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TOKAT GAZİOSMANPAŞA ÜNİVERSİTESİ ZİRAAT FAKÜLTESİ DERGİSİ

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TOKAT GAZİOSMANPAŞA ÜNİVERSİTESİ ZİRAAT FAKÜLTESİ

Tokat Gaziosmanpasa University, Faculty of Agriculture
TOKAT, TÜRKİYE

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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,
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Correlation, Genetic Variability, Heritability And Genetic Advance For Some Morphological Traits In Red Cabbage Lines (*Brassica oleracea* L.var. *capitata* subvar. *rubra*)

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Abstract: Genetic variability, heritability, genetic advance, genetic gain and correlation for traits were studied in 22 lines of red cabbage. The genotypes were evaluated for seven quantitative characters such as head weight, head diameter, head length, core length, head volume, head density and head shape index. Analysis of variance showed significant variation among the genotypes for all the studied yield and yield contributing characters. Head weight of the lines was highly significant positively correlated with head length, head diameter, core length and head volume. The phenotypic coefficient of variation were observed to be higher than the corresponding genotypic coefficient of variation for all the characters studied, indicated that the traits were influenced by environment. The high phenotypic and genotypic coefficient (PCV and GCV) was observed for head density (30.61 and 20.06) followed by head volume (24.72 and 20.49), core length (15.68 and 14.99) and head weight (10.66 and 9.65). High heritability (broad sense) values were recorded for traits such as for head length (91.56%), core length (91.38%) and head diameter (82.24%). The highest genetic advance as percent of mean was shown by head volume (35.0 %) followed by core length (29.52%) and head density (27.09%). As a result, high heritability coupled with high genetic advance was observed head length, head diameter, head volume and head density which are governed by additive gene and could be effectively used as selection criteria in the breeding programme of red cabbage varieties with high yield.

Keywords: Red cabbage, genetic variability, heritability, genetic advance, correlation

Kırmızı Lahana Hatlarında Bazı Morfolojik Özelliklerin Kalıtımı, Genetik Değişkenliği, Genetik İlerlemesi ve Korelasyonu

Öz: Bu makalede 22 farklı kırmızı lahana hattında baş ağırlığı, baş çapı, baş uzunluğu, baş hacmi, baş sıkılığı, iç sap uzunluğu ve baş şekil indeksi özellikleri için genetik değişkenlik, kalıtsallık, genetik ilerleme ve korelasyon incelenmiştir. Varyans analizinde genotipler arasında verim ve verime etki eden özelliklerde önemli farklılıklar olduğu saptanmıştır. Hatların baş ağırlığı, baş uzunluğu, baş çapı, iç sap uzunluğu ve baş hacmi özelliklerinde korelasyonun pozitif yönde önemli olduğu belirlenmiştir. İncelenen tüm özelliklerde fenotipik varyasyon katsayısının genotipik varyasyon katsayısından daha yüksek olduğu ve bu özelliklerin çevreden etkilendiği tespit edilmiştir. En yüksek fenotipik ve genotipik varyasyon katsayısı baş sıkılığında (30.61 ve 20.06) belirlenmiş, onu baş hacmi (24.72 ve 20.49), iç sap uzunluğu (15.68 ve 14.99) ve baş ğırlığı (10.66 ve 9.65) özellikleri takip etmiştir. Baş uzunluğu (% 91.56), iç sap uzunluğu (%91.38) ve baş çapı (%82.24) için geniş anlamda kalıtım yüksek bulunmuştur. En yüksek genetik ilerleme baş hacmi (%35.0), iç sap uzunluğu (% 29.52) ve baş sıkığı (% 27.09) özelliklerinde belirlenmiştir. Sonuç olarak, eklemeli gen tarafından yönetilen baş uzunluğu, baş çapı, baş hacmi ve baş yoğunluğu özelliklerinde genetik ilerleme ve kalıtım derecesinin yüksek olduğu, bunun da ıslah programlarında yüksek verimli kırmızı lahana çeşitlerini geliştirmede iyi bir seleksiyon kriteri olarak kullanılabileceği saptanmıştır.

Anahtar Kelimeler: Kırmızı lahana, genetik değişkenlik, kalıtım, genetik ilerleme, korelasyon

1. Introduction

Vegetable plays an important role in the balanced diet by providing not only energy but also supplying vital protective nutrients like, proteins, vitamins, minerals, dietary fibers, micronutrients and antioxidants. In vegetables, *Brassicaceae* are one of the most diversified families with wide range of variation in crops that supplied edible products (Kumar et al., 2020). Red cabbage belongs to the family *Brassicaceae* and is one of the most popular, nutritious vegetable crops. Red cabbage is among the winter areas with a growth potential in the Black Sea Region. Yield and quality characteristics are mostly hybrid preferences. Therefore, it is very important to develop hybrid

varieties with high quality, adaptability and yield characteristics.

Development of an effective breeding program depends on the existence of genetic variability for various economic characters in the gene pool (Rauf and Rahim, 2018). Genetic variability is a measure of the tendency of individual genotypes in a population to vary from one another. Variability is different from genetic diversity, which is the amount of variation seen in a particular population. The variability of a trait describes how much that trait tends to vary in response to environmental and genetic influences (Ullah et al., 2015).

Plant breeders always use their efforts in the development of new varieties. For this, knowledge of genetic variability present in available germplasm is essential for further improvement of the crop. Variation provides useful information to the plant breeder to determine the genetic potential of the populations for developing new varieties with desirable characters in any crop species. Certain morphological parameters serve as a tool for the estimation of genetic variability (Ali et al., 2013).

The concept of correlation was first given by Galton (1987), the knowledge of the nature and magnitude of genetic association among components of economic importance can help in improving the efficiency of selection by making possible use of suitable combination of characters. Correlations are more useful, especially for indirect selection and this type of selection can be advantageous over direct selection, only when the selected trait has very high heritability and breeding value of correlation between two traits is very high (Kumar et al., 2020). Correlation of some morphological characteristics of red cabbage helps breeders for selection.

However only variation is not enough for effective selection, genetic variation, heritability and expected genetic advance in important agronomic characters are required in order to arrangement better effective breeding strategies (Jalata et al., 2011). The knowledge of inter relationships among the various components and their direct and indirect effect on yield are essential to bring genetic improvement in red cabbage. Therefore, genetic measuring diversity and understanding the inheritance pattern of qualitative and quantitative traits are important for breeding programs. The present investigation has been conducted to assess the genetic variability, heritability and genetic advance studies in 22 genotypes of red cabbage.

2. Materials and Methods

The experiment was carried out at Black Sea Agricultural Research Institute, located in Samsun during winter season during 2019-2021 growing period. The seeds of red had cabbage varieties were sown on July. Seedlings were grown in an unheated plastic greenhouse. For seedling cultivation, seed trays (45 cell) with a 5.5 x 5.5 cm pore size were used. The cultivation medium consisted of a mixture of peat + perlite in a ratio of 3: 1 placed in the seed trays and vermiculite was used as a cover material after planting.

Table 1. Some morphological traits of red cabbage lines
Çizelge 1. *Kırmızı lahana hatlarının bazı morfolojik özellikleri*

Lines	Shape of Head	Top leaf color of the head	Covering of Head	Hardness of head	Wax on the outer leaf	Days to maturity (day)
K3	Broad obovate	Dark violet	Covered	Very tight	Strong	115
K5	Elliptic	Dark violet	Partially covered	Very tight	Weak	113
K14	Broad obovate	Dakr violet	Covered	Very tight	Strong	113
K15	Elliptic	Violet	Partially covered	Very tight	Absent	113
K20	Round	Dark violet	Covered	Medium tight	Absent	78
K26	Broad obovate	Dark violet	Covered	Very tight	Medium	115
K30	Broad ovate	Dark violet	Covered	Very tight	Strong	113
K32	Broad obovate	Dark violet	Covered	Very tight	Very weak	134
K36	Broad obovate	Violet	Partially covered	Very tight	Strong	95
K41	Elliptic	Dark violet	Partially covered	Very tight	Weak	113
K42	Broad ovate	Dark violet	Covered	Very tight	Strong	113
K47	Elliptic	Dark violet	Partially covered	Medium tight	Medium	113
K62	Round	Dark violet	Covered	Very tight	Medium	95
K69	Elliptic	Dark violet	Partially covered	Very tight	Strong	113
K76	Broad obovate	Light violet	Partially covered	Very tight	Medium	134
K78	Round	Dark violet	Covered	Very tight	Very weak	113
K79	Elliptic	Dark violet	Covered	Very tight	Strong	95
K80	Round	Dark violet	Covered	Very tight	Very weak	134
K81	Broad ovate	Dark violet	Covered	Very tight	Strong	113
K83	Elliptic	Violet	Covered	Very tight	Weak	113
K85	Round	Dark violet	Covered	Very tight	Absent	134
K97	Broad ovate	Violet	Partially covered	Very tight	Strong	113

All genotypes were transplanted in Randomized Complete Block Design (RCBD) with three replications. The experiment was established with 20 plants in each replication, with 100 x 40 cm in-row and inter-row spacing and row planting distances in the second week of August. Fertilization, irrigation and weed cleaning etc were followed regularly during the study. Harvesting was done when 90% of the plant population of each plot reached to maturity. Data were recorded on 10 randomly chosen plants of each genotype in each of the three replication for different characters, such as head weight (g), head diameter (cm), head length (cm), core length (cm), head volume (g cm-3) (head weight/head density), head density (cm3) (Tanaka and Niikura, 2003), head shape index (head diameter/head length).

2.1. Statistical analysis

The mean values of each genotype were computed for statistical analysis. Relationships among the examined traits were examined by a correlation analysis. Analysis of variance was performed for each character to determine whether there were differences between and within the populations. All statistical analyses were carried out to the data obtained after characterization using JMP 7.0.

Genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), broad sense heritability, genetic advance and genetic gain were computed as per standard formulas. The formula of genotypic correlation coefficients were estimated by Al-Jibouri et al. (1958). Phenotypic and genotypic coefficient of variation, heritability (broad sense) and genetic advance as percent of mean were estimated by the formula al suggested by Burton (1952), Lush (1949) and Johnson et al. (1955).

$$\text{Genetic variance (Vg)} = \frac{\text{Genotype Mean Square (GMS)-Error Mean Square (EMS)}}{\text{Number of Replications (r)}} \quad (1)$$

Environmental Variance=Error Mean Suare (EMS)

Phenotypic Variance (Vp)=Vg+Ve/r

Genotypic phenotypic and environmental coefficient of Variation was calculated as

$$GCV\% = \sqrt{\frac{Vg}{x}} \times 100 \quad (2)$$

$$PCV\% = \sqrt{\frac{Vp}{x}} \times 100 \quad (3)$$

$$ECV\% = \sqrt{\frac{Ve}{x}} \times 100 \quad (4)$$

GCV% : Genotypic coefficient of variation
Vg : Genotypic variance
PCV % : Phenotypic coefficient of variation
Vp : Phenotypic variance
ECV % : Environmental coefficient of variation
Ve : Environmental variance

$$\text{Broad Sense Heritability } (h^2B) = \frac{Vp}{Vg} \times 100 \quad (5)$$

$$\text{Genetic Advance (GA)} = GA = K\sqrt{Vp}H^2 \quad (6)$$

Where, K = 1.40 at 20% selection intensity for trait;
Vp : Phenotypic variance for trait
Genetic advance as percentage of mean is calculated as,

$$GA\% = \frac{GA}{X} \times 100 \quad (7)$$

Genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), broad sense heritability, genetic advance and genetic gain were computed as per standard formulas. The formula of genotypic correlation coefficients were estimated by Al-Jibouri et al. (1958). Phenotypic and genotypic coefficient of variation, heritability (broad sense) and genetic advance as percent of mean were estimated by the formula al suggested by Burton (1952), Lush (1949) and Johanson et al. (1955).

3. Result and discussion

Analysis of variance showed that there were significant differences among genotypes for all traits studied. Estimation of mean squares of accessions year and error for seven traits of 22 red cabbege lines are shown in Table 2. This is an indication of existence of sufficient amount of variability exist for in red cabbage. Similar results were determined by researchers examining different morphological traits in different Brassica species (Kibar et al., 2014; Thakur & Vidyasagar, 2016; Chatterjee et al., 2018; Aktar et al., 2019). Variability is the most important characteristic feature of any population is of remarkable importance in breeding programme. Estimation of genetic variability is an important precondition for realizing response to selection as the progress in breeding depends upon its amount, nature and magnitude of genetic variability (Nandhini at al., 2020). These

results are important for the further red of material on the selection of promising genotypes in red cabbage breeding.

The mean performance of genotypes for various characters is presented in Table 3. The mean values of genotypes were recorded for head weight (755.57–1244.11 g), head length (12.54-18.79 cm), head diameter (9.86-13.79 cm), core length (5.46-10.89 cm), head volume (719.49-1650.34 cm3), head density (2.18-3.64 g cm-3), head shape index (0.73-1.95) (Table 3). Different results were obtained for the properties studied under different environmental conditions in cabbage (Kaygısız Ascıogul, 2009; Sharma, 2010; Cervenski et al., 2011; Kibar et al., 2014; Özbakır Özer 2014; Singh et al., 2019; Sharma et al., 2019a).

Table 2. Analysis of variance for seven morphological traits of red cabbage lines.
Çizelge 2. *Kırmızı lahana hatlarının bazı morfolojik özelliği için varyans analizi.*

Lines	df	Head Weight (g)	Head length (cm)	Head diameter (cm)	Core length (cm)	Head volüme (g cm^{-3})	Head density (cm^3)	Head shape index
Replication	2	0.68	3.20	1.31	3.35	9.18	5.16	0.73
Genotypes	21	38955.50**	5.97**	3.48**	4.25**	241131.00**	0.30**	0.02**
Error	42	7067.30	0.50	0.62	0.37	75437.00	0.17	0.01

***, **:** Significant at 5 and 1 per cent levels, respectively

Table 3. Mean performance of 22 red cabbage lines for different morphological traits
Çizelge 3. *22 kırmızı lahana hattının farklı morfolojik özellikler için ortalama performansı*

Lines	Head weight	Head length	Head diameter	Core length	Head density	Head volume	Head shape index
K3	755.57	12.54	10.99	7.52	2.71	719.49	1.13
K5	1059.00	14.91	12.93	6.47	2.67	1139.48	0.97
K14	1040.99	15.52	12.24	6.10	2.56	937.47	1.23
K15	944.34	14.77	12.19	5.93	2.30	1240.29	0.82
K20	1055.23	14.13	13.12	6.72	2.77	1217.78	0.87
K26	1048.34	16.09	10.81	8.61	2.82	857.19	1.24
K30	1244,11	18.79	13.38	10.89	3.36	1650.34	0.78
K32	1191.34	15.73	10.81	8.80	3.16	1157.85	1.09
K36	1166.68	15.66	14.02	9.43	3.23	1562.96	0.73
K41	1133.57	15.80	13.23	7.57	2.94	1142.84	1.06
K42	1156.12	15.57	11.32	7.66	2.71	946.34	1.43
K47	1138.57	17.64	12.72	8.60	2.84	1376.09	0.78
K62	940.57	13.51	12.8	7.93	3.64	1145.75	0.87
K69	1184.10	16.10	9.86	8.03	2.22	874.56	1.42
K76	962.78	15.67	12.10	5.46	2.51	793.75	1.95
K78	1143.79	15.18	13.79	6.50	2.62	1447.58	0.80
K79	1073.46	14.88	11.88	7.26	2.18	1125.94	0.99
K80	1227.78	17.88	13.78	7.54	3.12	1522.29	0.87
K81	1025.46	15.90	11.10	7.89	2.94	988.26	1.02
K83	943.34	15.44	12.49	7.77	3.23	1201.79	0.84
K85	945.27	13.08	11.77	6.77	3.07	892.80	1.18
K97	1128.66	16.37	12.38	7.57	2.98	1288.20	0.89

The phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all traits (Table 4). Thus indicated the influences of environmental factor on these traits. Variability and association studies were carried out several Brassica species such as cauliflower (Chittora & Singh, 2015; Dey et al., 2015; Chıttora et al., 2016); Chatterjee et al., 2018; Kumar et al., 2018), knolkhol (Dolkar et al., 2018), cabbage (Sharma et al., 2019a, Sharma et al., 2019b), broccoli (Nandhini et al., 2020), kale (Wudneh, 2020; Gorka et al., 2021) and researchers reported higher the magnitude of phenotypic coefficient of variability than genotypic coefficient of variability.

The respective PCV and GCV was high for head weight (10.66, 9.65), head length (9.09, 8.70), head diameter (8.78, 7.96), core length (15.68, 14.99), head volume (24.72, 20.49), head density (30.61, 20.06) and head shape index (9.64, 7.45). Moderate PCV was recorded for core length, head volüme and head density. However, it was found low for head head diameter, head weight, head length and head weight. Similar type results are in with earlier findings of various researchers for net head weight (Atter et al., 2009, Meena et al., 2009, Thakur & Vidyasagar, 2016). Conversely, Kaur et al., 2018 reported high PCV for gross head weight

Table 4. Phenotypic (PCV) and genotypic (GCV) coefficients of variation, broad sense heritability (h^2B) and genetic advance (GA) (%) for various morphological traits in red cabbage

Çizelge 4. *Kırmızı lahana hatlarında bazı morfolojik özellikler için fenotipik (PCV) ve genotipik (GCV) varyasyon katsayıları, geniş anlamda kalıtım derecesi (h^2B) ve genetik ilerleme (GA) (%)*

Traits	GCV(%)	PCV(%)	h^2B(%)	GA	GA (%)
Head weight	9.65	10.66	81.86	192.16	17.98
Head length	8.70	9.09	91.56	2.66	17.15
Head diameter	7.96	8.78	82.24	1.82	14.87
Core length	14.99	15.68	91.38	2.24	29.52
Head volume	20.49	24.72	68.72	401.32	35.00
Head density	20.06	30.61	42.97	0.28	27.09
Head shape index	7.45	9.64	59.77	0.09	11.87

Variability is the most important characteristic feature of any population (Nandhini et al., 2020). In a population observed variation is due to both factors i.e. genetics and environmental where as genetic variability is the only heritable from generation to the next generation so the heritability alone does not give an idea about the expected gain in the next generation but it has to be considered in conjunction with the genetic advance (Ahsan et al., 2015). Genetic advance is also important due to observe of the expected genetic gain in the selection (Eşiyok et al., 2011).

Burton (1952) and Panse (1957) viewed that if a character is governed by non-additive gene action, it may have high heritability but low genetic advance, whereas, if it is governed by additive gene action, heritability and genetic advance both would be high. The broad sense heritability and genetic advance as percent of mean of the traits are presented in Table 4. Heritability estimates were classified as low (<50%), moderate (50-80%) and high (>80%) as suggested by Sharma (1994). Accordingly, we recorded high heritability for head length (91.56%), core length (91.38%), head diameter (82.24%) and head weight (81.86%). In the research, high heritability accompanied with a high genetic advance for head weight, head dimater and head length revealed the role of additive gene action and thus, a high genetic gain is expected from selection for these traits. Panse and Sukhatme (1978), stated that ıf a trait is governed by additive gene action, both heritability and genetic progression will be high. The result is in accordance with the findings for ascorbic acid content in cabbage (Singh et al., 2013), for days to first flowering in rapeseed (Hasan et al., 2014), for mineral content (Fe, Zn, Cu, Ca, Mn, K) in cabbage head, for total yield in cauliflower (Chittora & Singh, 2015), for minerals contents (Ca, Fe, Mg, Zn) in Chinese cabbage (Xie et al., 2018), for head weight and ascorbic acid in cabbage (Kaur et al., 218), for yield and its component traits in ethiopian kale (Wudneh, 2020).

The highest genetic advance as percent of mean was shown by head volume (35.0 %) followed by core length (29.52%) and head density (27.09%) (Table 4). Chittora and Singh (2015), reported highest genetic advance as per cent of mean was observed for net curd weight (39.54 %) followed by marketable curd weight (32.82 %), curd yield per hectare (32.81 %), harvest index (27.08%) and gross plant weight (27.30 %). Thakur and Vidyasagar (2016) also reported high genetic advance for gross weight and total yield per plot. High heritability coupled with moderate genetic advance for gross head weight, net head weight, number of non-wrapper leaves, head shape index and TSS (^{0}Brix) were reported by Sharma et al. (2019a). However, on the contrary to present findings Gorka et al.(2021) also observed high heritability with low genetic advance as percentage of mean was marked for all the three biochemical traits.

Knowledge of relationships between yield and its components is essential as this may help in constructing suitable selection criteria for yield (Kibar et al., 2014). For this purpose, correlation coefficients were calculated to determine the relationships between red cabbage traits. Significant differences were observed among all the genotypes for all the traits in table 5. Head weight of the lines was highly positively correlated with head length, head diameter, wcore length and head volume.

Cervenski et al. (1998) and Kibar et al. (2014) also reported that head weight significant and positive correlation with head diameter and head length. The results of our present analysis are in agreement with these. Owing to the high positive correlation between head weight and head diameter and head length; the selection of genotypes with desired head size and head weight will be effective to obtain high yielding cultivars/genotypes (Kibar et al. 2014). Meena et al. (2014), also reported that whole plant weight significant and positive correlation with curd length, curd breadth, total number of leaf, days to curd formation and days to 50% maturity in cabbage. While positive and significant correlation in curd weight with curd length, total number of leaf, leaves per plant, days to curd formation and days to 50 percent maturity in cauliflower by Dutta et al. (1992), Kanwar et al. (2010), Kumar et al. (2011), Sheemar et al. (2012), Nimkar (2013), (Nimkar and Soniya 2013).

Table 5. Correlation coefficients for morphological traits in red cabbage lines
Çizelge 5. *Kırmızı lahana hatlarında bazı morfolojik özelliklerinkorelasyon katsayıları*

Traits	Head weight	Head length	Head diameter	Core length	Head volume	Head density	Head shape index
Head weight	1.000	0.0661**	0.2725**	0.4067*	0.5693**	-0.1520**	-0.1858**
Head length		1.000	0.2336**	0.4783**	0.5176**	-0.19,31**	-0.4617**
Head diameter			1.000	0.0617**	0.7071**	-0.4129**	0.5190**
Core length				1.000	0.3945*	-0.2930**	-0.2619*
Head volume					1.000	-0.7317**	0.2852*
Head density						1.000	-0.2756*
Head shape index							1.000

***, **:** Significant at the 0.05 and 0.01 probability level, respectively

Some negative correlations were also observed among the red cabbage traits. Head weight was highly negatively correlated with head density and head shape index (Table 5). As can be seen from the table 5, head length, head diameter, core length, head volume and head density was highly negatively correlated observed head density and head shape index. Dey et al (2005) explained the knowledge of correlation among yield and its contributing traits may be helpful to a plant breeder to determine the degree of association between them and help to improve the efficiency of selection by the use of favourable combination of characters and to minimize the retarding effect of those characters which are negatively correlated.

4. Conclusion

The PCV was higher than the GCV for all the characters studied, which indicated that the envıronment ıs effectıve on the herıtage of the characters. High heritability in percentage of mean was observed for head length, head weight, head diameter and core length. On the other hand, the GA was determined the most in head volume, core length and head density characteristics. High positive correlation was observed in the same characteristics. These features need to be taken into account in the development of high yielding cabbage varieties.

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References

Ahsan, M.Z, Majidano, M.S., Bhutto, H., Soomro, A.W., Panhwar, F.H., Channa, A.R. & Sial, K.B. (2015). Genetic Variability, Coefficient of Variance, Heritability and Genetic Advance of Some Gossypium hirsutum L. Accessions. *Journal of Agricultural Science*, 7(2): 147-151 doi: 10.5539/jas.v7n2p147

Aktar, T., Nuruzzaman, M., Rana, M.S., Huda, M.M., Hossain, M.A & Hassan, L. (2019). Genetic parameters and diversity studies of yield and yield contributing characters in Brassica genotypes. *Journal of Bangladesh Agricultural University*, 17(3): 295–300. doi: 10.3329/jbau.v17i3.43200

Ali, Y., Rahman, H., Nasim, A., Azam, S. & Khan, A. (2013). Heritability and Correlation Analysis for Morphological and Biochemical Traits in *Brassica carinata* L. *Sarhad Journal of Agriculture*, 29 (3): 45-58

Al-Jibouri, H.A, Millar, P.A & Robinson, H.F. (1958). Genotypic and environmental variance and co-variances in cauliflower. *Agronomy Journal* 50: 633-637.

Allard, R.W. (1999). Principles of plant breeding. 2nd edn. New York, John Wiley & Sons. ISBN 10: 0471023094 ISBN 13: 9780471023098

Atter, R.S., Sharma, K.C. & Sundouri, A.S. (2009). Genetic variability, heritability and genetic advance studies in cabbage. *Indian Society of Plant Genetic Resources* 22: 62-65

Burton, G.W. (1952). Quantitative inheritance in grasses, Proceedings of 6th İnternational Grassland Congress, 1:227- 283.

Cervenski, J., Gvozdenovıc, D.J, Takac, A. & Bugarskı, D. (1998). Correlation between some of the yield components of cabbage (*Brassica oleracae* var. *capitata* L.). Proceedings of 2nd Balkan Symposium of Field Crops 1: 509-513.

Cervenski, J, Gvozdanovic-Varga, J., & Glogovac, S. (2011). Local cabbage (*Brassica oleracea* var. *capitata* L.) populations from Serbian Province of Vojvodina. *African Journal of Biotechnology*, 10, 5281–5285 doi: 10.13140/RG.2.2.20319.15528

Chatterjee, S., Aralikatti, O., Sharma, S., Mukherjee, D., Patil, S., Kanwar, H.S. & Choudhur, P. (2018). Studies of Genetic Variability, Heritability and Genetic Gain for Some Important Horticultural Traits in Cauliflower (*Brassica oleracea* var. *botrytis* L.). ***International Journal of Current Microbiology and Applied Sciences***,7(4):82-92. doi: 10.20546/ijcmas.2018.704.010

Chittora, A & Singh, D.K. (2015). Genetic variability studies in early cauliflower (*Brassica oleracea* var. *botrytis* L.). *Electronic Journal of Plant Breeding*, 6(3): 842-847.

Chıttora, A., Sıngh, D.K. & Kaushal, A. (2016). Genetıc varıabılıty, herıtabılıty and genetıc advance ın early maturıng caulıflower. *Annals of Plant and Soil Research* 18(3): 251-256

Dey, S.S., Behera, T.K., Pal, A & Munshi, A.D. (2005). Correlation and path coefficient analysis in bitter gourd (*Momordica charantia* L.). *Vegetable Science*, 32(2):173-176

Dey, S.S, Bhatia, R, Sharma, S., Sharma, K., Kumar, R, Sharma, V.K. & Parkash, C. (2015). Genetic divergence and

interaction among CUPRAC, FRAP and total phenolics content in cauliflower (*Brassica oleracea* var. *botrytis* L.). Indian. *Journal of Genetics and Plant Breeding*. 75:79-85. doi: 10.5958/0975-6906.2015.00010.3

Dolkar, R, Samnotra, R.K., Kumar, S., Gupta, R.K & Vijayakumar (2018). Variability for Ascorbic Acid, Beta Carotene and Minerals Content (Phosphorous, Potassium and Calcium) in Knolkhol (*Brassica oleracea* var. *gongylodes* L.) Genotypes. *International Journal of Current Microbiology and Applied Sciences*. 7(6): 1020-1025 doi: 10.20546/ijcmas.2018.706.120

Dutta, S.K, Korla. B.N & Sharma, P.P. (1992). Path coefficient analysis in late cauliflower. *Indian Journal of Agricultural Sciences* 76(1): 37-40.

Eşiyok, D., Bozokalfa, M.K. & Aşçıoğul, T.K. (2011). Variability, heritability and associatıon analysis in plant traits of swıss chard (*Beta vulgaris* subsp. *cicla*). *Genetika*, 43 (2): 239-252. Doi.10.2298/GENSR1102239E

Galton, F. (1987). Nature Inheritance. Mac Million London.

Gorka, S., Samnotra, R.K., Kumar, S. & Gupta, M. (2021). Variability studies for vitamin C, beta carotene and total phenol content in kale (*Brassica oleracea* L. var. *acephala*) genotypes. *Journal of Pharmacognosy and Phytochemistry*, 10(2): 1221-1227.

Hasan, E.U, Mustafa, H.S.B., Bibi, T., & Mahmood, T. (2014). Genetic variability, correlation and path analysis in advanced lines of rapeseed (*Brassica napus* L.) for yield components. *Cercetări Agronomice în Moldova*, 47(1): 157-159.

Jalata, Z., Ayana, A, & Zeleke, H. (2011). Variability, heritability and genetic advance for some yield and yield related traits in Ethiopian barley (*Hordeum vulgare* L.). *İnternational Journal of Plant Breeding and Genetics*. 5(1), 44-52 doi:10.3923/ijpbg.2011.44.52

Johnson, H.W., Robinson, H.F, & Comstock, R.E. (1955). Estimation of genetic and environmental variability in soybeans. *Agronomy Journal*, 47: 314–318.

Kanwar, H.S, Sharma, A., Kanwar, M.S., & Anand V (2010) Evaluation of cauliflower (*Brassica oleracea* var. *bortrytis* L.) genotypes for quantitative traits, their resistance against diamond back moth and cabbage white butterfly. *Journal of Research* 9(2): 156-163.

Kaur, M., Chadha, S., Kumar, N., Sehgal, N. & Kanwar, S. (2018). Characters association and path analysis among CMS and SI based cabbage hybrids under mid hill conditions of Himachal Pradesh, India. *International Journal of Current Microbiology and Applied Sciences*. 7(1): 424-430. doi:10.20546/ijcmas.2018.701.049

Kaygısız Aşçıoğul, T. (2009).Researches on the determınatıon of morphologıcal and molecular characterızatıon of some cabbage genotypes. Ege University. (MSc Thesis, Printed, İzmir).

Kibar, B., Karaağaç, O. & Kar, H. (2014). Correlation and path coefficient analysis of yield and yield components in cabbage. *Acta Scientiarum Polonorum HortorumCultus* 13(6): 87-97

Kumar, M., Sharma, S.R., Kalia, P. & Saha, P. (2011). Genetic variability and character association for yield and quality traits in early maturing Indian cauliflowers. *Indian Journal of Horticulture* 68(2): 206-211.

Kumar, A., Roy, C., Kumar, R., Kumar, R., Singh, V.K. & Sinha, S.K. (2018). Estimation of existing genetic variability, heritability and genetic advance in tropical cauliflower (*Brassica oleracea* var. *botrytis* L.). *Journal of Pharmacognosy and Phytochemistry*, 7(2): 2048-2050

Kumar, M., Rana, D.K., Choudhary, G.R., Kumar, H. & Kumar, M. (2020). Correlation coefficient studies in Knol-Khol (*Brassica oleracea* var. *gongylodes*) cv. White Vienna under Srinagar Garhwal Valley. *International Journal of Chemical Studies*, 8(4): 1244-1247

Lush, J.L. (1949). Heritability of quantitative characters in farm animals. Proceedings of 8th Congress of Genetics and Hereditas. 35: 356-375

Meena, M.L., Ram, R.B. & Rubee, L. (2009). Genetic variability and correlation studies for some quantitative traits in cabbage (*Brassica oleracea* var. *capitata* L.) under Lucknow conditions. *Progressive Horticulture*, 41, 89–93.

Meena, M.L., Ram, R.B., Lata, R. & Shastra, S.R. (2014). Determining yield components in cabbage (*Brassica oleraceae* var. *capitata* L.) through correlation and path analysis. *International Journal of Science and Nature* 1(1): 27-30.

Nandhini, D., Arumugam, T., Ganesan, K.N., Subramanian, K.S. & Keisar Lourdusamy, D. (2020). Assessment of variability in Broccoli (*Brassica oleracea* var. italica L.) genotypes. The Pharma Innovation Journal, 9(1): 338-340

Nimkar, S.A. (2013). Correlation and path coefficient studies in biparental progenies in cauliflower (Brassica oleracea var. botrytis L.).. *Research Journal of Agricultural Sciences*, 4(5/6):667-669.

Nimkar, S.A. & Soniya, A. (2013). Correlation and path coefficient studies in biparental progenies in cauliflower (*Brassica oleracea* var. *botrytis* L.). Research Journal of Agricultural Sciences 4(5/6): 667 669.

Özbakır Özer, M. (2014). The breedıng of a resıstant hybrıd cultıvar agaınst root-knot nematodes ın whıte head cabbage (brassica oleraceae var. capitata subvar. alba) genotypes. Ondokuz Mayıs University (Doctoral dissertation, PhD Thesis (Printed), Samsun)

Panse, V.G. (1957). Genetics of quantitative characters in relation to plant breeding. *Indian Journal of Genetics and Plant Breeding*, 47: 318-325

Panse, V.G. & Sukhatme, P.V. (1978). Statistical methods for Agricultural Workers. ICAR, New Delhi, 1978. 235-246.

Rauf, M.A. & Md Abdur Rahim, M.A. (2018). Genetic Variability Studies among Yield and Its Contributing Traits in Mustard (*Brassica napus* L.). *Advances in Zoology and Botany* 6(4): 101-108 doi: 10.13189/azb.2018.06040

Sharma, P. (1994). Genetic variability and path coefficient analysis in cabbage (*Brassica oleracea* var. *capitata*). Dr YS Parmar University of Horticulture and Forestry (M.Sc. Thesis, Printed, India).

Sharma, K.C. (2010). Genetic variability, characters association and path analysis in exotic lines of cabbage under mid hill, sub-humid conditions of Himachal Pradesh. *Journal of Hill Agriculture*, 1, 146–150.

Sharma, S., Chadha, S., Sharma, N. & Singh, P. (2019a). Genetic Evaluation of CMS Lines and their Maintainers for Yield and Horticultural Traits in Cabbage (*Brassica oleracea* var.*capitata* L.). *International Journal of Current Microbiology and Applied Sciences* 8(8): 2398-2408. Doi: 10.20546/ijcmas.2019.808.279

Sharma, S., Chadha, S., Sharma, N. & Singh, P. (2019b). Correlation and path analysis among CMS lines and their maintainers for yield and quality attributes in cabbage (*Brassica oleracea* var. *capitata* L.) *International Journal of Chemical Studies*, 7(5): 2731-2737.

Sheemar, G., Singh, D., Malik, A. & Kumar, A. (2012). Correlation and path analysis studies of economic traits in cauliflower (*Brassica oleracea* var. *botrytis* L). *Journal of Agriculture Technology* 8(5): 1791-1799.

Singh, S., Dey, S.S., Bhatia, R., Kumar, R., Sharma, K. & Behera, T.K. (2019). Heterosis and combining ability in cytoplasmic male sterile and doubled haploid based *Brassica*

oleracea progenies and prediction of heterosis using microsatellites. PLoS ONE 14(8): e0210772. doi: 10.1371/journal.pone.0210772.

Singh, B.K, Sharma, S.R. & Singh, B. (2013). Genetic variability inheritance and correlation for mineral contents in cabbage (*Brassica oleracea* var. *capitata* L.), Journal of *Horticultural Research*, 21(1): 91-97.

Tanaka, N. & Nikura, S. (2003). Characterization of early maturing F1 hybrid varieties in cabbage (*Brassica oleracea* L.). *Breeding Science* 53: 325-333.

Thakur, H. & Vidyasagar (2016). Estimates of genetic variability, heritability and genetic advances for yield and horticultural traits in cabbage (*Brassica oleracea* var. *capitata* L.). *Journal of Environment and Bio-Sciences.* 30:155-157.

Ullah, N., Farhatullah, N.A., Rahman, H.U., Fayyaz, L. & Amin, N.U. (2015). Genetic Variability Among Advanced Lines of Brassica. *Pakistan Journal of Botany* 47(2): 623-628.

Wudneh, A.Y. (2020). Genetıc varıabılıty, herıtabılıty and genetıc advance for vegetable yıeld and ıts component traıts ın ethıopıan kale (*Brassica carinata* A.). International *Journal of Plant Breeding and Crop Science*. 7(3): 946-952.

Xie, F., Zha, J., Tang, H., Xu, Y., Liu, X. & Wan, Z. (2018). Combining ability and heterosis analysis for mineral elements by using cytoplasmic male-sterile systems in non-heading Chinese cabbage (*Brassica rapa*). C*rop and Pasture Science*69: 296–302. doi: /10.1071/CP17357

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Ultrasound-Assisted Turkish Black Tea Extracts: Effect of Tannase Enzyme Supplementation on Amount of Tea Cream and Catechins

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Abstract: In this study, it was aimed to determine the changes in the amount of functional components of black tea extracts obtained by ultrasound assisted extraction and treated with tannase enzyme. Therefore, Turkish black tea extracts were supplemented with tannase enzyme by using an ultrasound-assisted extraction technique with different infusion temperatures (50 and 70°C), times (5, 10, 20 minutes), and tea: water ratios (1:100, 5:100, 10:100). Total phenolic, tea cream and catechin analyses were performed on the extracts. The amount of tea cream ranged between 0.56-1.25 g/100g black tea in the tannase-supplemented samples and 1.22-2.36 g/100g black tea in the control sample. It was also observed that the amount of cream obtained by ultrasonic extraction decreased by 38.89-59.11% with the tannase enzyme application.

Keywords: Catechin, ultrasound, phenolics, tannase, tea cream, tea polyphenols

Ultrason Destekli Türk Siyah Çay Ekstraktları: Tannaz Enzim Uygulamasının Çay Kreması ve Kateşin Miktarına Etkisi

Öz: Araştırmada, ultrason destekli ekstraksiyonla elde edilen ve tannaz enzimiyle muamele edilen siyah çay ekstraktlarının fonksiyonel bileşenlerinin miktarında meydana gelen değişmelerin belirlenmesi amaçlanmıştır. Bu amaçla, ultrason destekli ekstraksiyon tekniği kullanılarak farklı demleme süre (5, 10 ve 20 dakika), çay:su oranları (1:100; 5:100; 10:100) ve sıcaklık (50 ve 70°C) uygulanarak elde edilen Türk siyah çayı ekstraktlarına, tannaz enzimi ilavesi yapılmıştır. Ekstraktlarda çay kreması, toplam fenolik madde ve kateşin miktarlarının tespit edilmesine yönelik analizler gerçekleştirilmiştir. Çay kreması miktarı, tannaz enzimi uygulanmış örneklerde 0.56-1.25 g/100g siyah çay aralığında değişirken, kontrol örneklerinde 1.22-2.36 g/100g siyah çay aralığında değişmiştir. Ultrason destekli ekstraksiyonla elde edilen ekstraktlardaki krema miktarının tannaz enzim uygulaması ile %38.89-59.11 oranında azaldığı görülmüştür.

Anahtar kelimeler: Kateşin, ultrason, fenolikler, tannaz, çay kreması, çay polifenolleri

1. Introduction

Tea consumption habits are altering rapidly, and many new tea beverages are produced as an alternative to traditionally brewed tea. One of these products is ready-to-drink (RTD) tea, which has been produced and consumed globally for years (Liang et al., 2022). Commercial production of RTD tea comprises several processes like hot water extraction, selection and blending of tea leaves, aroma recovery, filtration, concentration, cream precipitation, drying, aggregation, and aromatization (Someswararao & Srivastav, 2012). Tea cream formation is a common problem faced in RTD tea production. It occurs just as a strong, hot tea infusion cools off (Guo et al., 2021). Even though tea cream formation is not believed to be a reason for deterioration, both consumers and producers do not prefer it. Since tea cream formation induces the loss of transparency, color, and taste, which in turn affects the physical and sensory properties and biological activities of tea beverages and diminishes the preferences of consumers (Dalpathadu et al., 2022; Wang et al., 2020).

Tannase (Tannin Acylhydrolase), an extracellular enzyme from the hydrolase class, is responsible for breaking down the ester bonds of hydrolyzable tannins like ethyl gallate, tannic acid, n-propyl gallate, isoamyl gallate, and methyl gallate as well as gallic acid esters. Acting on the ester bonds in tannic acid, tannase hydrolyzes it into glucose and gallic acid (Ristinmaa et al., 2022). Tannase enzyme is commonly utilized for ready-to-drink tea production to enhance tea products' color and

sensory qualities, to increase the antioxidant properties by facilitating the tea catechins biotransformation, and to prevent cream formation (Aharwar & Parihar, 2021).

Bioactive components' classical extraction from seeds or plants depends upon the solvent combination, heat and/or mixing under suitable conditions. Ultrasound-assisted extraction (UAE) is as efficient as other high-temperature and long-term extractions, and its most important advantage is that it significantly shortens the extraction time (Xia et al., 2006). The effectiveness of ultrasonic extraction is explained through the simultaneous increase in hydration during sonication and facilitating mass transfer from the material to the solvent in the degradation process. This situation increases mass transfer due to vortex formation and internal diffusion with the mechanical effect of ultrasound and allows more solvent penetration into the sample. In fruit juice and wine production, the efficiency of the enzyme used in ultrasound application increases, the amount of enzyme used decreases, and the amount of extracted functional components (such as phenolic substances) increase (Singla & Sit, 2021; Serna-Jiménez et al., 2022).

Türkiye comes fifth on the list of primary tea-producer countries after India, Sri Lanka, Kenya, and China in world tea production (Mangla et al., 2022). To our knowledge, little is known about Turkish tea composition and tea cream formation. Hence, the present study provided a significant opportunity to advance our understanding of how ultrasonic-assisted extraction and tannase enzyme affects tea cream formation. In addition, this study contributes to research on ultrasonic-assisted extraction and the tannase enzyme's effects on the chemical features of Turkish black tea infusions.

2. Materials and Methods

2.1. Material

Black tea samples as raw material [5 (BOP2: Broken Orange Pekoe] used in the experiments were purchased from the Güneysu-Ulucami Tea Factory Directorate of Çay-Kur Company, Türkiye. As the solvent, distilled water was utilized. Tannase enzyme was supplied from Kikkoman, Japan (Tannase-KTFH, 60554, activity: 500 U/g or higher, optimum temperature: 40°C, optimum pH: 5.0-5.5). To determine individual catechins content of black tea extracts, GA (Sigma), EGC (Fluka), and EGCG (Merck) were used.

2.2. Methods

2.2.1. Ultrasonic-assisted extraction

The extraction of black tea leaves was carried out with distilled water at three different tea: water ratios (1:100, 5:100, 10:100) at two different infusion temperatures (50 and 70°C) for three different times (5, 10, and 20 minutes) by using Ultrasonic water bath (Elmasonic S 100H, 37 KHz frequency, Ultrasonic power effective of 600 (W)). The preparation of the extracts were described previously (Ateş et al., 2022).

2.2.2. Determination of tea cream

The tea cream amount in black tea extracts was detected in accordance with Nagalakshmi et al.'s (1984) directions.

2.2.3. Determination of total phenolic content

Black tea extracts' total phenolic content was determined using Folin-Ciocalteu's phenol reagent following the reference method of ISO 14502-1 (Anonymous, 2005). Results were explained in gallic acid equivalent (g GAE/100 g dry black tea).

2.2.4. Determination of catechin composition of black tea extracts with HPLC

To identify the individual catechins (EGC, GA, and EGCG,) an HPLC device (Perkin Elmer Series-200) was utilized (Modified from Liang et al., 2002). Operational conditions were described previously (Ateş et al., 2022).

2.2.5. Statistical analysis

Statistical Package for the Social Sciences (SPSS) software (Version 17.0) was utilized for the analysis. All experiments were conducted in triplicate; means and standard deviations (SD) were used to explain the results. ANOVA with Duncan's test was used to compare data, which indicates a statistical significance ($p<0.05$).

3. Results and Discussion

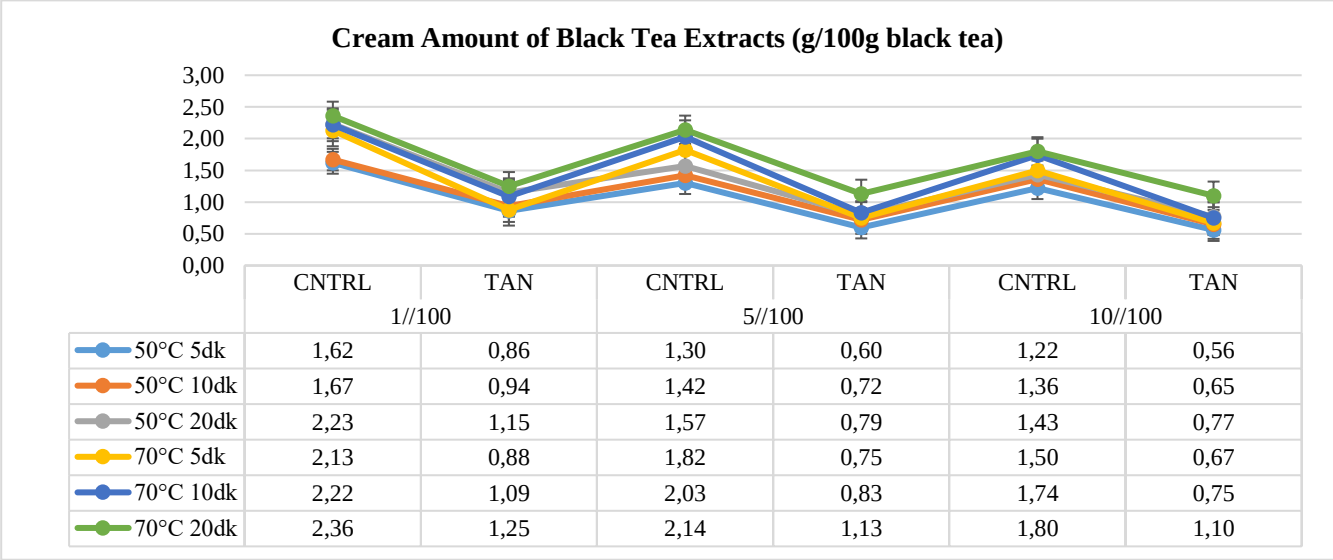
3.1. Cream amount of extracts

Figure 1 presents the cream amount of black tea extracts collected using different tea: water ratios, infusion times and temperatures, and tannase enzyme supplementation. The amount of tea cream in the samples obtained by ultrasonic extraction ranged between 1.22-2.36 g/100g black tea in the control samples and 0.51-1.25 g/100g in the tannase-supplemented samples.

Tea: water ratios, infusion time and temperatures, had a significant ($p<0.05$) impact on the amount of tea cream formed in the samples, statistically. The addition of enzymes also caused a reduction in the tea cream amount.

As the brewing time and temperature increased, the cream amount of the extracts increased, which was significant ($p<0.05$), statistically. In all application conditions in ultrasonic extraction, cream quantities of black tea extracts supplemented with tannase enzyme decreased more compared to control samples.

Similarly, Chandini et al. (2011) searched the effect of enzyme supplementation on tea cream formation to increase extraction quality using CTC-black tea. In the centrifuged (5600 g and 20 minutes) samples, the amount of cream was determined as 0.085±0.02% in the control samples, and 0.067±0.031%, 0.052±0.041% for 10 and 20 U/g-black tea in the samples with tannase enzyme, respectively. After the same samples were stored at 5°C for one week, the amount of cream was found to be 0.265±0.021% for the control sample, 0.079±0.011% and 0.065±0.032%, respectively, for 10 and 20 U/g-black tea in the tannase-supplemented samples.



	CNTRL	TAN	CNTRL	TAN	CNTRL	TAN
	1//100		5//100		10//100	
50°C 5dk	1,62	0,86	1,30	0,60	1,22	0,56
50°C 10dk	1,67	0,94	1,42	0,72	1,36	0,65
50°C 20dk	2,23	1,15	1,57	0,79	1,43	0,77
70°C 5dk	2,13	0,88	1,82	0,75	1,50	0,67
70°C 10dk	2,22	1,09	2,03	0,83	1,74	0,75
70°C 20dk	2,36	1,25	2,14	1,13	1,80	1,10

Figure 1. Cream Amount of Black Tea Extracts (g/100g black tea)
Şekil 1. *Siyah çay ekstraktlarının krema miktarı (g/100g siyah çay)*

Govindarajan et al. (2021) examined the tea cream by treating it with different tannase enzyme concentrations (0.05–0.2%). A decline in the cream formation up to 80.2% (0.091 g) in Kangra orthodox tea and 84.25% (0.124 g) in CTC was observed after treating the tannase enzyme at a concentration of 0.1%. Moreover, they found that in 100 ml of the reaction medium 0.390 and 0.520 g of tea cream formation occurred respectively. Together with the previously reported findings, the findings of this research indicated that the tannase enzyme could reduce black tea cream amounts.

3.2. Phenolic compounds of extracts

Total phenolic compounds of black tea extracts obtained by different tea: water ratios, infusion temperatures and times, and tannase enzyme supplementation are given in Figure 2. Total phenolics of samples extracted using the ultrasonic method with different extraction conditions varied between 1.67-3.69 g GAE/100 g dry black tea in the first extracts, and the samples with and without enzyme ranged between 1.84-3.89 g GAE/100 g dry black tea and 1.67-3.85 g GAE/100 g, respectively. The total quantity of phenolic substances in the black tea extracts increased when the infusion temperature and time rose, and the differences between these amounts were significant ($p<0.05$). It was determined that with the increase in the tea ratio in the extraction process, there was a decrease in the total amount of phenolic substances at all infusion temperatures and times, and these quantitative differences were significant ($p<0.05$). It was also discovered that with the increase of the tea: water ratio in the extraction process, in other words, with the decrease in the solvent (water) ratio, the transfer of phenolic substances to the extract decreases, and the yield of extract decreases in absolute terms. In all conditions, by comparison with the

control samples, there was an increase in total phenolics of enzyme-supplemented samples, which was found to be significant ($p<0.05$).

Rusaczonek et al. (2010) indicated that the total amount of phenolic substances in black tea after 5 minutes of infusion with water at boiling temperature at a 1:100 tea: water ratio was 112-151 mg GAE/g. Hanay (2011), using a tea: water ratio of 2.83:250 in Turkish black tea, declared that after 20 minutes of infusion at 90°C, the total phenolic content of the extract was 38.37±0.75 mg/g.

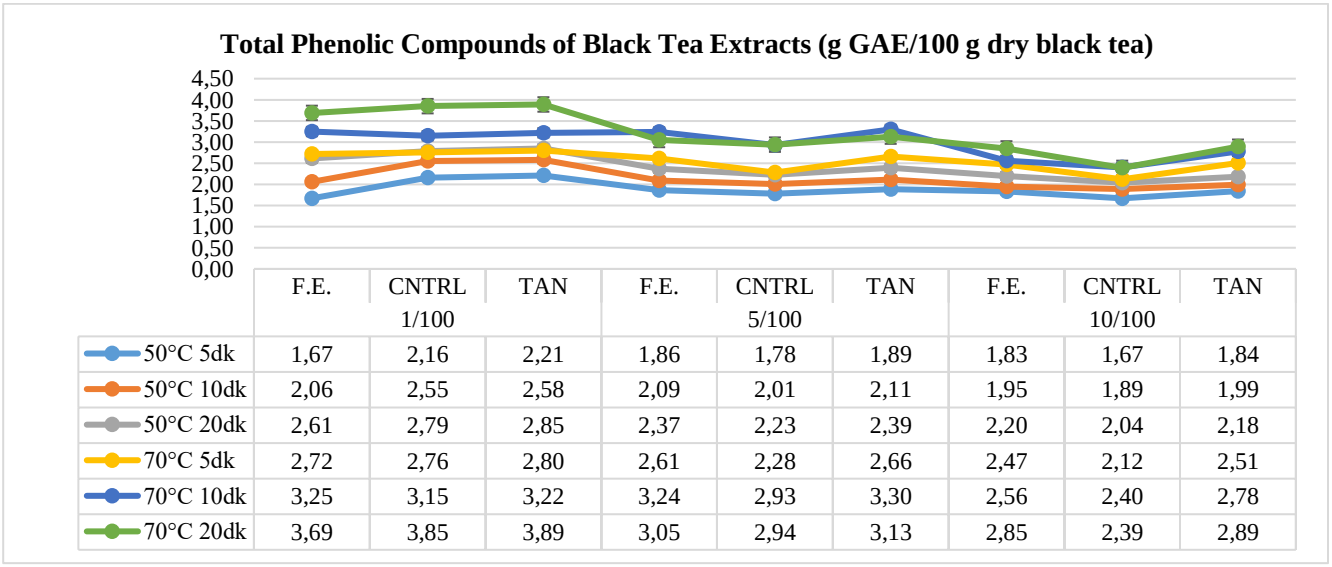
It was noticed that the amounts of total phenolic substance found in the current study are lower than the amounts discovered by other researchers. The differences in the amounts are believed to be related to the distinctions in tea type, harvest season, geographical origin, process, and extraction conditions.

3.3. Catechin amounts of black tea extracts

The most remarkable components of tea are phenolic compounds. The major tea polyphenols are catechins that constitute about 75-80% of the soluble solid fraction (Lu et al., 2009). The main tea catechins are catechin (C), gallocatechin (GC), epicatechingallate (ECG), epicatechin (EC), epigallocatechin (EGC), and epigallocatechingallate (EGCG), and EGCG accounts for more than 50% of phenolic compounds (Li et al., 2017). Catechins provide color, aroma, and taste in tea production. Thus, the astringency and bitterness of tea are due to catechins (Yang et al., 2007).

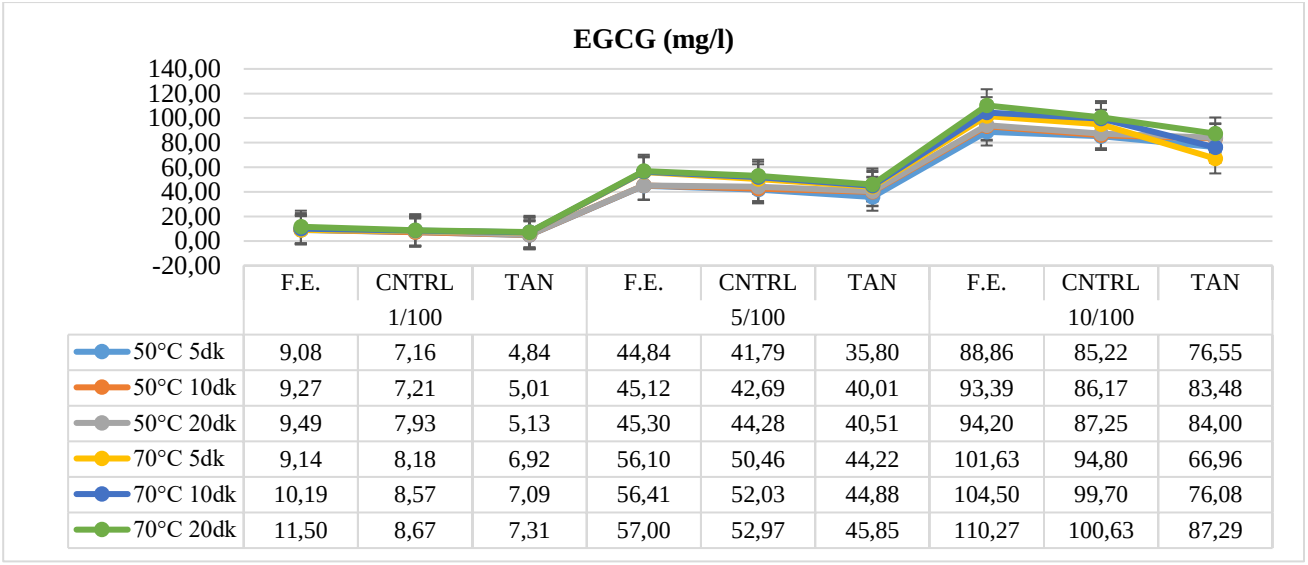
When infusion time is lengthened, chemical changes in the catechins may occur, and catechins' epi-forms can be changed to non-epi forms, called epimerization. The epicatechins existing in tea, which are EC, ECG, EGC, and, EGCG, are called cis-type. They can be transformed into their epimers which are non-epicatechins such as C, CG, GC and GCG. Epimerization, which can also occur at high temperatures, can be reversed. According to Wang et al. (2020), temperature rise resulted in the decline of catechin concentrations while their isomers increased. A diminishing trend in total catechins with the temperature rise demonstrated catechin degradation. Also, it was claimed that tea catechins could be changed to their epimers throughout the brewing, production, and storage processes of conventionally tea infusions and canned tea drinks (Saklar et al., 2015).

Figure 3 presents EGCG values of black tea extracts detected by different tea: water ratios, infusion temperatures and times, and tannase enzyme supplementation. The amount of EGCG in the samples found out by the ultrasonic extraction was 9.08-110.27 mg/l in the first extracts, 4.84-87.29 mg/l and 7.16-100.63 mg/l range in the tannase-supplemented and control samples, respectively.



	F.E.	CNTRL 1/100	TAN	F.E.	CNTRL 5/100	TAN	F.E.	CNTRL 10/100	TAN
50°C 5dk	1,67	2,16	2,21	1,86	1,78	1,89	1,83	1,67	1,84
50°C 10dk	2,06	2,55	2,58	2,09	2,01	2,11	1,95	1,89	1,99
50°C 20dk	2,61	2,79	2,85	2,37	2,23	2,39	2,20	2,04	2,18
70°C 5dk	2,72	2,76	2,80	2,61	2,28	2,66	2,47	2,12	2,51
70°C 10dk	3,25	3,15	3,22	3,24	2,93	3,30	2,56	2,40	2,78
70°C 20dk	3,69	3,85	3,89	3,05	2,94	3,13	2,85	2,39	2,89

Figure 2. Total Phenolic Compounds of Black Tea Extracts (g GAE/100 g dry black tea)
Şekil 2. *Siyah çay ekstraktlarının toplam fenolik madde değerleri (g GAE/100 g kuru siyah çay)*



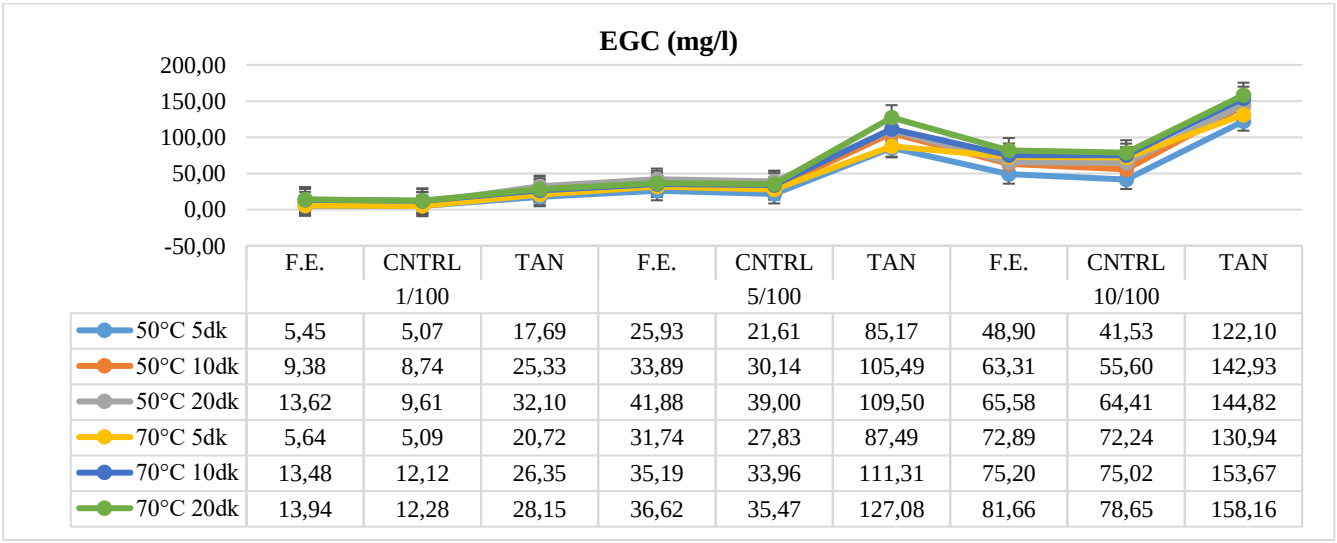
	F.E.	CNTRL 1/100	TAN	F.E.	CNTRL 5/100	TAN	F.E.	CNTRL 10/100	TAN
50°C 5dk	9,08	7,16	4,84	44,84	41,79	35,80	88,86	85,22	76,55
50°C 10dk	9,27	7,21	5,01	45,12	42,69	40,01	93,39	86,17	83,48
50°C 20dk	9,49	7,93	5,13	45,30	44,28	40,51	94,20	87,25	84,00
70°C 5dk	9,14	8,18	6,92	56,10	50,46	44,22	101,63	94,80	66,96
70°C 10dk	10,19	8,57	7,09	56,41	52,03	44,88	104,50	99,70	76,08
70°C 20dk	11,50	8,67	7,31	57,00	52,97	45,85	110,27	100,63	87,29

Figure 3. EGCG amount of black tea extracts (mg/l)
Şekil 3. *Siyah çay ekstraktlarının epigallokateşingallat (EGCG) miktarı (mg/l)*

It is apparent from this figure that the EGCG values of the extracts increased as a result of the increase in the tea: water ratio, infusion temperature and duration, and these increases were significant ($p<0.05$), statistically. With the tannase enzyme application at all tea: water concentrations, infusion temperatures and times, it was discovered that there were drops in the EGCG amounts of the samples, which was significant ($p<0.05$), statistically.

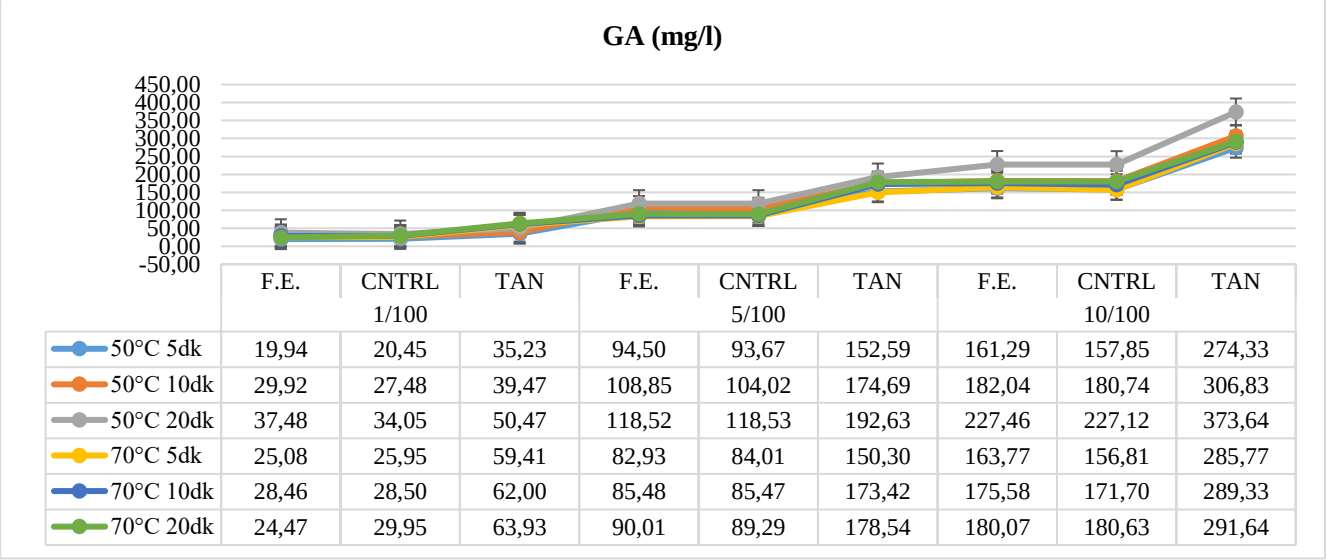
EGC values of black tea extracts obtained by different tea: water ratios, infusion temperatures and times, and tannase enzyme supplementation are presented in Figure 4. The amount of EGC in the samples of the ultrasonic extraction method was between 5.45-81.66 mg/l in the first extracts, 17.69-158.16 mg/l, and 5.07-78.65 mg/l in the samples with and without enzyme treatment, respectively.

The findings also revealed that the tea: water ratio and the infusion temperature had a significant ($p<0.05$) effect on the EGC values of the samples, statistically. An increase in the amount of EGC was detected when the temperature increased. With tannase enzyme application at all different infusion temperatures and times, the EGC values of the samples increased, which was found significant ($p<0.05$).



	F.E.	CNTRL 1/100	TAN	F.E.	CNTRL 5/100	TAN	F.E.	CNTRL 10/100	TAN
50°C 5dk	5,45	5,07	17,69	25,93	21,61	85,17	48,90	41,53	122,10
50°C 10dk	9,38	8,74	25,33	33,89	30,14	105,49	63,31	55,60	142,93
50°C 20dk	13,62	9,61	32,10	41,88	39,00	109,50	65,58	64,41	144,82
70°C 5dk	5,64	5,09	20,72	31,74	27,83	87,49	72,89	72,24	130,94
70°C 10dk	13,48	12,12	26,35	35,19	33,96	111,31	75,20	75,02	153,67
70°C 20dk	13,94	12,28	28,15	36,62	35,47	127,08	81,66	78,65	158,16

Figure 4. EGC amount of black tea extracts (mg/l)
Şekil 4. *Siyah çay ekstraktlarının epigallokateşin (EGC) miktarı (mg/l)*



	F.E.	CNTRL 1/100	TAN	F.E.	CNTRL 5/100	TAN	F.E.	CNTRL 10/100	TAN
50°C 5dk	19,94	20,45	35,23	94,50	93,67	152,59	161,29	157,85	274,33
50°C 10dk	29,92	27,48	39,47	108,85	104,02	174,69	182,04	180,74	306,83
50°C 20dk	37,48	34,05	50,47	118,52	118,53	192,63	227,46	227,12	373,64
70°C 5dk	25,08	25,95	59,41	82,93	84,01	150,30	163,77	156,81	285,77
70°C 10dk	28,46	28,50	62,00	85,48	85,47	173,42	175,58	171,70	289,33
70°C 20dk	24,47	29,95	63,93	90,01	89,29	178,54	180,07	180,63	291,64

Figure 5. GA amount of black tea extracts (mg/l)
Şekil 5. *Siyah çay ekstraktlarının Gallik Asit (GA) miktarı (mg/l)*

Figure 5 illustrates GA values of black tea extracts discovered by different tea: water ratios, infusion temperatures and times, and tannase enzyme supplementation. The amount of GA in the samples obtained by ultrasonic extraction ranged between 9.94-227.46 mg/l in the first extracts, 35.23-373.64 mg/l and 20.45-227.12 mg/l in the tannase-supplemented and control samples, respectively.

Findings revealed that the tea: water ratio, infusion temperature and time had a significant ($p<0.05$) effect on the GA values of the samples, statistically. The GA amounts of the extracts generally increased depending on the change in the tea: water ratios and the increase in the infusion temperature and time, which was significant ($p<0.05$). Moreover, GA amounts of the samples increased with applying tannase enzyme at all infusion temperatures and times, which was significant ($p<0.05$), statistically.

Previous studies revealed that black tea contains less catechins than green tea. In contrast, black tea possesses higher amounts of gallic acid. This situation is likely due to GA conversion from catechin gallates during fermentation (oxidation) of green tea to black tea. During biochemical oxidation, the amount of catechin (EGCG, ECG, EC, C, EGC, GCG) decreased while the amount of gallic acid increased (Gramza et al., 2005).

Türkmen (2007) declared the amount of EGCG in Turkish black teas by ultrasonic extraction (40 min.) as 0.70±0.01 mg/g dry weight. Further, Raghuwanshi et al. (2013) examined the effects of the tannase enzyme (*Penicillium Charlesii*) on the Kangra black tea extract (CTC method), infusion at 85°C for 20 minutes at a ratio of 5:100 tea: water. They found the amount of EGCG in the control and tannase-supplemented samples as 26.54 mg/g tea and 2.83 mg/g tea, respectively. The amount of EGC in control and tannase-supplemented samples was 18.96 mg/g tea and 42.12 mg/g tea, respectively. They also discovered that the amount of GA in control and tannase-supplemented samples was 10.10 mg/g tea and 113.2 mg/g tea.

What is more, Chandini et al. (2011) stated that the amount of EGC in the extract (at a ratio of 2:100 tea: water at 90°C for 40 minutes) using CTC-type black tea supplied from India was 3.69±0.16% in the control sample, 3.82±0.13% and 3.90±0.00%, respectively with 10 and 20 U/g dosage tannase in black tea.

Furthermore, Li et al. (2017) reported that the ratio of tannase to tea was 1:1 (v/w), and there was a decline in EGCG, from 246.5 µg/ml to 153.9 µg/ml. Yet, an increase was observed in gallic acid, from 21.9 µg/ml to 83.9 µg/ml. After treating inferior Tieguany in oolong tea leaves with tannase, EGCG was minimized by 37.6% .

As a result of the enzymatic treatment, a decrease in the gallated catechins (EGCG), and an increase in ungallated catechins (GA, and EGC) were detected. According to the previous findings of Chandini et al. (2011), after tannase split the ester bonds in ECG and EGCG, the transformation of EGCG to EGC and GA, hydrolyzation of GCG to GC and GA, and degradation of

ECG to EC and GA occurred. The increases in EGC amounts with the use of tannase enzyme in the present study are quite similar to the increases in EGC amounts and decreases in EGCG found by other researchers.

It was also reported by Saklar et al. (2015) that various factors affect the catechin contents of different tea cultivars such as type of tea, age of tea leaves, harvesting seasons and conditions, climate, cultivation practices, drying, and technological processes during tea production.

4. Results

In conclusion, the most significant finding to emerge from this study is that applying the tannase enzyme contributed to the reduction of cream formation, which is one of the problems in RTD tea production. The results indicated that the amount of cream in black tea extracts obtained by ultrasonic extraction decreased by 38.89-59.11% with the tannase treatment. At the same time, thanks to the reduction in cream formation with the application of tannase enzyme, it is seen that products with higher functional properties can be produced thanks to the fact that phenolic substances, especially catechins, which are the functional components of tea extracts, remain in the tea extract. It is hoped that the findings in the present study will make noteworthy contributions to the literature and serve as a base for future and more comprehensive studies.

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References

Aharwar, A., & Parihar, D. K. (2021). Talaromyces verruculosus tannase immobilization, characterization, and application in tea infusion treatment. *Biomass Conversion and Biorefinery*, 261-272. https://doi.org/10.1007/s13399-020-01162-6

Anonymous, (2005). Determination of Substances Characteristic of Green and Black Tea - Part 1: Content of Total Polyphenols İn Tea- Colorimetric Method Using Folin Ciocalteu Reagent. *International Standard (ISO) 14502-1*. https://www.Iso.Org/Standard/31356.Html

Ateş, E., Kaya, C., Yücel, E. E., & Bayram, M. (2022). Effects of ultrasound-assisted extraction procedure on total phenolics, catechin and caffeine content of green tea extracts. *Emirates Journal of Food and Agriculture*, *34*(8). https://doi.org/10.9755/ejfa.2022.v34.i8.2911

Chandini, S. K., Rao, L. J., Gowthaman, M. K., Haware, D. J., & Subramanian, R. (2011). Enzymatic treatment to improve the quality of black tea extracts. *Food chemistry*, *127*(3), 1039-1045. https://doi.org/10.1016/j.foodchem.2011.01.078

Dalpathadu, K. A. P., Rajapakse, H. U. K. D. Z., Jayasinghe, C. V. L., & Nissanka, S. P. (2022). Manufacturing of Low Haze Instant Tea Extracts Using Sri Lankan Broken Mixed Fannings (BMF) as Raw Materials. *Tropical Agricultural Research, 33*(4), 319-329. http://doi.org/10.4038/tar.v33i4.858

Govindarajan, R. K., Khanongnuch, C., Mathivanan, K., Shyu, D. J., Sharma, K. P., & De Mandal, S. (2021). In-vitro biotransformation of tea using tannase produced by Enterobacter cloacae 41. *Journal of Food Science and Technology*, 58, 3235-3242. https://doi.org/10.1007/s13197-021-05018-3

Guo, C., Chen, Y., Li, J., Zhan, F., Wei, X., & Li, B. (2021). Role of green tea nanoparticles in process of tea cream formation–A new perspective. *Food Chemistry*, 339, 128112. https://doi.org/10.1016/j.foodchem.2020.128112

Liang, Y., Lu, J., & Zhang, L. (2002). Comparative study of cream in infusions of black tea and green tea [Camellia sinensis (L.) O. Kuntze]. *International Journal Of Food Science & Technology*, 37(6), 627-634. https://doi.org/10.1046/j.1365-2621.2002.00589.x

Liang, S., Gao, Y., Fu, Y. Q., Chen, J. X., Yin, J. F., & Xu, Y. Q. (2022). Innovative technologies in tea-beverage processing for quality improvement. *Current Opinion in Food Science*, 47, 100870. https://doi.org/10.1016/j.cofs.2022.100870

Li, J., Xiao, Q., Huang, Y., Ni, H., Wu, C., & Xiao, A. (2017). Tannase application in secondary enzymatic processing of inferior Tieguanyin oolong tea. *Electronic Journal of Biotechnology*, *28*, 87-94. https://doi.org/10.1016/j.ejbt.2017.05.010

Lu, M. J., Chu, S. C., Yan, L., & Chen, C. (2009). Effect of tannase treatment on protein–tannin aggregation and sensory attributes of green tea infusion. *LWT-Food Science and Technology, 42*(1), 338-342. https://doi.org/10.1016/j.lwt.2008.05.015

Mangla, S. K., Kazançoğlu, Y., Yıldızbaşı, A., Öztürk, C., & Çalık, A. (2022). A conceptual framework for blockchain-based sustainable supply chain and evaluating implementation barriers: A case of the tea supply chain. *Business Strategy and the Environment*. https://doi.org/10.1002/bse.3027

Nagalakshmi, S., Ramaswamy, M. S., Natarajan, C. P., & Seshadri, R. (1984). The rôle of added carbohydrates in tea 'cream'solubilisation. *Food chemistry*, *13*(1), 69-77. https://doi.org/10.1016/0308-8146(84)90027-X

Raghuwanshi, S., Misra, S., & Saxena, R. K. (2013). Enzymatic treatment of black tea (CTC and Kangra orthodox) using *Penicillium charlesii* tannase to improve the quality of tea. *Journal of Food Processing and Preservation*, *37*(5), 855-863. https://doi.org/10.1111/j.1745-4549.2012.00721.x

Ristinmaa, A. S., Coleman, T., Cesar, L., Weinmann, A. L., Mazurkewich, S., Brändén, G., ... & Larsbrink, J. (2022). Structural diversity and substrate preferences of three tannase enzymes encoded by the anaerobic bacterium Clostridium butyricum. *Journal of Biological Chemistry*, *298*(4). https://doi.org/10.1016/j.jbc.2022.101758

Rusaczonek, A., Swiderski, F., & Waszkiewicz-Robak, B. (2010). Antioxidant properties of tea and herbal infusions-a short report. *Polish Journal of Food and Nutrition Sciences*, *60*(1).

Saklar, S., Ertas, E., Ozdemir, I. S., & Karadeniz, B. (2015) Effects of Different Brewing Conditions on Catechin Content and Sensory Acceptance in Turkish Green Tea Infusions. Journal of Food Science and Technology, 52(10), 6639-6646. https://doi.org/10.1007/s13197-015-1746-y

Serna-Jiménez, J. A., Torres-Valenzuela, L. S., & Mejía-Arango, G. (2022). Evaluation and comparison in caffeine extraction under green conditions: Solvent selection and ultrasound-assisted process. *Journal of Food Process Engineering*, *45*(11), e14157. https://doi.org/10.1111/jfpe.14157

Singla, M., & Sit, N. (2021). Application of ultrasound in

combination with other technologies in food processing: A review. *Ultrasonics Sonochemistry*, *73*, 105506. https://doi.org/10.1016/j.ultsonch.2021.105506

Someswararao, C., & Srivastav, P. P. (2012). A novel technology for production of instant tea powder from the existing black tea manufacturing process. *Innovative Food Science & Emerging Technologies*, *16*, 143-147. https://doi.org/10.1016/j.ifset.2012.05.005

Türkmen N. (2007). Farklı sınıf çaylarda kıvırma proseslerinin ve değişik hasat dönemlerinin çayın fenolik madde ve alkaloid bileşimine etkisi. Doktora Tezi, Ankara Üniversitesi Fen Bilimleri Enstitüsü Gıda Mühendisliği Anabilim Dalı, Ankara.

Wang, J. Q., Hu, X. F., Du, Q. Z., Zeng, L., Wang, S., Yin, J. F., & Xu, Y. Q. (2020). Effect of tannase on sediment formation in green tea infusion. *Journal of Food Measurement and Characterization*, *14*, 1957-1965. https://doi.org/10.1007/s11694-020-00442-z

Xia, T., Shi, S., & Wan, X. (2006). Impact of ultrasonic-assisted extraction on the chemical and sensory quality of tea infusion. *Journal of Food Engineering*, *74*(4), 557-560. https://doi.org/10.1016/j.jfoodeng.2005.03.043

Yang, D. J., Hwang, L. S., & Lin, J. T. (2007). Effects of different steeping methods and storage on caffeine, catechins and gallic acid in bag tea infusions. *Journal of Chromatography A*, *1156*(1-2), 312-320. https://doi.org/10.1016/j.chroma.2006.11.088

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Estimating Corn Yield Using Statistical, Machine Learning and Deep Learning Methods

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Abstract: Yield estimation is an important field of study in agriculture. Forecasting yields provides producers, consumers, traders and policymakers with important preliminary information and time to take necessary action. Corn is an important product in terms of international trade and is widely used in human and animal nutrition throughout the world. Adana produces the highest amount of corn sown both as main and secondary product in Türkiye. Therefore, in this study, corn yield was tried to be estimated by using various meteorological parameters and plant fertilizer usage amounts. For this purpose, statistical (Auto-ARIMA), machine learning (Random Forest) and deep learning (CNN, LSTM) methods were used. The study findings showed that all models used predicted maize yield highly accurately. However, the highest accuracy LSTM model estimated the yield of first corn crop.

Keywords: Yield estimation, deep learning, corn,

İstatistiksel, Makine Öğrenmesi ve Derin Öğrenme Yöntemleri ile Mısır Verimi Tahmini

Öz: Tarımda verim tahmini önemli bir çalışma alanıdır. Verimin önceden tahmin edilmesi üreticilere, tüketicilere, tüccarlara ve politika yapıcılara önemli ön bilgiler sunmakta ve gerekli tedbirlerin alınması için zaman sağlamaktadır. Mısır, dünya genelinde insan ve hayvan beslenmesinde yaygın olarak kullanılan, uluslararası ticaret açıdan da önemli bir üründür. Adana ülkemizde mısır üretiminin hem ana ürün olarak hem de ikincil ürün olarak en yüksek miktarda yetiştirilen ildir. Bu nedenle, bu çalışmada, çeşitli meteorolojik parametreler ve bitki gübre kullanım miktarları kullanılarak mısır verimi tahmin edilmeye çalışılmıştır. Bu amaç doğrultusunda, istatistiksel (Auto-ARIMA), makine öğrenmesi (Random Forest) ve derin öğrenme (CNN, LSTM) yöntemleri kullanılmıştır. Çalışma bulguları, kullanılan tüm modellerin mısır verimini yüksek oranda doğru tahmin ettiğini göstermiştir. Bununla birlikte en yüksek doğruluk LSTM modeli ile birinci mısır ürünü verimini tahminde bulunmuştur.

Anahtar Kelimeler: Verim tahmini, derin öğrenme, mısır

1. Introduction

Turkey is among the countries that produce a significant amount of corn worldwide. According to the data of the Turkish Ministry of Agriculture and Forestry, annual corn production in Turkey has been changing between 5-7 million tons on average in recent years (TSI, 2023). Turkey has an important ranking in world corn production. According to the amount of production, Turkey is generally among the top 20 countries in world corn production (FAOSTAT, 2023). However, the exact ranking may vary depending on the year and the amount of production. Turkey is a favorable country for corn production in terms of climate and soil characteristics. Corn is a plant that can be grown in various regions of Turkey. Corn production is common especially in Marmara, Aegean, Central Anatolia and Southeastern Anatolia regions.

As a fundamental agricultural product, corn is an important food source for human consumption and is widely used as animal feed. For Turkey's livestock sector, corn is a key ingredient for feed production. Corn production contributes to the provision of products such as maize flour and maize silage used as animal feed. The agricultural sector in Turkey is an important part of the economy. Corn is a product that plays an important role in agricultural exports and contributes to the agricultural economy. Increasing the domestic production of corn encourages the growth of the agricultural sector and reduces foreign dependency.

The Mediterranean Region, especially Çukurova, ranks first in Turkey's grain corn production. Last year, Adana ranked first with 1.036.130 tons of grain corn production in Turkey, which was 5 million 900 thousand tons. Adana province produces approximately 17.5% of Turkey's total corn production. Corn production in Adana can be done as the main crop or as a secondary crop. Since 2011, corn cultivation area and production as the primary product has followed a fluctuating but increasing course. As a second crop, a contraction is observed in its cultivation (Table 1).

Table 1. Corn cultivation in Adana Province
Çizelge 1. *Adana ili mısır üretimi*

	Sown Area (da) Primary Product	Sown Area (da) Second Product	Yield (kg/da) First Product	Yield (kg/da) Second Product	Production (ton) First Product	Production (ton) Second Product
2011	564.470	330.622	947	685	534.295	226.449
2012	540.837	251.452	923	729	499.148	183.314
2013	652.373	246.119	1.108	785	722.769	192.515
2014	720.870	198.710	1.180	780	850.720	154.931
2015	772.689	185.131	1.109	857	856.808	158.620
2016	811.721	155.649	1.145	1.010	929.455	157.151
2017	761.871	169.937	1.145	964	872.314	163.816
2018	611.651	127.778	1.162	1.031	710.940	131.757
2019	568.470	97.174	1.106	917	628.713	89.089
2020	624.954	76.596	1.188	1.011	742.503	77.475
2021	571.112	93.075	1.294	765	738.956	71.189
2022	780.283	86.700	1.051	788	820.050	68.298

Source: TSI, 2023

Yield estimation in agricultural activities provides producers with the opportunity to predict the amount of future production. These forecasts allow producers to plan production and effectively manage resources (water, fertilizer, seeds, etc.). Agricultural enterprises can determine the sowing time, plan the harvesting processes and adjust the production amount according to market demands in line with yield estimates. Agriculture is exposed to many risk factors. Factors such as climate changes, diseases, pests, natural disasters can negatively affect yield. Yield forecasting guides producers in developing risk management strategies by evaluating the effects of these risk factors. For example, in the case of low expected yields, producers may consider alternative product options or resort to risk reduction tools such as insurance. Yield forecasting plays an important role in the marketing and trading processes of agricultural products. Estimation of production quantity can be matched with market demand and adjusted to trade processes. It provides basic information on yield estimation, export planning and negotiation, especially in export-oriented agricultural products. Yield estimation helps to manage agricultural resources (water, soil, energy, etc.) efficiently. Forecasts contribute to making more informed decisions on issues such as water resources and irrigation schedules, fertilizer use, pesticide applications, and management of other agricultural inputs. This ensures the adoption of sustainable agricultural practices and the protection of natural resources.

Agricultural crop yield estimation has been studied as an important issue in the agricultural sector. Research in this field consists of the use of various methods and analyzes on different agricultural products. Matsuura et al. (2014) discuss a comparison of regression and machine learning models for maize yield prediction in Jilin, China. Analyzes using various datasets focus on identifying the ANN model with the best forecasting performance. Sharifi (2020) deal with yield prediction of field crops using satellite imagery and machine learning techniques. The data obtained from satellite images are combined with various machine learning algorithms to evaluate the performance of the models used in yield estimation. Fathima et al. (2020) present an agricultural crop yield estimation method based on climate data and data mining techniques. Relationships between climate data and agricultural data are analyzed using data mining techniques and models are built to predict future crop yields. Joshi et al. (2023) discuss a deep learning-based agricultural crop yield estimation method. Field images obtained using remote sensing data are processed with deep learning algorithms and models used to predict agricultural crop yields are developed. Kundu et al. (2022) consider yield estimation of field crops using machine learning methods and model coupling techniques. It is aimed to obtain more accurate and reliable yield estimates by using various machine learning algorithms and model fusion techniques. Paudel et al. (2022) make regional agricultural crop yield prediction based on ensemble machine learning methods through a case study in Shandong Province, China. The current study employs various methods from statistical, machine learning and deep learning fields. In this way, the study results will shed light on the applicability of different methodologies commonly used for prediction purposes in separate studies. The results are given in a comparative way to determine the best efficient method for prediction corn yield in Turkey. By combining different machine learning algorithms, it is tried to produce more accurate and reliable agricultural product yield predictions.

In this study, it is aimed to make future yield estimations by determining external factors such as climate and fertilization that affect corn yield in Adana province. For this purpose, Auto-ARIMA model, which is the most widely used statistical method, Random Forest, which is one of the most powerful machine learning methods, and Convolutional Neural Network (CNN) and Long Short-Term Memory neural networks, which are deep learning methods that have been increasingly used in recent years, were compared. has been applied. The data set and the codes of the applications produced within the scope of the study were shared in the public github repository for the benefit of other researchers.

2. Material and Methods

When corn is planted as the main product in Adana, it is planted in April - May and harvested in July-August. As a second crop, it is planted at the beginning of July at the latest and is harvested in September-October. For this reason, meteorological parameters of the April-October months measured in Adana province were taken from the General Directorate of Meteorology. These data include monthly average 10 cm soil temperature, average minimum temperature, average temperature, average wind speed and monthly total precipitation. In addition to these data, the amounts of nitrogen (N), phosphorus (P2O2) and potash (K2O) used in Adana province were included in the study as plant nutrition inputs. Thus, the amount of yield (kg/da) was tried to be estimated with 39 inputs (Table 2). Some important meteorological parameters such as evapotranspiration, global radiation etc. could be included in the study due to the large missing observations in their times series.

Table 2. Input variables
Çizelge 2. *Girdi değişkenleri*

Inputs	Input Category and Metric Unit
Nitrogen (N)	Numeric – tons
Phosphorus (P2O5)	Numeric - tons
Potas (K2O)	Numeric – tons
Total Plant Nutrient	Numeric - tons
Mean Soil Temperature at 10cm x 7 months (April-October)	Numeric - ^{0}C
Monthly Mean Minimum Temperature x 7 months (April-October)	Numeric – ^{0}C
Monthly Mean Wind Speed (April-October) x 7 months (April-October)	Numeric - m/sec
Monthly Mean Temperature x 7 months (April-October)	Numeric - ^{0}C
Monthly Total Precipitation x 7 months (April-October)	Numeric - mm

2.1. ARIMA

For the Auto-ARIMA method, it was tested for stationarity with the Augmented Dickey-Fuller test and the first differences of the non-stationary series were made stationary by taking the first difference and then standardized with the Min-Max scaling method. For CNN and LSTM methods, stationarity tests were not performed on the data.

ARIMA (Autoregressive Integrated Moving Average) is a model for analyzing a time series data, making predictions and estimating its future values. Auto-ARIMA chooses the best model by trying different ARIMA models to analyze time series data (Yermal & Balasubramanian, 2017). This method helps the model to automatically determine the optimal p, d, and q parameters. where p is the number of autoregressive terms; d is the degree of difference of the data; and q is the number of moving average terms.

$$(1 - \theta_1 B - \theta_2 B^2 - \cdots - \theta_p B^p)(1 - B)^D Y_t = (1 + \varphi_1 B + \varphi_2 B^2 + \cdots + \varphi_Q B^Q)\varepsilon_t$$

Where:

- Y_t is the value of the time series at time t,
- B is the backshift operator that represents the lag operator,
- θ_1, θ_2, … θ_p are the autoregressive parameters where P is the maximum order of autoregression,
- D is the maximum order of differencing,
- φ_1, φ_2, …, φ_Q are the moving average parameters where Q is the maximum order of the moving average,
- ε_t represents white noise, a random error term with mean zero and constant variance

The working principle of Auto-ARIMA starts by making the data stationary by determining the degree of difference applied to the data. A series of ARIMA models are then automatically generated using different p, d, and q values, and these models are applied to the residuals of the data. This process relies on various statistical criteria (eg AIC, BIC) to evaluate the performance of the models and select the best model. The best model is considered the one that provides the best fit and the lowest information loss.

2 2. CNN (Convolutional Neural Network)

CNN is an artificial neural network model that is widely used in the field of deep learning and is especially effective in visual data analysis such as image recognition, object detection and image classification. This model is inspired by biological neural networks and uses convolutional layers to detect local patterns of data. It consists of convolutional

layers, activation functions, pooling and fully-connected layers.

Pooling Layers: Pooling layers are used to reduce the spatial dimensions of the feature maps, reducing the number of parameters in the model and aiding in translation invariance. The most common pooling operation is max-pooling, which takes the maximum value within a small region of the feature map.

Activation Functions: Non-linear activation functions, such as ReLU (Rectified Linear Unit), are applied after convolutional and pooling layers to introduce non-linearity into the network, enabling it to learn complex patterns in the data.

Fully Connected Layers: After several convolutional and pooling layers, the feature maps are flattened and connected to one or more fully connected layers, which act as a traditional neural network for making final predictions.

Weight Sharing: One key feature of CNNs is weight sharing, which allows the same set of learnable filters to be applied to different parts of the input image. This helps reduce the number of parameters in the model and enables CNNs to generalize well to different locations of features in the input.

The CNN model is created by iteratively combining these basic components. Usually multiple convolutional layers and pooling layers are followed by fully connected layers (Kim, 2017). This architecture can produce effective results by learning hierarchical properties of data and offering advanced pattern recognition capabilities. Convolutional Layers: The fundamental building blocks of CNNs are convolutional layers. These layers apply convolution operations to the input image to extract various features. Convolution involves sliding a small filter (also called a kernel) over the input image and computing element-wise multiplications and summations to produce feature maps.

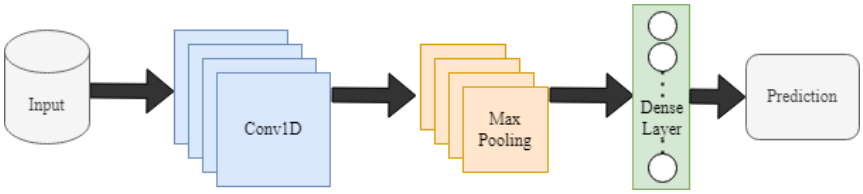

Figure 1. CNN architecture
Şekil 1. *CNN mimarisi*

2.3. LSTM (Long Short-Term Memory)

LSTM is a type of recursive neural network that is particularly effective in modeling data with long-term dependencies, such as time series data. It is mainly designed to address the vanishing gradient problem and effectively capture long-term dependencies in sequential data (Hochreiter & Schmidhuber, 1997). The key feature of LSTM is that it can more effectively handle long-term addictions compared to traditional recursive neural networks (Figure 2). This is accomplished using the cell state. The cell state is like a line that carries information inside the network and is maintained or changed over time. Another important component of LSTM are three gates used to control input data and make decisions: Forget Gate, Input Gate and Output Gate. These components of the LSTM enable the model to make better predictions by effectively capturing long-term dependencies and preserving important information.

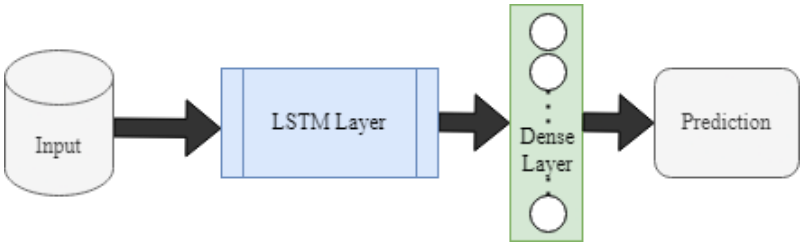

Figure 2. LSTM architecture
Şekil 2. *LSTM mimarisi*

2.4. Random Forest

Random Forest is an ensemble learning method that is widely used in the field of machine learning. This method is an assembly created by combining many decision trees. Each tree is trained on random samples of the dataset and makes predictions independently (Biau & Scornet, 2016). The formula for building a Random Forest model involves two main components: the process of creating individual decision trees and the voting mechanism to combine their predictions.

1. Building individual trees:

a. Selecting a Subset of Features: Given a dataset with "n" samples and "m" features, at each node of the decision tree, a random subset of features (typically denoted as "k") is selected to split the data. The value of "k" is usually much smaller than "m," and it remains constant throughout the tree-building process.

b. Data Bootstrapping: For training each tree, a random subset of the original data is sampled with replacement. This process, known as bootstrapping, creates a new dataset of the same size as the original but with some duplicate and missing samples.

c. Building Decision Trees: Using the selected features and the bootstrapped dataset, a decision tree is built recursively by selecting the best feature and split point at each node, based on criteria such as Gini impurity (for classification) or mean squared error (for regression).

2. Voting mechanism:

a. Classification: For classification tasks, each tree in the Random Forest independently predicts the class label of a sample. The final prediction is determined through majority voting, i.e., the class that receives the most votes from the individual trees is considered the final predicted class.

b. Regression: For regression tasks, the output of each tree in the Random Forest is a numerical prediction. The final prediction is obtained by averaging the predictions from all the individual trees.

Pmdarima Python library is used for the application of the Auto-ARIMA method. The implementation of the Random Forest model is made with the help of the Scikit-Learn library. The simplest possible architectural structure was created for the CNN and LSTM models. The CNN architecture is composed of 1 Conv1D layer with 63 neurons, 1 MaxPooling with pool size 2, 1 Dense Layer with 50 neurons and 1 Dense layer as output (Figure 1). On the other hand, LSTM architecture contains 1 LSTM layer with 50 neurons and 1 Dense layer as output (Figure 2). ReLu is chosen as activation and Adam is used as optimizer with a learning rate of 0.005, and both models were trained for 1000 epochs.

3. Results and Discussion

The data used in the study consists of monthly observations between 2011 and 2022. A total of 39 inputs including weather parameters, plant fertilizer and nutrients are used as inputs in order to predict the corn yield cultivated as first and second product in Adana province. The correlations between inputs and yield are shown in Figure 1. When there is no correlation between 2 variables (when correlation is 0 or near 0) the color is gray. The darkest red means there is a perfect positive correlation, while the darkest blue means there is a perfect negative correlation. Further details can be seen at the public Github repository (https://github.com/cevher/corn-yield-prediction/tree/master).

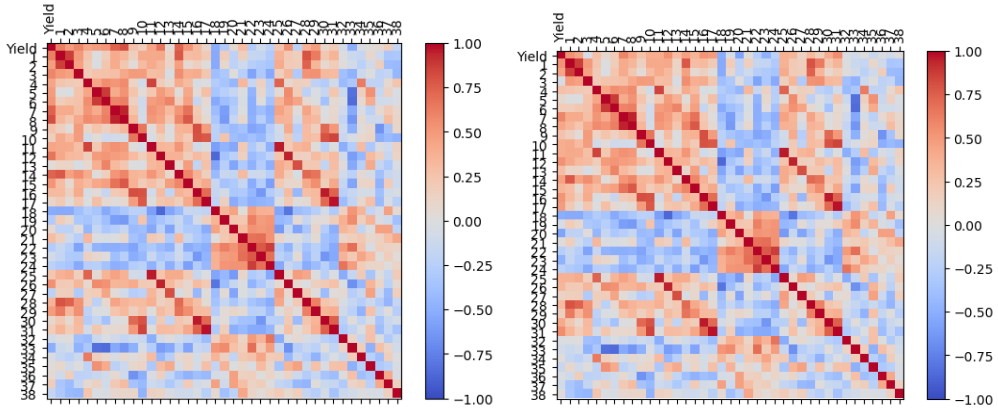

Figure 3. Correlation results between inputs and yield (1st and 2nd product, respectively)
Şekil 3. *Girdi değişkenleri ile verim (ilk ve ikinci ürün) arasındaki korelasyon sonuçları*

Table 3. Analysis results
Çizelge 3. *Analiz sonuçları*

	Corn Yield (First Product)			Corn Yield (Second Product)		
	MAE	**MSE**	**RMSE**	**MAE**	**MSE**	**RMSE**
Auto-ARIMA	0.2996	0.1024	0.3201	0.3151	0.1512	0.3888
Random Forest	0.3028	0.1040	0.3226	0.4082	0.1668	0.4084
CNN	0.2679	0.0724	0.2691	0.4362	0.2310	0.4806
LSTM	0.2471	0.0612	0.2475	0.5063	0.3379	0.5813

Prior to the application of Auto-ARIMA model, data was checked for stationarity using Augmented Dickey-Fuller test and first difference of data provided stationarity. Then, Min-Max scaler was used to standardize variables in order to eliminate any possible bias among data. Subsequently, data was split into 90% training and 10% test set. All models were applied separately to predict corn yield of the first and second cultivated products. Mean Squared Error, Mean Absolute Error and Root Mean Squared Error metrics were used to evaluate the accuracy of models. The results are summarized in Table 3.

The results indicate that all models are robust in predicting on yield within statistically acceptable level. However, it is noteworthy that models are more capable of predicting the yield for the 1st product corn. The highest accuracy was obtained with LSTM model for the yield of the first product corn. This was closely followed by CNN, Auto-ARIMA and Random Forest models. The study results clearly show that corn yield can be predicted with any of the models using the selected weather and plant nutrient input variables. The previous studies mainly used either remote sensing images or deep architectures of neural networks. To our knowledge, LSTM and CNN have not been used in predicting agricultural product yield in comparison with other common statistical methods. The results of this study reveal that corn yield can be accurately estimated by using the simplest possible architectures of CNN and LSTM when there are enough meteorological and nutrient input observations collected between planting and harvesting periods.

4. Conclusion

This study makes a comparative analysis on the prediction of corn yield using various statistical, machine learning and deep learning models. The dataset contains the monthly observations of weather parameters and annual amount of plant nutrients, fertilizers to forecast the corn yield cultivated as 1st and 2nd product in Adana Province, which is the biggest corn producing city in Turkey. Corn yield is quite significant as corn is consumed by humans and used intensively in animal feed production. Statistical, machine learning and deep learning models are used for this prediction purpose in a comparative way. All models are found quite apt at learning the relations between input variables and corn yield and provided accurate yield predictions for both first and second product corn. However, the models provided slightly better results for the first product corn. Overall, LSTM yielded the highest accuracy in predicting the yield of the first product corn. It was closely followed by CNN, Auto-ARIMA and Random Forest models. Further studies can be implemented to generalize the findings of the current study over other corn production areas. Also, this methodology can be extended to other agricultural products and additional meteorological and agricultural observations can be included in the analysis, as well.

References

Biau, G., & Scornet, E. A. (2016). Random forest guided tour. *TEST* 25, 197–227 doi.org/10.1007/s11749-016-0481-7

FAOSTAT, (2023). Food and Agriculture Organization of the United Nations, *Crops and Livestock Products Statistics*, https://www.fao.org/faostat/en/#data/QCL

Fathima, M., Sowmya K., Barker, S., & Kulkarni, S. (2020). Analysis of Crop Yield Prediction using Data Mining Technique. *International Research Journal of Engineering and Technology.* 07(5) 10.13140/RG.2.2.14424.52482.

Hochreiter, S. & Schmidhuber, J. (1997). Long Short-term Memory. *Neural computation*. 9. 1735-80. 10.1162/neco.1997.9.8.1735.

Joshi, A., Biswajeet P., Shilpa, G, & Subrata C. (2023). Remote-Sensing Data and Deep-Learning Techniques in Crop Mapping and Yield Prediction: A Systematic Review. *Remote Sensing.* 15(8). 10.3390/rs15082014

Kim, P. (2017). Convolutional Neural Network. In: MATLAB Deep Learning. *Apress, Berkeley, CA.* doi.org/10.1007/978-1-4842-2845-6_6Kundu, S., Ghosh, A., Kundu, A. & Girish P. (2022) A ML-AI Enabled Ensemble Model for Predicting Agricultural Yield, *Cogent Food & Agriculture*, 8:1, 10.1080/23311932.2022.2085717

Matsuura, K., Gaitan, C., Hsieh, W., & Cannon, A. (2014). Maize yield forecasting by linear regression and artificial neural networks in Jilin, China. *The Journal of Agricultural Science*. 10.1017/S0021859614000392.

Paudel, D., Boogaard, H., Wit, A., Velde, M., Claverie, M., Nisini, L. Janssen, S., Osinga, S., & Athanasiadis, I. (2022). Machine learning for regional crop yield forecasting in

Europe, *Field Crops Research*, 276, 10.1016/j.fcr.2021.108377.

Sharifi, A. (2020). Yield prediction with machine learning algorithms and satellite images. *Journal of the Science of Food and Agriculture*. 101. 10.1002/jsfa.10696.

TSI, (2023). Turkish Statistical Institute, *Crop Production Statistics*,https://data.tuik.gov.tr/Kategori/GetKategori?p=tarim-111&dil=2

Yermal, L. & Balasubramanian, P. (2017). Application of Auto ARIMA Model for Forecasting Returns on Minute Wise Amalgamated Data in NSE, *2017 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC), Coimbatore, India*, 2017, pp. 1-5, doi: 10.1109/ICCIC.2017.8524232.

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Fruit Characteristics of Some Standard Apple Cultivar/Rootstock Combination in Ordu Ecology

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Abstract: The main objective of this study was to evaluate the fruit quality characteristics and biochemical properties of Mondial Gala, Jeromine, and Granny Smith cultivars grafted on M9 full-dwarf clonal rootstock and Granny Smith, Fuji, Galaxy Gala, Red Chief, and Scarlett Spur cultivars grafted on MM 106 semi-dwarf clonal rootstock grown in Ordu (Türkiye) ecological conditions. During the research, fruit weight, fruit dimensional characteristics, fruit firmness, color characteristics, soluble solids content, titratable acidity, pH, vitamin C, total phenolic, total flavonoid and antioxidant activity of the cultivars were investigated. In the study, it was determined that, fruit weight, fruit firmness, SSC and Vitamin C 185.40 g (Mondial Gala/M9)-284.03 g (Scarlet Spur/MM 106), 69.73 N (Galaxy Gala/MM 106)-84.47 N (Granny Smith/M9), 8.29% (Scarlett Spur/MM 106)-14.27% (Fuji/MM 106), 58.00 mg (Scarlet Spur/MM 106)-112.33 mg (Granny Smith/M9), respectively. In addition, it was determined that Granny Smith, Red Chief, Mondial Gala, and Jeromine cultivars stand out in terms of bioactive compounds that positively affect human health compared to other cultivars. As a result, it has been revealed that apple cultivars grafted on M9 and MM 106 clone rootstocks examined in the study can be grown in high quality in Ordu ecology.

Keywords: Antioxidant, fruit firmness, *Malus domestica*, pomology, vitamin C

Ordu Ekolojisindeki Bazı Standart Elma Çeşit/Anaç Kombinasyonlarının Meyve Özellikleri

Öz: Bu çalışmanın temel amacı, Ordu (Türkiye) ekolojik koşullarında yetiştirilen M9 tam bodur klon anacı üzerine aşılı Mondial Gala, Jeromine ve Granny Smith çeşitleri ile MM 106 yarı bodur anacı üzerine aşılı Granny Smith, Fuji, Galaxy Gala, Red Chief ve Scarlett Spur çeşitlerinin meyve kalite özellikleri ile biyokimyasal içeriğini belirlemektir. Araştırmada çeşitlerin meyve ağırlığı, meyve boyutsal özellikleri, meyve sertliği, renk özellikleri, suda çözünebilir kuru madde miktarı, titre edilebilir asitlik, pH, C vitamini, toplam fenolik, toplam flavonoid ve antioksidan aktiviteleri incelenmiştir. Çalışmada meyve ağırlığı, meyve eti sertliği, SÇKM ve C vitamini içeriği sırasıyla 185.40 (Mondial Gala/M9)-284.03 g (Scarlet Spur/MM 106), 69.73 (Galaxy Gala/MM 106)-84.47 N (Granny Smith/M9), %8.29 (Scarlet Spur/MM 106)-%14.27 (Fuji/MM 106) ve 58.00 (Scarlet Spur/MM 106)-112.33 mg (Granny Smith/M9) arasında belirlenmiştir. Ayrıca Granny Smith, Red Chief, Mondial Gala ve Jeromine çeşitlerinin insan sağlığını olumlu yönde etkileyen biyoaktif bileşikler açısından diğer çeşitlere göre öne çıktığı saptanmışmıştır. Sonuç olarak, çalışmada incelenen M9 ve MM 106 klon anaçları üzerine aşılı elma çeşitlerinin Ordu ekolojisinde kaliteli bir şekilde yetiştirilebileceği tespit edilmiştir.

Anahtar kelimeler: Antioksidan, meyve eti sertliği, *Malus domestica*, pomoloji, vitamin C

1. Introduction

Apple (*Malus domestica* Borkh.), in the *Rosaceae* family's *Malus* genus, is among the oldest cultivated pome fruit species. It is reported that the origin of apples is Anatolia, Caucasus, and Central Asia (Bayazıt et al., 2019). At the same time, it is a fruit species that can easily adapt to many regions with its high adaptability and can be produced in large areas accordingly. Due to the fact that Türkiye is among the homelands, this fruit species is cultivated intensively in the ecological conditions of our country (Ozmen & Cekic, 2018).

With the development and using of full-dwarf and semi-dwarf rootstocks in apple cultivation, modern farming techniques have started to develop rapidly. In this sense, with the application of the intensive planting systems, and the development of the training and pruning techniques in fruit trees, an increase in yield to be obtained from the unit area, which is among the most important goals of modern fruit growing, has been achieved (Dadashpour et al., 2019). Therefore, the selection of the rootstock and cultivar to be used in breeding increases its importance day by day. It is

reported that rootstocks have an equal effect on growth vigor and productivity as in grafted scions (Gjamovski & Kiprijanovski, 2011). However, when choosing rootstocks and cultivars, ecological conditions such as light, humidity, temperature, and soil structure must be considered in the regions where production will be made. It is known that these factors significantly impact yield and fruit quality based on species and cultivars (Eskimez et al., 2020).

Despite the positive developments in dwarf apple cultivation in Türkiye in recent years, it is stated that traditional approaches in terms the of training systems and pruning practices continue, so the expected yield from the orchards cannot be obtained. It is reported that the studies should be carried out to determine the yield characteristics of the popular cultivars and rootstock combinations to eliminate this situation in our country (Ozkan & Kucuker, 2009). The ecological demands of the new cultivars developed the breeding studies show differences. Therefore, it is reported that the economic losses that may occur due to the wrong cultivar can be prevented by carrying out studies on adapting these cultivars in different regions of our country (Balta et al., 2020). As a matter of fact, in recent years, many studies have been reported to determine the performance of the different apple cultivars in different regions in Türkiye (Aksoy, 2017; Balta et al., 2020; Bolat et al., 2019; Ceylan, 2008; Ozturk & Ozturk, 2016; Oztürk et al., 2016; Ozongun et al., 2014; Ozongun et al., 2016; Soylu et al., 2003; Sensoy & Bostan, 2019; Turan & Karlıdag, 2022).

This study was carried out to determine the fruit quality characteristics of the different apple cultivars grafted on M9 full-dwarf and MM 106 semi-dwarf clonal rootstocks in Ordu (Türkiye) in 2017-2018 years. The findings obtained from the study will facilitate the selection of the cultivars for the producers who aim to grow apples in the region.

2. Materials and Methods

2.1. Plant Materials

The plant material of the study consisted of Mondial Gala, Jeromine, and Granny Smith cultivars grafted on M9 dwarf rootstock; Granny Smith, Fuji, Galaxy Gala, Red Chief, and Scarlett Spur cultivars grafted on MM 106 semi-dwarf rootstock in Ordu University, Faculty of Agriculture, Application and Research Center. Trees were planted with 3.0 x 1.2 m between rows and trained with the central leader system for M9 rootstock; 3.5 x 3.0 m between rows and pruned with the goble system for MM 106. Irrigation is done with a double-line drip irrigation system with 2 L/h drippers, and other cultural processes are also applied regularly.

2.2. Methods

The experiment was designed according to the completely randomized plots with three replications and four trees in each replication. Considering the planting year, trees with similar growth vigor were selected. Measurements and analyzes were carried out on trees in 2017 (3 years old) and 2018 (4 years old). However, since the fruit set did not occur in Fuji, Galaxy Gala, Red Chief, and Scarlett Spur cultivars grafted on MM 106 rootstock in 2017, these characteristics could not be examined.

2.2.1. Physical characteristics

Fruit weight (g) was determined with a digital precision scale (Desis, Türkiye) with an accuracy of 0.01 grams. Fruit sizes were determined by measuring with a digital caliper (Mitutoyo, Japan) with a sensitivity of 0.01 mm. Fruit firmness was determined with a penetrometer (FT-327, Italy) using an 11.1 mm tip by measuring two different places where the skins were peeled from the equatorial region of the fruit. Measurements were performed on 10 fruit for each replication. The skin color of the fruit (10 fruit) was determined using a colorimeter (Minolta, model CR-400, Tokyo, Japan) in CIE L*, a*, b*, chroma, and hue angle (McGuire, 1992).

2.2.2. Soluble solids content (SSC), titratable acidity (TA), pH and vitamin C

SSC was determined with a digital refractometer (PAL-1, McCormick Fruit Tech. Yakima, ABD) from the juice sample obtained without sediment from the fruit. According to Oztürk et al. (2016), TA was calculated in terms of malic acid. Vitamin C was determined using a reflectometer set (Merck RQflex plus 10, Germany).

2.2.3. Biochemical characteristics

To determine the total phenolics in the study, 600 µl of fresh fruit extract from each sample was diluted with 4.2 ml of distilled water. After adding 100 µl of Folin-Ciocalteu's reagent and 300 µl of 2% sodium carbonate (Na_2CO_3), the prepared solution was incubated for 30 minutes. Then, it was measured at 760 nm in a UV-Vis spectrophotometer (Shimadzu, Kyoto, Japan), and the results were calculated in gallic acid (mg GAE 100 g^{-1} fw) (Aglar et al., 2019). To determine the total flavonoid content, 500 µl of the extract from each sample was

diluted with 3.8 ml of methanol and 100 µl of ammonium acetate ($C_2H_7NO_2$). Then 100 µl of ammonium nitrate (NH_4NO_3) was added. After the prepared solution was incubated for 40 minutes, it was measured at 415 nm, and the results were presented as quercetin equivalents (mg QE 100 g^{-1} fw) (Chang, et al., 2002). The antioxidant activity was determined according to two different procedures of 2,2-diphenyl-1-picryl-hydrazyl-hydrate (DPPH) (Blois, 1958), and Ferric Ions (Fe^{+3}) Reducing Antioxidant Power (FRAP) (Benzie & Strain, 1996), and the results were expressed in µmol Trolox equivalent (TE) kg^{-1} fw.

2.4. Statistical Analysis

The data obtained from the experiment were analyzed in the JMP 16.0 software, and the 'Tukey Multiple Comparison Test' ($p<0.05$) was used to compare the differences between the means. Principal components and biplot graphs were constituted using fruit physical and color characteristics, and biochemical content determined in the rootstock/cultivar combinations investigated.

3. Results and Discussion

In the study, the fruit weight and fruit firmness varied between 185.40 g (Mondial Gala/M9)-284.03 g (Scarlet Spur/MM 106) and 69.73 N (Galaxy Gala/MM 106)-84.47 N (Granny Smith/M9), respectively (Table 1). The differences between the cultivars in fruit weight and fruit firmness were found to be statistically significant ($p<0.05$). Fruit weight and fruit firmness were important criteria in terms of commercial value in apples. The highest fruit weight was obtained in Scarlet Spur/MM 106 cultivar in the study, followed by Red Chief/M9 and Granny Smith/M9 cultivars. In terms of fruit firmness, the highest values were obtained from Granny Smith/M9, Granny Smith/MM 106, and Fuji/MM 106 cultivars. In a study carried out in Çarşamba (Samsun) ecological conditions, it was reported that the highest fruit weight and firmness were obtained from the Granny Smith cultivar as 187.7 g and 86.11 N, respectively (Balta et al., 2020). Oztürk et al. (2016), in their study conducted in Ordu province, reported the fruit weight was between 136.2 (Red Chief)-207.1 g, and the fruit firmness was between 63.43 (Mondial Gala)-82.83 N (Red Chief). In the measurements performed for fruit size, the fruit width of the cultivars was between 70.22 (Mondial Gala/M9)-82.52 mm (Red Chief/MM 106), the fruit thickness was between 63.02 (Mondial Gala/M9)-89.37 mm (Scarlet Spur/MM 106), and the fruit length was between 64.30 (Mondial Gala/M9)-74.83 mm (Granny Smith/M9) (Table 2). The differences between the cultivars in fruit size values were found to be statistically significant ($p<0.05$). In previous studies, the dimensional fruit characteristics have been reported; in the study carried out in Niğde conditions, fruit width was 70.09 (Galaxy Gala/M9)-75.86 mm (Granny Smith/M9), fruit length was 57.55 (Mondial Gala/M9)-66.68 mm (Granny Smith/M9) Ceylan (2008); in a study conducted in Ordu province, fruit width was 67.41 (Red Chief) - 77.60 mm (Granny Smith), fruit length was 58.65 (Red Chief) - 69.07 mm (Granny Smith) (Öztürk et al., 2016); in Çarşamba region, fruit width was 70.74 (Royal Gala)-74.34 mm (Granny Smith), fruit width was 72.67 (Royal Gala)-76.91 mm (Granny Smith) and fruit length was 62.29 (Royal Gala)-65.90 mm (Granny Smith) (Balta et al., 2020). It has been observed that the cultivars examined in terms of fruit weight have relatively higher values than other studies, and they have similarities in fruit firmness and fruit size. It is thought that the observed differences may be due to ecological factors, cultivar/rootstock differences and cultural practices.

Table 1. Fruit weight and firmness values of apple cultivars grafted on M9 and MM 106 clonal rootstocks
Çizelge 1. *M9 ve MM 106 klon anaçları üzerine aşılı elma çeşitlerinin meyve ağırlığı ve sertlik değerleri*

Cultivar/Rootstock	Fruit weight (g)			Fruit firmness (N/mm)		
	2017	2018	Mean	2017	2018	Mean
Mondial Gala/M9	184.14	186.66	185.40 c	79.99	63.46	71.72 c
Jeromine/M9	175.30	271.95	223.63 bc	80.07	67.94	74.01 c
Granny Smith/M9	196.21	282.22	239.21 abc	87.57	81.38	84.47 a
Granny Smith/MM 106	165.84	234.22	200.03 bc	87.68	80.92	84.30 a
Fuji/MM 106	nd*	205.81	205.81 bc	nd	83.06	83.06 ab
Galaxy Gala/MM 106	nd	197.87	197.87 bc	nd	69.73	69.73 c
Red Chief/MM 106	nd	250.14	250.14 ab	nd	71.84	71.84 c
Scarlet Spur/MM 106	nd	284.03	284.03 a	nd	69.80	69.80 c

*nd, non-defined. The difference between the means with the same letter in the same column is not significant ($p<0.05$).

Table 2. Fruit width, thickness and length of apple cultivars grafted on M9 and MM 106 clonal rootstocks
Çizelge 2. *M9 ve MM 106 klon anaçları üzerine aşılı elma çeşitlerinin meyve eni, kalınlığı ve boyu*

Cultivar/Rootstock	Fruit width (mm)			Fruit thickness (mm)			Fruit length (mm)		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
Mondial Gala/M9	66.13	74.31	70.22 b	60.80	65.25	63.02 e	55.56	73.05	64.30 b
Jeromine/M9	74.84	83.58	79.21 a	68.91	88.61	78.76 bc	62.49	74.10	68.30 ab
Granny Smith/M9	75.51	84.20	79.85 a	74.29	87.60	80.94 abc	70.60	79.06	74.83 b
Granny Smith/MM 106	76.02	82.79	79.40 a	73.59	80.21	76.90 bc	70.76	72.86	71.81 ab
Fuji/MM 106	nd*	79.07	79.07 a	nd	65.67	70.24 cd	nd	64.47	64.47 b
Galaxy Gala/MM 106	nd	76.67	76.67 ab	nd	65.67	65.67 de	nd	74.94	74.94 a
Red Chief/MM 106	nd	82.52	82.52 a	nd	85.79	85.79 ab	nd	68.90	68.90 ab
Scarlet Spur/MM 106	nd	78.98	78.98 a	nd	89.37	89.37 a	nd	74.71	74.71 a

*nd, non-defined. The difference between the means with the same letter in the same column is not significant ($p<0.05$).

Table 3. L*, a*, b* values of apple cultivars grafted on M9 and MM 106 clonal rootstocks
Çizelge 3. *M9 ve MM 106 klon anaçları üzerine aşılı elma çeşitlerinin L*, a*, b* değerleri*

Cultivar/Rootstock	L*			a*			b*		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
Mondial Gala/M9	56.92	56.56	56.74 a	23.89	23.31	23.60 ab	28.17	25.73	26.95 c
Jeromine/M9	32.15	37.69	34.92 d	18.63	21.18	19.91 b	8.78	13.83	11.31 e
Granny Smith/M9	54.03	60.07	57.05 a	-18.98	2.84	-8.07 d	38.20	30.43	34.31 b
Granny Smith/MM 106	55.72	60.84	58.28 a	-19.46	-59.77	-19.69 e	40.03	41.45	40.74 a
Fuji/MM 106	nd	61.46	61.46 a	nd	3.57	3.57 c	nd	30.89	30.89 bc
Galaxy Gala/MM 106	nd	50.65	50.65 b	nd	30.35	30.35 a	nd	26.44	26.44 c
Red Chief/MM 106	nd	44.23	44.23 c	nd	21.28	21.28 b	nd	21.13	21.13 d
Scarlet Spur/MM 106	nd	40.68	40.68 cd	nd	21.90	21.90 ab	nd	18.89	18.89 d

*nd, non-defined. The difference between the means with the same letter in the same column is not significant ($p<0.05$).

Table 4. Chroma and hue angle of apple cultivars grafted on M9 and MM 106 clonal rootstocks
Çizelge 4. *M9 ve MM 106 klon anaçları üzerine aşılı elma çeşitlerinin chroma ve hue açısı*

Cultivar/Rootstock	Chroma			Hue Angle		
	2017	2018	Mean	2017	2018	Mean
Mondial Gala/M9	40.89	35.39	38.14 b	52.37	49.32	50.85 d
Jeromine/M9	20.72	25.35	23.03 e	24.77	33.05	28.91 e
Granny Smith/M9	42.67	30.71	36.69 bc	116.42	84.45	100.43 b
Granny Smith/MM 106	44.53	45.99	45.26 a	115.96	115.67	115.81 a
Fuji/MM 106	nd	31.50	31.50 cd	nd	83.00	83.00 c
Galaxy Gala/MM 106	nd	40.90	40.90 ab	nd	41.36	41.36 de
Red Chief/MM 106	nd	30.21	30.21 d	nd	44.93	44.93 d
Scarlet Spur/MM 106	nd	29.36	29.36 d	nd	40.41	40.41 de

*nd, non-defined. The difference between the means with the same letter in the same column is not significant ($p<0.05$).

The differences between the cultivars in fruit color characteristics were found to be statistically significant ($p<0.05$). In the measurements to determine the fruit color, the L* value was found between 34.92 (Jeromine/M9)-61.46 (Fuji/MM 106), a* value was found between -19.69 (Granny Smith/MM 106)-30.35 (Galaxy Gala/MM 106), b* value was found between 11.31 (Jeromine/M9)-40.74 (Granny Smith/MM 106), C* was found between 23.03 (Jeromine/M9)-40.90 (Galaxy Gala/MM 106), and hue angle was found between 28.91 (Jeromine/M9)-115.81 (Granny Smith/MM 106) (Table 3, Table 4). Fruit color is one of the main features that directly affect consumer preference. The L* value represents the brightness of the fruit color. In the study, the brightest varieties of fruit skin were Fuji/MM 106, Granny Smith/MM 106, Granny Smith/M9 and Mondial Gala/M9. The a* value indicates the red-green color of the fruit. In this context, Galaxy Gala/MM 106, Mondial Gala/M9 and Scarlet Spur/MM 106 cultivars were the most red-colored, while Granny Smith/MM 106 and Granny Smith/M9 had green-colored fruit. The chroma value (C*) refers to the saturation of the color and defines the vividness or dullness of the color (Uzun & Ozturk, 2020). The cultivars with the highest C* value in the study were Granny Smith/MM 106 and Galaxy Gala/MM 106 cultivars. When the hue angle values were examined, it was seen that the hue angle values of the red-colored cultivars (Mondial Gala, Jeromine, Fuji, Galaxy Gala, Red Chief, Scarlet Spur) were lower than the green-colored Granny Smith cultivar combinations. Similarly, Ozturk & Ozturk (2016) reported that the hue angle was lower in red varieties than in varieties such as Granny Smith and Golden Delicious.

Table 5. Soluble solids content and titratable acidity values of apple cultivars grafted on M9 and MM 106 clonal rootstocks

Çizelge 5. *M9 ve MM 106 klon anaçları üzerine aşılı elma çeşitlerinin suda çözünebilir kuru madde içeriği ve titre edilebilir asitlik değerleri*

Cultivar/Rootstock	SSC %			TA, % malic acid		
	2017	2018	Mean	2017	2018	Mean
Mondial Gala/M9	13.53	11.57	12.55 b	0.39	0.31	0.35 cd
Jeromine/M9	12.23	12.47	12.35 b	0.69	0.34	0.52 c
Granny Smith/M9	12.10	12.37	12.23 b	1.46	1.13	1.29 a
Granny Smith/MM 106	13.28	11.03	12.16 b	1.24	0.85	1.05 b
Fuji/MM 106	nd	14.27	14.27 a	nd	0.39	0.39 cd
Galaxy Gala/MM 106	nd	11.77	11.77 b	nd	0.32	0.32 cd
Red Chief/MM 106	nd	11.87	11.87 b	nd	0.24	0.24 d
Scarlet Spur/MM 106	nd	8.29	8.29 c	nd	0.25	0.25 d

*nd, non-defined. The difference between the means with the same letter in the same column is not significant ($p<0.05$).

Table 6. pH and vitamin C of apple cultivars grafted on M9 and MM 106 clonal rootstocks

Çizelge 6. *M9 ve MM 106 klon anaçları üzerine aşılı elma çeşitlerinin pH ve C vitamini*

Cultivar/Rootstock	pH			Vitamin C mg 100 g^{-1}		
	2017	2018	Mean	2017	2018	Mean
Mondial Gala/M9	4.29	3.96	4.12 b	93.00	69.33	81.17 cd
Jeromine/M9	4.59	4.36	4.48 a	66.33	68.00	67.17 ef
Granny Smith/M9	3.96	3.53	3.75 c	102.00	122.67	112.33 a
Granny Smith/MM 106	4.01	3.70	3.86 c	97.50	97.00	97.25 b
Fuji/MM 106	nd	3.98	3.98 bc	nd	78.67	78.67 de
Galaxy Gala/MM 106	nd	3.99	3.99 bc	nd	76.00	76.00 de
Red Chief/MM 106	nd	4.23	4.23 ab	nd	92.00	92.00bc
Scarlet Spur/MM 106	nd	4.48	4.48 a	nd	58.00	58.00 f

*nd, non-defined. The difference between the means with the same letter in the same column is not significant ($p<0.05$).

Chemical properties are among the most important factors affecting the taste formation of products. In addition, it is stated that the products contribute to issues such as tolerance to stress factors and post-harvest physiology (Eskimez et al., 2020). Therefore, it is important to identify these features. Soluble solids content and titratable acidity values determined in cultivars are presented in Table 5, pH and vitamin C values are shown in Table 6.

The differences between the cultivars in SSC, TA, pH content, and Vitamin C were found to be statistically significant ($p<0.05$). Additionally, the SSC content was between 8.29% (Scarlett Spur/MM 106)-14.27% (Fuji/MM 106); TA content was between 0.24% (Red Chief/MM 106)-1.29% (Granny Smith/M9); pH content was between 3.75 (Granny Smith/M9)-4.48 (Jeromine/M9, Scarlet Spur/MM 106); and Vitamin C was between 58.00 mg (Scarlet Spur/MM 106)-112.33 mg (Granny Smith/M9). Accordingly, the cultivars with the highest vitamin C content were determined as Granny Smith/M9, Granny Smith/MM 106, Red Chief/MM 106, and Mondial Gala/M9, respectively. In previous studies, SSC, TA, and pH were reported; in Görükle conditions, SSC 12.9-15.8%, TA content 0.25-0.96%, pH 3.15-4.04 (Soylu et al., 2003); in Ordu conditions, SSC 9.13-11.25%, TA content is 0.27-0.67%, pH 3.23-3.82 (Oztürk et al., 2016); in Hatay conditions, SSC 11.38-14.83%, TA content 0.49-1.27%, pH 3.14-3.67, (Bayazit & Caliskan, 2017). Accordingly, the SSC, pH, and TA contents of the cultivars examined in the study were compatible with the literature.

The differences between the cultivars in total phenolics, total flavonoids, and total antioxidant capacity were found to be statistically significant ($p<0.05$). The total phenolics content in the cultivars varied between 102.88 mg 100 g^{-1} (Galaxy Gala/MM 106)-347.62 mg 100 g^{-1} (Red Chief/MM 106), the total flavonoid content between 20.31 mg 100 g^{-1} (Mondial Gala/M9)-186.97 mg 100 g^{-1} (Granny Smith/MM 106), and the total antioxidant activity varied between 980.2 µmol kg^{-1} (Fuji/MM 106)-2298.9 µmol kg^{-1} (Red Chief/MM 106) according to the DPPH test and between 2025.7 µmol kg^{-1} (Galaxy Gala/MM 106)-8214.0 µmol kg^{-1} (Mondial Gala/M9) according to the FRAP test (Table 7). Many studies determined apples' phenolic compound, total flavonoid, and antioxidant activity (Candrawinata et al., 2014; Kammarer et al., 2007; Marinova et al., 2005; Oztürk et al., 2016; Yue et al., 2012). Apples are known as an essential source of natural antioxidants thanks to vitamin C, flavonoids, and phenolic compounds found in their structure (González-Aguilar et al., 2008). Depending on these properties, when consumed regularly, it can help prevent some chronic diseases such as asthma, diabetes, and diseases

such as heart diseases and cancer, and protect human health (Boyer & Liu, 2004). In the study, the highest values regarding total phenolics were determined in Red Chief/MM 106, Granny Smith/MM 106, Mondial Gala/M9, and Granny Smith/M9 combinations, respectively. The highest values in terms of total flavonoids were determined in Granny Smith/MM 106, Granny Smith/M9, Galaxy Gala/MM 106, and Jeromine/M9 combinations. Butkeviciute et al. (2022) reported that proper matching of cultivar-rootstock combinations influenced the production of antioxidant-rich, high-quality, and nutritious fruits. According to the DPPH assay, the highest total antioxidant activity was found in Red Chief/MM106, Jeromine/M9, Mondial Gala/M9, and Granny Smith/M9 combinations, respectively; it was determined in Mondial Gala/M9, Red Chief/MM106, Granny Smith/M9, and Jeromine/M9 combinations according to FRAP assay.

Table 7. Total phenolics, total flavonoids and antioxidant activity of apple cultivars grafted on M9 and MM 106 clonal rootstocks

Çizelge 7. *M9 ve MM 106 klon anaçları üzerine aşılı elma çeşitlerinin toplam fenol, toplam flavonoid ve antioksidan aktivitesi*

Cultivar/Rootstock	Total phenolics (mg 100g^{-1})	Total flavonoids (mg 100 g^{-1})	Total antioxidant activity	
			DPPH (µmol kg^{-1})	FRAP (µmol kg^{-1})
Mondial Gala/M9	286.08 bc	20.31 f	1771.0 b	8242.0 a
Jeromine/M9	252.02 de	108.12 d	2159.5 a	6713.0 c
Granny Smith/M9	270.74 cd	148.52 b	1688.7 bc	7854.0 ab
Granny Smith/MM 106	301.30 b	186.97 a	1413.2 d	7501.0 b
Fuji/MM 106	229.35 e	99.24 d	980.2 e	3750.5 e
Galaxy Gala/MM 106	102.88 g	131.81 c	1440.3 d	2025.7 f
Red Chief/MM 106	347.62 a	104.18 d	2298.9 a	8072.0 ab
Scarlet Spur/MM 106	176.13 f	79.01 e	1540.6 cd	4620.2 d

The difference between the means with the same letter in the same column is not significant ($p<0.05$).

Figure 1. Component plot of the two-principal component in the investigated apple cultivars based on fruit properties and bioactive compounds

Şekil 1. *Meyve özellikleri ve biyoaktif bileşiklere bağlı olarak incelenen elma çeşitlerinde iki temel bileşenin bileşen grafiği*

As a result of principal component analysis, four components with an eigenvalue above one was formed. The first three components formed explained 82.1% of the data. PC 1 was associated with SSC, TA, vitamin C, pH, firmness, L*, a*, b*, chroma, hue angle, and total flavonoids, accounting for 45.1% of the data. PC 2, explaining 21.5% of the data, was related to fruit weight, fruit width, and fruit thickness. PC 3 is related to fruit length, total phenolics, and antioxidant activity (according to DPPH and FRAP) and explained 15.5% of the data (Figure 1).

4. Conclusion

The study showed that Mondial Gala, Jeromine, and Granny Smith cultivars grafted on M9 rootstock and Granny Smith, Fuji, Galaxy Gala, Red Chief, and Scarlet Spur apple cultivars grafted on MM 106 rootstock gave successful results in Ordu province ecology in terms of fruit characteristics. Fruit weight, which significantly affects consumer preference, was found to have the highest values in Scarlet Spur/MM 106, Red Chief/MM 106, and Granny Smith/M9 combinations; and fruit firmness was found to have the highest values in Granny Smith/M9, Granny Smith/MM 106, and Fuji/MM 106 combinations. In terms of bioactive properties that positively affect human health, it can be said that total phenolics stand out in the Red Chief/MM 106 combination and total flavonoids in the Granny Smith/MM 106 combination. In addition, it was determined that the antioxidant activity gave better results in Red Chief/MM 106 and Jeromine/M9 combinations according to the DPPH assay, and in Mondial Gala/M9, Red Chief/MM 106 and Granny Smith/M9 combinations according to the FRAP assay compared to other cultivars. Accordingly, it is thought that the findings obtained from the study are promising, and it will be helpful to examine the performances of these cultivars in the local ecology for a long time.

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References

Aglar, E., Saracoglu, O., Karakaya, O., Ozturk, B., & Gun, S. (2019). The relationship between fruit color and fruit quality of sweet cherry (*Prunus avium* L. cv. '0900 Ziraat'). *Turkish Journal of Food and Agriculture Sciences*, 1(1), 1-5.

Aksoy, B. (2017). Çarşamba'da M9 anacı üzerine aşılı bazı elma çeşitlerinin (Granny Smith, Royal Gala ve Galaxy Gala) verim ve bazı meyve kalite özelliklerinin incelenmesi (Tez No. 484435). [Yüksek lisans tezi, Ordu Üniversitesi]. Yükseköğretim Kurulu Başkanlığı, Ulusal Tez Merkezi.

Balta, M. F., Aksoy, B., Karakaya, O., & Uzun, S. (2020). Çarşamba ekolojik koşullarında yetiştirilen bazı standart elma çeşitlerinin verim ve meyve özellikleri. *Akademik Ziraat Dergisi*, 9(2), 187-192. https://doi.org/10.29278/azd.720106

Bayazıt, S., Kılıç, D., & Gündüz, K. (2019). Performance of Mondial Gala apple cultivars grafted on M9 apple rootstock in the Mediterranean region of Turkey. *Mustafa Kemal Üniversitesi Tarım Bilimleri Dergisi*, 24(1), 43-47.

Benzie, I. F., & Strain, J. J. (1996). The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": The FRAP assay. *Analytical Biochemistry,* 239(1): 70-76. https://doi.org/10.1006/abio.1996.0292

Blois, M. S. (1958). Antioxidant determinations by the use of a stable free radical. *Nature*, 181(4617), 1199-1200. https://doi.org/10.1038/1811199a0

Bolat, İ., Yılmaz, M., & İkinci, A. (2019). Akdeniz geçit kuşağında farklı dönemlerde olgunlaşan bazı elma çeşitlerinin performanslarının belirlenmesi. *Yuzuncu Yıl University Journal of Agricultural Sciences*, 29(2), 258-267. https://doi.org/10.29133/yyutbd.471552

Boyer, J., & Liu, R. H. (2004). Apple phytochemicals and their health benefits. *Nutrition journal*, 3, 1-15. https://doi.org/10.1186/1475-2891-3-5

Butkeviciute, A., Abukauskas, V., Janulis, V., & Kviklys, D. (2022). Phenolic content and antioxidant activity in apples of the 'Galaval' cultivar grown on 17 different rootstocks. *Antioxidants*, 11(2), 266. https://doi.org/10.3390/antiox11020266

Candrawinata, V. I., Golding, J. B., Roach, P. D., & Stathopoulos, C. E. (2014). Total phenolic content and antioxidant activity of apple pomace aqueous extract: Effect of time, temperature and water to pomace ratio. *International Food Research Journal*, 21(6), 2337-2344.

Ceylan, F. (2008). Bodur ve yarı bodur anaçlar üzerine aşılı bazı elma çeşitlerinin Niğde ekolojik şartlarında fenolojik ve pomolojik özelliklerinin tespiti (Tez No. 178302). [Yüksek lisans tezi, Selçuk Üniversitesi]. Yükseköğretim Kurulu Başkanlığı, Ulusal Tez Merkezi.

Dadashpour, A., Talaie, A. R., Askari-Sarcheshmeh, M. A., & Gharaghani, A. (2019). Influence of two training systems on growth, yield and fruit attributes of four apple cultivars grafted onto 'M. 9'rootstock. *Advances in Horticultural Science*, 33(3), 313-320. https://doi.org/10.13128/ahs-23353

Eskimez, İ., Polat, M., & Mertoğlu, K. (2020). M9 anacı üzerine aşılı Arapkızı, Jonagold ve Fuji Kiku elma (*Malus domestica* Borkh.) çeşitlerinin Isparta ekolojik koşullarında fenolojik ve fiziko-kimyasal özellikleri. *Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi*, 6(2), 152-159. https://doi.org/10.24180/ijaws.709110

Gjamovski, V., & Kiprijanovski, M. (2011). Influence of nine dwarfing apple rootstocks on vigour and productivity of apple cultivar 'Granny Smith', *Scientia Horticulturae*, 129(4), 742-746. https://doi.org/10.1016/j.scienta.2011.05.032

González-Aguilar, G., Robles-Sánchez, R. M., Martínez-Téllez, M. A., Olivas, G. I., Alvarez-Parrilla, E., & De La Rosa, L. A. (2008). Bioactive compounds in fruits: Health benefits and effect of storage conditions. *Stewart Postharvest Review*, 4(3), 1-10. https://doi.org/10.2212/spr.2008.3.8

Kammerer, D. R., Saleh, Z. S., Carle, R., & Stanley, R. A. (2007). Adsorptive recovery of phenolic compounds from apple juice. *European Food Research and Technology*, 224(5), 605-613. https://doi.org/10.1007/s00217-006-0346-5

Marinova, D., Ribarova, F., & Atanassova, M. (2005). Total phenolics and total flavonoids in Bulgarian fruits and vegetables. *Journal of the University of Chemical Technology and Metallurgy*, 40(3), 255-260.

McGuire, R. G. (1992). Reporting of objective color measurements. *HortScience*, 27(12), 1254-1255. https://doi.org/10.21273/HORTSCI.27.12.1254

Ozkan, Y., Küçüker, E., Çekiç, Ç., Mehder, B., & Çakır, A. (2009). Slender spindle (İnce iğ) sistemi uygulanmış bazı elma çeşitlerinde ağaç ve meyve özellikleri. *Tarım Bilimleri Araştırma Dergisi*, 2(2), 137-143.

Ozmen, Z. S., & Çekiç, Ç. (2018). Tokat Yöresinde Yetişen Yerel Elma Genotiplerinde Pomolojik Özelliklerin Tespiti. *Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi*, 35(Ek Sayı), 102-107. https://doi.org/10.13002/jafag4516

Ozongun, Ş., Dolunay, E., Öztürk, G., & Pektaş, M. (2014). Eğirdir (Isparta) şartlarında bazı elma çeşitlerinin performansları. *Meyve Bilimi*, 1(2), 21-29.

Ozongun, Ş., Dolunay, E., Pektaş, M., Öztürk, G., Çalhan, Ö., & Atay, E. (2016). Farklı klon anaçları üzerinde bazı elma çeşitlerinin verim ve kalite değişimleri. *Ege Üniversitesi Ziraat Fakültesi Dergisi*, 53(1), 35-42. https://doi.org/10.20289/zfdergi.179870

Ozturk, A., & Ozturk, B. (2016). Samsun ekolojisinde yetiştirilen standart bazı elma çeşitlerinin fenolojik ve pomolojik özelliklerinin belirlenmesi. *Anadolu Tarım Bilimleri Dergisi*, 31(1), 1-8. https://doi.org/10.7161/anajas.2016.31.1.1-8

Oztürk, B., Uzun, S., Bektaş, E., Yarılgaç, T., Karakaya, M., Karakaya, O., Gün, S., & Turga, E. (2016). Determination of yield and quality characteristics of some apple cultivars grafted on M9 rootstock under ecological conditions of Ordu province. *Bahçe*, 45: 492-497.

Soylu, A., Ertürk, Ü., Mert, C., & Öztürk, Ö. (2003). MM 106 anacı üzerine aşılı elma çeşitlerinin Görükle koşullarındaki verim ve kalite özelliklerinin incelenmesi-II. *Uludağ Üniversitesi Ziraat Fakültesi Dergisi*, 17(2), 57-65.

Sensoy, M., & Bostan, S. Z. (2019). Ulubey ilçesinde (Ordu) MM 106 ve M 9 anaçları üzerindeki 'Granny Smith' elma çeşidinin ilk yıllar verim ve pomolojik özellikleri. *Akademik Ziraat Dergisi*, 8(1), 9-12. https://doi.org/10.29278/azd.592940

Turan, S., & Karlıdag, H. (2022). Bazı elma çeşitlerinin Malatya ili Battalgazi ilçesi ova koşullarında performanslarının belirlenmesi. *Harran Tarım ve Gıda Bilimleri Dergisi*, 26(2), 169-180. https://doi.org/10.29050/harranziraat.1078373

Uzun, S., & Ozturk, B. (2020). Effects of aminoethoxyvinylglycine and modified atmosphere packaging treatments on the color characteristics and antioxidant activity of kiwifruit during cold storage and shelf life. *Journal of Postharvest Technology*, 8(4), 9-17.

Yue, T., Bai, X., Zhang, H., & Yuan, Y. (2012). Fractionation and anti-inflammatory effects of polyphenol-enriched extracts from apple pomace. Bangladesh Journal of Pharmacology, 7(1), 28-32. https://doi.org/10.3329/bjp.v7i1.10194

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Thrips (Insecta: Thysanoptera) Species in Pepper Fields in Tokat Province, Türkiye

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Abstract: Thrips (Thysanoptera) species in pepper fields was determined in Tokat province, Türkiye in 2021-2022. The density of thrips began to rise once the leaves emerged in late May, and the collection of thrips species started in June to October. In order to determine the thrips species common in the region, 25 flowers from a total of 25 plants randomly selected in the pepper field during each sampling period were taken into falcon tubes containing 60% ethyl alcohol. At the same time, the flowers and leaves of 25 plants, representing the field, were shaken onto white paper and the thrips were taken into 1.5 ml eppendorf tubes containing 60% ethyl alcohol with the help of a sable-tipped brush. In order to determine the common thrips species in the region, the flowers and leaves of 25 randomly selected plants in the pepper field in each sampling period were shaken on the white paper and the thrips were taken into 1.5 ml eppendorf tubes with the help of a sable-tipped brush. The assessment encompassed various thrips families belonging to the order Thysanoptera, specifically Thripidae, Aeolothripidae, and Phlaeothripidae. A total of 7 Thysanoptera species were identified in this study. The species were *Frankliniella occidentalis* (Pergande, 1895), *Thrips tabaci* (Lindeman, 1889), *Thrips meridionalis* (Priesner 1926) and *Chirothrips manicatus* (Haliday, 1836) in Thripidae family, and *Aeolothrips intermedius* (Bagnall, 1934) and *Aeolothrips fasciatus* (Linnaeus, 1758) in Aeolothripidae family, and *Haplothrips aculeatus* (Fabricius, 1803) in Phlaeothripidae family. Both adult and larval thrips were gathered from the flowers, with a significant abundance of larval thrips noted towards the end of June. In this study, the dominant species was *F. occidentalis* in pepper fields in Tokat province.

Keywords: Pepper , thrips, Thripidae, Aeolothripidae, Phlaeothripidae, Türkiye

Türkiye'de Tokat İlinde Biber Alanlarında Görülen Thrips (Insecta: Thysanoptera) Türleri

Öz: Türkiye'nin Tokat ili 2021-2022 yıllarında biber tarlalarında Thrips (Thysanoptera) türleri tespit edilmiştir. Mayıs ayı sonlarında yaprakların ortaya çıkmasıyla birlikte thrips yoğunluğu artmaya başlamış ve thrips türlerinin toplanması Haziran-Ekim ayları arasında yapılmıştır. Yörede yaygın olan trips türlerinin belirlenmesi amacıyla her örnekleme döneminde biber tarlasında rastgele seçilen toplam 25 bitkiden 25 çiçek%60'lık etil alkol içeren falkon tüplerine alınmıştır. Aynı zamanda tarlayı temsil edecek şekilde 25 bitkinin çiçek ve yarpakları beyaz kağıdın üzerine silkelenerek tripsler samur uçlu fırça yardımıyla 1,5 ml'lik efendorf tüplerine alınmıştır. Thysanoptera takımına ait Thripidae, Aeolothripidae ve Phlaeothripidae familyalarına ait 7 tür tespit edilmiştir. Türler, Thripidae familyasından *Frankliniella occidentalis* (Pergande, 1895), *Thrips tabaci* (Lindeman, 1889), *Thrips meridionalis* (Priesner 1926), *Chirothrips manicatus* (Haliday, 1836), *Aeolothrips intermedius* (Bagnall, 1934) ve Aeolothripidae familyasından *Aeolothrips fasciatus* (Linnaeus 1758) ve Phlaeothripidae familyasından *Haplothrips aculeatus* (Fabricius, 1803) tespit edilmiştir. Çiçeklerden hem ergin ve hemde larvalar toplanmıştır. Bu çalışmada Tokat ili biber alanlarında ana türün *F. occidentalis* olduğu ortaya konulmuştur.
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Anahtar kelimeler: Biber , thrips, Thripidae, Aeolothripidae, Phlaeothripidae , Türkiye

1. Introduction

Türkiye is a major producer of pepper, according to (2021) statistics, global pepper production reached 42.137.899 tons, with Türkiye ranking as the second-largest producer after Mexico, while the United States stood third (FAO, 2020). In 2021, Türkiye produced a total of 36.286.643 tons of pepper (FAO, 2023). Pepper production faces various pests, including aphids, flea beetles, pepper maggots, thrips, and European corn borers, all of which can cause substantial damage to the crops, additionally, several diseases. Thrips are a significant pest for horticultural crops globally as they can damage many crops and spread various plant viruses. Thrips has a slender and elongated body, measuring approximately 1-

2.5 mm or less in length, they have two pairs of fringed wings and exhibit a pale yellow to light brown colouration, generally adult females are larger than adult males, thrips are classified in the insect order Thysanoptera (Palmer et al., 1989). Thrips have the potential to affect both the quantity and quality of flower production in both greenhouse and field-grown plants, both larvae and adults cause damage by sucking plant sap from buds, flowers, and leaves, leading to distorted and discolored plant parts that exhibit gray or silver scars, in the damaged areas of the plant become filled with air, resulting in a silvery appearance with black spots (Bethke and Bates, 2013). Thrips have the ability to transmit various viruses, such as the tomato spotted wilt virus (TSWV) (Flint, 1998). Thrips species such as *Thrips tabaci* (Lindeman, 1889) and *Frankliniella occidentalis* (Pergande, 1895) can result in stippled and scarred petals, leaves, and other plant parts, leading to distorted terminals. These thrips are also significant carriers of TSW viruses, the life cycle of thrips encompasses an egg stage, two larval stages, a prepupal stage, a pupal stage, and an adult stage. The prepupal and pupal stages occur in protected locations or in the soil, thrips thrive better on flowering plants like sweet peppers compared to non-flowering plants (Hoddle etal., 2008). *Frankliniella occidentalis* and *T. tabaci* becomes active during the onset of spring and deposits its eggs on plant tissue. (Anonymous, 2002). Several studies were conducted to determine the thrips composition in tomato and pepper (Ssemwogerere et al., 2013), citrus species (Atakan, et al., 2016; Atakan, et al., 2021; Atakan and Pehlivan, 2021), fruit species (Hazır et al., 2011; Atakan, 2008), and winter vegetable (Atakan, 2008). In the study conducted by Ssemwogerere et al. (2013) a total of six thrips species (*Frankliniella occidentalis*, *Thrips tabaci*, *F. schultzei, Scirtothrips dorsalis*, *Ceratothrips ericae* and *Megalurothrips sjostedti)* determined in tomato field in Uganda and in pepper fields, beside these species *F. schultzei* was found. In the study performed in Adana, Türkiye, *F. occidentalis, T. tabaci,* and *Thrips hawaiiensis* were determined as a common species on citrus species (Atakan and Pehlivan, 2021). Based on the literature review, there are no studies on thrips compositions of pepper in Türkiye. So present study was conducted to determine the thrips species in pepper production areas of Tokat province, Türkiye.

2. Materials and Methods

The materials used in this study for thrips collection included a white paper, a fine brush petri dishes, plastic tubes and methanol.

Thrips species were sampled in pepper fields in the province of Tokat, Türkiye. Thrips individuals were collected from the districts in the pepper production areas during the years 2021-2022. Sampling was carried out in different districts including Tokat Centre, Erbaa, Turhal, Pazar and Niksar. In each sampling field, 25 plant leaves and flowers were carefully collected and transferred into 50 ml falcon tubes with 60% ethyl alcohol solution from randomly selected pepper plants in the pepper field. At the same time, the flowers and leaves of 25 plants, representing the field, were shaken onto white paper and the thrips were taken into 1.5 ml ephendorf tubes containing 60% ethyl alcohol with the help of a sable-tipped brush. In each sampling field we also sampled Solaneaceae family weed host plants for thrips. In pepper field areas especially *Solanum nigrum* L. is a common weed in pepper field areas. We sampled 25 *S. nigrum* flowers from each field. The flower samples were transported to the laboratory and thrips were placed in glass petri dishes for examination, to identify thrips species in pepper production areas of Tokat Province, Türkiye. They were observed using a stereomicroscope, thrips specimens, which were kept in AGA liquid (9 parts ethyl alcohol, 1-part glacial acetic acid, 1-part glycerin) for 2 days after collection and then taken in alcohol (60% ethyl alcohol), were kept in 10% NAOH liquid on the hot plate at 47°C for approximately 1 hour until a slight color change occurred in the individuals. Then, this liquid was allowed to enter the thrips body, and the body contents were cleaned by the very fine needle. After the samples were kept in 96% ethanol for 5 minutes, they were taken to Hoyer medium and microscope slides were made. Thysanoptera species were identified by Prof. Dr. Ekrem ATAKAN (Çukurova University, Faculty of Agriculture, Department of Plant Protection, Adana, Türkiye).

3. Results and Discussion

Thrips survey was carried out for two years, adults and larvae of thrips individuals belonging to the order Thysanoptera were collected from Tokat Province and its districts, Three different families of order Thysanoptera were found namely: Thripidae, Aeolothripidae and Phlaeothripidae. In (Table1) the determined thrips species

were given in family: Thripidae, *Frankliniella occidentalis (*Pergande, 1895), *Thrips tabaci* (Lindeman, 1889), *Thrips meridionalis* (Priesner, 1926) and *Chirothrips manicatus* (Haliday, 1836). In family Aeolothripidae were determined *Aeolothrips intermedius* (Bagnall, 1934) and *Aeolothrips fasciatus* (Linnaeus, 1758). In family Phlaeothripidae was determined *Haplothrips aculeatus* (Fabricius, 1803), the biggest group of thrips species belongs to the suborder Thripinae (Table 1).

In this study, 7 thrips species from three different families were found. The species are listed with their abundance (total numbers of individuals collected for a given species) in Table 2. While the major species were from the family Thripidae, the thrips were dominated by *F.occidentalis*, comprising (73.22%) of the total individuals. The percentages of *T.meridionalis* and *C. manicatus*were (0.1%). The total number of *H. aculeatus*with (0.2) individuals. There were no individuals of thrips belonging to *A. fasciatus* in 2021. This result agreed with (Deligeorgidis et al., 2005). They mentioned that the population of *F. occidentalis* and *T. tabaci* feeding on various types of vegetables from April to August or September, varied with the seasons. *Frankliniella occidentalis* species were identified in various locations, including the central area of Tokat, Erbaa, Niksar, Pazar, and Turhal. The samples collected indicated variations in population density.

In Table (2), the number of larvae and adult individuals (males and females) of *F. occidentalis* is presented. The largest samples of individuals were collected in the central area of Tokat, with a total of 20♀ 5♂ in 2021, and 18♀ 7♂ in 2022. The lowest number of individuals was collected in Pazar with 2♀ in 2021, also in Turhal founded 3♀ in 2023.This result agreed with (Kirk and Terry, 2003*).* Who mentioned that the western flower thrips (*F. occidentalis*) is a native of western North America, greenhouse pest in the U.S and capable present in Asia. The dominant species was *F. occidentalis* in pepper fields in Tokat Province. This result agreed with (Ertürk, 2018), who mentioned that the *F. occidentalis* which is an important pest in tomato and green pepper growing areas in Türkiye, the trials were conducted in Mersin, due to infestations of *F. occidentalis* damaging the export quality of tomatoes and green peppers.

Table (3) shows the data for individual T. tabaci, the results indicate that the highest numbers of males and females were found in the center, with approximately 21♀ 9♂ in 2021, and in Erbaa, with 14♀1♂ in 2021. However, the lowest number of individuals was observed in Pazar with 1♀ in 2022. This result agreed with (Atakan, 2008). Who mentioned that *F. occidentalis* and *T. tabaci* are dominant species in vegetable crops in Türkiye. They have been recorded in winter vegetables in the Çukurova region, the most thrips were collected from flowers or heads of vegetables in early spring**.**

The species *T. meridionalis* was observed in very low numbers, as indicated in (Table 4), only one female was observed in Pazar in 2021, suggesting that the species was not abundant there. This result agree with results of Aydın, (2020). In that study, the species *T. meridionalis*, belonging to the family Thripidae, was examined in three different orchards in the province of Isparta/ Türkiye, the selected orchards featured apple, cherry, and walnut trees, the active period for *T. meridionalis* was found to be between March 15th and April 1st, indicating that this variety appears for only a short period. In contrast Kaplan et al. (2016) found that *T. meridionalis* was an infrequent species (0.8%) in Mardin Province, Türkiye. However, *T. meridionalis* were observed in large numbers even though it seems to be active only short time in each year. This could be related to the seasonal blooming of its host plants and other environmental conditions (Alford 2007).

Table 1. Thrips species individuals and family in pepper fields of Tokat province in 2021-2022
Çizelge 1. *2021-2022 yılında Tokat ilinde biber alanlarında bulunan trips familyaları ve türleri*

Family	Thrips species	2021	2022	Total	Percent %)
Thripidae	*F. occidentalis (*Pergande, 1895)	141	127	268	73.22
	Thrips tabaci (Lindeman, 1889)	61	18	79	21.58
	Thrips meridionalis (Priesner, 1926)	1	0	1	0.27
	Chirothrips manicatus (Haliday, 1836)	0	1	1	0.27
Aeolothripidae	*Aeolothrips intermedius* (Bagnall, 1934)	3	0	3	0.82
	Aeolothrips fasciatus (Linnaeus, 1758)	0	12	12	3.28
Plaeothripidae	*Haplothrips aculeatus* (Fabricius, 1803)	0	2	2	0.55
Total		206	160	366	100.00

Table 2. Surveying results of *Frankliniella occidentalis* in the pepper fields of Tokat Province
Çizelge 2. *Tokat ilinde biber alanlarında bulunan Frankliniella occidentalis'in dağılımı*

Number of sample	Region	Province/ District	Coordinates		Altitude (meters)	Day-Month- year	No. of individual
			North	East			
1	Tokat	Center	40^{0}55′24′′	37^{0}39′21′′	610	20.07.2021	20♀ 5♂
2	Tokat	Center	40^{0}55′24′′	37^{0}39′21′′	610	15.08.2022	18♀ 7♂
3	Tokat	Gumenek	40^{0}42′24′′	36^{0}32′21′′	201	15.09.2021	1♀ 5♂
4	Erbaa	Kaleköyü	40^{0}44′55′′	36^{0}31′22′′	208	04.08.2022	3♀ 3♂
5	Erbaa	Karaağaç	40^{0}35′31′′	36^{0}55′47′′	317	04.08.2022	4♀ 3♂
6	Erbaa	Kızılçubuk	40^{0}40′39′′	36^{0}32′49′′	192	30.09.2021	5♀
7	Erbaa	Kızılçubuk	40^{0}44′31′′	36^{0}35′24′′	189	04.08.2022	4♀
8	Erbaa	Kızılköyü	40^{0}21′35′′	36^{0}38′22′′	628	04.08.2022	8♀ 2♂
9	Erbaa	Kızılköyü	40^{0}22′33′′	36^{0}40′59′′	624	04.08.2022	18♀ 4♂
10	Erbaa	Kızılköyü	40^{0}22′21′′	36^{0}41′20′′	625	04.08.2022	7♀ 1♂
11	Erbaa	Tebe kışlı	40^{0}42′24′′	36^{0}32′39′′	201	30.09.2021	5♀ 1♂
12	Erbaa	Tebe kışlı	40^{0}41′28′′	36^{0}32′19′′	199	30.09.2021	5♀ 1♂ 3l
13	Erbaa	Tepe kışla	40^{0}40′4′′	36^{0}38′21′′	220	04.08.2022	6♀ 1l
14	Erbaa	Tosunlar	40^{0}34′26′′	36^{0}54′50′′	296	30.09.2021	14♀ 1♂ 7l
15	Erbaa	Tosunlar	40^{0}44′52′′	36^{0}25′87′′	134	30.09.2021	2♀
16	Erbaa	Tosunlar	40^{0}41′28′′	36^{0}32′19′′	199	30.09.2021	2♀ 1l
17	Niksar	Hamidiye	40^{0}35′29′′	36^{0}56′10′′	277	30.09.2021	5♀ 3l
18	Niksar	Hayderbey	40^{0}33′57′′	36^{0}54′27′′	500	04.08.2022	6♀ 2♂ 1l
19	Niksar	Şahinli	40^{0}35′29′′	36^{0}56′10′′	277	30.09.2021	8♀ 1♂ 18l
20	Pazar	Center	40^{0}14′88′′	36^{0}12′07′′	553	15.09.2021	8♀ 2♂ 2l
21	Pazar	Center	40^{0}16′32′′	40^{0}16′34′′	561	11.11.2022	2♀ 1♂
22	Pazar	Köprübasi	40^{0}17′12′′	36^{0}21′78′′	554	15.09.2021	2♀ 1♂
23	Pazar	Ovayurt	40^{0}18′40′′	36^{0}14′59′′	539	11.11.2022	4♀ 1♂
24	Pazar	Üzümören	40^{0}16′50′′	36^{0}10′59′′	537	11.11.2022	8♀
25	Pazar	Center	40^{0}21′35′′	36^{0}38′59′′	569	15.09.2021	2♀
26	Pazar	Center	40^{0}16′56′′	36^{0}18′19′′	549	15.09.2021	2♀
27	Turhal	Dökmetepe	40^{0}18′19′′	36^{0}18′4′′	549	11.11.2022	7♀ 6♂
28	Turhal	Kat	40^{0}21′35′′	36^{0}38′59′′	569	15.09.2021	3♀ 3l
29	Turhal	Kat	40^{0}21′35′′	36^{0}38′31′′	636	15.09.2021	3♀

*(l) Letter indicated to the larvae number.

Table 3. *Thrips tabaci* survey in the pepper fields of Tokat Province
Çizelge 3. *Tokat ilinde biber alanlarında bulunan Thrips tabaci'nin dağılımı*

Number of sample	Region	Province/ District	Coordinated		Altitude (meters)	Day-Month-year	No. of species
			North	East			
1	Tokat	Center	40^{0}55′24′′	37^{0}39′21′′	610	15.08.2021	21♀ 9♂
2	Erbaa	Kale	40^{0}40′16′′	36^{0}38′19′′	224	30.09.2021	8♀
3	Erbaa	Kızılköyü	40^{0}22′14′′	36^{0}341′21′′	632	04.08.2022	2♀ 1♂
4	Erbaa	Tosunlar	40^{0}40′22′′	36^{0}29′17′′	193	30.09.2021	14♀ 1♂
5	Pazar	Center	40^{0}16′59′′	36^{0}17′23′′	553	15.09.2021	1♀ 7 l
6	Pazar	Center	40^{0}16′7′′	36^{0}74′9′′	545	04.08.2022	5♀
7	Pazar	Ovayurtköyü	40^{0}16′58′′	36^{0}12′2′′	540	04.08.2022	6♀
8	Pazar	Üzümören	40^{0}16′50′′	36^{0}10′59′′	537	04.08.2022	1♀
9	Turhal	Dökmetepe	40^{0}18′23′′	36^{0}17′37′′	555	11.11.2022	3♀

The species *T. meridionalis* was observed in very low numbers, as indicated in (Table 4), only one female was observed in Pazar in 2021, suggesting that the species was not abundant there. This result agree with results of Aydın, (2020). In that study, the species *T. meridionalis*, belonging to the family Thripidae, was examined in three different orchards in the province of Isparta/ Türkiye, the selected orchards featured apple, cherry, and walnut trees, the active period for *T. meridionalis* was found to be between March 15th and April 1st, indicating that this variety appears for only a short period. In contrast Kaplan et al. (2016) found that *T. meridionalis* was an infrequent species (0.8%) in Mardin Province, Türkiye. However, *T. meridionalis* were observed in large numbers even though it seems to be active only short time in each year. This could be related to the seasonal blooming of its host plants and other environmental conditions (Alford 2007).

The *Chirothrips manicatus* species appeared in very few numbers, in (Table 5) shows that only 1 female observed in Pazar in 2022. Additionally, this species was not found in the central location. This species founded in many province of Türkiye. Uzun Yiğit et al., (2022), mentioned that the *C. manicatus* was found in Afyonkarahisar, Antalya, Burdur, Konya, and Isparta cereals production areas.

The species *A. intermedius* was found in low numbers, in (Table 6) shows approximately 1♀ in the center in 2021 and 2♀ in Erbaa in 2021, *Aeolothrips intermedius* found in pepper flowers. This result agreed with Trdan et al., (2005), mentioned that the *A. intermedius*, which inhabit flowers, have been observed on a wide range of 30 host plant species across 16 different botanical families, particularly on the vegetative portions of cultivated plants. Research on the Thysanoptera fauna in Türkiye's Aegean region was conducted in the spring seasons of 1993 and 1995, the study covered several provinces, including Afyonkarahisar, Aydın, Denizli, İzmir, Manisa, Muğla, and Uşak, and resulted in new findings for both the region and the country, newly recorded species for the Turkish fauna included *T. meridionalis,T.tabaci*, *A. intermedius*, and *Haplothrips reuteri* (Karny).

The species *Aeolothrips fasciatus* was found in varying numbers, with 1♀ 1♂ in Erbaa, 2♀ 1♂ in Niksar, and 5♀ and 2♂ in Turhal in 2022, (Table 7).

Table 4. *Thrips meridionalis* survey in the pepper fields of Tokat Province
Çizelge 4. *Tokat ilinde biber alanlarında bulunan Thrips meridionalis'in dağılımı*

Number of sample	Region	Province/ District	Coordinated		Altitude (meters)	Day-Month year	No. of species
			North	East			
1	Pazar	Center	40º14′88′′	36º12′07′	553	15.09.2021	1♀

Table 5. *Chirothrips manicatus* survey in the pepper fields of Tokat Province
Çizelge 5. *Tokat ilinde biber alanlarında bulunan Chirothrips manicatus'un dağılımı*

Number of sample	Region	Province/ District	Coordinated		Altitude (meters)	Day-Month-year	No. of species
			North	East			
1	Pazar	Kaledere	$40^0$19′20′′	$36^0$13′18′′	541	11.11.2022	1♀

Table 6. *Aeolothrips intermedius* survey in the pepper fields of Tokat Province
Çizelge 6. *Tokat ilinde biber alanlarında bulunan Chirothrips manicatus'un dağılımı*

Number of sample	Region	Province/ District	Coordinated		Altitude (meters)	Day-Month-year	No. of species
			North	East			
1	Tokat	Center	$40^0$55′24′′	$37^0$39′21′′	610	16.09.2021	1♀
2	Erbaa	Tosunlar	$40^0$40′16′′	$36^0$38′19′′	224	30.09.2021	2♀

Table 7. *Aeolothrips fasciatus* survey in the pepper fields of Tokat Province
Çizelge *7. Tokat ilinde biber alanlarında bulunan Aeolothrips fasciatus'un dağılımı*

Number of sample	Region	Province/ District	Coordinated		Altitude (meters)	Day-Month-year	No. of species
			North	East			
1	Erbaa	Kaleköyü	$40^0$45′0′′	$36^0$31′21′′	207	04.08.2022	1♀ 1♂
2	Niksar	Hayderbey	$40^0$33′13′′	$36^0$54′53′′	315	04.08.2022	2♀ 1♂
3	Turhal	Center	$40^0$18′19′′	$36^0$18′4′′	549	11.11.2022	5♀ 2♂

Table 8. *Haplothrips aculeatus* survey in the pepper fields of Tokat Province
Çizelge 8. *Tokat ilinde biber alanlarında bulunan Haplothrips aculeatus'un dağılımı*

Number of sample	Region	Province/ District	Coordinated		Altitude (meters)	Day-Month- year	No. of species
			North	East			
1	Pazar	Kaledere	$40^0$19′20′′	$36^0$13′18′′	541	11.11.2022	1♀
2	Turhal	Şatroba	$40^0$17′12′′	$40^0$81′02′′	541	11.11.2022	1♀

The species *H. aculeatus* recorded in Pazar and Turhal in rate 1♂: 1♂ in 2022, (Table 8). This result agreed with findings of Çinkul etal., (2021). Who founded *Haplothrips* species in flowers of in the stone and pome fruit orchards in the districts of Balıkesir Province, Türkiye, in 2018 and 2019. This study was carried out to identify species belonging to Thysanoptera in stone and pome fruit orchards in the districts (Balya, Bandırma, Bigadiç, Burhaniye, Dursunbey, Erdek, Gönen, Havran, Kepsut and Manyas) of Balıkesir Province, Türkiye in 2018 and 2019. The survey revealed 32 Thysanoptera (thrips) species. Thrips were examined in 9900 flowers, leaves, and fruits species were, *H. reuteri T. meridionalis*.

3.1.Thrips Survey on the *Solanum nigrum*

In summer 2021-2022, a survey was conducted in various locations of Tokat province (Erbaa, Niksar, Pazar, Turhal and the center) to identify thrips species in the weeds surrounding pepper fields, the results shown that all the species found in these areas were *F. occidentalis.* The highest rate recorded in the center in the rate 12♀ 1♂ in 2021 (Table 9), and the number of *F. occidentalis* found in large numbers in Erbaa and Niksar, while the numbers were few in Turhal where it was found 9♀ in 2022.

In the summer of 2021-2022, a survey was conducted in various locations within Tokat Province, including Erbaa, Niksar, Pazar, Turhal, and the provincial center, to identify thrips species in the weeds surrounding pepper fields. The results indicated that all the species identified in these areas were *F. occidentalis*. The highest population was recorded in the provincial center, with a count of 12♀ and 1♂ in 2021, as shown in Table 9. *Frankliniella occidentalis* was also found in large numbers in Erbaa and Niksar. In contrast, the species was less abundant in Turhal, where only 9♀ were observed in 2022. This result agree with (Suganthy and Sakthivel, 2012) who mentioned that the *Solanum nigrum* Linn. is an annual herbaceous plant belongs to the family Solanaceae, it is commonly known as black nightshade, attacked different species of insect pests, like *Thrips* spp.

Table 9. *Frankliniella occidentalis* survey in the *Solanum nigrum* of Tokat province
Çizelge 9. *Tokat ilinde biber alanlarında Solanum nigrum üzerinde bulunan Frankliniella occidentalis'in dağılımı*

Number of sample	Region	Province/ District	Coordinated		Altitude (meters)	Day-Month-year	No. of species
			North	East			
1	Center	Gumenek	$40^0$21′35′′	$36^0$38′31′′	636	15.09.2021	11♀1♂
2	Center	Gumenek	$40^0$21′39′′	$36^0$38′59′′	603	15.09.2021	12♀ 1♂
3	Center	Kaleköyü	$40^0$40′39′′	$36^0$32′49′′	192	30.09.2021	2♀ 1♂
4	Erbaa	Kaleköyü	$40^0$40′39′′	$36^0$32′49′′	192	30.09.2021	3♀ 1♂
5	Erbaa	Kaleköyü	$40^0$44′55′′	$36^0$31′22′′	208	04.08.2022	21♀ 5♂
6	Erbaa	Karaağaç	$40^0$35′31′′	$36^0$55′47′′	317	04.08.2022	3♀
7	Erbaa	KızılÇubuk	$40^0$44′52′′	$36^0$25′87′′	134	30.09. 2021	18♀ 10♂
8	Erbaa	KızılÇubuk	$40^0$21′35′′	$36^0$38′22′′	628	04.08.2022	4♀ 1♂
9	Erbaa	Tosunlar	$40^0$41′28′′	$36^0$32′19′′	199	30.09. 2021	2♀ 1♂
10	Niksar	Hamidiye	$40^0$34′26′′	$36^0$54′50′′	296	30.09. 2021	11♀ 1♂
11	Niksar	Hayderbey	$40^0$33′57′′	$36^0$54′27′′	500	04.08.2022	11♀ 1♂
12	Niksar	Şahinli	$40^0$35′29′′	$36^0$56′10′′	277	30.09.2021	9♀
13	Niksar	Şahinli	$40^0$35′29′′	$36^0$56′10′′	277	30.09.2021	6♀ 1♂
14	Pazar	Center	$40^0$16′32′′	$40^0$16′34′′	561	11.11.2022	6♀ 1♂
15	Pazar	Ovayurtköyü	$40^0$18′40′′	$36^0$14′59′′	539	11.11.2022	4♀
16	Pazar	Center	$40^0$16′50′′	$36^0$10′59′′	537	11.11.2022	1♀
17	Pazar	Center	$40^0$17′12′′	$40^0$21′78′′	554	15.09.2021	6♀ 1♂
18	Turhal	Dökmetepe	$40^0$18′19′′	$36^0$18′40′′	549	11.11.2022	9♀

4. Conclusion

The results of this study have contributed to the identification of the Thysanoptera order in Tokat Province, Türkiye. Among the seven species identified from various families in this study, two thrips species, *F. occidentalis* and *T. tabaci*, were determined to be the primary species inhabiting the surveyed green pepper fields. However, there is no existing knowledge about the damage they cause or their economic importance in this region. Therefore, further studies are needed to address this issue. The survey indicated that *F. occidentalis* was the only thrips species identified in the weeds adjacent to pepper fields.

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References

Anonymous, (2002). Proposed rules: Interstate Movement of Gardenia from Hawaii. Federal Register, Volume 67, Number 94, Wednesday, May 15: pp. 34626–34630

Atakan, E. (2008). Thrips (Thysanoptera) species and thrips damage associated with strawberry in Adana and Mersin provinces, Turkey. Turkish Journal of Entomology, 32 (2): 91-101. ISSN 1010-6960

Atakan, E., Ölçülü, M., Pehlivan, S., and Satar, S. (2021). A new thrips species recorded in Turkey: *Thrips hawaiiensis* (Morgan, 1913) (Thysanoptera: Thripidae). Turkish Bulletin of Entomology,5(2): 77-84

Aydin,G., Şlachta, M., and Karaca, I. (2020). Detection and monitoring of Thrips meridionalis (Priesner, 1926) (Thysanoptera: Thripidae) with the colored sticky traps. Turkish Journal of Entomology, 44 (3): 285-294 ISSN 1010-6960 E-ISSN 2536-491X

Alford, D. V., 2007. Pests of Fruit Crops: A Color Handbook-A Color Handbook. Academic Press, 461 pp.

Bethke, J., A., and Bates, L. (2013). Pest Notes: Myoporum Thrips. Oakland: Univ. Calif. Agric. Nat. Res. Publ, 74165

Çinkula, B., Atakan, E., and Varlic, SV. (2021). Determination of thrips (Thysanoptera) fauna on stone and pome fruit trees in Balıkesir province, Türkiye. Plant Protection Bulletin, 2021, 61(4) : 38-45

Deligeorgidis, P., Ipsilandis, C., Fotiadou, C., Kaltsoudas, G., Giakalis, L., and Garsen, A. (2005). Fluctuation and distribution of *Frankliniella occidentalis* (Pergande) and *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) populations in greenhouse cucumber and tomato. Pak. J. Biol. Sci. 8 (8): 1105-1111.

Ertürk, S., Şen, F., Alkan, M., and Ölçülü, M. (2018). Effect of different phosphine gas concentrations against Frankliniella occidentalis (Pergande, 1895) (Thysanoptera: Thripidae) on tomato and green pepper fruit, and determination of fruit quality after application under low-temperature storage conditions. Turkish Journal of Entomology., 2018, 42 (2): 85-92 DOI: ISSN 1010-6960 E-ISSN

FAOSTAT;2020.Available: www.fao.org/faostat/en/#data/QC.

FAOSTAT;2023.Available: www.fao.org/faostat/en/#data/QC.

Flint, M. L. (1998). Pests of the Garden and Small Farm: A Grower's Guide to Using Less Pesticide. Oakland: Univ. Calif. Agric. Nat. Res. Publ. 3332.

Hoddle, M. S., Mound, L. A., and Paris, D. (2008).Thrips of California 2012 (CD- ROM) Australia: The University of Queensland. http://hdl.handle.net/102.100.100/120895index=1

Kirk, W.,D.,J., and Terry, L.,I. (2003). The spread of the western flower thrips *Frankliniella occidentalis* (Pergande). Agricultural and Forest Entomology 5: 301–310.

Kaplan, M., E., Bayhan and Atakan, E. (2016). Determination of Thysanoptera species, their seasonal abundance and distribution in vineyard areas of Mardin Province. Turkish Bulletin of Entomology, 6 (2): 161-168.

Suganthy, M., and sakthivel, P. (2012). Efficacy of botanical pesticides against major pests of black nightshade, *Solanum nigrum* linn. International Journal of Pharma and Bio Sciences. Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore,India. ISSN 0975- 6299.

TUIK, (2021). Türkiye İstatistik Kurumu, Bitkisel üretim istatistikleri. https://biruni.tuik.gov.tr / bitkiselapp/bitkisel.zul.

TUIK, (2023). Türkiye İstatistik Kurumu, Bitkisel üretim istatistikleri. https://biruni.tuik.gov.tr /bitkiselapp/ bitkisel.zul.

Trdan, S., Andjus, L., Raspudić, E., and Kač, M. (2005). Distribution of Aeolothrips intermedius Bagnall (Thysanoptera: Aeolothripidae) and its potential prey Thysanoptera species on different cultivated host plants. Journal of Pest Science, 78, 217–226.

Palmer, J.M., Mound, L.A., and du Heaume, G.J. (1989). Thysanoptera, CIE guides to insects of importance to man, Ed.: Betts CR., CAB Int. Inst. Entomol.,The Cambrian News Ltd, Aberystwyth, UK: 73pp

Uzun Yiğit, A. , Demirözer, O. and Minaei, K. (2022). Thrips species associated with cereals of the Lakes Region of Turkey with new records . Mediterranean Agricultural Sciences , 35 (1), 15-19 . DOI: 10.29136/mediterranean.1040263