaprakash & Hoy 2000; Pina et al. 2020).

2.3. Acaricide

In the study, a commercial preparation (Envidor SC 240) (Bayer) with Spirodiclofen active ingredient, which is in the 23rd group in the IRAC mechanism of action list, was used.

2.4. Antibiotic Administration

In the preliminary studies, it was determined that the GSS population was only infected with *Wolbachia* endosymbiont. In the study, Tetracycline antibiotic was applied to the GSS population in order to obtain the *T. urticae* population without *Wolbachia* endosymbiont. Cottons soaked in 0.05% (w/v) antibiotic were placed in 9 cm petri dishes. Bean leaf discs were placed on cotton. After 24 hours, 50 *T. urticae* larvae in the same period were transferred to beans. One day later, newly hatched larvae were placed on new leaf discs and distilled water was added daily to keep the cotton wet. Thus, the mites have been bred under antibiotics for a generation (Gotoh et al., 1995). Approximately one month later (after at least 3 generations), whether this population was infected with *Wolbachia* was determined by PCR studies. As a result of antibiotic administration, a population free of *Wolbachia* endosymbiont was obtained in the GSS population of *T. urticae*. This population was named the GSSN population. Thus, simultaneous selection of spirodiclofen was started in *T. urticae* with *Wolbachia* infected and *Wolbachia* uninfected two populations.

2.5. Spirodiclofen Selection Tests

The GSS and GSSN populations of *T. urticae* were used as starting populations for spirodiclofen selections. For selection processes, first of all, LC_{50} for spirodiclofen was determined in both mite populations. Spiodiclofen was applied to the larval stage of *T. urticae* in all LC_{50} trials for both mite populations. Trials were established as 1 control + 7 doses, 3 replications for each dose. When determining the application dose of Spirodiclofen, it was taken into account that there was no death less than 90% in the first dose and no more than 10% in the control group. For each replication, 25 mite larvae were added to the Petri dish. With the spirodiclofen concentrations prepared by diluting 50% for each dose, spraying was carried out with the help of spraying tower (Burkard Scientific, England) at 1 bar pressure, 2 mL of pesticide was applied to the leaf surface. Dead-alive counts were made at the end of the 7th day and LC_{50} and LC_{60} values were determined. The LC_{60} values determined for the selection dose of spirodiclofen were used for both mite populations. Spiodiclofen resistances were determined by dividing the LC_{50} values determined for each selection population with the LC_{50} values of the initial populations. Probit analysis was used to calculate LC_{50} values using POLOPlus software (LeOra, 2002). Selection studies in GSS and GSSN populations of *T. urticae* were continued until the 10 th selection.

2.6. Frequency Density of Wolbachia endosymbiont in Selection Populations

Wolbachia presence and frequency were determined at two selection intervals while selecting with spirodiclofen in GSS and GSSN populations of *T. urticae*. First of all, the presence of *Wolbachia* was determined from collective mites (50 units), and if detected, *Wolbachia* frequency density was determined by using 10-20 adult female mites. Thus, the relationship between the increase in spirodiclofen resistance in *T. urticae* and the frequency of *Wolbachia* was tried to be revealed. At the end and beginning of the selection, if *Wolbachia* is detected from the mites isolated individually, the nucleotide sequence was determined, up to a maximum of 10. In this way, in addition to *Wolbachia* frequency, possible changes in the sequence were detected in spirodiclofen-resistant and non-resistant individuals.

2.7. Enzyme Activities

α-naphtylacetate as substrates and the method developed by Stumpf and Nauen (2002) were used to determine the esterase activity kinetically. 20 adult females were homogenized in 100 µl sodium phosphate buffer (0.1M, pH 7.5). 25 µl of supernatant + 25 µl of phosphate buffer (0.2 M, pH: 6) was added

to the cells of the microplate. The study was initiated by adding 200 µl of substrate solution to the cells. The substrate solution was obtained by dissolving 30 mg of fastblue RR salt in 50 ml of 0.2 M sodium phosphate buffer and adding 500 µl of 100 Mm α - naphthylacetate to this mixture. Enzyme activity was read at 23°C, 450 nm for 10 minutes.

The method developed by Stumpf and Nauen (2002) was used to determine the GST enzyme kinetically. 30 adult females were crushed in 300 µl Tris HCL buffer (0.05M, pH:7.5). The total volume of 100 µl supernatant, 100 µl 1-chloro-2,4-dinitrobenzene (CDNB) and 100 µl reducedglutathione (GSH) was placed in the microplate cells. CDNB was prepared in 0.1% ethanol and 0.4 mM CDNB was found in the cells at the final concentration. The change in absorbance was read at 340 nm, 25 °C and 5 min.

In the determination of cytochrome P450 monooxygenase enzyme, p-nitroanisole (PNOD) as substrates and Rose et al. (1995) method was adapted and used. 50 female individuals were crushed with a plastic crusher at a homogenization buffer of 100 µl (0.05 MTris-HCl +1.15% KCl + 1mm EDTA pH (7.7). The mixture was cubed at 30 °C for 5 min by adding 45µl homogenization buffer + 45 µl supernatant+100µl 2mM PNOD to the microplate cells. The reaction was initiated by adding 10 µl 9.6 mM NADPH to the microplate cells. The enzyme activity of P450 was measured in a Versamax kinetic microplate reader (MolecularDevices) at 405 nm 30 ×C for 15 min.

In biochemical studies, control cells were read as non-homogeneous. Enzyme readings were performed four times. All enzyme activities were analyzed in the Softmax PRO software program and the results were given as mOD min^{-1} mg^{-1} protein. Bradford (1976)'s total protein determination method was used to determine the total protein amounts of the samples and Bovine Serum Albumin (BSA) was taken as standard. The enzyme assay results were analyzed using one-way analysis of variance (ANOVA) and the Tukey test to determine differences between populations.

3. Results

3.1. Molecular ıdentification of endosymbionts in *Tetranychus urticae*

The presence of 4 endosymbiont bacteria commonly found in arthropods in the GSS population of *T. urticae,* which was used as the origin, was investigated. Among the bacteria *Wolbachia* (1), *Cardinium* (2), *Rickettsia* (3) and *Spiroplasma* (4), only *Wolbachia* was detected in the GSS population (Figure 1).

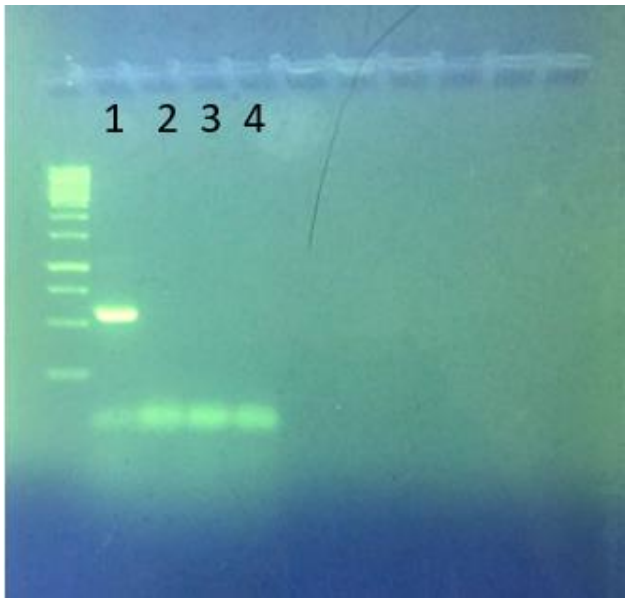

Fig. 1 Endosymbionts of *Tetranychus urticae* in the GSS population

Şekil 1*. Tetranychus urticae'nin GSS popülasyonunda endosimbiyontlar*

3.2. Spirodiclofen selection

The LC values determined as a result of spirodiclofen selection in the GSS population of *T. urticae* and the resistance ratios according to the LC_{50} value are given in Table 1. The resistance ratios determined against spirodiclofen in selection populations vary between 0.8 and 27 times. As a result, 27.0-fold resistance was determined in the S10 population obtained as a result of pre-selection pressure with spirodiclofen.

The LC values determined as a result of spirodiclofen selection in the GSSN population of *T. urticae* and the resistance ratios according to the LC_{50} value are given in Table 2. As a result of selection studies, resistance rates determined against spirodiclofen in selection populations vary between 2 and 103 times. As a result, 103.05-fold resistance was determined in the SN10 population obtained as a result of pre-selection pressure with Spirodiclofen.

3.3. Determination of *Wolbachia* endosymbiont by molecular method

The presence and frequency of *Wolbachia* were determined with both selection intervals in GSS, GSSN and selection populations of *T. urticae* (Table 3). When the table is examined, it is seen that the frequency of *Wolbachia* is higher in all non-antibiotic-treated GSS and selection populations than in antibiotic-treated GSSN and selection populations. As a result of the

studies, although there was a slight decrease in *Wolbachia* frequency in the population without antibiotics after spirodiclofen administration, it was observed that the frequency of *Wolbachia* increased again in advanced populations such as S8. As a result of antibiotic applications, *Wolbachia* bacteria were successfully eliminated in the majority of the population. It was observed that the frequency of *Wolbachia* in the population in subsequent generations did not increase significantly.

Table 1. LC, df, x^2 values and resistance ratios against spirodiclofen in GSS and selection populations of *Tetranychus urticae*

Çizelge 1. *Tetranychus urticae'nin GSS ve seleksiyon popülasyonlarında LC, df, x^2 değerleri ve spirodiclofen direnç oranları*

Population	n*	Slope±SE	LC_{50} (mg a.i. L^{-1}) (95% CL)	LC_{60} (mg a.i. L^{-1}) (95% CL)	df	x^2	R**
GSS	598	1.180±0.110	0.036 0.028-0.045	0.060 0.045-0.076	6	2.8	-
S1	603	1.611±0.146	0.038 0.024-0.048	0.043 0.033-0.052	6	2.5	1.0
S2	605	1.630±0.129	0.062 0.038-0.093	0.088 0.057-0.139	6	1.8	1.7
S3	582	1.427±0.137	0.151 0.096-0.218	0.228 0.156-0.328	6	2.0	4.2
S4	598	1.506±0.318	0.208 0.158-0.261	0.252 0.199-0.316	5	2.8	5.8
S5	578	1.398±0.134	0.258 0.184-0.295	0.318 0.212-0.395	5	2.5	7.1
S6	591	1.881±0.142	0.326 0.223-0.460	0.441 0.307-0.640	6	1.4	9.0
S7	602	1.486±0.186	0.578 0.196-0.956	0.856 0.384-1.490	6	1.9	16.0
S8	565	2.266±0.159	0.765 0.662-1.121	0.991 0.856-1.154	6	2.9	21.2
S9	584	1.848±0.168	0.919 0.645-1.233	1.260 0.924-1.706	5	2.3	25.5
S10	596	1.480±0.126	0.972 0.777-1.200	1.440 1.166-1.800	6	2.5	27.0

*: Total Number of Individuals
**: Resistance Ratio

Table 2. LC, df, x^2 values and resistance rates against spirodiclofen in GSSN and selection populations of *Tetranychus urticae*

Çizelge 2. *Tetranychus urticae'nin GSSN ve seleksiyon popülasyonlarında LC, df, x^2 değerleri ve spirodiclofen direnç oranları*

Population	n*	Slope±SE	LC_{50} (mg a.i. L^{-1}) (95% CL)	LC_{60} (mg a.i. L^{-1}) (95% CL)	df	x^2	R**
GSSN	598	2.102±0.165	0.019 0.014-0.024	0.024 0.019-0.031	6	1.2	-
SN1	575	1.822±0.151	0.038 0.028-0.050	0.052 0.040-0.069	6	1.8	2.0
SN2	592	1.463±0.335	0.158 0.115-0.206	0.187 0.141-0.249	6	1.6	8.3
SN3	578	1.639±0.140	0.163 0.086-0.172	0.189 0.127-0.230	6	2.2	8.5
SN4	565	1.162±0.113	0.195 0.122-0.213	0.273 0.211-0.355	5	2.5	10.2
SN5	563	1.589±0.215	0.583 0.353-1.020	0.842 0.336-1.521	5	2.8	30.6
SN6	585	1.480±0.130	1.032 0.751-1.423	1.528 1.120-1.956	6	1.5	54.3
SN7	603	1.754±0.140	1.063 0.806-1.384	1.780 1.140-1.968	6	2.8	55.9
SN8	592	1.962±0.167	1.221 1.000-1.464	1.944 1.370-2.275	6	2.4	64.2
SN9	576	1.778±0.140	1.392 1.072-1.773	2.232 1.514-2.496	5	1.7	73.2
SN10	569	1.985±0.180	1.958 1.652-2.320	2.965 2.456-3.201	6	2.5	103.05

*: Total Number of Individuals
**: Resistance Ratio

3.3. Determination of *Wolbachia* endosymbiont by molecular method

The presence and frequency of *Wolbachia* were determined with both selection intervals in GSS, GSSN and selection populations of *T. urticae* (Table 3). When the table is examined, it is seen that the frequency of *Wolbachia* is higher in all non-antibiotic-treated GSS and selection populations than in antibiotic-treated GSSN and selection populations. As a result of the studies, although there was a slight decrease in *Wolbachia* frequency in the population without antibiotics after spirodiclofen administration, it was observed that the frequency of *Wolbachia* increased again in advanced populations such as S8. As a result of antibiotic applications, *Wolbachia* bacteria were successfully eliminated in the majority of the population. It was observed that the frequency of *Wolbachia* in the population in subsequent generations did not increase significantly.

Table 3. *Wolbachia* frequency variation in GGS, GSSN and selection populations
Çizelge 3. *GGS, GSSN ve seleksiyon popülasyonlarında Wolbachia frekans değişimi*

Selection Populations	Without Antibiotics	Selection Populations	With Antibiotics
GSS	9/10	GSSN	0/10
S2	3/10	SN2	1/10
S4	6/10	SN4	2/10
S6	3/10	SN6	1/10
S8	7/10	SN8	0/10
S10	5/10	SN10	2/10

In addition, the sequences of certain parts of the *Wolbachia* gene sequences in the GSS, S10 and SN10 populations were revealed in *T. urticae*. However, no differences in gene sequences were detected for all three populations (Figure 2).

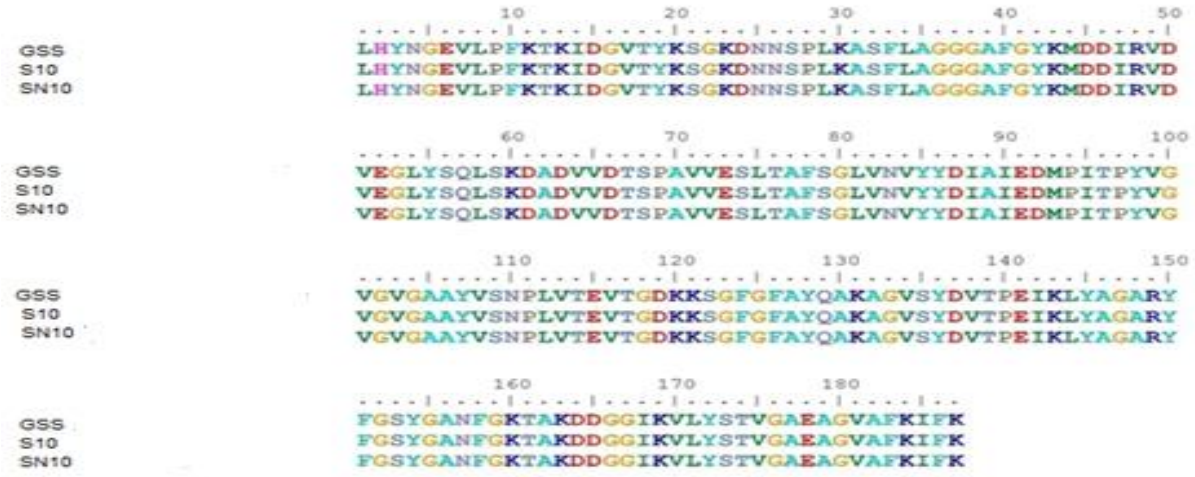

Fig. 2 Comparison of *Wolbachia* amino acid sequences in GSS, S10 and SN10 populations
Şekil 2. *GSS, S10 ve SN10 popülasyonlarında Wolbachia amino asit dizilimlerin karşılaştırılması*

3.4. Enzyme activities

Esterase, GST and P450 enzyme activities in GSS, GSSN and selection populations of *T. urticae* were determined at mOD min^{-1} mg^{-1} protein value, and the results are given in Table 4. Esterase enzyme amounts were found to be statistically similar in GSS and selection populations of *T. urticae*. In the GSSN and selection populations of *T. urticae*, the esterase enzyme amounts in the SN6, SN8 and SN10 populations are higher than the esterase enzyme amounts in the GSSN, SN2 and SN4 populations. When the increase in spirodiclofen resistance in *Wolbachia* uninfected populations and selections was examined, it was determined that the resistance increased significantly in SN6, SN8 and SN10 populations compared to SN4, SN2 and GSSN populations. The GST enzyme was found to be similar in the GSS and selection populations of *T. urticae*, and no statistical difference could be determined. Similarly, no difference was found between GST enzyme amounts in GSSN and selection populations of *T. urticae*. Among the GSS and selection populations of *T. urticae*, the amount of monooxygenase enzyme determined in the S6, S8 and S10 populations was found to be higher than in the GSS, S2 and S4 populations. The lowest amount of monooxygenase enzyme in the GSSN and selection populations of *T. urticae* was determined in the GSSN population and formed a statistical group different

from other populations. The amount of enzyme determined in SN2, SN4, SN6 and SN8 populations was similar. The highest amount of monooxygenase enzyme was determined in the SN10 population, which has 103 times spirodiclofen resistance, and formed a statistical group different from other populations.

Table 4 Esterase, GST and P450 enzyme activities in GSS, GSSN and selection populations of *Tetranychus urticae*

Çizelge 4*. Tetranychus urticae'nin GSS, GSSN ve seleksiyon popülasyonlarında esteraz, GST ve P450 enzim aktiviteleri*

Population	n*	Specific activity mOD min^{-1} mg^{-1} protein (±SE)	Specific activity mOD min^{-1} mg^{-1} protein (±SE)	Specific activity mOD min^{-1} mg ^{1} protein (±SE)
		Esteraz	GST	P450
GSS	4	11.63(±0.001) a**	3.5(±0.003) a**	0.0023(±0.002) b**
S2	4	11.88(±0.002) a	3.2(±0.003) a	0.0032(±0.002) b
S4	4	12.57(±0.002) a	3.8(±0.004) a	0.0035(±0.003) b
S6	4	11.16(±0.005) a	4.0(±0.002) a	0.0049(±0.003) a
S8	4	13.25(±0.004) a	3.6(±0.002) a	0.0053(±0.001) a
S10	4	13.52(±0.002) a	3.8(±0.001) a	0.0055(±0.001) a
GSSN	4	8.69(±0.003) c	2.9(±0.004) a	0.0017(±0.004) c**
SN2	4	8.92(±0.003) c	3.2(±0.004) a	0.0035(±0.004) b
SN4	4	8.72(±0.002) c	3.0(±0.003) a	0.0038(±0.003) b
SN6	4	13.75(±0.001) b	3.5(±0.002) a	0.0050(±0.003) b
SN8	4	14.48(±0.002) b	3.8(±0.002) a	0.0056(±0.002) b
SN10	4	18.90(±0.032) a	4.2(±0.003) a	0.0072(±0.002) a

* Number of recurrences

**The same letters indicate the same group statistically (P<0.05)

4. Discussion and Conclusion

There is no study in the literature to determine the relationship between insecticide/acaricide resistance development in endosymbionts and mites. However, there are studies in which the presence of some endosymbionts, especially in the Tetranychidae family. Vala et al. (2002) determined that *Wolbachia* in *T. urticae* did not affect the lifespan, but caused a change in the survival curves. Gotoh et al. (2003) determined that seven (16.7%) of 42 Tetranychidae species in Japan were infected with *Wolbachia*. Zang et al. (2013) determined that there is *Wolbachia* endosymbiont in Tetranychus species (*T. truncatus, T. phaselus, T. puerariсola* (Acari: Tetranychidae) and *T. urticae*) in China. Zélé et al. (2018) reported that the most common endosymbiont combination in the Tetranychidae family may be *Wolbachia* and *Cardinium*. Pina et al. (2020) reported that *T. truncatus* showed combinations of *Wolbachia* and *Cardinium* or *Spiroplasma* and *Rickettsia*, while *T. evansi, T. ludeni* and *T. urticae* only showed combinations of *Wolbachia* and *Cardinium*. These studies are important because they show that *Wolbachia* endosymbiont is common in *Tetranychidae* species. It is possible that *Wolbachia* symbiont, which is common in Tetranychidae species, is associated with the development of resistance in phytophagous mite species.

Concurrent selection of spirodiclofen was performed in the GSS and GSSN populations. In the GSS and selection populations, spirodiclofen resistance reached a maximum of 27 times. However, although there was a slight decrease in the *Wolbachia* frequency determined at intervals of both selections in the S2 and S6 populations, the frequency of *Wolbachia* was found to be higher in all populations than in the populations treated with antibiotics. In contrast, in GSSN and selection populations, a more rapid development of spirodiclofen resistance was determined after the 5th selection. In *Wolbachia* frequency determination studies performed with both selection intervals, much less *Wolbachia* presence was determined compared to populations that did not receive antibiotics. It was determined that spirodiclofen resistance increased up to 103 times in GSSN and selection populations that were treated with antibiotics. On the other hand, 27-fold spirodiclofen resistance was determined in GSS and selection populations containing *Wolbachia* more intensely. In the literature, high ratios of spirodiclofen resistance development have been reported in laboratory and field populations of *T. urticae* (Rauch & Nauen, 2003; Van Pottelberge et al., 2009a; Van Pottelberge et al., 2009b; Ferreria et al., 2015). However, these studies did not examine whether endosymbionts have an effect on high spirodiclofen resistance in pests. As a result of our study, it can be thought that there may be a negative relationship between the presence and density of *Wolbachia* and the development of spirodiclofen resistance in *T. urticae*.

However, it should be taken into account that the *Wolbachia* frequency density should be determined on a small number of individuals and random sampling may have an effect on the results. Therefore, it is thought that the relationship between *Wolbachia* presence and spirodiclofen resistance in *T. urticae* should be revealed more clearly by increasing the number of samples and repetitions in order to clearly demonstrate this connection in future studies.

Although there is no study on endosymbiont-pesticide resistance in mites, this issue has been investigated in some pests. Symbiont-mediated insecticide resistance/susceptibility varies according to insect species, symbiont species and chemical compound. In a study, the highest susceptibility to acetamiprid, thiametroxam, sporimesifen and pyripoxen was seen in multisymbiont whiteflies such as *Rickettsia-Arsenophonus*, *Rickettsia-Wolbachia* (Ghanim & Kontsedalov, 2009). As a matter of fact, it was emphasized that *Rickettsia* bacteria should be taken into account in the studies to determine insecticide resistance in *Bemisia tabaci* (Hemiptera: Aleyrodidae) populations (Kontsedalov et al. 2008).On the other hand, *Wolbachia* did not change the susceptibility of *Aedes aegypti* (Diptera: Culicidae) to the chemical insecticides bifenthrin, temephos and s-methoprene and *Bacillus thuringiensis* (Bt). In addition, it was determined that *Rickettsia*, coexisting with another symbiont *Arsenophonus*, increased the insecticide resistance against acetamiprid in *B. tabaci*, but did not affect the susceptibility to diafenthiuron. Fenitrothion, an organophosphorus insecticide, can contribute to insecticide resistance by being degraded by *Burkholderia*, a soil-borne symbiont. It has been reported that *S. kochii* in the bean beetle, *Riptortus pedestris* (Hemiptera: Alydidae), has a broad spectrum detoxification capacity and can hydrolyze parathion, an organophosphorus insecticide (DongLiu et al. 2019).

Detoxifying enzymes such as aromatic ester hydrolase, glucosidase, phosphatase and glutathione S-transferase in the pest's body can be activated by symbionts. It has been reported that changes in the activity of detoxification enzymes can lead to changes in the insecticide resistance of symbiont hosts (Kikuchi et al. 2012). In our study, no statistical difference was found between the amount of esterase enzyme in *Wolbachia* infected GSS and selection populations. On the other hand, when the antibiotic-treated GSSN and selection populations were examined, the highest esterase enzyme was determined in the SN10 population. It is observed that esterase amounts of SN6, SN8 and SN10 populations are significantly increased compared to GSSN, SN2 and SN4 populations. However, the rapid increase in spirodiclofen resistance, especially in populations after the SN5 population, suggests that there may be a relationship between resistance and esterase enzyme. At the same time, it is thought that the absence of *Wolbachia* endosymbionts may be effective in the rapid increase in resistance. Because spirodiclofen resistance did not increase much in non-antibiotic-treated GSS and selection populations. It was determined that the GST enzyme activity did not show a statistically significant change in the GSS and GSSN populations of *T. urticae* with and without antibiotic application, and in all selection populations. When P450 monooxygenase enzyme activity was examined, it was determined that the amount of enzyme in S6, S8 and S10 populations was higher in GSS and selection populations compared to other selection populations. Similarly, when the GSSN and selection populations were examined, the highest amount of monooxygenase enzyme was determined in the SN10 population. However, monooxygenase enzyme amounts were found to be higher in the SN2, SN4, SN6 and SN8 populations compared to the GSSN population. However, unlike the monooxygenase enzyme esterase enzyme, it has also increased in selection populations that have been administered antibiotics and those that have not. It has been determined that esterase and P450 enzymes are related to the increase in spirodiclofen resistance in *T. urticae* (Van Pottelberge et al., 2009; Kramer & Nauen, 2011; Badieinia et al., 2020). However, there is no direct study yet to prove that *Wolbachia* can reduce or detoxify the effects of insecticides on pests. However, there are other examples of symbionts that we know can detoxify toxic compounds. Fenitrothion, an organophosphorus insecticide, can cause insecticide resistance by being degraded by a soil-borne symbiont, *Burkholderia* (Hayatsu et al., 2000). In the bean beetle, *R. pedestris*, *S. kochii* endosymbiont can hydrolyze the organophosphorus insecticide parathion (Shen & Downd 1991).

In conclusion, endosymbionts, which show examples of living together in many living species in nature, are also frequently found in pests. Endosymbionts cause some changes in pests, especially on reproduction. However, it is thought that it may also have effects on the development of resistance, which causes difficulties in the control of pests. Knowing the relationship between insecticide

resistance and endosymbiont species and density in pests is important in terms of developing new strategies for control. This study is important in that it is the first study to determine the relationship between acaricide resistance and *Wolbachia* in *T. urticae*.

Acknowledgements

We thank the Scientific and Technical Research Council of Turkey (TÜBİTAK-TOVAG) for financially supporting the study with the Rapid Support Program numbered 120O959. The authors are highly thankful to Dr. Emre İNAK, Ankara University Agriculture Faculty Plant Protection Department, for contributing to molecular studies.

References

Badieinia, F., Khajehali, J., Nauen, R., Dermauw, W., & Van Leeuwen, T. (2020). Metabolic mechanisms of resistance to spirodiclofen and spiromesifen in Iranian populations of *Panonychus ulmi*. *Crop Protection* 134: 105-166.

Breeuwer, J.A.J., Stouthamer, R., Barns, S.M., Pelletier, D.A., Weisburg, W.G., & Werren, J.H, (1992). Phylogeny of cytoplasmic incompatibility microorganisms in the parasitoid wasp genus Nasonia (Hymenoptera: Pteromalidae) based on 16S ribosomal DNA sequences. *Insect Molecular Biology*, 1(1): 25-36. https://doi.org/10.1111/j.1365-2583.1993.tb00074.x.

Bretschneider, T., Fischer, R., & Nauen, R. (2007). Inhibitors of lipid synthesis (acetyl-CoAcarboxylase inhibitors) in modern crop crotection compounds. *Weinheim Germany.*

Broderick, N.A., Raffa, K.F., & Handelsman, J. (2006). Midgut bacteria required for *Bacillus thuringiensis* insecticidal activity. *PNAS*, 103:15196-15199.

Dermauw, W., Wybouw, N., Rombauts, S., Menten, B., Vontas, J., Grbic, M., Clark, R.M,, Feyereisen, R., & Van Leeuwen T (2013.) A link between host plant adaptation and pesticide resistance in the polyphagous spider mite *Tetranychus urticae*. *Proceedings of the National Academy of Sciences of the United States of America*, 110:113–122.

Dong Liu, X., & Fang Guo, H. (2019). Importance of endosymbionts *Wolbachia* and *Rickettsia* in insect resistance development. *Current Opinioniin Insect, Science*, 33:84–90, https://doi.org/10.1016/j.cois.2019.05.003.

Ferreira, C.B,S., Andrade, F.H.N., Rodrigues, A.R.S,, Siqueira, H.A.A., & Gondim, M.G.C. (2015). Resistance in field populations of *Tetranychus urticae* to acaricides and characterization of the inheritance of abamectin resistance. *Crop Protection*, 67:77-83, https://doi.org/10.1016/j.cropro.2014.09.022.

Ghanim, M., & Kontsedalov, S. (2009). Susceptibility to insecticides in the Q biotype of *Bemisia tabaci* is correlated with bacterial symbiont densities. *Pest Managament Science*, 65(9):939-942, https://doi.org/10.1002/ps.1795.

Gotoh, T., Noda, H., & Hong, X.Y. (2003). *Wolbachia* distribution and cytoplasmic incompatibility based on a survey of 42 spider mite species *(Acari: Tetranychidae*) in Japan. *Journal of Heredity*, 91:208–216.

Gotoh, T., Oku, H., Moriya, K., & Odawara, M. (1995). Nucleus-cytoplasm interactions causing reproductive incompatibility between two populations of *Tetranychus quercivorus* Ehara et Gotoh (Acari: Tetranychidae). *Journal of Heredity*, 74:405–414.

Hayatsu, M., Hirano, M., & Tokuda, S. (2000). Involvement of two plasmids in fenitrotion degradation by Burkholderia sp. strain NF100. *Applied Environmental Microbiology*, 66:1737-1740, https://doi.org/10.1128/AEM.66.4.1737-1740.2000**.**

Helle, W., & Sabelis, M.W. (1985). Spider mites: their biology, natural enemies and control. Amsterdam, Elsevier.

Hertig, M., & Wolbach, S.B. (1924). Studies on rickettsia- like microorganisms in insects. *Journal of Medical Research*, 44:329-374.

Jeyaprakash, A., & Hoy, M.A. (2000). Long PCR improves *Wolbachia* DNA amplification: wsp sequences found in 76%of sixty-three arthropod species. *Insect Molecular Biology*, 9(4): 393-405, https://doi.org/10.1046/j.1365-2583.2000.00203.x.

Kikuchi, Y., Hayatsu, M., Hosokawa, T., Nagayama, A., Tago, K., & Fukatsu, T. (2012). 'Symbiont-mediated insecticide resistance. *Proceedings of the National Academy of Sciences of the United States of America*, 109: 8618- 8622.

Kontsedalov, S., Zchori-Fein, E., Chiel, E., Gottlieb, Y., Inbar, M., & Ghanim, M. (2008). The presence of Rickettsia is associated with increased susceptibility of *Bemisia tabaci* (Homoptera: Aleyrodidae) to insecticides. Pest *Managament Science*, 64:789-792, https://doi.org/10.1002/ps.1595.

Kramer, T., & Nauen, R. (2011). Monitoring of spirodiclofen susceptibility in field populations of European red mites, *Panonychus ulmi* (Koch) (Acari: Tetranychidae), and the cross-resistance pattern of a laboratory-selected strain. *Pest Managament Science*, 67:1285–1293, https://doi.org/10.1002/ps.2184.

Miresmailli, S., & Isman, M.B. (2006). Efficacy and persistence of rosemary oil as an acaricide against two spotted spider mite (Acari: Tetranychidae) on greenhouse tomato. *Journal of Economic Entomology*, 99:2015–2023, https://doi.org/10.1093/jee/99.6.2015.

Pina, T., Sabater-Muñoz, B., Cabedo-López, M., Cruz-Miralles, J., Jaques, J.A., & Hurtado-Ruiz, M.A. (2020). Molecular characterization of *Cardinium*, *Rickettsia*, *Spiroplasma* and *Wolbachia* in mite species from citrus orchards. *Experimental and Applied Acarology*, 3:1-21.

Rauch, N., & Nauen, R. (2003). Spirodiclofen resistance risk assessment in *Tetranychus urticae* (Acari: Tetranychidae): a biochemical approach. *Pesticide Biochemical Physiology*,74:91-101, https://doi.org/10.1016/S0048-3575(02)00150-5.

Rose, R.L., Barbhaiya, L., Roe, R., Rock, G., & Hodgson, E. (1995). Cytochrome p450-associated insecticide resistance and the development of biochemical diagnostic assays in *Heliothis virescens*. *Pesticide Biochemical Physiology*, 51:178-191, https://doi.org/10.1006/pest.1995.1018.

Shen, S.K., & Dowd, P.F. (1991). Detoxification spectrum of the cigarette beetle symbiont *Symbiotaphrina kochii* in culture. *Entomology Experimental Applied*, 60:51-59, https://doi.org/10.1111/j.1570-7458.1991.tb01522.x.

Sinkins, S.P., & O'Neill, L.S. (2000). *Wolbachia* as a vehicle to modify insect populations. In: Handler AM, James AA (ed) Inscet trasngenesis- methods and applications. Boca, Raton, pp: 271- 284.

Stouthamer, R., Breeuwer, J.A.J., & Hurst, G.D.D. (1999). *Wolbachia* pipientis: microbial manipulator of arthropod reproduction. *Annual Review Microbiology*, 53(1):71- 102.

Stumpf, N., & Nauen, R. (2002). Biochemical markers linked to abamaectin resistance in *Tetranychus urticae* (Acari: Tetranychidae). *Pesticide Biochemistry and Physiology*, 72:111-121, https://doi.org/10.1006/pest.2001.2583.

Su, Q., Zhou, X.M., & Zhang, Y. J. (2013). Symbiont-mediated functions in insect hosts. *Communicative & Integrative Biology*, 6: e23804, https://doi.org/10.4161/cib.23804.

Vala, F., Weeks, A., Claessen, D., Breeuwer, J.A.J., & Sabelıs, M.W. (2002). Within- and between-population variation for *Wolbachia*-induced reproductive incompatibility in a haplodiploid mite. *Evolution*, 56:1331-1339.

Van Leeuwen, T., Pottelberge, S.V., & Tirry, L. (2005). Comparative acaricide susceptibility and detoxifying enzyme activities in field-collected resistant and susceptible strains of *Tetranychus urticae*. *Pest Managament Science*, 61:499-507.

Van Leuween, T., Tirry, L., Yamamoto, A., Nauen, R., & Dermauw, W. (2015). The economic importance of acaricides in the control of phytophagous mites and an update on recent acaricide mode of action research. *Pesticide Biochemical Physiology*, 12: 12–21.

Van Pottelberge, S., Khajehali, J., & Van Leeuwen, T. (2009a). Effects of spirodiclofen on reproduction in a susceptible and resistant strain of *Tetranychus urticae* (Acari: Tetranychidae). *Experimental Applied Acarology*, 47: 301-309.

Van Pottelberge, S., Van Leeuwen, T., & Khajehali, J. (2009b). Genetic and biochemical analysis of a laboratory-selected spirodiclofen-resistant strain of *Tetranychus urticae* Koch (Acari: Tetranychidae). *Pest Managament Science*, 65:358-366, https://doi.org/10.1002/ps.1698.

Wachendorff, U., Nauen, R., Schnorbach, H.J., Rauch, N., & Elbert, A. (2002). The biological profile of spirodiclofen (Envidor®)–a new selective Tetronic acid acaricide. *Bayer Crop Science*, 55:149–176.

Zélé, F., Weill, M., & Magalhães, S. (2018). Identifcation of spider mite species and their endosymbionts using multiplex PCR. *Experimental Applied Acarology*, 74(2): 123–138.

Zhang, Y.K., Zhang, K.J., Sun, J.T., Yang, X.M., Ge, C. & Hong, X.Y. (2013). Diversity of *Wolbachia* in natural populations of spider mites (genus Tetranychus): evidence for complex infection history and disequilibrium distribution. *Invertebrate Microbiology*, 65(3): 731–739.

Zhang, Z. (2003). Mites of greenhouses: identification biology and control. CABI Publishing, Wallingford.

Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi
Journal of Agricultural Faculty of Gaziosmanpasa University
https://dergipark.org.tr/tr/pub/gopzfd

Araştırma Makalesi/*Research Article*

JAFAG
ISSN: 1300-2910
E-ISSN: 2147-8848
(2023) 40(3) 125-129
doi:10.55507/gopzfd.1326924

Analysis of the Relationship between Almond Production and Almond Price with the Koyck Model

Tayfun ÇUKUR[1*], Figen ÇUKUR[2]

[1]Muğla Sıtkı Koçman University, Milas Vocational School, Department of Marketing and Advertising, Muğla
[2] Muğla Sıtkı Koçman University, Milas Vocational School, Department of Management and Organization, Muğla
***Corresponding author's email:** tayfun.cukur@hotmail.com

Alındığı tarih (Received): 13.07.2023 Kabul tarihi (Accepted): 29.09.2023

Abstract: In the current study, the Koyck model was used to determine the effect of almond prices on almond production in Türkiye. In the study, the period of 1970-2021 was examined and almond production was used as the dependent variable and almond price was used as the independent variable. According to the results of the analysis, the correlation between almond prices and the amount of almond production was found to be 0.952. The study determined that almond production is influenced by almond prices, and that any change in almond prices can lead to a noticeable change in almond production within a time frame of 2.67 years. On the other hand, it was determined that for the examined period, a one TL increase in almond prices in the current year led to a production increase of 0.002771 tons, while a one TL increase in almond prices in the previous period resulted in a production increase of 0.002015057 tons.

Keywords: Almond production, distributed lag model, Koyck

Bademde Üretim ile Fiyat İlişkisinin Koyck Modeli ile Analizi

Öz: Araştırmada Türkiye'de badem üretimi üzerinde badem fiyatlarının etkisini belirleyebilmek amacıyla Koyck modelinden yararlanılmıştır. Araştırmada 1970-2021 dönemi incelenmiş, badem üretimi bağımlı değişken, badem fiyatı ise bağımsız değişken olarak kullanılmıştır. Analiz sonuçlarına göre badem fiyatları ile badem üretim miktarı arasındaki korelasyon 0.952 bulunmuştur. Araştırmada badem üretiminin badem fiyatlarından etkilendiği, badem fiyatlarında meydana gelen değişikliklerin badem üretiminde hissedilebilir bir değişikliğe yol açabilmesi için gereken zamanın ise 2.67 yıl olduğu saptanmıştır. Diğer taraftan incelenen dönem için, cari yılda badem fiyatlarındaki bir TL'lik artışın üretim miktarında 0.002771 tonluk bir artış yarattığı, bir önceki dönemdeki badem fiyatlarındaki bir TL'lik artışın ise badem üretiminde 0.002015057 ton artırdığı belirlenmiştir.

Anahtar kelimeler: Badem üretimi, gecikmesi dağıtılmış model, Koyck

1. Introduction

The history of almond trees dates back to ancient Babylon, and it is reported by historians to be among the oldest cultivated fruits. It is also stated that almonds were found among the treasures in Egypt, specifically on the island of Pharos near Alexandria (Topçuoğlu and Yılmaz-Ersan, 2020). Almond is a tree species that produces hard-shelled fruits and is cultivated in climates characterized by dry and hot summers, as well as mild and rainy winters. Almond is an important agricultural product that has low soil selectivity and can even grow in arid lands. Almonds are a good source of vitamins and minerals, making them beneficial for human health. They are widely used as a snack, as well as in confectionery, chocolate and pastry products. Additionally, almond oil is widely used in the cosmetic industry and in the pharmaceutical industry (Aydoğdu and Şahin, 2020). From a commercial perspective, the desirable characteristics of a good almond variety include strong tree development, abundant flowering, late blooming, abundant and consistent fruit production, simultaneous fruit maturation, resistance to wind-induced fruit drop and ease of harvesting. Moreover, it should be resistant to environmental conditions, diseases, and pests (Eldoğan, 2020).

In the agricultural sector, for supply to adapt to price changes, it requires the passage of a production cycle. The length of a production cycle in the agricultural sector is typically one year. Sometimes, this duration can be even longer, as in the case of perennial plants. The necessity for a production cycle to pass in order for supply to respond to such demand and price changes stems from the fact that the quantity supplied is dependent on the price from the previous year (with a

lag). In conclusion, the supply quantity of the product produced in period t is dependent on the price of the period t-1 (Karkacıer, 1999).

When the relevant literature is examined, it is seen that there is very limited research using the Koyck model to determine the relationship between agricultural product prices and the production of agricultural products in Türkiye. Ağazade (2021) investigated the relationship between cotton production and cotton prices, Avcioğlu and Aksoy (2021) examined the relationship between pistachio production and pistachio prices, Berk (2017) studied the relationship between sunflower production and sunflower prices, Çelik (2014) explored the relationship between hazelnut shelled production and hazelnut shelled prices, Çelik (2015) analyzed the relationship between sheep milk production and sheep milk prices, Çobanoğlu (2010) examined the relationship between strawberry production and strawberry prices, Dikmen (2006) investigated the relationship between tobacco production and tobacco prices, Erdal and Erdal (2008) studied the relationship between dry onion production and dry onion prices, Özçelik and Özer (2006) explored the relationship between wheat production and wheat prices, Özsayın (2017) analyzed the relationship between cow milk production and cow milk prices, Doğan et al. (2014) examined the relationship between potato production and potato prices, Abdikoğlu and Unakıtan (2014) investigated the relationship between watermelon production and watermelon prices and Arısoy and Bayramoğlu (2017) attempted to determine the relationship between potato production and potato prices using the Koyck model.

The purpose of the current study is to reveal the relationship between almond production and almond prices in Türkiye using the Koyck model.

2. Materials and Method

2.1. Almond production in the world and in Türkiye

In the almond production, the United States ranks first with a share of 54.81%, followed by Spain in second place with a share of 9.14%, Australia in third place with a share of 7.15%, and Türkiye in fourth place with a share of 4.46% (Table 1) in 2021.

When almond production in Türkiye is examined, it is seen that almond production has been showing an increasing trend, particularly in recent years (Figure 1). It can be said that the increase in the number of fruit-bearing trees and productivity has played a significant role in this production increase. For example, in 2004, the number of fruit-bearing trees was 3450000, while in 2022, this number increased to 13616290. Similarly, the yield per tree increased from 11 kilograms in 2004 to 14 kilograms in 2022 (TÜİK, 2023).

Table 1. World almond production (2021)
Çizelge 1. *Dünya badem üretimi (2021)*

Country	Production (ton)	%
USA	2189040.00	54.81
Spain	365210.00	9.14
Australia	285605.05	7.15
Türkiye	178000.00	4.46
Morocco	169255.00	4.24
Iran	163568.20	4.10
Tunisia	75000.00	1.88
Italy	71620.00	1.79
China	45000.00	1.13
World	3993998.06	100.00

Source: FAO, 2023.

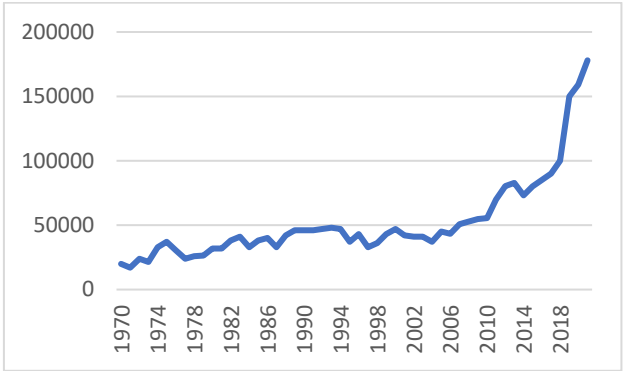

Figure 1. Almond Production in Türkiye by Years (tons)
Şekil 1. *Türkiye'de yıllar itibariyle badem üretimi (ton)*

In Türkiye, in 2022, almond production reached 190000 tons. In almond production in Türkiye, Adıyaman province ranked first in production with a share of 17.80%, followed by Mersin province with a share of 13.82%, Antalya province with a share of 5.97% and Muğla province with a share of 5.59% (TÜİK, 2023).

2.2. Koyck model

The Distributed Lag Koyck Model was used in the current study. In the study, the amount of almond production is taken as the dependent and the price of almonds as the independent variable. The variables used in the study cover the period from 1970 to 2021. The unit of almond price is taken as the price paid the producer (TL/kg), while the unit of the amount of almond production is taken as ton. The time series data for the amount of almond production and almond prices

were obtained from the TÜİK (Turkish Statistical Institute) database (TÜİK, 2023; TÜİK, 2014).

In regression models that use time series data, if the models include not only the current values of explanatory variables but also their past (lagged) values, such models are referred to as distributed lag models (Gujarati, 1999). The model used in the study is as follows, given in Equation 1.

$$Q_t = \alpha + \beta_0 P_t + \beta_1 P_{t-1} + \beta_2 P_{t-2} + ... + \beta_k P_{t-k} + u_t \quad (1)$$

Koyck proposed a method for estimating distributed lag models. Koyck assumes that all the β coefficients have the same sign and that they geometrically decline as follows (Gujarati and Porter, 1999).

$$\beta_k = \beta_0 \lambda^k \quad k=0,1\ldots \quad (2)$$

In the formula;
λ (0<λ< 1): The rate of decline or decay of the distributed lag
(1- λ): Speed of adjustment

As we go back into the distant past, each successive β coefficient numerically decreases even more. This implies that the impact of this lag on Y_t gradually diminishes, which is a reasonable assumption (Gujarati, 1999).

Attention should be paid to the following characteristics of the Koyck scheme (Gujarati and Porter, 1999): (1) By assuming negative values for λ, Koyck rules out the β's from changing sign (2) by assuming that λ < 1, he gives lesser weight to the distant β's than the current ones, and (3) he ensures that the sum of the β's, which gives the long-run multiplier, is finite. Namely,

$$\sum_{i=0}^{\infty} \beta_k = \beta_0 (\frac{1}{1-\lambda}) \quad (3)$$

As a result, the infinite lag model may be written as in Eq. 4 (Gujarati and Porter, 1999).

$$Y_t = \alpha+\beta_0 X_t+\beta_0\lambda X_{t-1}+\beta_0\lambda^2 X_{t-2}+.....+ \beta_0\lambda^k X_{t-k}+u_t \quad (4)$$

When the model is lagged by one period, the following is obtained:

$$Y_{t-1} = \alpha+\beta_0 X_{t-1}+\beta_0\lambda X_{t-2}+\beta_0\lambda^2 X_{t-3}+.....+ u_{t-1} \quad (5)$$

When the model is multiplied by λ, the following is obtained.

$$\lambda Y_{t-1} = \lambda\alpha+\beta_0\lambda X_{t-1}+\beta_0\lambda^2 X_{t-2}+\beta_0\lambda^3 X_{t-3}+.....+ \lambda u_{t-1} \quad (6)$$

When Y_t is subtracted from λY_{t-1}, the Eq. 7 is obtained.

$$Y_t - \lambda Y_{t-1} = (1-\lambda)\alpha+\beta_0 X_t+(u_{t-1}- \lambda u_{t-1})$$

$$Y_t = (1-\lambda)\alpha+ \beta_0 X_t+\lambda Y_{t-1}+v_t \quad (7)$$

3. Results and Discussion

In the study, first, the relationship between the amount of almond production and almond price was examined. As a result of the analysis, the correlation coefficient between almond price and the amount of almond production was calculated to be 0.952. This high correlation indicates that the variables are suitable for the Koyck model. In studies related to the subject, correlation coefficients between production and price were found to be 0.790 in garlic by Hasan and Khalequzzaman (2015), 0.850 in cow's milk by Özsayın (2017), 0.997 in sheep's milk by Çelik (2015), 0.940 in strawberries by Çobanoğlu (2010), 0.920 in dry onions by Erdal and Erdal (2008), 0.645 in shelled hazelnuts by Çelik (2014) and 0.638 in wheat by Özçelik and Özer (2006).

In the study, the lowest Schwarz criterion value was reached at 1 lag length (Table 2). This result indicates that the impact of almond price on almond production will last for one year, and after the first year, the effect of almond price on almond production will be zero. In the studies conducted by Özsayın (2017) and Hasan and Khalequzzaman (2015), the lag length was also found to be 1. On the other hand, there are studies where the lag length is found to be more than 1 year. The lag length was found to be 9 years in the study conducted by Çelik (2015) and 4 years in the study conducted by Çobanoğlu (2010). Similarly, in a study conducted by Ağazade (2021), the lag length was found to be 2 years, while in the study conducted by Doğan et al. (2014), it was also found to be 2 years. Similarly, in the studies conducted by Mbise (2016) and Turğut et al. (2023), the lag length was found to be 2 years. However, in the study conducted by Erdal and Erdal (2008), the lag length was found to be 5 years, and in the study conducted by Özçelik and Özer (2006), it was found to be 3 years. Furthermore, in the study where the Almon Lag Model was used, Özbay and Çelik (2016) found a lag length of 8 years. In the study that employed Koyck and Almon models, Dikmen (2006) found a lag length of 3 years. In another study that employed the Koyck and Almon models, Gürer (2020) found a lag length of 6 years.

In Table 3, the relationship between almond production and almond price according to the 1 lag length was determined by the least squares method. The model obtained in the study is statistically significant (p=0.000000) and R^2 was found to be 0.908552. The correlation between almond production and almond price is shown in Equation 9.

Table 2. Schwarz values for lag numbers
Çizelge 2. *Gecikme sayıları itibariyle schwarz değerleri*

Lag Length	Schwarz Criterion Value
k=1	**21.48251**
k=2	21.53162
k=3	21.55929
k=4	21.60366
k=5	21.60823

In Table 3, the relationship between almond production and almond price according to the 1 lag length was determined by the least squares method. The model obtained in the study is statistically significant (p=0.000000) and R^2 was found to be 0.908552. The correlation between almond production and almond price is shown in Equation 9.

$$Q_t = \alpha_0 + \beta_0 P_t + \beta_1 P_{t-1} + u_t \quad (8)$$

$$Q_t = 32682.72 + 0.004408 P_t + 0.003072 P_{t-1} \quad (9)$$

Table 3. The relationship between almond production and almond price according to the lag numbers
Çizelge 3. *Gecikme sayılarına göre badem üretimi ve badem fiyatı ilişkisi*

Variables	Coefficient	Standard error	t-statistics	Probability value
Constant	32682.72	1710.828	19.10345	0.0000
P_t	0.004408	0.002833	1.556113	0.1263
P_{t-1}	0.003072	0.003227	0.951944	0.3459

R^2= 0.908552 F= 238.4453 p= 0.000000

Table 4. The results of the Koyck model obtained
Çizelge 4. *Elde edilen Koyck modelinin sonuçları*

Variable	Coefficient	Standard error	t-statistics	Probability value
Constant	8790.566	3509.144	2.505046	0.0157
P_t	0.002771	0.000637	4.349928	0.0001
Q_{t-1}	0.727195	0.100305	7.249843	0.0000

R^2= 0.955526 F= 515.6362 p= 0.000000

According to the results of the Koyck model, it can be observed that all the variables (constant, P_t, Q_{t-1}) are statistically significant (P<0.05). When the results of the model are examined, it is seen that a 1 TL increase in almond price leads to a 0.002771 ton increase in almond production, while a 1-ton increase in the almond production in the previous period results in a 0.727195 tonnes increase in almond production (Table 4).

The mean lag was calculated using the formula $\lambda/(1-\lambda)$. The values were put into their places in the formula and the following result was obtained; 0.727195/(1-0.727195)=2.67. This result shows that it takes 2.67 years for the change in almond price to affect almond production. The average lag length was found to be 1.46 in the study conducted by Turğut et al. (2023), 1.75 in the study conducted by Çukur et al. (2023), 2.70 in the study conducted by Avcioğlu and Aksoy (2021), 0.1885 in the study conducted by Berk (2017), 2.27 in the study conducted by Abdikoğlu and Unakıtan (2014), 1.19 in the study conducted by Erdal and Erdal (2008) and 12.33 in the study conducted by Erdal et al. (2009).

Based on the Koyck model, the following operations are performed to reach the equation (9).

When the Koyck model is rewritten,

$$Q_t = \alpha_0 + \beta_0 P_t + \lambda Q_{t-1} + u_t \quad (10)$$

$$\beta_k = \beta_0 \lambda^k \quad (11)$$

As $0 < \lambda < 1$

β_0= 0.002771 λ= 0.727195

$\beta_1 = \beta_0 \lambda^1$ =(0.002771)(0.727195) = 0.002015057

$\alpha_0 = \alpha/(1-\lambda)$= 8790.566/(1-0.727195)= 32222.89

When the data obtained through the calculations above are substituted into the equation generated using the Koyck model, Equation (13) is obtained.

$$Q_t = \alpha_0 + \beta_0 P_t + \beta_1 P_{t-1} + u_t \quad (12)$$

$$Q_t = 32222.89 + 0.002771 P_t + 0.002015057 P_{t-1} \quad (13)$$

As evident from Equation (13), a 1% change in prices leads to a 0.002771 increase in production. It was determined that when there is 1 lag (P_{t-1}), a 1% change in price will increase production by 0.0002015057%.

4. Conclusion

In the study, the relationship between the amount of almond production and almond price in the period from 1970 to 2021 was examined with the help of Koyck model. The Schwarz criterion was used to determine the lag length and the lag length was found to be 1. In the Koyck model, in which the interaction between the amount of almond production and almond price was examined, the coefficient of determination was found to be 95%, and it was significant at the 1% level. It was

determined that the time required for the change in almond prices to cause a significant effect in almond production is 2.67 years. According to the results of the model, a 1 TL increase in almond prices leads to a 0.002771 ton increase in almond production, while a 1-ton increase in the almond production in the previous period results in a 0.727195 tonnes increase in almond production.

It is seen that almond production in Türkiye has been showing an increasing trend in recent years. Almond productivity has also increased over the years. The average yield per tree increased from 11 kilograms in 2004 to 14 kilograms in 2022 in Türkiye (TÜİK, 2023). On the other hand, domestic almond consumption in Türkiye has also increased in recent years. As seen, both almond supply and almond demand have increased in recent years in Türkiye. In the study conducted by Aydoğdu and Şahin (2020), it is stated that there will be continued increases in almond production areas, production quantities, consumption and prices. Therefore, the implementation of effective marketing policies is considered highly important for almond farmers in terms of market security.

References

Abdikoğlu, D.İ., & Unakıtan, G. (2014). Türkiye'de karpuz üretimi ile karpuz fiyatı arasındaki ilişkinin ekonometrik analizi. *XI. Ulusal Tarım Ekonomisi Kongresi*, Türkiye, 854-859.

Ağazade, S. (2021). Türkiye'de pamuk üretimi ile fiyatı arasındaki ilişkinin koyck yaklaşımı ile analizi. *Tekirdağ Ziraat Fakültesi Dergisi*, 18(3), 386-399. DOI: 10.33462/jotaf.681808

Arısoy, H., & Bayramoğlu, Z. (2017). Determination of the effect of price fluctuations on producer income the case of potatoes. *Turkish Journal of Agriculture-Food Science and Technology*, 5(11), 1342-1349. DOI: https://doi.org/10.24925/turjaf.v5i11.1342-1349.1356

Avcioğlu, U., & Aksoy, A. (2021). Analysis of correlation of pistachio production and income with the koyck models in Turkey. *Alinteri Journal of Agriculture Sciences*, 36(1), 71-76. DOI:10.47059/alinteri/V36I1/AJAS21012

Aydoğdu, M.H., & Şahin, Z. (2020). Türkiye badem üretimi: son dönemlerdeki değişimlerin genel analizi. *Euroasia Journal of Mathematics-Engineering Natural & Medical Sciences*, 8, 63-72.

Berk, A. (2017). The analysis of relationship between sunflower production and its price by using Koyck model in Turkey. *Custos e Agronegocio On Line*, 13(4), 42-53.

Çelik, Ş. (2014). Türkiye'nin kabuklu fındık üretiminde üretim-fiyat ilişkisinin Koyck yaklaşımı ile analizi. *Türk Tarım ve Doğa Bilimleri Dergisi*, 1(4), 524-530.

Çelik, Ş. (2015). Koyck ve Almon gecikme modeli ile koyun sütü üretiminde üretim- fiyat ilişkisinin analizi: Türkiye örneği. *Akademik Bakış Dergisi*, 50, 137-149.

Çobanoğlu, F. (2010). Koyck – Almon yaklaşımları ile çilek üretimi ve fiyat ilişkisinin analizi. *Türkiye IX. Tarım Ekonomisi Kongresi*, Türkiye, 72-79.

Çukur, T., Işın, F., & Çukur, F. (2023). Cevizde üretim ile fiyat ilişkisinin analizi. *Gaziosmanpaşa Bilimsel Araştırma Dergisi*, 12(1), 101-106.

Dikmen, N. (2006). Koyck-Almon yaklaşımı ile tütün üretimi ve fiyat ilişkisi. *Çukurova Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 15(2), 153-168.

Doğan, H.G., Gürler, A.Z., Ayyıldız, B., & Şimşek, E. (2014). Patates üretiminde üretim-fiyat ilişkisinin koyck yaklaşımı ile analitik olarak değerlendirilmesi (TR 71 bölgesi örneği). *Türk Tarım – Gıda Bilim ve Teknoloji Dergisi*, 2(1), 42-46.

Eldoğan, Ü. (2020). Dünya'da ve Türkiye'de badem. *Antep Fıstığı Araştırma Dergisi*, 8, 44-45.

Erdal, H., Erdal, G., & Esengun, K. (2009). An analysis of production and price relationship for potato in Turkey: a distributed lag model application. *Bulgarian Journal of Agricultural Science*, 15(3), 243-250.

Erdal, G., & Erdal, H. (2008). Kuru soğanda üretim fiyat etkileşimi. *Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi*, 25(1), 33-39.

FAO. (2023). Crops and livestock products, https://www.fao.org/faostat/en/#data/QCL.

Hasan, M.K., & Khalequzzaman, K.M. (2015). Relationship between production and price of garlic in Bangladesh: an analysis by using distributed lag model. *Bull. Inst. Trop. Agr., Kyushu Univ.*, 38, 31-38.

Gujarati, D.N. (1999). Temel Ekonometri. (Çevirenler: Ü. Şenesen, G.G. Şenesen). İstanbul: Literatür Yayınları.

Gujarati, D.N., & Porter, D.C. (1999). Basic Econometrics. New York: McGraw-Hill/Irwin.

Gürer, B. (2020). Investigation of the lagged effects of livestock supports on the animal production value in Turkey. *Eurasian Journal of Agricultural Research*, 4(2), 144-156.

Karkacıer, O. (1999). Genel Ekonomi (İktisada Giriş). Tokat: Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Yayınları.

Mbise, M. (2016). Influence of expected farm-gate price on maize production in Ludewa district of Njombe region, Tanzania: estimation of koyck lag model. *International Journal of Advanced Research*, 4(12), 292-299. DOI:10.21474/IJAR01/2393

Özbay, N., & Çelik, Ş. (2016). Türkiye'de karpuz üretiminde üretim-fiyat ilişkisinin almon gecikme modeli ile incelenmesi. *Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi*, 19(2), 141-146.

Özçelik, A., & Özer, O.O. (2006). Koyck modeliyle Türkiye'de buğday üretimi ve fiyat ilişkisinin analizi. *Tarım Bilimleri Dergisi*, 12(4), 333-339. DOI: 10.1501/Tarimbil_0000000398

Özsayın, D. (2017). Investigation of production and price relationship in cow milk production by koyck model approach. *Turkish Journal of Agriculture - Food Science and Technology*, 5(6), 681-686. DOI: https://doi.org/10.24925/turjaf.v5i6.681-686.1164

Topçuoğlu, E., & Yılmaz-Ersan, L. (2020). Fonksiyonel beslenmede bademin önemi. *Bursa Uludağ Üniversitesi Ziraat Fakültesi Dergisi*, 34(2), 427-441.

Turğut, U., Güler, D., & Engindeniz, S. (2023) The analysis of the relation between production and price in sunflower by koyck model. *Tarım Ekonomisi Dergisi*, 29 (1), 57-64.

TÜİK. (2023). Bitkisel Üretim İstatistikleri, https://data.tuik.gov.tr/Kategori/GetKategori?p=tarim-111&dil=1.

TÜİK. (2014). İstatistik Göstergeler 1923-2013, Ankara.

Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi
Journal of Agricultural Faculty of Gaziosmanpasa University
https://dergipark.org.tr/tr/pub/gopzfd

Araştırma Makalesi/*Research Article*

JAFAG
ISSN: 1300-2910
E-ISSN: 2147-8848
(2023) 40(3) 130-134
doi:10.55507/gopzfd. 1251826

Chemical Composition in Barley (*Hordeum vulgare* L.) as Affected by Hectoliter Weight

Mesut UYANIK[1]

[1]Manav Feed and Flour Industry and Trade Inc., Biga-Canakkale/Turkey
***Corresponding author's email:** mesut.uyanikk@gmail.com

Alındığı tarih (Received): 17.02.2023 Kabul tarihi (Accepted): 09.10. 2023

Abstract: This research was carried out to determine the effect of different hectoliter weights on some chemical properties of barley under laboratory conditions in 4 replications. In this study, barley having 4 different hectoliters weight (55, 60, 65 and 70 kg hl^{-1}) was used and crude protein, crude fiber, crude oil, crude ash and starch content were examined. The datas obtained were subjected to variance analysis according to the randomized plot design. According to the analysis of variance, the hectoliter weight had a statistically significant effect on all characters at the level of 1%. According to the results, crude protein ranged 9.83-12.18%, crude fiber 4.14-6.26%, crude oil 1.43-1.51%, crude ash 2.40-2.98% and starch 47.63-53.17% and as the hectoliter weight increased, the crude protein and crude fiber and crude ash content decreased, while the crude oil and starch content increased.

Key Words: Barley, Chemical property, Crude protein, Starch

Hektolitre Ağırlığının Arpa (*Hordeum vulgare* L.)' da Kimyasal Bileşime Etkisi

Öz: Bu araştırma farklı hektolitre ağırlıklarının arpada bazı kimyasal özelliklere etkisini belirlemek amacıyla laboratuvar koşullarında 4 tekerrürlü olarak yürütülmüştür. 4 farklı hektolitre ağırlığına (55, 60, 65 ve 70 kg/hl) sahip arpanın kullanıldığı bu araştırmada ham protein, ham selüloz, ham yağ, ham kül ve nişasta oranları incelenmiş olup, sonuçlar tesadüf parselleri deneme desenine göre varyans analizine tabi tutulmuştur. Yapılan varyans analizine göre, hektolitre ağırlığı incelenen tüm karakterler üzerine istatistiki olarak %1 düzeyinde önemli etki yapmıştır. Elde edilen sonuçlara göre, ham protein oranı %9.83-12.18, ham selüloz oranı%4.14-6.26, ham yağ oranı %1.43-1.51, ham kül oranı %2.40-2.98 ve nişasta oranı %47.63-53.17 arasında değişmiş olup, hektolitre ağırlığı arttıkça ham protein, ham selüloz ve ham kül oranı azalırken, ham yağ ve nişasta oranı artmıştır.

Anahtar Kelimeler: Arpa, Ham protein, Kimyasal özellik, Nişasta

1. Introduction

Barley (*Hordeum vulgare* L.), belongs *Poaceae* family, is one of the oldest cultivated plants. It ranks 2nd after wheat in Turkey in terms of harvested area and production while it ranks 4th in world cereal production after wheat, paddy and corn.

Today, the large majority of barley produced is used in animal nutrition. So, in Turkey, 90% of the barley produced is used in animal nutrition while the other part is used the malting industry (Sirat and Bahar, 2020). It has an important place in animal nutrition since it contains protein rich in lysine, especially with its low cellulose and high starch content (Dyulgerova et al., 2017). Besides, a small part of it is used as human food, except for North Africa and Asian countries where it is used as staple food. Recently, determination of high digestible fiber and β-glucan content and health effects increased the importance of barley as food (Baik & Ullrich, 2008; Sterna et al., 2015).

Generally, barley contains 8.2-14.5% crude protein, 4-6% crude fiber, 3-4% crude oil, 2-3% crude ash, 56-67% starch and 2.5-5.5% β-glucan (Aydoğan et al. 2017; Holopainen-Mantila, 2015) and this chemical composition creates the quality of barley. Hectoliter weight is the expression of 100 liters of barley in kg. Genetics, environmental factors, agricultural practices and their interaction, fullness, homogeneity, hull rate and endosperm structure of grain have an effect on the hectoliter weight (Andersson et al., 1999; İmamoğlu & Yılmaz, 2012; Öztürk et al., 2001). In addition, hectoliter weight is affected by the purity of grain and the grain moisture content and it decreases when the amount of foreign matter and grain moisture increases (Şehitoğlu, 2007). Hectoliter weight of barley has been considered in many studies, since it is an important physical property of barley (Aydoğan et al., 2017; Kendal & Doğan, 2014; Kızılgeçti et al., 2019; Oral et al., 2017; Öztürk et al., 2017; Sirat & Sezer, 2005). So,

the purpose of this study to determine the effect of hectoliter weight, which is an important quality parameter in barley, on these values.

2. Material and Method

This study, conducted to determine the effect of different hectoliter weights on some chemical properties of barley, was carried out according to randomized plot design with 4 replications at quality control laboratory of Manav Feed and Flour Industry and Trade Inc., located in Canakkale-Biga in Turkey. Mixed barleys with different hectoliter weights (55, 60, 65 and 70 kg hl^{-1}) supplied by the company from different suppliers were used as the material. In order to prevent the negative effect of low purity on hectoliter, barleys were sieved in 3 mm and hectoliter weight was determined at 100% purity by using a hectoliter measuring device. The barleys with different hectoliter weights used in this study are shown in figure 1.

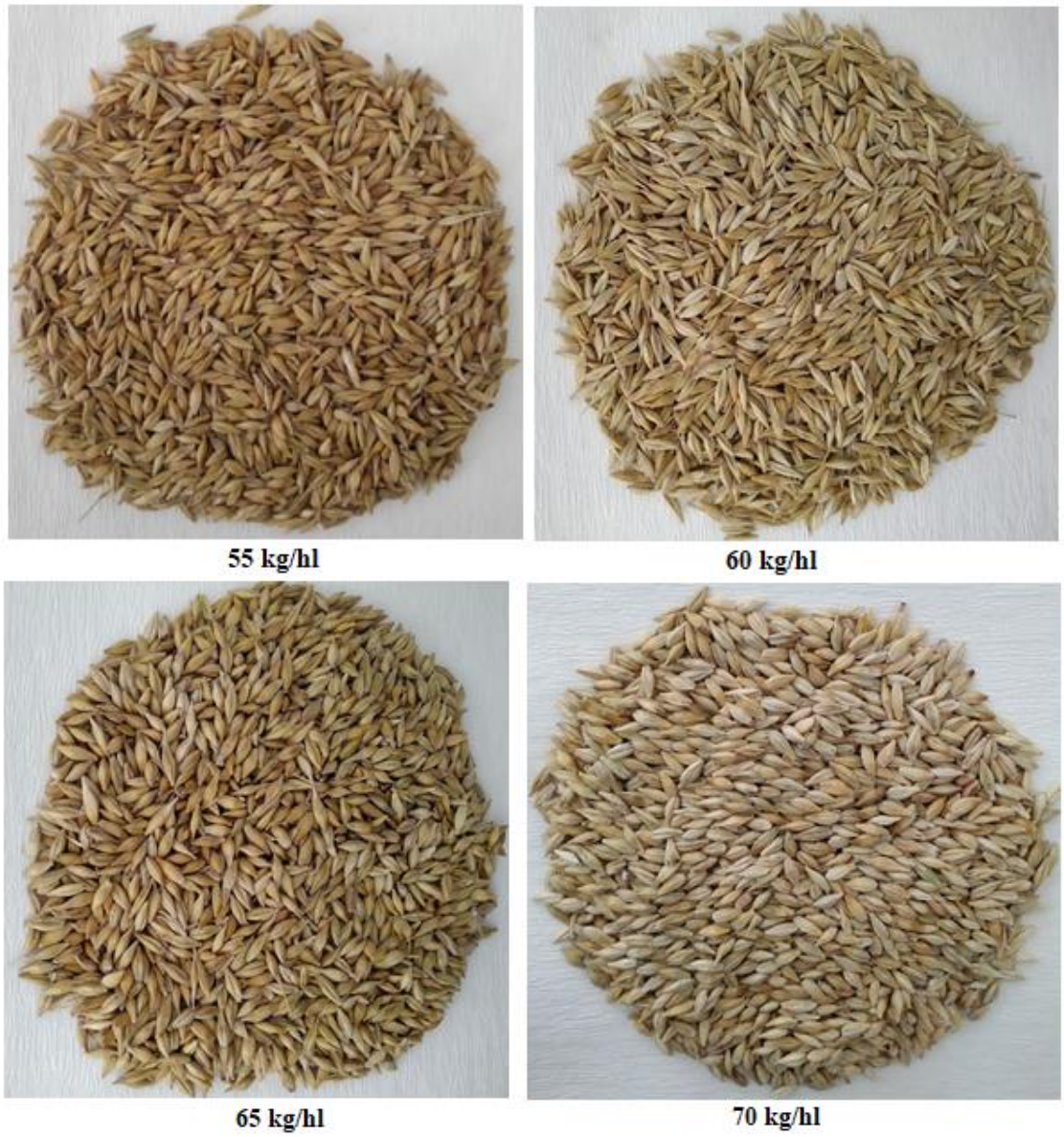

Figure 1. Barley with different hectoliter weights used in the study
Şekil 1. *Araştırmada kullanılan farklı hektolitre ağırlığına sahip arpalar*

Dry matter of samples was determined by using Precisa XM 60 brand moisture analyzer and these values changed between 89.00-89.59%. Then, crude protein, crude fiber, crude fat, crude ash and starch content were examined on this determined dry matter. Crude protein content (%) was determined according to the Kjeldahl method. This method is based on calculating the crude protein content by multiplying the amount of nitrogen in the sample (0.50 gr) with 6.25 (Kutlu 2008). Crude fiber (%) was determined according to the Weende method.

In this method, samples firstly were boiled with 1.25% H2SO4 and 28% KOH for 1 hour and filtered. The residue was incinerated in a muffle furnace at 550°C for 1 h, after washing with 1% H2SO4, 1% NaOH and acetone, after (Kutlu 2008). Crude fat (%) was extracted with petroleum ether (boiling range of 40−60°C) by using Soxhlet extraction method. Crude ash (%) was determined by incineration in a muffle furnace at 550°C for 4 h (Kutlu, 2008). Starch content (%) was determined by the Ewers polarimetric method, which based on the optical activity of starch (Farcaş et al., 2013). In this method, 2.5 g of sample was boiled with 1.128% 50 ml HCl solution in a water bath for 15 minutes and after adding 5 ml of Carez I and Carez II solutions, it was completed to 100 ml with distilled water and filtered. The optical refraction of this filtrate was determined by polarimeter and the starch content was calculated with the formula [(Optical refraction x 2000) / 181.5]. Variance analysis of data was performed according to the randomized plot design and the significance control of the means was made by LSD test.

3. Results and Discussion

Variance analysis results regarding the effect of hectoliter weight on examined properties (crude protein, crude fiber, crude fat, crude ash and starch content) in barley are given in table 1. As seen from table 1, the effect of hectoliter weight on the properties examined was statistically significant at the level of 1%.

The average values and significance groups of the examined properties depending on the hectoliter are given in table 2.

Table 1. Analysis of variance regarding the effect of hectoliter weight on some chemical compositions in barley
Çizelge 1. *Hektolitre ağırlığının arpada bazı kimyasal özellikler üzerine etkisine ilişkin varyans analizi*

Sources of Variation	Degrees of Freedom	*Mean of Squares*				
		Crude Protein (%)	Crude Fiber (%)	Crude fat (%)	Crude Ash (%)	Starch (%)
Hectoliter Weight	3	482.105**	120.911**	8.596**	28.533**	10019.413**
Error	12	0.005	0.031	0.001	0.002	0.644
General	15	96.425	24.207	1.720	5.708	2004.398
Coefficient Variation (%)		0.666	3.207	1.835	1.464	1.605

Table 2. Average values and significance groups of the examined properties
Çizelge 2. *İncelenen özelliklere ilişkin ortalama değerler ve önem grupları*

	Crude Protein (%)	Crude Fiber (%)	Crude Fat (%)	Crude Ash (%)	Starch (%)
Hectoliter Weight 55	12.18^{A}	6.26^{A}	1.43^{B}	2.98^{A}	47.63^{C}
Hectoliter Weight 60	11.48^{B}	5.74^{B}	1.44^{B}	2.73^{B}	47.66^{BC}
Hectoliter Weight 65	10.27^{C}	5.14^{C}	1.48^{AB}	2.53^{C}	51.51^{A}
Hectoliter Weight 70	9.83^{D}	4.74^{D}	1.51^{A}	2.40^{D}	53.17^{A}
$LSD_{(0.01)}$	0.157	0.379	0.058	0.084	1.733

As seen from table 2, crude protein content at different hectoliter weights varied between 9.83-12.18%. As the hectoliter weight increased, the crude protein content decreased and the highest and lowest crude protein values were determined at 55 kg hl^{-1} and 70 kg hl^{-1}, respectively. Crude protein contents obtained from this study are between 9.34-11.16%, reported by Budaklı et al. (2005) and 9.40-11.30% reported by Öztürk et al. (2001), These findings are consistent with the values of 11.70-15.10% presented by İmamoglu and Yilmaz (2012), 10.90-13.10% recorded by Sirat and Sezer (2005) and 13.4% reported by Aydoğan et al. (2017). Oral et al. (2017) reported higher values (14.00-17.20%) than the values obtained from this study. As seen, crude protein content in barley has shown wide variations in many studies. It has been determined that crude protein content changes under the influence of many factors such as: genotype (Öztürk et al., 2001), environmental conditions and agricultural practices; (Kendal & Doğan, 2014), the number of rows in spike (Kendal & Doğan, 2014), the fullness of the grain (Griffey et al., 2010) and mutation applications to seeds (Akgün et al., 2019). Besides, the protein content in barley is mostly in the aleuron layer of the grain (Evers & Millar, 2002). The decrease in the crude proein content depending on the increase in hectoliter weight can be explained by this situation. In barley grain, 75% of the endosperm weight consists of the starchy endosperm and the rest is aleuron layer (Holopainen-Mantina, 2015). So, as the grain fullness increases, the part of starchy endosperm will increase proportionally, and the crude protein content will decrease depending on the aleuron part.

Crude fiber, which is a polysaccharide consisting of lignin, cellulose and hemicellulose, is an important quality criterion in barley. Considering that most of the

barley produced is used as animal feed, it is desired that the crude fiber content is low in feed barley not the quality of the feed is to be affected negatively. In current study, a negative relationship was determined between the hectoliter weight and crude fiber content. So, the crude fiber content decreased, as the hectoliter weight increased (Table 2). In a research carried out by (Aydoğan et al., 2017), it has been determined that the crude fiber content in barley is affected by environmental conditions and varies between 5.90-7.30%. In another study, it was determined that the crude fiber content of barley changed between 5.15-6.10%, affected by the genotype and environmental factors (Aydoğan et al., 2011). Crude fiber content (4.74-6.26%) obtained from the current study is similar to the results of these researchers. The decrease in the crude fiber content depending on increasing hectoliter weight can be explained by the decrease in the hull content. In other words, as the grain fullness increases, the crude fiber content decreases depending on the decrease in the hull content. Bell et al. (1983) and Karaduman (2006)'s findings confirm this situation.

Crude oil content of barley in different hectoliter weights varied between 1.43-1.51% and three groups were formed statistically in averages. While the highest crude oil content was determined in a weight of 70 kg hl^{-1}, there was no significant difference in crude oil content in increasing hectoliter (55, 60 and 65 kg hl^{-1}). Studies have reported that the crude oil content of barley is low (Moreu, 2009; Osman et al., 2000,). Fedak and De La Roche (1977) reported in their study on 21 different barley lines that the crude oil content varied between 2.5-3.1%, while Madazimov et al. (1976) reported crude oil values ranged 1.67-2.30%. In another study, Alijošius, et al. (2016) reported that the crude oil content in barley varied between 1.09-2.00%. As seen, the crude oil content of barley varies depending on many factors. In this study, the increase in the crude oil values due to the increasing hectoliter can be related to the crude oil content of barley flour.

Crude ash values varied between 2.40-2.98% at different hectoliter weights and the crude ash content decreased as the hectoliter weight increased (Table 2). This situation can be related to the ratios of endosperm and aleuron layers in the grain. Indeed, Evers and Millar (2002) reported that the aleuron part of the grain contains protein, oil and mineral substances. Therefore, the ratio of endosperm in the grain will increase depending on increasing hectoliter weight and the ratio of aleuron will decrease. As a result, the crude ash content will decrease. This situation was reported by Dyulgerova et al. (2017), who reported a negative relationship between hectoliter weight and crude ash content.

Starch content is the most important property of barley in quality. Since the amount of beer to be obtained from barley depends largely on the content of starch it has, it is desirable that the hectoliter weight especially in malting barley is more than 66 kg (Atlı et al., 1989). In this study, starch content varied between 47.63% and 53.17% in different hectoliter weights and starch content was also increased depending on the increase in hectoliter weight. This situation is associated with an increase in the endosperm ratio due to grain fullness. This positive relationship between hectoliter weight and starch content also reported by Kaur et al. (2016), Dyulgerova et al. (2017) and Sirat and Bahar (2020). Different starch values were reported in other studies examining the starch content in barley. Baik and Ulrich (2008), Imamoğlu and Yilmaz (2012), Sterna et al. (2015) were detected 65-68%, 58.2-63.5%, 62.2-64%, respectively.

The starch content obtained from current study was lower than these values reported by these researchers. Thus, starch content is one of the quantitative characters that can change under the influence of many factors.

4. Conclusion

As a result, it was determined that the chemical properties of barley were significantly affected by the hectoliter weight. Positive and negative relationships were found between the examined chemical properties and the hectoliter weight. An increase in hectoliter weight led to a significant decrease in crude protein, crude fiber, and crude ash content, while starch content showed a significant increase. In addition, it was observed that the traits examined were also influenced by each other. As the crude protein content increased, the starch content decreased and as the crude fiber content decreased, the starch content increased. These results are also supported by the findings obtained from other studies. This study is important in being a guide when barley is used as a source of protein or starch.

References

Andersson, A. A. M., Elfverson, C., Andersson, R., Regne, S., & Aman, P. (1999). Chemical and physical characteristics of different barley samples, *Journal of the Science of Food and Agriculture*, 79: 979-986. https://doi.org/10.1002/(SICI)10970010(19990515)79:7<979::AID-JSFA313>3.0.CO;2-L

Akgün., İ., Karakoca, T.A., & Karaman, R. (2019). Effect of different gamma ray doses on some agricultural characteristics of two row barley (*Hordeum vulgare* L.), *Food*

Science and Technology, 7 (sp2): 86-92. https://doi.org/10.24925/turjaf.v7isp2.86-92.3152.

Alijošius, S., Juozas Švirmickas, G., Kliševičiūtė, V., Gružauskas, R., Šašytė, V., Racevičiūtė-Stupelienė, A., Daukšienė, A., & Dailidavičienė, J. (2016). The chemical composition of different barley varieties grown in Lithuania, *Veterinarija Ir Zootechnika*, 73(95): 9-13. https://www.researchgate.net/publication/311434685_The_chemical_composition_of_different_barley_varieties_grown_in_Lithuania

Atlı A., Koçak N., Köksel H. ve Tuncer T., 1989.Yemlik ve maltlık arpada kalite kriterleri ve arpa ıslah progamlarında kalite değerlendirmesi. Arpa Malt Semineri, Konya, s. 23-37

Aydoğan, S., Şahin, M., Göçmen Akçacık, A. & Ayrancı, R. (2011). Determination of high yielding and quality of barley genotypes in Konya conditions, *Selçuk Journal of Agriculture and Food Sciences*, 25 (1): 10-16. https://dergipark.org.tr/en/download/article-file/3112021

Aydoğan, S., Şahin, M., Göçmen, Akçacık, A., Demir, B., Hamzaoğlu, S. & Kara, İ. (2017). Evaluation of quality properties of barley genotypes in different locations, *Selçuk Journal of Agriculture and Food Sciences*, 31 (2): 8-13. https://doi:10.15316/SJAFS.2017.13

Baik, B.K. & Ullrich, S.E. (2008). Barley for food: Characteristics, improvement and renewed interest, *Journal of Cereal Science*, 48: 233–242. https://doi.org/10.1016/j.jcs.2008.02.002

Bell, J.M., Shires, A. & Keith, M.O. (1983). Effects of hull and protein contents of barley on protein and energy digestibility and feeding values for pigs, *Canadian Journal of Animal Science*, 63: 201-211. https://doi.org/10.4141/cjas83-023

Budaklı, E., Bayram, G., Türk, M. & Çelik, N. (2005). The effects of different levels of nitrogen on yield, yield components and quality in some two-rowed barley (*Hordeum vulgare* conv. distichon) varieties, *Journal of Agricultural Faculty of Uludag University*, 19 (2): 1-11. https://dergipark.org.tr/tr/download/article-file/154036

Dyulgerova, B., Dyulgerov, N. & Dimova, D. (2017). Variation in the chemical composition and physical characteristics of grain from winter barley varieties, *Agricultural Science and Technology*, 9 (3): 198 202. doi:10.15547/ast.2017.03.036

Evers, T. & Millar, S. (2002). Cereal grain structure and development: Some implications for quality, *Journal of Cereal Science*, 36: 261–284 https://doi.org/10.1006/jcrs.2002.0435

Farcaş, A., Tofana, M., Socaci, S., Salanta, L. & Doinita, B. (2013). Polarimetric determination of starch in raw materials and discharged waste from beer production, *Food Science and Technology*, 70 (1): 70-71. doi: https://doi.org/10.15835/buasvmcn-fst:9484

Fedak, G. & De La Roche, I. (1977). Lipid and fatty acid composition of barley kernels, *Canadian Journal of Plant Science*, 57: 257-260. https://doi.org/10.4141/cjps77-035

Griffey, C., Kurantz, M., Thomason, W., Taylor, F., Obert, D., Moreau, R, Flores, R., Sohn, M. & Hicks, K. (2010). Grain composition of Virginia winter barley and implications for use in feed, food, and biofuels production, *Journal of Cereal Science*, 51: 41–49. https://doi.org/10.1016/j.jcs.2009.09.004

Holopainen-Mantila, U. (2015). Composition and structure of barley (*Hordeum vulgare* L.) grain in relation to end uses. Phd Thesis, Faculty of Biological and Environmental Sciences, University of Helsinki.

Imamoğlu A. & Yılmaz N. (2012). Determination of yield and some quality properties of some barley (*Hordeum vulgare* L.) genotypes in Bursa ecological conditions, *Anadolu Journal of the Aegean Agricultural Research Institute*, 22 (2): 13–36.

Karaduman, Y. (2006). Kavuzsuz arpa potansiyeli. *Unlu mamuller Teknolojisi*, 74: 21-26.

Kendal, E. & Doğan, H. (2014). Impact of row number in barley head on yield, some quality and morphological parameters in barley, *Turkish Journal of Agricultural and Natural Sciences*, 1 (2): 132–142. https://www.researchgate.net/publication/317279529

Kaur, S., Kaur, H., Singh, P., Cheema, B.S. & Kumar, V. (2016). Genetic variation and evaluation of exotic barley (*Hordeum vulgare* L.) genotypes for grain protein content, starch content and agronomic traits, *Electronic Journal of Plant Breeding*, 7: 1114-1121. DOI: 10.5958/0975-928X.2016.00154.X

Kutlu, H.R. (2008). Yem değerlendirme ve analiz yöntemleri. Çukurova Üniversitesi Ziraat Fakültesi Zootekni Bölümü, Ders Notu, Adana. (unpublished)

Madazimov, S.H.T., Tukhtamuradov, Z.T. & Ibragimova, K.I. (1976). Fatty acid composition of uzker barley and changes during malting, *Pirkladnaya Biokhimiyai Microbiologiya*, 12 (5): 734.

Kızılgeçti, F. Yıldırım, M., Akıncı, C., Albayrak, Ö. (2019). Genotype and environment effects on the grain yield and quality traits of some in barley genotypes, *Journal of Agricultural and Nature Sciences*, 22 (3): 346-353. doi : 10.18016/ksutarimdoga.vi.499013

Moreu, R.A., (2009). Barley Oil. Gourmet and Health-Promoting Specialty Oils, p: 455-478.

Oral, E., Kendal, E. & Doğan, Y. (2017). Bazı yazlık Arpa (*Hordeum vulgare* L.) genotiplerinin verim ve kalite yönünden değerlendirilmesi, *Iğdır Üniversitesi Fen Bilimleri Enstitüsü Dergisi,* 7(1): 31-38. https://dergipark.org.tr/tr/download/article-file/417435

Osman, R.O., Abd El Gelil, F.M., El-Noamany, H.M. & Dawood, M.G. (2000). Oil content and fatty acid composition of some varities of bayley and sorghum grains, *Grasasy Aceites*, 51 (3): 157-162. doi: https://doi.org/10.3989/gya.2000.v51.i3.472

Öztürk, A., Çağlar, Ö. & Tufan, A. (2001). Adaptation of some barley cultivars in Erzurum conditions, *Atatürk University Journal of Agricultural Faculty*, 32 (2): 109-115. https://doi.org/10.31590/ejosat.1194185

Öztürk, İ., Kahraman, T., Avcı, R., Girgin, V.Ç., Çiftçigil, T.H., Tülek, A., Akın, K. & Tuna, B. (2017). Effect of various environmental conditions on agronomic characters and leaf diseases on barley (*Hordeum vulgare* L.) genotypes, *Journal of Bahri Dagdas Crop Research*, 6 (1): 48-56. https://dergipark.org.tr/en/download/article-file/476585

Sirat, A. & Sezer, İ. (2005). Samsun ekolojik koşullarına uygun arpa (*Hordeum vulgare* L.) çeşitlerinin belirlenmesi, *OMU Ziraat Fakültesi Dergisi*, 20 (3):72-81. https://www.acarindex.com/pdfs/337957

Sirat, A. & Bahar, B. (2020). Gümüşhane ekolojik koşullarında bazı altı sıralı arpa çeşitlerinin tane kalite özellikleri ve besin değerlerinin belirlenmesi. *Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi,* 6(2): 325-335. doi: 10.24180/ijaws.683462

Şehitoğlu, M. (2007). Arpa çeşitlerinde farklı tohumluk miktarlarının verim, verim öğeleri ve kalite özelliklerine etkileri (Tez No: 178872). [Yüksek Lisans tezi, Seçuk Üniversitesi]. Yükseköğretim Kurulu Başkanlığı, Ulusal Tez Merkezi

Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi
Journal of Agricultural Faculty of Gaziosmanpasa University
https://dergipark.org.tr/tr/pub/gopzfd

Araştırma Makalesi/*Research Article*

JAFAG
ISSN: 1300-2910
E-ISSN: 2147-8848
(2023) 40(3) 135-140
doi:10.55507/gopzfd.1380489

Investigation, Identification and Pathogenicity Assessment of Leaf and Soil-Borne Fungal Diseases Causing Yield Reduction in Vegetables in Antalya

Hale GÜNAÇTI[1*]

Biological Control Research Institute, Adana
***Corresponding author's email:** hale.gunacti@tarim.gov.tr

Alındığı tarih (Received): 24.10.2023 Kabul tarihi (Accepted): 13.12.2023

Abstract: Vegetables significantly contribute to Antalya, Türkiye's economy. This study aimed to investigate and identify fungal pathogens causing leaf and soil-borne diseases in leafy vegetable crops. Surveys were conducted in 2021, focusing on morphological and microscopic diagnosis, as well as the prevalence rate of these diseases in five regions (Aksu, Serik, Muratpaşa, Kepez, and Korkuteli). Isolates were obtained from both the leaves and roots of symptomatic plants, and pathogenicity tests were conducted. Survey results showed that lectuca downy mildew was the most important disease, with a 40% plant infection rate and 16.9% disease severity in most parts of the region. In areas where parsley was cultivated, *Fusarium* sp. was identified as the predominant soil-borne pathogen at 23.82%, and *Sclerotinia sclerotiorum* was prevalent in lettuce at 14.28%. The lowest incidence of *Albugo candida* was observed in cress. In conclusion, this study provides crucial insights into the prevalence of fungal diseases and the specific pathogens responsible for damage to lettuce, parsley, dill, cress, mint, and basil cultivation in Antalya province. The incidence and prevalence of these fungal diseases were assessed through surveys in Antalya. In conclusion, this study provides important information on fungal disease agents and their prevalence in lettuce, parsley, dill, cress, mint and basil cultivated areas in Antalya province.

Keywords: Disease incidence, leafy vegetable, prevalence.

Antalya'da Sebzelerde Verim Azalmasına Neden Olan Yaprak ve Toprak Kökenli Fungal Hastalıklarının Araştırılması, Tanımlanması ve Patojenitesi

Öz: Sebze tarımının Türkiye ve Antalya ekonomisine önemli katkısı vardır. Bu çalışma, yaprağı yenen sebzelerde verim kaybına neden olan yaprak ve toprak kökenli fungal patojenlerin araştırılmasını ve tanımlanmasını amaçlamıştır. Çalışma, 2021 yılında, Antalya ilinde yoğun sebze yetiştiriciliği yapılan Aksu, Serik, Muratpaşa, Kepez ve Korkuteli ilçelerinde yürütülmüştür. Hastalık etmeni fungal patojenlerin simptomolojik, morfolojik ve mikroskobik tanılamaları yapılmış ayrıca hastalık şiddeti ve yaygınlık oranları belirlenmiştir. Hastalık belirtisi gösteren bitkilerin hem yapraklarından hem de köklerinden izolatlar elde edilerek patojenite testleri yapılmıştır. Survey sonuçlarına göre, %40 bitki enfeksiyon oranı ve %16,9 hastalık şiddeti ile Mildiyö en önemli hastalık olarak tespit edilmiştir. Maydanoz yetiştirilen bölgelerde *Fusarium* sp. %23,82 oranı ile toprak kaynaklı baskın patojen olarak tanımlanmış olup bunu marulda %14,28 *Sclerotinia sclerotiorum* izlemiştir. En düşük görülme sıklığı ise terede *Albugo candida* olarak bulunmuştur. Sonuç olarak bu çalışma, Antalya ilinde marul, maydanoz, dereotu, tere, nane ve fesleğen yetiştirilen alanlarda fungal hastalık etmenleri ve yaygınlığı hakkında önemli bilgiler sunmaktadır.

Anahtar kelimeler: Hastalık şiddeti, yaprağı yenen sebzeler, yaygınlık oranı,

1. Introduction

Sustainable agriculture and reliable food are among the most important issues for all countries in the world. Among agricultural products, vegetables have an important place in human nutrition in Turkey as well as in the world. (Gupta &Prakash, 2009). The leafy vegetables consumed in their raw state, which are essential to our tables, are parsley, dill, cress, mint, basil and lettuce. These vegetables hold significant importance in our lives due to their appearance, colors, flavors and nutritional values. According to the 2021 TUIK data, Antalya has 3,556,424 da of agricultural area and 493,193 da of this agricultural area are engaged in vegetable agriculture. Within this total production, the production amount of leafy vegetables (lettuce, parsley, cress, mint and dill) is 60,677 tons (TUIK, 2021).

Failure to adhere to crop rotation in the areas where production takes place leads to vegetables being exposed to soil-borne diseases. The use of unlicensed and uninformed plant protection products by producers poses a threat to human health and the environment. In our country, studies on edible vegetables are generally limited to studies on the presence of the disease. Studies

on fungal diseases in edible vegetables in Turkiye; They can be listed as *Albugo candida* in cress and arugula, *Erysiphe heraclei* in dill, *Septoria petroselini* and *Plasmopara petroselini* in parsley, *Alternaria* spp, *Botrytis cinerea, Sclerotinia sclerotiorum* in lettuce, and *Peronospora belbahri* and *Botrytis cineria* in basil (Kurt 2003; Soylu & Soylu 2003; Ellialtıoğlu et al.,2007; Onaran and Yanar, 2009; Soylu et al. 2010; Ünlü and Boyraz 2010; Özer et al., 2018; Canpolat et al 2019; Uzunoğulları et al. 2022; Günaçtı, 2022;). Among the efforts towards control these diseases, fungicide applications against Septoria leaf spot disease in parsley and grey mold disease caused by *Botrytis cinerea* in lettuce are included (Polat and Coşkuntuna 2014; Tok, 2008).

Table 1. Same Vegetable Production Areas in Antalya, 2021
Çizelge 1*. Antalya ilinde bazı sebze üretim alanları miktarı, 2021*

District	Product					
	Lettuce	**Parsley**	**Dill**	**Cress**	**Mint**	**Basil**
Serik	4.435	95	15			10
Aksu	3.870	475	25	35		8
Muratpaşa	1.670	105	30	100		12
Kepez	1.112	430	55	15	40	6
Korkuteli	1.100	285	20	18		14
Totaly (da)	**12.187**	**1.390**	**145**	**168**	**40**	**50**

Antalya province has the most important place in the production and sales of leafy vegetables and is also the production region with the highest pesticide residue problem in these products. There have not been sufficient studies on fungal diseases of edible vegetables in the region. Antalya province has the most important place in the production and sale of leafy edible vegetables and is also the production region with the highest problem of pesticide residues in these products. There is no research on the incidence and prevalence of disease-causing fungi in leafy vegetables consumed in Antalya. In this study, it was aimed to define fungal diseases morphologically and microscopically and to determine disease occurrence rates and disease incidence rates in some leafy vegetable production areas in the region.

2. Material and Methods

Samples simple random sampling method were taken according to the disease symptoms in the plants and the disease rate was calculated by counting.

2.1. Survey and isolation of fungal pathogens

Isolates were collected in 2021 from 45 total field including lettuce, parsley, dill, cress, mint and basil plants in Antalya (Table 1). Samples simple random sampling method were taken according to the disease symptoms in the plants and the disease rate was calculated by counting. Approximately 14,000 da are grown annually in Antalya for fresh consumption. According to the simple random sampling method, selected fields were examined for disease symptoms, prevalence, and incidences (Bora and Karaca, 1970). Survey studies were programmed to cover at least 1% of the cultivation area. A total of 45 fields were investigated, and plant samples with root and crown rot, wilting and drying symptoms were collected. Plant samples brought to the laboratory were cut into small pieces including healthy and diseased parts and subjected to surface disinfection in 1% sodium hypochlorite (NaOCl) solution for 2-4 minutes. The diseased plant parts were then rinsed with sterile distilled water, dried thoroughly between sterile blotting papers and transferred to Petri dishes containing Potato Dextrose Agar (PDA-Merck) and Synthetic Nutrient Agar (SNA) medium under aseptic conditions. The samples were incubated at 22±2°C for and the developing fungi were purified for identification and then stored in slant agar at +4°C. Samples were brought to the Mycology Laboratory of the Biological Control Research Institute (BMAE). The disease rate in the production area was calculated from the percentage of infected plants. After the disease rates in the production area were determined, the prevalence rate was compared to the current average. (Bora ve Karaca, 1970).

2.2. Microscobic examination and morphological identification

Identification of soilborne pathogens, samples were taken from the root, crown and stem parts of diseased plants, and the identification of cultures developed as a result of isolation was carried out morphologically and microscopically using diagnostic keys in the literature (Agrios, 1998; Barnett & Hunter, 1998; Ellis,

1971;1976; Sneh et al., 1991; Leslie et al., 2006). Identification of obligate pathogens *(Erysiphe* spp., *Peronospora* spp.) based on morphological characteristics (column, color, spore shape and size) has been made. For microscopic analysis, leaf samples showing hairy mycelial development and chlorotic symptoms were determined under the microscope from plant leaves collected from the fields (Bulajic et al.,2009; Nawrocki 2004; Nawrocki and Mazur 2007; Soylu & Soylu 2003). Microscopic studies were investigated using a light microscope, the Olympus BX43 microscope and equipped with a digital camera.

2.3. Pathogenicity

Soil borne fungal pathogens were tested for pathogenicity according to soil inoculation methods described by Kunwar et al. (1989) and Ahmad and Sharma (1990). Wheat culture was prepared for inoculation into the soil. Wheat seeds soaked in water for 10 minutes were boiled. After the prepared inoculum was autoclaved in glass bottles, inoculation was made with discs taken from the colonies for proper growth of the fungi. Bottles were kept in incubator at 24–25 °C for 15 days. Fungal inoculum was first mixed into the potting soil one week after sowing. Then, 10 seeds per pot were planted in parsley seeds; lettuce seedlings were planted in such a way that there would be three seedlings in each pot. In control pots, only wheat was mixed, and disinfected seeds were planted. Trials with three replications have been made. Controls were inoculated with sterile water only. After inoculation, plants were kept at 20°C in a greenhouse. Disease assessments were performed four weeks later. The pathogen was re-isolated from inoculated plants using the method described above. Re-isolation of the pathogen was carried out and compared with the original inoculum to fulfill Koch's postulates.

2.4. Assessment of disease incidence and disease prevalence

During field surveys conducted in 2021, a lot of foliar and soilborne fungal diseases were observed in Antalya province. The surveys were carried out in November and December 2021, when optimum conditions for the diseases were available. Randomly selected 100 plants were taken from each field in all areas where lettuce, parsley, dill, cress, mint and basil are grown in fields in Antalya. The incidence of fungal diseases was determined according to the presence or absence of disease on the leaves and rots examined. The disease incidence and prevalence were calculated using the formulas below (Bora and Karaca 1970).

$$\textit{Disease incidence (\%)} = \textit{Number of diseased plant} \div \textit{total number of plants evaluated} \times 100 \quad (1)$$

$$\textit{Disease Prevalence (\%)} = \textit{Number of disease established fields} \div \textit{total number of surveyed fields} \times 100 \quad (2)$$

3. Result and discussion

A total of 270 plant samples showing disease symptoms were collected from areas where lettuce, parsley, dill, mint, and basil were cultivated during the 2021 growing season in Antalya.Survey studies were carried out in the leafy vegetable areas of Antalya province in 2021, and information about these areas is given in Table 2. As a result of the studies *B. lactucae R. solani, S. sclerotiorum* and *Fusarium* spp. in lettuce; *S. petroselini, Fusarium* spp. and *A. alternata* in parsley; *E. heraclei and Fusarium spp.* in dill; *Fusarium* spp. in mint, *P. belbahrii, B. cineria, Fusarium* spp. in basil and *Albugo candida* in cress were detected .

Isolations revealed that the most commonly identified fungus genus was *Fusarium* sp. It was also determined that *S. sclerotiorum* is common disease, causing damage to plants green parts. Other isolated fungi included *R. solani, A. alternata., E. heraclei, B. lactucae, P. belbahrii, B. cineria S. petroselini* and *Albugo candida.* These fungi showed varying levels of prevalence and the potential to cause damage in fields. As a result of isolations, downy mildew was the most important disease, with a 40% plant infection rate and 16.9% disease severity in most parts of the region. In areas where parsley was cultivated, *Fusarium* sp. was identified as the predominant soil-borne pathogen at 23.82%, and *Sclerotinia sclerotiorum* was prevalent in lettuce at 14.28%. The lowest incidence of *Albugo candida* was observed in cress.

White rot disease, caused by *Sclerotinia sclerotiorum,* has been reported to result in product losses of up to 95% in lettuce production worldwide (Clarkson et al., 2004; Smolinska and Kowalska, 2018; Mullen, 2001; Chitrampalam et al., 2011). Soil-borne pathogens such as *Fusarium oxysporum, Phoma exigua, Rhizoctonia solani, Sclerotinia sclerotiorum, Verticillium dahliae,* and *Pythium* spp. can cause diseases in lettuce such as wilting, root, and root collar rot (Dixon, 1984; Koike et al., 2007). Onaran and Yanar (2009) reported that *Sclerotinia sclerotiorum* is the most damaging disease in lettuce based on their study in the

Aegean Region, particularly in Izmir, Manisa and Aydın provinces.

Table 2. Fungal disease pathogens and prevalence detected in some vegetables
Çizelge 2. *Fungal hastalık etmenlerinin bazı sebzelerde bulunma oranı ve hastalık şiddeti*

Crops	Totaly area (da)	Surveyed area (da)	Disesesd survey area (da)	Disease Prevelance (%)	Disease Incidance (%)									
					Fusarium spp.	*Rhizoctonia solani*	*Alternari alternata*	*Sclerotinia sclerotiorum*	*Septoria petroselini*	*Bremia lactucae*	*Botrytis cineria*	*Peronospora belbahrii*	*Albugo candida*	*Erysiphe heracle*
Lettuce	12.187	20	8	40	14,64	8,83	-	14,28	-	16,9	-	-	-	-
Parsley	1.390	8	2	25	23,82	-	3,84	-	19,26	-	-	-	-	-
Dill	145	5	2	40	3,08	-	-	-	-	-	-	-	-	4,88
Cress	168	5	1	20	-	-	-	-	-	-	-	-	1,22	-
Mint	40	3	1	33,3	6,53	-	-	-	-	-	-	-	-	-
Basil	50	4	3	75	2,38	-	-	3,12	-	-	1,32	12,5	-	-

Parsley is susceptible to several fungal pathogens, with the most significant being Septoria leaf spot disease caused by *Septoria petroselini*, *Pythium* spp., *Fusarium* spp., *Rhizoctonia solani*, *Sclerotinia Sclerotiorum*, *Alternaria radicina*, *Alternaria petroselini*, *Cercospora* spp. and *Plasmopara petroselini* (Raid and Roberts, 2004; Kurt, 2003; Kurt & Tok, 2006, 2019; Soylu et al., 2010; Kurt et al., 2017; Nawrock, 2004; Glawe et al., 2005; Hershman, 1986). Among studies conducted in our country, fungal disease pathogen *Septoria petroselini* was first identified by Kurt in 2003 in Hatay province, where parsley cultivation is most prevalent. In a study conducted to identify fungal pathogens in the Central Anatolia Region, *Alternaria* spp. was detected in parsley and *Bremia lactucae* in lettuce (Ünlü and Boyraz, 2010).

In a study conducted during the 1981-1982 production season in South New Jersey, *F. oxysporum*, *F. solani*, *P. ultimum*, *P. irregulare*, and *R. solani* were isolated from parsley (Hershman, 1986). In a study by Nawrocki (2004), the most commonly detected pathogens in seedlings were *Alternaria radicina* and *Fusarium* spp., followed by *Cylindrocarpon destructans*, *R. solani* and *Stemphylium botryosum* in lower proportions. To effectively control these diseases, it is essential to use certificated seeds, practice crop rotation and ensure the collection and destruction of diseased plants and harvest residues. Chemical control against these diseases should commence as soon as the first symptoms manifest in the environment (Tok & Kurt, 2019; Anonymous, 2020).

In mint plants, fungal pathogens such as *Puccinia menthae*, *V. daliae*, *A. alternata*, and *R.solani* have been reported (Jurronis and Snieskienei, 2004; Zimowska, 2007). In our 2021 survey study, *Fusarium* spp. was identified as the causative agent of mint wilt disease, with a detection rate of 6.53%. The most commonly preferred control methods for managing this disease involve removing infected plants from the field and implementing crop rotation. It is imperative to promptly remove plants exhibiting wilt disease symptoms and prioritize crop rotation (Kalra et al., 2005; Demir, 2007).

In our study, *Erisiphe heraclei* was detected in dill at a rate of 4.88%. Suitable conditions for the pathogen include low light intensity and high humidity. The affected leaves generally wither and dry. Since the pathogen causes quality losses in the leaves, it is economically significant.

For leafy vegetables, the causative agent of powdery mildew is *Albugo candida* in dill. The disease appears on the upper surface of the leaf as raised white pustules or rings. In our study, *A. candida* was identified as the lowest prevalent disease at a rate of 1.22%.

Basil is one of the aromatic plants commonly used in salads and pasta. In this study, *Peronospora belbahrii* was identified at 12.5%, *Sclerotinia sclerotiorum* at 3.12%, *Fusarium* spp. at 2.38%, and *Botrytis cinerea* at 1.32%. In studies related to basil, *B. cinerea* was first detected in Özer et al. (2018), and *P. belbahrii* was first identified in our country by Günaçtı in 2022.

4. Conclusion

Vegetable cultivation is one of the major sources of income in Antalya. This study was to determine soil and leaf-origin fungal diseases causing a decrease in yield in vegetables such as lettuce, parsley, dill, mint, and basil. Survey studies were conducted in the districts of Serik, Muratpaşa, Korkuteli, and Aksu within Antalya province. As a result of the surveys in the edible vegetable areas of Antalya province, it has been observed that fungal disease agents, especially soil-

borne agents, are abundant, and it is thought that these data provide up-to-date information to the literature for the region.

In Turkey, due to the limited number of licensed plant protection products for leafy vegetables, cultural measures take precedence in the control of fungal diseases. Field studies revealed that farmers were not paying sufficient attention to cultural measures. Notable observations included excessive pesticide application, lack of emphasis on pesticide application periods, and inadequate care in the removal of diseased plants, which serve as a source of inoculum. Implementing biological control studies in leafy vegetable cultivation can lead to the production of high-quality products without pesticide residues. This approach minimizes chemical usage, preserves natural enemies, and mitigates the damage caused to the environment and the economy by unnecessary pesticide use.

Acknowledgements

The author would like to thank the General Directorate of Agricultural Food Control and Adana Biological Control Research Institute for their contributions.

Reference

Agrios, G. N. (1998). *Plant pathology*. Academic Press. New York

Ahmad, Q. & Sharma, R.N., (1990) . Sources of resistance to Fusarium wilt of chickpea in Bihar. *International Chickpea Newsletter*, 23, 20-21.

Anonymous (2020). Bitki Sağlığı, web site:http://www.bitkisagligi.net

Barnett H.L. & Hunter, B.B., (1998). Illustrated genera of imperfect fungi. St. Paul, MN,

Bora, T. & Karaca, İ., (1970) . *Kültür Bitkilerinde Hastalığın Ve Zararın Ölçülmesi.* Ege Üniversitesi Ziraat Fakültesi Yardımcı Ders Kitabı, (No:167) Ege Üniversitesi Matbaası

Bulajıć, A., Djekic, I., Lakic, N. & Krstic, B., (2009). The presence of *Alternaria* spp. on the seed of apiaceae plants and their influence on seed emergence. *Archives Biological. Science*, Belgrade, 61 (4), 871-881. DOI:10.2298/ABS0904871B

Canpolat, S. & Tülek, S. (2019). Orta Anadolu Bölgesi'nde yaprağı yenen sebzelerde görülen fungal hastalıkların belirlenmesi. *Plant Protection Bulletin*, 59(3), 39-46.) DOI: 10.16955/bitkorb.527754

Chitrampalam, P., Wu, B. M., Koıke, S.T. & Subbarao, K.V. (2011). Interactions between *Coniothyrium minitans* and *Sclerotinia minor* affect biocontrol efficacy of *C. minitans*. *Phytopathology* 101: 358-366. DOI:10.1094/PHYTO-06-10-0170

Clarkson, J.P., Phelps, K., Whipps, J.M., Young, C.S., Smith, J.A. & Watling, M. (2004). Forecasting Sclerotinia disease on lettuce: toward developing a prediction model for carpogenic germination of sclerotia. *Phytopathology* 94:268–279. DOI: 10.1094/PHYTO.2004.94.3.268

Demir, H. (2007). *Yaprağı Yenen Sebzeler*. Hasat yayıncılık.

Dixon, G.R., (1984). *Vegetable Crop diseases.*Macmillan, London.

Ellialtıoğlu, Ş., Sevengör, Ş. & Sezik E., (2007). Şanlıurfa'da Nane Tarımının Geliştirilmesi Üzerinde Çalışmalar. Şanlıurfa GAP GİDEM Bilgilendirme Toplantısı, 30 Mart 2007, Seminer Notları.

Ellis, M.B., (1971). Dematiaceous Hyphomycetes. Commonwealth Mycological Institute, Kew, London, UK. English.

Ellis, M.B., (1976). More Dematiaceous Hypomycetes. Commonwealth Mycological Institute, Kew, London, UK. English.

Glawe, D.A., Pelter, G.Q. & Du Toıt, L.J. (2005). First report of powdery mildew of carrot and parsley caused by *Erysiphe heraclei* in Washington State, *Plant Health Progress* DOI:10.1094/PHP-2005-0114-01-HN.

Gullino, M. L. (1995). Use of Chemicals for Managing Plant Diseases in Protected Crops. *Integrated Pest and Disease Management in Protected Crops*, 19-30 June, 1995, IAMZ, Zaragoza.

Gunacti, H. (2022). Morphological and molecular characterization of downy mildew on sweet basil (*Ocimum basilicum*) caused by *Peronospora belbahrii* in Turkiye. *Molecular Biology Reports* (2023) 50(3), 2343–2349 https://doi.org/10.1007/s11033-022-08218-y.

Gupta, S. & Prakash, J. (2009). Studies on Indian green leafy vegetables for their antioxidant activity, Plant Foods Hum. Nutr., 64, 39-45 Hershman, D.E. 1986. Etiology of parsley damping-off and influence of temperature on disease development. *Plant Disease*, 70, 927-930. DOI: 10.1007/s11130-008-0096-6

Jurronis, V., & Snieskiene, V. (2004). Diversity of phytophagous and pathogens and their damage to mints (Mentha). *Medicina* (Kaunas), 40, 779–82.

Kalra, A., H. B., Singh., R. Pandey. A., Samad. N. K., Patra & Sushil, Kumar..(2005). Diseases in Mint: Causal Organisms Distribution and Control Measures. *Journal of Herbs. Spices & Medicinal Plants*. 11:1-2. 71-91. DOI: 10.1300/J044v11n01_03.

Koike, S. T., Gladders, P., & Paulus, A. O. (2007). *Vegetable diseases: a color handbook*. Gulf Professional Publishing.

Kunwar, I.,K., Satyaprasad, K., &, Ramarao, P. (1989). Histopathology of chickpea plants infected with *Fusarium oxysporum f.sp. ciceri*. *International Chickpea Newsletter*, 20,17-18.

Kurt, S., (2003). First report of Septoria blight of parsley caused by *Septoria petroselini* in the Mediterranean Region of Turkey. *Plant Disease* 87(1):99. DOI: 10.1094/PDIS.2003.87.1.99A

Kurt, S., & Tok, F. M. (2006). Influence of inoculum concentration, leaf age, temperature, and duration of leaf wetness on Septoria blight of parsley. *Crop protection*, *25*(6), 556-561. https://doi.org/10.1016/j.cropro.2005.08.012

Kurt, Ş., Uysal, A., Kara, M., Soylu, S., & Soylu, E. M. (2017). First report of stem rot disease of parsley caused by *Sclerotinia sclerotiorum* in Turkey. *J. Plant Pathol.* 99 (1): 301. DOI: 10.1016/j.cropro.2005.08.012

Leslie, J., F., & Summerell, B.,A. (2006). The Fusarium laboratory manual. Blackwell Professional, Ames, Iowa, USA, 388 p.

Malathrakis, N. E. (1995). Foliar Diseases in Greenhouse Crops. *Integrated Pest and Disease Management in Protected Crops*, 19-30 June, IAMZ, Zaragoza.

Mullen, J. (2001). The Plant Health Instructor. Southern blight, Southern stem blight, White mold. *The Plant Health Instructor*. DOI: 10.1094/PHI-I-2001-0104-01.

Nawrocki, J. (2004). Occurrence of fungal diseases on parsley seedlings (*Petroselinum sativum* Hoffm.). *Acta fytotechnica et zootechnica*, Vol. 7, 2004, Special Number, Proceedings of the XVI. Slovak & Czech Plant Protection Conference

organised at Slovak Agricultural University in Nitra, Slovakia.

Nawrocki, J. & Mazur, S. (2007). Effectiveness of Biochikol 020 Pc in the control of carrot and parsley pathogens. *Polish Chitin Society*, Monograph XII, 2007, 211-215 p.

Onaran, A. ve Y., Yanar, (2009). Türkiye'de *Sclerotinia sclerotiorum* (Lib.) De Bary üzerinde yapılan çalışmalar. *Türk Bilimsel Derlemeler Dergisi* 2(2):7

Özer, G., Göre, E.M. & Bayraktar, H. (2018). First Report Of Gray Mold on Sweet Basil Caused by *Botrytis cinerea* in Turkey. *Journal of Plant Pathology*. Volume 100, page367 (2018). DOI: 10.1007/s42161-018-0075-1.

Polat, Z., ve A., Coşkuntuna, (2014). Örtüaltında yetiştirilen marulda Kurşuni küf (*Botrytis cinerea* Pers.) hastalığına karşı mücadele imkânlarının araştırılması. *Bitki Koruma Bülteni* 54(4):371- 380.

Raid, R. & Roberts, P. (2004). Florida Plant Disease Management Guide: Parsley, Institue of Food and Agricultural Sciences, University of Florida (IFAS) Extension, 2p.

Smolinska, U., & Kowalska, B. (2018). Biological control of the soil-borne fungal pathogen *Sclerotinia sclerotiorum*, a review. *Journal of Plant Pathology*, 100:1–12. DOI: 10.1007/s42161-018-0023-0

Sneh, B., Burpee, L. & Ogoshi, A., (1991). Identification of Rhizoctonia species. APS PRESS The American Phytopathological Society. St. Paul, Sf 133, Minnesota, USA.

Soylu, E.M., & Soylu, S., (2003). First report of powdery mildew caused by *Erysiphe heraclei* on dill (*Anethum graveolens*) in Turkey. *Plant Pathology*, 52, 423. https://doi.org/10.1046/j.1365-3059.2003.00845.x

Soylu, S., E.M. Soylu & Ş. Kurt, (2010). Downy mildew outbreak on parsley caused by *Plasmopara petroselini* in Turkey. *Plant Pathology*, 59(4):799. https://doi.org/10.1111/j.1365-3059.2009.02243.x

Tok, F.M., (2008). Chemical control of Septoria blight of parsley caused by *Septoria petroselini. Turk Journal Agriculture Forestry*, 32, 487-494.

TOK, F. M., & KURT, Ş. (2019). The effect of hot water treatment on seed transmission of Septoria petroselini, the causal agent of septoria blight on parsley. *Mustafa Kemal Universitesi Tarim Bilimleri Dergisi*, *24*(3), 210-216.

TUIK, Türkiye İstatistik Kurumu (2021). Bitkisel üretim istatistikleri. www.tuik.gov.tr

Uzunoğulları, N., Hantaş, C., Onur, Dura., Tunalı, N., Göksel, P. H., Polat, Z., ve Sönmez, İ. (2022). Marmara Bölgesi'nde Yaprağı Yenen Sebzelerde Görülen Hastalık ve Zararlıların Belirlenmesi. *Bahçe,* 51(1), 45-54. https://doi.org/10.53471/bahce.1038755

Ünlü, M.H, & Boyraz N., (2010). Konya Ilinde Tüketime Sunulan Meyve Ve Sebzelerde Patojen Fungal Flora Ve Bulunuş Oranlarının Belirlenmesi. *Selçuk Tarım ve Gıda Bilimleri Dergisi*, 24 (1), 70-79.

Zimowska, B. (2007). Fungi colonizing and damaging different parts of peppermint (*Mentha piperita* L.) cultivated in South-Eastern Poland. *Herba Pol.*, 53, 97–105.

Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi
Journal of Agricultural Faculty of Gaziosmanpasa University
https://dergipark.org.tr/tr/pub/gopzfd

Araştırma Makalesi/*Research Article*

JAFAG
ISSN: 1300-2910
E-ISSN: 2147-8848
(2023) 40(3) 141-154
doi:10.55507/gopzfd.1398587

Selection of Pear Gene Resources in Muş Region

Semih AYKUT[1*], Adnan DOĞAN[2]

[1]Tatvan Directorate of District Agriculture and Forestry, Bitlis
[2]Yüzüncü Yıl University, Faculty of Agriculture, Department of Horticulture, Van
***Corresponding author e-mail:** semihaykut@hotmail.com

Alındığı tarih (Received): 30.11.2023 Kabul tarihi (Accepted): 26.12.2023

Abstract: This study was carried out in Muş province and its districts between 2020-2022. In the study, phenological, pomological and chemical properties of local pear cultivars grown in Muş ecological conditions were obtained. In the region where 42 different local pear varieties determined as a result of the studies were grown, the superior local varieties within the scope of the study were determined by using the "Weighed Rating" method. In order to compare these local varieties with each other, 24 local pear cultivars were selected with superior characteristics in terms of fruit weight, eating quality, external appearance, rustiness, water-soluble dry matter content and fruit flesh hardness as a result of the weighted grading made in 2020. These 24 selected varieties were compared according to the weighted grading results in 2021 and finally 13 local pear varieties were determined as promising. Among the promising local pear cultivars, Güz Armudu-1, Paşa Armudu-2 and Sulu Armut cultivars received the highest scores, respectively. It is aimed to increase the quality of the promising local pear varieties, thus to protect genetic resources and to reveal genotypes that may be candidates for registration.

Keywords: Muş, pear, phenology, pomology, variety

Muş Yöresi Armut Gen Kaynaklarının Seleksiyonu

Öz: Bu çalışma 2020-2022 yılları arasında Muş ili ve ilçelerinde yürütülmüştür. Araştırmada Muş ekolojik koşullarında yetiştirilen mahalli armut çeşitlerinin fenolojik, pomolojik ve kimyasal özellikleri incelenmiştir. Çalışmalar sonucunda belirlenen 42 farklı mahalli armut çeşidinin yetiştirildiği bölgede, çalışma kapsamındaki ümitvar mahalli çeşitler "Ağırlıklı Derecelendirme" yöntemi kullanılarak belirlenmiştir. Belirlenen çeşitlerin birbirleriyle karşılaştırılması amacıyla 2020 yılında yapılan tartılı derecelendirme sonucunda meyve ağırlığı, yeme kalitesi, dış görünüş, paslılık durumu, suda çözünebilir kuru madde miktarı ve meyve eti sertliği bakımından 24 mahalli armut çeşidi üstün özellikli seçilmiştir. Seçilen bu çeşitlerde 2021 yılında yapılan tartılı derecelendirme sonuçlarına göre 13 mahalli armut çeşidi ümitvar olarak belirlenmiştir. Ümitvar olan mahalli armut çeşitleri içerisinde en yüksek puanı sırasıyla Güz Armudu-1, Paşa Armudu-2 ve Sulu Armut çeşitleri almıştır. Ümitvar mahalli armut çeşitlerinin kalitesinin artırılması, böylece genetik kaynakların korunması ve tescile aday olabilecek genotiplerin ortaya çıkarılması amaçlanmıştır.

Anahtar Kelimeler: Muş, armut, fenoloji, pomoloji, çeşit.

1. Introduction

Pear is one of the important fruit species that is suitable for our country's ecology, has favorable environmental conditions and has high nutritional value. Different species are grown in our country due to ecological conditions and different climate types. Approximately 85 fruit species are grown throughout our country. This number is around 138 worldwide (Ercişli, 2004). In this sense, Turkey has a high diversity and population throughout the world where different fruit species grow.

It is known that countries such as Turkey, Italy, France and Belgium are important locations for pear cultivation. The pear was first brought to the Americas by British and French colonists in 1630. Significant advances were made in pear cultivation in those region, and many studies were conducted on Western and Eastern pears (Karadeniz & Çorumlu, 2012; Yarılgaç & Yıldız, 2001).

Pear (Pyrus communis) is a fruit that is widely produced and consumed around the world. Pear, whose homeland is shown as Anatolia, Central Asia and the Caucasus, has a significant genetic diversity still waiting to be discovered in our country. It is reported that Turkey has a richness of more than 600 varieties as standard, summer, winter or local (Özbek, 1978; Özçağıran et al., 2004).

Selection studies on pear cultivars focus on various characters. These characters may differ depending on the purpose of the study. Among these, features such as

regular and high yield, fruit quality factors, resistance to diseases and damages, resistance to cold, resistance to Erwinia amylovora disease, fruit size, pH, acidity and growth strength of the tree are important (Büyükyılmaz et al., 1992; Özbek, 1978).

Many researchers have selected the pear genotypes formed as a result of natural foreign pollination, developed them by selection method, and carried out improvement studies using breeding methods. At the same time, it is among the studies carried out to reveal the degree of kinship and genetic relationships between varieties (Fischer, 2009; Yamamoto & Chevreau, 2009).

Researchers in our country are aware of the rich genetic variation and carry out studies to evaluate this source. These studies focus on selecting and characterizing genotypes with superior characteristics. Selection studies are among important studies that require extreme care and attention. The main purpose of these studies is to protect and improve our genetic diversity (Öz & Aslantaş, 2015).

551.086 tons of pear production was realized in Turkey in 2022. The highest production amount was recorded in Bursa province with 225,798 tons. It is observed that Bursa is followed by Antalya province with 58.797 tons. After Antalya province, production was realized in Mersin with 13,379 tons. Especially in Bursa and Antalya provinces, a significant amount of pear production is made, and these two provinces are in the leading position in terms of pear production. In the province of Muş, 550 tons of pears were produced in 2022 (TSI, 2022).

During the research process, field and laboratory studies were carried out in the regions where pear cultivation is intense between the years 2020-2022. After these studies, the criteria used for the "Weighed Rating" method were determined and the genotypes were classified according to these criteria, and the total weighted rating scores were calculated.

After these studies, the criteria used for the "Weighed Rating" method were determined and the genotypes were classified according to these criteria and the total weighted rating scores were calculated. Based on these scoring results, promising native varieties for Muş province and its districts were determined.

The aim of the study; selection of pears grown in the region, taking important steps to protect pear genetic diversity and determining suitable candidate genotypes for registration.

2. Material and Methods

2.1. Material

This research was carried out in the province of Muş and its districts between 2020-2022. The material of the research was composed of native pear varieties grown in Muş province and districts. Leaf and fruit samples of each cultivar were randomly collected from different parts of the trees at the full maturity stage. For the evaluation of qualitative and quantitative characteristics, 20 ripe fruits and leaves per cultivar were selected.

Muş Province is located within the borders of the Eastern Anatolia Region. It lies between 39°29' and 38°29' north latitudes and 41°06' and 41°47' east longitudes. The total area of Muş province is 8196 km² and its altitude is 1350 m (Figure 1).

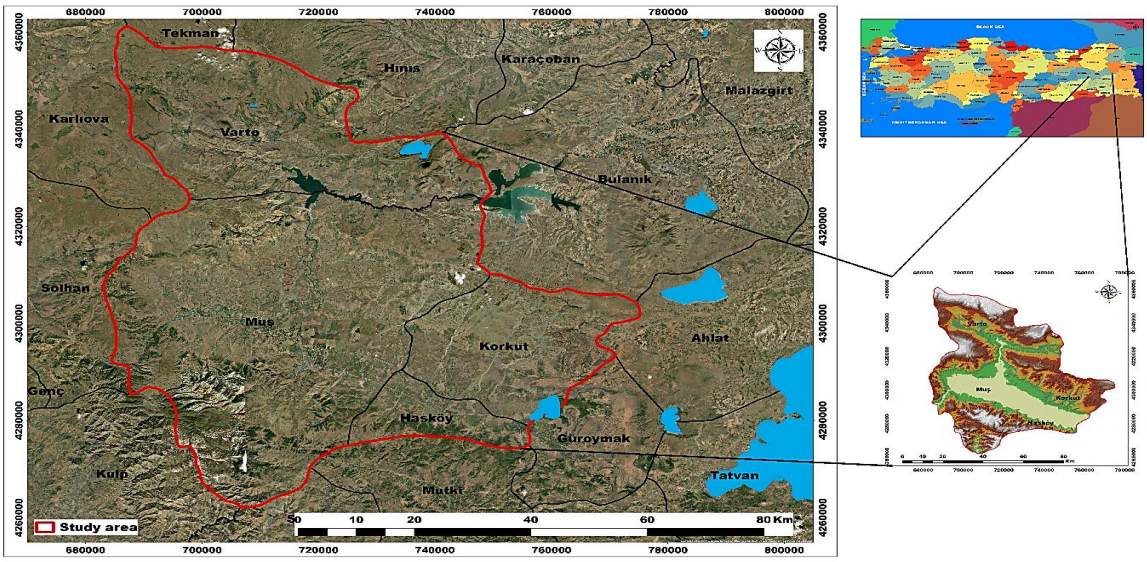

Figure 1. The map of Muş province where the research was conducted.
Şekil 1. *Araştırmanın yapıldığı Muş ilinin haritası.*

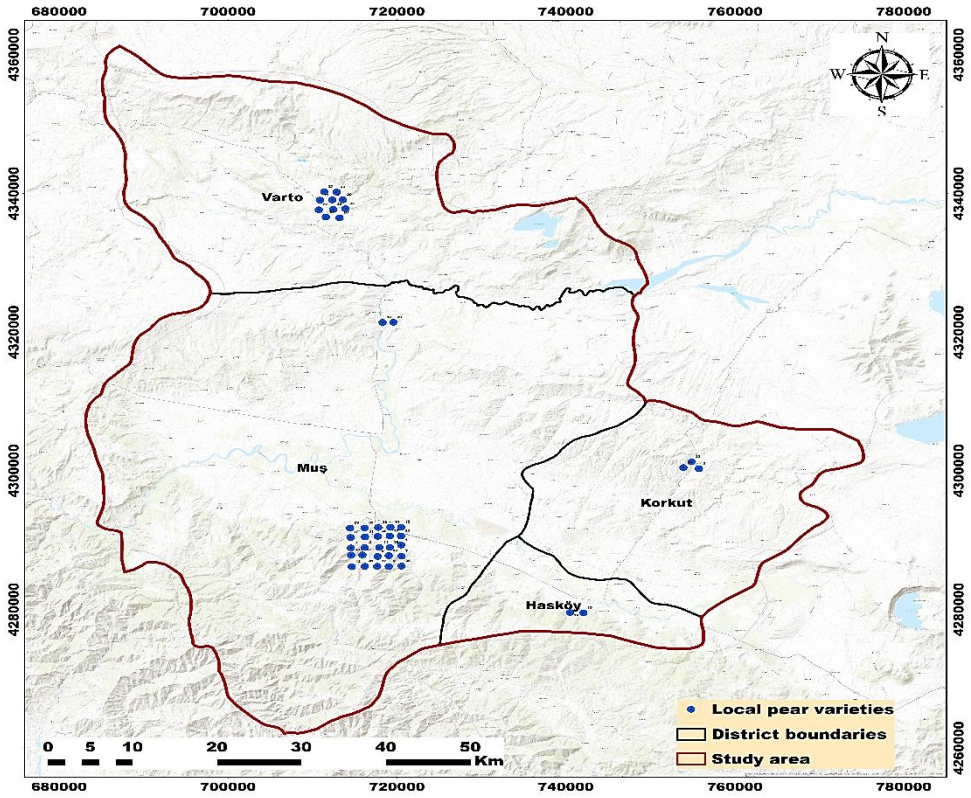

Figure 2. Coordinates of local pear varieties determined in Muş province in the research.
Şekil 2. *Araştırmada Muş ilinde belirlenen mahalli armut çeşitlerinin koordinatları.*

Table 1. General information of local pear varieties determined in Muş province
Çizelge 1. *Muş ilinde belirlenen mahalli armut çeşitlerine ilişkin genel bilgiler*

Local varieties sampled from different locations					
Sample No	**Varieties**	**Altitude**	**Sample No**	**Varieties**	**Altitude**
1	Abbasi	1417	22	Kültür-4	1546
2	Ampul	1478	23	Kültür-5	1546
3	Bal Armut	1487	24	Mayhoş	1526
4	Dağ Armudu	1546	25	Mecnunun Ar.	1511
5	Devecik	1525	26	Mihrani	1411
6	Elazığ	1510	27	Mor Armut-1	1547
7	Erkenci Karçin	1401	28	Mor Armut-2	1503
8	Geççi Karçin	1400	29	Pamukhala	1513
9	Güz Armudu-1	1412	30	Paşa Armudu-1	1277
10	Güz Armudu-2	1499	31	Paşa Armudu-2	1503
11	Güz Mihranisi	1510	32	Sert Armut	1524
12	Güzlük Armut	1497	33	Sulu Armut	1547
13	Haziran Gülü	1557	34	Şeker	1503
14	Hıyan	1505	35	Şuti	1412
15	Karakütük-1	1357	36	Van Armudu	1405
16	Karakütük-2	1351	37	Yaz Armudu-1	1412
17	Karanfil	1556	38	Yaz Armudu-2	1513
18	Kışlık	1282	39	Yazlık Armut	1489
19	Kültür-1	1546	40	Yerli Ankara	1513
20	Kültür-2	1547	41	Yeşil Mihrani	1557
21	Kültür-3	1546	42	Yuvarlak Karçin	1395

A harsh continental climate prevails in the province of Muş. The temperature ranges between -29°C and +37°C. The temperature is above +30°C on 120 days of the year and below 0°C on 120 days. It snows a lot in winter. Annual precipitation is between 350-1000 mm. Winters are very cold and long, summers are short, hot and dry (Anonymous, 2022).

In the province of Muş, producers grow different fruit trees around their houses and in their gardens in proportion to their possibilities. These fruit growing

activities do not have a commercial purpose in general, but production is carried out for family needs. In the province of Muş, cultivation activities in the form of a closed garden have been observed during our studies in recent years. Within the scope of the study, the areas where pear cultivation is carried out in Muş province were examined and 42 local pear varieties were detected. The local pear varieties identified in Muş provincial center, Hasköy, Korkut and Varto districts were marked for examination and processed on the map (Figure 2) by taking their coordinates. The names of the local varieties used in the study and the altitude values of the place where they are grown are shown in Table 1.

2.2. Method

Phenological, pomological and chemical analyzes of local pear cultivars grown in Muş province are based on the criteria specified in IBPGR (International Board for Plant Genetic Resources), UPOV (International Union for The Protection of New Varieties of Plants); fruit weight, fruit length (UPOV 37), fruit width (UPOV 38), fruit stem length (UPOV 50), fruit stem thickness (UPOV 51), fruit flesh firmness (UPOV 61), skin thickness, rusty condition, harvest date, from chemical properties; The amount of water-soluble dry matter, titratable acidity, fruit juice pH, sensory quality of eating and external quality parameters were examined within the framework of references (Büyükyılmaz & Bulagay, 1983; Büyükyılmaz et al., 1992; 1994; Kaya, 2008; Öztürk, 2010).

Of the 42 varieties examined in the study, those that were harvested before August 15 were recorded as "Summer", those that were harvested between August 15 and October 14 as "Autumn" and those that were harvested after October 14 were recorded as "Winter" pears, and these were subjected to weighted rating. The characteristics of a total of 42 genotypes as summer, fall and winter, selected according to the weighted grading made in 2020, were examined.

In the comparison of pear varieties determined in Muş province and districts with each other within the scope of the study, similar studies (Büyükyılmaz & Bulagay, 1983) and (Büyükyılmaz et al., 1992; 1994) used by (Michelson et al., 1958), the modified "Weighted Rating" method was used. According to the characteristics and the degree of importance based on the weighted rating, these characteristics (Büyükyılmaz & Bulagay, 1983; Büyükyılmaz et al., 1994; Çelikel-Çubukçu & Bostan, 2018; Öztürk, 2010), the relative scores and the class values are given in Table 3.

The sum of the weighted scores obtained by multiplying the class value score of each trait with the relative scores determined the total value score of the pear genotypes, which is the basis for the "Weighted Rating". Genotypes were divided into 3 groups as good, middle and bad according to their total value scores and groups were formed (Table 2).

Table 2. Total value score ranges "Weighted Rating"
Çizelge 2. *Toplam değer puanı aralıkları ''Tartılı Derecelendirme''*

Total Value Points		Group
2020	2021	
450 ≤	550 ≤	**Good**
351 – 449	450 – 549	**Medium**
350 ≥	400 ≥	**Bad**

As a result of the evaluation of the data of 2020, the varieties with the highest value score (with a score of 450 and above) in the good value group were selected in the selection of local pear varieties and they were re-examined in 2021. According to the grouping made in the total value score, local pear varieties that were in the good group (550 points and above) in 2021 were decided as promising.

3. Results

3.1. 2020 Studies

Fruit weights of local pear cultivars were found to be 17.76-284.81 g, fruit lengths of 24.92-103.87 mm, fruit widths of 30.47-94.85 mm, fruit stalk lengths of 16.83-62.16 mm, fruit stalk thicknesses of 2.07-5.03 mm, and skin thicknesses between 0.14-0.69 mm. Harvest dates for cultivars varied between July 25 and November 21. The harvest dates could not be determined since Elazığ, Yaz Armudu-2 and Yuvarlak Karçin cultivars show periodicity (Table 4).

The water-soluble dry matter contents of the local pear cultivars grown in Mus province where 9.4-20.5%, titratable acidity 0.13-0.83%, pH values 3.23-4.88, fruit firmness 1.82-11.30 kg $cm^{2\ -1}$. When the varieties were evaluated in terms of eating quality, it was determined that 4 of them had bad eating quality, 12 of them were medium, 9 of them were good and 14 of them were very good. When the cultivars were examined in terms of external quality, it was determined that 14 of them were medium, 14 of them were good, and 11 of them were very good. When the rustyness status of the pear varieties determined in Muş province was examined, it was determined that 3 of them were moderately rusty, 9 of them were slightly rusty, and 27 of them were rust-free or slightly rusty (Table 5).

Table 3. The characteristics based on the weighted rating, their relative scores, the class values and scores of the characteristics

Çizelge 3. *Tartılı derecelendirmeye dayalı özellikler, bunların göreceli puanları, sınıf değerleri ve özelliklerin puanları*

Criteria	Relative Points		Classes	Classes	Points
Fruit Weight (g)	**30**	**Summer**	60 ≥	Very small	1
			60.01 - 80	Small	3
			80.01 – 100.00	Medium	5
			100.01 – 120.00	Large	7
			120.01 ≤	Very large	9
		Autumn	60 ≥	Very small	1
			60.01 – 90.00	Small	3
			90.01 – 120.00	Medium	5
			120.01 – 150.00	Large	7
			150.01 ≤	Very large	9
		Winter	60.00 ≥	Very small	1
			60.01- 100.00	Small	3
			100.01 – 140.00	Medium	5
			140.01 – 180.00	Large	7
			180.01 ≤	Very large	9
Eating Quality	**20**		4.2 ≤	Very good	9
			3.3-4.1	Good	7
			2.4-3.2	Middle	5
			1.5-2.3	Bad	3
			1.4 ≥	Very bad	1
External Quality	**10**		4.2 ≤	Very good	9
			3.3-4.1	God	7
			2.4-3.2	Middle	5
			1.5-2.3	Bad	3
			1.4 ≥	Very bad	1
State of Rustiness	**5**			None or very low	9
				Low	7
				Medium	5
				High	3
				All surface covered	1
Water Soluable Dry Matter	**20**	**Summer**	12.74 ≥	Low	1
			12.75-15.01	Medium	3
			15.02 ≤	High	5
		Autumn	11.79 ≥	Low	1
			11.80-14.99	Medium	3
			15.00 ≤	High	5
		Winter	13.99 ≥	Low	1
			14.00-16.69	Medium	3
			16.70 ≤	High	5
Fruit Flesh Firmness (kg cm$^{2\ -1}$)	**15**	**Summer**	4.29 ≥	Soft	1
			4.30-6.31	Medium	3
			6.32 ≤	Hard	5
		Autumn	4.88 ≥	Soft	1
			4.89-6.96	Medium	3
			6.97 ≤	Hard	5
		Winter	5.76 ≥	Soft	1
			5.77-7.84	Medium	3
			7.85 ≤	Hard	5
TOTAL	**100**				

The total scores of the local pear cultivars grown in Muş as a result of the weighted grading are given in Table 6. Accordingly, Sulu Armut (750 points) got the highest score. This cultivar was followed by Paşa Armudu-2 with 720 points and Güz Armudu-1 with 700 points. The cultivar with the lowest score was Kültür-2 cultivar with 250 points. After the Kültür-2 variety, the Kültür-4 variety received the lowest score with 260 points, the Kültür-4 variety was followed by the Dağ Armudu variety with 290 points (Table 6).

Considering the scores obtained by the determined pear cultivars as a result of the "Weighted Rating" method, 21 pear cultivars in the good group with a score of 450 and above, and 3 pear cultivars (Elazığ, Yaz Armudu-2 and Yuvarlak Karçin) that could not be pomologically examined were selected to be examined

in 2021. Pear cultivars scored 30-270 points in terms of fruit size, 60-180 points in terms of eating quality, between 50-90 points in terms of external quality, 20-100 points in terms of water-soluble dry matter, and 15-75 points in terms of fruit flesh firmness (Table 6).

Table 4. 2020 fruit characteristics and harvest dates of local pear varieties
***Çizelge 4**. Mahalli armut çeşitlerinin 2020 yılı meyve özellikleri ve hasat tarihleri*

S.N.	Varieties	Fruit						
		Weight (g)	Width (mm)	Lenght (mm)	Stem Lenght (mm)	Stem thickness (mm)	Skin thickness (mm)	Harvest date
1	Abbasi	188.58	69.13	66.15	31.53	2.92	0.19	25-30 October
2	Ampul	184.35	60.55	74.81	28.14	3.44	0.51	24-30 August
3	Bal Armut	102.68	55.15	56.08	19.70	2.52	0.33	25-29 July
4	Dağ Armudu	21.47	31.15	25.21	16.83	4.72	0.69	01-14 November
5	Devecik	148.29	62.87	74.83	29.85	3.38	0.53	04-19 November
6	Elazığ	***	***	***	***	***	***	***
7	Erkenci Karçin	30.17	35.17	29.14	34.47	2.58	0.33	08-13 August
8	Geççi Karçin	40.86	38.43	30.74	40.17	2.61	0.41	010-9 Setember
9	Güz Armudu-1	140.39	61.74	80.93	62.16	3.19	0.14	20-27 September
10	Güz Armudu-2	116.81	57.65	77.20	56.11	3.38	0.24	23-29 September
11	Güz Mihranisi	97.52	55.93	57.89	38.88	4.27	0.47	01-09 October
12	Güzlük Armut	108.37	54.28	67.82	30.71	3.55	0.51	17-26 September
13	Haziran Gülü	133.24	63.02	64.77	36.48	3.14	0.37	27-31 July
14	Hıyan	56.47	43.75	52.20	29.92	3.53	0.62	01-08 September
15	Karakütük-1	87.76	53.82	54.04	39.37	3.84	0.48	16-26 October
16	Karakütük-2	60.42	42.14	55.49	33.71	2.93	0.37	10-21 November
17	Karanfil	26.88	30.47	29.13	29.58	2.67	0.53	10-18 September
18	Kışlık	135.92	68.66	57.95	26.67	4.06	0.56	20-31 October
19	Kültür-1	45.95	44.79	41.17	22.99	3.19	0.30	01-12 November
20	Kültür-2	25.7	33.29	30.13	39.38	2.25	0.32	17-30 October
21	Kültür-3	52.64	44.17	45.25	27.44	2.89	0.28	22-31 October
22	Kültür-4	56.91	48.38	45.92	32.20	2.39	0.53	16-28 October
23	Kültür-5	80.12	58.14	50.17	29.44	2.55	0.49	03-16 November
24	Mayhoş	152.28	60.45	73.26	37.71	3.54	0.37	20-27 August
25	Mecnunun Ar.	106.28	63.14	64.82	33.41	4.02	0.28	23-30 August
26	Mihrani	80.22	59.56	61.49	28.73	2.93	0.16	26-30 August
27	Mor Armut-1	140.36	53.47	72.41	40.13	4.88	0.24	07-13 October
28	Mor Armut-2	89.82	68.13	83.01	36.91	5.03	0.34	20-30 October
29	Pamukhala	68.11	52.81	59.10	23.12	3.87	0.17	01-08 September
30	Paşa Armudu-1	152.7	64.19	70.47	35.55	4.06	0.42	02-10 September
31	Paşa Armudu-2	284.81	94.85	103.87	58.17	4.45	0.22	23-29 September
32	Sert Armut	106.77	56.74	65.92	26.63	3.86	0.51	20-26 September
33	Sulu Armut	170.85	60.05	83.14	34.71	2.98	0.27	01-07 October
34	Şeker	17.76	31.03	24.92	27.52	2.07	0.47	18-30 October
35	Şuti	73.77	51.10	54.12	17.60	4.30	0.28	04-10 October
36	Van Armudu	115.45	55.79	70.31	50.05	4.11	0.44	01-12 November
37	Yaz Armudu-1	70.68	53.78	60.11	46.71	3.92	0.19	06-11 August
38	Yaz Armudu-2	***	***	***	***	***	***	***
39	Yazlık Armut	140.26	68.13	66.81	39.22	3.76	0.51	09-14 August
40	Yerli Ankara	100.88	62.86	54.37	25.93	4.16	0.38	01-08 October
41	Yeşil Mihrani	70.56	52.41	53.83	30.64	4.53	0.33	21-29 August
42	Yuvarlak Karçin	***	***	***	***	***	***	***

(S.N.=Serial Number)

Table 5. The year 2020 of local pear cultivars, chemical properties, fruit flesh firmness, eating quality, external quality and rustiness conditions

Çizelge 5. *Mahalli armut çeşitlerinin 2020 yılı, kimyasal özellikleri, meyve eti sertliği, yeme kalitesi, dış kalite ve paslılık durumları*

S. N.	Varieties	WSDM (%)	Acidity (%)	pH	Fruit flesh firmness (kg $cm^{2\ -1}$)	Eating quality	External quality	State of Rustiness
1	Abbasi	15.2	0.24	4.48	5.81	4.4	4.6	None or very low
2	Ampul	11.8	0.39	3.76	3.84	3.2	4.0	None or very low
3	Bal Armut	9.4	0.29	4.30	5.92	4.0	4.4	None or very low
4	Dağ Armudu	15.0	0.54	3.23	6.59	2.0	3.0	None or very low
5	Devecik	10.3	0.13	4.66	4.16	4.2	3.2	None or very low
6	Elazığ	***	***	***	***	***	***	***
7	Erkenci Karçin	12.8	0.14	4.51	3.88	4.4	4.0	None or very low
8	Geççi Karçin	15.8	0.38	4.12	2.86	3.8	3.4	Low
9	Güz Armudu-1	17.6	0.18	4.33	8.95	4.8	4.4	None or very low
10	Güz Armudu-2	15.1	0.26	3.94	4.63	4.2	4.2	None or very low
11	Güz Mihranisi	14.4	0.31	4.04	5.54	4.0	4.2	Low
12	Güzlük Armut	9.6	0.22	4.13	3.87	3.2	3.8	None or very low
13	Haziran Gülü	19.2	0.15	4.53	1.82	3.0	3.2	Medium
14	Hıyan	15.7	0.56	3.81	3.64	3.2	3.0	None or very low
15	Karakütük-1	18.9	0.32	3.93	3.08	2.2	2.8	Low
16	Karakütük-2	16.6	0.24	3.56	2.34	2.8	3.0	Low
17	Karanfil	12.6	0.25	4.16	5.03	4.2	4.0	None or very low
18	Kışlık	10.8	0.30	3.96	2.33	3.2	2.6	None or very low
19	Kültür-1	20.4	0.55	3.68	4.58	2.6	3.4	Low
20	Kültür-2	15.3	0.69	3.52	4.46	2.2	3.2	Low
21	Kültür-3	14.8	0.50	3.48	6.87	4.4	3.8	None or very low
22	Kültür-4	11.8	0.78	3.89	5.51	3.2	3.0	None or very low
23	Kültür-5	17.5	0.38	4.06	1.85	1.8	3.0	Medium
24	Mayhoş	11.1	0.41	3.70	2.44	3.8	2.8	None or very low
25	Mecnunun Arm.	18.0	0.16	4.34	5.77	4.0	3.6	None or very low
26	Mihrani	20.5	0.50	3.86	5.94	4.6	4.4	None or very low
27	Mor Armut-1	17.3	0.14	4.41	4.89	3.8	4.4	None or very low
28	Mor Armut-2	15.4	0.83	3.66	2.27	3.0	3.2	None or very low
29	Pamukhala	16.2	0.13	4.79	9.63	4.4	4.2	None or very low
30	Paşa Armudu-1	13.5	0.22	4.51	8.47	3.6	3.8	Low
31	Paşa Armudu-2	14.9	0.65	3.64	11.30	4.6	4.4	None or very low
32	Sert Armut	14.4	0.67	3.62	5.48	3.2	2.8	Medium
33	Sulu Armut	17.4	0.13	4.70	8.96	4.2	4.6	Low
34	Şeker	15.7	0.17	4.88	2.81	3.2	3.2	None or very low
35	Şuti	15.6	0.64	3.62	8.28	4.6	4.0	None or very low
36	Van Armudu	18.2	0.54	3.49	10.73	4.8	4.2	None or very low
37	Yaz Armudu-1	13.1	0.16	4.82	9.83	4.0	4.2	None or very low
38	Yaz Armudu-2	***	***	***	***	***	***	***
39	Yazlık Armut	16.4	0.24	3.60	2.09	4.2	3.4	None or very low
40	Yerli Ankara	14.2	0.31	3.41	2.46	3.8	3.2	Low
41	Yeşil Mihrani	10.2	0.40	3.55	6.11	3.2	4.0	None or very low
42	Yuvarlak Karçin	***	***	***	***	***	***	***

(S.N.=Serial Number, WSDM= Water-Soluable Dry Matter)

Table 6. Scores and total scores of local pear cultivars from weighted rating criteria in 2020
Çizelge 6.*.Mahalli armut çeşitlerinin 2020 yılı tartılı derecelendirmeden aldıkları puanlar ve toplam puanlar*

Serial Number	Varieties	Taken County	F.W.	E.Q.	E.Q.	S.R.	WSDM	F.F.F.	Total
1	Abbasi	Center	270	180	90	45	60	45	**690 (4)**
2	Ampul	Center	270	100	70	45	60	15	**560 (10)**
3	Bal Armut	Center	210	140	90	45	20	45	**550 (13)**
4	Dağ Armudu	Varto	30	60	50	45	60	45	290
5	Devecik	Korkut	210	180	50	45	20	15	**520 (18)**
6	Elazığ	Center	***	***	***	***	***	***	***
7	Erkenci Karçin	Center	30	180	70	45	60	15	400
8	Geççi Karçin	Center	30	140	70	35	100	15	390
9	Güz Armudu-1	Center	210	180	90	45	100	75	**700 (3)**
10	Güz Armudu-2	Center	150	180	90	45	60	15	**540 (16)**
11	Güz Mihranisi	Center	150	140	90	35	60	45	**520 (19)**
12	Güzlük Armut	Center	150	100	70	45	20	15	400
13	Haziran Gülü	Center	270	100	50	25	100	15	**560 (11)**
14	Hıyan	Center	30	100	50	45	100	15	340
15	Karakütük-1	Hasköy	90	60	50	35	100	15	350
16	Karakütük-2	Hasköy	90	100	50	35	60	15	350
17	Karanfil	Center	30	180	70	45	60	45	430
18	Kışlık	Center	150	100	50	45	20	15	380
19	Kültür-1	Varto	30	100	70	35	100	15	350
20	Kültür-2	Varto	30	60	50	35	60	15	250
21	Kültür-3	Varto	30	180	70	45	60	45	430
22	Kültür-4	Varto	30	100	50	45	20	15	260
23	Kültür-5	Varto	90	60	50	25	100	15	340
24	Mayhoş	Korkut	270	140	50	45	20	15	**540 (17)**
25	Mecnunun Armudu	Center	150	140	70	45	100	45	**550 (14)**
26	Mihrani	Center	90	180	90	45	100	45	**550 (15)**
27	Mor Armut-1	Varto	210	140	90	45	100	45	**630 (7)**
28	Mor Armut-2	Varto	90	100	50	45	60	15	360
29	Pamukhala	Center	90	180	90	45	100	75	**580 (9)**
30	Paşa Armudu-1	Center	270	140	70	35	60	75	**650 (5)**
31	Paşa Armudu-2	Center	270	180	90	45	60	75	**720 (2)**
32	Sert Armut	Korkut	150	100	50	25	60	45	430
33	Sulu Armut	Varto	270	180	90	35	100	75	**750 (1)**
34	Şeker	Center	30	100	50	45	60	15	300
35	Şuti	Center	90	180	70	45	100	75	**560 (12)**
36	Van Armudu	Center	150	180	90	45	100	75	**640 (6)**
37	Yaz Armudu-1	Center	90	140	90	45	60	75	**500 (20)**
38	Yaz Armudu-2	Center	***	***	***	***	***	***	***
39	Yazlık Armut	Center	210	180	70	45	100	15	**620 (8)**
40	Yerli Ankara	Center	150	140	50	35	60	15	**450 (21)**
41	Yeşil Mihrani	Center	90	100	70	45	20	45	370
42	Yuvarlak Karçin	Center	***	***	***	***	***	***	***

(**F.W:** Fruit Weight, **E.Q:** Eating Quality, **E.Q:** External Quality, **SR:** State of Rustiness, **F.F.F:** Fruit Fless Firmness, **WSDM:** Water-Soluable Dry Matter)

3.2. 2021 Studies

Fruit weight of the cultivars was 58.96-268.36 g, fruit length 32.77-99.83 mm, fruit width 31.11- 90.41 mm, fruit stalk length 22.39-59.46 mm, fruit stalk thickness 2.43-5.14 mm, fruit skin thickness 0.14-0.46 mm. The harvest dates of the varieties took place between July 15 and November 16 (Table 7).

In 2021, the amount of water-soluble dry matter (WSDM) of local pear varieties was found to be between 12.1-19.6%, titrable acidity values were found to be 0.14-0.61%, pH values were found to be 3.48-4.72, and fruit flesh hardness was found to be in the December 2.94-11.16 kg $cm^{2\ -1}$ range. When the varieties were evaluated in terms of eating quality, it was determined that 1 of them was bad, 4 of them medium, 10 of them good and 9 of them very good. When the cultivars were examined in terms of external quality, it was determined that 6 of them were medium, 9 of them were good, and 9 of them were very good. Looking at the rusty condition of the pear varieties determined in Muş province, it was determined that 10 of them were low rusty, and 14 of them were none or very low rusty (Table 8).

Table 7. Fruit characteristics and harvest dates of local pear varieties in 2021
***Çizelge** 7. Mahalli armut çeşitlerinin 2021 yılı meyve özellikleri ve hasat tarihleri*

Serial Number	Varieties	Fruit						
		Weight (g)	Width (mm)	Lenght (mm)	Stem Lenght (mm)	Stem thickness (mm)	Skin thickness (mm)	Harvest date
1	Abbasi	192.34	72.15	67.59	36.69	2.82	0.16	16-29 October
2	Ampul	170.19	56.43	69.16	30.93	3.67	0.46	12-19 August
3	Bal Armut	91.84	50.29	52.77	22.39	2.43	0.26	23-28 July
4	Devecik	146.29	60.39	73.55	27.00	3.08	0.45	01-16 November
5	Elazığ	58.96	46.57	49.91	28.08	2.84	0.33	05-11 September
6	Güz Armudu-1	146.53	63.26	78.86	58.87	3.11	0.16	15-20 September
7	Güz Armudu-2	113.75	57.81	76.88	59.46	3.10	0.19	19-25 September
8	Güz Mihranisi	96.01	57.98	59.62	35.75	3.99	0.43	20-26 September
9	Haziran Gülü	135.42	64.15	65.22	35.40	3.20	0.39	20-24 July
10	Mayhoş	126.95	52.63	64.82	34.66	3.58	0.29	11-16 August
11	Mecnunun Arm.	98.36	62.69	63.86	34.22	4.22	0.30	14-20 August
12	Mihrani	93.49	64.83	68.93	26.25	3.17	0.14	18-25 August
13	Mor Armut-1	135.84	51.67	69.92	42.96	5.14	0.27	1-8 October
14	Pamukhala	64.87	51.15	57.03	28.16	3.14	0.20	23-30 August
15	Paşa Armudu-1	160.60	66.67	71.61	33.03	3.83	0.38	20-28 August
16	Paşa Armudu-2	268.36	90.41	99.83	53.82	4.13	0.34	24-30 August
17	Sulu Armut	162.28	57.66	81.92	32.72	2.90	0.29	25-30 September
18	Şuti	70.99	49.35	52.43	24.75	4.15	0.28	22-29 September
19	Van Armudu	114.23	53.38	68.32	45.92	4.81	0.40	18-31 October
20	Yaz Armudu-1	80.78	50.85	58.50	46.38	3.42	0.23	01-05 August
21	Yaz Armudu-2	77.93	52.44	63.98	45.16	3.04	0.34	06-10 August
22	Yazlık Armut	118.14	65.41	61.98	44.28	3.95	0.44	03-06 August
23	Yerli Ankara	66.85	56.42	50.85	26.05	4.20	0.38	24-29 September
24	Yuvarlak Karçin	67.61	56.27	55.90	36.69	2.82	0.39	14-23 September

Table 8. The year 2021 of local pear cultivars, chemical properties, fruit firmness, eating quality, external quality and rustyness
***Çizelge 8.** Mahalli armut çeşitlerinin 2021 yılı, kimyasal özellikleri, meyve eti sertliği, yeme kalitesi, dış kalite ve paslılık durumları*

Serial Number	Varieties	WSDM (%)	Acidity (%)	pH	Fruit flesh firmness (kg $cm^{2\ -1}$)	Eating quality	External quality	State Of Rustiness
1	Abbasi	15,5	0.19	4.38	6.94	3.8	4.4	None or very low
2	Ampul	13,7	0.41	3.55	4.73	3.2	3.2	Low
3	Bal Armut	12,3	0.35	4.51	5.72	4.0	4.4	None or very low
4	Devecik	12,8	0.17	4.44	2.94	4.0	3.8	Low
5	Elazığ	15,4	0.25	4.41	6.53	4.2	4.4	Low
6	Güz Armudu-1	18,3	0.14	4.41	10.13	4.8	4.6	None or very low
7	Güz Armudu-2	15,1	0.27	3.95	4.13	4.2	4.2	None or very low
8	Güz Mihranisi	13,9	0.34	3.94	4.96	4.0	3.8	Low
9	Haziran Gülü	12,1	0.36	3.73	5.74	2.3	3.2	None or very low
10	Mayhoş	12,8	0.43	3.62	4.18	3.8	3.2	Low
11	Mecnunun Arm.	17,4	0.31	3.96	3.35	3.2	3.2	Low
12	Mihrani	17,8	0.40	3.49	6.33	4.6	4.4	None or very low
13	Mor Armut-1	18,2	0.20	4.23	5.33	4.0	4.4	None or very low
14	Pamukhala	17,0	0.19	4.51	9.57	4.4	3.8	None or very low
15	Paşa Armudu-1	14,1	0.20	4.69	9.12	3.2	4.0	Low
16	Paşa Armudu-2	13,5	0.61	3.48	9.95	4.4	4.0	None or very low
17	Sulu Armut	15,4	0.20	4.33	9.65	4.0	3.6	Low
18	Şuti	15,6	0.56	3.61	8.75	4.8	4.0	None or very low
19	Van Armudu	16,8	0.43	3.70	11.16	4.4	4.2	None or very low
20	Yaz Armudu-1	13,5	0.14	4.72	8.77	4.4	4.6	None or very low
21	Yaz Armudu-2	13,4	0.18	4.29	3.82	4.0	3.8	Low
22	Yazlık Armut	17,7	0.26	3.86	3.11	4.4	3.8	Low
23	Yerli Ankara	14,7	0.28	3.56	2.98	3.1	3.2	None or very low
24	Yuvarlak Karçin	19,6	0.42	3.54	4.67	3.8	4.2	None or very low

Table 9. Scores and total scores obtained from the weighted grading criteria of the local pear cultivars for 2021
Çizelge 9. *Mahalli armut çeşitlerinin 2021 yılı ağırlıklı deerecelendirme kriterlerinden alınan puanlar ve toplam puanlar*

Serial Number	Varieties	Taken County	F.W.	E.Q.	E.Q.	S.R.	WSDM	F.F.F.	Total
1	Abbasi	Center	270	140	90	45	60	45	**650 (4)**
2	Ampul	Center	270	100	50	35	60	15	530
3	Bal Armut	Center	150	140	90	45	20	45	490
4	Devecik	Korkut	210	140	70	35	20	15	490
5	Elazığ	Center	30	140	50	35	100	45	400
6	Güz Armudu-1	Center	210	180	90	45	100	75	**700 (1)**
7	Güz Armudu-2	Center	150	180	90	45	100	15	**580 (11)**
8	Güz Mihranisi	Center	150	140	70	35	60	45	500
9	Haziran Gülü	Varto	270	60	50	45	20	45	490
10	Mayhoş	Korkut	210	140	50	35	60	15	510
11	Mecnunun Armudu	Center	150	100	50	35	100	15	450
12	Mihrani	Center	150	180	90	45	100	45	**610 (8)**
13	Mor Armut-1	Varto	210	140	90	45	100	45	**630 (6)**
14	Pamukhala	Center	90	180	70	45	100	75	**560 (12)**
15	Paşa Armudu-1	Center	270	100	70	35	60	75	**610 (9)**
16	Paşa Armudu-2	Center	270	180	70	45	60	75	**700 (2)**
17	Sulu Armut	Varto	270	140	70	35	100	75	**690 (3)**
18	Şuti	Center	90	180	70	45	100	75	**560 (13)**
19	Van Armudu	Center	150	180	90	45	100	75	**640 (5)**
20	Yaz Armudu-1	Center	150	180	90	45	60	75	**600 (10)**
21	Yaz Armudu-2	Center	90	140	70	35	60	15	410
22	Yazlık Armut	Center	210	180	70	35	100	15	**660 (7)**
23	Yerli Ankara	Center	90	100	50	45	60	15	360
24	Yuvarlak Karçin	Center	90	140	90	45	100	15	480

(**F.W:** Fruit Weight, **E.Q:** Eating Quality, **E.Q:** External Quality, **SR:** State of Rustiness, **F.F.F:** Fruit Fless Firmness, **WSDM:** Water-Soluable Dry Matter)

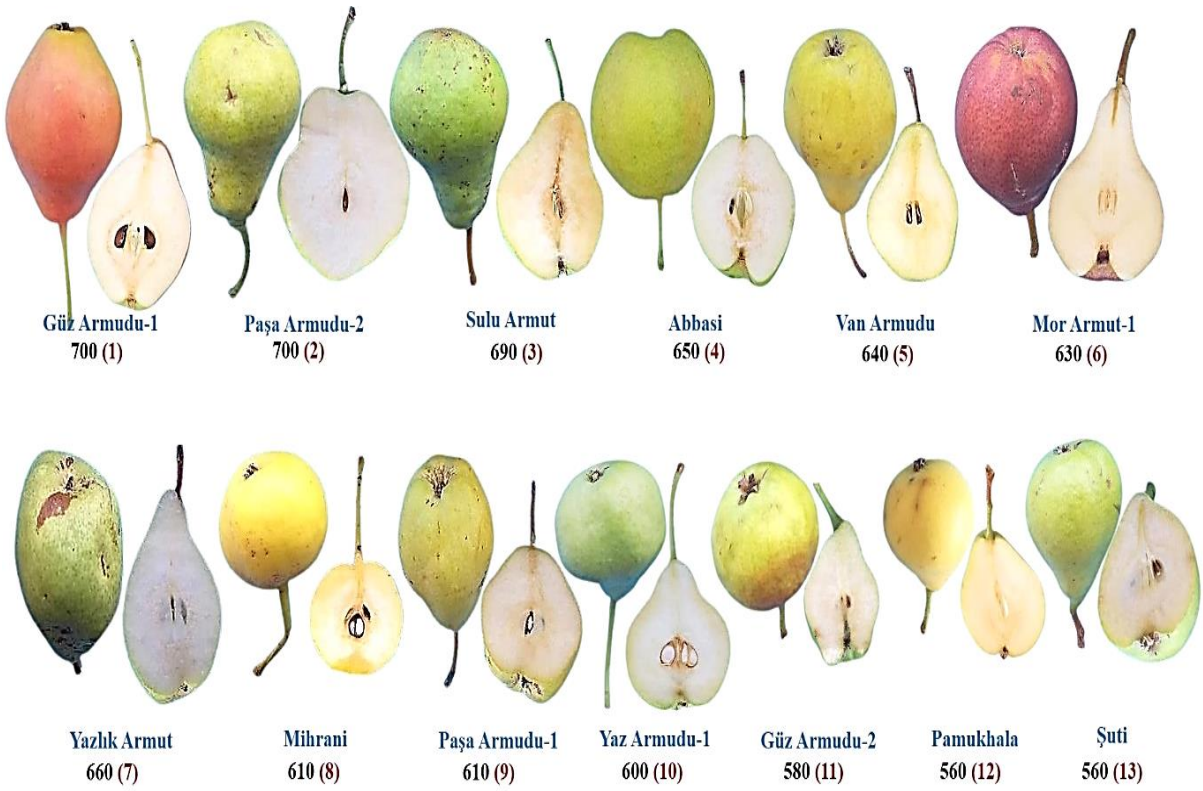

Figure 3. Cultivars determined as promising
Şekil 3*. Ümitvar olarak belirlenen çeşitler*

The cultivars scored 30-270 points in terms of fruit weight, 60-180 points in terms of eating quality, 50-90 points in terms of external quality, 35-45 points in terms of rustiness, 20-100 points in terms of water-soluble dry matter and 15-75 points in terms of fruit flesh firmness (Table 9).

Local pear varieties selected for the second year in Muş got scores between 360-700. According to this scoring, there are two varieties with the highest score. These are the Güz Armudu-1 and Paşa Armudu-2 varieties with 700 points. These varieties were followed by Juicy Pear with 690 points. In the scoring, the Yerli Ankara variety received the lowest score with 360 points. Considering the scores they got as a result of the "Weighed Rating" method from the selected pear varieties, 13 pear cultivars with a score of 550 and above were determined as promising (Table 9).

4. Discussion

Although our country is among the important pear producing countries, it is obvious that pear varieties are not yet at the desired level in terms of yield, quality and the low number of varieties that ripen at different times. One of the most important reasons for this is the lack of standard and quality varieties in line with the demands of the international market. In our country, in addition to the closed gardens created especially in recent years, production at a significant level is still provided by local varieties that people grow in collection gardens and in front of their own homes to meet local needs, and where maintenance and cultural processes are not carried out adequately. Local varieties have been evaluated as very valuable genetic resources by fruit breeders, but they are not widely accepted, especially in terms of national and international trade. Therefore, it is very important to determine the local varieties that can be standard varieties and to prevent the extinction of genetic resources.

Cultivation is a very important issue economically in our country. If economical cultivation is desired, the most important condition for this is to cultivate standard domestic and foreign varieties that meet the demands of the domestic and foreign markets. For this reason, it is very important to reveal productive and high-quality varieties suitable for the different ecologies of our country from our existing pear variety richness.

Bayındır et al. (2018) used the Weighed Grading method to determine promising varieties in local autumn varieties grown in Malatya province between 2014 and 2017, and the criteria used were fruit weight, TSS, eating quality, fruit flesh hardness and eating quality (sandiness).

Çelikel-Çubukçu and Bostan (2018) used the Weighed Grading method in their study to determine umivar varieties in summer, winter and autumn pear genotypes in Çaykara district of Trabzon province in 2012-2013. In the method, they used fruit weight, rustiness, eating quality and external quality criteria.

A study was carried out between 2009 and 2012 to determine the superior types of Çermail pear variety grown in the Erzincan plain. In the study, the Weighed Grading Method was used and yield, periodicity, fruit size, attractiveness, taste, fruit flesh hardness and TSS criteria were used as criteria (Gültekin, 2015).

In this study conducted in Muş province, the harvest dates of local pear cultivars in 2020 were between July 25-November 21, and in 2021 between July 20 and November 16. Harvest dates in 2020 in promising cultivars were between August 6 and November 12. In 2021, the harvest of promising varieties took place between August 1 and October 31 (Table 4 and Table 7).

Terkoğlu (2021), of his study on local pear varieties in Yüksekova district of Hakkari province in 2018-2019, found that the earliest local variety harvested in the first year was Hirmiyatirmehi between August 15 and September 4, and the earliest in both years of the research was Hirmizer, Hirmiyatirmehi and it has been reported that the latest Kurişi cultivar has reached the harvest maturity.

Fruit weights of local varieties determined in Muş province were measured between 21.47-284.81 g, fruit lengths of 24.92-103.87 mm and fruit widths between 30.47-94.85 mm in 2020. In 2021, fruit weights were 34.31-268.36 g, fruit lengths were 32.77-99.83 mm, and fruit widths were between 31.11-90.41 mm. In 13 cultivars identified as promising, fruit weights were 68.11-284.81 g, fruit lengths were 54.12-103.87 mm, and fruit widths were 51.10-94.85 mm in 2020 (Table 4 and Table 7).

In the similar study, fruit weights of promising summer, autumn and winter genotypes were determined between 81.30-221.35 in the study carried out in Çaykara district and 25 neighborhoods of Trabzon province (Çelikel et al., 2015). Yavuz and Pırlak (2018) reported that the fruit weights of 4 Asian pear cultivars (Hosiu, Kosiu, Hakko and Shinseiki) were determined as 122.00-206.00 g in a study conducted in the Ereğli district of Konya province to determine the phenological and pomological characteristics. In the research conducted in the ff district of Trabzon province to determine the pomological characteristics of local pear

varieties, the average fruit weight of 7 early and mid-season local pear varieties was determined to be 53.80-151.48 g (Cevahir & Bostan, 2017).

In 2020, fruit lengths were measured between 54.12-103.87 mm and fruit width between 51.10- 94.85 mm in promising cultivars. Paşa Armudu-2 is also the variety with the highest fruit size and fruit width (Table 4 and Table 7).

Acar (2007) determined the morphological and pomological characteristics of 18 local pear cultivars grown in and around Ünye. He determined fruit weights between 18.67-258.30 g, fruit length between 31.15-85.70 mm, and fruit width between 34.04 mm-81.96 mm. It is seen that the fruit weight values obtained from our study are compatible with the results of other researchers.

In local pear cultivars, fruit stalk lengths of 16.83-62.16 mm, fruit stalk thicknesses of 2.07-5.03 mm in 2020; In 2021, fruit stem lengths were measured between 22.39-59.46 mm, and fruit stem thicknesses were between 2.29-5.14 mm. In 13 varieties determined as promising, in 2020, fruit stalk lengths are between 17.60-62.16 mm, and fruit stalk thicknesses are between 2.52-4.88 mm; In 2021, fruit stem lengths were measured between 22.39-59.46 mm, and fruit stem thicknesses were between 2.43-5.14 mm (Table 4 and Table 7).

Oturmak et al. (2017) determined the fruit stem length between 19.87-50.10 mm and the fruit stem thickness between 2.45-7.98 mm in pear genotypes grown in Silvan, Kulp, Hazro districts and connected villages of Diyarbakır in 2016. The values determined in these studies and the values we determined in our study showed similarities in general.

It has been determined that 3 cultivars have little, and the remaining 10 cultivars have no or very little fruit skin rust in promising cultivars (Table 5 and Table 8).

Yılmaz (2020) examined the rustiness of the fruit skin of local varieties in his study in Fatsa district of Ordu province; He determined that 8 of them had 'low', 8 of them had 'none or low' rust, 10 of them had 'high' and 12 of them had 'medium' rust.

In fruit growing where thin skin is desired, skin thickness was found to be 0.14-0.44 mm in the first year and between 0.14-0.40 mm in the second year in promising cultivars (Table 4 and Table 7).

Yılmaz (2020) found the fruit skin thickness of local varieties to be between 0.38±0.12-0.98±1.34 mm in his study in Fatsa district of Ordu province. In studies, skin thickness data have shown similarities with our data.

Fruit flesh firmness in promising cultivars was 4.63-11.30 kg $cm^{2\ -1}$ in 2020; In 2021, it was found between 4.13-11.16 kg $cm^{2\ -1}$ (Table 5 and Table 8).

Terkoğlu (2021) determined the firmness of fruit flesh as 1.62±0.41 lb (Mellaki) and 11.51±0.10 lb (Şirya) in 2018; In 2019, it has determined that it varies between 1.63±0.42 lb (Mellaki) and 10.68±0.24 lb (Kurişi).

As can be seen, the fruit flesh firmness was found to be different from each other in studies conducted in different places, however, there was not much difference between the mentioned literature findings and the study findings.

In local pear cultivars in 2020, WSDM was found to be 9.4-20.5%, acidity 0.13-0.84%, and pH 3.23-4.88. In the promising cultivars, the WSDM was found to be between 13.1%-20.5%, acidity 0.13-0.65% and pH 3.49-4.82 in 2020. In local pear cultivars in 2021, WSDM was found between 12.1-19.6%, acidity between 0.14-0.61% and pH between 3.48-4.79%. In the promising cultivars, in 2021, WSDM was found to be 13.5-18.3%, acidity 0.14-061 and pH 3.48-4.72 (Table 5 and Table 8).

Polat and Bağbozan (2014), in a study they conducted on local pear cultivars, determined the amount of water-soluble dry matter of the fruits between 10.58-16.33%, the titratable acid content between 0.10-0.94%, and the pH of the juice between 3.21-5.41. Çelikel et al. (2015) stated that the water-soluble dry matter content of the genotypes determined as promising in Çaykara district varied between 9.7-16.6% and the titratable acid content ranged between 1.43%-16%. The findings of the chemical properties we obtained were shown to be between the same values with the literature findings.

It has been determined that 4 of the promising varieties have good eating quality and 9 of them have very good eating quality in 2020 and 2021. In promising varieties, it was determined that 2 of them had good external quality in 2020, 11 of them had very good external quality, and in 2021, 3 of them had good external quality and 10 of them had very good external quality (Table 5 and Table 8).

Büyükyılmaz et al. (1994) found that the quality of eating in promising pear varieties for the Marmara Region is very bad in Popska and Karagöynük varieties, bad in Doyenne d'Hiver varieties, medium in June Gold varieties, good in June Beauty, Devoe and Magness varieties, and very good in Williams Bovey, Klapov Lübimets varieties.

Büyükyılmaz et al. (1992) reported that Akça pears grown in the Eastern Marmara Region have a medium-good level of external quality.

The external quality (appearance) of pears is closely related to shape smoothness and attractiveness. The smoothness of the fruit shape in pears is closely related to the maintenance conditions. High soil and air humidity ensures the formation of large and properly shaped fruit (Özçağıran et al., 2004).

5. Conclusion and Recommendations

With this study carried out in 2020-2022, 13 of the 42 local pear cultivars grown in Muş province (Güz Armudu-1, Paşa Armudu-2, Sulu Armut, Abbasi, Van Armudu, Mor Armut-1, Mihrani, Paşa Armudu-1, Yazlık Armut, Yaz Armudu-1, Güz Armudu-2, Pamukhala and Şuti) were determined as promising.

It is thought that for the selected promising varieties it is possible to increase their superior characteristics even more when they are grown under controlled conditions or when necessary maintenance procedures are carried out. In this study, it will be possible to obtain more accurate results and to be compared with each other by cultivating all local varieties under equal conditions and at the same quality, and by performing cultural processes such as fertilization, spraying and irrigation of each local variety. Because it is a known fact that production practices such as care, irrigation, fertilization, fight against diseases and pests and pruning increase yield and fruit quality in fruit growing.

In this study, it is thought that there are local varieties with features and quality that can be standard varieties among the varieties determined as hopeful in Muş province. In this study we conducted in the province of Muş, it was observed that although the people of the region dealing with fruit growing had grown these local pear varieties for many years, there was no conscious production, that is, traditional agriculture was dominant.

With this study, fruit growing will be done more consciously in the region by determining the promising local pear varieties in Muş province. The people of the region will make a significant contribution to the economy of the region, especially the family, by cultivating these promising local pear varieties for many years.

While combating diseases, pests and weeds that cause very important losses in terms of quality and quantity in fruit growing, sustainability principles should be followed in agriculture, which is one of the most important principles of agriculture, and sensitive cultivation methods that give importance to human, environment and animal health should be applied. It is necessary to develop new agricultural policies that reduce or prohibit the use of pesticides in agricultural production. Especially in recent years, varieties resistant to diseases and pests obtained in the studies carried out within the scope of the methods used in the fight against plant diseases and pests, and the breeding of these varieties have started to attract a lot of attention.

It is an important fact that it is important to protect our superior local varieties, which are indispensable materials for breeding studies and, in addition to offering a different taste, are also an important genetic resource for the development of new types and varieties and they are of great importance for sustainability in agriculture.

In this study, it is among our aims to determine and reveal the richness of local pear varieties, which are known and loved by the local people and found in local markets, and to make the important and superior aspects of these varieties known, to spread more and better quality cultivation and to ensure the recognition of local varieties. In this context, varieties that can be standard varieties should be selected from the local varieties grown, necessary technical information should be given to the farmers who produce them, and new closed gardens should be established for higher quality fruit growing. Thus, it is thought that the local varieties with good characteristics that come to the forefront as a result of our research and adapt to the local ecology will be very effective in increasing the fruit production potential of the region.

References

Acar, S. (2007). *Morphological and pomological characteristics of local apple and pear cultivars grown in and around Ünye.* (Master Thesis). Ordu University Institute Of Natural And Applied Sciences, Ordu.

Anonymous, (2022). https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=MUS. *General Directorate of Meteorology, meteorological data information presentation and sales system*, Ankara. Access date: 05.01.2023.

Bayındır, Y., Çöçen, E., Macit, E., Gültekin, N., Toprak-Özcan, E., Aslan, A., Aslantaş, R. (2018). Selection of local autumn pear genotypes in Malatya region. *Academic Journal of Agriculture*, doi:10.29278/azd.440098.

Büyükyılmaz, M., & Bulagay, A.N. (1983). Promising pear varieties for the Marmara Region. *II. Garden* 12(2):5-14.

Büyükyılmaz, M., Bulagay, A.N., & Burak, M. (1992). Clone selection in maple pears grown in the Eastern Marmara Region. *Garden*, 21(1-2), 61-68.

Büyükyılmaz, M., Bulagay, A.N., & Burak, M. (1994). Promising Pear Varieties for Marmara Region -III. *Garden* 23(1-2): 79-92.

Cevahir, G.i Bostan, S.Z. (2017). Local pears of Of (Trabzon) district: Early and mid season varieties. *Fruit Science*, 4 (2), 19-25.

Çelikel-Çubukçu, G., & Bostan, S.Z. (2015). *Investigation of Breeding by Selection and Resistance to Fire Blight of Local Pear (pyrus spp) Genotypes Cultivated in Çaykara District* (Ph.D. Thesis). Ordu University Institute Of Natural And Applied Sciences, Department of Horticulture, Ordu. 244p.

Çelikel-Çubukçu, G., & Bostan, S.Z. (2018). Breeding by Selection of Local Pear (Pyrus spp.) Genotypes Cultivated in Çaykara District: I-Fruit Characteristics. *Gaziosmanpaşa University Journal of Faculty of Agriculture*, 35(4), 75- 88. https://doi.org/10.13002/jafag4511

Ercişli, S., 2004. A short review of the fruit germplasm resources of Turkey. *Genetic Resources and Crop Evolution* 51: 419–435.

Fischer, M. (2009). *Pear Breeding*: Breeding Plantation Tree Crops (Temperate Species), Ed.: Jain, SM., Priyadarshan, P.M., Springer+Business Media, New York, USA, 135-161.

IPGRI, (1983). *Descriptor list for pear (Pyrus)* http://www.ipgri.cgiar.org/system/page.asp? theme = 1

Karadeniz, T., & Çorumlu, M. S. (2012). İskilip pears. *Academic Journal of Agriculture*, 1 (2): 61-66.

Kaya, T. (2008). *Phenological, Morphological, Pomological and Molecular Identification of Apple Genetic Resources in Van Merkez, Edremit and Gevaş Districts* (Ph.D. Thesis). Yüzüncü Yıl University, Institute Of Natural And Applied Sciences, Van.

Michelson, L.F., Lachman, W.H., & Allen, D.D. (1958). The Use of the "Weighted-Rankit" Method in Variety Trials. Proc. Amer. *Soc. Hort. Sci.* 71:334-338.

Oturmak, İ., Özrenk, K., & Çavuşoğlu, Ş. (2017). Determination of some local pear (*Pyrus communis L.)* gene sources in Diyarbakır (Silvan, Kulp, Hazro) region. *International Journal of Agriculture and Wildlife Sciences*, 3 (2): 61-67. https://doi.org/10.24180/ijaws.353966

Öz, M.H., & Aslantaş, R. (2015). Morphological Characterization of Pear Genotypes in the Eastern Anatolia Region. *Journal of Atatürk University Faculty of Agriculture*, 46 (2): 93-106.

Özbek, S. (1978). *Special Fruiting (Fruit Types That Drop Their Leaves In Winter).*Çukurova University, Faculty of Agriculture, Publication Number: 128, Lecture Book: 11, Adana. 486p.

Özçağıran, R., Ünal, A., Özeker, E., & İsfendiyaroğlu, M. (2004). 'Temperate climate fruit species', *Soft Seed Fruits,* 2: 200.

Öztürk, A. (2010). *Morphological, Pomological and Molecular Characterization of Pear Genotypes in Sinop Province* (Ph.D. Thesis). Ondokuz Mayıs University, Institute Of Natural And Applied Sciences, Samsun.

Polat, M., & Bağbozan, R. (2014). Determination of some fruit characteristics of early native pear (*Pyrus communis L.*) types grown in Eğirdir (Isparta) ecology. *Süleyman Demirel University, Journal of the* Institute Of Natural And Applied Sciences, 21 (1): 9-12.

Terkoğlu, E. (2021). *Identification of Local Varieties Belonging To Some Soft And Stone Seed Fruit Species Grown in Yüksekova (Hakkari) Ecological Conditions* (Master Thesis). Yüzüncü Yıl University, Institute Of Natural And Applied Sciences, Van.

TSI, (2022). https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr. Access date 15.02.2023.

UPOV, (2000). International Union for the Protection of New Varieties of Plants: *Guidelines for the Conduct of Tests for Distinctness, Uniformity and Stability* (PEAR; *Pyrus communis* L.) http://www.upov.int/en/publications/tg-rom/tg015/tg_15_3.pdf. Access date: 09.02.2020.

Yamamoto, T., & Chevreau, E. (2009). Pear Genomics. In Genetics and Genomics of Rosaceae (*Plant Genetics and Genomics: Crops and Models*) (Eds: K.M. Folta, S.E. Gardiner), p:163-186.

Yarılgaç, T., & Yıldız, K. (2001). Some pomological characteristics of local pear cultivars grown in Adilcevaz district. *Yüzüncü Yıl University Journal of Agricultural Sciences*, 11 (2): 9-12.

Yavuz, M., & Pırlak, L. (2018). Phenological and pomological characteristics of some asian pear cultivars in Ereğli-Konya, *Selçuk Journal of Agriculture and Food Sciences*. 32 (3): 449-453. https://doi.org/10.15316/SJAFS.2018.121

Yılmaz, A. (2020). *Local Winter Pear Varieties of Fatsa (Ordu)* (Master Thesis). Ordu University, Institute Of Natural And Applied Sciences, Ordu.

Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi
Journal of Agricultural Faculty of Gaziosmanpasa University
https://dergipark.org.tr/tr/pub/gopzfd

Araştırma Makalesi/*Research Article*

JAFAG
ISSN: 1300-2910
E-ISSN: 2147-8848
(2023) 40(3) 155-162
doi:10.55507/gopzfd.1378164

Effect of Some Herbicide (Metribuzin, Pendimethalin and Fluazifop-p-Butyl) on *Bacillus cereus* and *Pseudomonas putida*

Vasfiye ILIKPINAR SAYGILI[1*], Izzet KADIOGLU[1], Sabriye BELGUZAR[1], Yusuf YANAR[1]

[1]Tokat Gaziosmanpaşa University, Faculty of Agriculture, Department of Plant Protection, Tokat,
***Corresponding author's email:** vasfiye.ilikpinar@gmail.com

Alındığı tarih (Received): 19.10.2023 Kabul tarihi (Accepted): 31.12.2023

Abstract: Beneficial bacteria are used as plant growth promoters in agriculture. The off-target effects of herbicides on beneficial bacteria are needed to be investigated. This study was carried out to determine the positive or negative effects of active compounds of herbicides on the reproduction of beneficial bacteria, *Bacillus cereus* and *Pseudomonas putida*. The herbicides used in this study contained active compounds such as Fluazifop-p-buthyl, Pendimethalin and Metribuzin. Effects of the active compounds were evaluated on the bacteria under *in vitro*, greenhouse and field conditions. Three doses of each active compound were used: the recommended dose (N), twice the recommended dose (2N) and three folds (3N) the recommended dose. It was observed that the increased dose of Pendimethalin, Fluazifop-p-buthyl, Metribuzin had significant effects on *B. cereus* and *P. putida* under *in vitro* conditions. Also, the increased dose of Pendimethalin, Fluazifop-p-buthyl significantly reduced the density of both bacteria. On the other hand, increasing doses of Pendimethalin decreased the density of *P. putida*, but did not affect that of *B. cereus*. Under greenhouse conditions, the density of *B. cereus* was not affected with increased doses of Fluazifop-p-buthyl and Metribuzin while the bacteria concentration were increased with doses of pendimethalin. As the doses of active substances increased, *P. putida* bacterial density also increased in greenhouse. Under field conditions, the recommended doses of Pendimethalin, Metribuzin did not inhibit *B. cereus* density, while the dose of Fluazifop-p-buthyl increased the bacterial concentration. Additionally, under similar conditions, Fluazifop-p-buthyl and Metribuzin did not affect *P. putida*, while Pendimethalin decreased concentration of *P putida*. In the present study results showed that increased active substances of Pendimethalin, Fluazifop-p-buthyl and Metribuzin are decreasing or increasing the densities of *P. putida* and *B. cereus* with dependent on experimental conditions. All these active substances are not eradicating the beneficial bacterial population in soil. It would be appropriate to give some quantitative values of the obtained results in the abstract.

Keywords: *Bacillus cereus,* density of bacteria, *Pseudomonas putida,* recommended dose, soil

Bazı Herbisitlerin (Metribuzin, Pendimethalin ve Fluazifop-p-Butil) *Bacillus cereus* ve *Pseudomonas putida* Üzerine Etkisi

Öz: Birçok faydası olan yararlı bakteriler tarımda bitki gelişimini destekleyici olarak kullanılmaktadır. Tarımsal alanlarda kullanılan herbisitlerin faydalı bakteriler üzerindeki hedef dışı etkilerinin belirlenmesi gerekmektedir. Bu çalışma, herbisitlerin faydalı bakteriler *Bacillus cereus* ve *Pseudomonas putida* 'nın çoğalmasına olumlu veya olumsuz etkilerini belirlemek amacıyla gerçekleştirilmiştir. Test edilen herbisit aktif maddeleri Fluazifop-p-buthyl, Pendimethalin ve Metribuzin'dir. Aktif maddelerin etkileri *in vitro*, sera saksı deneyleri ve tarla denemelerinde değerlendirilmiştir. Her herbisit için aktif maddenin üç dozu kullanılmıştır: önerilen doz (N), önerilen dozun iki katı (2N) ve önerilen dozun üç katı (3N). Artan Pendimethalin ve Fluazifop-p-buthyl dozları her iki bakterinin de yoğunluğunu azaltmaktadır. Öte yandan, artan Pendimethalin dozları *P. putida*'nın yoğunluğunu azaltırken, *B. cereus*'u etkilememiştir. Serada, *B. cereus*'un yoğunluğu Fluazifop-p-buthyl ve Metribuzin'in artan dozlarından etkilenmezken, pendimethalin ile artmıştır. Aktif maddelerin dozları arttıkça, serada *P. putida* bakteri yoğunluğu da artmıştır. Tarla denemelerinde, Pendimethalin ve Metribuzin'in önerilen dozları *B. cereus* yoğunluğunu engellemezken, Fluazifop-p-buthyl bakteri yoğunluğunu artırmıştır. Fluazifop-p-buthyl ve Metribuzin *P. putida* yoğunluğunu etkilemezken, Pendimethalin *P. putida* yoğunluğunu azaltmıştır. Bu çalışmada, sonuçlar herbisit etken maddeleri olan Pendimethalin, Fluazifop-p-buthyl ve Metribuzin'in *P. putida* ve *B. cereus*'un yoğunluklarını deneysel koşullara bağlı olarak artırdığını veya azalttığını, ancak topraktaki popülasyonlarını tamamen ortadan kaldırmadığını açıkça göstermiştir. Elde edilen sonuçlara ait bazı kantitatif değerlerin de özet kısmında verilmesi uygun olacaktır.

Anahtar kelimeleri: *Bacillus cereus,* bakteri yoğunluğu, *Pseudomonas putida,* tavsiye edilen doz, toprak

1. Introduction

The world population is increasing at an unprecedented rate and the ability to meet the dietary requirement is one of the goals of crop scientists. In developing countries, most part of their economy is based on agriculture. To increase the yield obtained from land area, it is necessary to adopt sustainable agricultural control methods to protect crops from pests, weeds and invasive plants (Digrak et al., 1998). Herbicides provide a powerful and chemical control option in the control of weed. However, active ingredients in herbicides may pose a threat to beneficial organisms in the soil. Therefore, it is necessary to determine whether newly developed herbicides have a negative impact on beneficial organisms in the soil before its application.

Although chemical pesticides contribute greatly to the increase in crop yield, they also tend to poison beneficial microorganisms. The effectiveness, low-cost and easy applicability of synthetic herbicides make them highly preferred by farmers (Gulec et al., 2015; Yavuz et al., 2017). Herbicides are one of the pesticides widely used in agricultural production and their use is increasing day by day (FAO, 2023; Kitis et al., 2016). While herbicides aid in the control of weeds, they also affect fungal pathogens and bacteria in the soil (Akbulut, 2008). The application of herbicides to the field soils can potentially affect soil beneficial bacteria and their activities (Madhuri et al., 2012). This can lead to stimulation, reduction or alteration of biological processes in the soil (Vig et al., 2008). There are many studies on the effects of herbicides on soil microflora. These literatures should be mentioned more in the introduction.

Beneficial bacteria in the soil improves soil fertility, soil aeration, and overcomes environmental problems such as pollution and soil degradation. *Pseudomonas putida* and *Bacillus cereus* are soil-borne bacteria that promote plant growth (Aktan and Soylu, 2020; Cakmakci, 2004; Gupta et al., 2015). Herbicides used in modern agricultural systems are preferred for their efficacy, while their potential harmful effects are often ignored. The effects of active substances-Metribuzin, Pendimethalin and Fluazifop-p-butyl- on *P. putida* and *B. cereus* are not known. Since soil beneficial bacteria may be affected by chemical pesticides, it is necessary to investigate the effects of common active substances on these beneficial organisms.

There are several beneficial bacteria species in soil microbiota. *Pseudomonas* and *Bacillus* are most prominent since they have good antagonistic properties against pathogens (Altin and Bora, 2005; Torun, 2015). There is no sufficient information about the off-target effects of herbicides (Karaaslan and Gur, 2009) on *Pseudomonas* and *Bacillus* bacteria. In the present study, the effects of herbicide active substances such as metribuzin, pendimethalin and fluazifop-p-butyl on growth and reproduction of *Pseudomonas* and *Bacillus* bacteria are investigated.

2. Material and Methods

2.1. Material

In the study, Metribuzin, Pendimethalin and Fluazifop-p-butyl, which are widely preferred by farmers for weed control, were used (Table 1). Isolates of *P. putida* and *B. cereus* were obtained from pepper production areas in a previous study conducted by Kayaaslan (2021).

Table 1. Herbicides used and their recommended doses.
Çizelge 1. *Kullanılan herbisitler ve önerilen dozlar*

Active substances	Mode of action	Recommended dose
Metribuzin	Broadleaf weeds	50-75 g/da
Pendimethalin	Annual grasses and broadleaf weed	500 ml/da
Fluazifop-p-butyl	Narrow leaf weeds	100 ml/da

2.2. Methods

2.2.1. *In vitro* tests

Three different doses of Metribuzin, Pendimethalin and Fluazifop-p-butyl were applied: the recommended dose (N), twice of the recommended dose (2N) and thrice of the recommended dose (3N) were added into nutrient agar (NA) medium. The NA, a 1000 ml solution was containing 20 g nutrient agar ((Merck, Germany), was used as medium in the study (Lelliot and Stead, 1987). The NA medium was autoclaved at 121 °C for 15 min and kept at 40 °C. The herbicides were added into the media at the determined concentrations (herbicides were calculated according to the liquid ratio for 20 ml of PDA to a petri dish) for each dose and mixed with a magnetic stirrer and poured into 90 mm diameter Petri dishes with a volume of 20 ml. Distilled water was used as a negative control. Bacterial isolates of *P. putida* and *B. cereus* which in stock culture at -20 °C, were cultivated on NA medium and incubated at 25±2 °C for 24 hours. Then, a bacterial suspension was prepared in saline buffer (0.85 g NaCl per liter) and adjusted to an absorbance value of 0.3 (A_{600}: 0.3) at 600 nm wavelength in a spectrophotometer (Madison WI 53711, USA). Bacteria density in suspension were $1x10^8$ cfu ml^{-1} and 100 µl of the suspensions were transferred to the NA medium containing the herbicides doses and

incubated at 25±2 °C for 24 hours. At the end of the incubation, bacterial colonies were collected, and densities were measured in a spectrophotometer (A600:0.3) (Belguzar et al., 2019). The experiments were conducted using the randomized block research design with five replications and the experiment was repeated twice.

2.2.2. Greenhouse tests

The effects of herbicides on *P. putida* and *B. cereus* were investigated in a pot experiment under greenhouse conditions. Each of pots were filled with 1 kg of sterile mixture of soil, peat and perlite (2 volume: 1 v: 1 v). A suspension of *B. cereus* and *P. putida* cultures was prepared at a density of $1x10^8$ cfu ml^{-1} (200 ml per pot). The prepared suspension was mixed with autoclaved soil and filled into pots (Belguzar et al., 2018). The N, 2N and 3N doses of Metribuzin, Pendimethalin, Fluazifop-p-butyl herbicides were applied according to the surface area of the pots (160x145 mm). The pots in the control group were filled with sterile soil inoculated with bacteria but no herbicides treatment. The bacteria containing pots were applied with N, 2N and 3N doses of herbicides individually. Soil samples were taken at 15-day intervals for 60 days to determine the bacterial density. Soil samples were taken from 10 cm depth, the samples were dried for a day under laboratory conditions and then were sieved through a 2 mm mesh sieve. Then, 10 g of the sieved soil samples was added to 90 ml nutrient broth medium and they were shaken at room temperature at 100 rpm for two hours on a shaker (IKA HS 501, Germany). The suspension (1 ml) was added to a tube containing 9 ml of physiological saline buffer (saline buffer - 0.85% NaCl) and this process was repeated 6 times (Schaad et al., 2001). In this way, six times (6) dilution series were prepared. Afterwards, 100 µl of the -4, -5 and -6 dilutions of the prepared series were s transferred on Nutrient Agar medium in 2 replicates and incubated at 25 ± 2 °C for 24 hours. Bacterial colonies in petri dishes were counted according to the plate counting technique (Klement et al., 1990).

2.2.3. Field study

The field studies were conducted in the experimental field of Agricultural Research and Application Center field at Tokat Gaziosmanpaşa University. 18l cans were filled with 15 kg of soil from the field and buried in the soil. A suspension of *B. cereus* and *P. putida* cultures was prepared at a density of $1x10^8$ cfu ml^{-1} (2 liter per can). The prepared suspension was mixed with field soil and filled into cans (Belguzar et al., 2018). The N dose of Metribuzin, Pendimethalin, Fluazifop-p-butyl herbicides was applied according to the surface area of the cans (236 x 236 mm). Only irrigation water was applied to the control cans. The field trials were established using a randomized block design with three replications and repeated twice. Four samples were taken from each treatment. Soil samples were taken from 20 cm depth and were dried for one day under laboratory conditions and sieved through a 2 mm sieve. Bacterial density in the field soil was determined as described in the greenhouse tests.

2.2.4. Statistical Analysis

For statistical evaluations of the results Mstat-C package program was used. The LSD test was used and differences between significant means were grouped according to 5% significance level. Doses and days were compared among themselves, and averages were taken. Herbicides and bacteria treatments were not compared among themselves.

3. Results

3.1. *In vitro* test

Pendimethalin, Metribuzin and Fluazifop-p-butyl showed different effects on *P. putida* and *B. cereus* under *in vitro* conditions (Table 2). N dose of metribuzin significantly reduced *B. cereus* bacteria compared to the control. The 2N and 3N doses reduced bacterial density more than the N dose, but the 2N dose was not statistically different from the 3N dose. In contrast to observations made on *B. cereus*, there was a direct relationship between Metribuzin doses and the density of *P. putida.*Thus as the doses of Metribuzin increased, an increase in the density of *P. putida* was observed .

Similarly, fluazifop-the increased doses of p-butyl decreased the density of *B. cereus*, while the inverse was observed for density of *P. putida* density. Compared to the control, the difference between them was not significant as increasing Pendimethalin doses increased. Pendimethalin herbicide treatment did not have any decreasing or increasing effect on *B. cereus* population irrespective of the various doses' treatment. However, it did have an increasing effect on *P. putida* density.

3.2. Pots experiments in greenhouse

Bacterial densities in pots were measured for 60 days at 15-day intervals and the effect of herbicides on the density of bacteria is summarized in Table 3 and Table 4. On the 15^{th} day, isolations of *B. cereus* from pot soils treated with fluazifop-p-butyl revealed a decrease in the

density of the bacteria. In contrast, the density of *P. putida* did not differ at N and 2N doses of the chemical but increase was observed at 3N dose treatment. Also, on the 30th day the density of *B. cereus* increased, whilst the density of *P. putida* was found to have decreased after isolation. On the 45th day, both bacterial densities were lower than control pots in all doses, but they were not significantly differences were observed. On the 60th day, it was determined that density of *B. cereus* decreased in all doses, while *P. putida* bacterial density increased at 2N dose, but did not differ in other doses. In general, the effect of fluazifop-p-butyl on *B. cereus* bacterial density was not significant at all doses compared to the control, while *P. putida* bacterial density increased at 2N and 3N doses.

Table 2. Metribuzin, Fluazifop-p-butyl and Pendimethalin effect on *Pseudomonas putida* and *Bacillus cereus* density (cfu/ml)
Çizelge 2. *Metribuzin, Fluazifop-p-butil ve Pendimethalinin Pseudomonas putida ve Bacillus cereus yoğunluğu üzerine etkisi*

Active substances	*Dose*	*Bacillus cereus*	*Pseudomonas putida*
Metribuzin	Control	2.044^{a}	1.713^{b}
	N	1.682^{b}	1.800^{ab}
	2N	0.398^{c}	1.919^{a}
	3N	0.445^{c}	1.856^{a}
Fluazifop-p-butyl	Control	2.044^{a}	1.713^{c}
	N	1.699^{b}	1.725^{c}
	2N	1.608^{b}	1.851^{b}
	3N	1.755^{b}	2.028 ^{a}
Pendimethalin	Control	2.044^{ns}	1.713^{b}
	N	2.084	2.271^{a}
	2N	2.058	2.196^{a}
	3N	2.115	2.218^{a}

^{NS}: not significant. Means followed by a different letter are in the same column significantly different at an alpha level of 0.05 according to LSD test

Table 3. Effect of different doses of herbicides on *Bacillus cereus* growth in pots (cfu/ml)
Çizelge 3. *Farklı dozlardaki herbisitlerin saksılarda Bacillus cereus büyümesi üzerine etkisi*

Active substances	**Doses**	**Days**				
		15	**30**	**45**	**60**	Mean
Fluazifop-p-buthyl	Control	13.70 ^{a}	4.00 ^{b}	6.00^{NS}	5.76 ^{a}	7.37^{NS}
	N	5.76 ^{b}	10.76 ^{a}	3.26	2.76 ^{c}	5.64
	2N	5.50 ^{b}	6.76 ^{ab}	5.76	4.00 ^{b}	5.51
	3N	7.00 ^{b}	11.00 ^{a}	3.00	2.50 ^{c}	5.88
Metribuzin	Control	13.76^{NS}	4.00^{NS}	6.00 ^{a}	5.76 ^{a}	7.38^{NS}
	N	10.26	5.50	6.76 ^{a}	5.50 ^{a}	7.01
	2N	12.00	6.00	3.76 ^{b}	2.50 ^{b}	6.07
	3N	27.60	6.26	4.26 ^{b}	4.76 ^{ab}	10.77
Pendimethalin	Control	13.70 ^{c}	4.00 ^{b}	6.00^{NS}	5.76^{NS}	7.38 ^{b}
	N	10.50 ^{c}	5.76 ^{b}	7.76	2.76	6.70 ^{b}
	2N	64.50 ^{a}	8.50 ^{b}	7.00	2.00	20.50 ^{a}
	3N	46.26 ^{b}	22.00 ^{a}	7.00	8.26	20.88 ^{a}

^{NS}: not significant. Means followed by a different letter in the same column are significantly different at an alpha level of 0.05 according to LSD test.

Compared to the control, there was no effect of N and 2N dose of metribuzin on the density of *B. cereus* at day 15, while density of *P. putida* increased only at 3N dose but they were not significant differences between them. The N dose of metribuzin had no effect on *B. cereus* density on the 45th and 60th days, while the 2N and 3N doses decreased the density *B. cereus*. At 45 and 60 days, the effect of metribuzin on density of *P. putida* was not statistically significant. In general, the effect of all three doses of metribuzin on the density of *B. cereus* bacteria was not statistically significant compared to the control. In *P. putida*, the N dose of the herbicide decreased the bacterial density compared to the control, while the difference between the other doses was not significant.

While the N dose of pendimethalin did not affect the bacterial density on day 15, 2N and 3N doses increased the density of *B. cereus* compared to control. There was

an increasing effect of pendimethalin on density *P. putida* at all three doses. The N and 2N doses of pendimethalin were compared to the control on day 30, the differences were not significant for density of *B. cereus*, while at 3N dose, the density increased. On day 30, the N dose of pendimethalin increased the density of *P. putida*. The 2N dose of pendimethalin was not different compared to the control, while the 3N dose had a decreasing effect on the bacterial density. On days 45 and 60, the effect of pendimethalin did not have a significant effect on the density of *B. cereus* at all doses. Also, on day 45, 2N dose of pendimethalin increased *P. putida* bacterial density, while there was no difference among other doses and control. On the 60th day, the effect of pendimethalin was not significant, although it reduced density of *P. putida*. In general, N dose of pendimethalin was not different from control, but the density of *B. cereus* increased at 2N and 3N doses. The N and 2N doses of the pendimethalin increased the density of *P. putida* compared to the control, while there was a significant difference between the 3N dose and control.

Table 4. Effect of different doses of herbicides on *Pseudomonas putida* growth in pots (cfu/ml)
Çizelge 4. *Farklı dozlardaki herbisitlerin saksılarda Pseudomonas putida büyümesi üzerine etkisi (cfu/ml)*

Active substances	Doses	Days				Mean
		15	30	45	60	
Fluazifop-p-buthyl	Control	1.75 ^{b}	3.00 ^{a}	4.25^{NS}	2.00 ^{bc}	2.75 ^{b}
	N	2.75 ^{b}	1.25 ^{c}	4.00	0.75 ^{c}	2.19 ^{b}
	2N	0.75 ^{b}	2.25 ^{b}	6.25	7.50 ^{a}	4.19 ^{a}
	3N	8.00 ^{a}	1.75 ^{bc}	5.25	3.25 ^{b}	4.56 ^{a}
Metribuzin	Control	1.75^{ab}	3.00^{NS}	4.25^{NS}	2.00^{NS}	2.75 ^{a}
	N	0.75^{b}	1.25	3.75	1.50	1.81 ^{b}
	2N	0.50^{b}	2.00	2.75	3.00	2.06 ^{ab}
	3N	2.75^{a}	1.75	4.50	1.50	2.63 ^{ab}
Pendimethalin	Control	1.75^{NS}	3.00^{b}	4.25^{b}	2.00^{NS}	2.75 ^{c}
	N	3.75	4.00^{a}	7.00^{b}	0.75	3.88 ^{b}
	2N	4.50	2.75^{b}	12.50^{a}	0.75	5.13 ^{a}
	3N	4.50	1.75^{c}	6.00^{b}	1.75	3.50 ^{bc}

^{NS}: not significant. Means followed by a different letter in the same column are significantly different at an alpha level of 0.05 according to LSD test.

3.3. Effects of herbicides on *Pseudomonas putida* and *Bacillus cereus* under field conditions

In the field trials, the effects of herbicides on bacteria were determined using the density of bacteria for 60 days at 15 days intervals. Bacteria were isolated from soils treated with herbicides at the recommended dose (Table 5). The active substances Pendimethalin and Fluazifop-p-butyl increased the density of *B. cereus* on day 15, while Metribuzin was not affected. The effect of herbicides on *P. putida* was not significant on day 15 compared to the control. The effects of Metribuzin, Fluazifop-p-butyl and Pendimethalin on density of *B. cereus* were not different from control. On day 30, the effect of active substances on *P. putida* was not significant. Active substances did not affect the density of *B. cereus* on day 45, while they decreased the density of *P. putida* under field conditions. When the effect of the recommended doses (N) of the herbicides on *B. cereus* were compared with the control, the difference between them was not significant. Only Metribuzin increased the density of *P. putida* bacteria, while Pendimethalin and Fluazifop-p-buthyl were not affected.

Table 5. Effect of herbicides on *Bacillus cereus* and *Pseudomonas putida* growth in field soil (cfu/ml)
Çizelge 5. *Herbisitlerin tarla toprağında Bacillus cereus ve Pseudomonas putida büyümesi üzerine etkisi (cfu/ml)*

	Herbicides/days	15	30	45	60	Mean
B. cereus	Control	4.75 ^{b}	5.00 ^{ab}	2.50 ^{b}	4.75^{NS}	4.25 ^{bc}
	Pendimethalin	11.00 ^{a}	8.25 ^{a}	2.50 ^{b}	6.00	6.94 ^{ab}
	Metribuzin	3.25 ^{b}	2.25 ^{b}	2.00 ^{b}	3.25	2.69 ^{c}
	Fluazifop-P-Buthyl	13.00 ^{a}	2.25 ^{b}	13.75 ^{a}	3.75	8.19 ^{a}
P. putida	Control	4.50 ^{NS}	4.50 ^{NS}	5.00 ^{a}	2.00 ^{b}	4.00 ^{a}
	Pendimethalin	5.25	3.50	1.25 ^{b}	1.50 ^{b}	2.88 ^{b}
	Metribuzin	4.50	5.25	1.50 ^{b}	3.25 ^{a}	3.63^{ab}
	Fluazifop-P-Buthyl	4.25	4.00	2.00 ^{b}	1.75 ^{b}	3.00 ^{ab}

^{NS}: not significant. Means followed by a different letter in the same column are significantly different at an alpha level of 0.05 according to LSD test.

In general, the density of *B. cereus* bacteria in soils treated with Fluazifop-p-buthyl was higher than the control, while the density of bacteria in soils treated with Metribuzin and pendimethalin was like the control.

When the effect of Metribuzin and Fluazifop-p-buthylon *P. putida* bacteria were compared with the control, the difference was not significant, while Pendimethalin decreased the density of *P. putida* bacteria. Finally, it was discovered that both bacteria were still viable in soil samples taken on day 60.

4. Discussion

In modern agriculture, pesticides (herbicides, fungicides, insecticides, etc.) are commonly used to increase crop yields and control various pests (weeds, fungal pathogens, and insects) (Thiour-Mauprivez et al., 2019). Pesticides are applied to prevent pests and not to adversely affect other living organisms (Guven and Koc, 2020). Irrespective of the importance of pesticides in agriculture, some active ingredients of herbicides may have adverse effects on growth and reproduction of non-target organisms (Madhuri et al., 2012). Therefore, the positive and negative effects of herbicide on the density of *Pseudomonas putida* and *Bacillus cereus* were investigated.

In vitro application of metribuzin decreased the density of *B. cereus* bacteria at all three doses. However, there was no effect of metribuzin doses on the density of *B. cereus* under greenhouse and field conditions. The negative effects of metribuzin active substances in vitro may be due to the fact that bacteria are only exposed to the active substance outside the nutrient agar. Whereas, in greenhouse and in the field, the ineffectiveness of metribuzin on bacterial growth may be due to organic matter or other microorganisms in the field soil that promote bacterial growth. At the recommended dose of Metribuzin, *P. putida* density under in vitro conditions was not affected, but density of *P. putida* increased at increasing doses. In greenhouse conditions, density of *P. putida* decreased at N dose of Metribuzin, but there is no effect at other doses. In the field, recommended dose of Metribuzin had no effect on density of *P. putida*. Kotan and Tozlu (2021) tested the bactericidal effects of herbicides with seven active ingredients against nine bacterial isolates using recommended doses under in vitro conditions and it was determined that metribuzin did not show bactericidal effect. Erguven (2019) investigated the influence of metribuzin on *Bacillus subtilis* in field trial, and emphasized that *B. subtilis* degraded Metribuzin, therefore *Bacillus subtilis* was not affected by this herbicide. Zaid et al. (2014) applied pre-emergence herbicides to pea fields and investigated their effects on soil microflora and nitrogen fixing bacteria. From their study, it was reported that metribuzin increased the soil bacterial density.

Pendimethalin did not affect the density of *B. cereus* under both in vitro and field conditions. In greenhouse conditions, pendimethalin increased the density of *B. cereus* bacteria at increasing doses. Oyeleke et al. (2011) reported that the recommended dose of pendimethalin decreased the microbial population and increasing doses of pendimethalin decreased the microbial population in the soil, supporting the results in the study. Pendimethalin increased the density of *P. putida* bacteria in both laboratory and greenhouse conditions. In the field, Pendimethalin caused a decrease in density of *P. putida*. Singh et al. (2021) reported that pendimethalin had the lowest inhibition on *P. fluorescens* compared to other herbicides under in vitro conditions. Raghavendra et al. (2017) observed that pendimethalin applied at the recommended dose reduced the density of Azotobacter, Rhizobium and phosphorus degrading bacteria compared to control, indicating similar results to the present study in field trials with pendimethalin. et al., 2011). Guven and Koc (2020) reported that pendimethalin caused a decrease in the number of bacteria in soil. On the other hand, Maheswari et al. (2016) observed minimum inhibition in Pendimethalin (0.3 ml/100 ml).

Fluazifop-p-buthyl decreased the density of *B. cereus* at all three doses in vitro, but there was no effect was observed under greenhouse condition. Fluazifop-p-buthyl increased the density of *B. cereus* in soil under field conditions. Fluazifop-p-buthyl did not affect *P. putida* at the recommended doses in vitro and greenhouse, while density *P. putida* increased at increasing dose. Under field conditions, there is no effect of Fluazifop-p-buthyl to *P. putida* density. Darine et al. (2015) determined that Fluazifop-p-buthyl increased the bacterial density in soil. Erguven and Nuhoglu (2020) reported that bacteria such as *Brevibacterium macrolides, Bacillus macrolides, Microbacterium chocolatum, Bacillus subtilis, Ochrobactrum thiophenivorans, Sphingomonas meloni* sand *Sphingomonas aquatilis* degraded the Fluazifop-p-buthyl in the soil, but the value was never zero.

Results showed that herbicides with the active substances such as Pendimethalin, Fluazifop-p-buthyl, Metribuzin increased the presence of *P. putida* and *B. cereus* beneficial bacteria in some conditions and decreased in some conditions but did not eliminate them. Lo (2010) reported that the pesticides stimulated the growth of some microorganisms in the soil, reduced the growth of others and even had no effect on some microorganisms. The density of *P. putida* and *B. cereus* bacteria initially increased after herbicide application.

Similarly, Oyeleke et al. (2011) reported also an increase in the density of bacteria in the soil at the beginning of herbicide application and reached a maximum of the density in the next few weeks. This may be due to soil microflora that can temporarily mineralize and use the herbicide as an energy source (Kunc et al., 1985).

5. Conclusion

In this study the herbicides' active substances resulted different effects on soil beneficial bacteria *in vitro*, greenhouse and in field conditions. However, in general, the herbicide active compounds either increased or did not significantly affect the growth of beneficial bacteria. The obvious negative effects of active substances in the *in vitro* may be since the bacteria were only exposed to the active substance and medium contents. In greenhouse and field, the lack of effect of the active compounds on bacterial growth, or even an increase, may be due to organic matters or other microorganisms in the field soil which promote bacterial growth or soil chemical and physical features. It may also be that the active substances are degraded by beneficial bacteria and, thereby their effect could be reduced. Finally, Pendimethalin, Fluazifop-p-buthyl and Metribuzin can be safely used at recommended doses for weed control as they did not harm *P. putida* and *B. cereus* bacteria under greenhouse and field conditions.

Acknowledgement

This work was supported by Tokat Gaziosmanpasa University Scientific Research Projects (BAP) Commission with project number 2021/26. This study was a part of the Ph.D. thesis of Vasfiye Ilikpinar Saygili.

References

Aktan, ZC., Soylu, S. (2020). Prevalence and characterization of plant growth promoting mechanisms of endophytic and epiphytic bacterial species ısolated from almond trees growing in Diyarbakır province of Turkey. KSÜ Journal of Agriculturaland Nature, 23 (3), 641-654. https://doi.org/10.18016/ksutarimdoga.vi.659802.

Altin, N., Bora, T., (2005). Common properties and effects of plant growth promoting rhizobacteria. Anadolu Journal of Aegean Agricultural Research İnstitute,15 (2), 87-103.

Akbulut, G. (2008). The effects of atrazine and acetochlor herbicides on biochemical and physiological parameters of *Zea mays L*. (Maize) *and P. sativum L*. (Pea) Plants. [Doctoral dissertation, Inonu University]. Turkish Council of Higher Education National Thesis Center.

Belguzar, S., Yanar, Y., Aysan, Y. (2018). Epidemiology of Tomato Bacterial Wilt Disease (*Clavibacter michiganensis* subsp. *michiganensis*) in Tokat Province. Journal of Tekirdag Agricultural Faculty. 15 (3): 9-16.

Belguzar, S., Sin, B., Kadioglu, İ., Yilmaz, M. (2019). The effect of some herbicides on soil.3rd International UNIDOKAP Black Sea Symposium "Sustainable Agriculture and Environment". 21-22-23 June 2019.

Cakmakci, R. (2004). Use of plant growth promoting rhizobacteria in agriculture. Ataturk University Research in Agricultural Sciences, 36 (1),97-107.

Darine, T., Alaeddine, C., Fethi, B., Ridha, M. (2015). Fluazifop-p-butyl (herbicide) affects richness and structure of soil. Biology and Biochemistry, 81, 89-97. https://doi.org/10.1016/j.soilbio.2014.10.030

Digrak, M., Kacar, N., Sonmez, A. (1998). Effects of the pomarsol, mitikol, rubigan and platoon on the soil microflora. Turkish Journal of Agriculture And Forestry, 23 (5):1071-1077.

Erguven, G O. (2019). İnvestigation of the bioremediation of herbicide metribuzin with *bacillus subtilis* bacteria at artifical agricultural field. International Journal of Pure and Applied Sciences, 5(1), 46-52. https://doi.org/10.29132/ijpas.529882.

Erguven, G., Nuhoglu Y. (2020). Bioremediation of fluazifop-p-butyl herbicide by some soil bacteria isolated from various regions of Turkey in an artificial agricultural field. Environment Protection Engineering, 46(3), 5-15. https://doi.org/10.37190/epe200301

Fao. (2023). Food and agriculture organization of the united nations. accessed from https://www.fao.org/faostat/en/#compare on June 22, 2023.

Gulec, D., Arslan, S., Tursun, N. (2015). The use of different gas injectors for developing flame cultivator torches. Journal of Agriculture Machinery Science, 11(3), 231-237.

Gupta, G., Parihar, S S., Ahirwar, N K., Snehi, S K., Singh, V. (2015). Plant growth promoting rhizobacteria (PGPR): current and future prospects for development of sustainable agriculture. J Microb Biochem Technol, 7(2), 096-102. https://doi.org/10.4172/1948-5948.1000188

Guven, A., Koc, İ. (2020). Diversity of non-targeted nematode, bacteria and microfungi populations in soil after some pesticide treatment. YYU Journal of Agricultural Science, 30(2), 252-265. https://doi.org/10.29133/yyutbd.689385.

Karaaslan, E., Gur, K. (2009). Effects of tree herbicides on the microbiological nitrification in two different soil texture. Selcuk Journal of Agricultureand Food Sciences, 23 (50), 68-74.

Kayaaslan, Z. (2021). Diagnosis, epidemiology and biological control of bacterial spot disease (*Xanthomonas euvesicatoria*) in pepper production areas of Tokat province. [Doctoral dissertation, Tokat Gaziosmanpasa University]. Turkish Council of Higher Education National Thesis Center.

Kitis, Y E., Yazir, B., Ozgonen Ozkaya., H. (2016). The effects of some soil herbicides on root colonization and spore number of mycorrhizal fungi glomusintraradices. Biological Diversityand Conservation, 9(2), 1-7.

Klement, Z., Mavridis, A., Rudolph, K., Vidaver, A., Perombelon, M.C.M. Moore, L.W. (1990). Inoculation of Plant Tissues. In Methods in Phytobacteriology. (Klement, Z., Rudolph. K. and Sands, D.C., Eds.) 95103. Academia Kiado.99 p.

Kotan, R., Tozlu, E. (2021). Determination of bactericidal effects of some pesticides on usefuland pathogenic bacteria. Journal of Tekirdag Agricultural Faculty, 18(2), 197-212. https://doi.org/10.33462/jotaf.737039

Kunc, F., Tichy, P., &Vancura, V. (1985). 2-4 dichlorophetexoxyaceticacid in the soil: mineralization and changes in the counts of bacteria decomposer. INRA Publ (Les Colloques de I'NRA No. 31).

Lelliott R A., Stead D E. (1987). Methods for the diagnosis of bacterial diseases of plants. Blackwell Scientific Publications.77p.

Lo, C. (2010). Effect of pesticides on soil microbial community.

Journal of Environmental Science and Health, Part B., 45(5), 348-359. https://doi.org/10.1080/03601231003799804

Madhuri, K N., Kumar, K V K., Reddy, N S., Rao, M S., Prathima, T., Kumar, M H, ... &Giridhar, V. (2012). Influence of organic fertilizers on the population levels of T*richoderma spp*. and *Pseudomonas fluorescens* in sugarcane. Journal of Sugarcane Research, *2*(1), 61-63.

Maheswari, N U., Barjana, B F., Senthilkumar, R. (2016) Development of herbicide tolerant rhizobium species from different leguminous plants. Int. J. Pure App. Biosci, 4(2), 245-249. http://dx.doi.org/10.18782/2320-7051.2235

Oyeleke, S B., Oyewole, O A., Dagunduro, J N. (2011). Effect of herbicide (pendimethalin) on soil microbial population. Isabb Journal Of Food and Agriculture Science, 1(3), 40-43.

Raghavendra, K S., Gundappagol, R C., Santhosh, G P. (2017). Impact of herbicide application on beneficial soil microbial community, nodulation and yield parameters of chickpea (*Cicer arietinum*L.). Bulletin of Environment, Pharmacologyand Life Sciences, 6 (1), 154-159.

Saygili, H., Sahin F., Aysan Y. (2006). Phytobacteriology.Meta Printing House.78p.

Schaad, N W., Jones, J., Chun, W. (2001). Laboratory guide for the identification of plant pathogenic bacteria (No.Ed. 3). American Phytopathological society (APS press).

Singh, M., Singh, R., Singh, P., GS, M. (2021). In vitro compatibility of *Pseudomonas fluorescens* with systemic weedicides. The Pharma Innovation Journal, 10(3), 920-923.

Thiour-Mauprivez, C., Martin-Laurent, F., Calvayrac, C., Barthelmebs, L. (2019). Effects of herbicide on non-target microorganisms: Towards a new class of biomarkers. Science of The Total Environment, 684, 314-325. https://doi.org/10.1016/j.scitotenv.2019.05.230

Torun, S. (2015). Effect of application of a microbial fertilizer that contains phosphorus solubilizing bacteria on some soil biological properties and growth and nutritional status of tomato plant. [Master dissertation, Akdeniz University]. Turkish Council of Higher Education National Thesis Center.

Vig, K., Singh, D K., Agarwal H C., Dhawan, A K., Dureja, P. (2008). Soil microorganisms in cotton fields sequentially treated with insecticides. Ecotoxicology and environmental safety, 69(2), 263-276. https://doi.org/10.1016/j.ecoenv.2006.12.008

Yavuz, R., Esmeray, M., Urin, V. (2017). The effect of some herbicides on maize and weed biomass. Journal of Bahri Dagdas Crop Research. 6 (2): 1-6.

Zaid, A M., Mayouf, M., Said, Y F. (2014). The effect of pre-emergent herbicides on soil microflora and n-fixing bacteria in pea field. International Journal of sciences: Basic and Applied Research, 15(1), 131-138.