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ABSTRACTING AND INDEXING SERVICES

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Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi

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Ek Beyaz LED Aydınlatma Uygulamalarının Biber Fidelerinin Kalite Özellikleri Üzerine Etkisi

Effect of Supplementary White LED Lighting Applications on Quality Characteristics of Pepper Seedlings

Yüksel Atakan Bal [1], **Aslıhan Çilingir Tütüncü** [2], **Harun Özer** [3], **Aysun Pekşen** [4]

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Öz: Çalışmanın amacı, gün içerisinde ışık şiddeti 100 µmol m^{-2} s^{-1}'nin altına düştüğünde, gün doğumundan gün batımına kadar gün boyu doğal gün ışığına ve gün doğumundan önce 3 saat ve gün batımından sonra 3 saat (fotoperiyodun uzatıldığı) olmak üzere yapılan beyaz LED ek aydınlatma uygulamalarının biber fide kalitesi üzerine etkilerini belirlemektir. Ek aydınlatma uygulamaları, kontrol (hiçbir ek aydınlatmanın yapılmadığı doğal gün ışığı koşulları) uygulaması ile karşılaştırılmıştır. Çalışma, 2024 Mart ayında cam serada yürütülmüştür. Fide kalitesini belirlemek amacıyla fide boyu, gövde çapı, kök uzunluğu, gövde, kök ve toplam fide kuru ağırlıkları, yaprak alanı, yaprak klorofil içeriği ve stoma iletkenlik değerleri ölçülmüştür. Beyaz LED ek aydınlatma uygulamalarının kök uzunluğu, toplam fide kuru ağırlığı, gövde çapı, yaprak alanı, yaprak klorofil içeriği ve stoma iletkenlik değerleri kontrole göre istatistiksel olarak önemli düzeyde ($p<0.05$) yüksek bulunmuştur. Stoma iletkenliği ve yaprak klorofil içeriği haricinde çalışmada incelenen özellikler bakımından en yüksek değerler gün içerisinde ışık şiddeti 100 µmol m^{-2} s^{-1}'nin altına düştüğünde yapılan ek ışık uygulamasından elde edilmiştir. Çalışmada, fotoperiyodun uzatılması yaprak klorofil içeriği ve stoma iletkenliğini artırırken, en kısa boylu bitkiler (5.95 cm) de bu uygulamadan elde edilmiştir. Gün içerisinde ışık şiddeti 100 µmol m^{-2} s^{-1} altına düştüğünde yapılan beyaz LED ek aydınlatma uygulamasının biber fide kalitesini önemli ölçüde artırdığı belirlenmiştir.

Anahtar Kelimeler: Aydınlatma, biber, biyomas, fide, ışık yoğunluğu, kalite

&

Abstract: The aim of the study was to determine the effects of supplementary white LED lighting applications on pepper seedling quality when the light intensity falls below 100 µmol m^{-2} s^{-1} during the day, compared to natural daylight throughout the day from sunrise to sunset, and from 3 hours before sunrise to 3 hours after sunset (extending the photoperiod). Supplementary lighting applications were compared with the control (daylight conditions without supplementary lighting). The study was carried out in a glass greenhouse in March 2024. To determine the seedling quality, seedling height, stem diameter, root length, stem, root and total seedling dry weights, leaf area, leaf chlorophyll content and stomatal conductance values were measured. Root length, total seedling dry weight, stem diameter, leaf area, leaf chlorophyll content and stomatal conductance values of different supplementary white LED lighting applications were statistically significantly ($p<0.05$) higher compared to the control. The highest values for the traits examined in the study, except for stomatal conductance and leaf chlorophyll content, were obtained from the supplementary light application when the light intensity fell below 100 µmol m^{-2} s^{-1} during the day. In the study, while the photoperiod extension increased the leaf chlorophyll content and stomatal conductance, the shortest plants (5.95 cm) were also obtained from this application. It was determined that the supplementary white LED lighting application significantly increased the pepper seedling quality when the light intensity fell below 100 µmol m^{-2} s^{-1} during the day.

Keywords: Lighting, pepper, biomass, seedling, light intensity, quality

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GİRİŞ

Sebze yetiştiriciliğinde yüksek verim ve kaliteli ürün elde etmek için, tohumluk kadar kullanılan fidelerin kalitesi de önemlidir. Fide yetiştiriciliği stres şartlarının kontrolü, hastalıklarla mücadele, verim ve kalite artışı gibi sağladığı katkılar nedeniyle sebze yetiştiriciliğinde önemli avantajlara sahiptir. Türkiye'de 2000'li yıllara kadar üreticiler yaygın olarak kendi ürettiği fideleri kullanırken, günümüzde ticari fide sektörünün gelişmesine bağlı olarak hazır fide kullanımı yaygınlaşmıştır (Demir vd., 2020). Sebze fideleri, ileri tarım tekniklerinin uygulandığı ticari işletmelerde kontrollü şartlarda üretilmektedir. Ticari fide sektöründe firma sayısının artması ve sektörün gelişmesi; fide kalitesinin artması ve fiyatların düşürülmesi bakımından önemli sonuçlar ortaya koymuştur. Gelişen sebze fidesi üretim sektörü ile yıllık 6 milyar adet fide üretim sayısına ulaşılmıştır. Sebze fidesi üretiminde ilk sırayı domates alırken bunu marul, biber, lahanagiller, hıyar, karpuz ve diğer türler takip etmektedir (Tüzel vd., 2020; Fidebirlik, 2022).

Fide büyümesi, sebze büyümesinin en kritik aşamalarındandır ve yüksek kaliteli sebze üretiminin temelini oluşturur. Yetiştiriciliğin istenen özelliklerde, sağlıklı ve homojen fideler ile yapılması şarttır (Özer, 2018; Öztekin ve Türe, 2019). Ticari fide üreticilerinin birim alandan elde edilen fide miktarını artırmak amacıyla küçük kök hacmine sahip fide kapları kullanmaları ve ışıklanma süresinin az olduğu bölge ve mevsimlerde yapılan fide üretimlerinde aşırı boylanma sorunu ile karşılaşılmaktadır. Aşırı boylanmaya bağlı cılızlaşma, hastalık ve zararlılara karşı hassasiyet, tarla tutumu ve adaptasyonda zorluk, geç çiçeklenme ve boğum aralığı artışına bağlı olarak verim kayıpları gibi istenmeyen sorunlar meydana gelmektedir. Bu durum da araştırmacıları özellikle yetersiz aydınlatma sorununun çözümüne yönelik çalışmalara yöneltmiştir. Fidecilik sektöründe fide boyu, boğum arası uzunluğu, gövde kalınlığı, yaprak sayısı ve kök gelişimi gibi fide kalitesini belirleyen parametrelerin sağlanabilmesi için yeni üretim teknikleri ve uygulamalar yapılmaktadır (Çopur ve Sarı, 2012; Uçan ve Uğur, 2021).

Fidelerde boy kontrolü için sulamanın azaltılması, soğuk su kullanımı, budama, fırçalama ve süpürme gibi kültürel uygulamalar etkili sonuçlar vermediği için genellikle başta Paclobutrazol olmak üzere Klormekuat klorür ve Daminozid vb. çeşitli büyümeyi geciktirici kimyasal kullanımı tercih edilmektedir (Uçan ve Uğur, 2021). Ancak kullanılan bu kimyasalların insan ve çevre sağlığı üzerine olumsuz etkiler oluşturabileceğine yönelik ciddi endişeler bulunmaktadır (Yamada vd., 2001; Uçan ve Uğur, 2021). Boy kontrolü için alternatif bir uygulama da ışık manipülasyonlarıdır (Clifford vd., 2004). Işık, bitki büyümesi ve gelişiminin tüm fizyolojik süreçlerinde temel rollere sahip önemli çevresel faktörlerden birisidir. Işık, bitkiler için enerji kaynağı görevi görür. Işık yoğunluğu, kalitesi, ışıklanma süresi ve yönü bitkilerin morfolojik ve fizyolojik özellikleri üzerine etkilidir ve bitki büyümesinde çok önemli bir role sahiptir. Düşük ışık koşulları özellikle gaz alışverişini etkileyerek bitki büyümesi ve üretkenliğini olumsuz etkilerken, aşırı ışık koşulları ise fotosentez yapan mekanizmalar üzerine zararlı etkilere neden olmaktadır (Li vd., 2017; Izzo vd., 2020; Pan vd., 2020; Zushi vd., 2020; Zheng vd., 2023). Işığın yoğunluğu ve kalitesi bitkilerin büyümesi, morfogenezi ve diğer fizyolojik tepkileri için önemlidir (Li ve Kubota, 2009).

Son yıllarda birçok araştırmacı fide kalitesi ve sebze üretimini artırmak amacıyla seralarda ideal yetiştirme ve aydınlatma koşullarının oluşturulmasına yönelik araştırmalara yönelmiştir. Yaygın olarak kullanılan yapay tamamlayıcı aydınlatma sistemleri floresan, yüksek basınçlı sodyum, metal halide, akkor telli ve LED lambalardır (Xu vd., 2016). Aydınlatma sisteminde uygulanan bu yapay ışık kaynaklarının belirgin dezavantajları vardır. Akkor ampullerin, floresan tüplerin, yüksek basınçlı sodyum lambaların ve metal halide lambaların güç tüketimi çok fazladır, aynı zamanda çok fazla ısı üretirler. Yapay ek aydınlatmanın maliyetinin düşürülmesinin büyük önem taşıdığı günümüzde, LED ışık kaynağı ek aydınlatma sisteminde en iyi seçimdir. LED ışık kaynaklarının enerji tüketiminin düşük olması yanı sıra uzun ömürlü olmaları, hafif olmaları, entegre edilmesinin kolay olması, ısı yaymaması ve farklı dalga boyunda ışık üretilebilmesi gibi avantajları bulunmaktadır (Xu vd., 2016; Wei vd., 2019; Palmitessa vd., 2021; Dyśko ve Kaniszewski, 2021; Zheng vd., 2021). Işık yoğunluğu ve aydınlatma süresi eksikliği olan koşullarda, LED ek aydınlatma sistemlerinin kullanımının fide kalitesi ve verimli üretim için önemli bir araç olacağı düşünülmektedir.

Biber (*Capsicum annum* L.), 2022 yılı verilerine göre dünyada 36.97 milyon ton üretilmektedir. Türkiye, 3.01 milyon ton ile dünya biber yetiştiriciliğinde Çin, Meksika ve Endonezya'dan sonra 4. sırada yer almaktadır

(FAO, 2024). Biber, dünyada ve ülkemizde ekonomik önemi olan ve yaygın olarak üretimi yapılan bir sebze türüdür. Ülkemizde hem örtüaltında hem de açıkta yetiştiriciliği yapılmaktadır. Biber üretiminde verim ve kaliteli üretim için fide kalitesi büyük önem taşımaktadır. Bitki türlerinin ek aydınlatmaya tepkileri farklıdır (Hernández ve Kubota, 2013) ve fide kalitesi için ek aydınlatmanın etkilerinin bitki türüne özgü belirlenmesi gerekmektedir. Bu nedenle çalışmada serada biber fidesi yetiştiriciliğinde en uygun ek LED aydınlatma sistemlerinin belirlenerek ortaya konulması hedeflenmiştir. Bu amaçla çalışmada ilkbahar döneminde biber fidesi yetiştiriciliğinde gün ışığına ek olarak üç farklı ek aydınlatma uygulamasının (gün içerisinde ışık şiddeti 100 μmol m^{-2} s^{-1}'nin altına düştüğünde yapılan beyaz LED ek aydınlatma, gün doğumundan gün batımına kadar gün boyu doğal gün ışığına ek beyaz LED aydınlatma ve gün doğumundan 3 saat önce ve gün batımından 3 saat sonra olmak üzere beyaz LED aydınlatma ile fotoperiyodun uzatıldığı uygulama) fide biyoması ve kalitesi üzerine etkileri araştırılmıştır.

MATERYAL VE METOT

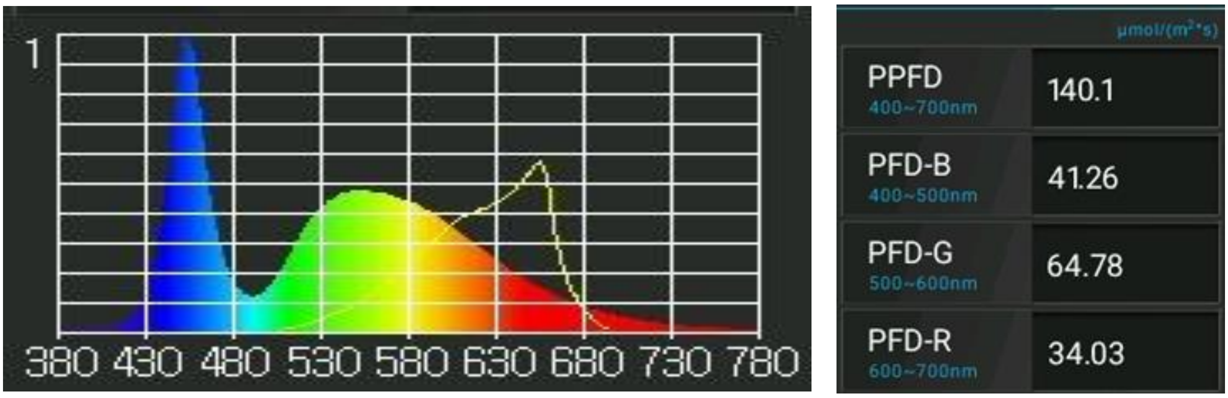
Çalışma, Ondokuz Mayıs Üniversitesi Ziraat Fakültesindeki cam serada (169 m^2) yer alan fide üretim odasında (3.3 m x 7 m) yürütülmüştür. Çalışmada gün ışığına ek olarak 3 farklı beyaz (400-700 nm) dalga boyunda yapılan ek aydınlatma uygulaması (1, 2 ve 3) incelenmiştir (Çizelge 1). Hiçbir ek aydınlatmanın yapılmadığı doğal gün ışığı koşulları kontrol uygulaması olarak ele alınmıştır. LED lamba ayarlamaları akşam saatlerinde hiçbir ışık kaynağı yokken sera iklim kontrol cihazı (LOGO-24CE, Siemens, Berlin, Almanya) ile otomatik olarak yapılmıştır.

Çizelge 1. Çalışmada ele alınan ek aydınlatma uygulamaları.
Table 1. Additional lighting applications considered in the study.

Dalga boyu		Işık uygulaması	DLI (μmol m^{-2} day^{-1})
Beyaz LED 400-700 nm	1	Gün içerisinde ışık şiddeti 100 μmol m^{-2} s^{-1}'nin altına düştüğünde gün ışığına ek aydınlatma	15.96
	2	Gün doğumundan gün batımına kadar gün boyu doğal gün ışığına ek aydınlatma	20.25
	3	Gün doğumundan 3 saat önce ve gün batımından 3 saat sonra olmak üzere yapılan ek aydınlatma ile fotoperiyodun uzatıldığı aydınlatma	16.54
Kontrol (Hiçbir ek aydınlatmanın yapılmadığı doğal gün ışığı koşulları)			15.63

Fide üretim odasında 1 m x 2.5 m x 0.85 m ebatlarında dört adet tezgâh bulunmaktadır. Denemede ele alınan her bir ışık uygulaması, bir tezgâh olacak şekilde düzenleme yapılmıştır. Beyaz LED (400-700 nm) lambalar (Grow Light G1, Plantekno, İstanbul, Türkiye) viyollerin üzerinde konumlandırılmıştır. Işık etkilerinin birbirine karışmaması için viyoller arasındaki mesafe ayarlanmıştır. LED lambaların aynı ışık şiddetini (140 μmol m^{-2} s^{-1}) bitki üzerine gönderebilmesi için spektrometre (LI-180, LI-COR, Hamburg, Germany) kullanılarak ayarlama yapılmıştır (Şekil 1).

Gün içerisinde ışık şiddeti 100 μmol m^{-2} s^{-1}'nin altına düştüğünde gün ışığına ek aydınlatma (1) ve gün doğumundan gün batımına kadar gün boyu doğal güneş ışığına ek aydınlatma (2) uygulamalarında ışık şiddetinin ayarlanmasında daha önceki yapılan çalışma bulguları dikkate alınmıştır (Rakutko vd., 2015; Matsuda vd., 2016; Wei vd., 2019). Çalışmalarda domates fidesi yetiştiriciliğinde genel olarak 100 ile 150 μmol m^{-2} s^{-1} arasındaki ek ışık şiddeti önerildiği için biberde de 140 μmol m^{-2} s^{-1} değeri kullanılmıştır. Ayrıca lambalar, viyollerdeki bitkilere belirtilen yoğunlukta ışığı sağlayacak mesafede tutulmuş ve fideler büyüdükçe mesafe korunacak şekilde yerleri ayarlanmıştır.



Şekil 1. Beyaz LED lambaların spektrum (PPFD) pozisyonlarının ayarlanması.
Figure 1. Adjusting the spectrum (PPFD) positions of white LED lamps.

Tezgâh üzerlerine sulama için bir metre yüksekliğinde mini sprinkler yerleştirilmiştir. Seranın ısıtılması için fanlı ısıtıcı (Evo5, EvoTech, Ankara, Türkiye) kullanılmıştır. Sıcaklık, nem (Hobo, MX2301A, Onset, Bourne, ABD) ve ışık değerleri (Hobo, H21, Onset, Bourne, ABD) veri kaydedicilerle ölçülmüştür. Yetiştiriciliğinin yapıldığı seradaki sıcaklık, oransal nem ve ışık değerleri Çizelge 2'de verilmiştir.

Çizelge 2. Sera içi iklim (sıcaklık, oransal nem ve ışık) değerleri.
Table 2. Greenhouse climate (temperature, relative humidity and light) values.

	Sıcaklık (^oC)	**Oransal nem (%)**	**Işık şiddeti (µmol m^{-2} s^{-1})**
En düşük	20.8	33.2	111.6
En yüksek	29.9	68.3	658.5
Ortalama	25.1	49.0	434.2

Çalışmada "Karizma" kıl tatlı biber çeşidi kullanılmıştır. Tohum ekimi 06.03.2024 tarihinde yapılmış ve ilk gerçek yapraklı dönemde (18.03.2024) ek ışık uygulamalarına başlanılmıştır. Biber tohumları, 216 gözlü (31 mm x 31 mm x 65 mm) ve 695 mm x 470 mm x 75 mm boyutlarındaki EPS viyollere ekilmiştir. Viyoller, torf (Klasman, KTS I, DRT, Antalya, Türkiye) ile doldurularak tohum ekiminden sonra ince bir vermikülit tabakası ile kaplanmıştır. Daha sonra viyoller fide üretim tezgâhlarına yerleştirilerek otomatik sulama (Esp-Rzx8, Rainbird, İstanbul, Türkiye) sistemine bağlı mini sprinkler ile sulanmıştır. Fidelerde ilk gerçek yapraklar görüldükten sonra haftada bir olmak üzere 400 ppm NPK'lı (15-15-15, Gübretaş) gübre uygulanmıştır.

Fidelerde Yapılan Ölçüm ve Gözlemler

Fidelerin kalitesini belirlemek amacıyla fideler dikim aşamasına geldiklerinde (dört gerçek yapraklı dönem) 3 tekerrürde ve her bir tekerrürde 10 fide olacak şekilde toplam 30 biber fidesinde ölçüm yapılmıştır. Fide boyu fidelerin kök boğazından büyüme noktasına kadar olan kısmın cetvel ile, gövde çapı ise fidelerin kök boğazının 1 cm üzerinden kumpas ile ölçülerek belirlenmiştir. Yaprak alanı hesaplanırken fidelerdeki tüm yapraklar A3 kâğıdı üzerine yapıştırılmış, daha sonra fotokopileri çekilmiştir. Fotokopiler üzerinden yaprak alanları planimetre kullanılarak (Placom Dijital Planimetre, SOKKISHA Planimeter Inc., Model KP-90) ölçülmüştür. Fide yapraklarının klorofil içeriği (CCI), klorofilmetre (CCM-200, Opti-Sciences, ABD) kullanılarak sabah 09:00-11:00 saatleri arasında tespit edilmiştir. Yapraklardaki stoma iletkenliği (mmol m^{-2} s^{-1}) değerleri ise porometre (SC-1, Decogon Devices, Pullman, USA) kullanılarak sabah 09:00-11:00 saatleri arasında belirlenmiştir.

Kök uzunluğu fidelerin kök boğazından en uzun kökün uç noktasına kadar olan mesafenin cetvel yardımıyla ölçülmesi ile belirlenmiştir. Fide kuru ağırlıklarının belirlenmesinde; fideler köklere zarar verilmeden sökülmüş, kökler yıkanmış ve kök, gövde ve yapraklar olmak üzere kısımlarına ayrılmıştır.

Daha sonra fidenin ayrılan kısımları ayrı ayrı kese kâğıtlarına yerleştirilerek 80°C sıcaklıktaki etüve yerleştirilmiş ve 48 saat sabit ağırlığa gelinceye kadar kurutulmuştur. Örnekler 0.01 g'a duyarlı terazi ile tartılarak fide kısımlarının kuru ağırlıkları tespit edilmiştir.

İstatistik Analizler

Araştırma, Tesadüf Parselleri deneme desenine göre 3 tekerrürlü olarak kurulmuştur. Elde edilen verilerin istatistiksel analizinde IBM SPSS versiyon 20.0 istatistik analiz programı kullanılmıştır. Ortalamalar arasındaki farklılıkların gruplandırılmasında "Duncan Çoklu Karşılaştırma" testinden yararlanılmıştır.

BULGULAR VE TARTIŞMA

Farklı beyaz LED ek aydınlatma uygulamalarının fide boyu, kök uzunluğu, gövde kuru ağırlığı, kök kuru ağırlığı ve toplam fide kuru ağırlığı üzerine etkileri istatistiksel olarak önemli ($p<0.05$) bulunmuştur. En yüksek fide boyu (9.17 cm) ise gün içerisinde ışık şiddeti 100 µmol m^{-2} s^{-1}'nin altına düştüğünde yapılan beyaz LED ek aydınlatma uygulamasından elde edilmiştir. Fide boyu bakımından bu uygulama ile gün doğumundan gün batımına kadar gün ışığına ek beyaz LED aydınlatma uygulaması (8.98 cm) arasında istatistiksel fark bulunmamıştır (Çizelge 3). Fide boyunun uzun olması, kuru madde birikiminin az olması durumunda sorun teşkil etmektedir. Ancak bu çalışmada yukarıda ifade edilen uygulamalardaki fidelerin gövde, kök ve toplam fide kuru ağırlıkları ile gövde çapı değerlerinin yüksek olması (Çizelge 3 ve Çizelge 4) nedeniyle fide boylarının sorun oluşturmadığı sonucuna varılmıştır. Ayrıca Matsuo vd. (2019) yaptıkları çalışmada kırmızı LED uygulamaları altında yetiştirilen fidelerin daha uzun boylu olduklarını bildirmişlerdir. Çalışmada en kısa fide boyu (5.95 cm), gün doğumundan önce ve gün batımından sonra 3'er saat olmak üzere beyaz LED aydınlatma ile fotoperiyodun uzatıldığı uygulamada tespit edilmiştir (Çizelge 3). Bu durum uzun fotoperiyodun biber fideleri üzerinde stres oluşturmasından kaynaklanmış olabilir. Uzun fotoperiyodun domates bitkilerindeki büyüme üzerinde etkileri olumsuz bulunmuştur (Ménard vd., 2005). Demers vd. (1998), sera domates mahsulü için en iyi fotoperiyodun 14 saat olduğunu, 14 saatten uzun fotoperiyotların domates bitkisinin büyümesini ve verimini artırmazken, 20 saat veya daha uzun fotoperiyotların yaprak klorozuna neden olduğunu, hatta büyümeyi ve verimi azaltabildiğini bildirmişlerdir.

Gövde, kök ve toplam fide kuru ağırlıklar incelendiğinde; en yüksek değerler, aralarında istatistiksel fark bulunmayan gün içerisinde ışık şiddeti 100 µmol m^{-2} s^{-1}'nin altına düştüğünde yapılan beyaz LED ek aydınlatma ve gün doğumundan gün batımına kadar gün boyu gün ışığına ek beyaz LED aydınlatma uygulamalarından elde edilmiştir (Çizelge 3). Bu bulgular, artan ışık şiddeti ile kuru ağırlık değerlerinin arttığını bildiren Wei vd. (2019)'nin bulguları ile benzerdir. Domates fidesi yetiştiriciliğinde, özellikle kırmızı/mavi ışık oranının 1.2 ve ışık şiddetinin 150 µmol m^{-2} s^{-1} olduğu koşullarda kırmızı ve mavi ışığın birlikte kullanımının kaliteyi artırdığı belirlenmiştir (Zheng vd., 2021). Kırmızı ve mavi ışık uygulamasının kuru ve yaş ağırlık artışı sağlamasının, fotosentez enzimlerinin (RuBP oksigenaz-karboksilaz (rubisco) ve PEP karboksilaz) aktivitelerinin artışına bağlı olduğu ifade edilmektedir (Shin vd., 2008; Matsuda vd., 2016; Anuchai ve Hsieh, 2017; Gao vd., 2020). Ayrıca bu iki ek aydınlatma uygulamasında fidelerin yaprak alanlarının da daha yüksek olduğu belirlenmiştir (Çizelge 4). Toplam yaprak alanının artması, tüm bitkinin fotosentez seviyesini artırmakta ve kuru madde birikimini teşvik etmektedir (Claypool ve Lieth, 2020; Li vd., 2021). Çalışma bulguları ek aydınlatma uygulamalarının yaprak alanını artırarak biyokütleyi artırabileceğini göstermektedir. Wang vd. (2022) yaptıkları çalışmada sabah ve akşam 3 saat ek LED aydınlatma yapıldığında kök ağırlığının önemli oranda arttığını bildirmişlerdir. Gün doğumundan önce ve gün batımından sonra 3'er saat olmak üzere beyaz LED aydınlatma ile fotoperiyodun uzatıldığı uygulamada kök ve toplam fide kuru ağırlığı değerleri, kontrol uygulamasından daha yüksek bulunmakla birlikte diğer ek ışık uygulamalarından düşük bulunmuştur (Çizelge 3).

Gün ışığına ek beyaz LED ışık uygulamaları hem kök uzunluğu hem de kök kuru ağırlığını artırmıştır (Çizelge 3). Çalışmada elde edilen bulgular, fide aşamasında gün ışığına ek tam spektrumlu floresan lamba ile aydınlatmanın kök uzunluğunu kontrole göre %11.9 artırdığını bildiren Öztekin ve Türe (2019)'nin çalışma bulgularına benzer bulunmuştur. En düşük kök uzunluğu, kök kuru ağırlığı ve toplam fide kuru ağırlığı değerleri hiçbir ek aydınlatmanın yapılmadığı gün ışığı koşullarında (kontrol) tespit edilmiştir

(Çizelge 3). Hazır fide sektöründe köklerin kalitesi çok önemlidir. Köklerin kalitesi, fidelerin nakilden sonra büyümesine ve gelişimine doğrudan etki ederek ürünlerin kalitesini ve verimini etkilemektedir (Wei vd., 2020). Işık yoğunluğunun düşük olması sebze fidelerinin üretim sürelerinin uzamasına ve kalitesinin düşmesine neden olabilir. Ek aydınlatma (beyaz, beyaz+kırmızı ve kırmızı+mavi) uygulamalarının fidelerde net fotosentez, kök aktivitesi ve nişasta içeriğini artırdığı bildirilmiştir (Zheng vd., 2021; Zhang vd., 2022). Kırmızı ve mavi LED (8:2) uygulamalarının da fotosentez hızını artırarak kök aktivitesi ve verimi önemli oranda artırdığı saptanmıştır (Lin vd., 2013; Paponov vd., 2020). Benzer şekilde domates fidelerinde kırmızı (%70) ve mavi (%30) ışığa %30 yeşil ışık ilavesinin kök uzunluğunu önemli oranda artırdığı belirlenmiştir (Li vd., 2021).

Çizelge 3. Farklı ek beyaz LED aydınlatma uygulamalarının fide boyu, kök uzunluğu, gövde kuru ağırlığı, kök kuru ağırlığı ve toplam fide kuru ağırlığı üzerine etkileri.

Table 3. Effects of different supplementary white LED lighting applications on seedling height, root length, stem dry weight, root dry weight and total seedling dry weight.

Dalga boyu	Işık uygulaması	Fide boyu (cm)	Kök uzunluğu (cm)	Gövde kuru ağırlığı (g)	Kök kuru ağırlığı (g)	Toplam fide kuru ağırlığı (g)
Beyaz LED 400-700 nm	1	9.17 a	7.22 a	0.38 a	0.40 a	1.10 a
	2	8.98 a	7.78 a	0.36 a	0.41 a	1.07 a
	3	5.95 b	7.45 a	0.20 b	0.33 ab	0.77 b
Kontrol		7.32 ab	6.62 b	0.24 b	0.22 b	0.66 b

Sütundaki farklı harfler arasında istatistiksel olarak $p<0.05$ düzeyinde önemli fark vardır. 1: gün içerisinde ışık şiddeti 100 μmol m^{-2} s^{-1}'nin altına düştüğünde yapılan beyaz LED ek aydınlatma, gün doğumundan gün batımına kadar gün ışığına ek beyaz LED aydınlatma ve gün doğumundan önce 3 saat ve gün batımından sonra 3 saat olmak üzere beyaz LED aydınlatma ile fotoperiyodun uzatıldığı uygulama

Biber fidelerinin gövde çapı, yaprak alanı, yaprak klorofil içeriği ve stoma iletkenliği ek aydınlatma uygulamalarından istatistiksel olarak önemli düzeyde etkilenmiştir. En yüksek gövde çapı ve yaprak alanı gün içerisinde ışık şiddeti 100 μmol m^{-2} s^{-1}'nin altına düştüğünde yapılan beyaz LED ek aydınlatma uygulamasında belirlenmiştir. Bunu gün doğumundan gün batımına kadar gün boyu gün ışığına ek beyaz LED aydınlatma uygulaması izlemiştir (Çizelge 4). Farklı dalga boyunda LED uygulamalarından kırmızı ve mavi ışığın birlikte uygulanmasının fide gövde çapını önemli oranda artırdığı, en düşük gövde çapının kırmızı ışık uygulamasından elde edildiği bildirilmiştir (Rakutko vd., 2015; Hernández vd., 2016; Kim ve Hwang, 2019; Soltani vd., 2023; Li vd., 2023). Bu durumun fotoreseptörlerin (fitokromlar) hücre bölünmesini ve gelişimini teşvik etmesinden kaynaklandığı ifade edilmektedir (Taiz ve Zeiger, 2008; Yousef vd., 2021; Soltani vd., 2023). Gövde çapı sebzelerin vejetatif dönemdeki büyümesini açıklayan önemli parametrelerden bir tanesidir. Kökten suyun taşınmasında ve karbonhidratların yer değiştirmesinde önemli bir role sahiptir. Genel olarak domates fidelerinde dengeli bir büyüme istenirken, gövde çapının yüksek olmasının uzun vadede yüksek verim artışı ile sonuçlandığı bildirilmiştir (Özer ve Kandemir, 2016). Yaprak alanındaki artış (Çizelge 4), ek aydınlatmanın fidelerin büyümesini ve gelişimini hızlandırdığını göstermektedir. LED lamba ile yapılan aydınlatmanın alçak plastik tünelde yetiştirilen domateslerin yaprak sayısını kontrole göre %17.3 artırdığı belirlenmiştir (Köksal vd., 2013). Domates fidelerinde genel olarak uzak kırmızı ışık ve tam spektrum LED uygulamalarının diğer dalga boylarına göre yaprak alanını önemli oranda artırdığı ifade edilmektedir (Cookson vd., 2005; Kim ve Hwang, 2019). Beyaz ışık ve tam spektrum LED uygulamaları da yaprak alanını önemli oranda artırmıştır (Zhang vd., 2022). Benzer şekilde bu çalışmada da ek aydınlatma uygulamaları kontrole göre yaprak alanının artmasını sağlamıştır.

En yüksek yaprak klorofil içeriği gün doğumundan önce ve gün batımından sonra 3'er saat olmak üzere beyaz LED aydınlatma ile fotoperiyodun uzatıldığı uygulama (17.5 CCI) ve gün doğumundan gün batımına kadar gün boyu gün ışığına ek beyaz LED aydınlatma uygulamasından (17.2 CCI) elde edilmiştir.

Fotoperiyodun uzatılmasının yaprak klorofil içeriğini olumlu etkilediği belirlenmiştir. En düşük yaprak klorofil uygulaması ise kontrol uygulamasında tespit edilmiştir (Çizelge 4). Öztekin ve Türe (2019) yaptıkları çalışmada marul bitkisinde gün ışığı+ floresan lamba uygulamasının fidelerde klorofil miktarını artırdığını bildirmişlerdir. Domates fidesi yetiştiriciliğinde farklı lambaların [ışık yayan diyot (LED), floresan lamba (FL) ve yüksek basınçlı sodyum buharlı lamba (HPS)] kullanıldığı çalışmada en yüksek yaprak klorofil içeriği FL lamba uygulamasından elde edilirken en düşük değer ise LED ve HPS lamba uygulamalarından elde edilmiştir (Rakutko vd., 2015). Farklı ışık şiddetinde (60, 150, 240 ve 330 µmol m^{-2} s^{-1}) uygulanan kırmızı ve mavi ışığın domates fidelerinin yaprak klorofil içeriğini ışık şiddeti 240 µmol m^{-2} s^{-1} olduğu uygulamaya kadar artırdığı ve daha sonra ışık şiddeti arttığında klorofil içeriğinin azaldığını bildirmişlerdir (Zheng vd., 2023).

Çizelge 4. Farklı ek beyaz LED aydınlatma uygulamalarının gövde çapı, yaprak alanı, yaprak klorofil içeriği, stoma iletkenliği üzerine etkileri.

Table 4. Effects of different supplementary white LED lighting applications on stem diameter, leaf area, leaf chlorophyll content, stomatal conductance.

Dalga boyu	Işık uygulaması	Gövde çapı (mm)	Yaprak alanı (cm^2)	Yaprak klorofil içeriği (CCI)	Stoma iletkenliği (mmol m^{-2} s^{-1})
Beyaz LED 400-700 nm	1	2.09 a	10.5 a	14.7 b	130.8 b
	2	1.92 ab	8.2 ab	17.2 a	150.5 b
	3	1.86 ab	7.2 b	17.5 a	176.3 a
Kontrol		1.78 b	6.6 b	13.8 b	104.8 c

Sütundaki farklı harfler arasında istatistiksel olarak $p<0.05$ düzeyinde önemli fark vardır. 1: gün içerisinde ışık şiddeti 100 µmol m^{-2} s^{-1}'nin altına düştüğünde yapılan beyaz LED ek aydınlatma, gün doğumundan gün batımına kadar gün ışığına ek beyaz LED aydınlatma ve gün doğumundan önce 3 saat ve gün batımından sonra 3 saat olmak üzere beyaz LED aydınlatma ile fotoperiyodun uzatıldığı uygulama

Çalışmada en yüksek stoma iletkenlik değerleri, gün doğumundan önce ve gün batımından sonra 3'er saat olmak üzere beyaz LED aydınlatma ile fotoperiyodun uzatıldığı uygulamadan elde edilmiştir. Bu uygulamayı diğer ek aydınlatma uygulamaları izlemiştir. Ele alınan ek ışık uygulamalarında yetiştirilen fidelerin stoma iletkenlik değerlerinin kontrolden önemli düzeyde yüksek olduğu tespit edilmiştir (Çizelge 4). Özer (2012), stoma iletkenliği ile fotosentez hızı arasında olumlu ve önemli bir ilişki olduğunu, stoma iletkenliği artıkça fotosentez hızının da arttığını bildirmiştir. He vd. (2019) LED ışık takviyesi ve takviyesi olmadan yetiştirilen Çin brokolisi fidelerinin büyüme ve kalite parametrelerini incelemişler ve ek aydınlatmanın fidelerin CO_2 asimilasyonu, stoma iletkenliği ve verimlilik gibi fotosentetik parametrelerini iyileştirdiğini bildirmişlerdir. Diğer bir çalışmada domates fidesi yetiştiriciliğinde farklı (50, 100 ve 150 µmol m^{-2} s^{-1}) ek beyaz aydınlatma uygulamasının 100 µmol m^{-2} s^{-1} ışık şiddetine kadar stoma iletkenliğini arttığı, ancak belli bir eşik (150 µmol m^{-2} s^{-1}) değerden sonra azalttığı belirlenmiştir (Wei vd., 2019). Hem sabah hem de akşam ışık takviyesinin domates yapraklarındaki rubisco enziminin aktivitesini arttırarak fotosentez ve karbonhidrat oluşumunu olumlu etkilediği ifade edilmektedir (Izzo vd., 2020; Yousef vd., 2021; Wang vd., 2022). Ancak bu çalışmada en yüksek stoma iletkenlik değerleri (Çizelge 4) gün doğumundan önce ve gün batımından sonra 3 saat olmak üzere beyaz LED aydınlatma ile fotoperiyodun uzatıldığı uygulamadan elde edilmesine rağmen, bu uygulamadan fide kuru ağırlığı (Çizelge 3) bakımından aynı ölçüde bir artış tespit edilmemiştir.

Kaliteli fidelerin, büyüme aşamasında çevresel stresten uzak, sağlıklı, kalın yapraklı, iyi gelişmiş kök sistemlerine sahip, uygun büyüklükte olmaları gerekmektedir (Lee vd., 2010). Gün içerisinde ışık şiddeti 100 µmol m^{-2} s^{-1}'nin altına düştüğünde yapılan beyaz LED ek aydınlatma ve gün doğumundan gün batımına kadar gün boyu gün ışığına ek beyaz LED aydınlatma uygulamalarından Zheng vd. (2021)'nin bulgularına benzer sonuçlar elde edilmiştir. Kırmızı ve mavi ışığı bünyesinde barındıran beyaz (Şekil 1) LED ek ışık uygulamaların fide kalitesini artırdığı belirlenmiştir.

SONUÇ

Çalışmada, ek beyaz LED aydınlatma uygulamalarının yetersiz güneş ışığı koşullarında serada yetiştirilen biber fidelerinin büyümesini ve gelişimini desteklediği ortaya konulmuştur. En yüksek yaprak klorofil içeriği ve stoma iletkenliği ile en kısa boylu fideler, gün doğumundan önce 3 saat ve gün batımından sonra 3 saat olmak üzere beyaz LED ek aydınlatma ile fotoperiyodun uzatıldığı uygulamadan elde edilmiştir. Sonuç olarak, fide boy kontrolü yönünden fotoperiyodun uzatıldığı uygulama ön plana çıkmıştır. Bununla birlikte denemeden elde edilen verilere göre gün içerisinde ışık şiddeti 100 μmol m^{-2} s^{-1}'nin altına düştüğünde ve gün doğumundan gün batımına kadar gün ışığına ek beyaz LED aydınlatma uygulamalarının biber fidelerinin boyu, kök uzunluğu, fide kuru ağırlıkları, gövde çapı ve yaprak alanlarını önemli oranda artırdığı belirlenmiştir. Bu çalışmada ek aydınlatma uygulamalarının ekonomik boyutu incelenmemiş olmakla birlikte, gün boyu ek aydınlatmanın maliyeti göz önüne alındığında gün içerisinde ışık şiddetinin 100 μmol m^{-2} s^{-1}'nin altına düştüğünde yapılacak aydınlatmanın tercih edilmesi önerilmektedir. Bundan sonra yapılacak çalışmalarda ek aydınlatma uygulamalarının fide üretim maliyeti üzerine etkilerinin incelenmesi faydalı olacaktır.

ÇIKAR ÇATIŞMASI

Yazarlar arasında herhangi bir çıkar çatışması yoktur.

YAZAR KATKISI

Birinci ve ikinci yazar araştırmanın yürütülmesi ve verilerin elde edilmesinde, üçüncü ve dördüncü yazar araştırmanın planlanması, sonuçların değerlendirilmesi ve yazılmasında görev almışlardır.

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Research Article

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Phenological and Morphological Characteristics of Some Medlar Cultivars Grafted onto Quince Rootstocks*

Ayva Anaçları Üzerine Aşılı Bazı Muşmula Çeşitlerinin Fenolojik ve Morfolojik Özellikleri

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Abstract: This study was conducted to evaluate the phenological and morphological characteristics of 'Akçakoca77' and 'Istanbul' medlar cultivars grafted on three different quince clone rootstocks [Quince BA29 (BA29), Quince A (QA) and Quince C (MC)] during 2021 and 2022 years. The earliest flowering was observed in the 'Istanbul' grafted on the BA29 and the MC rootstock, the latest flowering was observed in the 'Akçakoca77' grafted on the MC rootstock, and the latest harvest was observed in 'Istanbul' grafted on the BA29 rootstock. The BA29 and the QA rootstocks had higher rootstock diameter, trunk diameter, and tree height than the MC rootstock. The 'Istanbul' medlar cultivar had a higher crown volume than the 'Akçakoca77' cultivar. The trunk cross-sectional area was lower on the MC rootstock (11.05 cm²) than on the BA29 and the QA rootstocks in terms of rootstock averages and higher on the 'Istanbul' cultivar (28.58 cm²) than the 'Akçakoca77' cultivar (20.43 cm²) in terms of cultivars averages. Rootstock and cultivars had a significant effect on leaf area. The leaf area of the 'Akçakoca77'/QA combination was higher than the other combinations. Annual shoot length was higher in the QA rootstock (38.63 cm) than the MC rootstock (25.89 cm) in terms of rootstocks, and the 'Istanbul' (44.27 cm) was higher than 'Akçakoca77' cultivar (21.40 cm) in terms of cultivars. According to this research, the research needs to be continued for a more extended period to obtain more precise results and recommend the most appropriate cultivar/rootstock combination.

Keywords: *Mespilus germanica*, cultivar, flowering, quince rootstock, tree and leaf characteristic

&

Öz: Bu çalışma, üç farklı ayva klon anacı [Quince BA29 (BA29), Quince A (QA) ve Quince C (MC)] üzerine aşılanmış 'Akçakoca77' ve 'İstanbul' muşmula çeşitlerinin 2021 ve 2022 yıllarında fenolojik ve morfolojik özelliklerini değerlendirmek amacıyla yürütülmüştür. En erken çiçeklenme BA29 ve MC anacı üzerine aşılanmış 'İstanbul' çeşidinde, en geç çiçeklenme MC anacı üzerine aşılanmış 'Akçakoca77' çeşidinde, en geç hasat ise BA29 anacı üzerine aşılanmış 'İstanbul' çeşidinde gözlemlenmiştir. BA29 ve QA anaçlarının anaç çapı, gövde çapı ve ağaç yüksekliği MC anacından daha yüksek bulunmuştur. 'İstanbul' muşmula çeşidinin taç hacmi 'Akçakoca77' çeşidinden daha yüksek bulunmuştur. Gövde kesit alanı anaç ortalamaları açısından MC anacı üzerinde (11.05 cm²), BA29 ve QA anaçlarına göre daha düşük, çeşit ortalamaları açısından ise 'İstanbul' çeşidinde (28.58 cm²), 'Akçakoca77' çeşidine (20.43 cm²) göre daha yüksek bulunmuştur. Yaprak alanı üzerine anaç ve çeşitler önemli etki göstermiştir. 'Akçakoca77'/QA kombinasyonunun yaprak alanı diğer kombinasyonlardan daha yüksek bulunmuştur. Yıllık sürgün uzunluğu anaç açısından QA anacında (38,63 cm) MC anacına (25.89 cm) göre, çeşitler açısından ise 'Istanbul' (44.27 cm) 'Akçakoca77' çeşidine (21.40 cm) göre daha yüksek bulunmuştur. Araştırma sonucunda daha kesin sonuçlar elde etmek ve en uygun çeşit/anaç kombinasyonunu önermek için araştırmanın daha uzun süre devam ettirilmesi gerektiği sonucuna varılmıştır.

Anahtar Kelimeler: *Mespilus germanica*, çeşit, çiçeklenme, ayva anaci, ağaç ve yaprak özellikleri

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INTRODUCTION

Medlar (*Mespilus germanica*) belongs to the Rosaceae family (Milovan et al., 2013). The culture of medlar has spread little in Türkiye. However, there are studies on its medicinal properties (Bibalani and Mosazadeh-Sayadmahaleh, 2012). Medlar is native to Western Asia, Southern Europe, and North America (Baytop, 1999). It is a temperate climate plant and resistant to frost (Güngör et al., 2007). Medlar is botanically a pome fruit species. Medlar is consumed less frequently than apples and pears and has a wide range of uses by humans (Phipps et al., 2003), but it is also used as an ornamental plant and medicinal plant. Medlar has a high antioxidant capacity and some fatty acids (palmitic acid, citric acid, oleic acid, and linoleic acid) (Canbay et al., 2015). Medlar is found naturally in open forests, undergrowth under forests, rocks, and maquis in our country, and it is also cultivated as an indoor garden (Dönmez and Aydınözü, 2012). In Türkiye, medlar was produced with 5.217 tons in 2023, and Bursa ranked first with 1.175 tons (22.5%), followed by Çanakkale with 603 tons (11.6%), Sinop with 479 tons (9.2%) and Samsun with 440 tons (8.4%) (TSI, 2024). In Türkiye, the use of modern fruit growing systems in areas where the land structure is unfavorable for agriculture or in narrow areas will contribute to the development of fruit growing. The selection of species and varieties suitable for such regions should also be done correctly (Öztürk and Serttaş, 2018). The growth and development of plants and their phenological stages have a large annual variability. Individual factors (genes, age) and environmental factors (temperature and soil conditions, irrigation, disease and pests, etc.) significantly affect the growth and development of plants (Jackson, 2003). The correct characterization of phenological stages is the key to obtaining high quality and optimum weight of fruits, since there is a series of maintenance operations (pruning, fertilizers, diagnosis of physiological disorders, application of bioregulators, weed control, harvesting, pest control, etc.) that depend on the knowledge of specific phenological stages (Salazar et al., 2006; Salinero et al., 2009).

In modern fruit growing, clonal (vegetative) rootstocks are preferred instead of seedling rootstocks in orchard establishment. Seedling rootstocks are preferred less in fruit growing because they form larger tree canopy than clonal rootstocks, start yielding later, maintenance requires more labor, etc. Clonal rootstocks are preferred because they increase the yield per unit area as a result of dense planting, provide precocity, cultural procedures such as pruning, thinning, spraying, and harvesting can be applied more efficiently, and as a result, fruit quality is higher (Corso and Bonghi, 2014). In medlar cultivation, quince, hawthorn, pear, and buckthorn (*Crataegus oxyacantha*) rootstocks can be used to provide dwarfing and suitability for different soil types (Lombard and Westwood, 1987; Webster et al., 2008). Nowadays, instead of seedling rootstocks, quince clone rootstocks such as BA29, QA, MC, Adams, and Sydo are predominantly used in the establishment of modern orchards due to their dwarfing traits and increase precocity and fruit quality and ability to adapt to different soil types (Lewko et al. 2007). Generally, the variety/varieties grafted onto only one quince clone rootstock are used as saplings in newly established medlar orchards. In high-density (HDP) orchards, Adams and MC rootstocks, which are more dwarf than others, are used more (Jackson, 2003). To obtain optimum vegetative and generative growth from fruit trees, appropriate planting density, rootstock selection, and the orchard's ecological conditions should be considered (Hepaksoy, 2019). Determining the most suitable rootstock for growing conditions is crucial for successful fruit trees' phenological development and morphological growth. No study investigates the effects of both rootstocks and cultivars on medlar cultivation by grafting onto different rootstocks in same orchard. This study aims to determine the phenological and morphological characteristics of 'Istanbul' and 'Akçakoca77' medlar cultivars grafted onto different quince clone rootstocks, which are used more frequently than seedling rootstocks in medlar cultivation.

MATERIAL AND METHOD

Material

The research was carried out in the orchard established with 1-year old saplings within the scope of the project PYO.ZRT.1906.15.007 at Bafra Agricultural Research and Application Center with the support of Ondokuz Mayıs University Project Management Office in 2018. The research material consisted of 'Istanbul' and 'Akçakoca77' medlar cultivars grafted on BA29 (BA29), Quince A (QA), and Quince C (MC) quince clone rootstocks. Since MC rootstock is the most used dwarf rootstock (Jackson, 2003), planting was done in high density with this rootstock compared to BA29 and QA rootstocks. The cultivars grafted on MC were planted at a distance of 1.5 x 3.5 m (191 plants ha^{-1}), while the cultivars grafted on BA29 and QA were planted at a distance of 3.0 x 3.5 m (95 plants ha^{-1}). Medlars were irrigated with a drip irrigation system from the second week of May until the end of September. Fertilization was done with 15 - 30 - 15 + ME fertigation method in May and with 20 - 20 - 20 compound fertilizer in the second week of August. Weed control was done using mulch on the rows and tilling the soil with a rotovator between the rows.

Climate and Soil Characteristics of The Experimental Area

The experiment area has low clay (%2.73-10), medium silt (%13.21-20), medium sand (%6.5-20), slightly alkaline (pH 7.5), salt-free (0.2-0.3 dS m^{-3}), low organic matter (%0.3-0.5), low lime content (%3-6 $CaCO_3$), low nitrogen content (%0.03-0.06), medium phosphorus (5-10 ppm) and soil depth more than 1 m. Black Sea climate prevails in the Bafra district. Summers are cool, and winters are slightly cold in Bafra, which receives 750-1000 mm of yearly rainfall. Average humidity in April and May is 77% - 79%, while absolute humidity in summer is at most 28%. Rainfall is highest in November and lowest in May. Annual rainfall is 700 m on average, with 100 rainy days per year (TSMS, 2024). The maximum, minimum, and average temperature (°C), humidity (%), and precipitation (monthly, mm) values detected in the study area are given in Figure 1 and Figure 2.

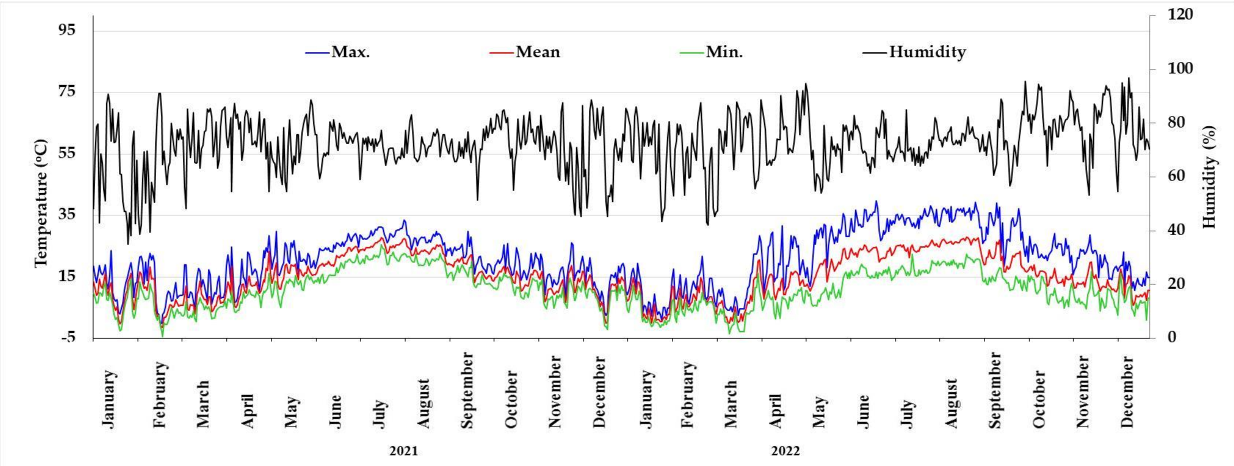

Figure 1. Air temperature (°C) and relative humidity (%) values observed in the experiment area.
Şekil 1. Deneme alanında gözlemlenen sıcaklık (°C) ve nem değerleri (%).

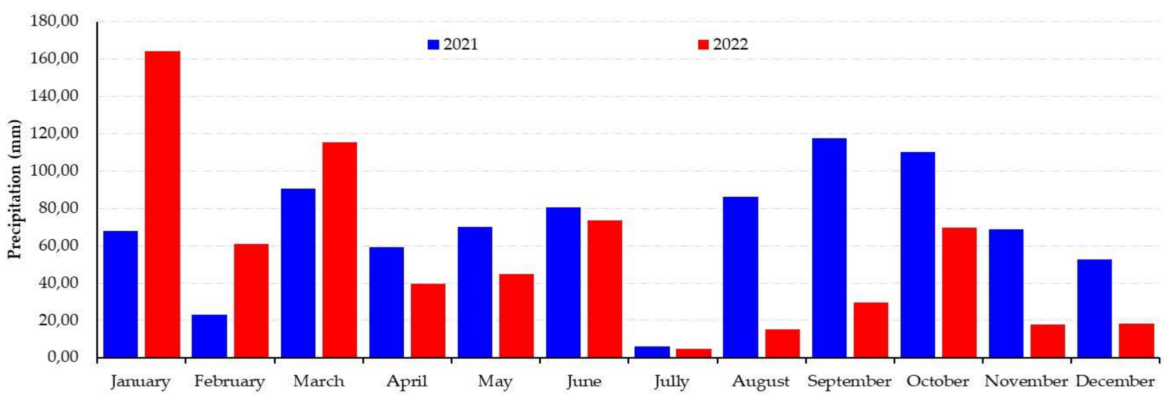

Figure 2. Monthly rainfall (mm) observed in the experiment area.
Şekil 2. Deneme alanında gözlemlenen aylık yağış miktarı (mm).

Method

Phenological stages of medlar cultivars grafted on different quince rootstocks such as beginning of bud break (BB, code 07), first leafing (FiL, code 11), first flowering (FiF, code 60), full flowering (FuF, code 65), end of flowering (EF, code 69), fruit set (FS, code 72), fruit maturity (FM, code 87), days from full flowering to harvest (DFFTH) and leaf falling (LF, code 97) were determined according to the BBCH scale (BBCH = Biologische Bundesanstalt Bundessortenamt and CHemical industry) reported by Meier et al. (2009) for fruit trees and Atay (2013) for medlar. Morphological traits such as tree height (m), trunk diameter (mm), rootstock diameter (mm), crown height (m), trunk cross-sectional area (TCSA) (cm^2), crown volume (m^3), leaf width and length (cm), petiole length and thickness, and annual shoot length (cm) were determined by the previous studies (Öztürk and Öztürk, 2014; Akçay et al., 2016; Cristofori et al., 2019). Leaf area was calculated according to the equation of Mendoza- de-Gyves et al. (2008).

Statistical Analysis

According to the Factorial Experiment Design in Randomized Blocks, the research was conducted with 3 different quince rootstocks and 2 medlar cultivars, with 3 replications and 5 plants in each replicate. The results acquired from the research were analyzed in the statistical package program (IBM SPSS 21.0). Differences between means were compared in the 'Duncan Multiple Comparison Test' at a 5% probability level, and differences were expressed with different letters.

RESULTS AND DISCUSSION

Phenological Characteristics

Beginning of bud break (BB, first green leaf tips just visible), first leafing (FiL), first flowering (FiF), full flowering (FuF), end of flowering (EF), fruit set (FS), fruit maturity (harvest, FM=HD), days from full flowering to harvest (DFFTH) and leaf falling (LF) dates are given in Table 1. In 2021, BB occurred between 8-22 April. The latest BB occurred in the 'Akçakoca77' (22 April) on the BA29 rootstock, and the earliest in the 'Istanbul' (8 April) on the QA rootstock. The latest FiL occurred in the 'Akçakoca77' (22 April) on the BA29, and the earliest in the 'Istanbul' (17 April) on the QA and the MC. The FiF was observed between 20 and 29 May. The earliest FiF was determined in the 'Istanbul' (20 May) on BA29 and MC, and the latest in 'Akçakoca77' (29 May) on BA29 rootstock. Full flowering was observed between 22-31 May, the earliest in 'Istanbul' (22 May) on MC rootstock and the latest in 'Akçakoca77' (31 May) on BA29. The end of flowering occurred between 29 May - 11 June. The latest EF was observed in the 'Akçakoca77' (11 June) on the BA29, and the earliest in the 'Istanbul' (29 May) on the MC rootstock. The latest FS was observed in the 'Akçakoca77' (17 June) on the BA29, and the earliest in the 'Istanbul' (9 June) on the MC rootstock. The HD occurred between 4 and 22 November. The latest HD was determined for the 'Istanbul' (22 November) on the BA29 rootstock and the earliest for the 'Akçakoca77' (4 November) on the MC, and the days from full flowering to harvest varied between 157 and 178 days. The longest DFFTH was observed in 'Istanbul' (178 days) on BA29 rootstock, and the smallest DFFTH was observed in 'Akçakoca77' (157 days) on MC. Leaf falling occurred between 17-26 December, and the LF was observed in 'Akçakoca77' (26 December) on BA29 rootstock and the earliest in 'Istanbul' (17 December) on MC (Table 1).

In 2022, a bud break was observed from 28 March to 9 April. The latest BB occurred in the 'Akçakoca77' (9 April) on the BA29 rootstock, and the earliest in the 'Istanbul' (28 March) grafted on the MC rootstock. The first leafing was observed between 5-10 April. The latest first leafing was observed in the 'Akçakoca77' (10 April) on the BA29 and MC rootstocks and the earliest in the 'Istanbul' (5 April) on the MC. The first flowering was determined between 8 and 15 May. The latest first flowering occurred in the 'Akçakoca77' (15 May) grafted on the BA29, and the earliest in the 'Istanbul' (8 May) grafted on the MC rootstock. Full flowering was observed between 13 and 18 May. The latest full flowering was observed in the 'Akçakoca77' (18 May) grafted on the BA29 and the QA, and the earliest in the 'Istanbul' (13 May) grafted on the MC rootstock. The end of flowering was determined between 20 and 30 May. The latest end of flowering occurred in the 'Akçakoca77' (30 May) grafted on the QA rootstock, and the earliest in the 'Istanbul' (20 May) grafted on the MC rootstock. The fruit set was determined between 27 May and 4 June. The latest fruit set was observed in 'Akçakoca77' (4 June) grafted on the BA29 rootstock, and the earliest in the 'Istanbul' (27 May) grafted on the QA rootstock. The fruit maturity was determined between 2 and 23

November. The latest harvest maturity occurred in the 'Istanbul' (23 November) grafted on the BA29 and the earliest in the ‘Akçakoca77’ grafted on the MC rootstock (2 November). The days from full flowering to harvest varied between 167 and 188. The highest days from full flowering to maturity occurred in 'Istanbul' (188 days) on BA29 rootstock, and the lowest occurred in 'Akçakoca77' (167 days) on QA. Leaf falling was observed between 25 and 30 December. The latest leaf falling was observed in the ‘Akçakoca77’ (30 December) on the BA29 and the QA rootstocks, and the earliest in the ‘Istanbul’ (25 December) grafted on the MC (Table 1).

Table 1. Phenological characteristics of medlar cultivars grafted on different quince clone rootstocks in 2021 and 2022.
Çizelge 1. Farklı ayva klon anaçları üzerine aşılı muşmula çeşitlerinin 2021 ve 2022 yılı fenolojik özellikleri.

Cultivar	Rootstock	BB	FiL	FiF	FuF	EF	FS	HD	DFFTH	LF
2021										
Istanbul	BA29	13-Apr	20-Apr	20-May	25-May	08-Jun	10-Jun	22-Nov	178	24-Dec
	QA	08-Apr	17-Apr	21-May	27-May	06-Jun	10-Jun	20-Nov	174	20-Dec
	MC	10-Apr	17-Apr	20-May	22-May	29-May	09-Jun	17-Nov	175	17-Dec
Akçakoca77	BA29	22-Apr	22-Apr	29-May	31-May	11-Jun	17-Jun	12-Nov	162	26-Dec
	QA	17-Apr	19-Apr	25-May	29-May	09-Jun	12-Jun	09-Nov	161	22-Dec
	MC	16-Apr	18-Apr	22-May	28-May	08-Jun	12-Jun	04-Nov	157	19-Dec
2022										
Istanbul	BA29	31-Mar	07-Apr	11-May	16-May	28-May	30-May	23-Nov	188	27-Dec
	QA	31-Mar	08-Apr	11-May	16-May	26-May	27-May	18-Nov	183	27-Dec
	MC	28-Mar	05-Apr	08-May	13-May	20-May	29-May	13-Nov	181	25-Dec
Akçakoca77	BA29	09-Apr	10-Apr	15-May	18-May	29-May	04-Jun	08-Nov	171	30-Dec
	QA	06-Apr	08-Apr	14-May	18-May	30-May	31-May	05-Nov	167	30-Dec
	MC	07-Apr	10-Apr	11-May	15-May	27-May	31-May	02-Nov	168	28-Dec

BB: Beginning of Bud Break, FiL: First Leafing, FiF: First Flowering, FuF: Full Flowering, EF: End of Flowering, FS: Fruit Set, HD: Harvest Date, DFFTH: Days From Full Flowering to Harvest, LF: Leaf Falling.

As a result of the study, it was determined that there were differences in phenological observations not only between years but also between rootstocks and cultivars. The differences observed between the years are directly related to the temperature and relative humidity. The temperature and the relative humidity of March - April - May, when medlar starts to grow, was slightly higher in 2022 than in 2021 (Figure 1), resulting in an earlier onset of phenology. In addition, the precipitation in March - April - May was higher in 2021 than in 2022 (Figure 2), and the temperatures in these months were lower in 2021 than in 2022, resulting in a delay in the phenological stages of medlar. However, the difference was not clearly evident and appeared in the form of a few days. Although the phenological characteristics of the cultivars are mainly affected by temperature, the relative humidity also has some effect (Özbek, 1977). The discrepancies observed in phenological traits between rootstocks and cultivars can be attributed to the differences in growth forces and genetic traits. Indeed, BA29 and QA rootstocks have higher vigor than MC rootstocks. In addition, among the quince clone rootstocks, MC rootstock, which has weak growth vigor, was found to grow earlier than other rootstocks, and its phenological characteristics were determined to be earlier than other rootstocks (Öztürk, 2021). Kurt et al. (2022) cited that phenological stages occurred earlier in cultivars grafted onto MC rootstock than in BA29 and QA quince rootstocks. The differences between varieties regarding phenological characteristics are due to genetic structure. As a matter of fact, it has been stated in the studies conducted on the subject that genetic differences also affect the phenological characteristics of the varieties (Atay, 2013; Akçay et al., 2016; Yılmaz et al., 2016; Cosmulescu et al., 2020). Cristofori et al. (2019) stated that there were differences in terms of bud break, full flowering, fruit set, and harvest time between medlar cultivars ‘Precoce’, ‘Comune’, ‘Gigante’, and ‘Goccia’ grafted on BA29 quince clone rootstock, emphasized that flowering in medlar cultivars was in mid and late May and harvest was in late October and early November. In medlar, Duman (2019) reported that the first flowering in Aybastı district of Ordu province was between 21 and 30 May, full flowering was between 25 May and 7 June, and the end of flowering was between 30 May and 13 June; Yılmaz et al. (2016) cited that flowering started between 26 April and 6 May and lasted for 10 to 12 days in Tokat province of Türkiye. Similarly, it was reported that the phenological characteristics of 'Istanbul' and 'Akçakoca77' medlar cultivars grafted on BA29 quince clone rootstock in the Akçakoca district of Düzce province were earlier in the 'Istanbul' medlar cultivar than the 'Akçakoca77' cultivar (Akçay et al., 2016). It can be said that the observed difference is due to ecological conditions.

Morphological Characteristics

The morphological characteristics of the medlar given in Table 2 were statistically significant ($p< 0.05$). Rootstock diameter ranged between 40.90 - 67.25 mm regarding rootstock averages and 52.45 - 62.65 mm in cultivar averages. Rootstock diameter was the highest in BA29 (64.50 mm) and QA (67.25 mm) rootstocks and the lowest in MC (40.90 mm). The rootstock diameter of the 'Istanbul' (62.65 mm) was higher than that of the 'Akçakoca77' (52.45 mm). In terms of rootstock diameter, 2022 (61.75 mm) year was higher than 2021 (53.35 mm). According to rootstock x cultivar interaction, the highest rootstock diameter was determined in 'Istanbul' (73.18 mm, 79.36 mm) on BA29 and QA rootstocks, and the lowest was in 'Istanbul'/ MC (35.43 mm) (Table 2). Kurt et al. (2022) reported that the influence of quince clone rootstocks (BA29, QA, and MC) was significant on rootstock diameter regarding the year, cultivar, and rootstocks. They cited that differences between the years in the study can be attributed to the growth, development, and increasing age of the trees. The differences in diameter among the rootstocks can be attributed to the different growth strengths of the rootstocks. As a matter of fact, it has been emphasized that the diameter of rootstocks with weak growth, such as MC rootstock, is lower than those with strong growth (Jackson, 2003). Since the cultivars affected the rootstocks on which they were grafted in terms of growth and development, the rootstock diameter of the vigorously growing cultivar 'Istanbul' was found to be higher than that of the weakly growing cultivar 'Akçakoca77'. This situation is related to the genetic characteristics of the cultivars. It can be said that since vigorously growing cultivars perform more photosynthesis than weakly growing cultivars, they increase the strength of the rootstocks on which they are grafted and thicken the diameter of the rootstock.

Trunk diameter ranged between 36.26 - 62.03 mm for rootstocks and 49.80 - 56.66 mm for cultivars. The BA29 (62.03 mm) and QA (61.40 mm) rootstocks had higher trunk diameter than the MC rootstock (36.26 mm). The trunk diameter of the 'Istanbul' (56.66 mm) was higher than that of the 'Akçakoca77' (49.80 mm). With regard to rootstock x cultivar interactions, the highest trunk diameter was determined in the 'Istanbul' (71.32 mm and 70.30 mm) on the BA29 and the QA rootstocks, and the lowest was in the MC/ 'Istanbul' (28.38 mm) combination (Table 2). It was found that the influences of research years, cultivars, and rootstocks on trunk diameter were statistically significant. The rootstocks significantly influence trunk diameter (Kurt et al., 2022; Öztürk and Faizi, 2022). It is cited that cultivars and rootstocks with vigorous growth have higher trunk diameters than those with weak growth (Sugar and Basile, 2011).

Tree height was found to vary from 164.50 cm to 228.10 cm regarding rootstock averages. The highest tree height was determined on the QA (228.10 cm) and the BA29 (225.82 cm) rootstocks and the lowest on the MC (164.50 cm) rootstock. Tree height was higher in the 'Istanbul' (223.17 cm) than in the 'Akçakoca77' (189.12 cm) cultivar. Tree height varied between 138.67 - 270.87 cm regarding rootstock x cultivar and also the highest tree height was determined in the 'Istanbul' cultivar on the QA and the BA29 rootstocks (270.87 cm and 259.97 cm), and the lowest was detected in the 'Istanbul' cultivar on the MC (138.67 cm) (Table 2). Tree height is affected by rootstocks and cultivars (Dondini and Sansavini, 2012). Akçay et al. (2016) reported that the growth vigor of the 'Istanbul' and the 'Akçakoca77', two of the medlar cultivars they examined, was different and that the 'Akçakoca77' medlar cultivar grafted on semi-dwarf and dwarf rootstocks, grew semi-upright and spreading, while the 'Istanbul' medlar cultivar grew more upright. Medlar cultivars on quince clone rootstocks were reported to be shorter than those on the seedlings and other rootstocks (Sebek et al., 2017). It can be said that the findings related to tree height detected in the study are in accordance with previous studies, and the differences that emerged are due to ecological conditions, tree age, and genetic differences.

Table 2. Change in morphological characteristics of medlar cultivars according to quince rootstocks.
Çizelge 2. Ayva anaçlarına göre muşmula çeşitlerinin morfolojik özelliklerinin değişimi.

Rootstocks	Cultivars	Rootstock diameter (mm)	Trunk diameter (mm)	Tree height (cm)	Trunk cross-sectional area (cm^2)	Crown volume (m^3)
BA29	Istanbul	73.18 a	71.32 a	259.97 a	40.16 a	1.10 a*
	Akçakoca77	55.83 b	52.74 b	191.68 b	23.40 b	0.82 b
QA	Istanbul	79.36 a	70.30 a	270.87 a	39.16 a	1.15 a
	Akçakoca77	55.13 b	52.51 b	185.34 b	22.22 b	0.76 b
MC	Istanbul	35.43 d	28.38 c	138.67 c	6.44 c	0.59 c
	Akçakoca77	46.38 c	44.15 b	190.33 b	15.66 b	0.83 b
Main Factor Effects						
Year	2020	53.35 b**	46.87 b	187.42 b	19.07 b	0.79 b
	2021	61.75 a	59.60 a	224.86 a	29.94 a	0.88 a
Rootstock	BA29	64.50 a	62.03 a	225.82 a	31.78 a	0.96 a
	QA	67.25 a	61.40 a	228.10 a	30.69 a	0.95 a
	MC	40.90 b	36.26 b	164.50 b	11.05 b	0.71 b
Cultivar	Istanbul	62.65 a	56.66 a	223.17 a	28.58 a	0.95 a
	Akçakoca77	52.45 b	49.80 b	189.12 b	20.43 b	0.80 b
Significance						
Year		0.008	0.001	0.015	0.012	0.016
Rootstock		0.016	0.001	0.013	0.005	0.006
Cultivar		0.023	0.002	0.010	0.011	0.010
Year x Rootstock		0.045	0.002	0.144	0.025	0.013
Year x Cultivar		0.207	0.207	0.305	0.329	0.298
Rootstock x Cultivar		0.008	0.001	0.005	0.033	0.009
YearxRootstockx Cultivar		0.958	0.034	0.001	0.178	0.039

*: Differences between means shown with different letters in the same column are significant.
**: Differences between means shown with different letters in the same row are significant.

The highest TCSA was found in the BA29 (31.78 cm^2) and QA (30.69 cm^2) rootstocks; the lowest was in the MC rootstock (11.05 cm^2). The TCSA was higher in the 'Istanbul' (28.58 cm^2) than in the 'Akçakoca77' cultivar (20.43 cm^2). In terms of cultivar x rootstock interactions, the highest TCSA was determined in the 'Istanbul' (40.16 cm^2, 39.16 cm^2) on the BA29 and the QA rootstocks, and the lowest was in the 'Istanbul' (6.44 cm^2) on the MC. Regarding year averages, a higher TCSA was determined in 2022 than in 2021 (Table 2). The difference detected between the years in the research is due to the increase in plant growth and development. As a matter of fact, it is stated that the difference between years in some fruit species is due to the difference in growth and development (Yılmaz et al., 2016; Öztürk et al., 2022). The difference between cultivars and rootstocks is due to the mutual effects of rootstocks and cultivars on each other. Jackson (2003) reported that rootstocks affect the development of the cultivars grafted on them, and cultivars affect the rootstocks. Our study determined that the trunk cross-sectional area of MC rootstock, which developed more dwarf, was less than the other rootstock. Rom and Carlson (1987) reported that the growth of cultivars grafted on weak rootstocks was feeble, while the growth of cultivars grafted on vigor rootstocks was strong. Cristofori et al. (2019) noted that the influence of cultivars and research year on TCSA was significant in 4 medlar cultivars grafted on the BA29 quince clone rootstock. They stated that there was an increase in the TCSA as the years progressed and emphasized that the highest TCSA regarding cultivars was 'Precoce' (215.67 cm^2), and the lowest was 'Gigante' (164.20 cm^2). In previous studies, it was possible to compare cultivars since they were usually grafted on only one rootstock, while rootstock comparisons could not be made. However, the results obtained from this study are consistent with those of previous studies.

Crown volume was determined between 0.71 - 0.96 m^3 for rootstock averages and 0.80 - 0.95 m^3 for cultivar averages. Among the rootstocks, the BA29 (0.96 m^3) and the QA (0.95 m^3) rootstocks had the highest crown volume than the MC (0.71 m^3) rootstock. The crown volume of the 'Istanbul' cultivar (0.95 m^3) was higher than the 'Akçakoca77' (0.80 m^3). Crown volume was higher in 2022 (0.88 m^3) than in 2021 (0.79 m^3). Regarding rootstock x cultivar averages, the highest crown volume was determined in the 'Istanbul' (1.15 m^3, 1.10 m^3) on the QA and the BA29 rootstocks, and the lowest was in the 'Istanbul' (0.59 m^3) on the MC (Table 2). Rootstocks have significant effects on the crown volume of the cultivars on which they are grafted in fruit species emphasized that the crown volume of cultivars grafted on dwarf rootstocks is smaller than the cultivars grafted on vigorous rootstocks (Loreti et al., 2002; Lepsis and Drudze, 2011; Öztürk, 2021). The growth and development pattern and strength of the cultivars significantly affect crown volume. The cultivars with strong growth characteristics grafted on strong-growing rootstocks have a larger crown structure and volume than cultivars with weak growth characteristics grafted on weak-growing rootstocks (Rom and Carlson, 1987; Dondini and Sansavini, 2012).

Petiole lengths ranged from 0.69 to 0.77 cm regarding rootstock averages. The highest petiole length was found on the QA rootstock (0.77 cm) and the lowest on the MC rootstock (0.69 cm). The 'Akçakoca77' cultivar (0.78 cm) had a higher petiole length than the 'Istanbul' cultivar (0.68 cm) using cultivar averages. Regarding rootstock x cultivar interaction, petiole length ranged from 0.53 cm to 0.85 cm. Petiole length was highest in the 'Akçakoca77' (0.85 cm) on the MC rootstock and the lowest in the 'Istanbul' (0.53 cm) on the MC rootstock (Table 3). The petiole length in medlar was found to be 19.8-23.2 mm by Sebek et al. (2019); 6.4-12.0 mm by Uzun and Bostan (2019); 4.9-6.3 mm by Aydın et al. (2020).

Petiole thickness varied from 1.69 mm to 1.88 mm in terms of rootstocks. The highest petiole thickness was found on the BA29 and the MC rootstocks (1.88 mm, 1.85 mm), and the lowest on the QA rootstock (1.69 mm). Regarding cultivar x rootstock effect, petiole thickness ranged from 1.59 mm to 1.93 mm, and the highest petiole thickness was found in the 'Istanbul' on the MC and the BA29 rootstocks (1.93 mm, 1.89 mm) and the 'Akçakoca77' on the BA29 rootstock (1.87 mm); the lowest in the 'Istanbul' on the QA rootstock (1.59 mm) (Table 3). In previous studies on medlar, petiole thickness varied between 2.00-2.80 mm in 27 medlar genotypes in Tonya district of Trabzon province (Közen and Bostan, 2016); 1.30-1.80 mm in 18 medlar genotypes in Sürmene district of Trabzon province (Uzun and Bostan, 2019); 0.60-0.80 mm in medlar genotypes growing naturally in Beykoz district of 'Istanbul' province (Aydın et al. 2020). In the studies mentioned above, it was determined that there were differences between genotypes in terms of leaf petiole thickness. However, the research found no difference between the examined cultivars regarding petiole thickness. This is due to genetic variations and differences in maintenance conditions. While the genotypes examined in the previous studies were located in different areas with different maintenance and growing conditions, the varieties in this study were on different rootstocks under the same maintenance and nutrition conditions.

Leaf length varied from 10.88 cm to 11.93 cm for rootstocks. The leaf length was higher in the QA rootstock (11.93 cm) than in the MC rootstock (10.88 cm). The leaf length was higher in the 'Akçakoca77' cultivar (12.24 cm) than in the 'Istanbul' cultivar (10.45 cm). In terms of rootstock x cultivar interaction, leaf length varied between 9.34-12.64 cm, and the highest leaf length was found in the 'Akçakoca77' (12.64 cm) grafted on the QA rootstock and the lowest in the 'Istanbul' (9.34 cm) grafted on the MC rootstock (Table 3). The effects of year, rootstock, and variety on leaf length were determined to be significant. The growth characteristics of rootstocks and cultivars affected leaf length. In previous studies in medlar, leaf length was reported to vary between 81.0-123.5 mm by Közen and Bostan (2016); 6.5-10 cm by Sülüşoğlu-Durul and Ünver (2016); 34.53-74.27 mm by Khadivi et al. (2019); 76-106 mm by Uzun and Bostan (2019); 0.60-0.80 mm by Aydın et al. (2020). In the studies mentioned above, it was determined that there were differences between genotypes in terms of petiole thickness, while in our study, there was no difference between the examined cultivars in terms of petiole thickness. This is due to genetic variations and differences in maintenance conditions. While the examined genotypes in the previous studies were located in different areas with different maintenance and growing conditions, the cultivars in this study were on different rootstocks under the same maintenance and nutrition conditions.

Table 3. Change in leaf characteristics of medlar cultivars according to quince rootstocks.
Çizelge 3. Ayva anaçlarına muşmula çeşitlerinin yaprak özelliklerindeki değişim.

Rootstocks	Cultivars	Petiole Length (cm)	Petiole Thickness (mm)	Leaf Length (cm)	Leaf Width (cm)	Laef Area (cm²)	Annual Shoot Length (cm)
BA29	Istanbul	0.76 ab	1.89 a	10.77 d	4.38 b	33.74 c	48.15 b*
	Akçakoca77	0.71 b	1.87 a	11.88 bc	5.73 a	48.80 b	19.83 d
QA	Istanbul	0.75 ab	1.59 b	11.22 cd	4.62 b	37.10 c	53.52 a
	Akçakoca77	0.79 ab	1.79 ab	12.64 a	6.00 a	54.25 a	19.83 d
MC	Istanbul	0.53 c	1.93 a	9.34 e	3.98 c	26.58 d	23.73 d
	Akçakoca77	0.85 a	1.78 ab	12.41 ab	5.93 a	52.72 ab	20.66 d
Main Factor Effect							
Year	2021	0.73 a**	1.88 a	11.51 a	5.08 a	42.64 a	32.20 a
	2022	0.73 a	1.73 b	11.17 b	5.14 a	41.76 a	33.47 a
Rootstock	BA29	0.73 ab	1.88 a	11.32 b	5.06 b	41.27 b	33.99 b
	QA	0.77 a	1.69 b	11.93 a	5.31 a	45.67 a	38.63 a
	MC	0.69 b	1.85 a	10.88 c	4.95 b	39.65 b	25.89 c
Cultivar	Istanbul	0.68 b	1.80 a	10.06 b	4.33 b	32.47 b	44.27 a
	Akçakoca77	0.78 a	1.81 a	12.24 a	5.89 a	51.92 a	21.40 b
Significance							
Year		0.814	0.009	0.002	0.114	0.341	0.401
Rootstock		0.032	0.019	0.007	0.001	0.004	0.001
Cultivar		0.001	0.803	0.035	0.004	0.005	0.001
Year x Rootstock		0.074	0.116	0.095	0.104	0.085	0.990
Year x Cultivar		0.001	0.212	0.007	0.103	0.070	0.792
Rootstock x Cultivar		0.001	0.049	0.023	0.003	0.008	0.001
Year x rootstock x Cultivar		0.044	0.031	0.015	0.124	0.003	0.949

*: Differences between means shown with different letters in the same column are significant.
**: Differences between means shown with different letters in the same row are significant.

Leaf width ranged between 4.95-5.31 cm for rootstock averages and 4.33-5.89 cm for cultivar means. The leaf width was the highest in the QA rootstock (5.31 cm) and the lowest in the BA29 and the MC rootstocks (5.06 cm, 4.95 cm). The leaf width of the 'Akçakoca77' cultivar (5.89 cm) was higher than the 'Istanbul' cultivar (4.33 cm). Regarding the rootstock x cultivar, the leaf width was highest in the 'Akçakoca77' on the QA, the MC and the BA29 rootstocks (6.00 cm, 5.93 cm, and 5.73 cm, respectively) and the lowest in the 'Istanbul' (3.98 cm) on the MC rootstock (Table 3). Sülüşoğlu-Durul and Ünver (2016) reported that the leaf width of medlar genotypes varied between 3.50-5.60 cm.

The leaf area varied between 39.65-45.67 cm² in terms of rootstocks. The leaf area was the highest in the QA (45.67 cm²) and the lowest in the BA29 and the MC rootstocks (41.27 cm², 39.65 cm²). Leaf area was higher in the 'Akçakoca77' cultivar (51.92 cm²) than in the 'Istanbul' cultivar (32.47 cm²) (Table 3). Mendoza-de Gyves et al. (2008) reported that leaf area varied between 10-55 cm2 in medlar genotypes. Cosmulescu et al. (2020) reported that leaf size plays an essential role in plant growth and productivity and selection of new genotypes, that leaf shape and size may vary among genotypes of the same species and that leaf area varied between 22.95-48.8 cm² in medlar genotypes. Our research showed a significant difference between rootstocks and cultivars regarding leaf area. It can be said that the difference in leaf area among varieties is due to genetic structure. Mendoza-de-Gyves et al. (2008), who stated that 8 medlar genotypes examined in Italy, differed in leaf size and area, reported that leaf area varied between 10.00-55.00 cm^2 in genotypes. Similarly, Cosmulescu et al. (2020) found that medlar leaf area varied between 22.95-48.8 cm^2. Rootstocks have a significant effect on the leaf area of varieties (Öztürk and Öztürk, 2014; Kurt et al. 2022). The differences in vegetative growth observed in fruit species and varieties are due to genetic and ecological factors (Rom and Carlson, 1987; Jackson, 2003). The difference in leaf areas of varieties grown on rootstocks with different growth vigours in the same ecological conditions is due to genetic structure. It is also reported that leaf area, which is an essential criterion for production considering the photosynthetic activity in fruit trees, is significantly affected by biotic (species, cultivars, genotypes, age of the tree, and pests) and abiotic (weather, soil properties, irrigation, planting spacing, etc.) factors (Cosmulescu et al., 2020).

Regarding rootstock average, annual shoot length (ASL) varied from 25.89 cm to 38.63 cm. The highest ASL was found on the QA (38.63 cm) and the lowest on the MC (25.89 cm) rootstock. The ASL was higher in the 'Istanbul' (44.27 cm) than in the 'Akçakoca77' cultivar (21.40 cm) (Table 3). In this study, the annual shoot length of strong-growing rootstocks was higher than that of weak-growing rootstocks. In addition to the growth strength of rootstocks, the growth characteristics of cultivars also affected shoot growth. Compared to the 'Akçakoca77' cultivar, the annual shoot length of the 'Istanbul' cultivar, which showed more vigorous growth, was higher. Cristofori et al. (2019) reported a difference between annual shoot length varieties of 15.00-26.70 cm in 4 different medlar varieties grafted on the BA29 quince clone rootstock in Italy. The growth vigor of rootstocks affects the growth and development vigor of the plants grafted on them. It has been reported that the annual shoot length, which indicates adequate growth and development of fruit trees, is higher in strong-growing trees than in weak-growing trees (Jackson, 2003). As a matter of fact, Kurt et al. (2022) cited that the influence of rootstocks on ASL was significant and that the ASL of the MC rootstock, which showed weak growth, was shorter than other rootstocks.

CONCLUSION

This study determined that different quince clone rootstocks affected the phenological and morphological characteristics of 'Istanbul' and 'Akçakoca77' medlar cultivars. The research used quince clone rootstocks, which have been used more intensively in recent years compared to medlar seedling rootstocks. The study attempted to reveal which cultivar/rootstock combination could be recommended to growers. Among the cultivar/rootstock combinations, the MC rootstock showed weaker plant growth than the other cultivar/rootstock combinations in both cultivars used in the study. The 'Istanbul' cultivar grafted on the BA29 and the QA rootstock showed better plant growth performance than other rootstock/cultivar combinations. Mainly, the sandy-loamy soil, which is very suitable for the growth of quince clone rootstocks, contributed to the better growth of the trees. Both cultivars in the study were found to be suitable for medlar cultivation in the ecological conditions in which the research was conducted. As a result of the research, it was determined that both cultivars ('Istanbul' and 'Akçakoca77') had sufficient fruit sets and were economically profitable varieties.

Regarding rootstocks, the MC rootstock can be preferred for early harvesting as it reaches harvest maturity earlier than the others. In addition, MC rootstock can be used for high-density planting due to its dwarf growth compared to other rootstocks. Recently, medlar cultivation on quince clone rootstocks has been recommended for consumer demand and as a production area where producers can earn sufficient economic income. In addition, the research results are essential for growers engaged in medlar cultivation or aiming to do so as suitable cultivar /rootstock combinations are revealed. According to the current research results, the 'Istanbul' cultivar with the BA29 rootstock can be recommended to growers because of its better performance than other cultivars/rootstocks. However, since the trees used in the experiment were 5 years old young trees that have yet to reach full yield, the research needs to be continued for a long time, and more studies are needed to reach certain results for the medlar plant.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest with respect to the research, authorship, and/or publication of this article.

DECLARATION OF AUTHOR CONTRIBUTION

Yakup Mert Kul: Investigations, Visualization, Writing of original draft. **Ahmet Öztürk**: Supervision, Data analysing, Visualization, Review and editing.

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Research Article

Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi

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Identification of Relationships Between Chemical and Agromorphological Traits in Raspberry (*Rubus idaeus* Linnaeus) Genotypes by Multivariate Analysis

Ahududu (*Rubus idaeus* Linnaeus) Genotiplerinde Kimyasal ve Agromorfolojik Özellikler Arasındaki İlişkilerin Multivariate Analizi ile Belirlenmesi

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Abstract: In this study, agro-morphological characteristics of raspberry (*Rubus idaeus* Linnaeus) genotypes naturally grown in Çivril, the central district of Bolu province in Türkiye were determined. In the study, parameters belonging to the genotypes were determined as follows: fruit weight was between 2.52 g (Genotype 4) and 1.30 g (Genotype 2), fruit width was between 18.18 mm (Genotype 6) and 15.33 mm (Genotype 2), fruit length was between 18.45 mm (Genotype 6) and 12.87 mm (Genotype 2), seed width was between 1.30 mm (Genotype 4) and 1.10 mm (Genotype 6), seed height was between 2.37 mm (Genotype 1) and 1.84 mm (Genotype 6). In addition, in genotypes, fruit stem thickness ranged from 0.91 mm (Genotype 4) to 0.67 mm (Genotype 5), fruit stem pit depth ranged from 13.99 mm (Genotype 6) to 10.58 mm (Genotype 5), fruit stem pit width ranged from 10.08 mm (Genotype 4) to 7.82 mm (Genotype 9). Also, genotype 3 (13.80%) had the highest soluble solids content (SSC) and Genotype 9 (3.60%) had the highest titratable acidity (TA). The pH values observed in the genotypes varied between 3.06 and 3.29. Also, in color value parameters, the highest L*, a*, b*, chroma and hue° angle values were 32.22 (Genotype 8), 23.75 (Genotype 1), 12.86 (Genotype 1), 27.10 (Genotype 1) and 28.22 (Genotype 1), respectively. As a result of the study, it was concluded that various genotypes that stand out in terms of agro-morphological characteristics can be evaluated as breeding material in functional raspberry production.

Keywords: Raspberry, morphology, soluble solids content (SSC), titratable acidity value (TA), color parameters

&

Öz: Bu çalışmada, Türkiye'de Bolu ili merkez ilçesi Çivril yöresinde doğal olarak yetişen ahududu (*Rubus idaeus* Linnaeus) genotiplerine ait meyvelerin agro-morfolojik özellikleri belirlenmiştir. Çalışmada, genotiplere ait parametrelerde, meyve ağırlığı 2.52 g (Genotip 4) ile 1.30 g (Genotip 2), meyve eni 18.18 mm (Genotip 6) ile 15.33 mm (Genotip 2), meyve boyu 18.45 mm (Genotip 6) ile 12.87 mm (Genotip 2), çekirdek eni 1.30 mm (Genotip 4) ile 1.10 mm (Genotip 6), çekirdek boyu 2.37 mm (Genotip 1) ile 1.84 mm (Genotip 6) arasında saptanmıştır. Ek olarak, genotiplerde, meyve sap kalınlığı 0.91 mm (Genotip 4) - 0.67 mm (Genotip 5); meyve sap çukur derinliği 13.99 mm (Genotip 6) - 10.58 mm (Genotip 5); meyve sap çukur genişliği 10.08 mm (Genotip 4) - 7.82 mm (Genotip 9) aralığında tespit edilmiştir. Ayrıca, en yüksek çözünebilir katı madde miktarı (SÇKM) açısından Genotip 3 (% 13.80) genotipi, en yüksek titre edilebilir asitlik (TA) değeri açısından Genotip 9 (% 3.60) genotipi daha baskın olmuştur. Genotiplerde gözlenen pH değerleri ise 3.06 ile 3.29 arasında değişmiştir. Ayrıca, renk değeri parametrelerinde, en yüksek L*, a*, b*, kroma ve hue° açısı değerleri, sırasıyla, 32.22 (Genotip 8), 23.75 (Genotip 1), 12.86 (Genotip 1), 27.10 (Genotip 1) ve 28.22 (Genotip 1) olarak bulunmuştur. Çalışmada sonuç olarak, agro-morfolojik özellikler açısından öne çıkan çeşitli genotiplerin fonksiyonel ahududu üretiminde ıslah materyali olarak değerlendirilebileceği kanısına varılmıştır.

Anahtar Kelimeler: Ahududu, morfoloji, çözünebilir katı madde miktarı (SÇKM), titre edilebilir asitlik değeri (TA), renk parametreleri

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INTRODUCTION

There are 15 subgenera in the genus *Rubus* spp. of the Rosaceae family and these genera contain approximately 740 species. The most important species of this genus are *R. sanctus*, *R. divaricatus*, *R. conothyrsoides* and *R. capricollensis*. Raspberry, one of these species, is taxonomically a fruit belonging to the species *Rubus idaeus* Linnaeus (Rosaceae: Rosales) (Hummer, 2010). *R. idaeus*, native to the Americas and Europe, can grow in hilly-mountainous, high altitudes (above 1000 m) and moist-rich soils. Raspberry is one of the horticultural crops that can easily grow anywhere in the world with temperate climatic conditions, even though they originated in America and Europe (Giovanelli et al., 2014). Raspberry, which have a thorny plant structure, can grow about one and a half meters in length and generally bloom white flowers from late June to early July.

A useful characteristic of raspberry is that its fruit remain on the market long enough. Indeed, raspberry can remain intact from approximately mid-July to the end of October, and this advantageous characteristic makes them a very popular product for both producers and consumers (Glisic and Milosevic, 2017). Mostly consumed fresh, raspberries are now widely used in the pharmaceutical, agricultural and food industries as well as the cosmetics industry (Brodowska, 2017; Gomes et al., 2017). The characteristic red berries of raspberries, which can range from small to certain sizes, have a pleasant taste, smell and aroma. The fruiting time of raspberries is usually between June and August. The raspberry leaves, which can be silvery or white in color, are grouped together in groups of three or five on the plant. Most consumers who are interested in this fruit prefer the leaves as much as the fruit itself, and raspberry leaves can be used fresh or dried in the production of herbal teas (Cefali et al., 2019).

As in many European countries, raspberry cultivation is also practiced in Türkiye (Erturk and Gecer, 2012). While fruit production in the country is mainly carried out on the Aegean coast, Bursa province of the Marmara Region ranks first in production. According to raspberry production data for 2022, 6652 tons of raspberries were produced in a total area of 798.1 hectare (ha) in Türkiye (TÜİK, 2022). Raspberries contain significant levels of antioxidants, anthocyanins, vitamin C, minerals, proteins, fatty acids, and carbohydrates, which contribute to the protection and improvement of human and animal health (Kula and Krauze-Baranowska, 2015; Teng et al., 2017; Nowak et al., 2018). Due to their high dietary fiber content, raspberries are widely recommended by dieticians and health professionals for their benefits in a healthy and balanced diet (Li et al., 2019). Raspberries, known for their benefits such as facilitating digestion, strengthening immunity, energizing the body, and regulating blood sugar, are popular for their beneficial properties (Zha and Koffas, 2017).

This study was conducted to determine the agro-morphological characteristics of various raspberry fruit genotypes. The main goal of the study was to document these genotypes and analyze their bioactive properties, which are important for understanding their potential health benefits and agricultural value. In addition, statistical distributions and descriptions of raspberry genotypes based on their agro-morphological characteristics were analyzed in this study.

MATERIAL AND METHOD

Fruit Material

In this study, samples of raspberry genotypes growing naturally in Çivril locality in the central district of Bolu province of Türkiye were taken. In the study, the initial step was fieldwork to identify and collect raspberry fruit samples from the region's various genotypes. Once the samples were gathered, they were carefully placed in suitable containers to ensure their preservation during transport. These containers were labeled with necessary information about the genotypes and locations, and the samples were taken to a laboratory for further analysis. At the laboratory, the agro-morphological characteristics of the raspberry samples, including size, shape, color, and texture, were examined to assess the diversity and quality of the genotypes. Following the initial observations, the fruit samples were frozen at -20°C to preserve their integrity for subsequent analyses. The next phase of the research was focused on analyzing some of the bioactive properties of the raspberry samples. Bioactive compounds are substances found in plants that have an effect on living organisms, including potential health benefits like antioxidant, anti-inflammatory, and antimicrobial effects. In order to assess these properties, advanced laboratory techniques were employed after the samples had been properly stored. All the morphological and physicochemical analyses were conducted at the Faculty of Agriculture Laboratory, Bolu Abant İzzet Baysal University. These analyses provided valuable information about the chemical composition of the raspberry fruits, including factors like acidity, sugar content, and the presence of bioactive compounds, which could be important for both nutritional and commercial purposes. This comprehensive study not only helps to document the diversity of naturally growing raspberry genotypes in the region but also contributes to a better understanding of their potential uses in food, health, and agriculture.

Determination of Agro-Morphological Characteristics of Fruits

In this study, various physical and chemical characteristics of raspberry genotypes were measured using standardized methods to ensure accuracy and consistency. Here's a breakdown of the methods used for each parameter:

Fruit Weight (g): Twenty fruits from each raspberry genotype were randomly selected. These fruits were weighed individually using a precision balance with a sensitivity of 0.01 g. The arithmetic mean of the weight values was then calculated, giving the average fruit weight for each genotype (Kalyoncu, 1996).

Fruit Width and Length (mm): To measure the size of the fruit, 10 fruit samples were randomly selected from each genotype. Their width and length were measured using a caliper sensitive to 0.01 mm, and the results were recorded for each genotype (Kalyoncu, 1996).

Seed Width and Height (mm): The study also focused on seed size. Ten seeds from each genotype were randomly taken and their width and height were measured using a caliper sensitive to 0.01 mm, following the procedure outlined by Karadeniz et al. (1996).

Fruit Stem Thickness and Stem Pit Width (mm): Ten fruit stalk samples were randomly selected from each genotype to measure the thickness of the fruit stem and the width of the stem pit. These measurements were taken using a caliper with a 0.01 mm precision, and the arithmetic mean of the values was calculated to determine the fruit stem thickness and stem pit width (Kalyoncu, 1996).

Fruit Stem Length and Stem Pit Depth (mm): Similar to the measurements for stem thickness, the length of the fruit stem and the depth of the stem pit were measured from 10 randomly selected fruit stalks for each genotype using a 0.01 mm sensitive caliper. The average of these measurements was then calculated (Kalyoncu, 1996).

Soluble Solids Content (SSC) (%): The soluble solids content, which is an indicator of sugar concentration, was determined using a hand refractometer (Atago PAL-1, Washington, USA). This measurement was expressed as a percentage (Esitken, 1992).

Titratable Acidity (TA) (%): To determine the titratable acidity (TA) of the fruit juices, 20 fruits from each genotype were squeezed through cheesecloth to extract their juice. Approximately 10 mL of the extracted juice was diluted to 50 mL with distilled water. The diluted juice was titrated with 0.1 N NaOH until the pH reached 8.1. Based on the amount of NaOH used, the TA value was calculated in terms of malic acid using a specific formula (Karacali, 2002; Tas et al., 2023).

These methods were designed to provide accurate and reliable data on the physical and chemical characteristics of raspberry genotypes, contributing to a better understanding of their agro-morphological and bioactive properties.

$$TA: \frac{NAOH\ spent\ (ml)\ x\ 0.1\ x\ 0.067\ (malic\ acid)\ x\ 100}{amount\ of\ juice\ used\ (ml)} \quad (1)$$

In this section of the study, several additional physical and chemical characteristics of the raspberry genotypes were measured, and statistical analyses were used to evaluate the results. Here's a detailed explanation of the methods used:

SSC/TA Ratio: The ratio of soluble solids content (SSC) to titratable acidity (TA) was calculated by dividing the SSC value by the TA value. This ratio provides a measure of the sweetness-to-acidity balance in the fruit, which is an important factor in flavor quality (Karacali, 2002).

Juice pH Value: To determine the pH of the fruit juice, a homogeneous mixture was prepared by extracting juice from 20 randomly selected fruits. Once the juice reached room temperature, approximately 10 mL of it was placed into a 50 mL beaker, and a pH meter (Thermo, OrionStar A111, USA) was used to measure the pH. The electrode of the pH meter was immersed in the juice mixture, and the reading was recorded once it stabilized (Esitken, 1992).

Fruit Skin Color: The skin color of the raspberries was measured using a Konica Minolta CR-400 colorimeter. Several color parameters were recorded: L*: The luminance value, where 0 indicates black and 100 indicates white. a*: Positive a* values represent red, while negative a* values represent green. b*: Positive b* values represent yellow, while negative b* values represent blue. Chroma: This value represents the intensity or saturation of the fruit skin color. Hue°: This value represents the hue or actual color of the fruit. A hue angle of 0° corresponds to red, 90° corresponds to yellow, 180° corresponds to green, and 270° corresponds to blue. The Hue° value also indicates the distance from the vertical axis in color space, giving an indication of the intensity of the color. These color values were calculated for each fruit using three reciprocal measurements taken from the equatorial region of the fruit, ensuring that the color assessment was consistent across all samples (Ertekin et al., 2006).

Statistical Analysis

To analyze the agro-morphological data collected in the study, Student's t-test (LSD test) was employed to determine if there were significant differences among the genotypes. The experiment was conducted using a randomized plot design with 3 replications, and each replication contained 15 plants. This design ensured that the results were statistically valid and accounted for variability between genotypes. For data analysis, SAS Version 9.1 (SAS Institute Inc., Cary, NC, USA) was used. When pairwise F tests showed significant differences, means were compared using Tukey's posthoc test. This test is commonly used in research to compare group means after a significant F test, providing detailed insight into which groups differ from each other (Gentleman et al., 2004). These methods ensured that the data collected on fruit weight, color, acidity, and other characteristics were analyzed rigorously, providing statistically valid conclusions about the differences between raspberry genotypes.

RESULTS AND DISCUSSION

Agro-Morphological Characteristics of Fruits

Türkiye due to its favorable geographical location, has a rich diversity of fruits, including raspberries, which are valued for their beneficial phytochemicals. This study focused on selected raspberry genotypes, where fruit samples were collected and subjected to various measurements and analyses to determine their agro-morphological characteristics. The results revealed statistically significant differences among the genotypes with respect to these characteristics, with a significance level of $p \leq 0.05$. A key finding was the significant difference in fruit weight among the genotypes ($p \leq 0.05$). When comparing the genotypes, Genotype 4 exhibited the highest fruit weight at 2.52 g, while Genotype 2 had the lowest fruit weight at 1.30 g. Moreover, genotypes such as Genotype 4 (2.52 g), Genotype 6 (2.49 g), Genotype 8 (2.25 g), and Genotype 5 (2.20 g) stood out in terms of their relatively higher fruit weight (Table 1). The study's findings are consistent with previous research on raspberry fruit weight: Tosun et al. (2009) found fruit weights ranging from 1.47 to 2.32 g in the raspberry variety 'Heritage'. Yang et al. (2020) reported the highest fruit weight of 4.20 g in the raspberry variety 'Tulameen' grown in Shanxi, North China. Augšpole et al. (2021), conducting research in Latvia, found the highest fruit weight of 2.74 g in the 'Polana' variety. Ahmed et al. (2014) recorded the highest fruit weight of 3.49 g in raspberries from the Neriyan Sharif region in Azad Jammu District, Pakistan. Zejak et al. (2021), in their study in Montenegro, reported the highest fruit weight of 3.47 g in the 'Polka' variety. These findings are in line with the results of this study, indicating that raspberry fruit weight can vary significantly depending on the variety and growing conditions. This study adds to the growing body of research on raspberry genotypes, providing valuable insights into their agro-morphological characteristics and helping to inform future breeding and cultivation practices.

The differences among genotypes in terms of fruit width and fruit length data were found statistically significant ($p \le 0.05$). Accordingly, when the genotypes were analyzed, the highest fruit width (18.88 mm) was determined in Genotype 6 and the lowest fruit width (15.33 mm) was determined in Genotype 2. Moreover, when the genotypes were evaluated in terms of high fruit width, Genotype 6 (18.88 mm), Genotype 5 (18.22 mm), Genotype 4 (18.08 mm) and Genotype 3 (17.99 mm) genotypes stood out, respectively (Table 1). When the genotypes were analyzed in terms of fruit length, the highest fruit length (18.45 mm) was determined in Genotype 6 and the lowest fruit length (12.87 mm) was determined in Genotype 2. In addition, when the genotypes were evaluated in terms of high fruit length, Genotype 6 (18.45 mm), Genotype 4 (16.04 mm), Genotype 8 (15.30 mm), Genotype 7 (15.26 mm) and Genotype 1 (15.19 mm) were the dominant genotypes, respectively (Table 1). Ahmed et al. (2014) reported a maximum fruit length of 9.1 mm and a fruit width of 11.4 mm in raspberry fruits from Topa, Azad Jammu Region, Pakistan. In another study, Augšpole et al. (2021) conducted their research in Latvia and reported the highest fruit length (11 mm) in the 'Shahrazada' raspberry variety and the maximum fruit width (49.83 mm) in the 'Daiga' variety. When the data of the above-mentioned literature studies on fruit width and length were analyzed together with the data of this study, similar results were obtained, except for the result of Augšpole et al. (2021) on fruit width. On the other hand, it is thought that the partial difference in the study may be due to genotype/variety, geographical location, ecological factors, soil characteristics and years.

The differences among genotypes in terms of seed width and seed height data were found statistically significant ($p \le 0.05$). Accordingly, when the genotypes were analyzed, the highest seed width (1.30 mm) was determined in Genotype 4 and the lowest seed width (1.10 mm) was determined in Genotype 6. Moreover, when the genotypes were evaluated in terms of high seed width, Genotype 4 (1.30 mm), Genotype 1 (1.28 mm), Genotype 5 (1.27 mm) and Genotype 2 (1.26 mm) genotypes stood out, respectively (Table 1). When the genotypes were analyzed in terms of seed height, the highest seed height (2.37 mm) was determined in Genotype 1 and the lowest seed height (1.84 mm) was determined in Genotype 6. In addition, when the genotypes were evaluated in terms of high seed height, Genotype 1 (2.37 mm), Genotype 3 (2.14 mm), Genotype 4 (2.10 mm), Genotype 5 (2.02 mm) and Genotype 2 (2.00 mm) were the dominant genotypes, respectively (Table 1). No literature study was found in terms of seed width and height in raspberries, and it is thought that the data obtained in this study on seed width and height may contribute to various researches on this subject.

While the differences among genotypes in terms of fruit stem thickness, fruit stem pit depth and fruit stem pit width data were statistically significant ($p \le 0.05$), the differences among genotypes in terms of fruit stem length were not statistically significant ($p \ge 0.05$). Accordingly, when the genotypes were analyzed in terms of fruit stem thickness, the highest fruit stem thickness (0.91 mm) was determined in Genotype 4 and the lowest fruit stem thickness (0.67 mm) was determined in Genotype 5. Moreover, when the genotypes were evaluated in terms of high fruit stem thickness, Genotype 4 (0.91 mm), Genotype 8 (0.80 mm), Genotype 6 (0.76 mm)=Genotype 7 (0.76 mm)=Genotype 9 (0.76 mm) genotypes stood out, respectively. When the genotypes were analyzed in terms of fruit stem pit depth, the highest fruit stem pit depth (13.99 mm) was determined in Genotype 6 and the lowest fruit stem pit depth (10.58 mm) was determined in Genotype 5. In addition, when the genotypes were evaluated in terms of high fruit stem pit depth, Genotype 6 (13.99 mm), Genotype 8 (12.42 mm) and Genotype 4 (12.40 mm) genotypes were more dominant, respectively. When the genotypes were analyzed in terms of fruit stem pit width, the highest fruit stem pit width (10.08 mm) was determined in Genotype 4 and the lowest fruit stem pit width (7.82 mm) was determined in Genotype 9. Furthermore, when the genotypes were evaluated in terms of high fruit stem pit width, Genotype 4 (10.08 mm), Genotype 7 (9.46 mm), Genotype 8 (9.23 mm), Genotype 6 (9.10 mm) and Genotype 3 (8.97 mm) stood out, respectively (Table 2). There is no literature study on fruit stem thickness, fruit stem pit depth and fruit stem pit width in raspberry, and it is thought that the results obtained in this study may contribute to various researches on this subject.

Table 1. Determination of seed height, seed width, fruit weight, fruit length and fruit width values in raspberry genotypes.

Çizelge 1. Ahududu genotiplerinde çekirdek boyu, çekirdek eni, meyve ağırlığı, meyve boyu ve meyve eni değerlerinin belirlenmesi.

Genotypes	Seed height (mm)	Seed width (mm)	Fruit weight (g)	Fruit length (mm)	Fruit width (mm)
Genotype 1	2.37 ± 0.11 a*	1.28 ± 0.05 a	1.95 ± 0.11 c	15.19 ± 0.62 bc	17.72 ± 0.44 bc
Genotype 2	2.00 ± 0.07 bcd	1.26 ± 0.06 ab	1.30 ± 0.06 d	12.87 ± 0.27 e	15.33 ± 0.31 d
Genotype 3	2.14 ± 0.05 b	1.24 ± 0.04 abc	1.92 ± 0.05 c	13.96 ± 0.29 de	17.99 ± 0.26 abc
Genotype 4	2.10 ± 0.07 b	1.30 ± 0.06 a	2.52 ± 0.10 a	16.04 ± 0.31 b	18.08 ± 0.35 abc
Genotype 5	2.02 ± 0.04 bc	1.27 ± 0.05 ab	2.20 ± 0.05 b	14.98 ± 0.43 bcd	18.22 ± 0.32 ab
Genotype 6	1.84 ± 0.05 d	1.10 ± 0.04 c	2.49 ± 0.11 a	18.45 ± 0.49 a	18.88 ± 0.39 a
Genotype 7	1.96 ± 0.06 bcd	1.17 ± 0.04 abc	1.92 ± 0.04 c	15.26 ± 0.27 bc	17.22 ± 0.26 c
Genotype 8	1.97 ± 0.07 bcd	1.22 ± 0.05 abc	2.25 ± 0.09 b	15.30 ± 0.65 bc	17.90 ± 0.28 bc
Genotype 9	1.90 ± 0.04 cd	1.14 ± 0.05 bc	1.88 ± 0.07 c	14.68 ± 0.30 cd	17.46 ± 0.33 bc

Table 2. Determination of fruit stem thickness, fruit stem length, fruit stem pit depth and fruit stem pit width values in raspberry genotypes.

Çizelge 2. Ahududu genotiplerinde meyve sap kalınlığı, meyve sap uzunluğu, meyve sap çukur derinliği ve meyve sap çukur genişliği değerlerinin belirlenmesi.

Genotypes	Fruit stem thickness (mm)	Fruit stem length (mm)	Fruit stem pit depth (mm)	Fruit stem pit width (mm)
Genotype 1	0.68 ± 0.02 b*	22.18 ± 2.40 a	11.31 ± 0.34 bc	8.37 ± 0.27 de
Genotype 2	0.68 ± 0.08 b	24.18 ± 1.00 a	10.82 ± 0.34 c	7.93 ± 0.17 e
Genotype 3	0.69 ± 0.07 b	21.53 ± 2.00 a	10.85 ± 0.42 c	8.97 ± 0.24 bcd
Genotype 4	0.91 ± 0.04 a	23.41 ± 1.84 a	12.40 ± 0.48 b	10.08 ± 0.54 a
Genotype 5	0.67 ± 0.03 b	21.93 ± 1.50 a	10.58 ± 0.22 c	8.61 ± 0.23 cde
Genotype 6	0.76 ± 0.04 ab	20.52 ± 0.67 a	13.99 ± 0.62 a	9.10 ± 0.34 bcd
Genotype 7	0.76 ± 0.05 ab	20.74 ± 0.52 a	11.70 ± 0.25 bc	9.46 ± 0.28 ab
Genotype 8	0.80 ± 0.03 ab	21.00 ± 0.50 a	12.42 ± 0.65 b	9.23 ± 0.24 bc
Genotype 9	0.76 ± 0.06 ab	21.66 ± 0.48 a	10.91 ± 0.45 c	7.82 ± 0.21 e

*: The difference between the means indicated with the same letter in the same column is insignificant (P<0.05).

When the data were evaluated in terms of the SSC ratio, the differences between the genotypes were found to be statistically significant (p≤0.05). Accordingly, when the genotypes were analyzed, the highest SSC content (13.80%) and the lowest SSC content (8.10%) were found in Genotype 3 and Genotype 5, respectively. In addition, when the genotypes were evaluated in terms of high SSC content, Genotype 3 (13.80%), Genotype 2 (13.73%), Genotype 7 (10.33%) and Genotype 8 (9.08%) were in the forefront, respectively (Table 3). Tosun et al. (2009) found that the SSC content of raspberry variety named 'Heritage' ranged between 10.87-13.60%. Zejak et al. (2021), in their study carried out in Montenegro, reported the highest SSC content as 13.63% in 'Polka' raspberry variety. Dujmović Purgar et al. (2012), in their study on raspberries in Croatia, observed that the highest SSC content was 11.50%. Giuffrè et al. (2019) found that the highest SSC content in raspberry was 9.44%. The results of the above-mentioned literature studies on the SSC content and the SSC results of this study supported each other.

When the TA values of the fruit juices of raspberry genotypes were analyzed, statistically significant differences were found (p≤0.05). Accordingly, the highest TA value (3.60%) was found in Genotype 9 and the lowest TA value (1.98%) was found in Genotype 2. In addition, when the genotypes were evaluated in terms of high TA value, Genotype 9 (3.60%), Genotype 3 (3.40%), Genotype 6 (3.13%), Genotype 7 (3.10%)

and Genotype 8 (3.06%) genotypes stood out, respectively (Table 3). Ahmed et al. (2014) determined the highest TA value as 2.17% in raspberry fruits from Neriyan Sharif location of Azad Jammu District of Pakistan. Dujmović Purgar et al. (2012) observed the highest TA value of 1.91% in raspberries from Croatia. Giuffrè et al. (2019) found the highest TA value in raspberries as 2.08%. When the results of the above-mentioned literature studies in terms of TA values in raspberry were compared with the results of this study, it was concluded that the studies supported each other. Regarding the subject, Davarynejad et al. (2013) reported that the titratable acidity values determined in fruits could be directly related to the respiration rate and ethylene synthesis processes in the fruit. In addition, it is thought that the differences observed between studies may be due to factors such as genotype, geographical location, ecological conditions, soil properties and years. When raspberry genotypes were evaluated in terms of SSC/TA ratio, statistically significant differences were found (p≤0.05). Accordingly, the highest SSC/TA ratio (6.93) was found in Genotype 2 and the lowest SSC/TA ratio (2.38) was found in Genotype 9. Moreover, when the genotypes were analyzed in terms of high SSC/TA ratio, it was observed that Genotype 2 (6.93), Genotype 1 (4.32) and Genotype 3 (4.05) genotypes were more prominent, respectively (Table 3). When the data were analyzed in terms of juice pH, statistically significant differences were found between the pH values of the juices of raspberry genotypes (p≤0.05). Accordingly, the highest pH value (3.29) among the genotypes was found in Genotype 2. It was also found that the pH values observed in all genotypes in the study were very close to each other (between 3.06 and 3.29) (Table 3). Augšpole et al. (2021), in their study conducted in Latvia, examined the highest pH value of 3.23 in 'Daiga' raspberry variety. Ahmed et al. (2014) determined the highest pH value as 3.05 in raspberry fruits from Neriyan Sharif location of Azad Jammu District of Pakistan. Dujmović Purgar et al. (2012) observed the highest pH value as 3.18 in their study on raspberries in Croatia. The results of the sample literature studies given above in terms of pH value and the pH value results in this study supported each other.

Table 3. Determination of pH, soluble solids content (SSC), titratable acidity (TA) value and SSC/TA values in raspberry genotypes.
Çizelge 3. Ahududu genotiplerinde pH, çözünebilir katı madde miktarı (SÇKM), titre edilebilir asitlik (TEA) değeri ve SÇKM/TEA değerlerinin belirlenmesi.

Genotypes	pH	SSC (%)	TA (%)	SSC/TA
Genotype 1	3.18 ± 0.01 b	8.73 ± 0.24 cd	2.02 ± 0.95 e	4.32 ± 0.02 b
Genotype 2	3.29 ± 0.05 a	13.73 ± 0.24 a	1.98 ± 0.95 e	6.93 ± 0.03 a
Genotype 3	3.17 ± 0.02 b	13.80 ± 0.23 a	3.40 ± 0.37 e	4.05 ± 0.01 bc
Genotype 4	3.06 ± 0.03 c	8.33 ± 0.38 cd	2.32 ± 0.22 a	3.59 ± 0.02 cd
Genotype 5	3.10 ± 0.04 bc	8.10 ± 0.57 d	2.60 ± 0.60 d	3.11 ± 0.03 e
Genotype 6	3.06 ± 0.05 c	8.23 ± 0.15 cd	3.13 ± 0.41 c	2.62 ± 0.01 fg
Genotype 7	3.09 ± 0.02 bc	10.33 ± 0.35 b	3.10 ± 0.35 b	3.33 ± 0.01 de
Genotype 8	3.18 ± 0.03 b	9.08 ± 0.26 c	3.06 ± 0.43 b	2.96 ± 0.02 ef
Genotype 9	3.09 ± 0.02 bc	8.60 ± 0.23 cd	3.60 ± 0.53 b	2.38 ± 0.01 g

*: The difference between the means indicated with the same letter in the same column is insignificant (P<0.05).

In this study, the skin color of raspberry fruits was analyzed using the L*, a*, b* color model, and significant differences between the genotypes were observed in terms of these parameters (p≤0.05). L* Value (Lightness/Darkness): The L* value indicates the lightness of the fruit skin, with higher values corresponding to lighter colors and lower values to darker colors. Upon analyzing the data, statistically significant differences were found in L* values between the genotypes. The genotype with the lightest fruit color was Genotype 8, with an L* value of 32.22. This was followed by Genotype 6 (31.93), Genotype 2 (31.73), Genotype 9 (31.68), Genotype 5 (31.62), and Genotype 4 (31.19). The darkest fruit color was observed in Genotype 1, which had an L* value of 28.82 (Table 4). a* Value (Red-Green Chromaticity): The a* value represents the red-green chromaticity axis, with positive values indicating a red hue and negative values indicating green. Significant differences were found among the raspberry genotypes for a* values. The highest a* value, indicating the most intense red color, was observed in Genotype 1 (23.75), followed by Genotype 9 (23.31) and Genotype 4 (23.03). On the other hand, the lowest a* value, indicating less redness, was observed in Genotype 6 (19.73) (Table 4). b* Value (Yellow-Blue Chromaticity): The b* value measures the yellow-blue axis, where positive b* values indicate yellow and negative b* values indicate blue. In this study, significant differences were observed in b* values across genotypes. The genotype with the highest b* value, indicating the most yellow hue, was Genotype 1 (12.86), followed by Genotype 9 (11.41) and Genotype 4 (10.71). The lowest b* value was found in Genotype 7 (9.18), indicating less yellow and a shift toward blue (Table 4). Overall, these results show that raspberry genotypes exhibit a wide range of skin color characteristics. Genotype 1 stands out with the darkest and most intensely red fruit color, along with the highest yellow hue, while Genotype 8 has the lightest skin color. These color differences are important in consumer preference and can also be indicators of phytochemical content, especially anthocyanins, which contribute to the red pigmentation in raspberries. The statistical significance of these differences ($p \leq 0.05$) reinforces the variation in fruit skin color among the raspberry genotypes studied.

In this study, additional parameters of fruit skin color, including chroma and hue° values, were measured alongside the L*, a*, and b* values. Statistically significant differences were found between the raspberry genotypes for these color characteristics ($p \leq 0.05$), adding further insight into the variation in fruit appearance among the genotypes. b* Value (Yellow-Blue Chromaticity, Continued): Along with the genotypes mentioned earlier, other genotypes with relatively high b* values, which indicate a stronger yellow hue, were Genotype 3 (10.43), Genotype 6 (9.94), Genotype 5 (9.91), and Genotype 2 (9.80) (Table 4). Chroma (Color Intensity/Saturation): The chroma value refers to the intensity or saturation of the fruit's color, with higher values indicating more vivid color. The differences in chroma values among the raspberry genotypes were statistically significant ($p \leq 0.05$). Genotype 1 had the highest chroma value (27.10), showing the most intense color, while Genotype 6 had the lowest chroma value (22.11), indicating a less saturated color. Genotype 1 was followed by Genotype 9, which had a chroma value of 25.96 (Table 4). Hue° Value (Color Tone/Intensity): The hue° value represents the specific shade or tone of the color and is a measure of the angular distance in color space, with different angles corresponding to different hues. Statistically significant differences ($p \leq 0.05$) were found in hue° values among the genotypes. Genotype 1 exhibited the highest hue° value (28.22), indicating the most intense color, while the lowest hue° values (23.76) were observed in both Genotype 7 and Genotype 8. Genotype 1 was followed by Genotype 6 (26.73), Genotype 2 (26.17), and Genotype 9 (26.04) in terms of hue° intensity (Table 4). These findings are consistent with previous research. For instance, Augšpole et al. (2021), in their study conducted in Latvia, determined the highest L*, a*, and b* values as 29.13, 17.32, and 7.77, respectively, in the 'Daiga' raspberry variety. When compared to the results of this study, the L*, a*, and b* values for various genotypes align well with these findings, indicating that the studies support each other. Both studies highlight the diversity in skin color characteristics among different raspberry varieties, which can influence consumer appeal and market value. These color parameters—L*, a*, b*, chroma, and hue°—are important in evaluating the visual quality of raspberries, which is a key factor in consumer preferences and marketability.

The principal coordinate plane distributions of the correlation between agromorphological and biochemical traits of fruits of raspberry genotypes identified by PC analysis are given in Figure 1. It is seen that the total variation is significantly explained by the first two principal component axes with a value of 47.3%. The first principal component axis accounts for 27.8% of the total variation and the second principal component axis accounts for 19.5% of the total variation. These axes were found to be important in the evaluation of the analysis. Among the parameters defined by PC analysis, color values (L*, a*, b*, Chroma and Hue°) are in parallel with each other and have a positive relationship. Similarly, fruit weight, fruit width and fruit length are parallel to each other. While a negative correlation was observed between fruit stem length and fruit stem thickness, a positive correlation was observed between seed width and seed height. Similarly, a positive correlation was observed between the ratio of SSC/TA and pH, while a negative correlation was observed between SSC and TA (Figure 1).

Table 4. Determination of fruit skin color characteristics in raspberry genotypes.
Çizelge 4. Ahududu genotiplerinde meyve kabuk rengi özelliklerinin belirlenmesi.

Genotypes	L*	a*	b*	Chroma	Hue°
Genotype 1	28.82 ± 1.17 c*	23.75 ± 0.82 a	12.86 ± 0.99 a	27.10 ± 1.04 a	28.22 ± 1.63 a
Genotype 2	31.73 ± 0.40 ab	19.88 ± 0.58 e	9.80 ± 0.42 bc	22.18 ± 0.68 d	26.17 ± 0.56 abc
Genotype 3	30.53 ± 0.62 abc	21.37 ± 0.95 b-e	10.43 ± 0.72 bc	23.80 ± 1.14 bcd	25.76 ± 0.89 bcd
Genotype 4	31.19 ± 0.92 ab	23.03 ± 0.63 abc	10.71 ± 0.50 bc	25.39 ± 0.75 abc	24.88 ± 0.60 bcd
Genotype 5	31.62 ± 0.37 ab	22.12 ± 0.62 a-d	9.91 ± 0.40 bc	24.24 ± 0.72 bcd	24.07 ± 0.31 cd
Genotype 6	31.93 ± 0.49 ab	19.73 ± 0.89 e	9.94 ± 0.52 bc	22.11 ± 1.01 d	26.73 ± 0.57 ab
Genotype 7	30.06 ± 0.30 bc	20.65 ± 0.86 de	9.18 ± 0.62 c	22.32 ± 1.15 d	23.76 ± 0.83 d
Genotype 8	32.22 ± 1.02 a	20.90 ± 0.92 cde	9.22 ± 0.51 c	22.85 ± 1.04 cd	23.76 ± 0.36 d
Genotype 9	31.68 ± 0.38 ab	23.31 ± 0.66 ab	11.41 ± 0.43 ab	25.96 ± 0.77 ab	26.04 ± 0.39 abc

*: The difference between the means indicated with the same letter in the same column is insignificant (P<0.05).

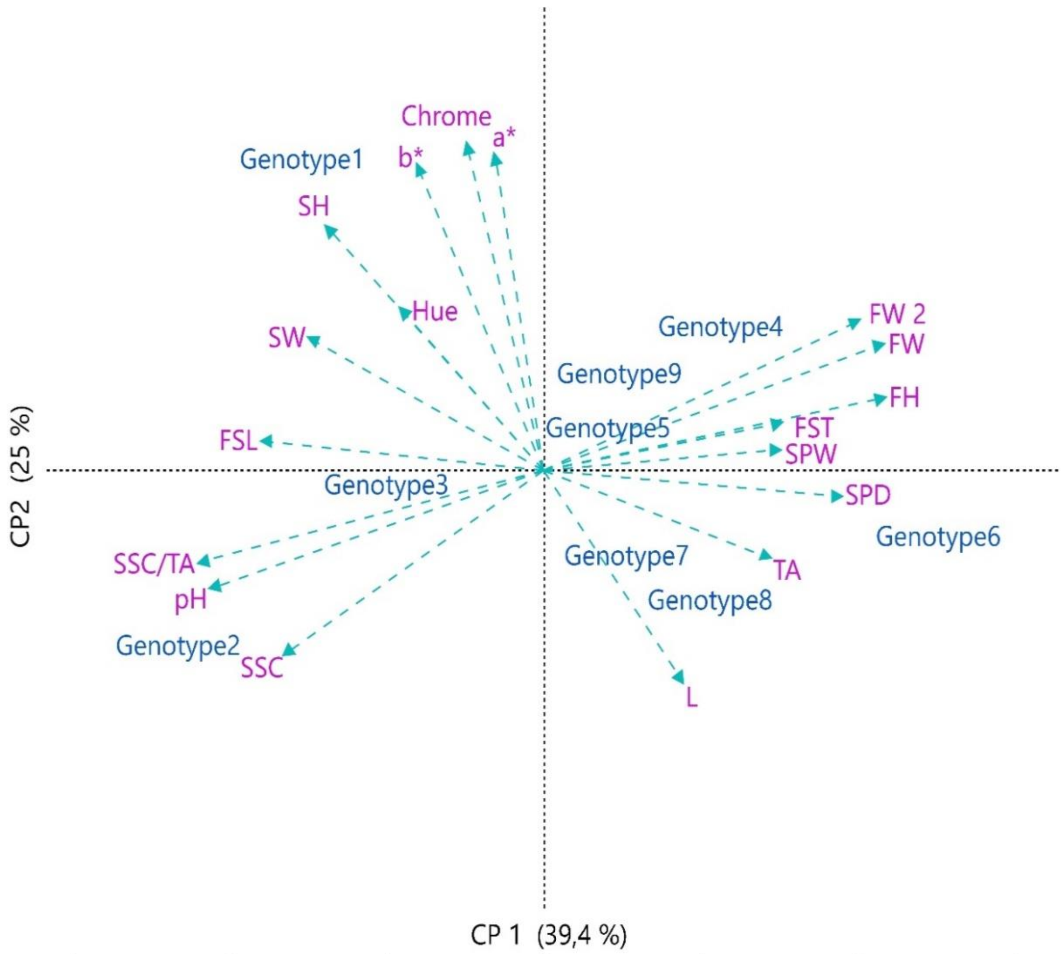

Figure 1. Distribution of agromorphological and chemical components of raspberry genotypes according to principal component analysis. FW: Fruit Weight, FW 2: Fruit Width, FH: Fruit Height, SPW: Stem Pit Width, SPD: Stem Pit Depth, FSL: Fruit Stem Length, FST: Fruit Stem Thickness, SW: Seed Width, SH: Seed Height, SSC: Soluble solids content, TA: Titratable acidity.
Şekil 1. Ahududu genotiplerinin agromorfolojik ve kimyasal bileşenlerinin temel bileşen analizine göre dağılımı. FW: Meyve Ağırlığı, FW 2: Meyve Eni, FH: Meyve Boyu, SPW: Sap Çukur Genişliği, SPD: Sap Çukur Derinliği, FSL: Meyve Sap Uzunluğu, FST: Meyve Sap Kalınlığı, SW: Çekirdek Eni, SH: Çekirdek Boyu, SSC: Çözünebilir Katı Madde Miktarı, TA: Titre EdilebilirAsitlik.

Cluster analysis was performed among agromorphological and biochemical compounds in raspberry genotypes. In the hierarchical clustering analysis, the genotypes were divided into four different clusters. In genotype 1 measurements, a*, b*, chroma and Hue° values, seed width and seed height were found significant, while L* and titratable acidity values were found insignificant. Genotype 2 fruits were found to be significant in terms of pH, SSC/TA and SSC values and they formed a separate cluster. Fruit weight, fruit width, fruit length and fruit stem pit were found to be significant in the analysis of genotype 6 fruits, whereas fruit stem length, seed width, seed height, pH, SSC/TA, SSC, a* and chroma values were found to be insignificant and formed a separate cluster (Figure 2).

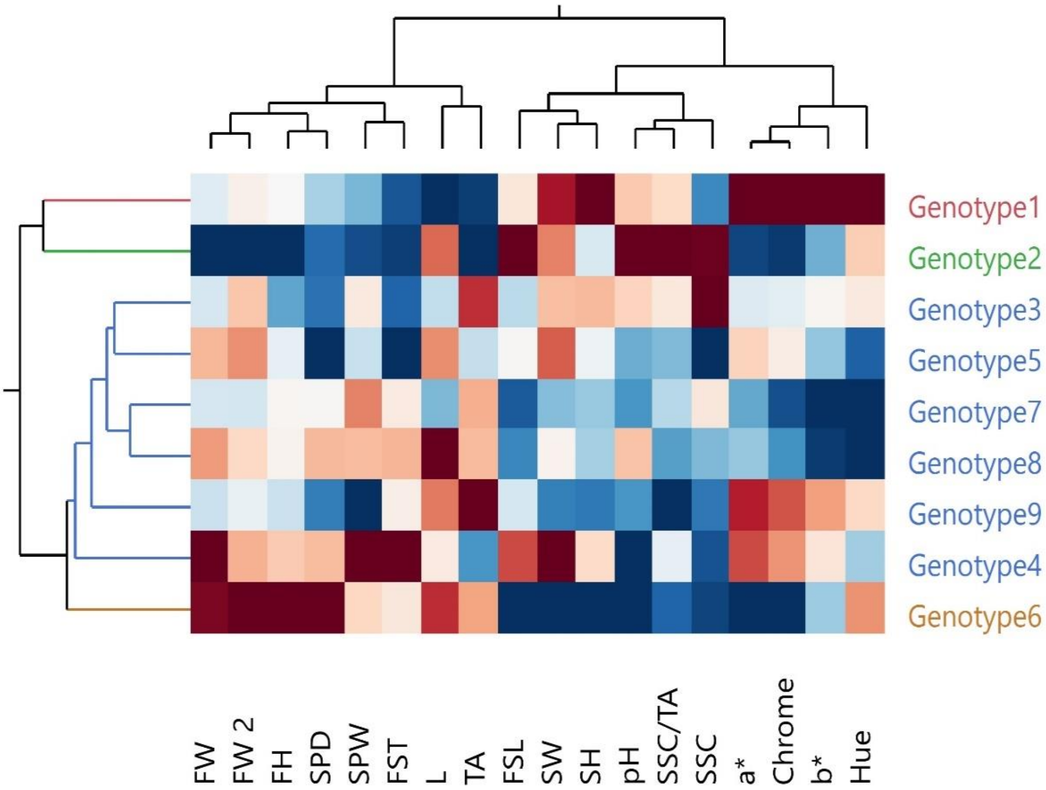

Figure 2. Heatmap analysis of agromorphological and biochemical compounds of raspberry genotypes. The color scale color from blue to red shows the minimum to maximum values for each trait.
Şekil 2. Ahududu genotiplerinin agromorfolojik ve biyokimyasal bileşiklerinin ısı harita analizi. Mavi ile kırmızı arasındaki renk skalası her özellik için minimumdan maksimuma değerleri gösterir.

CONCLUSION

In this study, agro-morphological characteristics of fruits of 9 raspberry genotypes grown in Bolu province were investigated. It was determined that Genotype 4 (2.52 g) was promising in terms of fruit weight in terms of agro-morphological content. In addition, in genotypes, the highest fruit width and length were found in Genotype 6 (fruit width: 18.18 mm, fruit length: 18.45 mm) and the highest seed width and height were found in Genotype 4 (1.30 mm) and Genotype 1 (2.37 mm) genotypes, respectively. Genotype 4 (0.91 mm), Genotype 6 (13.99 mm) and Genotype 4 (10.08 mm) genotypes were more prominent in the parameters of fruit stem thickness, fruit stem pit depth and fruit stem pit width, respectively, and no statistically significant difference was observed between the genotypes in the fruit stem length parameter.

The content of the SSC in fruits is one of the main criteria that is important in determining the ripeness period of a fruit and thus directly affects consumption. In this study, Genotype 3 genotype was significantly superior to the other genotypes in terms of the highest SSC content (13.80%). Genotype 9 was more dominant in terms of the highest TA value (3.60%). On the other hand, in the study, Genotype 2 genotype was more prominent in terms of high pH value, while the pH values observed in all genotypes ranged between 3.06 and 3.29. In the study, Genotype 1 (a*: 23.75, b*: 12.86, chroma: 27.10, hue°: 28.22) was significantly more dominant than the other genotypes in terms of a*, b*, chroma and hue° values, while Genotype 8 had better L* color value (L* value 32.22). Accordingly, as a result of the study, it was concluded that various genotypes that stand out in terms of agro-morphological characteristics can be evaluated as breeding material in functional raspberry production.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest regarding this article.

DECLARATION OF ETHICS COMMITTEE

This study did not require any ethics committee decision/report.

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Research Article

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Activity of Fosthiazate Against Root-Knot Nematode, *Meloidogyne incognita* (Kofoid & White) Chitwood (Nemata: Heteroderidae) on Tomato and Pepper in Greenhouse Conditions

Fosthiazate'in Sera Koşullarında Domates ve Biberde Kök-ur nematodu, *Meloidogyne incognita* (Kofoid & White) Chitwood (Nemata: Heteroderidae)'ya Karşı Etkinliği

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Abstract: Plant-parasitic nematodes (PPNs) are recognized as highly damaging obligate parasites, causing significant reductions in crop yield and quality. Nematicides, which are chemical agents, are employed to enhance crop yield by managing PPNs. Fosthiazate, scientifically known as [O-ethyl S-(methylpropyl) (2-oxo-3-thiazolidinyl)-phosphonothioate], represents a novel organothiophosphate compound proven effective against various nematodes, including potato cyst nematodes (CNs), root-knot nematodes (RKNs), and others. Its mode of action involves targeting the nervous system of the specific nematode pests, inhibiting acetylcholinesterase (AChE), and disrupting normal nerve impulse conduction. In Türkiye, the fosthiazate is registered against RKNs (*Meloidogyne* spp.) in several vegetable crops. This study was conducted to investigate the activity of Tripp 900EC (900 g L^{-1} Fosthiazate) against *Meloidogyne incognita* (Kofoid & White) Chitwood (Nemata: Heteroderidae) on tomato and pepper in greenhouse conditions. The Tripp 900 EC (900 g L^{-1} Fosthiazate) proved to be an effective treatment that inhibited *M. incognita* population by 91.2% and 94.6% on tomato and pepper, respectively. Furthermore, gall formation on the tomato and pepper dropped after Fosthiazate treatment following Fluopyram by 88.5% and 86.2%, respectively. The results indicate that fosthiazate has great potential in controlling *M. incognita* in greenhouse tomato and pepper cultivations.

Keywords: Fosthiazate, management, plant parasitic nematodes, crops

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Öz: Bitki paraziti nematodlar (BPN), tarımsal ürünlerin veriminde ve kalitesinde önemli düşüşlere neden olan oldukça zararlı zorunlu parazitler olarak kabul edilmektedir. Nematisitler, BPN'leri kontrol altına alarak ürün verimini artırmak için kullanılmaktadır. Bilimsel olarak [O-etil S-(metilpropil) (2-okso-3-tiyazolidinil)-fosfonotiyoat] olarak bilinen Fosthiazate, patates kist nematodları (PKN), kök ur nematodları (KUN) ve diğer BPN'ler dahil olmak üzere çeşitli nematodlara karşı etkili olduğu kanıtlanmış yeni bir organik fosfor bileşiğidir. Etki şekli, belirli nematod zararlılarının sinir sistemini hedef almayı, asetilkolinesterazı (AChE) inhibe etmeyi ve normal sinir uyarı iletiminin bozulmasını içerir. Türkiye'de fosthiazate, çeşitli sebze ürünlerinde KUN'larına (*Meloidogyne* spp.) karşı ruhsatlıdır. Bu çalışma, Tripp 900EC'nin (900 g L^{-1} Fosthiazate) sera koşullarında domates ve biberde KUN'a, *Meloidogyne incognita* (Kofoid & White) Chitwood (Nemata: Heteroderidae)'ya karşı etkinliğini araştırmak amacıyla yürütülmüştür. Tripp 900EC (900 g L^{-1} Fosthiazate), *M. incognita* popülasyonunu domates ve biberde sırasıyla %91.2 ve %94.6 oranında inhibe eden etkili bir uygulama olduğunu kanıtlamıştır. Ayrıca domates ve biberde gal oluşumu Fluopyram'ı takiben Fosthiazate uygulamasından sonra sırasıyla %88.5 ve %86.2 oranında azalmıştır. Sonuçlar, fosthiazatın serada domates ve biber yetiştiriciliğinde *M. incognita*'yı kontrol altına almada büyük potansiyele sahip olduğunu göstermektedir.

Anahtar Kelimeler: Fosthiazate, mücadele, bitki paraziti nematodlar, mahsuller

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INTRODUCTION

Root-knot nematodes (RKNs) are one of the most damaging plant parasitic nematodes (PPNs) known for causing significant damage to various crops in agriculture, leading to considerable yield losses (Rutter et al., 2022). In Türkiye, the presence of *Meloidogyne incognita* (Kofoid & White) Chitwood (Nemata: Meloidogynidae), a species of RKNs, results in a major threat to tomato (*Solanum lycopersicum* L.) and pepper (*Capsicum annuum* L.), causing considerable damage (Kepenekci et al., 2016). In addressing the challenges posed by nematodes, most farmers employ a range of control methods such as the use of chemicals, plant varieties that possess resistance or tolerance to nematodes, and the practice of crop rotation (Rutter et al., 2022).

However, due to the lack of resistant or sufficiently tolerant varieties against *Meloidogyne incognita* in Türkiye, synthetic nematicides are the most commonly preferred control methods. Economic limitations also play a role, as extended crop rotations are needed for effective nematode control (Kepenekci, 2012; Imren et al., 2017). Apprehensions regarding the potential adverse effects of agricultural chemicals on the environment and human health, combined with alterations in European Union (EU) legislation, could lead to additional limitations on the accessibility and use of specific nematicides in Türkiye.

Fosthiazate is a nematicide that acts by directly inhibiting acetylcholinesterase (AChE), disrupting normal nerve impulse conduction in targeted nematodes, particularly *Meloidogyne* spp. (Rutter et al., 2022). Its effectiveness has been demonstrated in controlling nematodes in various crops such as tobacco, potato, tomato, banana, and peanut (Rich et al., 1994; Chabrier et al., 2002; LaMondia, 2002; Tobin et al., 2008; Cui et al., 2017). Various formulations of fosthiazate are authorized in Türkiye for controlling *Meloidogyne* spp. in crops such as tomato, potato, pepper, cucumber, and banana, according to the Plant Protection Products (PPP) regulations in 2016. Specifically, for tomato cultivation in Türkiye, fosthiazate is officially registered in combination with abamectin, with a formulation consisting of 10% fosthiazate and 0.5% abamectin in granule form. In Türkiye, several nematicides, including fosthiazate, fluopyram, abamectin, and bionematicides like *Purpureocillium lilacinum* strain PL1, are registered against *Meloidogyne* spp.. However, However, their effectiveness still needs to be elucidated in practice. Therefore, the main objective of this study was to assess the effectiveness of fosthiazate (900 g L^{-1}) in controlling *Meloidogyne incognita* on peppers and tomatoes under greenhouse conditions in Türkiye.

MATERIAL AND METHOD

Two large-scale greenhouses situated in the Adanalıoğlu and Homurlu districts of Mersin province were chosen as the experimental locations because of their history of significant natural infestation by *M. incognita* (55 larvae 100 cm^3 of $soil^{-1}$). The experiments were initiated during the autumn of 2020 and the spring of 2021, respectively. The experimental treatments were organized in a randomized block design. The design included four replications to enhance the statistical robustness of the study.

The treatments included: (a) furrow application of fosthiazate 900EC (TRIPP® 900 EC, Doğal Ltd., İstanbul, Türkiye) at a rate of 2.5 L per hectare; (b) furrow application of fosthiazate 900EC at a rate of 2.0 L per hectare; (c) furrow application of fosthiazate 900EC at a rate of 1.5 L per hectare; (d) furrow application of fluopyram 40% SC (Velum Prime® SC 400, Bayer AG, Leverkusen, Germany) at a rate of 1.2 L per hectare; (e) untreated control (Table 1). Each plot consisted of five rows and followed a randomized block design with four replicates. The plot size was 25 m^2, accommodating approximately 100 tomato plants per plot. To prevent cross-contamination, each plot received a separate 1.3 cm water block irrigation the day before chemical application. This pre-application irrigation aimed to ensure better absorption and effectiveness of the chemicals without inter-plot contamination.

Table 1. Nematicides used in greenhouse trials.
Çizelge 1. Sera denemelerinde kullanılan nematisitler.

Product	Active ingredient	Active ingredient rate* (g L^{-1})	Dose (L ha^{-1})	Active ingredient (g ha^{-1})
TRIPP® 900 EC	Fosthiazate	900	2.5	2250
TRIPP® 900 EC	Fosthiazate	900	2.0	1800
TRIPP® 900 EC	Fosthiazate	900	1.5	1350
Velum Prime® SC	Fluopyram	400	0.6	240

The application rates of chemicals were determined based on both prior research findings and the guidelines provided on the product labels. Consequently, fosthiazate was applied 3-6 days before the planting, while fluopyram was applied one day before planting. Following the chemical application, six-week-old 'Torry F1' tomato seedlings were transplanted onto the beds. These beds were spaced 1.5 meters apart, with each bed accommodating 20 tomato plants arranged at a spacing of 0.5 meters on the row. Conventional flood irrigation practices were used, taking into account the precise water needs of the crops. Furthermore, herbicides, insecticides, and fungicides were administered weekly, commencing three weeks after the treatment, following the recommended guidelines of that period.

Plant vigor ratings were assessed 45 days after treatment (DAT) using a scale ranging from 0 to 100%, where 0% indicated plant death and 100% represented optimum growth. The measurement of plant heights was conducted on ten randomly selected plants at the same time. Simultaneously, the infection of RKN was evaluated by carefully extracting roots and assigning a rating for galls of nematode on a scale of 0–10. This scale ranged from 0 (indicating no galls) to 10 (representing 90–100% of roots being galled). Following the gall rating analysis, the fresh weight of the roots was recorded. Furthermore, nematode populations were assessed 45 DAT by gathering soil samples from the rhizosphere of ten tomato plants per plot through the use of a soil probe (2.5 cm wide by 20 cm deep). Nematodes were then extracted, identified based on genera, and quantified from 100 cm^3 of soil using standard centrifugation and sieving procedures. The root galling index caused by *M. incognita* was determined at 45 DAT by inspecting the roots of six plants per plot and evaluating the extent of damage to the roots.

Statistical analysis

Before analysis, data were tested for normal distribution and arcsine-transformed. ANOVA Fisher's LSD test ($P<0.01$) was used to determine the differences among treatments. The statistical analysis was conducted using SPSS for Windows, Version 16.0 (SPSS Inc., Chicago, IL, USA).

RESULTS AND DISCUSSION

Fosthiazate and fluopyram significantly reduced the gall formation on the roots of tomatoes and peppers compared to control treatments (Table 2). All application rates of fosthiazate significantly decreased the root galling index on both tomatoes and peppers (Table 2). Plots treated with fluopyram and fosthiazate at a rate of 2.5 L ha^{-1} had the maximum plant height, reaching 39.2 cm.

Saad et al. (2011) documented that the use of fosthiazate and abamectin led to an increase in plant fresh weight and height in tomatoes. Additionally, Saad et al. (2012) observed that the use of fosthiazate, crustacean, and cadusafos significantly increased the root length in tomato plants infested with *M. incognita.*

Table 2. Effects of nematicides on *M. incognita* root gal formation in the greenhouse trials.
Çizelge 2. Sera denemelerinde nematisitlerin M. incognita'nın köklerde gal oluşumu üzerine etkileri.

Product	Active ingredient	Doses ($L\ ha^{-1}$)	Root galling indeks*	
			Tomato	Pepper
TRIPP® 900 EC	Fosthiazate ($900\ g\ L^{-1}$)	2.5	1.1 a	1.4 a
TRIPP® 900 EC	Fosthiazate ($900\ g\ L^{-1}$)	2.0	4.9 b	5.4 b
TRIPP® 900 EC	Fosthiazate ($900\ g\ L^{-1}$)	1.5	5.8 c	6.5 c
Velum Prime® SC	Fluopyram ($400\ g\ L^{-1}$)	0.6	1.2 a	1.5 a
Non-treated (Control)	-	-	7.6 d	8.1 d

*The nematode root galling index, assessed 45 days after treatment (DAT), was measured on a scale of 0 to 10. In this scale, 0 indicates no galls, while 10 represents 100% of roots exhibiting galling.

The results confirm the potent nematicidal activity of fosthiazate observed in greenhouse tests. Treatments from both fosthiazate and fluopyram proved effective in reducing population levels of *M. incognita* (Table 3). Untreated plots with tomatoes exhibited the highest nematode count and root galling index. By contrast, fosthiazate at a dose of 2.5 $L\ ha^{-1}$ emerged as the most efficient treatment in mitigating nematode counts and root galling caused by RKNs early in the season (Table 3).

Table 3. Effect of fosthiazate and fluopyram on *Meloidogyne incognita* in greenhouse trials.
Çizelge 3. Fosthiazate ve fluopyram'ın sera denemelerinde Meloidogyne incognita üzerine etkisi.

Product	Active ingredient	Doses ($L\ ha^{-1}$)	Nematodes* (100 cm^3 soil)	
			Tomato	Pepper
TRIPP® 900 EC	Fosthiazate ($900\ g\ L^{-1}$)	2.5	11 a	14 a
TRIPP® 900 EC	Fosthiazate ($900\ g\ L^{-1}$)	2.0	41 b	46 b
TRIPP® 900 EC	Fosthiazate ($900\ g\ L^{-1}$)	1.5	58 c	55 c
Velum Prime® SC	Fluopyram ($400\ g\ L^{-1}$)	0.6	13 a	12 a
Non-treated	-	-	74 d	69 d

* Nematodes (*Meloidogyne incognita*) present in 100 cubic centimetres of soil were counted 45 days after treatment (DAT) using a conventional method involving sieving and centrifugation in both cultivation periods.

Meloidogyne spp., RKNs, are detrimental soil-borne pathogens and responsible for significant global economic losses amounting to $157 billion (Abad et al., 2008). Controlling poses challenges due to their ability to live in the roots of plants (Radwan et al., 2012). Various chemical nematicides are employed for RKN control. Previous reports have demonstrated the efficacy of fosthiazate in managing RKNs in cucumber, leading to reduced root gall indices and increased crop yield in comparison to untreated control groups (Toth et al., 2019). Furthermore, studies indicate that when used in combination with other nematicides, fosthiazate reduces the root galling activity of *M. incognita*, consequently enhancing the yield of tomato (Landi et al., 2018).

Numerous reports have highlighted the commendable nematicidal properties and a distinct mode of action of fosthiazate compared to presently existing nematicides. The efficacy of fosthiazate in reducing populations of RKNs, as observed in this study, aligns with previous findings indicating its effectiveness against *Meloidogyne* spp. in various crops such as tobacco (Pullen and Fortnum, 1999; Rich et al., 1994) and peanuts (Minton et al., 1993).

The current study's results are in agreement with earlier studies reporting inhibition of *G. rostochiensis* in potatoes and pepper after fosthiazate, *P. lilacinus* strain PL1, and fluopyram treatments. Fosthiazate, classified as an organophosphate pesticide, exhibits high nematicidal activity and provides robust and consistent control against RKNs (Rich et al., 1994), CNs (Tobin et al., 2008), and root-lesion nematodes (Kimpinski et al., 1997) in a diverse range of crops, including bananas, tomatoes, potatoes, and various vegetables. These compounds warrant further exploration for combining fosthiazate with other nematicides and control methods such as trap cropping, crop rotation, partially resistant and/or tolerant cultivars, and potentially antagonistic organisms within the Integrated Pest Management (IPM) strategy to optimize their efficacy against PPNs.

CONCLUSION

The obtained results highlight the high nematicidal activity of fosthiazate against *M. incognita*, demonstrating its capacity to enhance marketable tomato and pepper yields and establishing it as a promising nematicide. Nevertheless, further investigations are necessary to explore its prolonged effectiveness, elucidate promotion mechanisms, assess dissimilar dosages, and determine the optimal planting time after application in crops.

CONFLICT OF INTEREST

The authors have no competing interests to declare that are relevant to the content of this article.

DECLARATION OF AUTHOR CONTRIBUTION

All authors contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by Mustafa İmren and Ebubekir Yüksel. The first draft of the manuscript was written by Mustafa İmren and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Determination of Mite Fauna in Common Bean Plantations of Central Anatolia Region and Seasonal Population Fluctutation of Major Pest Species

Orta Anadolu Bölgesi Fasulye Ekiliş Alanlarında Akar Faunasının Tespiti ve Önemli Zararlı Türün Sezonsal Popülasyon Değişimi

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Abstract: Common bean (*Phaseolus vulgaris* L.), a member of the Fabaceae family, are annual herbaceous plant originating from Central America. Common beans are among the most consumed legumes worldwide. There are numerous biotic and abiotic factors that affect common bean yield, with mites forming a significant group of pests among the biotic factors. The aim of this study, conducted in three different provinces from 2017 to 2018, was to identify mite species as biotic factors and monitor population fluctuations of major mite pest species on common beans. The identified plant pest mite species were *Tetranychus urticae* Koch, *Tetranychus atlanticus* (McGregor), *Tetranychus solanacearum* (Cobanoglu & Ueckermann, 2015), and *Schizotetranychus asparagi* (Oudemans, 1928), with *T. urticae* being the most prevalent pest in beans. The populations of these pest species were monitored at 2-4 week intervals, and field infection rates (%), district average infection rates (%), and provincial average infection rates were determined. Additionally, the average mite density per leaf (mites/leaf) was calculated. In Ankara province, infection rates started at 22.31% and reached 100%, with mite density per leaf ranging from 0.0 to 1.92. In Konya province, infection rates started at 27.03% and reached 88.99%, with mite density per leaf ranging from 0.08 to 49.57. In Afyonkarahisar province, infection rates started at 5.55% and reached 100%, with mite density per leaf ranging from 0.83 to 27.57. This study is the first faunistic survey in the region, identifying *S. asparagi* in Türkiye for the first time among the harmful mite species, and *T. solanacearum* was detected for the first time on common bean.

Keywords: Acari, faunistic, first report, *Schizotetranychus asparagi*, *Tetranychus urticae,* phytophagus mite

&

Öz: Fabaceae familyasından olan fasulye (*Phaseolus vulgaris* L.), Orta Amerika menşeli tek yıllık otsu bir bitki türüdür. Fasulye, bütün ülkelerde olduğu gibi ülkemizde de en fazla tüketilen baklagillerdendir. Fasulye verimini etkileyen çok sayıda biyotik ve abiyotik faktör bulunmakta olup, biyotik faktörler içerisinde ise akarlar önemli bir zararlı grubu oluşturmaktadır. Bu çalışmanın amacı 2017-2018 yılları arasında 3 farklı ilde biyotik faktör olarak fasulyede zararlı olan akar türlerini ve önemli türün popülasyon değişiminin belirlenmesidir. Bitki zararlısı akar türlerinden *Tetranychus urticae* Koch, *Tetranychus atlanticus* (McGregor), *Tetranychus solanacearum* (Cobanoglu&Ueckermann, 2015) ve *Schizotetranychus asparagi* (Oudemans, 1928) tespit edilmiştir. Bu türler arasında fasulyede en yaygın zarar yapan türün *T. urticae* olduğu belirlenmiştir. Zararlı türün popülasyonu 2-4 haftalık aralıklarla farklı tarihlerde yapılan sayımlarda tarla bulaşma oranı (%), ilçe ortalama bulaşma oranı (%) ve il ortalama bulaşma oranları saptanmıştır. Ayrıca yaprak başına düşen ortalama akar yoğunluğu (yaprak/adet) hesaplanmıştır. Buna göre Ankara ilinde bulaşma oranı %22.31 ile başlayıp %100'e kadar çıktığı, yaprak başına düşen akar sayısının 0.0 ile 1.92 adet arasında değiştiği; Konya ilinde ise %27.03 ile başlayan bulaşma oranının %88.99 kadar ulaştığı, yaprak başına düşen akar sayısının ise 0.08 ile 49.57 adet arasında değiştiği; Afyonkarahisar ilinde ise %5.55 ile başlayan bulaşma oranının %100'e kadar çıktığı, yaprak başına düşen akar sayısının ise 0.83 ile 27.57 adet arasında değiştiği belirlenmiştir. Fasulyede faunistik olarak bölgede yapılan ilk çalışma olup, ayrıca belirlenen zararlı akar türleri arasında Türkiye'de ilk kez *S. asparagi* tespit edilmiştir**.** Ayrıca *T. solanacearum* fasulye bitkisinde ilk tespiti yapılmıştır.

Anahtar Kelimeler: Acari, faunistik, ilk kayıt, *Schizotetranychus asparagi*, *Tetranychus urticae*, fitofag akar

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INTRODUCTION

Common bean (*Phaseolus vulgaris* L. Fabaceae), which can be consumed both fresh and dried, are an annual herbaceous plant species. Due to Türkiye's diverse climate and varying soil structures, beans can grow in almost every region with suitable conditions. Since they are not particularly selective regarding cultivation conditions, their production area is extensive. In Türkiye, fresh and dried beans are cultivated on a total area of 389.726 and 884.569 decares (da), respectively. In the provinces where the study was conducted (Ankara, Afyonkarahisar, Konya), this ratio is reported to be 22.270 da (fresh) and 105.596 da (dry) (Tuik, 2023).

Many mite species, including those affecting tomatoes, eggplants, cucumbers, and beans, have been reported to cause significant damage (Yoldaş et al., 1990; Estebanes-Gonzalez and Rodriguez-Navarro, 1991; Boom et al., 2003; Furtado et al., 2005; Sidumo et al., 2007; Petanovic and Vidovic, 2009; Canbay et al., 2011; Ozsisli and Cobanoglu, 2011; Kumar et al., 2013; Cobanoglu and Kumral, 2014; Razdoburdin et al., 2014; Meck et al., 2013). Although there is substantial record of both phytophagus and beneficial mite fauna of cultivated plants in Türkiye, there are very few records on phytophagous mites detected in bean fields. A comprehensive investigation of the harmful mite fauna associated with bean cultivation is very important. Mites can cause severe economic losses, particularly through damage to common beans that can lead to significant yield reductions.

The mite fauna in common bean cultivation in Türkiye is especially significant due to the widespread damage caused by species such as *Tetranychus urticae* Koch. (Acarina: Tetranychidae). *T. urticae* is a cosmopolitan species found in Europe, Asia, Africa, Australasia, Caribbean islands, and North America (Migeon et al., 2010). This pest feeds on many cultivated crops and over 1000 plant species in both greenhouse and field conditions (Migeon and Dorkeld, 2014). It feeds on the leaves of the plants, inhibiting their growth and development. Intensive damage can also lead to web formation, reduced photosynthesis, leaf wilting, drying, and shedding, ultimately resulting in yield losses and a decline in quality. Under favorable conditions and without adequate control measures, severe damage to fruits, twigs, leaves, and young shoots is common, leading to economic losses in common bean cultivation, a significant concern for producers. Consequently, a comprehensive understanding of this pest species impact and the development of effective control strategies are crucial. In addition to economic losses, mite damage to bean crops can have environmental impacts. The excessive use of chemical pesticides to control pest mites can harm the environment and disrupt the natural balance (Van Leeuwen et al., 2015; Guedes et al., 2016). Understanding the impact of mite fauna on common bean cultivation is essential to identify potential future threats from these pests.

Studying pest mite fauna can help reduce economic losses in common bean cultivation and promote sustainable agricultural practices. In conventional chemical control management, broad-spectrum acaricides are often sprayed to reduce population levels. However, these acaricides can also eliminate natural enemies, including native fauna. Knowledge of the population dynamics of a phytophagous insect and its natural enemies aid in identifying factors that can significantly contribute to regulating a pest insect. Such knowledge includes when the plants will be affected economically by the target insect pest and which sources of mortality are the most important in regulating the pest. By monitoring pest populations and considering natural enemy populations, unnecessary spraying can be avoided (Attia et al., 2012; Koca and Kütük, 2020). These studies also facilitate the development of environmentally friendly control strategies, supporting efforts to reduce the use of chemical pesticides.

The literature survey reveals that identifying the mite fauna, understanding the spatial distribution and population dynamics of common species, and assessing their damage potential are essential. For this purpose, the mite fauna was investigated for the first time in Ankara, Afyonkarahisar and Konya provinces. This information will contribute to the development of integrated pest management strategies and effective measures for sustainability in common bean production.

MATERIAL AND METHOD

Survey Areas

Population fluctuation studies of mite species were conducted in the villages of Çubuk (Dumlupınar, Taşpınar, and Gürdarpı), Kazan (Ciğir, İçören, Alpagut, and Merkez) and Ayaş (Başbereket, Ortabereket, Feruz, Çukurören, Canilli, and Pınaryaka) districts in Ankara in 2017. In Afyonkarahisar province, studies were carried out in 2018 in Merkez (Sülün and Halımoru), Şuhut (Merkez, Çakırözü, Akyuva), Emirdağ (Tezköy, Yavuzköy, Tabaklar). In Konya province, studies were carried out in 2018 in Altınekin (Akçaşar, Ölmez, Dedeler), Kadınhanı (Hacımemetli, Karahisarlı, Yaylayaka, Doğanlar and Karayürüklü), and Çumra (Beylerce, Merkez, Fethiye, İçeri Çumra) (Figure 1).

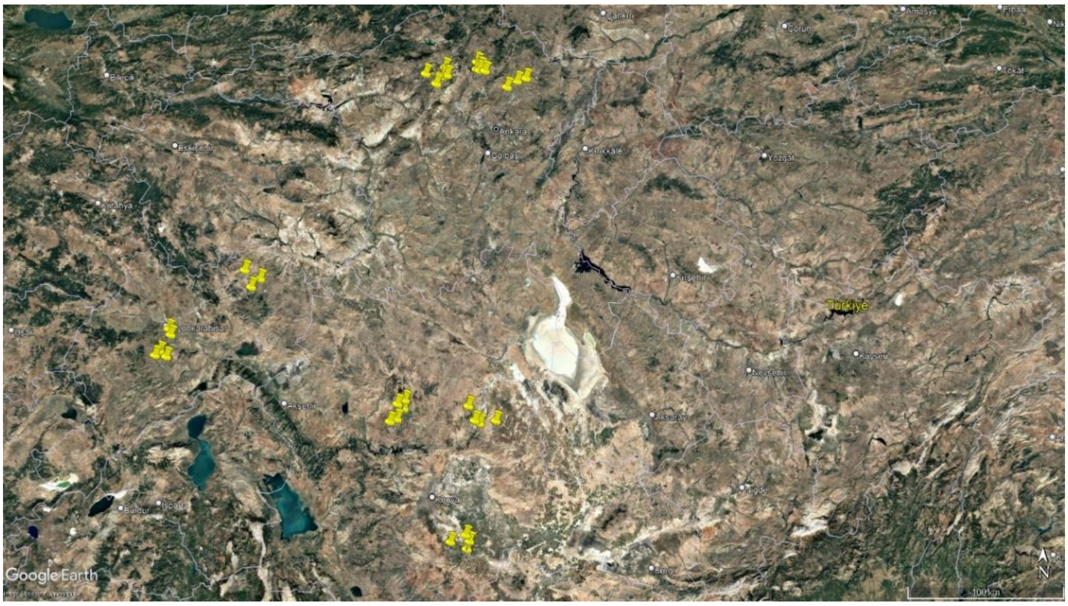

Figure 1. Satellite image of the places where fieldwork was carried out to determine the phytophagus acari fauna in Ankara, Afyonkarahisar, Konya provinces.

Şekil 1. Ankara, Afyonkarahisar, Konya illerinde fitofag akar faunasını belirlemek için saha çalışması yapılan yerlerin uydu görüntüsü.

Sample Collection **And I***dentification of Mite Species*

Surveys were conducted between May and October, following the methodology outlined by Bora and Karaca (1970). A random sampling approach, encompassing 1% of the total common bean areas, were employed, with field selection based on the number of fields to be observed. To ensure representative sample and mite species identification, fields were surveyed diagonally, with 20 plants selected at random each decare. These plants were then examined visually, aided by a hand lens if needed. At least 60 leaves and stem samples collected from the lower, middle and upper leaves of these 20 different plant samples were placed in polyethylene bags in paper bags, labeled, placed in an ice box and brought to the laboratory (Cobanoglu and Kumral, 2014). Sampling was conducted at 2-4 week intervals for two years from the predetermined areas, following the specified methods.

The samples brought to the laboratory were stored at +4°C until the examination. The upper and lower surfaces of the leaves and stem specimens were first visually inspected with a stereo microscope. The mites collected were individually placed in Eppendorf tubes containing 70% alcohol and morphologically identified to species level under a microscope (Leica, LED 2000, Taiwan) according to Zhang (2003). Mite specimens were identified by Prof. Dr. Sultan Çobanoğlu and Prof. Dr. Nabi Alper Kumral.

Determination of Infestation Rates and Densities of Mite Species

To determine the infestation rate in the field, the number of infestation plants was counted from samples taken at various points across the common bean fields (Table 1). The rate was calculated relative to the total number of plants using the formula:

$$\text{Infestation rate} = \frac{\text{Number of infestation bean plants}}{\text{Total number of bean plants}} \times 100$$

The average infestation rate for each province (district) was calculated by multiplying the infestation rate for each field by its area, summing these products for all examined fields, and dividing by the total area (Bora and Karaca, 1970). The prevalence of mite species was determined by dividing the infected area by the total area, considering whether the field was infected or not, without factoring in density, while taking the field's size into account.

Common bean leaves (60 leaves) were collected from the fields at 7-10 day intervals to determine the density of pest species. These samples were immediately examined under a stereomicroscope, and all active stages of mites were counted. Additionally, the same samples were placed in a Berlese funnel for extraction, and the collected mites were counted and identified under a microscope. The area indices of the lower, middle, and upper leaves collected during the 1st, 2nd, and 3rd stages of common bean leaf sampling, were calculated. The number of mites per cm^2 was determined by dividing the total number of mites in the collected samples by the total area of the sampled bean leaves (Kumral and Cobanoglu, 2016).

Table 1. Number of plants sampled according to the size of the common bean fields.
Çizelge 1. Fasulye tarlalarında alanın büyüklüğüne göre örnekleme sayısı.

Field size (da)	Number of plants to be sampled
1-5	20
6-10	25
11-20	30
20 <	35

RESULTS AND DISCUSSION

In this study, we detected 6 mite species, belonging to the Tetranychidae and Tydeidae families (Table 2). *Tetranychus urticae* Koch, *Tetranychus turkestani* Ugarov & Nikolski, and *Tetranychus solanacearum* (Cobanoglu & Ueckermann 2015) were specifically identified. Additionally, two species from the family Tydeidae were recorded: *Tydeus caudatus* (Dugés, 1834) and *Tydeus californicus* (Banks, 1904). Among these, *T. urticae* was found to be the most prevalent species in bean fields across the provinces of Ankara, Konya, and Afyonkarahisar (Table 2).

Table 2. Mite species detected in common bean fields in 2017-2018.
Çizelge 2. Fasulye tarlalarında 2017-2018 yıllarında tespit edilen akar türleri.

Team	Family	Species	Identified location
Prostigmata	Tetranychidae	*Tetranychus urticae* Koch 1836	Ankara, Konya Afyonkarahisar
		Schizotetranychus asparagi (Oudemans, 1928)	Konya
		Tetranychus turkestani Ugarov & Nikolski	Ankara
		Tetranychus solanacearum (Cobanoglu & Ueckermann 2015)	Afyonkarahisar
	Tydeidae	*Tydeus caudatus* (Dugés, 1834)	Ankara
		Tydeus californicus (Banks,1904)	Ankara

Seasonal Dynamics, İnfection Rates, Densities of Harmful Mite Species

According to surveys conducted in Ankara in 2017, the infection rate started at 41.25% in July and increased to 100% by September. In Kazan district, the infection rate began at 29.70% and similarly reached 100% by September in Çubuk. In contrast, in the Ayaş district, the infection rate started at 22.31% and increased to 45.45%. Pest densities ranged from a low of 0.61 mites per leaf in Çubuk to a high of 1.77 mites per leaf in Kazan (Table 3, Figure 2). The surveys indicated that infection rates, prevalence, and pest densities per leaf increased steadily across the different observation dates.

Table 3. Infestation rate (%) of pest mites detected in the districts of Ankara province in 2017.
Çizelge 3. Ankara ili ilçelerinde 2017 yılında tespit edilen zararlı akarların bulaşma oranı (%).

Work location		July				September			
Province	District	Density (number of mites cm^{-2})	Total number of the mites per leaf	Infestation rate (%)	Prevalence rate (%)	Density (number of mites cm^{-2})	Total number of the mites per leaf	Infestation rate (%)	Prevalence rate (%)
Ankara	Çubuk	0.012	0.61	41.25	100.0	0.007	1.32	100.0	100.0
	Kazan	0.004	0.18	29.70	100.0	0.009	1.77	100.0	100.0
	Ayaş	0.002	0.13	22.31	100.0	0.006	1.09	45.45	100.0
Average		0.006	0.31	31.09	100.0	0.007	1.39	81.82	100.0

In 2018, the studies conducted in Afyonkarahisar province revealed varying infestation rates across different districts. In the central district, the infection rate started at 79.79% in June and reached 100% in both July and August. Similarly, in Şuhut district, the infestation rate was 78.20% in June and also reached 100% in July and August, remaining at that level until harvest. In Emirdağ district, the infection rate was 46.21% in June, increasing to 97.37% in July, and reached 100% in August. The number of mites per leaf started at 0.28 in Şuhut and 0.28 in Emirdağ, peaking at 18.92 and 16.47 mites per leaf, respectively. In the central district of Afyonkarahisar province, the highest number of pests per leaf was recorded at 19.25. It was observed that infestation rates, densities, prevalence, and pest numbers per leaf increased steadily across the different observation dates (Table 4, Figure 3).

Table 4. Infestation rate (%) of pest mites detected in the districts of Afyonkarahisar and Konya provinces in 2018.
Çizelge 4. Afyonkarahisar ve Konya illerinin ilçelerinde 2018 yılında tespit edilen zararlı akarların bulaşma oranı (%).

Work location		June				July				August			
Province	District	Density (number of mites cm-2)	Total number of the mites per leaf	Infestation rate (%)	Prevalence rate (%)	Density (number of mites cm-2)	Total number of the mites per leaf	Infestation rate (%)	Prevalence rate (%)	Density (number of mites cm-2)	Total number of the mites per leaf	Infestation rate (%)	Prevalence rate (%)
Afyonkarahisar	Merkez	0.0101	1.15	79.79	100.0	0.08	15.81	100	100.0	0.10	19.25	100.0	100.0
	Şuhut	0.008	0.28	78.20	100.0	0.07	13.55	100	100.0	0.10	18.92	100.0	100.0
	Emirdağ	0.0027	0.28	46.21	100.0	0.06	10.04	97.37	100.0	0.08	16.47	100.0	100.0
Average		0.0069	0.57	68.06	100.0	0.07	13.13	99.12	100.0	0.093	18.21	100.0	100.0
Konya	Altınekin	0.003	0.14	20.95	100.0	0.016	1.88	80.60	100.0	0.09	17.08	87.11	100.0
	Kadınhanı	0.003	0.15	24.95	100.0	0.021	2.35	93.53	100.0	0.08	14.46	87.01	100.0
	Çumra	0.008	0.41	34.96	100.0	0.026	2.96	89.45	100.0	0.10	18.62	100.0	100.0
Average		0.0035	0.233	26.95	100.0	0.021	2.396	87.86	100.0	0.09	16.72	91.373	100.0

In Konya province, the infestation rate started at 20.95% in June and increased to 80.60% in July in Altınekin district. The rate increased to 87.11% in August. In the Kadınhanı district, the infestation rate began at 24.95% in June, peaked at 93.53% in July, and decreased to 87.01% by the end of August. In the Çumra district, the infestation rate started at 34.96% in June, reached 89.45% in July, and hit 100% in August. The number of mites per leaf was initially 0.14 in the Altınekin district, rapidly increasing to 17.08. Similar trends were observed in the Kadınhanı and Çumra districts, where the highest densities reached 14.46 and 18.62 mites per leaf, respectively. Surveys conducted on different dates showed that infestation rates, densities, prevalence, and pest densities per leaf increased over time (Table 4, Figure 4).

In all three provinces, the highest infestation rates were observed in July and August. In Ankara province, the average rate began at 31.09% and increased to 81.82%. In Konya province, the average rate started at 26.95% and increased to 91.37% by August, just before harvest. In Afyonkarahisar province, the average infestation rate started at 68.06% in June, increased in July, and reached 100% in August.

The seasonal population of *T. urticae*, which began appearing at the end of June, increased significantly in July and August, reaching its highest level by the end of August. Studies indicated substantial damage due to this increase. By mid-July, the number of *T. urticae* surpassed the economic damage threshold (3 mites per leaf) in Afyonkarahisar and Konya provinces (Anonymous, 2008). In Ankara province, however, the pest population did not exceed the economic damage threshold. During our observations in common bean fields of Ankara, both *T. urticae* and *E. finlandicus* were detected together. Beneficial organisms, particularly *E. finlandicus*, are thought to have helped keep pest populations under control. Similarly, Soysal (2016) found that *E. finlandicus* with *T. urticae* in surveys of bean and cucumber fields in the open fields and greenhouses of the Ordu region.

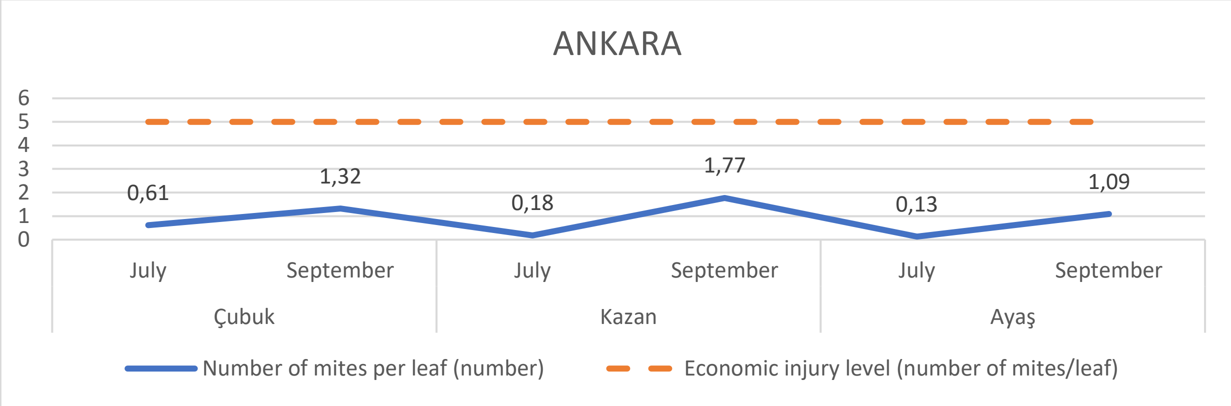

Figure 2. Average number of mites per leaf during the vegetation period in Ankara province in 2017.
Şekil 2. Ankara ilinde 2017 yılında vejetasyon dönemi boyunca yaprak başına düşen ortalama akar sayısı.

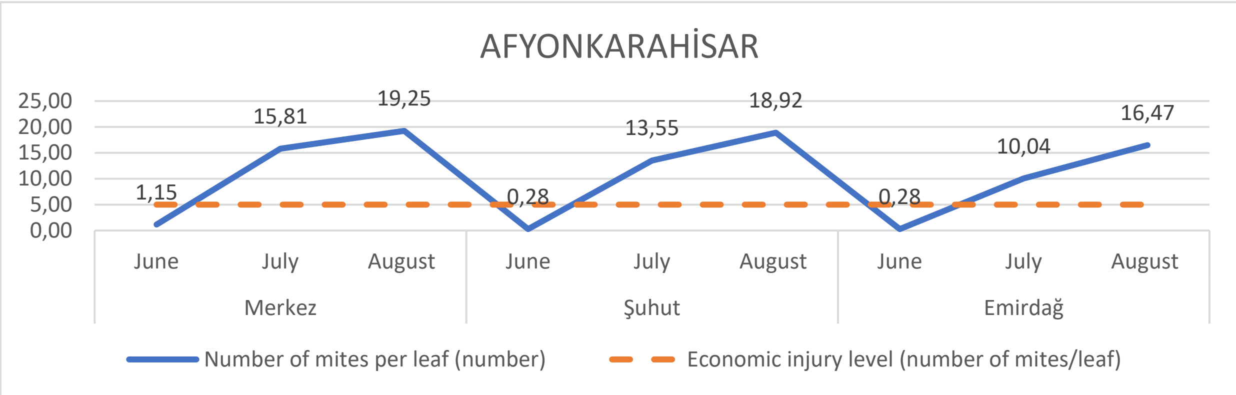

Figure 3. Average number of mites per leaf during the vegetation period in Afyonkarahisar province in 2018.
Şekil 3. Afyonkarahisar ilinde 2018 yılı vejetasyon dönemi boyunca yaprak başına düşen ortalama akar sayısı.

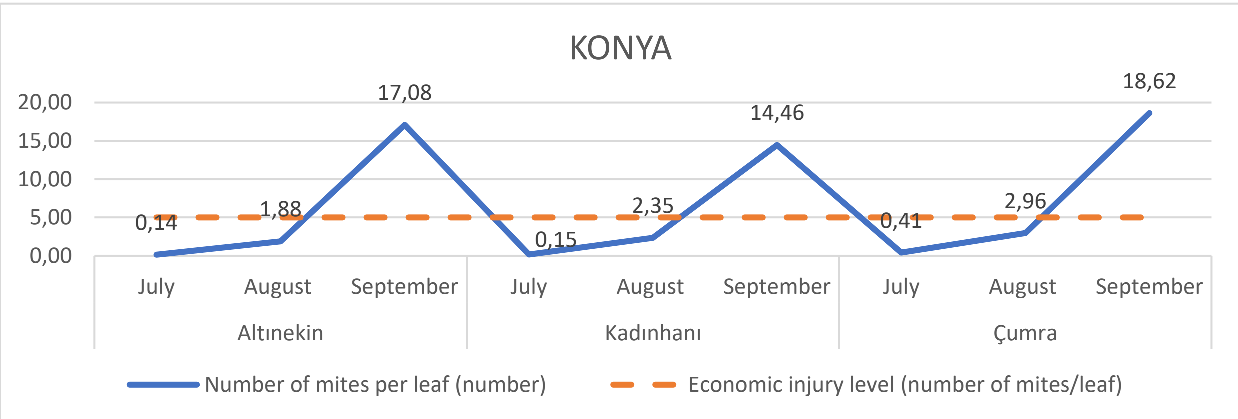

Figure 4. Average number of mites per leaf during the vegetation period in Konya province in 2018.
Şekil 4. Konya ilinde 2018 yılı vejetasyon dönemi boyunca yaprak başına düşen ortalama akar sayısı.

Tetranychus urticae is recognized as a common and economically significant pest species in common beans. Studies conducted in all three provinces confirmed the prevalence of *T. urticae* and its significant economic impact. Polat and Kasap (2011) reported that the population of *T. urticae* began increasing in July, reaching its peak by the end of September and into the first half of October. They observed that high populations of *T. urticae* caused plants to begin drying out during these periods. In another study, Kumar et al. (2013) assessed the population density of *T. urticae* on eggplant (*Solanum melongena* L.), bitter gourd (*Momordica* *charantia* L.), okra (*Abelmoschus esculentus* L.), gourd (Cucurbitaceae), and cowpea (*Vigna chinensis* L.) plants. They reported mite populations per leaf as follows: eggplant (53.34 mites), cowpea (47.37 mites), okra (42.83 mites), and gourd (37.93 mites), respectively. As stated in previous studies, *T. urticae* has the potential to infest and damage various vegetables. Therefore, similar to the literature, the average number of mites per common bean leaf was lowest in Ankara (0.31 mites) and highest in Afyonkarahisar province (18.21 mites).

Tetranychus turkestani, also known as *Tetranychus atlanticus* McGregor, was detected in samples taken from the Altınekin district of Konya. This phytophagous mite is an important pest species in Türkiye and globally, particularly affecting crops such as strawberries, beans, cucumbers, eggplants, tomatoes, cowpeas, and squash (both in field and greenhouse settings), where it feeds by sucking cell contents (Jeppson et al., 1975; Ongoren et al., 1975; Helle and Sabelis, 1985; Bolland et al., 1998; Cıkman 1995; Cakmak et al., 2003; Zhang, 2003; Hoy, 2011; Ozsisli and Cobanoglu, 2011). This species can also be found under bark and among debris of trees (Mellott and Connell, 1965). Its presence has been documented in various studies conducted in Türkiye. Studies in the Aegean Region identified *T. urticae* as the most common mite species, with *Tetranychus cinnabarinus* (Boisduval, 1867) and *T. atlanticus* also found in beans (Ongoren et al., 1975). Cıkman (1995) reported *T. urticae, T. cinnabarinus,* and *T. atlanticus* in tomatoes among different vegetable crops in Şanlıurfa province. Ulusoy et al. (1999) identified phytophagus and beneficial arthropod species in cherry trees in Niğde and Adana, including *T. atlanticus*.

Tetranychus solanacearum was identified for the first time in common beans by Cobanoglu & Ueckermann, marking a new record for Türkiye and globally (Cobanoglu et al., 2015). Specimens were collected from solanaceous plants including *Solanum nigrum* L., *Solanum dulcamara* L., *Solanum melongena* L., *Solanum rostratum* Dunal., *Datura stramonium* L., and *Lycopersicon esculentum* L. in Ankara province. Subsequently, Kumral and Cobanoglu (2016) also detected this species in eggplant fields in Ankara and Bursa provinces. Limited information is available about this species, which thrives under favorable conditions for growth and development, feeding intensively on beans and rapidly multiplying, thereby causing significant leaf damage. Its feeding behavior on bean plants can lead to substantial yield reduction, eventually resulting in plant desiccation and death. Due to its recent discovery in Türkiye and globally, comprehensive studies are needed to understand its distribution, hosts, biology, and effective control methods.

The pineapple mite, *S. asparagi*, was identified for the first time in Türkiye. This species is distributed in Africa, Europe, the USA, Puerto Rico, and Hawaii. It typically forms large populations, especially during the summer months, and its hosts include *Protasparagus* species and occasionally pineapple. It is known to be phytophagus to crops grown both in field and greenhouse environments. This mite is characterized by its red coloration when alive and lays its eggs at the base of leaf branches. Feeding by *S. asparagi* causes leaf discoloration. Infected plants exhibit stunted growth, reduced fruit production, or even complete failure to set fruit, with severe infestations potentially leading to plant desiccation. It is suggested that infection can be prevented by using clean seedlings or saplings (Meyer, 1974, 1987, 1996; Jeppson et al., 1975; Ben-David et al., 2007). Its presence in Türkiye was documented for the first time in this study. In a similar study, another species, *Schizotetranychus ibericus* Reck, 1947 (Acari: Prostigmata), was reported from Ankara, Türkiye (Cobanoglu et al., 2023).

In this study, *T. caudatus* and *T. californicus* were found to exclusively in Ankara province. These species are reported to feed on pollen, honeydew, or sweet substances secreted by insects, and certain predatory mite species (Phytoseiidae) may feed on Tydeid species when their primary prey is absent (Jeppson et al., 1975). It has been suggested that *T. caudatus* could serve as an alternative food source for predatory mites, especially in orchards, where chemical control measures are not applied (Baker, 1970; Darbemamieh et al., 2010, 2016). While it is evaluated that *T. caudatus* does not cause significant economic damage due to its limited distribution and sparse occurrence on plants, it has been recognized as a pest requiring control measures because of its extensive infestations in raspberry, persimmon, and apricot crops in New Zealand, albeit not in our country (Jones et al., 1996). Therefore, it is considered essential to assess the population status and density of *Tydeus* spp.

As a result of this study, six phytophagous mite species belonging to the Tetranychidae and Tydeidae families were identified across three different provinces. In a similar study conducted in India, various mite species, including Tetranychidae, Tenuipalpidae, Tarsonemidae, and Eriophyidae, were identified in vegetables, with these phytophagous mite groups causing damage primarily between April to July and September to October during severe summer months. Mehrkhou et al. (2008) conducted a study in Tehran, Iran, in 2005 to assess the population density and distribution of *T. urticae* on cucumber and different bean varieties. Among the bean varieties studied, the highest number of mites per leaf was observed in Sunray (59.37 mites per leaf), while the lowest was found in Parastoo (4.73 mites per leaf).

T.urticae was found to be the most abundant and economically important species in all three provinces. The spider mite *T. urticae* has a worldwide distribution, mainly in Europe, Asia and North and South America, and feeds on approximately 1500 described plant species belonging to 70 genera (Bolland et al., 1998). When the population densities of the mite species were analysed, it was found that they did not exceed the economic damage threshold in Ankara province (Figure 2). Our study found *T. urticae* and *E. finlandicus* to be common in bean fields in Ankara. It was suggested that *E. finlandicus*, a beneficial species, may play a significant role in suppressing mite populations in Ankara. *E. finlandicus* feeds on various mite species, including Tetranychidae, Eriophyidae, Tyroglyphidae, and Tarsonemidae, as well as on pollen, fungal spores, hyphae, insect eggs and larvae, and honeydew. This predatory behavior underscores its importance in the biological control of spider and eriophyid mites (Kostiainen and Hoy, 1994; Schausberger, 1997, 1998; Broufas and Koveos, 2000; Abdallah et al., 2001; Broufas and Koveos, 2001).

In the provinces of Konya and Afyonkarahisar, the population of mites was found to exceed the economic damage threshold (Figure 3-4). However, studies conducted across all three provinces showed that the prevalence rate reached 100% depending on the month. This study was conducted in different districts of Afyonkarahisar, Ankara, and Konya provinces, where cultivation is intensive.

CONCLUSION

This study monitored phytophagus mite species in common bean fields throughout their growth cycle and determined their densities. Among the identified plant pest mite species were *T. urticae*, *T. atlanticus*, *T. solanacearum*, and *S. asparagi.* Additionally, neutral mites *T. caudatus* and *T. californicus* were detected in these fields. During the entire vegetation period of beans, the highest infestation rates were observed in July and August in all three provinces. This situation demonstrates that mite species can adapt rapidly despite the increase in temperature in our country, which is influenced by global warming. Especially with long-term adaptation, it is thought that mites can spread over a wider area andacross a wide range of environmental temperatures.

Our finding that *T. urticae* was identified as the most prevalent pest species in beans. Globally, *T. urticae* is recognized as one of the most destructive mite pests in agricultural crops. This pest poses significant challenges for control due to its exceptionally rapid reproductive rate and ability to develop resistance to chemical treatments. Therefore, continuous monitoring of its population throughout the growing season is essential, and efforts should be made to suppress its population using non-chemical control methods when necessary.

According to our findings, many mite species other than *T. urticae* were detected for the first time in bean fields. This study represents the first faunistic study on bean mites in the region, and *T. solanacearum* Ankara and *S. asparagi* were identified for the first time in Türkiye. It is important to know the phytophagus mite species in bean fields, to monitor their population densities, and to investigate their biology and natural enemies. It is thought that determining the effect of climate change on pest organisms and periodically monitoring and controlling the changes in pest populations over the years are of great importance in pest control, particularly because of the impact of developmental and reproductive temperatures.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

DECLARATION OF AUTHOR CONTRIBUTION

AB writing the original draft and review and editing, AB and NG field and laboratory studies, HD laboratory studies, NAK and SC identified the mite specimens and the review – editing.

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Research Article / Araştırma Makalesi

Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi

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Tarım Kredi Kooperatif Ortaklarının Bitki Koruma Ürün Grubu Hakkında Bilgi Düzeyi ve Etkileri Konusunda Görüşlerinin Belirlenmesi: Iğdır İli Örneği

Determination of Agricultural Credit Cooperatives Partners' Knowledge Level and Their Opinions on the Effects of Plant Protection Product Group: The Case of Iğdır Province

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Öz: Tarımsal kooperatifler, çiftçilerin sosyal ve ekonomik kalkınmalarının temelini oluşturan örgütlerdir. Kooperatifler ortaklarına ekonomik güç kazandırırken, aynı zamanda eğitim faaliyetleri ile bilinç düzeylerini artırıcı görevleri de bulunmaktadır. Iğdır ilinde bitkisel üretim yapan kooperatif ortağı 100 üretici ile yüz yüze görüşmeye dayalı anket çalışması yapılmıştır. Bu çalışma ile kooperatif ortaklarının sosyo-ekonomik özellikleri, bitki koruma ürün grupları anlam/etiket rengi bilme durumu, bitki koruma ürünleri kalıntı ve çevre ile insan sağlığına etkileri konusunda görüşlerinin tespit edilmesi amaçlanmıştır. Ortakların büyük çoğunluğu (%53) ilköğretim mezunu, ortalama yaşı 47.87 ve aylık tarımsal geliri 20,314TL'dir. Ortakların %26'sı tarım dışı bir işte çalışmakta olup %70'inin ise tarım dışı geliri bulunmaktadır. Ortakların insektisit, fungisit, herbisit ve nematisitin anlamını bilme oranı sırasıyla; %52, %41, %52, %16 olup etiket rengini bilme oranı ise sırasıyla; %59, %55, %69 ve %17'dir. Merkez Tarım Kredi Kooperatif ortaklarının bitki koruma ürün grupları anlam ve etiket rengini bilme oranları Yaycı Tarım Kredi Kooperatif ortaklarına göre daha yüksektir ($p<0.05$). Bitki koruma ürünlerinin çevreye verdiği zarar konusunda en yüksek katılımı olduğu önerme "Yararlı böcek ve arılarda zarar oluşturur" önermesi (4.69 puan) iken insana verdiği zarar konusunda en yüksek katılımın olduğu önerme ise "Kanserojen etkisi olur" önermesidir (4.62 puan). Merkez Tarım Kredi Kooperatif ortaklarının bitki koruma ürünlerinin çevreye verdiği zararlar konusundaki önermelere katılım düzeyi Yaycı Tarım Kredi Kooperatif ortaklarına göre daha fazla olup bu fark istatistiksel olarak anlamlı bulunmuştur ($p<0.05$). Çiftçilerin bitki koruma ürünlerinin insan sağlığına verdiği zararlar ile ilgili önermelere katılımında ortağı olduğu kooperatife göre anlamlı bir fark olmadığı belirlenmiştir ($p>0.05$). Kooperatif çalışanlarının bitki koruma ürünlerinin satışında kooperatif ortaklarının bilgi düzeyine göre yaklaşım geliştirmesi daha güçlü bir iletişimin kurulmasına ve dolayısıyla daha bilinçli ilaç kullanılmasına katkı sağlayacaktır.

Anahtar Kelimeler: Tarım kredi kooperatif ortakları, bitki koruma ürünü, bilgi düzeyi, ortakların görüşü

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Abstract: Agricultural cooperatives are organizations that form the basis of farmers' social and economic development. While providing economic power to their members, they also have the task of increasing awareness levels through educational activities. A survey based on face-to-face interviews was conducted with 100 cooperative members engaged in plant production in Iğdır province. The aim was to determine the socio-economic characteristics of the cooperative members and the opinions on the knowledge of plant protection product groups' meaning/label color, plant protection product residues and their effects on the environment and human health. The majority of the members (53%) are primary school graduates, the average age is 47.87 and their montly agricultural income is 20,314 TL. 26% of the members work in a non-agricultural job and 70% of them have non-agricultural income. The rate of members knowing the meaning of insecticide, fungicide, herbicide and nematicide is 52%, 41%, 52%, 16%, respectively and the rate of knowing the label color is 59%, 55%, 69% and 17%, respectively. The rates of knowing the meaning of plant protection product groups and label color of the Central Agricultural Credit Cooperative members are higher than the partners of the Yaycı Agricultural Credit Cooperative ($p<0.05$). The proposition with the highest agreement on the damage caused by plant protection products to the environment is "It causes harm to beneficial insects and bees" (4.69 points), while the proposition with the highest agreement on the damage caused to humans is "It has a carcinogenic effect" (4.62 points). The level of agreement of the Central Agricultural Credit Cooperative members to the propositions on the damage caused by plant protection products to the environment is higher than the Yaycı Agricultural Credit Cooperative members, and this difference was found to be statistically significant ($p<0.05$). It was determined that there was no significant difference in the agreement of the farmers to the propositions on the damage caused by plant protection products to human health according to the cooperative they were a member of ($p>0.05$). The development of an approach by cooperative employees in the sale of plant protection products according to the knowledge level of cooperative members will contribute to the establishment of stronger communication and therefore to more conscious use of pesticides.

Keywords: Agricultural credit cooperative partners, plant protection product, level of knowledge, partners' opinion

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GİRİŞ

Kooperatifler, dünya genelinde toplumların daha iyi bir yaşam sürmesine önemli katkılar sağlayan, demokratik ve gönüllülük esasına dayalı örgütlerdir. Özellikle gelişmiş ülkelerde sosyal ve ekonomik kalkınmanın temelini oluşturan bu örgütler, üyelerine ekonomik güç kazandırırken, aynı zamanda sosyal dayanışmayı da güçlendirmektedir. Tarım sektöründe sürdürülebilirliğin sağlanması, üreticilerin sorunlarına çözüm bulunabilmesi ve ekonomik ve sosyal refah seviyelerinin artırılabilmesi için kooperatifleşme kaçınılmaz bir ihtiyaçtır (Kılıç Topuz vd., 2022a). Dünyada 570 milyon çiftçi, 1.2 milyon tarımsal kooperatife üyedir. Dünyadaki tarımsal kooperatifler toplam kooperatiflerin %40'ını oluşturmaktadır. Ayrıca Tarım kooperatifi üyeleri ise, toplam kooperatif üyelerinin yaklaşık %50'sini oluşturmaktadır (International Cooperatives Alliance [ICA], 2019).

Türkiye'de tarımsal amaçlı kooperatiflerin sayıları, tabi oldukları kanun Tarım Reformu Genel Müdürlüğü [TRGM] (2024) verilerinden elde edilerek derlenmiş olup Çizelge 1'de gösterilmektedir. Tarımsal üretimde önemli rol oynayan 11754 kooperatif bulunmaktadır. Bu kooperatiflere yaklaşık 3.6 milyon çiftçi ortak olarak kayıtlı durumdadır. Kooperatiflerin %56.5'i Tarımsal Kalkınma (TK), %21.2'si Sulama Kooperatifi (SK) ve %13.8'i ise Tarım Kredi Kooperatifi (TKK) olarak faaliyet göstermektedir.

Çizelge 1. Türkiye'de tarımsal amaçlı kooperatifler.
Table 1. Agricultural cooperatives in Türkiye.

Kooperatif	Kanun	Kooperatif Sayısı	Ortak Sayısı
-Tarımsal Kalkınma Kooperatifi	1163 S.K.	6641	735606
-Sulama Kooperatifi	1163 S.K.	2488	320948
-Su Ürünleri Kooperatifi	1163 S.K.	591	31628
-Pancar Ekicileri Kooperatifi	1163 S.K.	31	1399339
Ara Toplam		9751	2487521
-Tarım Kredi Kooperatifi	1581 S.K.	1618	853869
Ara Toplam		11369	3341390
-Tarım Satış Kooperatifi*	4572 S.K.	338	332925
-Tütün Tarım Satış Kooperatifi*	1196 S.K.	18	939
-Yaş Meyve ve Sebze Pazarlama Koop.*	1163 S.K.	29	2953
Genel Toplam		11754	3678207

Türkiye'de kırsal alanın refah düzeyinin artırılmasında önemli rol oynayan TKK Türkiye genelinde 17 bölge birliği, 1625 birim kooperatifi, 189 hizmet bürosu ile kırsal alanda yaşayan üreticilerin tarımsal üretimine katkıda bulunmakta ve çiftçilerin ürünlerini değerlendirerek aralıksız hizmet vermektedir (Tarım Kredi Kooperatifleri [TKK], 2022). Iğdır ilinde ise Erzurum bölge birliğine bağlı Iğdır (Merkez) TKK, Yaycı TKK, Aralık TKK, Tuzluca TKK ve Taşburun TKK olmak üzere 5 aktif TKK ve 1 hizmet bürosu (Melekli) üreticilere hizmet vermektedir (TKK, 2024).

TKK'lerin bitki koruma ürünleri satışı yapmaları üreticilerin hem bu ürünler hakkında bilgi sahibi olmaları hem de kolay temin edebilmeleri bakımından tarım sektörü için büyük öneme sahiptir. Bitki koruma ürünlerinin kullanımı, tarımsal ürün kayıplarını önlemenin temel stratejilerinden biridir. European and Mediterranean Plant Protection Organization [EPPO] (2004)'e göre bitki koruma ürünleri; tarımsal üretim, peyzaj ve ormanlık alanlarda, depolanmış bitki ürünlerinde ve ekime yönelik olmayan arazilerde, zararlıları yok ederek, uzaklaştırarak veya büyümelerini sınırlayarak bitkileri veya bitki ürünlerini korumak, yabancı otları veya istenmeyen bitkileri yok etmek veya büyümelerini sınırlamak, bitkilerin büyümesini kontrol etmek veya değiştirmek (besin maddesi dışında) amacıyla kullanılmak üzere tasarlanmış, kimyasal veya biyolojik nitelikteki maddeler veya madde karışımları veya mikroorganizmaların (mantarlar, virüsler, bakteriler, protozoalar veya diğer mikroskobik kendi kendini çoğaltan biyotik varlıklar) formüle edilmiş preparatları olarak tanımlanmaktadır. Bitki koruma ürünleri (BKÜ) ayrıca pestisitler olarak da adlandırılır ve en az bir aktif madde içerir. Bu aktif maddeler, BKÜ'lerin hedef zararlılar, hastalıklar veya yabancı otlar üzerinde kontrol edici bir etki göstermesini sağlayan kimyasallar, mikroorganizmalar, feromonlar, bitki ekstraktları veya virüsler olabilir. Ayrıca yardımcı maddeler, güvenli hale getiriciler ve sinerjistler gibi diğer birçok bileşenleri de içerebilir (Cilia ve Kandris, 2023). Pestisitler; fiziksel yapı ve formülasyon şekillerine, hedef zararlı ve hastalık grubu ile bunların biyolojik dönemine, içerdikleri aktif maddenin cins ve grubuna, zehirlilik derecesine ve kullanım tekniğine göre farklı şekillerde sınıflandırılabilmektedir. Pestisitler etki ettiği organizma grubuna göre; insektisit, akarisit, nematisit, rodentisit, fungusit, herbisit, bakterisit, algisit, repellentler vb. gibi çeşitli alt sınıflara ayrılabilmektedir. Etki ettiği organizma grubuna göre en yaygın kullanılan pestisit grupları, insektisit, fungisit ve herbisitlerdir (Kurşun vd., 2022). Bu bağlamda, çeşitli BKÜ'leri verim kayıplarını azaltmak veya ortadan kaldırmak ve yüksek ürün kalitesini korumak amacıyla zararlı, hastalıkları, yabancı otları ve diğer bitki patojenlerini kontrol etmek için tarımsal üretimde yaygın olarak kullanılmaktadır (Damalas ve Eleftherohorinos, 2011). Ne yazık ki BKÜ'lerin aşırı ve yanlış kullanımının insanlar, bitkiler, hayvanlar ve yaban hayatı üzerinde toksik etkileri olduğu bilinmektedir (Schulz vd., 2002).

Levitan (2000), pestisitlerin kullanımıyla ilişkili olarak; hedef biyotada beklenmeyen olumsuz etkiler, gıda, su, toprak ve havada pestisit kalıntısı riski, zararlılara karşı direnç, hastalık veya gıda ve lif kaybı, doğa veya tarımsal ekosisteme zarar verilmesi gibi riskleri belirlemiştir. BKÜ'lerinin çiftçilerin sağlığı üzerinde ciddi olumsuz etkiler yaratma potansiyeli; yüksek verim elde etmek için BKÜ'lerin gerekli olduğu yoğun tarımsal üretimden kaynaklı değil, çiftçilerin BKÜ'lerin kullanımıyla ilişkili potansiyel sağlık etkileri konusundaki bilgisizliğinden kaynaklandığı vurgulanmaktadır (Palis vd., 2006; Anderson ve Meade, 2014). Çiftçiler genellikle BKÜ'lerin insan sağlığı üzerindeki potansiyel olumsuz etkilerinin farkında değildir ve yeterli koruyucu önlemler olmadan aşırı miktarda BKÜ kullanabilirler. BKÜ'lerin zararlı etkilerinin farkında olan çiftçiler bile genellikle bu farkındalığı uygulamalarına yansıtamazlar (Damalas ve Abdollahzadeh, 2016). Çiftçiler, esas olarak BKÜ ile ilaç solüsyonlarının hazırlanması ve uygulanması veya püskürtme ekipmanının temizlenmesi sırasında yüksek düzeyde BKÜ'lere rutin olarak maruz kalmaktadırlar (Damalas ve Koutroubas, 2016). BKÜ'lerin kullanımı zararlı ve hastalık kontrolü için seçilen yöntem olduğunda; ürünlerin sahada etkililiğini, kişi ve çevre güvenliği ve yasal uyumluluğu sağlamak için doğru şekilde kullanılması önemlidir. BKÜ kullanımı sırasında güvenlik uygulamalarına ilişkin yetersiz bilgi ve anlayış ile bitki koruma ekipmanlarının gerekliliği hakkındaki yanlış inançlar, çiftçilerin BKÜ kullanımından kaynaklanan risklere karşı kendilerini koruma yeteneklerini ciddi şekilde etkileyebilmektedir (Jors vd., 2006; Zhang ve Lu, 2007; Barzman vd. 2015). Bu nedenle çiftçilerin bitki koruma ürünleri hakkında bilgi düzeylerinin belirlenmesi, tarımsal üretimin yanı sıra insan ve çevre sağlığının sürdürülebilirliği açısından oldukça önem arz etmektedir. Bazı çiftçiler, bitki koruma ürünleri hakkında bilgi seviyesini artırarak bitki koruma ürünlerini daha etkin şekilde kullanabilir, sağlık tedbirlerini daha doğru yerine getirebilir ve çevreye karşı daha duyarlı olabilir.

TKK ile ilgili ülke genelinde çok sayıda araştırma incelendiğinde, araştırmaların daha çok kooperatiflerin mali yapısı ve finansal performansı üzerine olduğu dikkat çekmektedir (Kılıç Topuz vd., 2022b). Iğdır ilinde ise; üyelerin tarımsal örgütlerin genel kurul toplantısına katılımını etkileyen faktörler, tarımsal örgütlerin mevcut durumu ve yönetici profili, hayvancılık işletmelerinin üretim ve pazarlamada yaşadıkları örgütlenme sorunlarının analiz, kırsal kalkınma kooperatifi üyelerinin örgütlenme ve kooperatif faaliyetleriyle ilgili problemleri gibi kooperatifler ile ilgili çeşitli konularda çok sayıda çalışmaya literatürde rastlanılmıştır (Karadaş vd., 2014, Karadaş vd., 2015; Alptekin, 2018; Kılıç Topuz, 2021; Kılıç Topuz vd., 2022a). Ancak, TKK'ler ortaklarının bitki koruma ürünleri hakkında bilgi düzeyinin belirlenmesine yönelik herhangi bir araştırmaya rastlanılmamıştır. Yapılan çalışmanın literatürde, bu yöndeki boşluğu doldurması beklenmektedir.

Çiftçilerin bitki koruma ürünleri hakkında bilgi düzeyi, coğrafi konum, eğitim seviyesi, tarımsal tecrübe veya ilaç bayileri/tarım danışmanlarından edindikleri bilgiye göre büyük farklılıklar gösterebilir. Bu nedenle; bu çalışma ile Iğdır ili Tarım Kredi Kooperatif ortaklarının sosyo-ekonomik özellikleri ve bitki koruma ürünleri hakkında bilgi düzeylerinin belirlenmesi amaçlanmaktadır.

MATERYAL VE METOT

Bu çalışma, Iğdır ilinde bitki koruma ürünü satan Tarım Kredi Kooperatifi ortakları ile 2024 yılı Ocak-Mart ayları arasında yapılmıştır.

Araştırma Alanı

Araştırmada kullanılan veriler Iğdır ili ve ilçelerinden tarımsal üretim yapan Tarım Kredi Kooperatif ortaklarından elde edilmiştir (Şekil 1). Türkiye'nin en doğusunda yer alan Iğdır ili, Kuzeydoğusunda Aras nehri ve bu nehrin yatağından oluşturduğu Ermenistan sınırı, doğuda Nahçıvan ve İran sınırı, güneyinde Ağrı ili, kuzey batısında ise Kars ili bulunmaktadır (Özger ve Karadaş, 2022).

Şekil 1. Araştırma alanı (Datawrapper, 2024).
Figure 1. Research area (Datawrapper, 2024).

Veri Toplama Yöntemi

Iğdır ilinde bitkisel üretim yapan kooperatif ortağı üreticiler ile yüz yüze görüşme yöntemiyle gerçekleştirilen anket çalışmasından elde edilen veriler araştırmanın ana materyalini oluşturmaktadır. Anket formu; kooperatif ortakların sosyo-ekonomik özellikleri, bitki koruma ürün grupları anlam/etiket rengi bilme durumunu, bitki koruma ürünü kalıntıları hakkında görüşlerini, bitki koruma ürünlerinin insan sağlığına/çevreye etkileri konusunda bilgi düzeylerini tespit etmeye yönelik sorular içermektedir. İkincil veri olarak yerli ve yabancı yayınlar, kamu kurum ve kuruluşların kayıtları ve istatistikî verilerinden faydalanılmıştır.

Örnekleme Yöntemi

Araştırma alanı olarak, Iğdır Merkez, Aralık, Karakoyunlu ve Tuzluca ilçeleri seçilmiş olup, bu bölgede bitkisel üretim yapan ve kooperatif ortağı olan çiftçi sayıları Iğdır Tarım Kredi Kooperatiflerinden alınmıştır. Iğdır ilinde faaliyet gösteren ve bitki koruma ürünü satışı yapan 2 tarım kredi kooperatifi karşılaştırılacaktır. Araştırmanın popülasyonunu Iğdır ilinde bitkisel üretim yapan ve bitki koruma ürünü satın alma tercihini ortağı olduğu Merkez Tarım Kredi Kooperatifi veya Yaycı Tarım Kredi Kooperatifi'nden yapan 959 çiftçi oluşturmaktadır.

Yamane (2010) Basit Tesadüfi Örnekleme Yığın Oran Tahmini Yöntemi kullanılarak %90 güven düzeyi, %10 hata payı ve örnek hacmini maksimum yapacak şekilde p ile q değerleri 0.5 olarak alınmış olup örneklem büyüklüğü 87 olarak hesaplanmıştır. Hatalı, eksik veya yetersiz cevap gibi olumsuz durumlar için %20 fazla anket yapılmış olup değerlendirme 100 anket üzerinden yapılmıştır.

$$n = \frac{N\ x\ t^2\ x\ pq}{(N-1)\ x\ D^2 + t^2\ x\ p\ x\ q} \tag{1}$$

n= Populasyonu temsil edecek kooperatif ortağı sayısını

N= Populasyondaki küme büyüklüğünü

D= Kabul edilen veya arzu edilen örnekleme hatasını (0.10)

t= Tablo değerini (1.96)

p= Hesaplanması istenen oranı (0.5)

q= 1-p

$$n = \frac{959\ x\ 1.96^2\ x\ 0.5x0.5}{(959-1)\ x\ 0.1^2 + 1.96^2\ x\ 0.5x0.5} = 87.38 \quad (2)$$

Iğdır ilinde bitki koruma ürünü satan kooperatiflerin ortak sayısına göre yapılan anket sayısının dağılımı Çizelge 2'de gösterilmiştir. Merkez Tarım Kredi Kooperatif Ortağı çiftçi ile 62 anket ve Yaycı Tarım Kredi Kooperatif Ortağı çiftçi ile 38 anket değerlendirmeye alınmıştır.

Çizelge 2. Ortak sayısına göre anketlerin oransal dağılımı.
Table 2. Proportional distribution of surveys by the number of partners.

Kooperatifler	Ortak sayısı (N)	Yüzde (%)	Asgari Anket Sayısı (n)	İlave Anket Sayısı (n)	Yapılan Anket Sayısı(n) veya Oranı (%)
Merkez Tarım Kredi Koop.	622	64.9	56	6	62
Yaycı Tarım Kredi Koop.	337	35.1	31	7	38
Toplam	959	100.0	87	13	100

Çalışma kapsamında görüşme gerçekleştirilen kooperatif ortağı çiftçilerin yaşadıkları ilçeler Çizelge 3'de gösterilmiştir. Çiftçilerin 58'i Merkezde ve bağlı köylerde, 20'si Karakoyunlu ilçesinde, 15'i Aralık ilçesinde ve 7'si Tuzluca ilçesinde yaşamaktadır.

Çizelge 3. Anketlerin ilçelere göre dağılımı.
Table 3. Distribution of surveys by district.

İlçeler	Merkez Tarım Kredi Koop.		Yaycı Tarım Kredi Koop.		Genel Toplam
	Sayı (n)	Oran (%)	Sayı (n)	Oran (%)	Oran (%)
Merkez	35	56.5	23	60.5	58.0
Karakoyunlu	16	25.8	4	10.5	20.0
Aralık	5	8.1	10	26.3	15.0
Tuzluca	6	9.7	1	2.6	7.0
Toplam	62	100.0	38	100.0	100.0

Analiz Yöntemi ve Araştırma Hipotezi

Araştırma bulgularının analizinde; frekans dağılımı, yüzde ve aritmetik ortalama gibi tanımlayıcı istatistikler kullanılmıştır. Çalışmanın 2 farklı araştırma hipotezi vardır. Birinci araştırma hipotezi (H1): "Iğdır İli Tarım Kredi Kooperatif ortaklarının bitki koruma ürün grubu hakkında bilgi düzeyi ilçelere göre farklılık gösterir" ve ikinci araştırma hipotezi (H2): "Iğdır İli Tarım Kredi Kooperatif ortaklarının bitki koruma ürünlerinin etkileri konusunda ilçelere göre farklılık gösterir" olarak kurulmuştur. Çalışmada; açık uçlu soru, iki seçenekli ve çok seçenekli sorularla birlikte 5'li Likert tipi sorular kullanılmıştır. Likert tipi sorularda ortalamaların yorumlanmasında Palaz ve Boz (2008) tarafından kullanılmış olan Likert skalası tercih edilmiştir. Bu skalada her bir sorunun likert ortalaması hesaplanmıştır. Ortalamaların değeri için aşağıdaki yorumlama skalası geliştirilmiştir: Ortalama 1.00-1.49 arası = Kesinlikle Katılmıyorum, 1.50-2.49 arası=Katılmıyorum, 2.50-3.49 arası=Orta düzeyde katılıyorum, 3.50-4.49 arası=Katılıyorum ve 4.50-5.00 arası=Kesinlikle Katılıyorum şeklinde skala kullanılmış olup sonuçlar bu skalaya göre yorumlanmıştır. Çalışmada kategorik değişkenler arasındaki ilişki Ki- Kare testi ile analiz edilmiştir. Gürbüz ve Şahin (2014) Ki- Kare bağımsızlık testinin; iki değişken arasında anlamlı bir ilişki olup olmadığı, değişkenlerin birbirinden bağımsız olup olmadığı veya bir değişkene ait verinin diğer değişkenin farklı kategorilerine göre anlamlı bir farklılık gösterip göstermediğini analiz etmek amacıyla kullanıldığını ifade etmektedir. 2*2 Çapraz tablolarda hücreye düşen birim sayısı 5'den küçük olduğu durumda Fisher's exact testi yapılmıştır. Araştırmanın veri seti parametrik testlerin normal dağılım varsayımı karşılanmadığı için Mann-Whitney U testi ve Kruskal-Wallis testi tercih edilmiştir.

Mann-Whitney-U test genellikle bağımsız örneklem t-testinin alternatifi olarak kullanılan parametrik olmayan bir testtir (Perme ve Manevski, 2019). Gözlenen farklılıkların anlamlılığını belirlemek için kriter olarak 0.05 veya daha düşük P değeri kullanılmıştır. Tablo gösteriminde genel toplam 100' eşit olduğu durumlarda sayı (n) ve oran (%) birbirine eşit olduğu için sadece oran (%) kullanımı tercih edilmiştir.

BULGULAR VE TARTIŞMA

Ortakların Sosyo-ekonomik Özellikleri

Araştırma kapsamına dahil edilen kooperatif ortaklarının sosyo-ekonomik ve yapısal özellikleri Çizelge 4'de gösterilmiştir. Ortakların %99'u erkek, %85'i evli ve hanehalkı sayısı ortalama 3.96 kişidir. Sayılı ve Adıgüzel (2013)'ün derlediği önceki çalışmaların ortalamasına göre tarımsal üretimle uğraşanların hane nüfusunun 6 ve üzerinde olduğu rapor edilmiştir. Eğitim düzeylerine göre ise, ortakların %53'ü ilköğretim, %35'i ortaöğretim ve %11'i üniversite mezunudur. Bilgin (2005) üreticilerin %37,5'inin 55 ve üstü yaşa sahip ve %68.10'unun ilkokul mezunu, Dedeoğlu ve Yıldırım (2006) üreticilerinin ortalama yaşının 48.10 yıl olduğu ve %73.69'unun ilköğretim düzeyinde eğitim gördüğünü ve Kendirlioğlu (2008) üreticilerin %33'ünün 35-45 yaş aralığında bulunduğunu ve %57.00'sinin ilkokul mezunu olduklarını belirtmişlerdir. Bu sonuçlar çalışmamızda elde edilen verileri desteklemektedir. Genel olarak ortaklar okur-yazar düzeyinin üzerinde, ancak düşük bir eğitim seviyesine sahiptir. Akçabey ve Paksoy (2023) tarafından Gaziantep ilinde üreticilerin eğitim seviyesinin düşük olduğu sonucuna varılan bir çalışmada; tarımsal üretimle ilgili herhangi bir yeniliğe kolaylıkla uyum sağlayabilmeleri için çiftçi eğitim ve yayım faaliyetlerine öncelik verilmesinin gerekliliği vurgulanmıştır.

Çizelge 4. Ortaklarının sosyo-ekonomik özellikleri.
Table 4. Socio-economic characteristics of partners.

Değişken	**Kategori**	**Merkez Tarım Kredi Koop.**		**Yaycı Tarım Kredi Koop.**		**Genel Toplam**
		Sayı (n)	**Oran (%)**	**Sayı (n)**	**Oran (%)**	**Oran (%)**
Cinsiyet	Kadın	1	1.6	0	0.0	1.0
	Erkek	61	98.4	38	100.0	99.0
	Toplam	62	100.0	38	100.0	100.0
Yaş (Ort.:47.87 yıl)	≤40	24	38.8	9	23.7	33.0
	41-54	19	30.6	14	36.8	33.0
	55≤	19	30.6	15	39.5	34.0
	Toplam	62	100.0	38	100.0	100.0
Medeni durum X2(1) = 0.163, p>0.05	Evli	52	83.9	33	86.8	85.0
	Bekar	10	16.1	5	13.2	15.0
	Toplam	62	100.0	38	100.0	100.0
Hanehalkı sayısı (Ort.: 3.96 kişi)	≤3	26	41.9	14	36.8	40.0
	4-5	26	41.9	21	55.3	47.0
	6≤	10	16.1	3	7.9	23.0
	Toplam	62	100.0	38	38	100.0
Eğitim	Okur-yazar	1	1.6	0	0.0	1.0
	İlköğretim	27	43.5	26	68.4	53.0
	Ortaöğretim	25	40.3	10	26.3	35.0
	Üniversite	9	14.5	2	5.3	11.0
	Toplam	62	100.0	38	100.0	100.0
Aylık tarımsal gelir (Ort.: 20.314TL)	0-13000	9	14.5	24	63.2	33.0
	13001-20000	27	43.5	4	10.5	31.0
	20001≤	26	41.9	10	26.3	36.0
	Toplam	62	100.0	38	100.0	100.0

Önem seviyesi: * p-değeri < 0.01; ** p-değeri < 0.05

Çalışma bulgularımıza göre ortakların aylık tarımsal geliri ortalama 20314 TL düzeyindedir. Everest ve Yercan (2016) tarafından yapılan bir çalışmaya göre, çiftçilerin %45.78'inin tarım faaliyetinden elde ettikleri yıllık gelirleri ortalama 10001-25000 TL aralığında yer alırken, çiftçilerin %60'ının aylık tarımsal gelirleri 25000 TL'nin altındadır. Ortakların tarım dışı gelir durumu Çizelge 5' de gösterilmiştir. Çalışmada yer verilen ortakların %74'ü yalnızca tarım ile uğraşmaktadır. Aynı zamanda ortakların %70'nin tarım dışı gelire sahip olduğu dikkat çekicidir. Bu tarım dışı gelir yıllık olarak ortalama 9028.57 TL seviyesindedir. Tarım dışı gelirin kaynağı, ortaklar arasında %65 oranında tek bir kaynağa dayandırılmaktadır. Tarım dışı gelir kaynağı açısından ortakların %42.8 emekli maaşını, %35.9 ticari gelirini, %26.6 düzenli çalışma karşılığı maaşını ve %7.8'i kira gelirini kaynak olarak göstermiştir. Sayılı ve Adıgüzel (2013) tarafından Tokat ilinde yapılan bir çalışmada kooperatif ortaklarının toplam aile geliri içerisinde tarım dışı gelirlerinin (kira geliri, emekli maaşı vb.) oranı %19.13'tür. Ortakların tarımsal gelirlerine ek olarak emekli maaşı, kira gibi ek gelirlerinin varlığı olup olmadığının ele alındığı İzmir ilinde yapılan benzer bir çalışmada; genel olarak ortakların %79.6'sının tarım dışı gelirinin olmadığı, %20.4'ünün ise tarım dışı gelirinin olduğu belirlenmiştir (Yercan ve Kınıklı, 2018). Çalışmamızda birden fazla tarım dışı gelire sahip olan ortakların sayısı 5 kişi ile sınırlı olmasına rağmen, tarım dışı gelire sahip olanların oranı çalışmamızda oldukça yüksek düzeydedir. Ortakların %42.8'nin emekli maaşını ek gelir olarak göstermesi, üreticilerin önemli bir bölümünün yaş itibari ile tarımsal üretim açısından yeterli dinamizme sahip olmadığını göstermektedir. Kooperatif ortakları; ortağı oldukları kooperatife göre tarım dışı işte çalışma durumları ve tarım dışı gelire sahip olma durumları incelendiğinde istatistiksel olarak anlamlı fark bulunmuştur. Merkez TKK ortakları Yaycı TKK ortaklarına göre tarım dışı işte çalışanlar ($p<0.05$) ve tarım dışı gelire sahip olanlar daha fazladır ($p<0.01$).

Çizelge 5. Ortakların tarım dışı gelir durumu.
Table 5. Non-farm income status of partners.

Değişken	Kategori	Merkez Tarım Kredi Koop.		Yaycı Tarım Kredi Koop.		Genel Toplam
		Sayı (n)	Oran (%)	Sayı (n)	Oran (%)	Oran (%)
Tarım dışı işte çalışma durumu	Hayır	40	64.5	34	89.5	74.0
Fisher's exact test; p<0.05	Evet	22	35.5	4	10.5	26.0
	Toplam	62	100.0	38	38.0	100.0
Aylık tarım dışı gelir*	Yok	10	16.1	20	52.6	30.0
(Ort.: 9028.57TL)	Var	52	83.9	18	47.4	70.0
X2(1) = 14.949, p<0.01	Toplam	62	100.0	38	100.0	100.0
Tarım dışı gelir kaynağı sayısı	0	10	16.1	20	52.6	30.0
(Ort.: 0.73 adet)	1	47	75.8	18	47.4	65.0
	2≤	5	8.1	0	0.0	5.0
	Toplam	62	100.0	38	100.0	100.0
Sahip olunan tarım dışı gelirler	Maaş	14	25.5	3	16.7	26.6
	Ticari gelir	22	40.0	1	5.5	35.9
	Kira geliri	5	9.1	0	0.0	7.8
	Emekli maaşı	14	25.5	14	77.8	42.8
	Toplam	55	100.0	18	100.0	100.0

Önem seviyesi: * p-değeri < 0.01; ** p-değeri < 0.05
[a]Çoklu seçim yapılmıştır

Ortakların Tarımsal İşletme Özellikleri

Ortakların %72'si karma üretim yapan işleme iken %28'i bitkisel üretim yapan işletmedir. Başaran (2003) tarafından yapılan bir çalışmada, bulgularımızı destekler nitelikte veriler edilmiş ve ortakların %48.40'ının en yüksek oranla işletmelerinde bitkisel ve hayvansal üretime birlikte yer verdikleri tespit edilmiştir. Sayılı ve Adıgüzel (2013) tarafından Tokat ilinde yapılan bir çalışmada kooperatif ortaklarının ortalama olarak 35.20 yıldır tarımsal üretim faaliyetinde bulundukları tespit edilmiştir. Ortakların ortalama tarımsal üretimdeki tecrübesi 21.36 yıldır ve %64'ü 10 yıldan uzun süredir tarımsal üretim içerisinde yer almaktadır. Toplam arazi varlığı açısından ortalama arazi varlığı 66.47 da (dekar) olup, 65 da ve üzerinde arazi varlığına sahip ortakların oranı %36 düzeyindedir. Ortakların ortalama bahçe arazisi varlığı 7.24 da civarındayken, tarla arazisi varlığı 58.07 da düzeyindedir. Ortakların %51'i bahçe arazisine, %16'sı ise tarla arazisine sahip değildir. Sayılı ve Adıgüzel (2013) ortakların ortalama olarak %88.44'ünün tarla arazisi, %8.15'inin meyve arazisi ve %3.41'inin ise bahçe arazisine sahip olduğunu belirlemiştir. Başaran (2003) çalışmasında, kooperatif ortağı üreticilerin %34'ünün en yüksek oranla 50 da alandan küçük arazilerde tarımsal üretim yaptıklarını saptamıştır. Bu çalışmada, 0-30 da arasında toplam arazi varlığına sahip üreticilerin oranı yaklaşık %34'dur. Kooperatif ortakları, ortağı oldukları kooperatife göre işletme tipi (p<0.05), tarımsal tecrübe (p<0.05), toplam tarım arazi varlığı (p<0.01), tarla arazi varlığı (p<0.05) incelendiğinde istatistiksel olarak anlamlı fark bulunmuştur (Çizelge 6).

Çizelge 6. Ortakların işletme özellikleri.
Table 6. Partners' agricultural business characteristics.

Değişken	Kategori	Merkez Tarım Kredi Koop.		Yaycı Tarım Kredi Koop.		Genel Toplam
		Sayı (n)	Oran (%)	Sayı (n)	Oran (%)	Oran (%)
İşletme tipi**	Bitkisel üretim	13	21.0	15	39.5	28.0
$X^2(1) = 4.002$, $p<0.05$	Bitkisel ve hayvansal	49	79.0	23	60.5	72.0
	Toplam	62	100.0	38	100.0	100.0
Tarımsal tecrübe (yıl)**	0-10	27	43.5	9	23.7	36.0
(Ortalama:21.36)	11-30	28	45.2	16	42.1	44.0
$X^2(1) = 8.821$, $p<0.05$	31≤	7	11.3	13	34.2	20.0
	Toplam	62	100.0	38	100.0	100.0
Toplam Arazi varlığı (da)*	0-30	9	14.5	25	65.8	34.0
Ortalama: 66.47	31-65	22	35.5	8	21.1	30.0
$X^2(2) = 28.736$, $p<0.01$	65≤	31	50.0	5	13.2	36.0
	Toplam	62	100.0	38	100.0	100.0
Bahçe arazisi varlığı (da)	0	26	41.9	25	65.8	51.0
Ortalama: 7.24	1-10	20	32.3	7	18.4	27.0
$X^2(2) = 5.734$, $p<0.10$	11≤	16	25.8	6	15.8	22.0
	Toplam	62	100.0	38	100.0	100.0
Tarla Arazisi varlığı (da)*	0	5	8.1	10	26.3	16.0
Ortalama: 58.07	1-50	21	33.9	22	57.9	42.0
$X^2(2) = 18.419$, $p<0.01$	51≤	36	58.1	6	16.8	42.0
	Toplam	62	100.0	38	100.0	100.0

Önem seviyesi: * p-değeri < 0.01; ** p-değeri < 0.05

Ortakların Bitki Koruma Ürün Grupları Anlam ve Etiketlerini Bilme Durumu

Ortakların bitki koruma ürünlerinin anlamına ve etiket renklerine hakim olma düzeyini gösteren veriler Çizelge 7'de görülmektedir. Verilere göre; böcek ilacı olarak bilinen insektisitin ortakların %52'si anlamını, %59'uda rengini bilmektedir. Fungus ilacı olan fungusitin %41'i anlamını bilmekte, %55'i etiket renginden anlayabilmektedir. Yabancı ot ilacı olan herbisitlerin ortakların %52'si anlamını biliyor ve %69'u etiket renginden tanıyor. Nematod ilacı olarak bilinen nematisitin ortakların %84'ü anlamını bilmiyor ve %83'ü etiket renginden de tanımıyor. Ortağı oldukları kooperatife göre kooperatif ortaklarının bitki korumu ürün gruplarının anlam ve etiket rengini bilme durumu incelendiğinde Merkez TKK ortaklarının Yaycı TKK ortaklarına göre bitki korumu ürün gruplarının anlam ve etiket rengini bilme durumu daha yüksek düzeyde olup farklı önem seviyelerinde istatistiksel olarak anlamlıdır (p<0.01; p<0.05). Aydın ili zirai mücadele uygulamalarının değerlendirildiği bir çalışmada anket yapılan üreticilerin %93.54'ü satın aldıkları pestisitlerin ambalaj üzerindeki etiket bilgileri okuduklarını ve % 87.09'u etiket üzerindeki son kullanma tarihini dikkate aldıklarını bildirmişlerdir (Boz vd., 1998). Meyve-sebze üreticilerinin pestisit kullanımına yönelik benzer bir çalışmada üreticilerin en fazla kullandığı pestisit türleri sırasıyla insektisitler, fungusitler ve herbisitler şeklindedir. Ancak üreticilerin %48.19'unun kullandıkları pestisitin içeriği hakkında bilgi sahibi olmadıkları tespit edilmiştir (Erdal vd., 2019). Çalışmamızda kooperatif ortaklarının önemli bir bölümünün pestisit gruplarından insektisit ve herbisit konusunda anlam ve etiket rengine bağlı olarak ayrım yapabildiği görülürken, nematisit konusunda çiftçilerin %80'inin üzerinde oranla hem etiket rengi hem anlamını bilme konusunda bilgi sahibi olmadığı tespit edilmiştir.

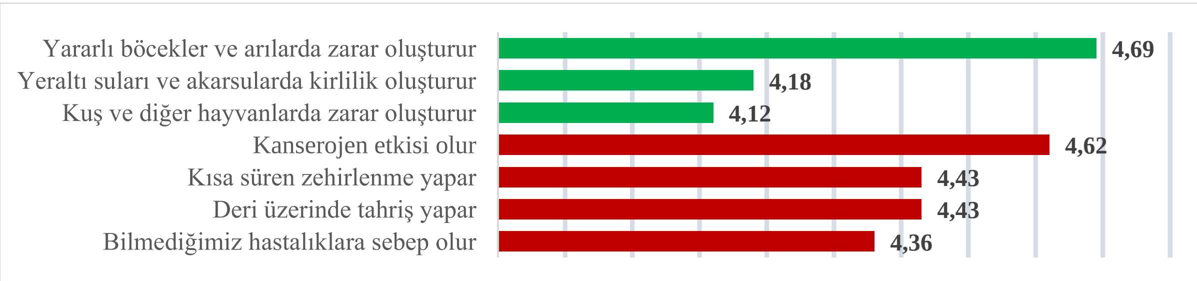
Çizelge 7. Ortakların bitki koruma ürün gruplarının anlam ve etiket rengini bilme durumu.
Table 7. Partners' knowledge of the meaning and label colours of plant protection product groups.

Bitki Koruma Ürünü	Kriter	Durum	Merkez Tarım Kredi Koop.		Yaycı Tarım Kredi Koop.		Genel Toplam
			Sayı (n)	Oran (%)	Sayı (n)	Oran (%)	Oran (%)
İnsektisit	Anlamını bilme *	Hayır	15	24.2	33	86.8	48.0
	$X^2(1) = 37.047$, $p<0.00$	Evet	47	75.8	5	13.2	52.0
	Etiket rengini bilme*	Hayır	14	22.6	27	71.1	41.0
	$X^2(1) = 22.883$, $p<0.00$	Evet	48	77.4	11	28.9	59.0
Fungisit	Anlamını bilme*	Hayır	26	41.9	33	86.8	59.0
	$X^2(1) = 19.641$, $p<0.00$	Evet	36	58.1	5	13.2	41.0
	Etiket rengini bilme*	Hayır	18	29.0	27	71.1	45.0
	$X^2(1) = 16.808$, $p<0.00$	Evet	44	71.0	11	28.9	55.0
Herbisit	Anlamını bilme**	Hayır	14	22.6	34	89.5	48.0
	Fisher's exact test; $p<0.01$	Evet	48	77.4	4	10.5	52.0
	Etiket rengini bilme**	Hayır	12	19.4	19	50.0	31.0
	$X^2(1) = 37.047$, $p<0.05$	Evet	50	80.6	19	50.0	69.0
Nematisit	Anlamını bilme**	Hayır	47	75.8	37	97.4	84.0
	Fisher's exact test; $p<0.05$	Evet	15	24.2	1	2.6	16.0
	Etiket rengini bilme**	Hayır	46	74.2	37	997.4	83.0
	Fisher's exact test; $p<0.05$	Evet	16	25.8	1	2.6	17.0

Önem seviyesi: * p-değeri < 0.01; ** p-değeri < 0.05

Ortakların Bitki Koruma Ürünlerinin Çevre ve İnsan Sağlığına Etkileri Konusunda Görüşleri

Bitki koruma ürünlerinin insan sağlığı ve çevreye etkileri konusunda önermelere ortakların katılım düzeyleri Şekil 2'de gösterilmiştir. İnsan sağlığı konusunda kooperatif ortakları; kısa süre zehirlenme yapar (4.43), deri üzerini tahriş yapar (4.43) ve bilmediğimiz hastalıklara sebep olur (4.36) önermelerine katılıyor olup kanserojen etkisi olur (4.62) önermesine kesinlikle katılmaktadır. Bitki koruma ürünlerinin çevreye etkisi konusunda kooperatif ortakları; kuş ve diğer hayvanlara zarar oluşturur (4.12), yer altı suları ve akarsularda kirlilik oluşturur (4.18) önermelerine katılıyor olup yararlı böcekler ve arılarda zarar oluşturur (4.69) önermesine kesinlikle katılmaktadır. Antalya ilinde yapılan bir çalışmada, üreticilerin tarımsal ilaçların çevreye etkileri konusundaki görüşleri ele alınmıştır. Üreticilerin %77'si pestisitlerin göl/akarsularda kirlilik oluşturabileceği, %74.6'sı yararlı böceklere veya arılara zararlı olabileceği ve %69.3'ü kuşlara zararlı olabileceği yönünde görüş bildirmişlerdir (Tiryaki ve Akar, 2018). Antalya ilinde tarımsal ilaç kullanımı ile ilgili olarak yapılan başka bir çalışmada, üreticilerin %70.4'ü tarımsal ilaçların ürünlerde kalıntı bıraktığına inanmaktadır. Ayrıca üreticilerin %96.8'i aşırı ilaç kullanımının çevreyi olumsuz etkilediğini düşünürken, %20.19'u da ilaç seçiminde sorunları olduğunu belirtmişlerdir (Özkan vd. 2016). Tiryaki ve Akar (2018)' e göre üreticilerin %34.1'i bazı tarım ilaçlarının kalıntı bırakabileceğini düşündüklerini, %81.5'i pestisitlerin insan sağlığına zarar vereceğini, %79.1'i ilaçlamanın çevreye zarar verdiğini düşünmektedir. Çalışmamızdaki bulgular üreticilerin büyük bir bölümünün, tarım ilaçlarının çevre, insan ve canlı yaşamına olumsuz etkileri konusunda bilinçli olduğu göstermektedir.



Şekil 2. Bitki koruma ürünlerinin çevre ve insan sağlığına etkileri konusunda ortaklarının görüşleri.
Figure 2. Opinions of partners on the effects of plant protection products on the environment and human health.

Bitki koruma ürünlerinin çevre ve insan sağlığına etkileri konusunda çiftçilerin ortağı olduğu kooperatife göre önermelere katılma durumları Çizelge 8'de gösterilmiştir. Merkez TKK ortakları bitki koruma ürünlerinin çevreye verdiği zararlar ile ilgili önermelere Yaycı TKK ortaklarına göre daha yüksek düzeyle katıldıkları ve bu farkın istatistiksel olarak anlamlı olduğu belirlenmiştir ($p<0.05$). Bitki koruma ürünlerinin insana verdiği zarar konusundaki önermelere katılım çiftçilerin ortağı olduğu üst birlik durumuna göre incelendiğinde anlamlı bir farkın olmadığı saptanmıştır ($p>0.05$).

Çizelge 8. Ortakların bitki koruma ürünlerinin çevre ve insan sağlığına etkileri konusunda görüşleri.
Table 8. Partners' views on the effects of plant protection products on the environment and human health.

Önerme	Kooperatif	Ortalama	Mann-Whitney U Test	p-değeri
Çevreye verdiği zararlar				
Kuş ve diğer hayvanlarda zarar oluşturur	Merkez Tarım Kredi Kooperatifi	4.32	871.000	0.016**
	Yaycı Tarım Kredi Kooperatifi	3.79		
Yeraltı suları ve akarsularda kirlilik oluşturur	Merkez Tarım Kredi Kooperatifi	4.40	828.500	0.006**
	Yaycı Tarım Kredi Kooperatifi	3.82		
Yararlı böcek ve arılarda zarar oluşturur	Merkez Tarım Kredi Kooperatifi	4.92	914.000	0.001**
	Yaycı Tarım Kredi Kooperatifi	4.32		
İnsana verdiği zararlar				
Kısa süren zehirlenme yapar	Merkez Tarım Kredi Kooperatifi	4.42	1115.000	0.597
	Yaycı Tarım Kredi Kooperatifi	4.45		
Kanserojen etkisi olur	Merkez Tarım Kredi Kooperatifi	4.61	1175.000	0.975
	Yaycı Tarım Kredi Kooperatifi	4.63		
Deri üzerinde tahriş yapar	Merkez Tarım Kredi Kooperatifi	4.52	1044.000	0.261
	Yaycı Tarım Kredi Kooperatifi	4.29		
Bilmediğimiz hastalıklara sebep olur	Merkez Tarım Kredi Kooperatifi	4.44	1046.000	0.264
	Yaycı Tarım Kredi Kooperatifi	4.24		

Ortakların Bitki Koruma Ürünlerinin Hasat Edilen Ürün Üzerinde Kalıntı Bırakması Hakkında Görüşleri

Bitki koruma ürünlerinin hasat edilen ürün üzerinde kalıntı bırakma riskleri hakkında ortakların görüşleri ile ilgili veriler Çizelge 9'da sunulmuştur. Ortakların %45'i ürünler kalıntı bırakabilir, %16'sı kalıntı yıkama ile yok olur, %21'i kalıntı bırakmaz ve %18'i kalıntı riski hakkında fikrinin olmadığını dile getirmiştir. Bitki koruma ürünlerinin hasat edilen ürün üzerinde kalıntı bırakma riskleri hakkındaki görüşlerin çiftçilerin ortağı olduğu kooperatife göre farklılık göstermemektedir ($p>0.05$).

Çizelge 9. Ortakların bitki koruma ürünlerinin hasat edilen ürün üzerinde kalıntı bırakması hakkında görüşleri.
Table 9. Partners' views on residues left by plant protection products on harvested crops.

Kategori	Merkez Tarım Kredi Koop.		Yaycı Tarım Kredi Koop.		Genel Toplam
	Sayı (n)	Oran (%)	Sayı (n)	Oran (%)	Oran (%)
Kalıntı bırakabilir	30	48.4	15	39.5	45.0
Kalıntı yıkama ile yok olur	11	17.7	5	13.2	16.0
Kalıntı bırakmaz	11	17.7	10	26.3	21.0
Fikrim yok	10	16.1	8	21.1	18.0
Toplam	62	100.0	38	199.0	100.0

X2(3) = 1.867, p >0.05

Isparta ili elma üretiminde tarımsal ilaç kullanımı ile ilgili olarak yapılan bir araştırmanın sonuçlarına göre, üreticilerin %38.53'ünün ilaç kalıntılarının yıkanma ile kaybolacağını, %22.02'sinin ilaçların kalıntı bırakmayacağını düşündüklerini ve %42.20'sinin ilaçlamadan sonra ambalajları rasgele çevreye attıkları tespit edilmiştir (Demircan & Yılmaz, 2005). Antalya ilinde yapılan bir çalışmada, üreticilerin ilaç kalıntısı hakkındaki görüşlerine göre üreticilerin %23.3'ü ilaç kalıntılarının yıkanma ile kaybolacağını, % 24.9'u kalıntı bırakmayacağını, % 34.1'i bazı tarım ilaçlarının kalıntı bırakabileceğini, % 17.7'si ilaç kalıntısı hakkında bilgisinin olmadığını belirtmişlerdir. Ayrıca çalışmamızda, üreticilerimizin %71.2'si tarım ilacı alırken ruhsatlı olup olmadığına dikkat ettiğini belirtmişlerdir (Tiryaki ve Akar, 2018). Bu çalışmada üreticilerin %61'i pestisitlerin ürünler üzerinde kalıntı bırakılabileceği yönünde hem fikirdir. Önceki çalışmalar ve bu çalışma verilerine bakıldığında üreticilerin önemli bir kısmının pestisitlerin kalıntı bırakma riski konusunda bilgi sahibi fakat kalıntı riskinin olmadığı yönünde fikir beyan ettiği görülmektedir. Bu durum, tarımsal üretimde bitki koruma ürünlerinin bilinçsizce kullanılma sebeplerindendir.

SONUÇ

Ülkemizde tarım çalışanlarının ve Iğdır ili Tarım Kredi Kooperatif ortaklarının bitki koruma ürünleri konusunda bilgi ve davranışları ile ilgili tespit edilen bulguların genel olarak önceki çalışmalar ile benzerlik gösterdiği belirlenmiştir. Bu çalışmada ortakların ağırlıklı olarak erkek ve evli bireylerden oluştuğu, yaşlarının orta yaş ve üzerinde olduğu (41 ve üzeri), eğitim düzeylerinin genel anlamda düşük ve hane halkı sayısının 4 kişi civarında olduğu görülmektedir. Ayrıca ortaklar çoğunlukla karma işletme tipine sahiptir. Ortakların büyük bir bölümünün, tarım dışı gelir kaynağının emekli maaşı olduğu görülmektedir. Bu durum tarım ile uğraşan bireylerin yaş ortalamalarının oldukça yüksek olduğunun bir göstergesidir. Ülkemizde üreticilerin büyük çoğunluğu bitki koruma ürünlerinin uygulama zamanına kendisi karar vermekte, kullanacağı ilacı ve dozunu kendisi belirlemektedir. Çalışmamızda görüldüğü gibi, ortakların önemli bir bölümü bitki koruma ürünlerinin etiket bilgilerine hâkim değildir. Ayrıca bitki koruma ürünlerinin kalıntı riski hakkında bilgi sahibi değildir veya bu durumu önemsememektedir. Tarımsal üretimin ve biyolojik dengenin sürdürülebilirliği açısından oldukça riskli sorunlar ortaya çıkarabilir. Ancak genel anlamda ortakların bitki koruma ürünlerinin çevre ve canlılara olan olumsuz etkisi konusunda bilince sahip olduğu dikkat çekmektedir. İlçelere göre incelendiğinde; Merkez TKK ortaklarının Yaycı TKK ortaklarına göre bitki koruma ürünlerinin çevreye verdiği zarar konusuna katılımlarında istatistiksel olarak anlamlı bir farkın olduğu ($p<0.05$), insana verdiği zarar konusunda ise istatistiksel olarak anlamlı bir farkın olmadığı belirlenmiştir ($p>0.05$). Bunun yanında, Merkez TKK ortaklarının Yaycı TKK ortaklarına göre bitki korumu ürün gruplarının anlam ve etiket rengini bilme durumu daha yüksek düzeyde olup bu farkın istatistiksel olarak anlamlı olduğu saptanmıştır ($p<0.05$). Kooperatif çalışanlarının bitki koruma ürünlerinin satışında ortaklarının bilgi düzeyine göre yaklaşım geliştirmesi daha güçlü bir iletişimin kurulmasına ve dolayısıyla daha bilinçli ilaç kullanılmasına katkı sağlayacağı düşünülmektedir.

Tarım çalışanlarının bitki koruma ürünleri konusunda bilgi ve bilinç düzeylerinin artırılması, sürdürülebilir bir tarım ve sağlıklı bir çevre için oldukça önemlidir. Bu amaçla, eğitim, danışmanlık, denetim ve farkındalık oluşturma gibi farklı alanlarda çalışmaların birlikte yürütülmesi gerekmektedir. Bitki koruma ürünlerinin çevre ve insan sağlığı üzerindeki olumsuz etkilerini minimize etmek amacıyla, tarım sektöründe çalışan tüm grupların bu konuda yetkin hale getirilmesi gerekmektedir. Bu kapsamda düzenlenecek eğitimlerde, bitki koruma ürünlerinin toksikolojisi, ekotoksikolojisi, güvenli kullanım uygulamaları, acil durum müdahalesi ve atık yönetimi konularında teorik ve pratik bilgiler verilmelidir.

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Yazarlar arasında herhangi bir çıkar çatışması yoktur.

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Yazarların makaleye katkıları eşit düzeydedir.

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Research Article

Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi

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Determination of Agricultural Machinery Usage Efficiency in Tokat Province Using Geographical Information Systems*

Coğrafi Bilgi Sistemleri Kullanılarak Tokat İlindeki Tarım Makinaları Kullanım Etkinliğinin Belirlenmesi

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Abstract: This study aimed to create a database on the presence of machinery on a district basis by mapping the utilization activities of agricultural tools and machinery used in the crops cultivated in Tokat and its districts and only in wheat agriculture with geographical information systems. In this context, the machines were divided into seven groups (Soil Tillage Machinery, Sowing and Planting Machinery, Maintenance and Fertilization Machinery, Plant Protection Machinery, Harvesting Machinery, Combine Harvester, and Tractors). The statistics on the cultivated areas and the number of machines on a district basis were obtained from the Turkish Statistical Institute. The calculated machine impact areas and planted areas were converted into circular areas and their radii were calculated. The calculated radii were converted into district-based maps with the help of ArcGIS 10.8 software. It was determined that there is a need for subsoilers, combi-harrow, stone collecting machinery, rotary cultivators, soil leveling machinery, rotary tiller, arc opening plough, seedling planting machinery, balers, and combine harvesters in Tokat. While the highest need was identified for balers, the highest surplus was identified for tractors. When the common crops and the machines commonly used in wheat agriculture are evaluated, it is concluded that production planning is important and planning should be made in accordance with the crop pattern.
Keywords: Agricultural machinery, machine ımpact area, geographical ınformation systems, effective working capacity

&

Öz: Bu çalışmada Tokat ve ilçelerinde tarımı yapılan ürünlerde ve sadece buğday tarımında kullanılan tarım alet ve makinelerinin kullanım etkinlikleri coğrafi bilgi sistemleri ile haritalanarak belirlenmiştir. Bu kapsamda makineler 7 gruba (Toprak İşleme Alet/Makineleri, Ekim ve Dikim Makineleri, Bakım ve Gübreleme Makineleri, Bitki Koruma Makineleri, Hasat Makineleri, Biçerdöverler, Traktörler) ayrılmıştır. Türkiye İstatistik Kurumundan ilçe bazında ekilen alanlar ve makine sayıları alınmıştır. Makine etki alanları ile ekili alanlar, dairesel alana dönüştürülerek yarıçapları hesaplanmıştır. Hesaplanan yarıçaplar ArcGIS 10.8 programı yardımıyla ilçe bazında haritalara dönüştürülmüştür. Tokat genelinde dipkazan, kombikürüm, taş toplama makinesi, toprak frezesi, toprak tesviye makinesi, rototiller, ark açma pulluğu, fide dikme makinesi, balya makinesi ve biçerdöver ihtiyacı olduğu belirlenmiştir. En çok ihtiyaç balya makinesinde iken en çok ihtiyaç fazlalığı traktörde tespit edilmiştir. Yaygın tarımı yapılan ürünler ile buğday tarımında kullanılan makineler değerlendirildiğinde üretim planlamasının önemli olduğu ve ürün desenine göre planlamanın yapılması gerektiği sonucuna varılmıştır.
Anahtar Kelimeler: Tarım makineleri, makine etki alanı, coğrafi bilgi sistemi, efektif iş başarısı

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INTRODUCTION

To meet the needs of human nutrition, shelter, and clothing, it is essential to follow innovations in agriculture. Increasing agricultural productivity by enhancing yield per unit area significantly relies on the importance of advancing technology. The effective use of farm technologies in practices such as irrigation, fertilization, plant protection, and mechanization leads to an increase in productivity.

Agricultural mechanization involves conducting plant and animal production activities using power sources and machinery. Tasks that are not feasible with human and animal labor are accomplished through mechanization, allowing for production over larger areas, in shorter time frames, and with less labor. It minimizes the dependence of production activities on climatic and environmental conditions. Unlike other agricultural practices, agricultural mechanization indirectly affects yield increases. By enabling the use of new technologies, it enhances the effectiveness and cost-efficiency of technological applications and contributes to the improvement of working conditions (Özgüven et al., 2010).

Among the inputs used for agricultural production, mechanization represents a significantly high cost. If the farm owner selects equipment that is not suitable for the product group being cultivated or the size of the land, without considering local conditions, profitability will be adversely affected, potentially even leading to losses for the farm. Therefore, it is crucial to select appropriate machinery and make proper planning tailored to the farm's needs. The widespread adoption of mechanization can be achieved through this approach (Toğa, 2006).

When planning mechanization, using average data from very large areas can lead to significant errors. In this context, it is more accurate to evaluate smaller, homogenous areas rather than very large regions. Therefore, mechanization planning should be carried out at the levels of the enterprise, enterprise group, district, province, region, and country for a more realistic approach (Evcim, 1990).

The presence of surplus machinery in the agricultural enterprise, or the continuation of production activities with agricultural machinery that has completed its economic and mechanical lifespan, is an important cost factor that business owners often overlook. For effective agricultural production, it is crucial for the operator to maintain sufficient power in the enterprise and to have machinery within the economic lifespan suitable for this power (Yıldırım, 2019).

As in all industrial sectors, computer programs play a crucial role in advancing agriculture and effectively utilizing innovations. Geographic Information Systems (GIS), Remote Sensing (RS), and Global Positioning Systems (GPS) are used at various stages of agricultural production. These techniques are employed in soil tillage, planting, fertilization, spraying, and harvesting operations, as these applications directly affect productivity.

Geographic Information System (GIS) is a digital information system that enables the collection, storage, processing, and display of data to meet specific objectives (Uluğtekin and Bildirici, 1997). GIS accelerates information flow, facilitates effective and accurate analysis, enables easy data updating, and enhances productivity by saving labor and time (Uluğtekin and Bildirici, 1997). GIS, widely used today for its ability to make accurate and rapid decisions, is also extensively utilized in the field of agriculture.

In this study, the aim is to create a database at the district level regarding the machinery inventory status for the districts of Tokat. This will be achieved by considering the types of crops grown, the number of machines that have not reached their mechanical and economic lifespan, and the cultivated areas. The machinery coverage and cultivated areas will be mapped using GIS.

MATERIAL AND METHOD

Tokat province consists of 35.83% agricultural land, 12.12% meadow and pasture land, 44.12% forest land, and 7.93% other types of land (TSI, 2021).

In Tokat province, 62.4% of the areas used in agriculture consist of clay loam, 18.7% clay, 17.6% loam, 1% heavy clay, and 0.3% sandy types of soil (Tetik and Oğuz, 2004; Karaman, 2006).

Of the agricultural areas of Tokat province, 69.60% is arable agriculture, 4.78% is vegetable agriculture, 4.73% is fruit agriculture, 9.23% is other agricultural areas and 11.66% is vacant land suitable for agriculture (TSI, 2021). While field agriculture is at the forefront, it is also noteworthy that there is a high proportion of empty areas suitable for agriculture.

Considering the farmers registered in the Agricultural Information System and registered land assets, the number of enterprises and average enterprise sizes of the districts of Tokat are shown in the table. The average enterprise size in Tokat is 43 da (Table 1) (Anonymous, 2021).

Table 1. Number of enterprises and average enterprise sizes in Tokat districts
Çizelge 1. Tokat ilçelerindeki işletme sayıları ve ortalama işletme büyüklükleri

District	Number of Enterprises	Area (da)	Average Enterprise Sizes (da)
Almus	738	21.936	29
Artova	1.314	72.285	55
Başçiftlik	456	12.980	28
Erbaa	5.448	159.737	29
Merkez	5.841	211.497	36
Niksar	3.038	121.043	39
Pazar	1.616	54.614	33
Reşadiye	1.368	48.342	35
Sulusaray	1.325	64.339	48
Turhal	3.493	166.379	47
Yeşilyurt	978	57.809	59
Zile	6.059	389.500	64
Total	31.674	1.380.461	43

Classification of Agricultural Tools and Machinery

There are a total of 192.382 units of 76 different agricultural tools and machines in the Tokat center and districts. Within the scope of the study, agricultural tools and machines commonly used by enterprise owners in Tokat agriculture were evaluated. Agricultural tools and machines used in the whole province were categorized into 7 classes.

1. Soil Tillage Machinery (Mouldboard Plow, Disc Harrow, Toothed Harrow, Subsoiler, Combi Harrow, Cultivator, Roller, Stone Collecting Machinery, Soil Levelling Machinery, Rotary Cultivator, Rotary Tiller),

2. Sowing and Planting Machinery (Combined Seed Drill, Seedling Planting Machinery, Pneumatic Planting Machinery, Potato Planting Machinery),

3. Maintenance (Plant Care-Welfare Machinery) and Fertilization Machinery (Arc Opening Plough, Manure Spreading Machinery, Chemical Centrifugal Fertilizer Spreader, Tractor Drawn Hoeing Machinery),

4. Plant Protection Machinery (Field Crop Sprayer, Orchard Sprayer),

5. Harvesting Machinery (Baler, Corn Forage Harvester, Hay Rake, Sugar Beet Harvester, Potato Harvester, Tractor Drawn Mower),

6. Combine Harvester,

7. Tractors.

Calculation of Machine Impact Area

The machine impact area calculation for each agricultural machinery group was calculated with the help of equation (1) (Yıldız et al., 2007; Yıldırım, 2019).

$$A = F_{ef} \; x \; n \; x \; t \; x \; g \qquad (1)$$

A : Machine impact area (da $year^{-1}$)
F_{ef} : Effective working capacity (da h^{-1})
n : Number of machines (unit)
t : Daily working time (h day^{-1})
g : Number of annual workable days (days $year^{-1}$)

Calculation of Machine Effective Working Capacity

Effective working capacity means real or ideal work success. It is calculated by adding the auxiliary time required for the completion of the task to the actual working time (Dinçer, 1970). The machine effective working capacity was calculated using equation (2).

$$F_{ef} = b \; x \; V \; x \; k \qquad (2)$$

b : Machine working width (m)
V : Forward speed (km h^{-1})
k : Time-use coefficient (%)

In the Tokat region, the brands of commonly used agricultural machinery were identified, and the working widths specified in the company catalogues were used as data.
Machine forward speeds and time-use coefficients are provided in Table 2 (Özmerzi et al., 2004).

Table 2. Forward speeds and time-use coefficients of agricultural machinery
Çizelge 2. Tarım makinelerine ait ilerleme hızları ve zamandan yararlanma katsayıları

Agricultural Machinery	Effective Working Capacity (da h^{-1})	Working Width (m)	Forward Speed (km h^{-1})	k (%)
Mouldboard Plow	4.32	0.90	6	0.80
Disc Harrow	12.75	2.50	6	0.85
Toothed Harrow	16.20	2.25	9	0.80
Subsoiler	7.65	1.80	5	0.85
Combi Harrow	11.48	2.25	6	0.85
Cultivator	18.36	2.70	8	0.85
Roller	16.83	2.20	9	0.85
Arc Opening Plough	5.04	0.90	7	0.80
Stone Collecting Machinery	5.46	1.40	6	0.65
Soil Levelling Machiner	8.93	2.10	5	0.85
Rotary Cultivator	6.80	2.00	4	0.85
Rotary Tiller	7.44	1.75	5	0.85
Seedling Planting Machinery	3.90	2.00	3	0.65
Combined Seed Drill	12.60	2.25	8	0.70
Potato Planting Machinery	4.50	1.50	5	0.60
Pneumatic Planting Machiner	16.80	3.00	8	0.70

Table 2. Continue.

Çizelge 2. Devamı.

Agricultural Machinery	Effective Working Capacity (da h^{-1})	Working Width (m)	Forward Speed (km h^{-1})	k (%)
Manure Spreading Machinery	13.44	2.40	8	0.70
Chemical Centrifugal Fertilizer Spreader	84.00	14.00	8	0.75
Tractor Drawn Hoeing Machinery	14.00	2.50	7	0.80
Field Crop Sprayer	50.40	12.00	7	0.60
Orchard Sprayer	28.50	9.50	5	0.60
Baler	6.24	1.30	6	0.80
Corn Forage Harvester	4.06	1.25	5	0.65
Hay Rake	18.36	2.70	8	0.85
Sugar Beet Harvester Machinery	9.45	2.70	5	0.70
Potato Harvester	3.15	1.50	3	0.70
Tractor Drawn Mower	11.22	1.65	8	0.85
Combine Harvester	13.16	4.70	4	0.70

The tractor effective working capacity for each district was calculated by taking the arithmetic average of the effective working capacities of the machines in that district.

Number of Machines

The presence of agricultural machinery, planted, and harvested areas in Tokat province and its districts were obtained from the Turkish Statistical Institute (TSI) (TSI, 2021).

When the economic life of agricultural machinery is accepted as 10 years, it is considered that 50% of the machines have completed their economic life (Yıldırım, 2019). In this context, 50% of the machines in the machinery parks in Tokat and its districts in the class of tillage tools/machines, sowing and planting machines, maintenance and fertilization machines, plant protection machines, and harvesting machines were taken into consideration.

Combine harvesters generally use the contracting system. For this reason, the economic life of the harvesters in Tokat province was accepted as 10 years and included in the calculations (Yıldırım and Konak, 2019).

In Turkey, 43% of the existing tractor park has completed its economic life (Özgüven, et al., 2010). In this study, 57% of the tractors in Tokat and its districts were included in the study.

Data on Tillage, Sowing and Planting, Maintenance and Fertilisation, Plant Protection, Harvesting Machines, and Harvester and Tractor groups are taken from TSI (TSI, 2021).

Daily Working Time

In the calculation of the impact area of agricultural machinery, the daily working time was taken as 8 hours (Yıldız et al., 2007).

Number of Annual Workable Days

The number of workable days in agriculture is expressed as the number of days that any agricultural tool and machine can perform the desired task, that is, it can work in the field. In determining the number of workable days, the process was divided into three groups by considering the most time-consuming agricultural production activities: soil tillage, maintenance, and harvesting operations (Kuşçu, 2008).

The number of workable days was calculated based on the averages of daily average temperature, total precipitation, and soil temperature at a depth of 10 cm from 2010 to 2021, considering the criteria given by Kuşçu (2008). (MGM, 2021; Alan, 2023).

Planted Areas Used In Impact Area Calculation

Separate evaluations were made for all plants widely cultivated in Tokat province and wheat plant. These data were taken from (Alan, 2023).

In the calculation of machine impact area for machine classes based on Tokat and districts, calculations were made by determining the workable day interval by taking into account the operations carried out in the products widely cultivated and the tools and machines used for these operations.

For the wheat cultivated throughout the province of Tokat, the operations carried out and the workable day intervals for these operations were determined and the radius of the machine impact area radius and the planted area radius for the districts were determined and mapped with the help of the ArcGIS program.

Calculation of Planted Area and Machine Impact Area Radii

The impact areas (da) calculated according to equation (3) for each machine group were converted into circular areas on a district basis and the radius (m) of this area was calculated. In addition, according to the agricultural production pattern in each district, the planted areas were considered as a circle, and the radius of these areas was determined. The planted area radius and the machine impact area radius were calculated with the help of equation (3) (Yıldız et al., 2007).

$$r = \sqrt{A/\pi} \tag{3}$$

r : Planted area / Machine impact area radius (m)
A : Planted area / Machine impact area (m^2)

Calculation of the required number of machines

The required number of agricultural machinery/agricultural machinery group (*RNM*) was calculated by proportioning the areas of influence of the machines to the areas where tillage/planted/harvested was carried out (Yıldırım, 2019).

$$RNM = A/F_{ef} \tag{4}$$

Mapping With Geographic Information Systems

Geographical Information Systems (GIS) is a system that collects location-based data, can display these collected data, and has features that enable the combination of maps and tables. In this way, it provides statistical analyses with the help of maps and classification of information by using the database and plays an important role in planning (Yomralıoğlu, 2000; Akbaş et al., 2008; Başayiğit et al., 2008). Within the scope of this study, the mapping process with GIS consisted of 4 stages.

1. Creation of Tokat province map: The map downloaded from the General Directorate of Mapping was transferred to ArcGIS 10.8 program.

2. Preparation of database: The planted area and machine numbers of the districts of Tokat were taken from the Turkish Statistical Institute. The planted area and machine impact area radii were calculated and the database was created.

3. Making analyses based on position: Analyses were made for each district separately by taking into account the planted area and machine impact area radii and the number of machines.

4. Obtaining result maps: Maps were created for each machine group used in common crops. In the machinery groups used in wheat agriculture, maps were obtained for tillage tools/machines, fertilizing machines, and tractors.

RESULTS AND DISCUSSION

Soil Tillage Machinery

Maps of the cultivated area and machine impact area of Tokat districts are given in Figure 1. The total cultivated area in Tokat is 2.720.720 da and the cultivated area radius is 29.428 m. The total impact area of tillage tool/machines was calculated as 193.657.313 da and the impact area radius was 248.280 m. It was determined that the machine impact area is 70 times larger than the cultivated area in Tokat. The fact that the machine impact area is very large is due to the high number of mouldboard plows, toothed harrows, and cultivators. This value, which was found 2.6 times in the study conducted for Erzurum province (Yıldız et al., 2007) and 33 times in the study conducted for Konya (Yıldırım, 2019), shows that the trend is similar to our study. Among the districts of Tokat, the highest value was obtained in the Merkez district 120 times, and the lowest value was obtained in the Başçiftlik district 39 times. At the same time, in all districts, there are more machines than required as well as inadequate machines. Among the districts, Zile has the highest number of tillage tools/machines and Başçiftlik has the lowest number. While 27.240 machines are used throughout the province, 5.276 machines are considered sufficient. The unbalanced distribution of machinery in the province of Tokat, where field, vegetable, and fruit agriculture is intensively carried out, in other words, the fact that the number of machinery is more or less than it should be can be seen as a result of unplanned behavior.

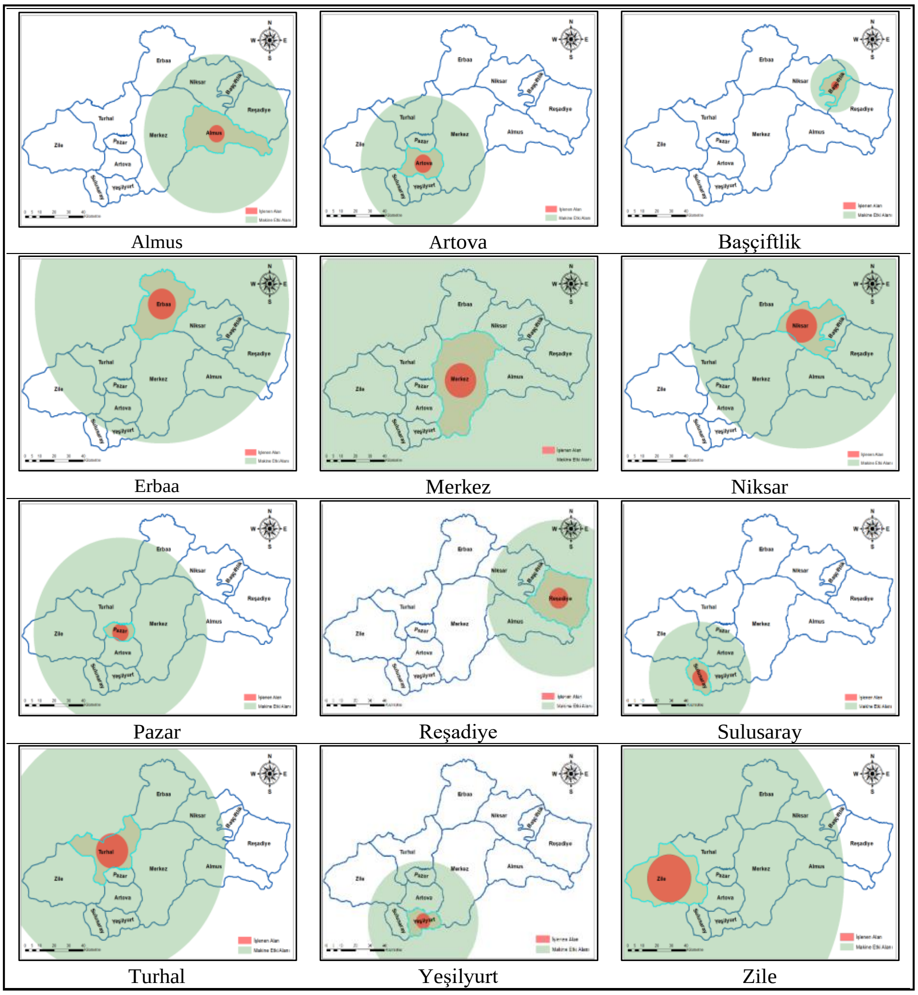

Figure 1. Maps of cultivated areas and machine impact areas in the districts of Tokat

Şekil 1. Tokat ilçelerinde işlenen alan ve makine etki alan haritaları

Sowing and Planting Machinery

The total planted area in the whole province is 2.467.235 da and the planted area radius is 28.024 m. The total sowing/planting machines impact area has been calculated as 4.279.843 da, with an impact area radius of 36.910 meters. It was determined that the machine impact area was approximately 2 times more than the planted area in the whole province (Figure 2). Except for seedling planting machines, the surplus was determined in other machines. Among the districts, the highest number of sowing/planting machines is in Zile and the lowest number is in Başçiftlik district. While 872 machines are sufficient in total, 633 extra machines are used.

In the study conducted in Erzurum province, the sowing/planting machines impact area covered 60% of the cultivated area (Yıldız et al., 2007), whereas, in this study, it was found to affect 73% more area than the planted area. It can be said that mechanical sowing is more widespread in Tokat province.

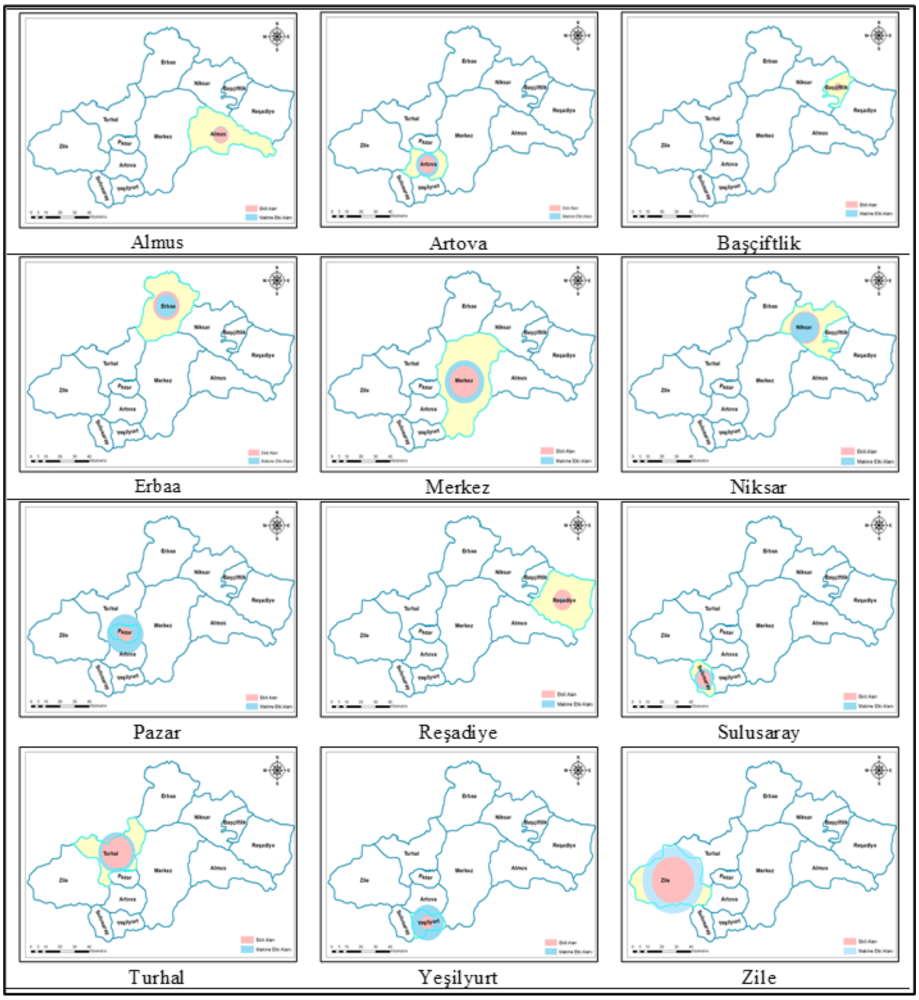

Figure 2. Maps of planted areas and machine impact areas in the districts of Tokat

Şekil 2. Tokat ilçelerinde ekili alan ve makine etki alan haritaları

Maintenance and Fertilization Machinery

Maintenance and fertilized area and machine impact area maps of Tokat districts are given in Figure 3. The total maintenance and fertilized area in Tokat is 2.893.670 da and the radius of the area is 30.349 m. The total maintenance and fertilization machines impact area is 122.079.548 da and the impact area radius is 197.127 m. It was determined that the machine impact area in the whole province is 41 times greater than the fertilized area. The reason for the high machine impact area is due to the chemical centrifugal fertilizer spreader. Among the districts of Tokat, this value is highest in the Pazar district with 122 times and lowest in the Başçiftlik district. In the study conducted in Konya province, it was determined that the highest need in the maintenance and fertilization machinery group was for the manure spreading machine (Yıldırım, 2019).

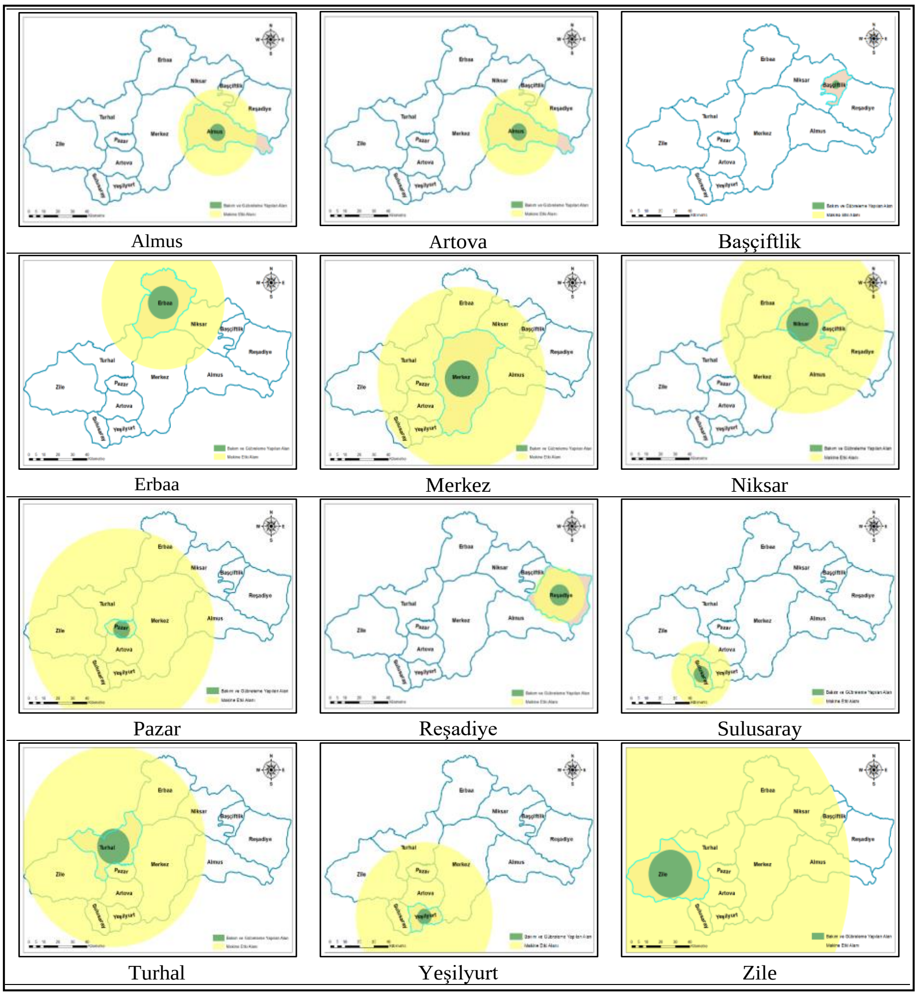

Figure 3. Maps of maintenance and fertilized areas and machine impact areas in the districts of Tokat
Şekil 3. Tokat ilçelerinde bakım ve gübreleme yapılan alan ve makine etki alan haritaları

Plant Protection Machinery

The sprayed area and machine impact area maps of Tokat districts are given in Figure 4. The total sprayed area in Tokat is 2.893.670 da and the sprayed area radius is 30.349 m. The plant protection machinery' total impact area is 44.194.255 da and the impact area radius is 118.606 m. In the whole province, It is calculated that the machine impact area is 14 times more than the sprayed area. Among the districts of Tokat, this value is highest in the Merkez district at 26 times and lowest in the Başçiftlik district.

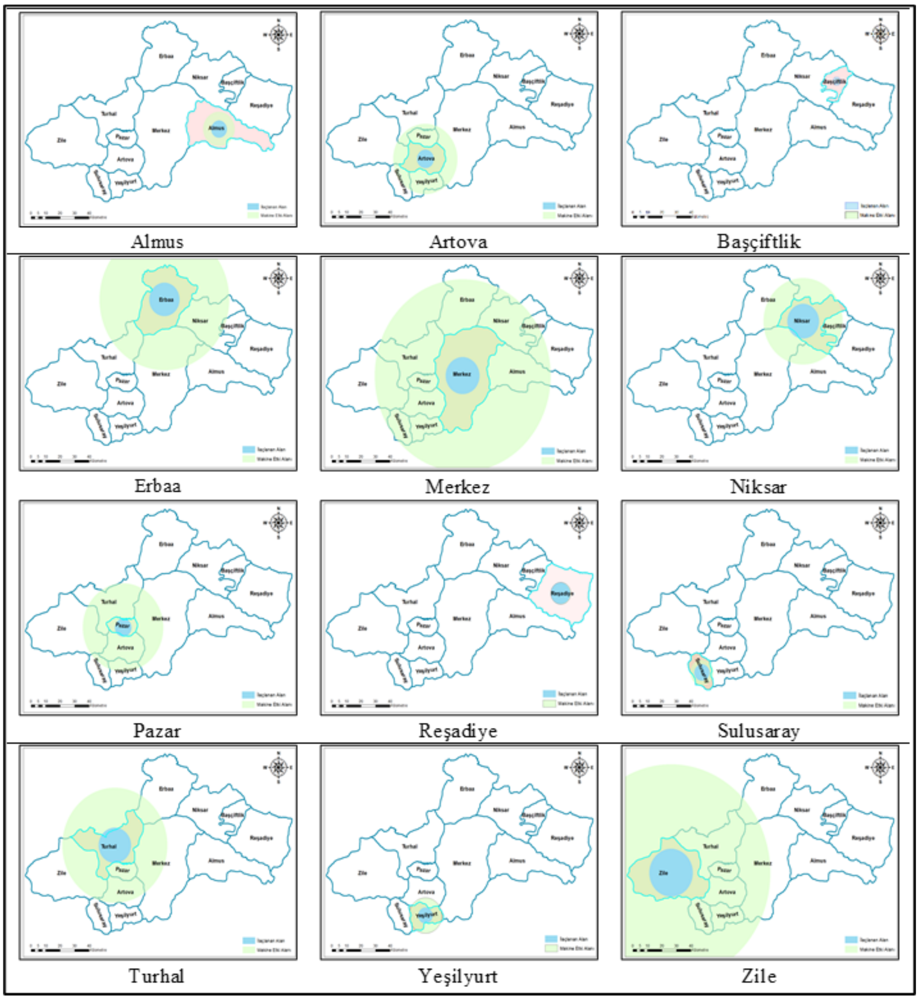

Figure 4. Maps of sprayed areas and machine impact areas in the districts of Tokat
Şekil 4. Tokat ilçelerinde ilaçlama yapılan alan ve makine etki alan haritaları

Harvesting Machinery

Harvested area and machine impact area maps of Tokat districts are given in Figure 5. The total harvested area in Tokat is 2.102.523 da and the harvested area radius is 25.870 m. The harvesting machinery' total impact area was calculated as 3.888.714 da and the impact area radius was 35.183 m. It was determined that the machine impact area in Tokat was 0.8 times smaller than the harvested area. Among the districts of Tokat, the highest value was obtained in the Pazar district with 13 times, and the lowest value was obtained in the Turhal district at 0.16 times.

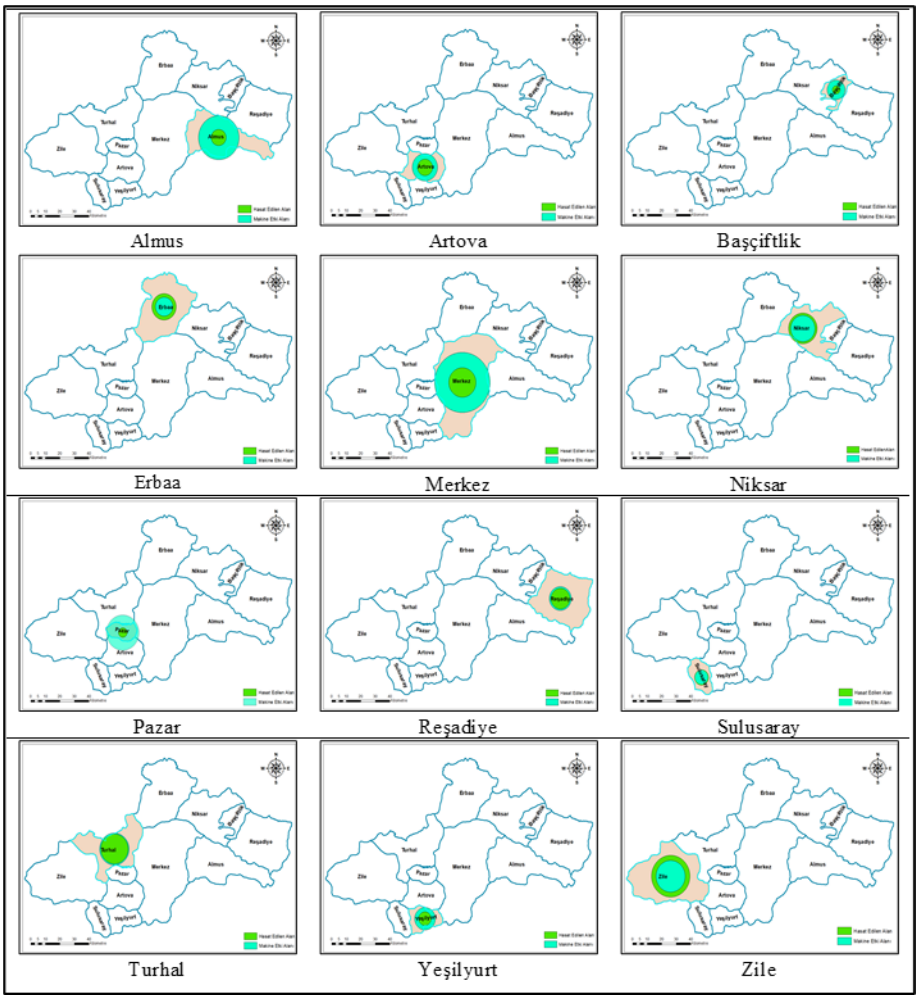

Figure 5. Maps of Harvested Areas and Machine Impact Areas in the Districts of Tokat
Şekil 5. Tokat ilçelerinde hasat edilen alan ve makine etki alan haritaları

Combine Harvester

The maps of harvested areas by combine harvesters and machine impact areas for the districts of Tokat are shown in Figure 6. The total harvested area by combine harvester in Tokat is 1.903.404 da and the harvested area radius is 24.614 m. The combine harvesters' total impact area is 760.332 da and the impact area radius is 15.557 m. It was determined that the machine (combine harvester) impact area was 0.39 times smaller than the harvested area in Tokat.

Almus, Başçiftlik, Niksar and Reşadiye districts have no harvester. Except for the Merkez district, it was determined that all other districts need combine harvesters. The districts with the highest need for combine harvesters are the Zile, Niksar, and Erbaa districts respectively. While there were 124 combine harvesters in Tokat, it was determined that there was a need for 209 more combine harvesters. The need for combine harvesters during the season is met by the contracting system with combine harvesters coming from other provinces. In the study conducted in Konya province, results with a similar trend were obtained (Yıldırım, 2019).

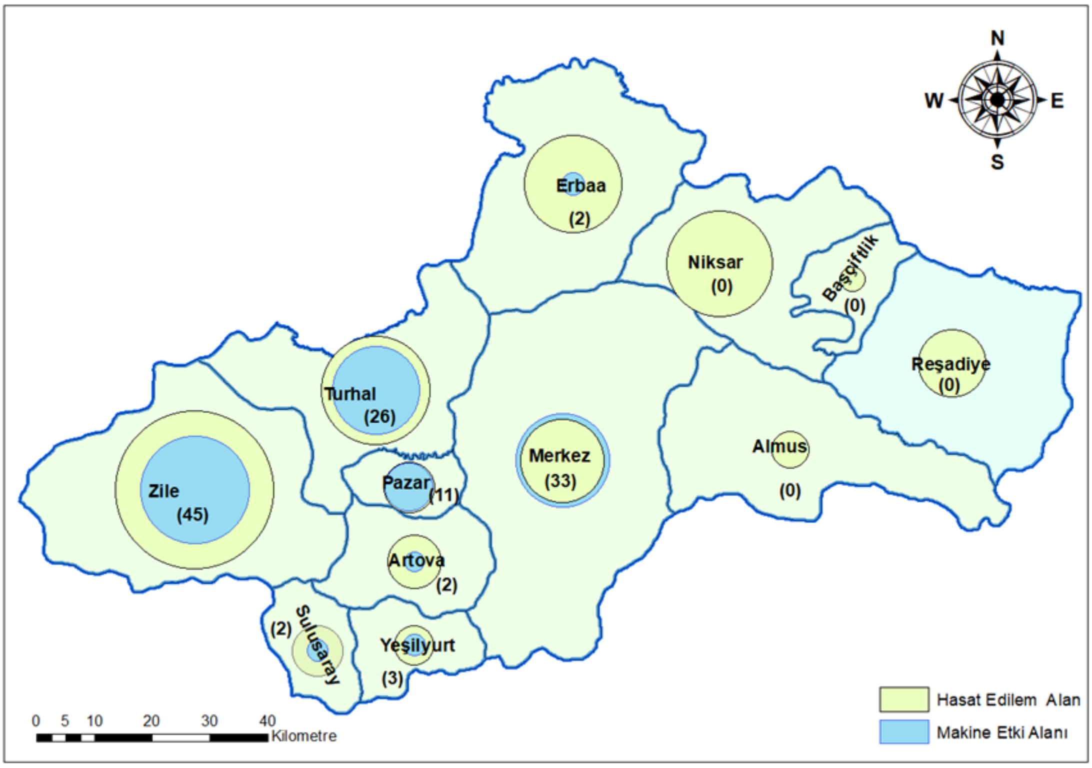

Figure 6. Map of machine numbers, harvested areas, and machine impact areas in the districts of Tokat
Şekil 6. Tokat ilçelerinin makine sayıları dağılım, hasat edilen alan ve makine etki alan haritası

Tractors

The maps of tractor-operated areas and machine impact areas for the districts of Tokat are shown in Figure 7. The total tractor-operated area in Tokat is 2.893.670 da and the operated area radius is 30.349 m. The total tractor impact area is 99.875.199 da and the impact area radius is 178.301 m. It was determined that the machinery (tractor) impact area is 35 times larger than the tractor-operated area in Tokat. Among the districts of Tokat, the highest value was obtained in the Merkez district 72 times, and the lowest value was obtained in the Sulusaray district 19 times.

There are 16.982 tractors in Tokat. While the required number of tractors is 500, it has been determined that there is an excess of 16.482 tractors. There is a considerable difference between these numbers, which is also significant for the national economy. A method must be devised by the government to find a solution. In the study conducted in Konya province, results with a similar trend were obtained (Yıldırım, 2019). While the lowest number of tractors is in Başçiftlik, the highest number of tractors is in the Merkez district. There are many times more tractors in each district than it should be. The reason for this can be said to be that tractor ownership is seen as social status, used in construction and transport works and unconscious planning.

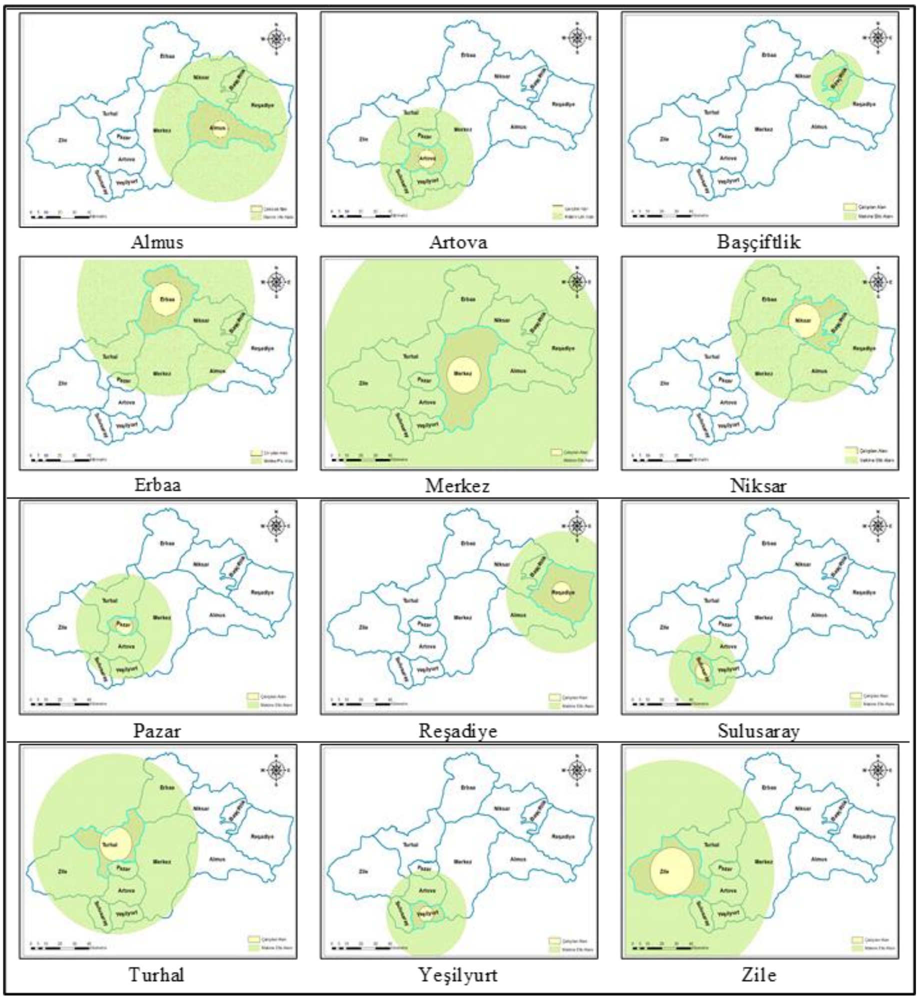

Figure 7. Maps of tractor-operated areas and machine impact areas in the districts of Tokat
Şekil 7. Tokat ilçelerinde traktörle çalışılan alan ve makine etki alan haritaları

Machine Utilization Efficiency

Up to this point, the machine utilization efficiency has been evaluated in the crops commonly cultivated in Tokat province. The machine utilization efficiency was also evaluated in areas only in wheat agriculture in Tokat province, and similar results were obtained.

When the 7 machinery groups determined for the plants commonly cultivated in Tokat are evaluated, there are 27.240 machines in the tillage tools/machinery group. The most surplus machines (21.964) are in this group. However, 5.276 machines are sufficient for the region. It is determined that the machine impact area is 70 times larger than the cultivated area in Tokat. In our country, traditional tillage still maintains its attractiveness and interest continues. For the machines in this group, methods such as renting and common use are generally not preferred. Farmers prefer to purchase machines that they can access more easily (such as small machines, and subsidized machines). In this context, the moldboard plow is the most preferred machine with an excess of 11.607 units. Stone collecting machines are generally used by the Tokat Directorate of Agriculture and Forestry through renting and also through a contracting system. Although the most needed machine is the stone collecting machine, it may not be correct to talk about its deficiency since it is supplied from nearby provinces through a contracting system. In particular, the lack of the subsoiler was determined in all districts (except Pazar and Zile districts). It is thought that the lack of a subsoiler is due to the lack of sufficient knowledge about this tool/machine. The misconception that the chisel plow performs the same task as the subsoiler also contributes to this conclusion. According to the districts, plant pattern and enterprise size also affect the need for machinery in this group. For example, the fact that the excess of disc harrow is mostly in the Zile district may be due to the widespread sunflower agriculture.

In the sowing and planting machinery group, there are 1.505 machines. While a total of 872 machines are sufficient, an additional 633 machines are being used. It is determined that the machine impact area is approximately 2 times more than the planted area in the whole province. In Tokat province, where wheat is widely cultivated, combined seed drill is used the most and there are 489 extra machines. In the districts where this machine is lacking, broadcast sowing is preferred. Potato planting machines are in excess in the whole province. This is due to Niksar district where potato cultivation is intensive. Since tobacco is cultivated in Erbaa and Niksar, seedling planting machines are used only in these districts.

There is an excess in the total number of machines in the maintenance and fertilization machinery group. While the number of machines used is 3.284, it is determined that 1.016 machines are sufficient. It was determined that the machine impact area is 41 times more than the fertilized area in the whole province. The excess in this group is due to the chemical centrifugal fertilizer spreader, which is 2.062 more than normal. The reason for the excess of this machine is that it is used in wheat cultivation. The most needed machine is the manure spreading machine. The lack of this machine is because farm manure is widely distributed by manpower or soil leveling shovels in small enterprises throughout Tokat.

In the plant protection machinery group, of the 2.542 machines used, 2.329 are surplus. It was calculated that the machine impact area is 14 times more than the sprayed area in the whole province. Excess was found both in field crop sprayers and orchard sprayers. Especially motorized orchard sprayers are concentrated in the regions where garden agriculture is carried out in Tokat. It can be said that the reason for the idle machinery is that the enterprises prefer to purchase individually in order not to miss the limited agricultural protection periods.

There are 2.486 machines in the harvesting machinery group. While 2.218 machines are sufficient in total, an additional 268 machines are being used. Although the surplus seems to be relatively balanced, it is noteworthy that the need for balers and the surplus of other machines balance each other. In terms of the number of machines, there are deficiencies and excesses in this group among the districts. The number of balers needed in the whole province is 1.414 and this need is met through renting. The rental method is also used in the sugar beet harvester. The need for potato harvesters is met by using plows or cultivators for potato harvesting. It is determined that the machine impact area is 0.8 times smaller than the harvested area in Tokat.

It was calculated that the machine (combine harvester) impact area was 0.39 times smaller than the harvested area in Tokat. While there are 124 combine harvesters in the whole province, it was determined that there is a need for 209 more combine harvesters. The need for combine harvester in the season is met by the contracting system with combine harvesters from other provinces. Combine harvester contracting system is widely used in harvesting practices in our country and our region. The harvesting across the country starts on 15 May with wheat harvesting and ends in 2 to 2.5 months from the coastal region to the inland regions. Afterward, it continues with sunflower, maize, and rice harvesting. It may not be correct to talk about deficiency or excess due to the contracting system.

It is calculated that the machinery (tractor) impact area is 35 times larger than the tractor-operated area across Tokat. Although 500 tractors are sufficient in the whole province, it was determined that 16.482 tractors are surplus in the tractor-operated area. The reason for this can be said to be that tractor ownership is seen as a social status and it is used in construction and transport works as well as agricultural works. It is also utilized for investment purposes (Kasap et al., 1991).

In the evaluation of the machine utilization efficiency in only wheat agriculture and common crops cultivated, more deficiencies were detected in the machines (except balers) used in wheat agriculture for all machines where deficiencies were detected. This is due to the limited number of workable days. In terms of the number of machines, it was determined that the excess was less in the machines with more than the necessary number (except for the combined seed drill). For this reason, rather than making province or district-wide planning, planning according to the plant pattern and enterprise-based planning will give more accurate results. Because the average data to be taken from large areas in mechanization planning may cause mistakes. Therefore, it would be more realistic to make planning from enterprise size to country-wide (Evcim, 1990).

CONCLUSION

Agricultural tools and machines used in only wheat agriculture and the common crops cultivated in 12 districts of Tokat province were classified into 7 groups. For the machines in each group, the machine impact areas were calculated based on the district, and the situation was determined for the machines in the machine groups by comparing them with the cultivated area. The number of machines in the group and the impact areas and cultivated areas converted into circular areas were converted into maps with the help of the ArcGIS 10.8 program.

In Tokat province where field, vegetable, and fruit agriculture are intensively carried out, the unbalanced distribution of machinery, i.e. the fact that the number of machinery is more or less than it should be, can be seen as a result of unplanned behavior. In this sense, it can be said that production planning is important and planning should be made according to the plant pattern.

The idle machines identified as a result of the study conducted for Tokat province cause high production inputs for the enterprises. For this reason, it can be suggested to use common machinery or to generalize machinery contracting system, to renew the machines that have completed their economic life, and to carry out state-supported projects for the machines whose deficiency is determined. Industrialists can also be guided and orientated according to the needs of the region.

CONFLICT OF INTEREST

There is no conflict of interest between the authors.

AUTHOR CONTRIBUTIONS

The authors' contributions to the article are equal.

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Effects of Drought and Salinity Stress on Antioxidant Enzymes and Yield Parameters of Laurel Plant (*Laurus nobilis* L.)

Kuraklık ve Tuzluluk Stresinin Defne Bitkisinin (*Laurus nobilis L.*) Antioksidan Enzimler ve Verim Parametreleri Üzerine Etkileri

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Abstract: Plants are exposed to various environmental stressors throughout their life cycle, including cold, drought, high temperature, salt, and heavy metals. These environmental variables, known as abiotic stressors, lead to oxidative stress and promote the formation of reactive and dangerous reactive oxygen species in plants. In this study, laurel plants were exposed to two different abiotic stress conditions (salinity (10 dS m^{-1}), drought). Under both stress conditions, chlorophyll content, stomatal conductance and antioxidant enzyme activities Glutathione S-transferase (GST), glutathione reductase (GR), guaiacol peroxidase (GPx), ascorbate peroxidase (APx) were determined. Chlorophyll content was observed to decrease by 58.53% and 40.31% for drought and salinity treatments, respectively, compared to the control treatment. In addition, stomatal conductance was reduced by 52.75% and 35.15% for drought and salinity treatments, respectively. These results indicate that chlorophyll content and stomatal conductance of laurel plants were more affected by drought stress than salinity. The activity of all antioxidant enzymes decreased in both drought and salinity stress. GR and GPx were significantly reduced by 49.29% and 74.51%, respectively, in drought treatment compared to the control group. In addition, GST and APx activity decreased by 22.01% and 6.26%, respectively, in salinity stress compared to the control group. According to the data obtained, GR and GPx enzyme activities in laurel plants were more affected by drought stress, while GST and APx enzyme activities decreased more significantly under salinity stress.
Keywords: *Laurus nobilis L.*, antioxidant, enzyme activity, stress factor, chlorophyll

&

Öz: Bitkiler yaşam döngüleri boyunca soğuk, kuraklık, yüksek sıcaklık, tuz ve ağır metaller dahil olmak üzere çeşitli çevresel stres faktörlerine maruz kalırlar. Abiyotik stresler olarak bilinen bu çevresel değişkenler oksidatif strese yol açmakta ve bitkilerde reaktif ve tehlikeli reaktif oksijen türlerinin oluşumunu teşvik etmektedir. Bu çalışmada, Defne bitkisi 2 farklı abiyotik stres koşuluna (tuzluluk (10 dS m^{-1}), kuraklık) maruz bırakılmıştır. Her iki stres koşulunda da klorofil içeriği, stoma iletkenliği ve antioksidan enzim aktiviteleri Glutatyon S-transferaz (GST), glutatyon redüktaz (GR), guaiakol peroksidaz (GPx), askorbat peroksidaz (APx) belirlenmiştir. Klorofil içeriğinin kontrol uygulamasına kıyasla kuraklık ve tuzluluk uygulamaları için sırasıyla %58.53 ve %40.31 oranında azaldığı gözlenmiştir. Buna ek olarak, stoma iletkenliği kuraklık ve tuzluluk uygulamaları için sırasıyla %52.75 ve %35.15 oranında azalmıştır. Bu sonuçlar, defne bitkilerinin klorofil içeriği ve stoma iletkenliğinin kuraklık stresinden tuzluluğa göre daha fazla etkilendiğini göstermektedir. Tüm antioksidan enzimlerin aktivitesi hem kuraklık hem de tuzluluk stresinde azalmıştır. GR ve GPx, kontrol grubuna kıyasla kuraklık uygulamasında sırasıyla %49.29 ve %74.51 oranında önemli ölçüde azalmıştır. Ayrıca, GST ve APx aktivitesi tuzluluk stresinde kontrol grubuna kıyasla sırasıyla %22.01 ve %6.26 oranında azalmıştır. Elde edilen verilere göre, defne bitkisinde GR ve GPx enzim aktiviteleri kuraklık stresinden daha fazla etkilenirken, GST ve APx enzim aktiviteleri tuzluluk stresi altında daha önemli ölçüde azalmıştır.
Anahtar Kelimeler: *Laurus nobilis L.*, antioksidan, enzim aktivitesi, stres faktörü, klorofil

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INTRODUCTION

Climate change is predicted to become more visible due to global warming caused by excessive industrialization to meet human demands, and rising carbon emissions generated by the world's rapid population growth. Climate change will cause unfavorable changes in the precipitation regime, as well as the use of low-quality water in agricultural production and the inability of some regions to irrigate agricultural lands (Zandalinas et al., 2018). Salt and drought stress are the two major abiotic stress factors that limit plant morphological and physiological development and degrade yield and quality. The rise in salt-containing soils produced using saline waters, drainage water, wastewater in agricultural irrigation, and drought due to climate change plays a significant part in the loss of productive farm areas (Machado and Serralheiro, 2017).

Drought stress causes plant transcriptional reprogramming, followed by physiological responses such as antioxidant generation, osmolyte synthesis, and stomatal closure (Ding et al., 2013). It has been established that reactive oxygen species (ROS), which begin to accumulate in plants under drought stress, are the product of metabolism, which plays a role in the plant's signal transmission process (Cabello et al., 2014). Excessive plant accumulation of these reactive oxygen species can cause cell death through chain reactions such as lipid peroxidation and DNA damage. Non-enzymatic antioxidants in plants protect non-photosynthetic zones from reactive oxygen species, whereas enzymatic antioxidants mitigate their effects by reducing reactive oxygen species (Osakabe et al., 2014).

Salt stress is the most significant abiotic stressor, an imbalance in edaphic conditions and devastating impacts on plant growth and physiological functioning (Shahbaz and Ashraf, 2013). Salt stress leads to the degradation of physiological and chemical components after creating osmotic and ion stress in the plant. Plants are also subjected to oxidative stress at the subcellular level. These are the primary causes of long-term plant damage caused by salt stress (Acosta-Motos et al., 2015). As a result of the osmotic stress generated by salt stress, the amount of water in the plant decreases. Such a case is known as a physiological drought. As a result of physiological droughty, cell growth slows and eventually stops. Although plants require Na^+ and Cl^- ions, increased quantities of Na^+ and Cl^- ions in ion stress caused by osmotic stress compete with nutrients such as K^+ and Ca^{2+}, resulting in a nutritional deficiency (Hu and Schmidhalter, 2005). High concentrations of these ions in leaves can damage cell activity and eventually cause programmed cell death. Furthermore, increased Na^+ and Cl^- ion levels inhibit protein synthesis, plant lipid metabolism, and enzyme performance. Also, the presence of such ions in high concentrations may promote the creation of reactive oxygen species, producing severe oxidative stress in plants. The body has defensive systems known as antioxidants to avoid creating free radicals due to numerous reactions and structural damage. By responding swiftly to the radicals generated, these defense mechanisms avoid oxidation and peroxidation (Dündar and Aslan, 1999). Antioxidants form an electron target and affix free radicals to it (Aydemir and Sarı, 2009). The basic roles of antioxidants are to detoxify excess free radicals protect cells from the destructive effects of radicals, and contribute to the prevention of many diseases (Pham-Huy et al., 2008). They help cells operate properly and maintain their integrity. The damaging effects of free radicals do not impact the organism as long as the equilibrium between free radicals and antioxidants is maintained. With various components, oxygen metabolized in metabolism leads to the creation of active oxygens. Active oxygens degrade the structure of lipids, carbohydrates, and proteins (Önenç and Açıkgöz, 2005). Endogenous and exogenous antioxidants are the two types of antioxidants that neutralize free radicals and maintain the oxidant/antioxidant balance to protect the organism (Gupta et al., 2014). In addition, endogenous antioxidants are divided into two groups as enzymatic and nonenzymatic. Plants have developed several defense mechanisms, as well as signaling actions, to regulate both the formation and the removal of ROS to avoid oxidative damage (Hasanuzzaman et al., 2018). The antioxidant defense system efficiently scavenges excess ROS by the coordinated action of different enzymes that include glutathione reductase (GR), Glutathione S transferase (GST), ascorbate peroxidase (APX), Guaiacol peroxidase (GPX) as well as by the involvement of multiple nonenzymatic reactions (Soares et al., 2019; Al Mahmud et al., 2018).

The Laurel plant is a plant that falls into the category of forest products and the laurel plant, which has a wide distribution area in Turkey, is encountered in Antalya, Mersin, Hatay, İzmir, Muğla, and Bursa, especially on the Black Sea coasts. *Laurus nobilis L.* is an aromatic and medicinal plant belonging to the Lauraceae family, which comprises approximately 2500-3500 species (Dobroslavic et al., 2022). It is an evergreen shrub native to the Mediterranean region and is also known by a number of other names, including sweet laurel, Grecian laurel, true laurel and simply laurel (Anzano et al., 2022). Turkey is the primary producer of L. nobilis, exporting it to 64 countries (Anzano et al., 2022). Approximately 97% of the global total production is sourced from Turkey. In addition to its aromatic properties, *L. nobilis* has been esteemed for millennia for its purifying attributes. *L. nobilis* is widely cultivated in many parts of the world and is primarily used as a culinary herb. The different body parts and essential oil (EO) of L. nobilis have been demonstrated to possess a multitude of intriguing properties with potential applications in a diverse range of fields, including agriculture, medicine, food, and the pharmaceutical industry. The leaves are frequently employed as a pungent, aromatic seasoning for soups, fish, meats, stews, puddings, vinegar, and beverages. Due to its antimicrobial and insecticidal properties, laurel is utilized as a food preservative in the food industry (Sırıken et al., 2018). Additionally, the cosmetics industry incorporates L. nobilis EO into creams, perfumes, and soaps (Ordoudi et al., 2022).

Many researchers have conducted numerous studies on the influence of essential oils produced by the laurel plant and the antioxidant capacity of the laurel plant when the literature is evaluated (Ramos et al., 2012; Santoyo et al., 2006). In light of this, the response and yield characteristics of the antioxidant enzyme system in laurel plants under stress conditions were not examined. The effects of drought and irrigation water salinity which have significant negative effects on plants were investigated in this study, as were the activities of Glutathione S-transferase (E.C. 2.5.1.18 GST), Guaiacol Peroxidase (E.C. 1.11.1.17 GPx), Ascorbate Peroxidase (E.C. 1.11.1.11 APx) and Glutathione Reductase (E.C. 1.8.1.7 GR) members of the antioxidant mechanism in the laurel plant, as well as chlorophyll content and stomatal conductivity which are photosynthetic parameters were studied.

MATERIAL AND METHOD

Experiment Area and Growing Conditions

This study was conducted at the Ondokuz Mayıs University Faculty of Agriculture, Research area, in a 120 m^2 greenhouse under rain-shelter conditions between November 2019 and January 2020. The temperature and relative humidity of the environment were monitored using an electronic data logger (KISTOCK KMO Data logger). During the experiment, the temperature ranged between 12 and 17 ^{0}C, while the relative humidity ranged between 68.7% and 81.4%.

This study used pots with a depth of 31 cm, bottom and top diameters of 36 cm and 38 cm, respectively, for seedling planting. Then, the air-dried soils were sieved with the help of a sieve with a pore size 4 mm, and 32 kg of sieved soil was added to the pots. The experimental soil texture was loamy, which has 52.3% sand, 9.4% clay, and 38.3% silt. The pH of the soil was 8.28, and the EC (dS m^{-1}) was 0.63.

Experiment Design and Irrigation

The study was conducted in a randomized design with 1 factor and 3 replications. For this, applications were made in the experiment as the control group (0.38 dS m^{-1}), the salinity group (10 dS m^{-1}), and the drought group (no water). Thus, a total of 9 plastic pots were used in the experiment. One-year-old laurel seedlings were planted on the first day of November and irrigated twice a week with tap water. Saline water and drought applications were started 3 weeks after planting the seedlings. NaCl and $CaCl_2$ salts were used to prepare saline water. The field capacity of each pot was determined before beginning of the experiment. The pots were saturated with tap water, and then the soil surface was covered with plastic to prevent evaporation. After drainage was completed, each pot was weighed and recognized as the respective pot's field capacity weight (WFC). Equation 1 (Kiremit and Arslan, 2018; Ünlükara et al., 2010) was used to calculate the amount of irrigation water supplied to each pot based on their treatment. Each pot was weighed before irrigation. Irrigation was only applied to the control group (0.38 dS m^{-1}) and the salt stress group (10 dS m^{-1}). Irrigation water was not used to the plants in the drought group from the beginning of the experiment until harvest.

$$IW = \frac{\frac{W_{FC} - W_{\rho}}{\rho_W}}{1 - LF} \quad (1)$$

Where; IW; irrigation water amount (L), WFC; Field capacity value of the pot (kg), LF; Leaching fraction, Wϱ; Weight of the pot before irrigation (kg), ϱw; the volume weight of water (1 kg L^{-1}). Furthermore, the amount of drainage water was measured after each irrigation.

Stomatal Conductance and Chlorophyll Content

A SPAD meter (SPAD-502 Plus) was used to determine the chlorophyll content of the leaves of laurel plants by taking measurements at three different points on the fully developed upper leaves of the plants and calculating an average value. In addition, the same procedures were carried out with a portable porometer (Delta-T AP4) to determine the stomatal conductance (mmol m^{-2} s^{-1}) of the plants.

Preparation of Extracts

Leaf samples were taken 3, 6 and 9 weeks after the first stress treatments for enzyme analysis. The leaf samples were weighed on a precision balance and the total weight was adjusted to approximately 1 g. The samples were cut into small pieces, placed in a mortar and mechanically crushed using liquid nitrogen until they were pulverized. The pulverized samples were placed in a 50 ml tube and 5 ml of 0.5 mM EDTA, 0.1 mM PVP and 100 mM KH_2PO_4 (pH 7.7) crushing buffer were added. Centrifugation was carried out at 15,000 x G and +4 ºC for 20 minutes. At the end of centrifugation, the supernatant was filtered using a Pasteur pipette and filter paper and the homogenate was transferred to another tube.

Protein Determination

The protein content of the extracts was determined according to the Bradford method (Bradford, 1976). This method is based on the binding of the dye Coomassie Brilliant Blue G-250 to proteins in different concentrations, resulting in a blue solution with varying color intensity. In order to carry out protein determination using this method, a standart curve must be created. For this purpose, 1, 2, 4, 6, 10 and 16 µl of bovine serum albumin (BSA) solution containing 1 mg protein per 1 ml was added to the tubes. After the volumes of all tubes were made up to 100 µl with distilled water, 900 µl of 1x Bradford solution was added and the final volume was made up to 1 ml. The tubes were mixed by vortexing and incubated for 10 minutes. At the end of this time, instantaneous measurements were performed at 595 nm in a spectrophotometer and the results were converted to a standard curve. The values were read photometrically at 595 nm by mixing 96 µl distilled water, 900 µl Coomassie Brilliant Blue G-250 and 4 µl supernatant samples in a quartz cuvette. The protein content was determined using a standard graph based on the values obtained from each sample.

Determination of Enzyme Activities

The leaf samples were taken and stored at -20 °C for enzymatic analyses 3, 6 and 9 weeks after the first application. All spectrophotometric analyses were performed using a spectrophotometer for UV-visible light at 25 °C (Shimadzu UV–1800).

The activity of GR was measured at 340 nm due to the oxidation of NADPH using 200 mM TRIS buffer (pH 7), 2 mM GSSG, 2 mM NADPH and 100 µl supernatant. The spectrophotometric methods were performed at 340 nm for 2 min with the kinetic rate setting (Carlberg and Mannervik, 1975).

The activity of GST, a waveform of the dinitrobenzene-5-glutathione product (DNB-SG) formed using CDNB, was measured using 20 mM TRIS buffer (pH 7.5), 20 mM GSH, 25 mM CDNB and 100 µl supernatant. The increase in absorbance at 340 nm was observed for 2 minutes (Habig et al., 1974).

The activity of the APX enzyme was determined by measuring the rate of ascorbate oxidation using a spectrophotometer. APX activity was measured by observing the decretion in absorbance of ascorbate oxidation at 290 nm for 2 minutes. The mixture of reaction (1 ml) includes 20 mM TRIS buffer (pH 6.0), 1 mM EDTA, 20 mM H_2O_2, 2.5 mM L(+)-ascorbic acid (ASA) and enzyme extract (Cakmak et al., 1993).

The activity of the GPX enzyme was detected using the method of Sisecioglu et al., (2010). This method is based on the oxidation of the chromogenic substrate guaiacol by H_2O_2 and the observation of the increase in absorbance by the formed colored compound (tetraguaiacol). The reaction solution contained 200 mM KH_2PO_4 buffer (pH 6.0), 50 mM H_2O_2 and 100 mM guaiacol and the absorbance increase in the supernatant was observed at 470 nm for 2 min.

Statistical Analysis

A one-way ANOVA statistically analyzed stomata conductivity and chlorophyll content values, and significant differences among means were separated by using the Duncan test at the %5 probabilty level using SPSS 25.0 statistical software ($p<0.05$). Data are given as mean values ± standard deviation. Each data point is the mean of three independent replicates ($n = 3$). Each replicate consisted of one plants. The bar graphs were drawn in Microsoft Excel 2019.

RESULT and DISCUSSION

The Effect of Salinity and Drought Stresses on Photosynthetic Parameters

The effect of different stress factors on stomatal conductivity and chlorophyll content in the leaves of the laurel plant is shown in Figures 1 and 2. The main effect of irrigation water salinity and drought stress for stomatal conductance and chlorophyll content was statistically significant ($p< 0.05$). Stomatal conductivity and chlorophyll content decreased in both drought and salinity stress compared to the control group. Stomatal conductance was determined as 176.01 (mmol m^{-2} s^{-1}) in the control group, 111.73 (mmol m^{-2} s^{-1}) in the salinity group, and 82.68 (mmol m^{-2} s^{-1}) in the drought stress group, respectively. The stomatal conductance value decreased by 36.15% in the salinity treatment and 52.75% in the drought treatment. According to these results, drought's effect on the stomatal conductance of laurel plants was greater than that of salinity.

The chlorophyll content in the leaves of the laurel plants was determined as 70.90 CCl in the control group, 43.32 CCl in the salinity stress group, and 29.40 CCl in the drought stress group, respectively (Figure 2). Chlorophyll content value decreased by 40.31% in salinity treatment and 58.53% in drought treatment compared to the control. According to these results, drought's effect on the chlorophyll content of laurel plants was higher than that of salinity.

Salt stress causes Na^+ toxicity and ionic imbalance in plant cells, interfering with vital metabolic processes such as protein synthesis, enzymatic reactions, and ribosome function (Alkharabsheh et al., 2021; Mushtaq et al., 2020). Other essential nutrients such as potassium, magnesium, ammonium, nitrate, and phosphate are competed with the high concentration of Na^+ salt used (Shabala and Cuin, 2008). Furthermore, salinity-induced osmotic stress impairs the photosynthetic mechanism by decreasing stomatal conductance. As a result of the reduced CO_2 input, the rate of photosynthesis decreases (Ouyang et al., 2017). In the study of Ben Ayed et al., in 2018 on the effects of NaCl salts applied in different doses on the growth and mineral parameters of the laurel plant, they reported that there was a decrease in chlorophyll content with the increase in the salinity level applied to the plants (Ben Ayed et al., 2018). The decreased chlorophyll content is accepted as one of the main markers of metabolic problems in plants exposed to drought stress; it is also known that decreases in protein levels and enzyme activity cause the closure of leaf stomata and dehydration (Levitt, 1980).

Plant physiological processes are directly or indirectly affected by inadequate water availability. Photosynthesis is directly affected in plants that are subjected to drought stress (Li et al., 2018; Wang et al., 2019). Drought stress reduces plant morphological and physiological characteristics, photosynthesis, leaf water potential and stomatal conductance (Bhusal et al., 2019). The two main factors that cause plants to close their stomata during drought are hydraulic signals (leaf water potential, cell turgor) and chemical signals (e.g. abscisic acid). Abscisic acid (ABA), synthesized in roots and transported to guard cells by transpiration runoff, binds to the hypothetical ABA receptor in guard cells and causes stomatal closure under drought stress conditions (Teiz and Zeiger, 1998). Drought stress can cause excessive ROS production in plants (Abdelaal et al., 2021). Overproduction of ROS in plants due to stress causes protein denaturation, lipid peroxidation, DNA damage, carbohydrate oxidation, pigment degradation and impairment of enzymatic activity (Hasanuzzaman et al., 2019). Drought-induced stomatal closure reduces the plant's ability to use sunlight. Similarly, drought stress disrupts plant nutrient homeostasis and photosynthesis (Razi and Muneer, 2021). Under drought stress, plant cells lose turgor due to lack of water, which inhibits plant growth (Nardini, 2022).

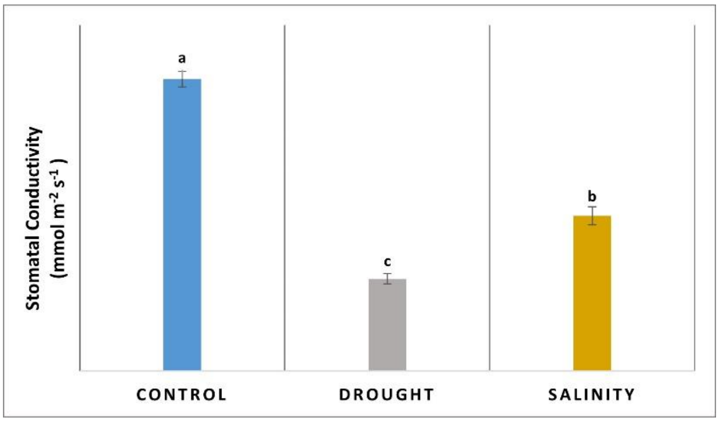

Figure 1. Graphs of stomatal conductivity in laurel plants under stress conditions. Means ± SD. (n=3) means denoted by different letters indicate a significant difference among the treatments at a p < 0.05 level according to Duncan's test.
Şekil 1. Stres koşulları altında defne bitkilerinde stoma iletkenliği grafikleri. Ortalamalar ± SD. (n=3) farklı harflerle gösterilen ortalamalar, Duncan testine göre p < 0.05 düzeyinde uygulamalar arasında anlamlı bir fark olduğunu göstermektedir.

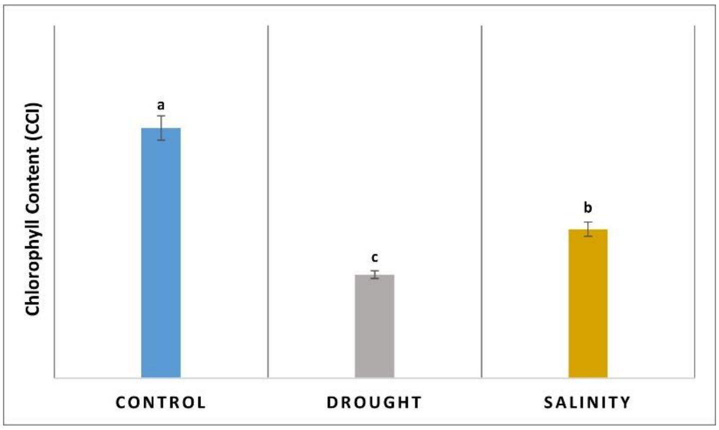

Figure 2. Graphs of chlorophyll content in laurel plants under stress conditions. Means ± SD. (n=3) means denoted by different letters indicate a significant difference among the treatments at a p < 0.05 level according to Duncan's test.
Şekil 2. Stres koşulları altında defne bitkilerinde klorofil içeriği grafikleri. Ortalamalar ± SD. (n=3) farklı harflerle gösterilen ortalamalar, Duncan testine göre p < 0.05 düzeyinde uygulamalar arasında anlamlı bir fark olduğunu göstermektedir.

Antioxidant Enzymes

The results of the effect of salinity and drought stress on the activities of antioxidant enzymes in laurel plants for three periods are shown in Figure 3. The main effect of irrigation water salinity and drought stress for GR, GST, GPX and APX specific activity was statistically significant ($p< 0.05$). The average specific activity (three measurements) of GR enzyme was determined to be 0.71 (EU mg^{-1}) in the control group, 0.57 (EU mg^{-1}) in the salinity group, and 0.36 (EU mg^{-1}) in the drought group. The activity of the enzyme was reduced by 19.71% in the salinity group and 49.29% in the drought group compared to the control.

According to these results, drought's effect on GR enzyme activity in laurel plants was higher than salinity. The results clearly showed that there were differences between the groups according to the activity readings made three weeks after in GR enzyme. The results of the first measurements showed that the specific activities decreased by 32.71% in the salt stress group and 46.72% in the drought group compared to the control group. Besides, the specific activity values in the drought group decreased by 20.83% more than the salinity group. In the measurements made 6 weeks later, the salt and drought groups showed a lower decrease compared to the third week decreasing by 7.27% in the salt group and 65.45% in the drought group compared to the control group. Moreover, the specific activity in the drought group decreased by 62.74% more than the salt stress group. The data obtained nine weeks after the application revealed a 5.76% reduction in the specific activities of the plants in the salt stress group in comparison to the control group. In the drought group, this rate was determined to be 33.53%. Also, the specific activity in the drought group plants decreased by 32.65% more than the salinity group. GR, a flavoenzyme with a disulfide group, is active in the AsA-GSH cycle and converts oxidized glutathione (GSSG) into its reduced form (GSH) (De Vega et al., 2003). GR thus regulates the cellular GSH/GSSG ratio and provides a GSH source for the enzymes glutathione peroxidase, which removes hydrogen peroxide, and dehydroascorbate reductase, which reduces oxidized ascorbate. In order to see the effects of hydrogen sulphide on common bean plant under salt stress, T1 (irrigated with water as control); T2 (50 μM NaHS); T3 (100 μM NaHS); T4 (irrigated with 75 mM NaCl); T5 (50 μM NaHS + 75 mM NaCl); T6 (100 μM NaHS + 75 mM NaCl); T7 (irrigated with 150 mM NaCl); T8 (50 μM NaHS + 150 mM NaCl); and T9 (100 μM NaHS + 150 mM NaCl). To evaluate the effect of H2S in modulating salt stress, the activities of antioxidant enzymes (CAT, POX, SOD, APX, GR, NR) in the leaves of common bean plants were measured. Compared to control plants, CAT, POX, SOD, APX, GR and NR activities were found to increase significantly with increasing NaCl concentrations. CAT (65.3%), POX (43.4%), SOD (134.8%), APX (140.4%), GR (43.4%) and NR (20.5%) activities were higher in plants irrigated with high concentrations of salt stress (150 mM) compared to non-stressed plants (Dawood et al., 2022). In a study conducted to investigate the effects of salt stress on antioxidant enzyme activity and lipid peroxidation in the above- and below-ground parts of two maize genotypes BR5033 (salt tolerant) and BR5011 (salt sensitive) grown under control and salt stress conditions (solution containing 100 mM NaCl), it was reported that GR activity increased in a time-dependent manner in control and salt-stressed plants of BR5033 and BR5011 genotypes. It was found that GR activity was higher in the leaves of plants under salt stress than in the control group, and that GR activity was less affected by salinity in the roots of BR5033, but decreased by about 30% in the roots of BR5011 after 15 days of salt application (de Azevedo et al., 2006). In a study on mustard plants, 100 and 200 mM NaCl concentrations increased GR activity by about 20 % and 25 % on day 90 of treatment (Ahmad et al., 2017). Increasing salt concentrations significantly increased GR activity in different kiwifruit genotypes compared to control plants (Abid et al., 2020). The GR activity of rice plants exposed to three different NaCl concentrations increased approximately 1.5 times (Wutipraditkul et al., 2015). In this study, GR activity decreased under irrigation water salinity and drought stress. GR, an enzymatic flavoprotein antioxidant involved in removing H_2O_2 in the AsA-GSH cycle, could not contribute to the fight against salinity-induced oxidative stress in the aerial parts of laurel plants.

For GST, the average specific activity was determined as 3.61 (EU mg^{-1}) in the control group, 2.82 (EU mg^{-1}) in the salinity group, and 2.86 (EU mg^{-1}) in the drought group. Specific activity values for GST enzyme decreased by 22.01% in salinity treatment and 20.90% in drought treatment compared to the control. When the activity of the GST was analyzed periodically, the specific activity value decreased by 2% in the salinity stress treatment compared to the control group in the first period including the 3 weeks after the application, while no change was observed in the drought stress treatment. In the second period, the specific activity value was reduced by 43.65% in the salinity stress group and by 33.74% in the drought stress group compared to the control. In the third period, while these rates were 34.76% in the salinity group, the specific activity value in the drought group decreased by 44.92%. According to these results, salinity stress had the highest effect on the specific activity of GST in the second period, at 43.65%. In drought stress, this effect was 44.92% in the third period. It was determined that the effects of salinity and drought stress on GST activity in laurel plants varied periodically. GST, which generally utilizes the reduced form of glutathione (GSH), is involved in the detoxification of xenobiotics and toxic lipid peroxides, redox signaling through the reduction of dehydroascorbate, maintenance of reducing pools such as AsA, α-tocopherol, and anthocyanins, primary metabolism, and biochemical reactions of secondary products such as flavonoids (Dixon et al., 2011). In Brassica juncea plants under salt stress, GST activity increased by about 47 % in all 30, 60 and 90-day treatments (Ahmad et al., 2017). In another study with mustard, it was observed that the GST activity of $NaCl^-$ stressed plants increased by more than 88% (Ahmad et al., 2018). In a study investigating the role of antioxidant defence system and glyoxalase system in tomato plants under salt stress and recovery period, an experiment was established by treating 15-day-old tomato plants (Solanum lycopersicum L. cv. Pusa Ruby) grown hydroponically with 150 and 250 mM NaCl for 4 days. According to the enzyme activity results of the plant samples, APX activity increased significantly with salinity (250 mM NaCl) compared to the unstressed control condition, but this activity decreased after the recovery period. GR activity was slightly decreased under salt exposure compared to the unstressed condition, but increased after the recovery period. The thiol-dependent enzymes, GPX and GST, showed increased activity in response to NaCl stress compared to control, but both activities decreased after the recovery period (Parvin et al., 2019).

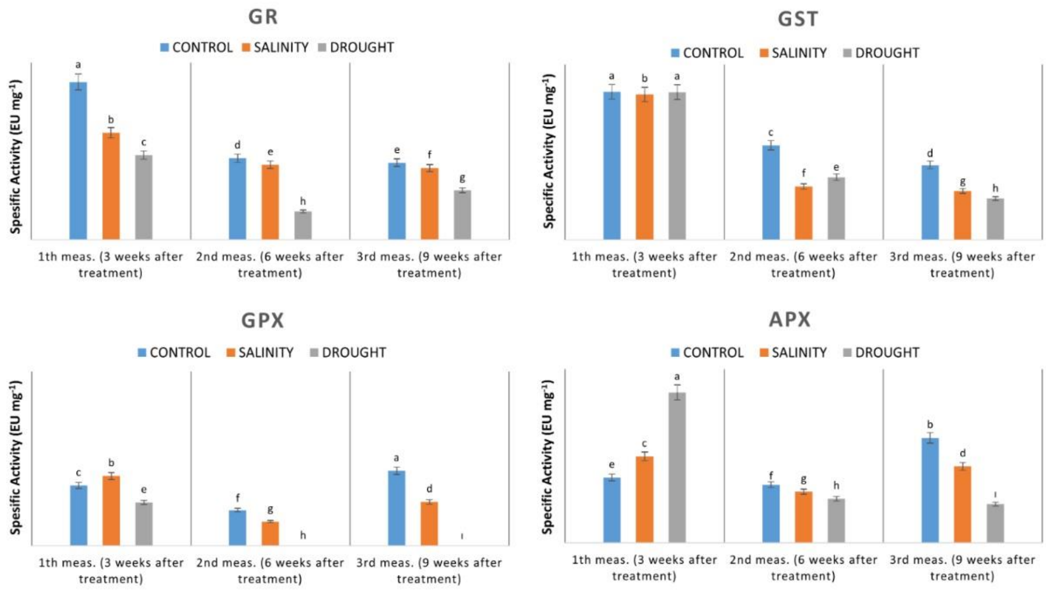

Figure 3. Activity results of GPx APx GST, GR antioxidant enzymes. Means ± SD. (n=3) means denoted by different letters indicate a significant difference among the treatments at a $p < 0.05$ level according to Duncan's test.

Şekil 3. GPx APx GST, GR antioksidan enzimlerinin aktivite sonuçları. Ortalamalar ± SD. (n=3) farklı harflerle gösterilen ortalamalar, Duncan testine göre p < 0.05 düzeyinde uygulamalar arasında anlamlı bir fark olduğunu göstermektedir.

The average specific activity of GPX enzyme in laurel plants in the treatments was 29.43 (EU mg^{-1}) in the control group, 23.73 (EU mg^{-1}) in the salinity group, and 7.5 (EU mg^{-1}) in the drought group. The specific activity decreased by 19.36% in the salinity treatment compared to the control, while this rate diminished by 74.51% in the drought treatment. According to the results of these measurements, drought's effect on GPX enzyme activity in laurel plants was significantly higher than salinity. The results of the first measurement of GPX enzyme showed that the specific activity increased by 15.84% in the salt stress condition compared to the control group and decreased by 28.09% in the drought group. In addition, the specific activity in the drought group plants decreased by 37.93% more than the salinity stress-treated plants. After 6 weeks, it decreased by 32.30% in the salt stress group compared to the control. Specific activities decreased by 99.40% in the drought stress compared to the control group. In addition, specific activity decreased by 99.11% more in the drought group than in the salt stress group. According to the data obtained 9^{th} weeks, the specific activity decreased by 41.47% in the salt stress group compared to the control group, and this rate was determined as 99.89% in the drought group. GPX is primarily involved in the removal of hydrogen peroxide by oxidizing aromatic electron donors such as guaiacol and pyrogallol (Schuller et al., 1996). In a study on salt stress in two maize genotypes, it was reported that APX activity was significantly increased in the leaves of both genotypes as a result of salt stress. However, it was unaffected in the roots of BR5033 (salt tolerant), while it decreased slightly, albeit significantly, in the roots of BR5011 (salt sensitive). In BR5033 plants under salt stress, APX and GPX activities in leaves increased by about 137% and 58%, respectively, after the tenth day of stress compared to control plants. Salinity also increased APX and GPX activities in the leaves of BR5011, but these increases were lower than those observed in BR5033. On the other hand, salt stress decreased APX and GPX activities in the roots of BR5011 by about 29% and 55%, respectively, while these enzyme activities were not affected in the roots of BR5033 (de Azevedo et al., 2006). POD activity increased by about 60% in Brassica chinensis plants exposed to NaCl stress (Ren et al., 2020). In a study conducted on two types of clover plants, specifically Xinmu No. 1 (stress-tolerant) and Northstar (stress-sensitive), it was observed that peroxidase (GPX) activity was higher in the roots than in the shoots for both varieties under normal conditions. However, upon treatment with 200 mM NaCl, a significant reduction (approximately 50%) in GPX activity was noted in the roots of Northstar when compared to control conditions. In contrast, Xinmu No. 1 exhibited a GPX activity level that was approximately 1.96 times higher than that of Northstar, indicating only a marginal decrease (Wang et al., 2009).

The mean specific activity of the APX was 8.78 (EU mg^{-1}) in control group, 8.23 (EU mg^{-1}) in the salinity stress group, and 8.96 (EU mg^{-1}) in the drought stress group. The specific activity value for the APX enzyme decreased by 6% in the salinity treatment compared to the control, while this rate increased by 2% in the drought treatment. In addition, the rate of decrease in the first period of the application was determined as 40.82% in salinity stress compared to the control group, while it was determined as 70.58% in the drought stress group. According to these measurements, drought's effect on APX activity in the laurel plant was significantly higher than salinity in the first period. According to the results of the first measurement of APX enzyme, the specific activity increased by 32.22% in the plant groups exposed to salt stress compared to the control group and decreased by 129.97% in the drought group. In addition, the specific activity in the drought group plants increased by 73.92% compared to the salinity group. After 6 weeks, it reduced by 11.80% in the salt stress group compared to the control group. Specific activities in the drought stress group decreased by 23.76% compared to the control group. Moreover, the specific activity in the drought group plants decreased by 13.55% more than salt stress. The measurements taken 9th weeks showed that the specific activity decreased by 27.22% in the salt-stressed plants compared to the control group, and this rate was 63.20% in the drought group. As one of the main components of the AsA-GSH cycle, ascorbate peroxidase, which plays one of the main roles in controlling intracellular ROS levels, is considered one of the most important enzymes in protecting cells from oxidative stress (Kumar et al., 2018). Antioxidant activity and stress tolerance were studied in tobacco plants exposed to NaCl stress; it was found that APX activity in the leaves decreased by about 29% as a result of NaCl treatment compared to the control (Che et al., 2022). In Lolium perenne, NaCl stress caused a decrease in APX activity (Wu et al., 2017). In rice seedlings, NaCl stress caused a significant decrease in APX activity in the aerial part (Mekawy et al., 2018). In maize plants grown with different NaCl concentrations, it was found that APX activity decreased significantly as a result of salt stress (Gong et al., 2011), and it was concluded that the oxidative attack caused by the applied stress may have significantly weakened the plants antioxidant defense system. The results of this study are consistent with the results reported by Nalina et al. (2021) showing that GR and APX activities in Tea (*Camellia sinensis* (L) O. Kuntze) decreased under drought stress in the two plant genotypes they used in the study. In the present study, the salinity of irrigation water led to an increase in APX activity in the aerial parts of laurel plants. In view of the results, it can be said that the APX enzyme played one of the major roles in the elimination of hydrogen peroxide under salt stress conditions and is one of the important catalysts of the AsA-GSH cycle. Salinity can disturb the balance between antioxidant enzymes and reactive free radicals, and oxidative stress that occurs in parallel with the increase in salinity can weaken the antioxidant system by producing deleterious effects (Foyer and Noctor, 2003). The study clearly demonstrates that drought stress has a significant impact on Medicago sativa L. The results indicate that when treated with 200 mM NaCl, APX activity in shoots and roots of alfalfa plants of the two cultivars used increased significantly. These findings provide strong evidence for the impact of drought stress on alfalfa plants and highlight the importance of stress-tolerant cultivars in mitigating the effects of drought. It is noteworthy that Xinmu No. 1, which is stress-tolerant, exhibited higher APX activity in shoots and roots compared to Northstar, which is stress-sensitive (1.59-fold and 1.48-fold increase, respectively) (Wang et al., 2009). In the present study, the salinity of the irrigation water and the drought stress to which the laurel plants were subjected caused a decrease in APX activity. Given these results, it can be said that the APX enzyme does not play a significant role in the eliminating hydrogen peroxide under salinity and drought conditions and is not one of the critical catalysts of the AsA-GSH cycle.

CONCLUSION

In this study, the effects of salinity and drought stresses on photosynthetic parameters and antioxidant enzyme activities in laurel (*Laurus nobilis L.*) plants were investigated. Overall, present findings showed that salinity and drought stress had a negative effect on chlorophyll content, stomatal conductance and antioxidant enzyme activities in laurel plants. Drought stress inhibited photosynthesis more than salt stress due to decreased chlorophyll content and stomatal conductance. Antioxidant enzyme activity levels were less tolerant to drought stress compared to salinity stress. Considering the increase in saline and drought areas due to global warming and changes in precipitation regime, it will be possible to better determine the potential value of the laurel plant in terms of the producing of high-yielding and economically important plants. Detailed determination of the effects of salinity and drought stress on laurel may be a new research source for breeders and plant scientists by helping to develop genetically modified resistant plants against these stress factors.

CONFLICT OF INTEREST

The authors declare no conflicts of interest concerning this article's research, authorship, and/or publication.

DECLARATION OF AUTHOR CONTRIBUTION

D.E. and H.A. designed the study; M.Y carried out the experiments; M.Y., D.E. and H.A. analyzed the data, wrote and revised the manuscript. All authors read and approved the final manuscript.

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Research Article

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A Study on Morphological and Agronomic Traits of Sainfoin Populations (*Onobrychis sativa* Scop.) in Semi-Arid Conditions

Yarı Kurak Koşullarda Korunga Genotiplerinin (*Onobrychis sativa* Scop.) Morfolojik ve Agronomik Özellikleri Üzerine Bir Araştırma

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Abstract: Plant species belonging to the leguminous family are very important for the quality and quantity of rangelands in semiarid regions. New varieties should be developed from the delicious, long-lasting, and high-quality plant species in this family for our rangelands that have rapidly deteriorated due to mismanagement. For this reason, sainfoin breeding study was initiated to develop new cultivars. In the first period, the seven collected sainfoin populations from the rangeland areas of the Central and Eastern Anatolia Regions were planted with control cultivars, Özerbey-03 and Lütfibey, in a nursery plot at the research station located in the Gölbaşı district of Ankara in 2015. At the initiating period of this breeding study (in 2016 and 2017), morphological (plant height, stem diameter, and stem number) and agronomic traits (fresh forage and dry forage yields) were determined. According to the obtained results, The L-1787 had the highest values in plant height, fresh forage, and dry forage yields of all populations. Moreover, among all populations, L-1747 had the lowest fresh forage and dry forage yield. The L-1781 had the highest stem number, while Lütfibey had the lowest. The Özerbey-03 and L-1781 had the thickest stems. L-1781, L-1787 anwd L-1788 populations exhibited higher fresh and dry feed yield due to higher stem number and larger stem diameter compared to control varieties. These populations can also be utilized for future breeding studies to develop new cultivars. Additionally, the methods of Cluster Analysis and Principal Component Analysis were used to identify similar traits and their similarity levels.

Keywords: Sainfoin populations, morphological traits, agronomic traits, cluster analysis, principal component analysis

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Öz: Baklagiller familyasına ait bitki türleri, yarı kurak bölgelerdeki meraların kalitesi ve miktarı için çok önemlidir. Yanlış yönetim nedeniyle hızla bozulan meralarımız için bu familyada yer alan lezzetli, uzun ömürlü ve kaliteli bitki türlerinden yeni çeşitler geliştirilmelidir. Bu doğrultuda yeni çeşitlerin geliştirilmesi amacıyla korunga ıslah çalışması başlatılmıştır. Bu amacı gerçekleştirmek için korunga ıslah çalışması yeni çeşitlerin geliştirilmesi amacıyla başlatılmıştır. İlk aşamada, Orta ve Doğu Anadolu Bölgelerinin mera alanlarından toplanan yedi korunga populasyonu, 2015 yılında Ankara'nın Gölbaşı ilçesinde bulunan araştırma istasyonunda tesis edilen bir gözlem bahçesinde kontrol çeşitleri olan Özerbey-03 ve Lütfibey ile birlikte ekilmiştir. Projenin ikinci ve üçüncü yılarında (2016 ve 2017), morfolojik (bitki boyu, sap kalınlığı ve sap sayısı) ve agronomik özellikler (yeşil ot ve kuru ot verimleri) tespit edilmiştir. Elde edilen sonuçlara göre, L-1787 tüm populasyonlar arasında bitki boyu, yeşil ot ve kuru ot verimi bakımından en yüksek değerlere sahip olmuştur. Ayrıca, tüm popülasyonlar arasında L-1747 en düşük yeşil ot ve kuru ot verimine sahip olmuştur. L-1781 en yüksek sap sayısına sahipken, Lütfibey en düşük sap sayısına sahiptir. Özerbey-03 ve L-1781 en kalın sapa sahip olmuştur. L-1781, L-1787 ve L-1788 populasyonları, kontrol çeşitleriyle karşılaştırıldığında, daha fazla sap sayısı ve daha geniş sap çapı nedeniyle daha yüksek yeşil ve kuru ot verimi sergilemiştir. Bu populasyonlar, yeni çeşitlerin geliştirilmesi için gelecekte yapılacak ıslah çalışmalarında da kullanılabilir. Ayrıca benzer özelliklerin ve benzerlik düzeylerinin belirlenmesi amacıyla Kümeleme Analizi ve Temel Bileşenler Analizi yöntemleri kullanılmıştır.

Anahtar Kelimeler: Korunga populasyonu, morfolojik özellikler, agronomik özellikler, kümeleme analizi, temel bileşenler analizi

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INTRODUCTION

Sainfoin (*Onobrychis sativa* Scop.) is one of the most significant forage legumes, and farmers respect it for its great palatability, nutritional content, and non-bloating characteristics (Delgado et al., 2008; Tan and Sancak, 2009; Gea et al., 2011; Özkan and Bilgen, 2019; Açıkgöz, 2021). Sainfoin has been cultivated for hay in many regions of the world including Asia, Europe and North America for hundreds of years (Frame et al., 1998; Bhattarai et al. 2016; Açıkgöz, 2021). Sainfoin, also known as holy clover, is a perennial forage legume with deep roots that is frequently grown alongside forage grasses to lessen the risk of bloat and to increase soil fertility as a result of its capacity to fix nitrogen (Lu et al., 2000; Tan and Sancak, 2009; Bhattarai et al., 2016; Özkan and Bilgen, 2019; Açıkgöz, 2021). The dry forage yield of sainfoin ranges between 2.5 and 10 ton ha-1 depending on ecological, climatic, and soil conditions (Açıkgöz, 2021; Çaçan et al., 2023). For the first cut, traditional harvesting of sainfoin is typically done between the bud and mid-flowering stages, producing about 70% of the annual yield (Mohajer et al., 2013; Açıkgöz, 2021). The sainfoin plant is one of the most important forage crops in Türkiye, as it grows in semiarid conditions and can be used in rangeland improvement and artificial pasture establishment (Anonymous, 2023a). For this reason, there is a need for registered sainfoin cultivars that can be planted as a mixture and alone. In Türkiye, 10 sainfoin cultivars have been registered (Anonymous, 2023b). By making use of our rich genetic resources, it will be possible to develop new varieties suitable for the arid conditions of the region and present them to production, thus contributing to more economical and sustainable livestock breeding. Agriculture and plant breeding are undergoing a revolution in response to calls for the development of more diverse, sustainable, agricultural systems. A key part of this is plant breeding, the improvement of existing crops and development of new ones that provide agronomic products and critical ecosystem services (Butkutė al., 2018; Schlautman et al., 2018). Breeding forage crops have some problems, such as being used for many different purposes, being perennial, weak seedling development, and taking a long time to develop cultivars (Sabancı and Tosun, 2009; Tan and Serin, 2009). Plant genetic resources serve as crucial sources of genetic variation that are essential for augmenting the nutritive value, yield potential, and resilience of crop species through artificial selection (Schlautman et al., 2018). For each species, breeding populations need to be developed and selected to find genetic variation in important breeding traits and assess how the trait responds to selection (Miller and Hanna, 1995; Schlautman et al., 2018). Phenotypic selection involves identifying genetic variations for traits of interest and combining them to make distinct populations and/or genotypes (Demir and Turgut, 1999; Tucak et al., 2014; Schlautman et al., 2018). Recently two institutions, The Land Institute in the US and Adana Alparslan Türkeş Science and Technology University in Türkiye, conducted similar sainfoin studies to select phenotypes for improved seed yields and quality (Karabulut et al., 2023). In the present sainfoin breeding program, the collected seven populations from rangelands were used in Central and Eastern Anatolia regions. During the first period of that program, new nursery plots were established to assess materials collected under rained conditions. Here, one plant was planted in each well-spaced pit, thus ensuring the best-growing conditions for each plant. Plants showing good growth characteristics were selected here. Then, these plants will be planted under competitive conditions, that is, in rows, more frequently, and their morphological characteristics and yield potentials will be determined. This process will be continued for several generations to increase the chances of success in developing new varieties (Robins and Jensen, 2020). At the beginning of breeding programs, in order to select the desired plants, it is important to understand the relationships and similarities between populations and traits. Therefore, we conducted a cluster analysis and principal component analysis. The objective of this research was to (1) evaluate the morphological and agronomic traits of sainfoin populations and (2) identify the high-yield populations in semiarid regions for future breeding studies.

MATERIAL AND METHOD

Seven sainfoin populations from our country's semi-arid climate were employed in the study, as well as two control cultivars, Özerbey-03 and Lütfibey (Table 1). This study was conducted at the Field Crops Central Research Institute's Gölbaş İkizce Research and Application Farm in 2015, 2016, and 2017.

Table 1. Information about the locations of collected population seeds.

Çizelge 1. Toplanan populasyon tohumlarının yerleri hakkında bilgi.

Number	Genotypes code	Taken institute / responsible institute	Province	Location	Altitute (m)
1	L-1745	Eastern Anatolia Agricultural Research	Ardahan	Ardahan	1750
2	L-1746	Eastern Anatolia Agricultural Research	Kars	Kars	1900
3	L-1747	Eastern Anatolia Agricultural Research	Erzurum	Erzurum-Güzelyayla village	2150
4	L-1781	Centre Agriculture Research for Field Crops	Sivas	Sarkisla, Demirkopru village	1380
5	L-1782	Centre Agriculture Research for Field Crops	Erzurum	Kombet village, Guzelyurt village	2010
6	L-1787	Centre Agriculture Research for Field Crops	Erzurum	Pasinler, Buyukdere village	1750
7	L-1788	Centre Agriculture Research for Field Crops	Aksaray	Gülağaç, Aşıklı höyük	1118
8	Özerbey-03	Centre Agriculture Research for Field Crops	-	Released for semiarid conditions	-
9	Lütfibey	Eastern Anatolia Agricultural Research	-	Released for semiarid conditions	-

Sainfoin populations and control cultivars were planted in pots in the spring of 2015, March, 23-27. When seedlings grew up to 5 cm, twenty-four plants from each population were transferred to the field as one plant per the digging hole at 70x70 cm distances in the date 2015, May, 4-8. The plants transferred to the field were watered for establishment purposes. After transferring, 18 kg ha-1 N, and 46 kg ha^{-1} P_2O_5 fertilisers were implemented in the soil and the soil was pressed with a roller of ploughing. If necessary, weed control was performed manually. Data was not collected in the year 2015 when the seeding took place. Data was collected on the morphological and agronomic traits from May 9 to May 12, 2016, and May 12 to May 15, 2017. As plants reached the 50% flowering period, plant height (PH, cm), stem diameter (SD, mm), stem number (SN, number), were determined in the nursery parcel during the years of 2016 and 2017 (Ünal and Eraç, 2000; Anonymous, 2019). Then plants were cut and weighted to determine fresh forage per plant (FFY, g $plant^{-1}$). After fresh forage was weighed, the plants were placed in the drying cabinet at 70°C for 48 h, and the dry forage weight was weighted to find dry forage yield per plant (DFY, g $plant^{-1}$) (Tekkanat and Soylu, 2005). In the research area, the soil texture is clayey-loam, the organic matter content is low at 1.31%, the phosphorus content is adequate at 94.7 kg ha^{-1}, the potassium content is high at 1498.6 kg ha^{-1}, and the soil is salt-free at 0.565 dS m^{-1}. However, the lime rate is excessively high at 31.31%, and the pH level is slightly alkaline at 7.70 (Anonymous, 2015). During the experimental seasons of 2016, and 2017, total precipitation, average temperatures, and average relative humidity were 537.2, 363.0 and 229.8 mm; 10.5, 10.6, and 9.9 °C; 63.8, 61.6, and 59.9% at Gölbaşı, Ankara, respectively (Anonymous, 2017) (Table 2). Long term average precipitation, temperatures, and relative humidity are 399.4 mm and 12.5 °C, and 59.2%

at Gölbaşı, Ankara, respectively. For long term on Gölbaşı location, average temperature was higher than those in trial years, but average relative humidity was lower than those in trial years. The annual precipitation amount was higher than in the trial years, except for the first year. During the experimental seasons of 2016, and 2017, total precipitation, average temperatures, and average relative humidity were 537.2, 363.0 and 229.8 mm; 10.5, 10.6, and 9.9 °C; 63.8, 61.6, and 59.9% at Gölbaşı, Ankara, respectively (Anonymous, 2017) (Table 2). Long term average precipitation, temperatures, and relative humidity are 399.4 mm and 12.5 °C, and 59.2% at Gölbaşı, Ankara, respectively. For long term on Gölbaşı location, average temperature was higher than those in trial years, but average relative humidity was lower than those in trial years. The annual precipitation amount was higher than in the trial years, except for the first year. Morphological and agronomic trait data of populations were evaluated by performing basic statistical analyses (mean, lowest and highest value, standard deviation, and coefficient of variation) in an Excel program in Microsoft Office 2016. Cluster Analysis (CA), and Principal Component Analysis (PCA) were performed study data set in JMP 2013 statistical program.

Table 2. Climatic data of the study area.
Çizelge 2. Çalışma alanının iklim verileri.

Months	Average temperature (°C)				Relative humidity (%)				Precipitation (mm)			
	2015	2016	2017	LT*	2015	2016	2017	LT	2015	2016	2017	LT
1	0.3	-1.3	-5.0	0.8	77.8	92.4	77.4	76.3	54.3	66.4	20.2	41.6
2	0.4	5.4	-0.3	2.5	70.4	83.3	70.1	70.2	39.0	18.6	5.4	36.3
3	4.7	5.7	5.2	6.7	66.3	76.5	62.1	61.8	92.1	67.0	31.4	42.5
4	6.9	12.0	8.1	11.7	53.1	54.0	54.4	58.4	25.0	12.0	16.0	49.7
5	14.6	13.0	13.0	16.4	61.4	60.9	56.9	54.5	67.2	59.0	27.6	46.7
6	16.3	19.0	17.3	20.9	65.8	50.0	57.6	48.7	133.7	7.2	25.2	29.4
7	21.6	22.1	22.6	24.6	39.1	41.6	41.8	42.8	5.1	1.8	0.4	9.8
8	22.4	22.5	21.9	24.6	43.9	47.7	48.8	43.2	25.4	27.2	26.0	10.8
9	21.3	16.1	19.8	19.3	48.6	49.5	40.0	49.2	29.1	42.3	30.4	23.3
10	12.8	11.3	9.8	13.1	78.8	54.9	57.4	61.0	58.5	7.7	9.8	36.0
11	7.1	4.6	4.7	7.3	69.9	56.2	73.7	69.3	5.6	19.6	11.2	31.8
12	-1.9	-2.9	2.0	2.6	90.6	72.4	78.6	75.3	2.2	34.2	26.2	42.1
Total / average	10.5	10.6	9.9	12.5	63.8	61.6	59.9	59.2	537.2	363.0	229.8	399.4

RESULTS AND DISCUSSION

Morphological Traits

The average, minimum, maximum, standard deviation and coefficient of variation values of plant height, stem diameter, and stem number of sainfoin populations are presented in Table 3. Moreover, in Figure 1, the morphological characteristics of the populations for the years 2016, and 2017, as well as two-year average values, are given in the graphs. When this table is evaluated, it can be seen that the variation in the number of stems (CV%=19.64) is quite wide among the traits considered. This gives us the opportunity to select populations having more stem numbers. In addition, populations are similar to each other in terms of other traits. When the sainfoin populations were evaluated in terms of plant height, the average was 70.5 cm. There was a difference between years and the second year had higher plant height than the first year. The L-1787 population had the tallest plant (Figure 1).

Table 3. Basic statistics in plant height, stem diameter and stem number of sainfoin populations.
Çizelge 3. Korunga genotiplerinin bitki boyu, sap çapı ve sap sayısına ilişkin temel istatistikler.

Basic statistics	Plant height (cm)			Stem diameter (mm)			Stem number (number)		
	2016	2017	Ave.	2016	2017	Ave.	2016	2017	Ave.
Average	65.8	75.1	70.5	5.6	5.5	5.6	29.1	53.8	41.5
Minimum	57.4	68.8	65.6	4.8	4.4	4.9	19.3	38.7	29.1
Maximum	73.7	83.6	77.7	6.6	6.4	6.3	40.6	72.0	56.3
Standard error	1.86	1.76	1.27	0.21	0.21	0.18	2.07	4.27	2.71
Variation coefficient (%)	8.51	7.06	5.41	11.38	11.80	9.81	21.35	23.81	19.64

The values of plant height in literatures were measured as follows: 30-90 cm (Davis, 1970); 81- 104 cm (Alibegoviç and Gatariç, 1989); 30-100 cm (Gülcan and Anlarsal, 1993); 105.2 cm (Karagöz, et al., 2001); 34–122 cm (Aygün et al., 2007); 12.25 – 107.28 cm (Balabanlı et al., 2007); 79.59 cm (Ünal et al., 2007). Moreover, some researchers found that the values of plant height were 61.14 cm (Tan and Sancak, 2009); 86.4cm (Erkovan et al., 2009); 70.23 -100.40 cm (Cebeci, 2011); 29 - 98 cm (Çeçen et al., 2015); 22.57-27.23 cm (İlgin, 2017). The present study data are higher than those of Tan and Sancak (2009) and İlgin (2017), but they are similar to other research data. The average stem diameter was 5.6 mm (Table 3). Özerbey and L-1781 had the thickest stem, while the stem of L-1747 and L-1746 populations was the thinnest (Figure 1). The stem's slender diameter is a favourable characteristic in terms of its quality. The stem diameter values in previous experiments were detected as follows: 6.6 mm (Karagöz et al., 2001); 4.53 mm (Ünal and Fırıncıoğlu, 2002); 4.0 mm (Albayrak and Ekiz, 2004); 3.13 mm (Ünal and Fırıncıoğlu, 2007). Furthermore, some authors stated that the stem diameter ranged from 6.0 to 9.1 mm (Ertuş et al., 2012); from 2.83 to 3.63 mm (İlgin, 2017); from 5.8 to 6.9 mm (Koç and Akdeniz, 2017). This study result was thicker than values of Ünal and Fırıncıoğlu, (2002); Albayrak and Ekiz, (2004); Ünal and Fırıncıoğlu, (2007), and İlgin, (2017). But it had lower than data of Karagöz et al. (2001), and Koç and Akdeniz (2017). The number of stems was measured as 41.5 on a two-year average. It is seen that there is a significant difference between years, and the value in the second year is higher. The rainfall in March 2016 was sufficient, but the fact that the temperature was above the average in April and the precipitation and relative humidity were below the average put stress on the plants. In this case, the plants were forced to develop rapidly and prevented normal development. The effect of this current situation was clearly negatively seen in the plant height and number of stems. Although precipitation was below average in March and April 2017, lower temperatures allowed plants to develop slowly and benefit more from existing moisture in the soil. These two factors had a positive impact on plant growth. As the Lütfi Bey cultivar had the lowest number of stems, population L-1781 had the highest number of stems, followed by population L-1787. This trait has a strong relationship with dry yield (Figure 1). Therefore, it's essential for yield. It is seen that it is correct to choose the number of stems with the highest variation among the traits examined, and it is appropriate to choose the populations with the highest number of stems. Bakoğlu et al. (1999); Ünal and Fırıncıoğlu., (2007); Balabanlı et al. (2007) reported that the number of stems was 19.74; 13.00; 15.77, and 0.00– 6.40, respectively. This study result was more stem number than values of previous trials. The reason for this is that since this study was carried out in the nursery plot, each plant has an area where it can grow comfortably and therefore has more moisture and nutrients. In addition, Cebeci (2011); Ertuş et al. (2012); Parlak et al. (2014); Koç and Akdeniz, (2017) counted stem numbers as follows 21.44-80.40; 8.70-28.80; 2.20-6.20; 15.00-18.00, respectively. According to Elçi et al. (1996), plants with a high number of stems are an essential selection factor in sainfoin breeding and are resistant to insects that harm the sainfoin. Higher stem number discovered in studies conducted in a variety of ecologies show that populations and environmental conditions have an impact on the number of stems (Delgado et al., 2008).

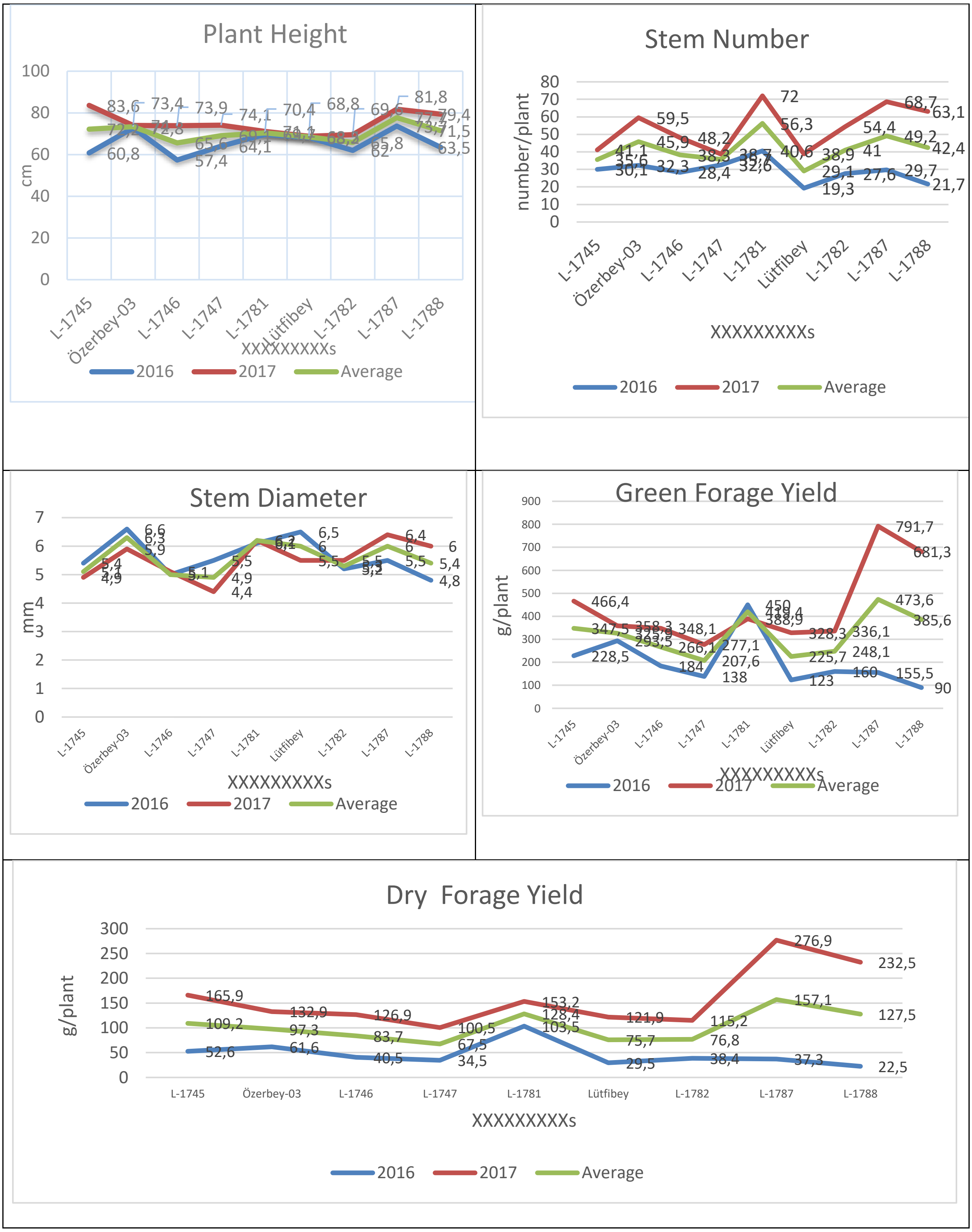

Figure 1. Values of morphological, and agronomic traits of the populations in 2016, 2017, and two-year average.
Şekil 1. Genotiplerin morfolojik ve tarımsal özelliklerinin 2016, 2017 yılı değerleri ve iki yıllık ortalama değerleri.

Agronomic Traits

The average, minimum, maximum, standard deviation and coefficient of variation values of fresh and dry forage yields belonging to the populations are given in Table 4. Furthermore, in Figure 1, the agricultural characteristics of the populations for the years 2016, and 2017, as well as two-year average values, are shown in the graphs. When this table is looked, it can be seen that the variation is similar in FFY and DFY. This gives us the chance to select populations with higher yields. When the sainfoin populations were evaluated in terms of fresh forage yield (FFY), the average was 322.2 g plant^{-1} (Table 4). A difference was observed between the years, with the second year showing a larger FFY than the first. In the previous section, it was explained that productivity in the first year was lower than in the second year due to stress conditions. In addition, in the second year, temperature increases were both slower and less in March and April. L-1787 exhibited the highest fresh forage yield of all the populations. The population L-1781 and L-1788 had the second and third turn for DFY, respectively as well as more than two cultivars. In previous researches, fresh forage yields were determined to be 87-170 g plant^{-1} (Ünal and Fırıncıoğlu, 2002); 94-297 g plant^{-1} (Ertuş et al., 2012) in literatures. The average dry forage yield was 102.6 g plant^{-1}, L-1747 and L-1787 had the lowest and highest dry forage yield (DFY), respectively (Table 4). L-1781 and L-1788 populations produced higher yields than the control cultivars and were ranked second and third for DFY. In earlier studies, dry forage yields were identified at 94.9 g plant^{-1} (Karagöz et al., 2001); 29.5-79.5 g plant^{-1} (Ertuş et al., 2012). The variability in yield is greatly influenced by environmental factors (Bato et al., 2021) as well as the genetic traits of the cultivars employed. Moreover, the high coefficient of variation in yield values shows that it is possible to choose productive cultivars.

Table 4. Basic statistical data in fresh and dry forage yields of sainfoin populations.
Çizelge 4. Korunga genotiplerinin yaş ve kuru ot verimlerine ilişkin temel istatistiksel veriler.

Basic statistics	Fresh forage yield (g plant^{-1})			Dry forage yield (g plant^{-1})		
	2018	**2019**	**Ave.**	**2018**	**2019**	**Ave.**
Average	202.5	441.8	322.2	46.7	158.4	102.6
Minimum	90.0	277.1	207.6	22.5	100.5	67.5
Maximum	450.0	791.7	473.6	103.5	276.9	157.1
Standard error	36.83	58.94	30.76	8.08	19.65	10.07
Variation coefficient (%)	54.58	40.02	28.64	51.94	37.21	29.46

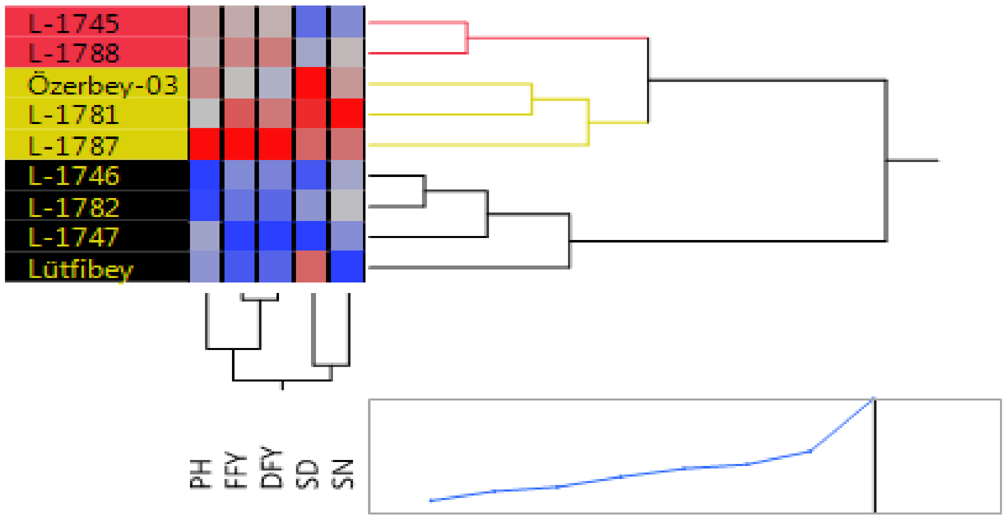

Figure 2. The results of cluster analysis of observed traits and XXXXXXXXXs.
Şekil 2. Gözlemlenen özelliklerin ve genotiplerin küme analizi sonuçları.

Principal Component Analysis (PCA)

The Principal Component Analysis (PCA) was conducted to examine the correlations between the traits measured and populations in the present study on the biplot graph, and to determine the percentage share of these traits and populations in the variation in the study data set (Figure 3). The analysis results of PCA related to the averages of measured traits and populations are illustrated in Figure 3. The two-year averages, namely PCA1 and PCA2, accounted for 72.2% and 13.9% of the total variation (86.1%), respectively. The traits PH, FFY, and DFY were in the same place (Group 1=G1) in the biplot graph due to their high level of similar correlation (Figure 3). Although the other two traits were close to the first group, they were settled down in separate places (Group 2=G2; Group 3=G3). Population L-1787 had the highest data in PH, FFY, and DFY traits. Özerbey and L-1781 had the thickest SD, while L-1746 and L-1747 had the thinnest SD trait (Figure 3).

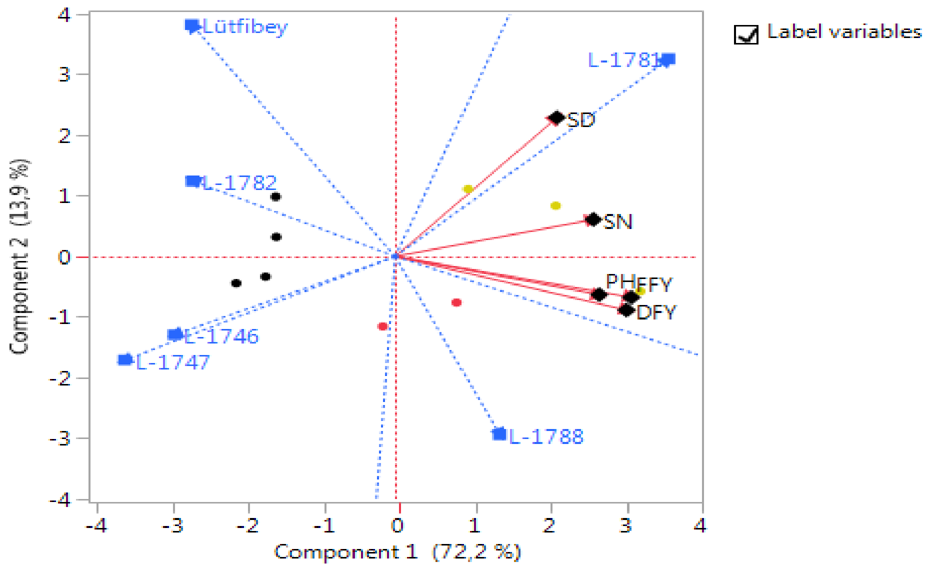

Figure 3. The results of principle component analysis of observed traits and populations.
Şekil 3. Gözlemlenen özelliklerin ve genotiplerin temel bileşen analizinin sonuçları.

CONCLUSIONS

In 2016 and 2017 of this breeding program, morphological traits such as plant height, stem diameter and number of stems, as well as agricultural traits such as fresh and dry forage yield, were determined. The plant height of L-1787 was the highest, while L-1746 and L-1782 had the lowest height. The L-1781 had the highest stem number, moreover, it was also the thickest with Özerbey-03. When the findings of this two-year study were analyzed, the L-1781, L-1787, and L-1788 populations produced the highest fresh and dry forage yields. Based on PH, FFY, and DFY, cluster analysis revealed that populations were split into two groups (A and B). Populations with high PH, FFY, and DFY were found in Group A. The observed attributes and populations according to the main component analysis were displayed in the biplot graph. The traits PH, FFY, and DFY were grouped together in Group 1 on the biplot graph due to their high correlation. Although the other two traits were close to the first group, they were situated in different locations. In this biplot graph, population L-1787 exhibited the highest plant height and the most significant yield of fresh and dry forage. As Özerbey and L-1781 had the thickest SD, L-1746 and L-1747 had the thinnest SD trait. When the results of this two-year study are evaluated, the L-1781, L-1787, and L-1788 populations with their superior performance compared to control varieties, are promising for the development of sainfoin cultivars. These populations should be tested in a variety of yield experiments, including micro-yield, yield, and regional studies.

CONFLICT OF INTEREST

There is no conflict of interest.

AUTHOR CONTRIBUTION

The corresponding author contributed to the field studies, taking observations, analysing the data and writing the article. The second author contributed to field studies, analysis and interpretation of data, and corrections in the article. The third and fourth authors contributed to field studies and observations.

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Research Article

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Vermicompost Treatment Boosts Root System Architecture in Lentil Under Low-Organic Matter Field Conditions*

Vermikompost Uygulaması Düşük Organik Maddeye Sahip Tarla Koşullarında Mercimekte Kök Sistem Mimarisini Geliştirir*

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Abstract: The Although the above-ground parts are important in most cultivated plants, all plants need to have a healthy and strong root system to appear healthy, meet their water and nutrient needs properly, and produce high yields and quality products. This study aims to monitor the effects of different vermicompost doses on the root system architecture of lentils under field conditions at periodic intervals. The study was conducted as a field trial at the Faculty of Agriculture of Siirt University during the 2018-19 season. Four different vermicompost doses were used in the study, and examinations were made on plant materials collected at three different periods. According to the research results, it was determined that root development significantly accelerated after 40-60 days from emergence. Lateral root formation increased by 119% from the 40th to the 60th day. The results denoted that vermicompost doses up to 10 t ha^{-1} promoted total root biomass and dry matter accumulation, however, higher than 5 t ha^{-1} inhibited lateral root formation and growth. As a result, the use of vermicompost in lentil production areas, not exceeding 5 tons per 5 hectares, has been identified as a sustainable and organic practice that positively affects root development and lateral root formation.

Keywords: Dry matter accumulation, lateral root, lens culinaris, organic manure, *Shavelomics*

&

Öz: Çoğu kültür bitkisinde önemli olan kısımlar toprak üstü aksamlar olsa da tüm bitkilerin sağlıklı görünmesi, su ve besin maddesi ihtiyaçlarını düzgün bir şekilde karşılaması, yüksek verim ve kaliteli ürün oluşturması için sağlıklı ve güçlü bir kök sistemine sahip olması gerekmektedir. Bu çalışmanın amacı farklı vermikompost dozlarının tarla koşullarında uygulanmasına bağlı olarak mercimekte kök sistem mimarisi üzerine etkilerini periyodik aralıklarla takip etmektir. Çalışma 2018-19 sezonunda Siirt Üniversitesi, Ziraat Fakültesinde tarla denemesi olarak gerçekleştirilmiştir. Çalışmada 4 farklı vermikompost dozu kullanılmış ve 3 farklı dönemde toplanan bitkisel materyaller üzerinde incelemeler yapılmıştır. Araştırma sonuçlarına göre, kök gelişiminin çıkıştan 40-60 gün sonra önemli ölçüde ivme kazandığı belirlenmiştir. Öyle ki, lateral kök oluşumu 40. günden 60. güne kadar %119 oranında artış göstermiştir. Sonuçlar, hektar başına 10 ton vermikompost dozuna kadar olan miktarların toplam kök biyo-kütlesini ve kuru madde birikimini teşvik ettiğini ancak hektar başına 5 tonu aşan miktarların yan kök oluşumunu ve büyümesini engellediğini gösterdi. Sonuç olarak, mercimek üretim alanlarında, hektar başına 5 tonu aşmayacak şekilde vermikompost kullanımı, kök gelişimini ve yan kök oluşumunu olumlu yönde etkileyen sürdürülebilir ve organik bir uygulama olarak belirlenmiştir.

Anahtar Kelimeler: Kuru madde birikimi, lateral kök, *Lens culinaris*, organik gübre, shavelomics

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INTRODUCTION

This lentil (*Lens culinaris* Medikus) is a vital pulse crop grown in all but a few regions of the World for human and animal nutrition. Its grain and straw are rich in protein, starch, dietary fiber, and some micronutrients such as Zn, Fe, and β-carotene but low in sodium and fat (Li and Ganjyal, 2017). Due to its effects on soil chemical composition and microbial population, lentil is an important part of rotation systems with cereals that contribute to sustainable agriculture (Erskine et al., 2018). According to Statpup data, 5.4 million tons of lentils were produced on 5.2 million hectares worldwide in 2023-24. Red and green lentils account for 85.5% and 14.5% of the lentil-cultivated areas, respectively. According to FAO (2023), Canada ranks first with 1.606 million tons, followed by India with 1.490 million tons. Türkiye cultivated 290 thousand hectares and produced 400 thousand tons of lentils.

The most important factors for high grain yield and quality are genotype selection, protection against pathogens, and supplying nutrition requirements. On the other hand, researchers indicate that morphological characteristics are directly correlation in yield attributes in grain legumes (Özaktan et al., 2022, 2023). The early vegetative stage has a vital role in adaptability, growth and yield components in lentil due to restriction by various stress factors such as salinity, drought, chilling and waterlogging (Erman et al., 2021). Legumes require a starter nitrogen application to begin symbiotic nitrogen fixation (Huang et al., 2016) and phosphorus addition for effective root growth (Singh and Singh, 2016). However, excessive chemical fertilizers have threatened human and animal health, microorganisms, soil quality, and the environment (Nayana and Ritu, 2017). Vermicompost, which is a next-generation and environment-friendly organic material, stands out as an important source to prevent the harmful effects of chemical fertilizers and to meet the nutrient requirements that the plant needs during growth and development (Ceritoglu et al., 2018).

Vermicompost or vermicast is rich in antioxidants, nutrition, vitamins, humic substances, and various phyto-hormones. It is superior compared to other organic materials such as farm manure, green manure produced by various plant materials and poultry manure (Tognetti et al., 2013). Moreover, vermicompost contributes to forming an effective root system (Blouin et al., 2019) and rich rhizosphere by improving soil microbial activity and productivity (Dominguez et al., 2019). It was demonstrated that different fractions of vermicompost positively affect the rhizosphere root characteristics, nodulation and mycorrhizal population (Jing et al., 2017; Maji et al., 2017).

The first step in optimum plant growth depends on the constitution of an effective root system. All root traits of plants, described as root system architecture (RSA), determine water and nutrition uptake efficiency, tolerance to stress factors, and growth regime of plants (Saleem et al., 2018). Various techniques have been used to investigate such as plexiglass plate method (Hohn and Bektas, 2020), hydroponic systems (Qiao et al., 2018), cylindrical container technique (Açıkbaş et al., 2021) and shovelomics (Burridge et al., 2016). Although the other methods have some advantages such as non-destructive and easy screening of the RSA, easy root development observation, time-saving processing, easy repeatability and no need for any root washing, the shovelomics technique enables to investigation of root characteristics in natural habitats and more clearly understand of their responses (Trachsel et al., 2011). Shovelomics is a method in which plants are excavated by a shovel under field conditions. Then, roots are carefully washed, scanned by a scanner and analyzed by image analysis software (Ceritoglu et al., 2020)

Although researchers have examined the effects of vermicompost applications on lentil growth, yield, and quality under laboratory (Ceritoglu et al., 2021) and field conditions (Ceritoglu and Erman, 2020), investigating the impact of vermicompost application on the root system architecture of lentils under field conditions highlights the uniqueness of this study. Additionally, periodic sampling based on different doses of vermicompost applications and the examination of results increases the study's importance in monitoring vermicompost effectiveness. This study aimed to research some root characteristics and observe periodic alterations in RSA using the shovelomics method under low organic matter field conditions.

MATERIAL AND METHOD

Experimental Materials

The *Lens culinaris* cv. Fırat 87 was used in the experiment. Fırat 87, registered in 2012 by GAP International Agricultural Research and Training Center, is a large-seed lentil and has high adaptation to the region (GAPUTAEM, 2019). It has been the most used cultivar in the region for many years and has high stability in terms of agronomic and yield traits. The vermicompost was obtained from a traditional company (Ekosol Tarım ve Hayvancılık A.Ş) and its chemical composition was summarized in Table 1.

Table 1. Some physico-chemical components of vermicompost used in the study.
Çizelge 1. *Çalışmada kullanılan vermikompostun bazı fiziko-kimyasal komponentleri.*

OM (%)	TN (%)	ON (%)	C/N	EC (dS m^{-1})	HA+FA (%)	MM (%)	pH	TP (%)	TK (%)
35	1.2	1.0	14	5.0	20	35	6.8	1.5	2.1

(OM: Organic matter, TN: Total nitrogen, ON: Organic nitrogen, C/N: Carbon/nitrogen ratio, EC: Electrical conductivity, HA: Humic acid, FA: Fulvic acid, MM: Maximum moisture, TP: Total phosphorus, TK: Total potassium)

Experimental Location

The experiment was conducted in the 2018-2019 growing season in the Siirt University, Türkiye. The city is located on 37° 57' N and 41° 51' E, Southeastern Anatolia Region of Türkiye. The altitude of the location is 585 m.

Experimental Soil and Climatological Characterization of the Region

Soil samples taken from A horizone were analyzed in the Central Laboratory of Siirt University. It was composed of medium-deep soil which is enough in potassium, low in organic matter and soluble phosphorus content, mild saline, and limy. The pH was light alkaline near neutral and the texture was clay loam. Characteristics of the experimental soil was given in Table 2.

Table 2. Some chemical properties of soil taken from the experiment area before sowing time.
Çizelge 2. *Ekim öncesinde deneme alanından alınan toprağın bazı kimyasal özellikleri.*

Depth (cm)	Texture	pH	EC (dS m^{-1})	Lime (%)	OM (%)	P_2O_5 (kg da^{-1})	K_2O (kg da^{-1})
0-20	Clay-loam	7.59	6.68	9.2	0.8	1.66	155

(OM: Organic matter)

The region exhibits characteristics of terrestrial climate. Temperature values of the vegetation period were nearly similar to the long years' average ranges. However, the rainfall during 2018-19 were erratic and higher compared with the long years average. Some climate data were given in Figure 1.

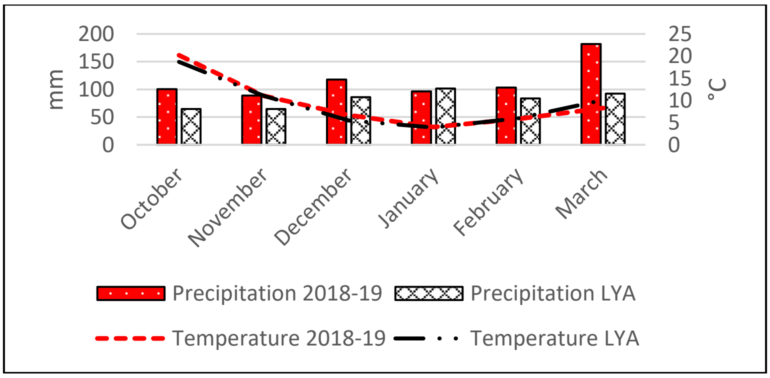

Figure 1. Climatological data of the experimental area during 2018-19 and long years average.
Şekil 1. *Deneme alanının 2018-19 süresince ve uzun yıllar ortalamasındaki klimatolojik veriler.*

Plant Material and Experimental Design

Each plot was formed from 5 rows. The row spacing and length were arranged as 25 cm (Kraska et al., 2020) and 5 m, respectively (1x5=5 m^2). The distances between plots and blocks were set as 1.5 m due to vermicompost application. So, vermicompost applied to each plot is aimed not to affect other plots. Also, 140 kg diammonium phosphate (DAP) ha^{-1} was applied as a starter dose with sowing under the seed drill (Dona et al. 2020). The 200 seeds m^{-2} per plot (Biçer, 2014) was sown on 15th December in dry conditions.

The study was conducted in a completely rendomized split-plot design with 5 replications. Three different times with 20 days intervals, i.e., 20, 40 and 60 days later emergence (DAE), and five doses of vermicompost (control, V1: 2.5 t ha^{-1}, V2: 5 t ha^{-1}, V3: 7.5 t ha^{-1}, and V4: 10 t ha^{-1}) were used in the experiment. Observation time and vermicompost treatment were placed in the main and sub-plots, respectively. Vermicompost materials were mixed into soil 30 days before sowing.

Weed control was done by mechanical methods 4 weeks after stand-establishment. Any herbicide or insecticide was used throughout the experimental process. The experiment was laid out under rainfed conditions.

Excavation of Plants, Image Analysis and Observations

The 10 samples were selected from each plot at each observation time and carefully excavated by shovel. Firstly, plants were gently shaken to remove coarse soil, and then they were labeled and placed in plastic bags. Plants were washed and removed adhered soil particles on roots. Then, plants were cut at root neck. Root fresh weight (RFW) was determined. Root samples were scanned on colored scale at 600 dpi resolution using a portable scanner (ISCAN, handheld scanner). Root images were analyzed using ImageJ image analysis software to evaluate the phenotypic variability of root architecture. Taproot length (TRL), number of lateral roots (NLR) and total lateral root length (TLRL) was determined with image analysis (Ceritoglu et al., 2020). After the phenotyping process, root samples were placed in an oven set to 68 °C for 3 days and root dry weight (RDW) was observed to determine dry matter accumulation.

Statistical Analysis

The normality of the data was tested using the Shapiro-Wilks (1965) normality test. The data showing normal distribution were subjected to statistical analysis (ANOVA) for the evaluation of significance within characteristics. Tukey's honestly significant difference test (Tukey's HSD) test was applied to calculate multiple comparison values using JMP (Pro 14) statistical analysis software.

RESULTS AND DISCUSSION

Results

Four vermicompost doses treated lentil plots under field conditions and alterations in RSA were periodically observed at three different times, i.e., 20, 40 and 60 DAE. Thus, the experiment provided the observation of root distribution under normal field conditions and also the determination of alterations with organic matter additions into soils. Analysis of variance indicated that observation time caused statistically significant differences ($p<0.01$) in all characteristics. The RDW, NLR and TLRL were significantly ($p<0.01$) affected by vermicompost doses but did not influence RFW and TRL. In addition, TxV interaction led to statistically significant differences in RDW and TLRL at $p<0.01$ and $p<0.05$, respectively (Table 3).

The study recorded that RFW increased in parallel with the developmental period, reaching its highest root weight at 60 DAE. The periods with the lowest (0.0786 g) and highest (0.2646 g) RFW values were determined to be 20 and 60 DAE, respectively. Similar results were observed for RDW as well. That is, the lowest (0.0290 g) and highest (0.0675 g) RDW values were detected at 20 and 60 DAE, respectively. It was observed that increasing vermicompost doses enhanced dry matter accumulation in the roots. Particularly, 7.5 and 10 tons ha^{-1} vermicompost doses significantly increased RDW, though they were statistically within the same group. Regarding the TxV interaction, RDW ranged from 0.0188 to 0.0882 g. The lowest and highest RDW were detected in plants without vermicompost on the 20th day and 10 t ha^{-1} of vermicompost on the 60th day, respectively (Table 4).

Table 3. Analysis of variance for data belong to different observation times and vermicompost levels.
Çizelge 3. *Farklı gözlem dönemleri ve vermikompost seviyelerine ait data için varyans analizi.*

Traits	Mean of square - F prob.		
	Time (T)	Vermicompost (V)	TxV
Root fresh weight	0.2163**	0.0023ns	0.0019ns
Root dry weight	0.0093**	0.0020**	0.00015**
Taproot length	388.4**	3.68ns	11.06ns
Number of lateral roots	691.3**	60.7**	9.1ns
Total lateral root length	21107.9**	798.8*	200.2*

Table 4. Root fresh weight and dry weight during growing period under different vermicompost levels.
Çizelge 4. *Farklı vermikompost seviyeleri altında farklı gelişme dönemlerinde kök yaş ve kuru ağırlıkları.*

Observation time	Vermicompost doses					
	Root Fresh Weight (g)					
	Control	V1	V2	V3	V4	Mean
20 DAE	0.0798	0.0913	0.0734	0.0751	0.0732	0.0786 C
40 DAE	0.1798	0.1595	0.1569	0.1870	0.1727	0.1712 B
60 DAE	0.2292	0.2809	0.2593	0.3100	0.2435	0.2646 A
Mean	0.1629	0.1772	0.1632	0.1907	0.1631	
	Root Dry Weight (g)					
20 DAE	0.0188 e	0.0301 de	0.0221 e	0.0390 d	0.0348 d	0.0290 C
40 DAE	0.0401 cd	0.0408 cd	0.0381 d	0.0606 b	0.0585 b	0.0476 B
60 DAE	0.0583 b	0.0571 b	0.0515 bc	0.0821 a	0.0882 a	0.0675 A
Mean	0.0392 B	0.0427 B	0.0372 B	0.0606 A	0.0605 A	

(DAE: Day after emergence, V1: 2.5 t ha^{-1}, V2: 5 t ha^{-1}, V3: 7.5 t ha^{-1}, and V4: t ha^{-1})

Table 5. Root characteristics during growing period under different vermicompost levels.
Çizelge 5. *Farklı vermikompost seviyeleri altında farklı gelişme dönemlerinde kök karakteristiği.*

Observation time	Vermicompost doses					
	Number of Lateral Roots					
	Control	V1	V2	V3	V4	Mean
20 DAE	5.4	6.8	11.0	9.4	6.2	7.8 B
40 DAE	7.4	10.0	9.2	7.8	6.6	8.2 B
60 DAE	13.6	18.4	20.8	17.8	14.8	17.1 A
Mean	8.8 B	11.7 AB	13.7 A	11.7 AB	9.2 B	
	Taproot Length (cm)					
20 DAE	9.3	9.1	9.4	8.3	9.5	9.1 B
40 DAE	8.8	7.0	10.1	8.8	9.8	9.9 B
60 DAE	13.7	17.0	14.4	18.2	15.5	15.8 A
Mean	10.6	11.1	11.3	11.7	11.8	
	Total Lateral Root Length (cm)					
20 DAE	8.5 d	13.2 d	26.7 b-d	15.8 d	8.4 d	14.5 C
40 DAE	21.4 cd	22.3 cd	28.6 b-d	25.3 b-d	26.4 b-d	24.8 B
60 DAE	52.6 a-c	74.6a	82.8a	78.1 a	57.8 ab	69.2 A
Mean	27.5 B	36.7 AB	46.0 A	39.7 AB	30.9 AB	

(DAE: Day after emergence, V1: 2.5 t ha^{-1}, V2: 5 t ha^{-1}, V3: 7.5 t ha^{-1}, and V4: 10 t ha^{-1})

According to the research results, NLR showed a significant increase particularly between 40-60 DAE. While the increase in NLR values was approximately 5% between 20-40 DAE, the increase rate was determined to be 119% between 40-60 DAE. When examining the effect of vermicompost addition on NRL, it was observed that the NLR increased up to a level of 5 t ha^{-1}, but then decreased with higher doses. Plants treated with 10 t ha^{-1} vermicompost were inhibited and fell into the same statistical group as the control plants. Effective root depth, or in other words, TRL, significantly varied only according to observation periods. The lowest (9.1 cm) and highest (15.8 cm) TRL were detected at 20 DAE and 60 DAE, respectively. Both the number of lateral roots on the taproot and the total length of secondary roots varied significantly according to observation times. The TLRL was determined to be 14.5 cm at 20 DAE and 69.2 cm at 60 DAE. Vermicompost applications had a similar effect on TLRL values as they did on NLR. The TLRL reached its maximum value (82.8 cm) at a level of 5 t ha^{-1}, but decreased to 30.9 cm with 10 t ha^{-1} vermicompost application. In the study, it was determined that TLRL values ranged from 8.5 to 82.8 cm depending on the TxV interaction, with the lowest and highest values detected at 20 DAE without vermicompost and at 60 DAE with 5 t ha^{-1} vermicompost application, respectively (Table 5).

DISCUSSION

Experiment results showed that root growth increased and lateral root formation was promoted depending on the development periods of the plants. It was determined that there was not much difference in the accumulation of dry matter in the plant and the factors forming the RSA between 20-40 DAE, but during the 60 DAE period, there was rapid development that led to significant differences (Table 4, 5). Erman et al. (2008) indicated that lentil has a slow growth rate during early growting stage. Because low temperature restricts vegetative growth especially at the early growth period (Öktem et al., 2008). Also, low temperatures especially the night period reduces physiological and metabolic activities, thereby, water and nutrient uptake, cell division, morphological growth are restricted (Khan et al., 2017). In addition, low temperatures lead to induce noteworthy changes in gene expression and lipid composition of biomembrane, thereby, many tropical or sub-tropical plants are damaged or killed at low temperatures which are lower than 10 °C (Niu and Xiang, 2018). During the experiment, the 40 DAE period corresponded to January, while the 60 DAE period, when the study was completed, corresponded to February. According to Figure 1, the average temperatures and rainfall showed a slight increase towards February. Additionally, it is believed that the growth rate increased because the developing plant roots were able to better utilize the water and nutrient elements in the soil.

Increasing vermicompost doses provided higher total biomass and dry matter accumulation in plants. On the other hand, vermicompost doses by 5 t ha^{-1} promoted lateral root formation and growth, however, higher doses inhibeted them. Sinha et al. (2010) reported that the application of vermicompost increased the total biomass of chickpeas (*Cicer arietinum*) and peas (*Pisum sativum*) by enhancing the number of primary and secondary branches. Vermicompost is a material rich in macro and micronutrients, hormones, vitamins, amino acids, some enzymes, antioxidants, humic substances, and organic matter (Arancon et al., 2004). Vermicompost, which acts as a slow-release fertilizer, not only provides the necessary nutrients for the plant but also significantly increases the amount of bacteria (PGPR) that promote plant growth in the root region (Benitez et al., 2005). Therefore, it is thought that it might contribute to the increase in root development by enhancing the density of bacterial species that aid in the formation of root nodules and the uptake of other plant nutrients. Additionally, different researchers have identified that the water retention capacity of soils with a lack of organic matter is reduced (Yılmaz and Alagöz, 2008; Blouin et al., 2019). Thus, it is estimated that the increased amount of organic matter in the soil towards the 60 DAE period prepares an environment where roots can develop comfortably, facilitating the uptake of water and nutrients by adhering to the organic material. Furthermore, it is known that humic and fulvic acid compounds present in vermicompost have positive effects on root and shoot development in plants, contributing to the dissolution of organic compounds in the root region and easing nutrient uptake (Bozoğlu et al., 2004; Öktem et al., 2017). Conversely, Rupani et al. (2018) investigated the effects of vermicompost applied at different doses on germination and seedling development. The study found that low doses of vermicompost had positive effects on germination and contributed to the formation of a more efficient root system in the early seedling stage. However, as the doses of vermicompost increased, the pH of the environment deteriorated, making nutrient uptake more difficult, and the negative effects of ion toxicity were observed. The findings of Rupani et al. (2018) support the results obtained from our research.

Similarly, Ceritoglu ve ark. (2021) demonstrated that although optimum doses of vermicompost had a stimulative effect on germination and seedling growth, higher doses restrict growth and development depending on genotypes in grain legumes.

CONCLUSION

The experiment focused on periodic sampling under different doses of vermicompost and alteration of root system architecture. The results denoted that vermicompost doses up to 10 t ha^{-1} promoted total root biomass and dry matter accumulation, however, higher than 5 t ha^{-1} inhibited lateral root formation and growth. Moreover, it was concluded that root development, which progresses relatively slower until 40 days after emergence, showed a significant increase in the 40-60 day period. As a result, the use of vermicompost in lentil production areas, not exceeding 5 tons per 5 hectares, has been identified as a sustainable and organic practice that positively affects root development and lateral root formation.

CONFLICT OF INTEREST

The author declares that there are no conflicts of interest.

DECLARATION OF AUTHOR CONTRIBUTION

The MC designed and laid out the experiment, collected data, subjected the statistical analysis and wrote Ms.Draft.

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Research Article

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The Impact of Mycorrhiza and Trichoderma Treatment on Malondialdehyde Levels and Antioxidant Activity in Common Beans under Drought Stress

Kuraklık Stresi Altındaki Fasulyelerde Mikoriza ve Trichoderma Tedavisinin Malondialdehit Düzeyleri ve Antioksidan Aktivitesi Üzerindeki Etkisi

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Abstract: As global temperatures rise and drought conditions become increasingly frequent, the need to develop sustainable agricultural practices has become paramount. Enhancing crop resilience to water scarcity is essential to secure food supplies for a growing global population. This study examined the effects of Arbuscular Mycorrhizal Fungi (AMF) and *Trichoderma harzianum* on the physiological responses and growth of common bean (*Phaseolus vulgaris*) under 100% and 50% irrigation regimes. Under a 50% irrigation regime, AMF and *Trichoderma harzianum* inoculation led to substantial increases in plant height (34.5%) and root length (16.79%), compared to the control. Additionally, significant enhancements were observed in chlorophyll a (175%), chlorophyll b (194%), and total chlorophyll (180%) content in plants subjected to *T. harzianum* inoculation under water deficit. The application of AMF resulted in an 18% increase in total carotenoid content, showing its efficacy in sustaining photosynthetic pigments. Furthermore, the study revealed that both treatments significantly reduced malondialdehyde (MDA) accumulation, with reductions of 46.3% compared to the control under drought conditions. Catalase (CAT), increased by 201% with *T. harzianum* application under full irrigation and by 217% with AMF under reduced irrigation, highlighting the role of these biostimulants in mitigating oxidative stress. Principal component analysis (PCA) further confirmed that these treatments effectively maintained cellular integrity and enhanced stress tolerance. These findings underscore the potential of AMF and *T. harzianum* as vital tools in enhancing crop resilience against drought, with significant implications for sustainable agriculture in arid and semi-arid regions.

Keywords: Drought tolerance, biostimulants, oxidative stress mitigation, AMF, global warming

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Öz: Küresel sıcaklıkların artması ve kuraklık koşullarının giderek daha sık hale gelmesiyle birlikte, sürdürülebilir tarım uygulamalarını geliştirme ihtiyacı her zamankinden daha önemLi hale gelmiştir. Su kıtlığına karşı bitki direncinin artırılması, artan dünya nüfusunun gıda tedarikini güvence altına almak için hayati bir öneme sahiptir. Bu çalışmada, Arbusküler Mikoriza Fungus (AMF) ve *Trichoderma harzianum*'un, fasulye (*Phaseolus vulgaris*) bitkisinin fizyolojik tepkileri ve büyümesi üzerindeki etkileri %100 ve %50 sulama rejimLeri altında incelenmiştir. %50 sulama rejimi altında, AMF ve *T. harzianum* inokülasyonu, kontrol grubuna kıyasla bitki boyunda %34.5, kök uzunluğunda ise %16.79 oranında önemLi artışlar sağlamıştır. Ayrıca, su kısıtı koşullarında *T. harzianum* uygulanan bitkilerde klorofil a (%175), klorofil b (%194) ve toplam klorofil (%180) içeriğinde belirgin artışlar gözlemLenmiştir. AMF uygulaması, toplam karotenoid içeriğinde %18'lik bir artış sağlayarak fotosentetik pigmentlerin sürdürülebilirliğini göstermiştir. Bunun yanı sıra, her iki uygulamanın da malondialdehit (MDA) birikimini önemLi ölçüde azalttığı, kuraklık koşullarında kontrol grubuna kıyasla %46.3 oranında azalma sağladığı tespit edilmiştir. Katalaz (CAT), tam sulama altında *T. harzianum* uygulamasıyla %201, azaltılmış sulama altında ise AMF ile %217 artış göstermiştir, bu da bu biyostimülanların oksidatif stresi hafifletmedeki rolünü vurgulamaktadır. Temel bileşen analizi (PCA), bu tedavilerin hücresel bütünlüğü etkili bir şekilde koruduğunu ve stres toleransını artırdığını doğrulamıştır. Bu bulgular, AMF ve *T. harzianum* nın, kuraklığa karşı bitki direncini artırmada hayati araçlar olarak potansiyelini, kurak ve yarı kurak bölgelerde sürdürülebilir tarım için önemLi sonuçlarla birlikte ortaya koymaktadır.

Anahtar Kelimeler: Kuraklığa tolerans, biyostimülanlar, oksidatif stres azaltma, AMF, küresel ısınma

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INTRODUCTION

Common beans (*Phaseolus vulgaris*), commonly called the "Poor Man's Meat" due to their high mineral, protein, and vitamin content, are a vital food source for over 300 million people worldwide (Blair et al., 2013; Yilmaz et al., 2023). According to the FAO, the global bean production area was 36.8 million hectares, with a production volume of 28.35 million tonnes in 2022 (FAO, 2024). A significant portion of this production occurs on lands with limited irrigation capabilities, leading to yield losses of up to 80% during unexpected drought periods (Rosales et al., 2012). Drought, resulting from extreme and rapid changes in climate conditions worldwide, is one of the most devastating abiotic stresses affecting plants during their growth and development stages. The frequency, severity, and duration of drought stress, along with the type of crop and agricultural region, amplify the extent of damage, posing a significant threat to global food security by reducing crop productivity (Khatun et al., 2021). In less developed and low-to-middle-income countries, more than 34% of plant and animal production losses are attributed to drought (FAO, 2021). The yield of major crops in drought-affected regions is projected to decrease by over 50% by the year 2050. (Malhi et al., 2021). Increasing droughts due to global climate change and conflicts from regional disputes led to 691 to 783 million people facing hunger worldwide in 2022 (WHO, 2023). The greatest challenge for agriculture in the coming years will be the sustainable production of sufficient food to meet the growing global demand (Agbodjato et al., 2022). Enhancing the drought tolerance of common bean is crucial for agricultural sustainability and food security (Yeken, 2023). To effectively address these challenges, it is paramount to develop plant varieties that are resistant to drought stress and to implement appropriate agricultural techniques. These strategies are essential for ensuring agricultural sustainability and securing global food supplies in the face of increasing environmental stressors.

In plants coping with drought stress, abscisic acid accumulates in the roots, while the flow of K+ ions from the leaves accelerates. This raises leaf temperature and speeds up transpiration, causing stomatal closure and reducing photosynthetic activity (Anjum et al., 2011; Farooq et al., 2012; Kaur and Asthir, 2017). Impaired water relations restrict shoot growth but enhance root growth (Claeys and Inzé, 2013). Drought stress impacts numerous cellular processes, including molecular and biochemical functions, signal perception, nutrient uptake, and photosynthesis (Wahab et al., 2022). It also affects hormone production, reducing growth and crop productivity (Prasad et al., 2011; Farooq et al., 2012). Drought stress induces cellular dehydration, leading to secondary stresses such as osmotic and oxidative stress (Yang et al., 2021). This condition results in increased production of reactive oxygen species (ROS) in cellular compartments like chloroplasts and mitochondria (Foyer and Hanke, 2022). Plants have developed various strategies to manage the increase in ROS, including ROS detoxification and the maintenance of cellular redox balance (Wahab et al., 2022). The detoxification mechanism involves an antioxidative defense system comprising both enzymatic and non-enzymatic components (Soares et al., 2019; Ilyas et al., 2021). Additionally, plants' adaptive strategies in response to drought stress include osmoregulation mechanisms, cellular water potential maintenance, and water use efficiency enhancement. These strategies are critical for improving plant survival and productivity (Gupta et al., 2020; Öztürk et al., 2021). Various approaches exist to combat drought, but recently, the use of biostimulants as a sustainable strategy has gained attention. Biostimulants have emerged as a significant solution in modern agriculture to enhance crop productivity under the pressures of increasing population and environmental degradation (Lephatsi et al., 2022). Among biostimulants, arbuscular mycorrhizal fungi (AMF) and *Trichoderma harzianum*, which support plant-root symbiosis and optimize nutrient uptake, are particularly noteworthy. AMF is primarily used as a biofertilizer capable of forming symbiotic interactions with approximately 90% of crop plants (Ferlian et al., 2018; Yilmaz et al., 2022). By colonizing plant roots, AMF enhances water and nutrient availability, soil health, and productivity, thereby increasing plant resilience to stress conditions (Wu and Zou, 2017; Yilmaz et al., 2023). Numerous studies have demonstrated AMF's beneficial effects, including improved plant growth, reduced drought damage, and rapid recovery once stress is alleviated (Abdel-Salam et al., 2018; Zhang et al., 2019; Begum et al., 2019; Mathur et al., 2019; Sheteiwy et al., 2021; Eshaghi Gorgi et al., 2022). Trichoderma's efficacy against drought stress involves mechanisms such as morphological adaptations to avoid drought, physiological and biochemical changes to develop drought tolerance, and enhanced post-drought recovery (Shukla et al., 2012; Kaur and Kumar, 2020; Boorboori and Zhang, 2023). Various studies have shown that *Trichoderma harzianum* enhances plant growth by increasing nutrient access through root colonization and elevating enzyme levels that reduce reactive oxygen species (ROS), thereby conferring stress resistance (Shukla et al., 2012; Mona et al., 2017; Khoshmanzar et al., 2020).

This study aims to investigate the effects of AMF and *Trichoderma harzianum* inoculation on a dwarf common bean variety under 50% water deficit conditions, focusing on plant growth parameters, chlorophyll a, chlorophyll b, total chlorophyll, carotenoids, malondialdehyde (MDA), and the activities of ascorbate peroxidase (APX), superoxide dismutase (SOD), and catalase (CAT) enzymes. This research is significant as it explores novel biostimulant applications to enhance drought tolerance in common beans, offering potential advancements in agricultural sustainability and resilience against environmental stressors.

MATERIAL AND METHOD

Plant Material

The dwarf common bean variety "Yunus 90," obtained from the Eskişehir Transitional Zone Agricultural Research Institute, was used as the plant material. The study was conducted in the research greenhouse of the Faculty of Agriculture at Bolu Abant İzzet Baysal University between April and June 2024.

AMF and Trichoderma Applications

For the mycorrhiza application, a powder form ERS (Endo Roots Soluble) package containing 9 different AMFs was obtained from Bioglobal®. The package contains 78.85 propagules gram^{-1} of mycorrhiza. The contents of the package include fungi: *Glomus intraradices* (25), *Glomus aggregatum* (24), *Glomus mosseae* (24), *Glomus clarum* (1), *Glomus monosporus* (1), *Glomus deserticola* (1), *Glomus brasilianum* (1), *Glomus etunicatum* (1), and *Gigaspora margarita* (1). The application was carried out as recommended by the company for 7500 seedlings/250 grams. Additionally, Trichoderma fungus, specifically *Trichoderma harzianum* Rifai KRL-AG2 strain T-22 Planter Box, was purchased from Bioglobal®. The powder mixture contains $4x10^8$ (400 million spores/g) fungi per gram. The application was performed as recommended by the company (7500 seedlings/50 grams). The AMF and *T. harzianum* were applied in powder form to the seedbed before planting. Before sowing, the seeds were surface-sterilized by immersing them in 1% sodium hypochlorite for 2 minutes and then rinsing them three times with sterile distilled water. The pots, each with a capacity of 1 kg, were filled with a mixture of 2/3 soil and 1/3 peat (Abant torf®). Three seeds were planted in each pot. Immediately after emergence, the seedlings were thinned to leave one plant per pot. The study was designed with 3 treatments (Control, AMF, *Trichoderma harzianum*) and 2 irrigation periods (100% Field Capacity (Full), 50% Field Capacity (Half). The experiment was conducted in a randomized plot design with three replications. To determine the field capacity, the soil was saturated with water and allowed to stand for 24 hours. The amount of water held by the soil particles against gravity was weighed to determine 100% field capacity (Özel et al., 2016). Depending on the air temperature, the pots were weighed every 2-3 days, and the amount of water lost was calculated and brought to the desired field capacity. The transition to 50% field capacity irrigation was gradually made after the common bean seedlings produced true leaves. The plants were harvested after a 5-week growing period. Leaf samples were immediately stored at -80°C until analysis.

Physical Analyses, Chlorophyll, and Carotenoid Contents

As a physical analysis, the stem and root lengths (cm) of each plant in the experiment were measured. Total chlorophyll, total carotenoid, chlorophyll a, and b were determined using the Arnon method (Arnon, 1949). 0.1 gram leaf sample was homogenized with 80% acetone. The absorbance of the final mixture was determined at wavelengths of 663, 645, and 470 nm using a UV-visible spectrophotometer. The concentration of chlorophyll (a, b, total) was expressed as mg/g fresh weight. The determination of chlorophyll a, b, and total was carried out using the formula by Arnon:

$$\text{Chlorophyll a (mg g}^{-1}\text{ F.W)} = (12.7\ A663\ 2.69\ A645) \times V / 1000 \times g \quad (1)$$

$$\text{Chlorophyll b (mg g}^{-1}\text{ F.W)} = (22.9\ A645 - 4.68\ A663) \times V / 1000 \times g \quad (2)$$

$$\text{Total chlorophyll (mg g}^{-1}\text{ F.W)} = (20.2\ A645 + 8.02\ A663) \times V / 1000 \times g \quad (3)$$

100 mg leaf sample was homogenized with 80% (v/v) acetone and filtered using filter paper. In the obtained extract, absorbance values were measured at 470 nm with a spectrophotometer to determine the carotenoid content.

$$\text{Carotenoid (mg g}^{1}\text{)} = [((1000 \times A470) - (2.27 \times Cla) - (81.4 \times Clb)) / 227] \times V / g \quad (4)$$

Here, V represents the volume of the extract, g represents the sample volume (mg), Cla represents chlorophyll-a, Clb represents chlorophyll-b, and A represents the absorbance at specific wavelengths.

Malondialdehyde (MDA) Analysis

Lipid peroxidation levels were determined by measuring the malondialdehyde (MDA) content, a product of lipid peroxidation. 500 mg plant sample was homogenized with 10 mL of 0.1% trichloroacetic acid (TCA). The mixture was centrifuged at 15,000 RPM. From the supernatant, 1 mL was taken, and 4 mL of the reaction mixture (20% TCA, 0.5% 2-thiobarbituric acid) was added. The mixture was incubated in a water bath at 95°C for 30 minutes. The rapidly cooled samples' absorbance was measured at 532 and 600 nm wavelengths (Sairam and Saxena, 2000; Canal et al., 2023).

Ascorbate Peroxidase (APX), Catalase (CAT), and Superoxide Dismutase (SOD) Analysis

The activity of ascorbate peroxidase (APX) was determined by measuring the change in absorbance at 290 nm. 200 mg sample was homogenized with 2 mL of extraction mixture (0.1 M sodium phosphate, 0.5 mM sodium EDTA, and 1 mM ascorbic acid). The mixture was then centrifuged at 15.000 RPM. To 2.8 mL of reaction mixture (50 mM sodium phosphate (pH:7), 0.5 mM ascorbic acid, 0.1 mM EDTA), 0.1 mL of sample extract was added. After adding 0.1 mL of 0.1 mM H_2O_2, the mixture was incubated for 60 minutes. The activity was calculated against an ascorbic acid standard, prepared by diluting 100 µM ascorbic acid (Yilmaz and Kulaz, 2019). Superoxide dismutase (SOD) enzyme activity was analyzed by measuring the inhibition of the photochemical reduction of nitroblue tetrazolium (NBT), according to the method proposed by Beauchamp and Fridovich (1971). 200 mg sample was homogenized with 2 mL of extraction mixture (0.1 M sodium phosphate and 0.5 mM sodium EDTA). The mixture was then centrifuged at 15.000 RPM. For SOD analysis, 0.1 mL of supernatant was taken, and 2.9 mL of reaction mixture (11.33 mM methionine, 75 µM nitroblue tetrazolium, 0.1 mM EDTA, 50 mM sodium phosphate (pH: 7.8), 50 mM sodium carbonate) and 0.1 mL of 2 mM riboflavin were added and vortexed. The tubes were then placed under light (75 mol m^{-2} s^{-1} (40 W)) for 15 minutes to start the reaction. Readings were taken at 560 nm. For catalase (CAT) analysis (EC 1.11.1.6), a reaction solution containing 0.036% hydrogen peroxide and 50 mM sodium phosphate (pH: 7) was prepared. 3 mL of the prepared reaction mixture was placed in a quartz cuvette and inserted into the spectrophotometer. Then, 100 microliters of the supernatant obtained from the SOD analysis extraction were added. Absorbance values were taken at 240 nm with a UV-visible spectrophotometer at 0 and 60 seconds (Beers and Sizer, 1952).

Statistical Analysis

The study was conducted in randomized plot designs consisting of three biological and three technical replicates for each treatment. The effects of water restriction AMF and Trichoderma inoculation were determined by performing a one-way analysis of variance (ANOVA). Differences between control and AMF and *T. harzianum* treatments were evaluated using LSD test. Correlation analysis was utilized to eliminate the intrinsic correlations of yield parameters and enzymes, and correlations were conducted only between yield characteristics and enzymes/chlorophyll for water restriction levels. Pearson's coefficient was used in the correlation analyses, and the data were visualized using the 'corplot' R package (Wei et al., 2017). The relationship between water-restricted AMF and *T. harzianum* applications and the examined characteristics was determined using principal component analysis (PCA) with the 'ggplot2' R package (Wickham, 2016).

RESULTS AND DISCUSSION

Growth Parameters

The study reveals that common bean subjected to a 50% irrigation regime exhibited significant reductions in both stem and root lengths compared to those under a 100% irrigation regime. Inoculation with AMF (Arbuscular Mycorrhizal Fungi) and *Trichoderma harzianum* significantly influenced plant height and root length in both irrigation treatments ($p \leq 0.05$, $p \leq 0.01$) (Figure 1; Table 1). Under 100% irrigation, plant height increased by 19.4%, from 21.50 cm to 25.67 cm, while under 50% irrigation, plant height rose by 34.5%, from 14.00 cm to 18.83 cm, compared to the control. Similarly, root length increased by 15.13%, from 46.33 cm to 53.34 cm, under 100% irrigation, and by 16.79%, from 39.67 cm to 46.33 cm, under 50% irrigation. Regarding the effects of inoculation, no significant difference in plant height and root length was observed between AMF and *T. harzianum* treatments under 100% irrigation. Under 50% irrigation, a statistically significant difference in plant height was observed between AMF and *T. harzianum* inoculations, whereas no significant difference was found in root length.

Table 1. Statistically significant differences of full irrigation, half irrigation regimes, mycorrhiza, and *T. harzianum* treatments.

Çizelge 1. Tam sulama, yarım sulama rejimleri, mikoriza ve T. harzianum tedavilerinin istatistiksel olarak anlamlı farklılıkları.

Trait	$F_{Half\ Irrigation}$	$F_{Full\ Irrigation}$	$F_{Irrigation*Treatment}$
Plant Height	28.30**	14.60**	0.28^{ns}
Root Lenght	11.26**	9.21*	1.49^{ns}
Chlorophyll a	64.77**	6.39*	13.48*
Chlorophyll b	51.39**	2.03^{ns}	13.45*
Total Chlorophyll	60.87**	4.97^{ns}	13.28*
Total Carotenoid	3.14^{ns}	56.11**	7.24*
MDA	16.62**	2.81^{ns}	2.71^{ns}
SOD	5.12*	13.71**	4.25*
CAT	25.11**	7.57*	10.20*
APX	20.19**	12.76**	0.89^{ns}

İndicate significant differences according to LSD test; ns: non-significant, * *($p \leq 0.05$)*, ** *($p \leq 0.01$)*

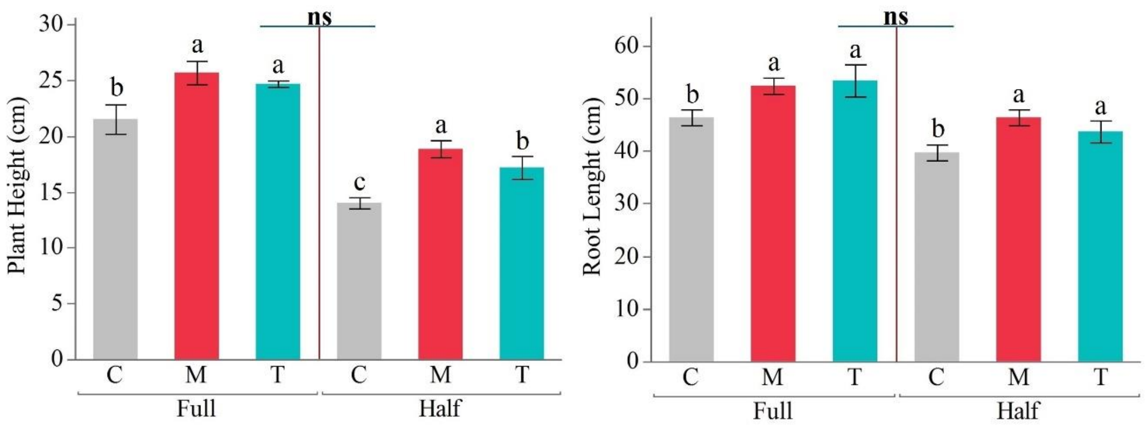

Figure 1. Effect of AMF (M) and *Trichoderma harzianum* (T) on plant height (cm) and root length (cm) of common bean under different irrigation regimes (100%-50%) conditions (C: Control, Different letters indicate significant differences according to LSD test, ns: not significant)

Şekil 1. Farkı sulama rejimi (%100-%50) koşullarında AMF (M) ve Trichoderma harzianum'un (T) fasulyenin bitki boyu (cm) ve kök uzunluğu (cm) üzerine etkisi (C: Kontrol, Farklı harfler LSD testine göre önemLi farklılıkları göstermektedir, ns: önemsiz)

The findings of this study are consistent with previous research indicating that water stress significantly impedes plant growth, affecting both stem and root development (Li et al., 2019; Pavithra and Yapa 2018; Begum et al., 2019; Mona et al., 2017; Bashyal et al., 2021). The enhanced growth observed in plants treated with AMF and *T. harzianum* can be attributed to the improved water and nutrient uptake facilitated by these microorganisms, as supported by similar studies (Poveda et al., 2019; Nanjundappa et al., 2019). Specifically, AMF have been shown to enhance root hydraulic conductivity and improve drought tolerance by maintaining higher water potential and photosynthetic rates (Abdalla et al., 2023; Abdalla and Ahmet, 2021). Similarly, Trichoderma spp. are known for their role in enhancing plant growth under stress conditions through mechanisms such as increased root growth, improved nutrient uptake, and induced systemic resistance (Gupta and Bar, 2020; Azad and Kaminskyj 2016). The significant increase in plant height and root length under 50% irrigation with microbial inoculation highlights the potential of AMF and *T. harzianum* as biostimulants to mitigate the adverse effects of drought stress. This is particularly important for sustainable agriculture in arid and semi-arid regions where water scarcity is a major challenge (Meddich et al., 2022).

Chlorophyll-a, Chlorophyll-b, Chlorophyll a/b, Total Chlorophyll and Total Carotenoid

In this study, under the 100% irrigation regime, chlorophyll a values ranged from 0.0027 to 0.0052 mg g^{-1} F.W., chlorophyll b values ranged from 0.0014 to 0.0023 mg g^{-1} F.W., total chlorophyll content ranged from 0.0042 to 0.0075 mg g^{-1} F.W., and total carotenoid content ranged from 275.88 to 495.35 mg g^{-1} F.W. (Figure 2; Table 1). Under the 50% irrigation regime, chlorophyll a values ranged from 0.004 to 0.011 mg g^{-1} F.W., chlorophyll b values ranged from 0.0017 to 0.0050 mg g^{-1} F.W., total chlorophyll content ranged from 0.0057 to 0.016 mg g^{-1} F.W., and total carotenoid content ranged from 344.32 to 426.84 mg g^{-1} F.W.

In common beans subjected to 100% irrigation, significant differences were observed in all parameters except for chlorophyll b (chlorophyll a, total chlorophyll, total carotenoid) at $p \leq 0.05$ *and* $p \leq 0.01$ (Table 1). The application of AMF significantly increased the chlorophyll a, total chlorophyll, and carotenoid contents of common bean compared to the control group, with increments of 92.6% for chlorophyll a, 78.6% for total chlorophyll content, and 79.2% for total carotenoid content. Although the increase for chlorophyll b was 64.3%, it was not statistically significant. Under 50% irrigation, common beans exhibited statistically significant differences at $p \leq 0.05$ in all parameters except for total carotenoid content (chlorophyll a, chlorophyll b, and total chlorophyll). In common beans subjected to 50% water restriction, *T. harzianum* inoculation significantly increased the contents of chlorophyll a, chlorophyll b, and total chlorophyll compared to the control group, with increments of 175% for chlorophyll a, 194% for chlorophyll b, and 180% for total chlorophyll. The most significant increase in total carotenoid content compared to the control was observed with AMF application (18%); however, no statistical difference was found among the treatments.

The results of this study highlight the significant impact of irrigation regimes on chlorophyll and carotenoid content in common bean, providing insights that align with and expand upon existing literature. Moderate to severe drought conditions reduce leaf number and area, diminishing the levels of key photosynthetic pigments, such as chlorophylls and carotenoids. This reduction ultimately disrupts plants' photosynthetic efficiency (Zhang et al., 2018; Mashabela et al., 2023; Spinoso-Castillo et al., 2023; El-Sawah et al., 2023). Chlorophyll degradation is enhanced by the increased expression of chlorophyll-degrading enzymes, while the biosynthesis of chlorophyll is reduced due to the downregulation of its associated enzymes, leading to a decrease in chlorophyll content (Ilyas et al., 2021; Saxena et al., 2022). Nevertheless, inoculating plants with Arbuscular Mycorrhizal Fungi (AMF) under drought conditions has been shown to mitigate these effects by enhancing chlorophyll levels (Shankar et al., 2024). In a study involving *Cicer arietinum*, it was observed that drought stress reduced chlorophyll a (Chl a), chlorophyll b (Chl b), and total chlorophyll content by 54.61%, 46.81%, and 39.84%, respectively. However, AMF inoculation significantly alleviated these reductions, resulting in increases of 60.08%, 40.87%, and 45.87% in Chl a, Chl b, and total chlorophyll content, respectively (Hashem et al., 2019). Similar observations were reported in *Zea mays, Triticum aestivum, Nicotiana tabacum, and Rosa damascena Mill.* (Hu et al., 2020; Begum et al., 2019; Mathur et al., 2019; Begum et al., 2020; Abdel-Salam et al., 2018).

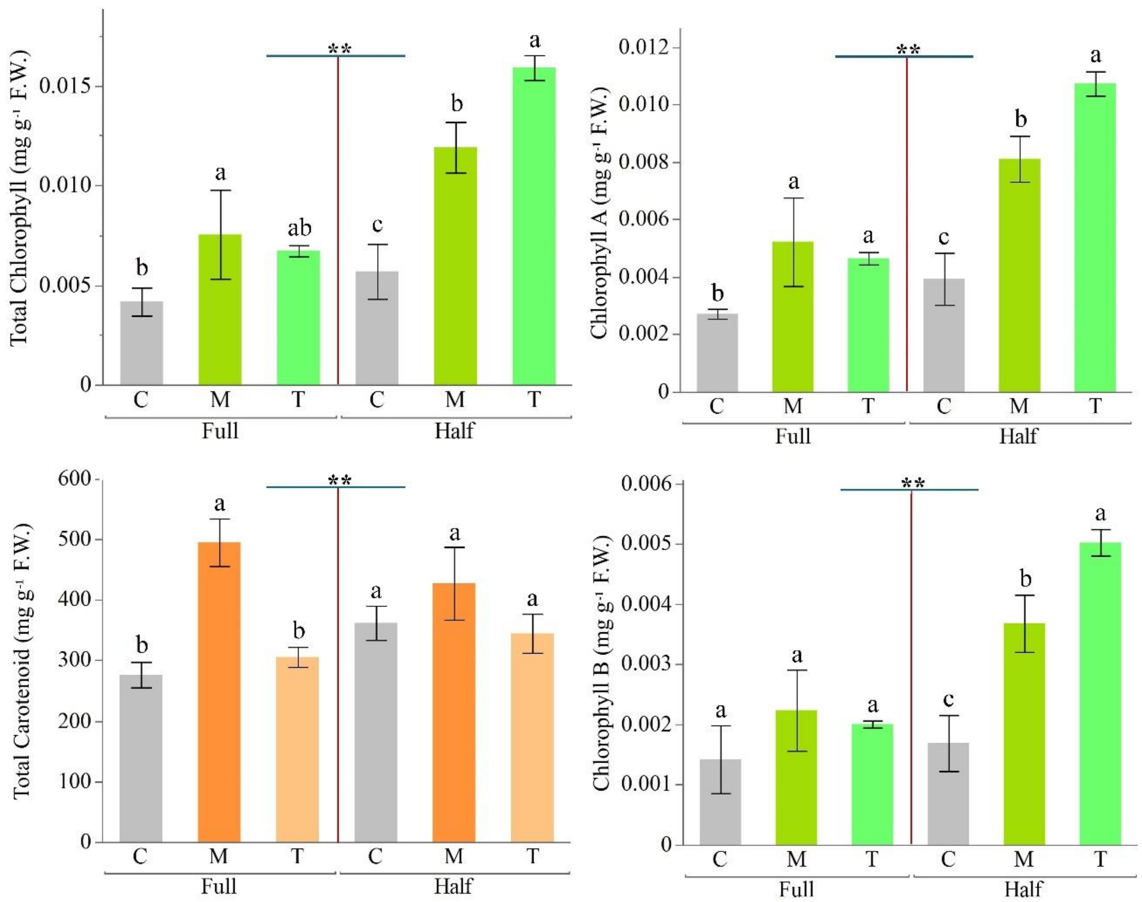

Figure 2. Effect of AMF (M) and *Trichoderma harzianum* (T) on chlorophyll a, b, total chlorophyll, and total carotenoid content of common bean under different irrigation regimes (100%-50%) conditions. (C: Control, Different letters top of the bars indicate significant differences according to LSD test, ** ($p \leq 0.01$).

*Şekil 2. AMF (M) ve Trichoderma harzianum'un (T) farklı sulama rejimLeri altında (%100-%50) fasulyenin klorofil a, b, toplam klorofil ve toplam karotenoid içeriğine etkisi. (C: Kontrol, Çubukların üstündeki farklı harfler LSD testine göre önemLi farklılıkları göstermektedir,,** ($p \leq 0.01$).*

In the study by Shukla et al. (2015), seed biopriming with drought-tolerant isolates of *T. harzianum* significantly increased chlorophyll a and b content in *Triticum aestivum* under drought stress. This enhancement in chlorophyll levels contributed to maintaining the plants' photosynthetic capacity, thereby improving their overall drought tolerance. Similar results have been observed in studies involving *Oryza sativa*, *Zea mays*, and *Glycine max*, where *T. harzianum* application enhanced chlorophyll content and improved drought tolerance (Pandey et al., 2016; Musaddaq et al., 2021; Nahrawy et al., 2020). These findings highlight the potential of AMF and *T. harzianum* to protect and maintain chlorophyll levels in plants under drought-stress conditions. The use of AMF and *T. harzianum* plays a critical role in maintaining chlorophyll and carotenoid levels under drought conditions by enhancing antioxidant activity and reducing oxidative stress. This physiological response not only preserves photosynthetic efficiency but also supports the overall metabolic stability of plants, allowing them to better withstand water-limited environments. The ability of these biostimulants to modulate stress-related metabolic pathways suggests their potential as effective tools for improving crop resilience to drought.

Malondialdehyde (MDA) Levels and Antioxidant Enzymes (SOD, CAT, APX) Activity

In this study, MDA accumulation in common bean under the 100% irrigation regime ranged from 13.08 to 16.52 nmol g^{-1} F.W., with the highest levels observed in the control group (Figure 3; Table 1). Although MDA levels were 26.3% higher in the control plants compared to those treated with *T. harzianum*, the difference was not statistically significant. Under the 50% irrigation regime, MDA levels ranged from 16.34 to 23.91 nmol g^{-1}

F.W. Significant differences ($p \leq 0.01$) were observed between the control and both *T. harzianum* and AMF treatments, with no statistical difference between *T. harzianum* and AMF themselves. Notably, MDA accumulation in the control plants was 46.3% higher compared to those treated with AMF. These results indicate that *T. harzianum* and AMF are highly effective in reducing oxidative damage in common bean under drought stress. By clearly demonstrating the ability of these biostimulants to mitigate oxidative stress, the study underscores their potential to enhance plant resilience under challenging environmental conditions. The significant reduction in MDA accumulation, particularly under the 50% irrigation regime, aligns with findings from other studies on different crops. For example, in *Triticum aestivum* (wheat), *T. harzianum* similarly reduced MDA levels, indicating decreased lipid peroxidation and enhanced stress tolerance (Shukla et al., 2015; Singh et al., 2020). Additionally, *Oryza sativa* (rice) studies have shown that AMF inoculation leads to lower MDA accumulation, further supporting the role of these biostimulants in protecting plant cell membranes under stress conditions (Pandey et al., 2016).

These consistent findings across different crops suggest that the application of *T. harzianum* and AMF can be a broadly effective strategy to enhance plant resilience to drought-induced oxidative stress. These biostimulants' ability to reduce lipid peroxidation and protect cell integrity under limited water availability highlights their potential for improving crop performance in arid and semi-arid regions.

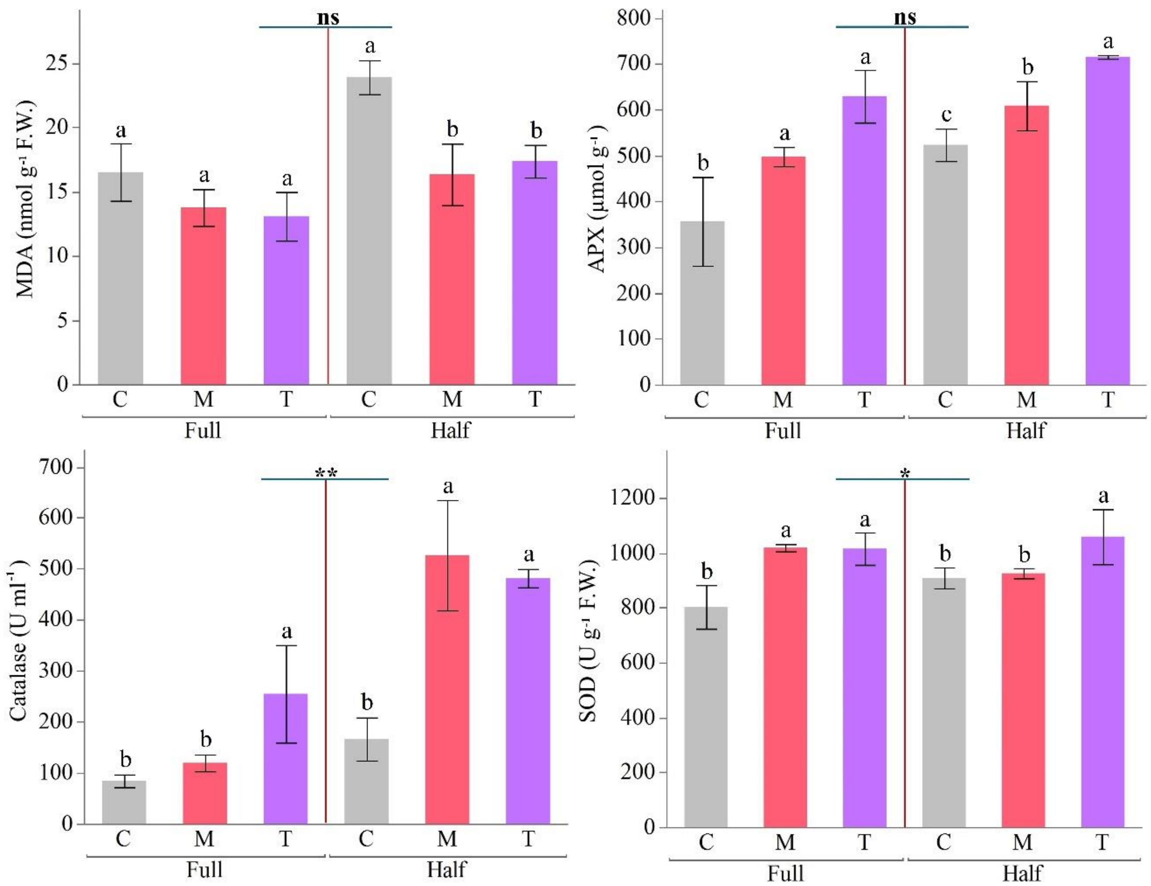

Figure 3. Effect of AMF (M) and *Trichoderma harzianum* (T) treatments on malondialdehyde (MDA) levels, superoxide dismutase (SOD), catalase (CAT), and ascorbate peroxidase (APX) activities in common bean under different irrigation regimes (100%-50%) conditions (C: Control, Different letters top of the bars indicate significant differences according to LSD test, ns: non-significant, * ($p \leq 0.05$), ** ($p \leq 0.01$)).

*Şekil 3. AMF (M) ve Trichoderma harzianum (T) uygulamalarının farklı sulama rejimLeri altında (%100-%50) fasulyede malondialdehit (MDA) düzeyleri, süperoksit dismutaz (SOD), katalaz (CAT) ve askorbat peroksidaz (APX) aktiviteleri üzerine etkisi (C: Kontrol, Çubukların üstündeki farklı harfler LSD testine göre anlamLı farklılıkları göstermektedir, ns: anlamsız, * (p ≤ 0.05), ** (p ≤ 0.01)).*

In this study, the activities of antioxidant enzymes in common bean grown under a 100% irrigation regime were assessed. The ascorbate peroxidase (APX) activity ranged from 356.66 to 629.60 μmol g^{-1}, catalase (CAT) activity ranged from 84.62 to 254.94 U mL^{-1}, and superoxide dismutase (SOD) activity ranged from 802.97 to 1018.09 U mL^{-1} F.W. The application of *T. harzianum* led to the most significant increases in enzyme activities compared to the control plants, with APX, CAT, and SOD activities increasing by 76.5%, 201%, and 26.8%, respectively. Statistically significant differences ($p \leq 0.05$, $p \leq 0.01$) were observed between the control and the treatments (AMF and *T. harzianum*) across all analyses. However, aside from CAT, the differences in SOD and APX activities between AMF and *T. harzianum* were not statistically significant.

Under the 50% irrigation regime, APX activity ranged from 523.38 to 715.30 μmol g^{-1}, CAT activity ranged from 166.09 to 526.51 U mL^{-1}, and SOD activity ranged from 908.41 to 1058.40 U mL^{-1} F.W. The highest increase in APX activity was observed with *T. harzianum* inoculation, showing a 36.7% increase compared to the control plants. Significant differences ($p \leq 0.01$) were found among all treatments. In terms of CAT activity, AMF inoculation led to the highest increase (217%) compared to the control, though no significant difference was found between the AMF and *T. harzianum* treatments. Regarding SOD activity, no significant difference was detected between the control and AMF treatments, with *T. harzianum* leading to the highest increase (16.5%) compared to the control. Statistical analysis between the 100% and 50% irrigation groups revealed no significant differences in MDA and APX activities, while significant differences were observed in SOD ($p \leq 0.05$) and CAT ($p \leq 0.01$) activities. This analysis highlights the role of *T. harzianum* and AMF in modulating antioxidant enzyme activities, which are crucial for mitigating oxidative stress in common bean under varying irrigation conditions. The findings suggest that these biostimulants enhance the plant's defense mechanisms, particularly in response to drought-induced oxidative stress, with differential effects depending on the specific enzyme and irrigation regime.

The observed increases in ascorbate peroxidase (APX), catalase (CAT), and superoxide dismutase (SOD) activities align with previous research, indicating that these biostimulants enhance the antioxidant defense system of plants. Specifically, *T. harzianum* has been shown to upregulate genes encoding antioxidant enzymes, thereby increasing their activity and reducing reactive oxygen species (ROS) levels (Yan et al., 2021; Zehra et al., 2017). Similarly, AMF has been found to boost antioxidant enzyme activities in various crops, contributing to improved stress tolerance and reduced oxidative damage (Begum et al., 2019; He et al., 2020; Hashem et al., 2019). The substantial increase in CAT activity, particularly under AMF treatment, underscores its critical role in detoxifying hydrogen peroxide and preserving membrane integrity under stress conditions. This finding is consistent with other studies that have identified CAT as a key enzyme in mitigating oxidative damage during drought stress, likely due to its high runover rates, which make it highly efficient at neutralizing hydrogen peroxide (Sofo et al., 2015; Hussain et al., 2019). The differential effects of *T. harzianum* and AMF on specific antioxidant enzymes depending on the irrigation regime highlight the potential of these biostimulants to target specific stress-related pathways, optimizing the plant's overall defense strategy. The broader implications of these findings suggest that *T. harzianum* and AMF could be valuable tools in sustainable agriculture, particularly in regions where water availability is limited. By enhancing stress tolerance, these biostimulants can improve crop resilience, leading to better growth and yield outcomes under challenging environmental conditions (Duc et al., 2018; Sun and Shahrajabian, 2023; Fazeli-Nasab et al., 2022).

Principal Component Analysis (PCA) Interrelations Among the Studied Characteristics

Principal Component Analysis (PCA) was employed to reduce the dimensionality of the dataset, allowing for the identification of key variables and the underlying structure within the data (Demirel et al., 2021; Türkoğlu et al., 2023). The PCA biplot analysis (Figure 4) reveals the distinct impact of AMF (M) and *Trichoderma harzianum* (T) treatments on various physiological and biochemical parameters in common bean, particularly under different irrigation regimes. The two principal components (PC1 and PC2) account for a combined 77.8% of the total variance, with PC1 explaining 48.8% and PC2 explaining 29%. The analysis demonstrates that both AMF and *T. harzianum* treatments are strongly associated with increased activities of key antioxidant enzymes such as superoxide dismutase (SOD), ascorbate peroxidase (APX), and catalase (CAT), as well as enhanced chlorophyll content (Chl a, Chl b, total chlorophyll). These findings indicate that these treatments effectively mitigate oxidative stress and maintain cellular integrity, particularly under drought conditions represented by the 50% irrigation regime. Conversely, the control (C) group, especially under limited water supply, shows a strong association with higher malondialdehyde (MDA) levels, indicating increased oxidative damage and reduced stress tolerance.

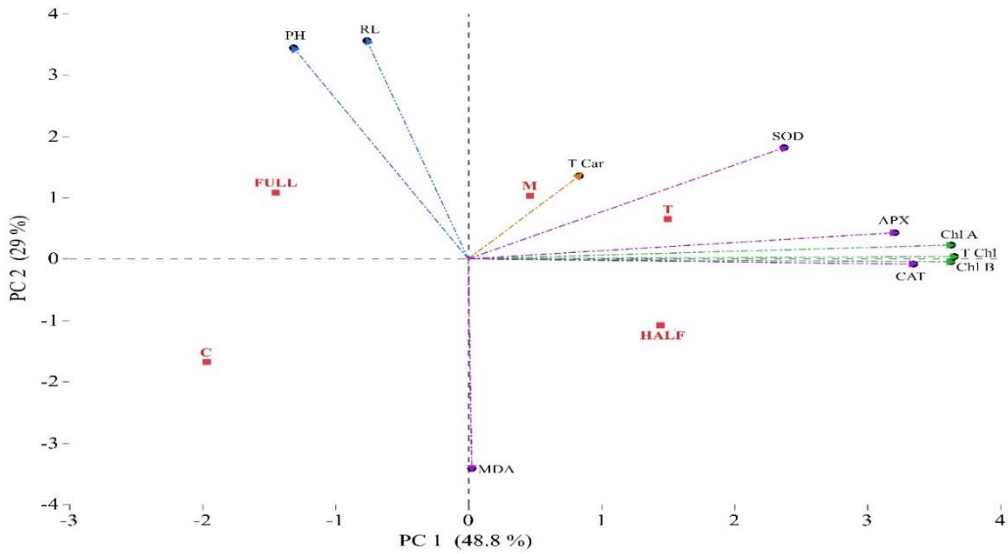

Figure 4. The biplot from PCA analysis illustrates the distribution of the AMF (M) and *Trichoderma harzianum* (T) treatments. The variables included in the analysis are Full: 100% irrigation regime, Half: 50% irrigation regime, C: Control, PH: Plant Height, RL: Root Length, Chl a: Chlorophyll a, Chl b: Chlorophyll b, T Chl: Total Chlorophyll, T Car: Total Carotenoid, SOD: Superoxide Dismutase, APX: Ascorbate Peroxidase, CAT: Catalase, MDA: Malondialdehyde.

Şekil 4. PCA analizinden elde edilen biplot, AMF (M) ve Trichoderma harzianum (T) uygulamalarının dağılımını göstermektedir. Analizde yer alan değişkenler şunlardır: Tam: %100 sulama rejimi, Yarım: %50 sulama rejimi, C: Kontrol, PH: Bitki Boyu, RL: Kök Uzunluğu, Chl a: Klorofil a, Chl b: Klorofil b, T Chl: Toplam Klorofil, T Car: Toplam Karotenoid, SOD: Süperoksit Dismutaz, APX: Askorbat Peroksidaz, CAT: Katalaz, MDA: Malondialdehit.

The biplot further illustrates that *T. harzianum* and AMF treatments support better maintenance of photosynthetic pigments and antioxidant defenses, which are crucial for sustaining plant health under stress. The clustering of plant height (PH) and root length (RL) with the 100% irrigation regime (Full) underscores the importance of adequate water availability for optimal growth, yet the effectiveness of biostimulants in enhancing stress tolerance is evident from their proximity to antioxidant markers even under reduced irrigation. The inverse relationship between MDA and antioxidant parameters, as shown by their opposing positions in the biplot, highlights the role of these treatments in lowering oxidative damage. This comprehensive analysis reinforces the potential of AMF and *T. harzianum* as vital components in improving plant resilience to environmental stressors, particularly in water-limited conditions.

CONCLUSION

This study provides compelling evidence of the effectiveness of Arbuscular Mycorrhizal Fungi (AMF) and *Trichoderma harzianum* in improving the drought tolerance of common beans under varying irrigation conditions. The significant increases in plant growth parameters, chlorophyll and carotenoid content, and antioxidant enzyme activities observed in treated plants highlight the potential of these biostimulants to mitigate the adverse effects of drought stress. The reduction in malondialdehyde (MDA) levels and the substantial enhancement of catalase (CAT), superoxide dismutase (SOD), and ascorbate peroxidase (APX) activities indicate that these treatments are effective in reducing oxidative damage and maintaining cellular stability under water-deficit conditions. These findings suggest that integrating AMF and *T. harzianum* into agricultural practices could be a strategic approach to enhancing crop resilience in regions facing water scarcity. Further research should focus on exploring the molecular mechanisms underlying these responses and assessing the long-term benefits of these biostimulants across different crops and environmental conditions.

CONFLICT OF INTEREST

The author declares no conflicts of interest concerning this article's research, authorship, and/or publication.

DECLARATION OF AUTHOR CONTRIBUTION

The author solely contributed to the conception, design, execution, analysis, and interpretation of the study, as well as the writing and revision of the manuscript.

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Research Article / Araştırma Makalesi

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Farklı Gübre Kaynaklarının ve Dozlarının Makarnalık Buğdayın (*Triticum durum* L.) Verimine Etkisi

The Effect of Different Fertilizer Sources and Doses on the Yield of Durum Wheat (*Triticum durum* L.)

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Öz: Bu çalışmada organik ve inorganik kaynaklı gübrelerin ve dozlarının makarnalık buğdayın verim ve verim öğelerine etkisi ve azot kullanım etkinliği yönünden değerlendirilmesi amaçlanmıştır. Araştırma 2019-2020 yılında Diyarbakır'da Dicle Üniversitesi Ziraat Fakültesine ait serada gerçekleştirilmiştir. Çalışmada bitki materyali olarak Dicle Üniversitesi Ziraat Fakültesi tarafından tescil ettirilen Sena makarnalık buğday çeşidi kullanılmıştır. Gübre uygulaması için organik ve inorganik kaynaklı 6 farklı gübre kaynağı ve bu gübrelerin 5 farklı dozu uygulanmıştır. Elde edilen sonuçlara göre, küçükbaş hayvan gübresi ve kompoze gübre (20-20-0) uygulamaları, tane verimi ve biyolojik verim değeri açısından en yüksek sonuçları vermiştir. Tane verimi için en yüksek değer N_3 dozunda, biyolojik verim değeri için ise N_5 dozunda elde edilmiştir. Farklı gübre uygulamaları arasında en yüksek azot kullanım etkinliği kompoze gübre (20-20-0), sertifikalı ticari organik gübre (Seleda) ve solucan gübresi kaynaklarıyla elde edilirken, en düşük azot kullanım etkinliği büyükbaş ve küçükbaş hayvan gübre kaynaklarında görülmüştür. Uygulanan dozlara göre en yüksek azot kullanım etkinliği N_1 dozunda, en düşük ise N_0 dozunda elde edilmiştir. Gübre kaynakları arasında yapılan analizlerde, azot kullanım etkinliği ile tane verimi arasında sertifikalı ticari organik gübre (Seleda), tavuk gübresi, solucan gübresi ve küçükbaş hayvan gübre kaynaklarında pozitif ilişkiler belirlenmiştir. Ayrıca, solucan gübresi dışında diğer tüm gübre kaynaklarında SPAD ile verim arasında pozitif korelasyonlar gözlemlenmiştir.
Anahtar Kelimeler: Buğday, doz, gübre, organik, verim

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Abstract: In this study, it was aimed to evaluate the effects of organic and inorganic fertilisers and doses on yield and yield components of durum wheat and nitrogen use efficiency. The research was carried out in the greenhouse of Dicle University Faculty of Agriculture in Diyarbakır in 2019-2020. Sena durum wheat variety registered by Dicle University Faculty of Agriculture was used as plant material in the study. For fertiliser application, 6 different fertiliser sources of organic and inorganic origin and 5 different doses of these fertilisers were applied. According to the results of the study, sheep and farmyard manures and compound fertiliser (20-20-0) applications had the highest results in terms of grain yield and biological yield. The highest value for grain yield was obtained at N_3 dose and for biological yield value at N_5 dose. Among the different fertiliser treatments, the highest nitrogen use efficiency was obtained with compound fertiliser (20-20-0), certified commercial organic fertiliser (Seleda) and vermicompost fertiliser sources, while the lowest nitrogen use efficiency was observed in farmyard and sheep manure sources. According to the applied doses, the highest nitrogen use efficiency was obtained at N_1 dose and the lowest at N_0 dose. In the analyses between fertiliser sources, positive correlations between nitrogen use efficiency and grain yield were determined in certified commercial organic manure (Seleda), chicken manure, vermicompost and sheep manure sources. In addition, positive correlations were observed between SPAD and yield in all fertiliser sources except vermicompost.
Keywords: Wheat, dose, fertiliser, organic, yield

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GİRİŞ

Buğday, Anadolu'da yıllardır yetiştirilen ve çiftçilerimiz için en önemli gelir kaynaklarından birini oluşturan bir tahıl bitkisidir. Türkiye genelinde, temel besin maddeleri arasında tahıl ve tahıl bazlı ürünler ilk sıralarda yer almaktadır. Dünya'da 187 ülkede 72.3 milyon ha (toplam tarımın %5'ini oluşturmaktadır) alanda organik tarım ve 4.1 milyon ha alanda da organik tahıl (en fazla buğday ve pirinç) üretimi yapılmaktadır. Dünya'da toplam tarım alanının %0.6'sını organik tahıl oluşturmaktadır. Organik tahıl üretimi alanı içinde organik buğday üretim alanının payı ise %36'dır (International Federation of Organic Agriculture Movements, 2020). Türkiye'de toplam tarım alanının %1.4'ünde organik tarım yapılmakta ve organik tahıl yetiştiriciliğinde ağırlıklı olarak buğday yetiştirilmektedir. Ülkemizde 2023 yılında yaklaşık 139 bin ton organik buğday üretimi yapılmıştır (Türkiye İstatistik Kurumu, 2023).

Son yıllarda dünya genelinde yaşanan iklim değişikliği ve nitrat kirliliği, insan sağlığı için bir tehdit oluşturmaktadır. Bu nedenle, kimyasal gübreler yerine organik gübrelerin kullanımı giderek daha önemli hale gelmiştir, çünkü organik kaynaklı gübrelerin kullanımı insan sağlığı ve çevre kirliliği açısından daha olumlu sonuçlar doğurabilir. Tarımsal üretimde verimliliği artırmak için gübre uygulamaları önemlidir; ancak, uygulanan gübre miktarı, türü ve zamanlaması değişebilir ve bu alandaki bilgi eksikliği, canlıların sağlığı ve çevrenin zarar görmesine neden olabilir. Yanlış gübre uygulamaları sonucunda topraklarda tuzlanma, ağır metallerin birikimi, besin maddesi dengesizliği, mikroorganizma aktivitesinin bozulması, suda ötrofikasyon ve nitrat birikimi, atmosfere azot ve kükürt içeren gazların salınımı gibi sorunlar ortaya çıkabilir (Sönmez vd., 2008). Azot içeren kimyasal gübreler, buğday yetiştiriciliğinde önemli olsa da, organik gübrelerle desteklenerek azaltılmalıdır. Organik gübreler, bitkisel ve hayvansal atıklardan oluşan, toprak yapısını iyileştiren, bitkilere besin sağlayan ve besin elementlerinin alımını kolaylaştıran gübrelerdir. Organik gübreler, toprak mikroorganizmalarına karbon ve enerji kaynağı sağlarlar ve toprak özelliklerini iyileştirebilirler, bu da verimliliği ve kaliteyi artırır (Shirani vd., 2002; Özalp, 2010). Araştırmalar, azotça zengin organik gübre uygulamalarının buğdayda yüksek verim ve biyolojik verim artışına katkıda bulunduğunu göstermektedir (Camara vd., 2003). Gübrelerin verim artışındaki rolü üretim koşullarına bağlı olarak değişse de, genellikle gübre kullanımının verim üzerinde %40 ile %60 arasında bir etkisi olduğu belirtilmektedir (Stewart vd., 2005).

Çiftlik gübrelerinin tarımsal arazilere uygulanması, besin elementlerinin geri kazanımı için oldukça yaygın bir yöntemdir. Ayrıca, toprağın fiziksel özelliklerini iyileştirerek tamponlama kapasitesini, infiltrasyonu, yoğunluğu, köklerin nüfuzunu, sıkışmasını ve su tutma kapasitesini artırır (Özalp, 2010). Bazı araştırmalar, kurak bölgelerde buğdaya çiftlik gübresi uygulamasının bitki gelişimini, verimi ve su kullanım verimliliğini artırdığını bildirmişlerdir (Sushila ve Gajendra, 2000). Sığır gübresi uygulamasının toprağın verimliliğini iyileştirdiği ve buğdayın tane verimini artırdığı bildirilmiştir (Öztürk vd., 2012). Organik gübrelerin toprak özelliklerini etkilediği, tavuk gübresi ve çiftlik gübresinin bu parametrelerde en etkili gübreler olduğu belirtilmiştir. Çiftlik gübresinin en yüksek organik karbon, toplam azot ve toplam potasyum değerlerine sahip olduğu, tavuk gübresinin ise en yüksek toplam fosfor ve mikrobiyal biyolojik verim değerlerine sahip olduğu gözlemlenmiştir (Kaur vd., 2005). Solucan gübresinin, toprağın gözenekli yapısını artırarak su ve hava tutma kapasitesini artırdığı ve bitki besin maddelerinin yıkanmasını engellediği, uzun vadede toprak yapısını iyileştirdiği ve hastalık ve zararlılardan koruduğu ifade edilmiştir (Tejada ve González, 2009).

Buğdayda uygun azotlu gübrelemenin tane verimini ve ürün kalitesini artırdığı ve azotlu gübrenin ekimle birlikte, kardeşlenme ve çiçeklenme döneminde verildiğinde bitkiler tarafından azot alımının arttığı bildirilmiştir (Atar, 2017). Organik gübre veya kompostun kimyasal gübre ile kombine olarak uygulanmasının buğday verimi ve verim bileşenleri üzerine daha iyi sonuçlar verdiği belirlenmiştir (Cheraghi vd., 2016). Araştırmacılar makarnalık buğdayda sıvı azot uygulama dönemlerinin tane verimini önemli ölçüde etkilediğini (Hiltbrunner vd., 2005; Zemichael vd., 2017), azotun farklı zamanlarda bölünerek ve organik sıvı gübre ile ilave olarak verildiği uygulamalarda ise camsı tane oranı hariç, diğer tarımsal özellikler yönünden istatistiksel olarak önemli etkilerinin bulunduğunu bildirmişlerdir (Altuntaş ve Akgün, 2016). Gökşen (2019), organik sıvı gübre uygulamalarının makarnalık buğdayda tane verimi, bin tane ağırlığı ve hektolitre ağırlığını artırdığını bildirmiştir. Aksu (2017), iki ton/da^{-1}'a kadar yapılan ahır gübrelemesinin buğdayda verim ve kalite üzerine olumlu etkide bulunduğunu bildirmiştir. Kara ve Gül (2013), organik kaynaklı bazı gübrelerin ekmeklik ve makarnalık buğday çeşitlerinde tane verimi, verim komponentleri ve protein oranı üzerine önemli ve olumlu etkileri olduğunu bildirmişlerdir. Araştırmacılar organik sıvı gübrelerin, kısa sürede bitki bünyesine geçtiğini ve bitkiye yarayışlı hale geldiğini (Bechini ve Marino, 2009) ve ekimden önce çiftlik gübresi ve sapa kalkma döneminde de organik sıvı gübre uygulanmasının, organik makarnalık buğday üretimi açısından önemli olduğunu bildirmişlerdir (Mutlu vd., 2020).

Bu çalışma, organik ve inorganik kaynaklı gübrelerin ve dozlarının makarnalık buğdayın verim ve verim öğelerine etkisi ve azot kullanım etkinliği yönünden değerlendirilmesi amacıyla yapılmıştır.

MATERYAL VE METOT

Araştırma 2019-2020 yılında Diyarbakır'da Dicle Üniversitesi Ziraat Fakültesine ait serada gerçekleştirilmiştir. Çalışmada bitki materyali olarak Dicle Üniversitesi Ziraat Fakültesi tarafından tescil ettirilen Sena makarnalık buğday çeşidi kullanılmıştır. Gübre uygulaması için Çizelge 1'de özellikleri verilen toprağa organik ve inorganik kaynaklı 6 farklı gübre kaynağı (Büyükbaş hayvan gübresi, küçükbaş hayvan gübresi, solucan gübresi, tavuk gübresi, sertifikalı ticari organik gübre (Seleda) ve kompoze gübre (20-20-0)) ve bu gübrelerin 5 farklı dozu uygulanmıştır. Ayrıca gübre uygulanmayan bir grup da kontrol (N_0) olarak denemeye alınmıştır. Dozlar belirlenirken tavsiye edilen optimum gübre dozu ortaya gelecek şekilde iki alt ve iki üst dozu hesaplanmıştır (Çizelge 2 ve 3).

Çizelge 1. Araştırmada kullanılan deneme toprağının bazı fiziksel ve kimyasal özellikleri.
Table 1. Some physical and chemical properties of the experimental soil used in the research.

Analiz Adı	Sonuçlar	Değerlendirme	Analiz Adı	Sonuçlar	Değerlendirme
Saturayon (%)	63.00	Killi Tınlı	Kalsiyum (ppm)	10717.89	Çok Yüksek
Tuzluluk (dS m^{-1})	0.92	Tuzsuz	Magnezyum (ppm)	471.78	Orta
pH	8.11	Hafif Alkali	Sodyum (ppm)	26.65	Düşük
Organik Madde (%)	0.71	Düşük	Demir (ppm)	9.29	Çok Yüksek
Azot (%)	0.04	Düşük	Bakır (ppm)	1.61	Orta
Fosfor (ppm)	4.00	Düşük	Mangan (ppm)	16.50	Orta
Potasyum (ppm)	314.45	Yüksek	Çinko (ppm)	0.08	Düşük

Çizelge 2. Araştırmada kullanılan gübrelerin içerikleri.
Table 2. Contents of fertilizers used in the research.

Gübreler	Toplam Azot İçeriği (%)	Organik İçerik (%)	Diğer İçerikler (%)
BHG	3.82	61.59	Organik karbon %25; P_2O_5 %4; Fe %0.3; Hümik + fülvik asit %25
KHG	4.98	68.30	P_2O_5 %0.03
SG	1.50	40.0	Hümik + fülvik %15; P_2O_5 %3
TG	4.09	57.89	P_2O_5 %0.03
STOG (Seleda)	3.0	50.0	Hümik+ fülvik %12.5; P_2O_5 %0.6; K_2O %1.3; CaO %0.3
KG (20-20-0)	20.0	-	P_2O_5 %20

BHG: Büyükbaş Hayvan Gübresi, KHG: Küçükbaş Hayvan Gübresi, SG: Solucan Gübresi, TG: Tavuk Gübresi, STOG: Sertifikalı Ticari Organik Gübre (Seleda), KG: Kompoze Gübre (20-20-0)

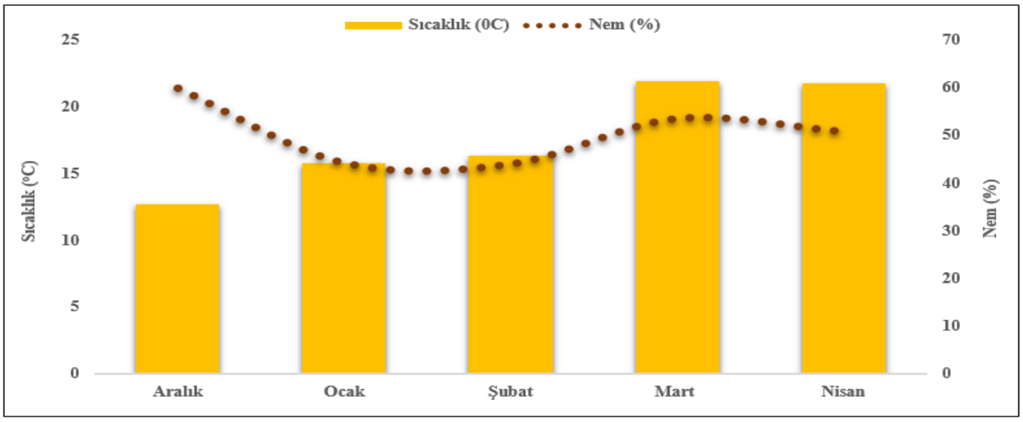
Çalışma "Tesadüf Bloklarında Bölünmüş Parseller Deneme Deseni"ne göre 4 tekerrürlü olarak yürütülmüştür. Tohumlar 8 litrelik toprak ile doldurulan saksılara, her saksıda 4 bitki olacak şekilde 06.12.2019 tarihinde ekilmiştir. Ekim işlemi ile birlikte katı formdaki gübrelerde toprağa uygulanmıştır. Sulama işlemi ekimden itibaren otomatik damla sulama sistemi ile 3 günde bir her bir saksıya 200 ml su olacak şekilde yapılmıştır. Araştırma dönemine ait sera ortamının sıcaklık ve nem değerleri Şekil 1'de verilmiştir.

Çizelge 3. Araştırmada kullanılan gübrelerin uygulama dozları.
Table 3. Application doses of fertilizers used in the research.

	Dozlar				
Gübreler	N_1	N_2	N_3	N_4	N_5
BHG	500 kg da^{-1} = 10 g $saksı^{-1}$	1 ton da^{-1} = 20 g $saksı^{-1}$	2 ton da^{-1} = 40 g $saksı^{-1}$	4 ton da^{-1} = 80 g $saksı^{-1}$	6 ton da^{-1} = 120 g $saksı^{-1}$
KHG	500 kg da^{-1} = 10 g $saksı^{-1}$	1 ton da^{-1} = 20 g $saksı^{-1}$	2 ton da^{-1} = 40 g $saksı^{-1}$	4 ton da^{-1} = 80 g $saksı^{-1}$	6 ton da^{-1} = 120 g $saksı^{-1}$
SG	250 kg da^{-1} = 5 g $saksı^{-1}$	375 kg da^{-1} = 7.5 g $saksı^{-1}$	500 kg da^{-1} = 10 g $saksı^{-1}$	625 kg da^{-1} = 12.5 g $saksı^{-1}$	750 kg da^{-1} = 15 g $saksı^{-1}$
TG	50 kg da^{-1} = 1 g $saksı^{-1}$	100 kg da^{-1} = 2 g $saksı^{-1}$	150 kg da^{-1} = 3 g $saksı^{-1}$	200 kg da^{-1} = 4 g $saksı^{-1}$	250 kg da^{-1} = 5 g $saksı^{-1}$
STOG (Seleda)	40 kg da^{-1} = 0.8 g $saksı^{-1}$	50 kg da^{-1} = 1 g $saksı^{-1}$	60 kg da^{-1} = 1.2 g $saksı^{-1}$	70 kg da^{-1} = 1.4 g $saksı^{-1}$	80 kg da^{-1} = 1.6 g $saksı^{-1}$
KG (20-20-0)	4 kg da^{-1} = 0.4 g $saksı^{-1}$	8 kg da^{-1} = 0.8 g $saksı^{-1}$	12 kg da^{-1} = 1.2 g $saksı^{-1}$	16 kg da^{-1} = 1.6 g $saksı^{-1}$	20 kg da^{-1} = 2 g $saksı^{-1}$
Kontrol			0		

BHG: Büyükbaş Hayvan Gübresi, KHG: Küçükbaş Hayvan Gübresi, SG: Solucan Gübresi, TG: Tavuk Gübresi, STOG: Sertifikalı Ticari Organik Gübre (Seleda), KG: Kompoze Gübre (20-20-0)

Araştırmada; başaklanma süresi (gün), fizyolojik olum süresi (gün), bayrak yaprak klorofil içeriği (SPAD), bitki boyu (cm), başak uzunluğu (cm), başakta başakçık sayısı (adet), başakta tane sayısı (adet), başakta tane ağırlığı (g), tane verimi (g), biyolojik verim (g) ve azot kullanım etkinliği (AKE) özellikleri incelenmiştir. Elde edilen değerlerin varyans ve korelasyon analizleri "Tesadüf Bloklarında Bölünmüş Parseller Deneme Deseni"ne göre JMP Pro 13 istatistik paket programı yardımıyla gerçekleştirilmiştir.



Şekil 1. Araştırma dönemine ait sera ortamının bazı iklim verileri.
Figure 1. Some climatic data of the greenhouse environment during the research period.

BULGULAR VE TARTIŞMA

Farklı gübrelerin ve dozlarının makarnalık buğdayda verim ve verim unsurları üzerine olan etkilerinin belirlenmeye çalışıldığı bu araştırmada; gübre, doz ve gübre x doz interaksiyonlarının etkileri ile azot kullanım etkinliğine ait değerleri Çizelge 4, 5 ve 6'da verilmiştir.

Çalışmadan elde edilen sonuçlar, tane veriminin ve verim bileşenlerinin tavuk gübresi ve büyükbaş hayvan gübresi uygulamalarıyla önemli ölçüde arttığını göstermiştir (Çizelge 4, 5 ve 6). Tarımda organik gübrelerin kullanımı bitki verimini, toprak pH'sını, organik karbonun ve toprakta kullanılabilir N, P ve K'yı iyileştirir (Rautaray vd., 2003). Çizelge 4'ten görüleceği üzere makarnalık buğdayda en yüksek SPAD değeri kompoze gübre ve küçükbaş hayvan gübrelerinde tespit edilmiştir. Ayrıca doz ortalamasına göre en yüksek SPAD değeri N_5'ten ve en düşük SPAD değeri de azot gübresi uygulanmayan N_0 dozundan elde edilmiştir. Bütün gübre kaynakları, bitkilerin beslenme koşullarında iyileşme sağlayarak hiç gübre verilmeyen kontrol uygulamasına göre SPAD değerini önemli ölçüde artırmıştır (Çizelge 4). Araştırmacılar bulgularımıza benzer olarak en yüksek SPAD değerini kompoze gübre uygulamasından elde etmiş ve azot alımındaki artışa bağlı olarak buğdayda SPAD değerinin arttığını bildirmişlerdir (Bulut, 2012; Fois vd., 2009; Özkan vd., 2021; Singh vd., 2002; Spaner vd., 2005). Araştırmada büyükbaş hayvan gübresi, tavuk gübresi ve küçükbaş hayvan gübresinin bitki boyunu arttırıcı etkisinin olduğu, ancak solucan gübresinin kontrol grubundan sonra minimum düzeyde etkiye sahip olduğu saptanmıştır (Çizelge 4). Özkan vd. (2021) ve Delden (2001), buğdayda bitki boyunun organik ve inorganik gübrelerin uygulanmasıyla arttırılabileceğini belirtmiştir. Aksu (2017), sonbaharda buğday ekimi öncesi yapılan çiftlik gübresi uygulamasının bitki boyu üzerinde olumlu bir etkisi olduğunu saptamıştır.

Çizelge 4. Gübrelerin ve uygulama dozlarının incelenen özellikler üzerine etkisi.
Table 4. The effect of fertilizers and application doses on the examined traits.

		Uygulama Dozları													
	Gübreler	**N_0**		**N_1**		**N_2**		**N_3**		**N_4**		**N_5**		**Ortalama**	
SPAD Değeri	BHG	32.87	n	39.37	h-m	34.33	mn	38.93	ı-m	46.13	d-g	46.50	c-f	39.69	b
	KHG	32.87	n	44.07	e-h	49.40	a-d	48.97	a-e	51.80	ab	51.03	a-d	46.36	a
	SG	32.87	n	39.10	h-m	40.60	h-l	40.27	h-l	41.00	h-k	35.87	l-n	38.28	b
	TG	32.87	n	39.07	h-m	33.37	n	41.10	g-k	43.87	e-ı	42.70	f-j	38.83	b
	STOG (Seleda)	32.87	n	38.70	j-m	37.93	j-n	39.50	h-l	36.47	k-n	48.00	b-e	38.91	b
	KG (20-20-0)	32.87	n	46.63	c-f	51.53	a-c	53.77	a	51.53	a-c	53.60	a	48.32	a
	Doz Ortalama	**32.87**	**d**	**41.16**	**c**	**41.19**	**c**	**43.76**	**b**	**45.13**	**ab**	**46.28**	**a**	**41.73**	
	DK (%)	**7.50**													
	AÖF (0.05)	**G: 2.19**, D: 2.10**, G*D: 5.16****													
Bitki Boyu (cm)	BHG	52.33	l	69.33	b-h	75.67	ab	68.83	c-h	75.17	a-c	77.50	a	70.81	a
	KHG	52.33	l	74.17	a-c	74.83	a-c	72.00	a-e	67.17	d-h	65.00	f-ı	68.58	ab
	SG	52.33	l	54.00	j	56.67	j	55.50	j	57.17	kl	57.83	kl	56.58	d
	TG	52.33	l	71.00	b-g	64.67	g-j	75.00	a-c	73.50	a-d	73.67	a-c	69.36	ab
	STOG (Seleda)	52.33	l	55.67	l	58.00	kl	63.33	h-k	68.77	c-h	59.50	ı-l	60.60	c
	KG (20-20-0)	52.33	l	68.83	c-h	69.17	c-h	68.83	c-h	71.33	a-f	66.50	e-h	67.17	b
	Doz Ortalama	**52.33**	**c**	**65.50**	**b**	**66.50**	**ab**	**67.25**	**ab**	**68.85**	**a**	**66.67**	**ab**	**65.51**	
	DK (%)	**6.02**													
	AÖF (0.05)	**G: 2.64**, D: 2.66**, G*D: 6.54****													
Başak Uzunluğu (cm)	BHG	3.32	ı	3.64	ı	4.17	g-ı	5.01	fg	6.10	b-d	6.43	b-d	4.80	cd
	KHG	3.32	ı	6.06	b-e	6.11	b-d	6.63	bc	4.95	f-h	6.38	b-d	5.59	a
	SG	3.32	ı	4.05	g-ı	3.45	ı	3.69	ı	3.75	ı	3.38	ı	3.63	e
	TG	3.32	ı	5.04	e-g	5.63	c-f	5.73	b-f	5.63	c-f	5.54	d-f	5.17	bc
	STOG (Seleda)	3.32	ı	3.42	ı	3.96	hı	5.69	b-f	6.65	b	4.00	hı	4.53	d
	KG (20-20-0)	3.32	ı	4.87	f-h	4.93	f-h	8.15	a	5.01	fg	5.56	d-f	5.33	ab
	Doz Ortalama	**3.32**	**d**	**4.51**	**c**	**4.71**	**c-f**	**5.82**	**a**	**5.35**	**b**	**5.21**	**b-d**	**4.83**	
	DK (%)	**5.99**													
	AÖF (0.05)	**G: 0.42**, D: 0.40**, G*D: 1.02****													

**: P≤0.01 düzeyinde önemli, DK: Düzeltme Katsayısı, AÖF: Asgari Önemli Farklılık, G: Gübre, D: Doz, BHG: Büyükbaş Hayvan Gübresi, KHG: Küçükbaş Hayvan Gübresi, SG: Solucan Gübresi, TG: Tavuk Gübresi, STOG: Sertifikalı Ticari Organik Gübre (Seleda), KG: Kompoze Gübre (20-20-0)

Gübrelerin ve dozlarının buğday bitkisinin başak uzunluğu, başakta başakçık sayısı, başakta tane sayısı ve başakta tane ağırlığı özellikleri üzerine etkileri incelendiğinde; gübrelerin etkisi, gübre dozlarının etkisi ve gübre-gübre dozu interaksiyonun etkisi istatistiksel olarak önemli bulunmuştur. Küçükbaş hayvan gübresi ve kompoze gübre (20-20-0) uygulamalarının başak özellikleri üzerine etkisi istatistiki olarak önemli bulunmuştur. Uygulama dozlarından N_3'ün en yüksek değerin elde edildiği doz olduğu belirlenmiştir. Gübre uygulamaları ve dozları birlikte değerlendirildiğinde ise en yüksek değerler genel olarak kompoze gübre (20-20-0) uygulamasının N_3 dozundan elde edilmiştir. Ayrıca başak özellikleri bakımından solucan gübresinin kontrolden sonra diğer gübre türlerine oranla daha düşük değerler verdiği saptanmıştır

(Çizelge 4 ve 5). Hammad vd. (2011) yaptıkları çalışmada, en yüksek başak uzunluğunu geleneksel gübre (9.28 cm) uygulamasında, en yüksek başakta başakçık sayısı (14.9 adet) ve başakta tane sayısını (49.25 adet) ise farklı organik gübrelerin kombinasyonu uygulamasından elde etmiştir. Özkan vd. (2021) ortalama SPAD değerinin 27.70 – 47.83, başak uzunluğunun 3.68 – 6.87 cm, başakta başakçık sayısının 8.48 – 17.83 adet, başakta tane sayısının 8.05 – 22.22 adet ve başakta tane ağırlığının 0.29 – 1.05 g arasında yer aldığını bildirmişlerdir. Kara ve Gül (2013), iki yıllık çalışmada en yüksek sonuçları ticari gübre uygulamasında, en düşük sonuçları ise deniz yosunu gübresinden elde ettiklerini bildirmişlerdir. Aksu (2017), azot dozunun çiftlik gübre ile kombinasyonun başakta tane sayısının daha da yüksek seviyelere ulaşabildiğini belirtmiştir. Organik gübre kullanımı, bitki büyümesini teşvik etmek ve verimi artırmak için etkili bir gübreleme yöntemidir (Adekiya vd., 2020; Li vd., 2022; Lu vd., 2000; Yang vd., 2020). Yüksek azot içeriğine sahip kompoze gübre (20-20-0) buğday büyümesini daha iyi desteklemiştir (Çizelge 2); bunun nedeni kompoze gübrenin organik gübrelere kıyasla toprakta hızlı bir şekilde ayrışmasıdır (Adediran vd., 2005; Bayhan ve Yıldırım, 2021; Özkan, 2024). Bu sonuçlar diğer çalışmalar ile uyumludur (Qaswar vd., 2020; Wang vd., 2020).

Çizelge 5. Gübrelerin ve dozlarının incelenen özellikler üzerine etkisi.
Table 5. The effect of fertilizers and doses on the examined traits.

		Gübre Dozları													
	Gübreler	**N_0**		**N_1**		**N_2**		**N_3**		**N_4**		**N_5**		**Ortalama**	
Başakta Başakçık Sayısı (adet)	BHG	7.45	l	9.07	kl	9.38	j-l	15.29	d-g	16.70	b-d	17.92	b	12.85	b
	KHG	7.45	l	16.08	b-e	15.77	c-f	17.58	bc	12.40	hı	16.47	b-d	14.51	a
	SG	7.45	l	9.29	kl	7.63	l	7.88	l	8.13	l	8.77	kl	8.41	d
	TG	7.45	l	13.57	gh	15.38	d-g	15.17	d-g	15.42	d-g	15.26	d-g	13.92	a
	STOG (Seleda)	7.45	l	7.42	l	8.12	l	14.23	e-h	15.79	c-f	10.63	ı-k	10.82	c
	KG (20-20-0)	7.45	l	11.48	ı	11.40	ıj	20.23	a	9.05	kl	14.00	f-h	12.48	b
	Doz Ortalama	**7.45**	**e**	**11.15**	**d**	**11.28**	**d**	**15.06**	**a**	**12.91**	**c**	**13.84**	**b**	**12.16**	
	DK (%)	**10.19**													
	AÖF (0.05)	**G: 0.73**, D: 0.84**, G*D: 2.08****													
Başakta Tane Sayısı (adet)	BHG	12.63	n	12.90	mn	13.00	mn	25.25	f-ı	28.18	c-f	34.23	b	21.03	c
	KHG	12.63	n	33.03	b	30.66	b-e	30.75	b-d	21.20	jk	31.83	bc	26.68	a
	SG	12.63	n	16.55	lm	11.25	n	11.25	n	12.00	n	11.18	n	12.48	e
	TG	12.63	n	22.36	ıj	18.38	kl	24.17	g-j	26.42	f-h	27.63	d-g	21.93	c
	STOG (Seleda)	12.63	n	11.75	n	13.13	mn	28.41	c-f	32.83	b	16.38	lm	19.19	d
	KG (20-20-0)	12.63	n	27.00	e-g	22.75	h-j	38.90	a	24.22	g-j	17.42	l	23.82	b
	Doz Ortalama	12.63	e	20.60	c	18.19	d	26.45	a	24.14	b	23.11	b	20.85	
	DK (%)	**10.83**													
	AÖF (0.05)	**G: 1.06**, D: 1.58**, G*D: 3.86****													
Başakta Tane Ağırlığı (g)	BHG	0.39	m	0.50	lm	0.51	lm	1.14	f-h	1.57	bc	1.82	a	1.00	b
	KHG	0.39	m	1.58	a-c	1.51	b-d	1.49	b-d	0.87	I-k	1.47	c-e	1.23	a
	SG	0.39	m	0.77	jk	0.39	m	0.45	lm	0.48	lm	0.42	m	0.50	d
	TG	0.39	m	0.95	h-j	0.89	ı-k	1.24	e-g	1.31	d-g	1.27	d-g	1.02	b
	STOG (Seleda)	0.39	m	0.44	lm	0.49	lm	1.24	e-g	1.38	c-f	0.67	k-l	0.78	c
	KG (20-20-0)	0.39	m	1.09	g-ı	1.11	g-ı	1.71	a-b	1.18	f-h	1.24	e-g	1.14	a
	Doz Ortalama	0.39	c	0.89	b	0.88	b	1.21	a-c	1.13	a	1.15	a	0.95	
	DK (%)	**7.44**													
	AÖF (0.05)	**G: 0.14**, D: 0.11**, G*D: 0.28****													

**: P≤0.01 düzeyinde önemli, DK: Düzeltme Katsayısı, AÖF: Asgari Önemli Farklılık, G: Gübre, D: Doz, BHG: Büyükbaş Hayvan Gübresi, KHG: Küçükbaş Hayvan Gübresi, SG: Solucan Gübresi, TG: Tavuk Gübresi, STOG: Sertifikalı Ticari Organik Gübre (Seleda), KG: Kompoze Gübre (20-20-0)

Çizelge 6'da görüldüğü üzere tane verimi ve biyolojik verim değeri bakımından farklı gübre uygulamalarının etkisi değerlendirildiğinde en yüksek değerler küçükbaş hayvan gübresi ve kompoze gübre (20-20-0) uygulamalarından elde edilmiştir. Uygulama dozları arasında tane verimi için N_3 dozu, biyolojik verim değeri içinde N_5 dozu yüksek değer vermiştir. Gübre uygulamaları ve uygulama dozları birlikte değerlendirildiğinde ise her iki özellik bakımından da N_5 dozu ön plana çıkmış ancak gübre uygulaması farklılık göstermiştir. Ayrıca incelenen diğer özelliklerde olduğu gibi solucan gübresinin kontrol grubundan sonra en düşük değerleri verdiği saptanmıştır. Özkan vd. (2021), ortalama tane verimini 1.09 – 3.56 g bitki^{-1}; biyolojik verimi 2.69 – 8.04 g bitki^{-1} olarak tespit etmişlerdir. Shen vd. (2020), iki yıl üst üste %20 inorganik N içeren organik gübrenin buğday verim bileşenlerini iyileştirdiğini ve tek başına kimyasal gübreye kıyasla verimi artırdığını bulmuştur. Ayrıca, buğday verimi her bir verim bileşeni ile önemli ölçüde pozitif korelasyon göstermiştir. Bu sonuçlar, organik gübre kullanımının buğday büyümesini teşvik ederek ve verim bileşenlerini iyileştirerek verimi artırdığını göstermiştir ki bu da Wen vd. (2018)'nin sonuçlarıyla tutarlılık göstermektedir. Benzer çalışmalar, organik gübre kullanımının bitki büyümesini teşvik ettiğini ve tane dolum döneminin ortasından sonuna kadar yaprak yaşlanmasını geciktirerek besin maddesi alımını ve verimi artırdığını göstermiştir (Geng vd., 2019; Zhao vd., 2015). Önceki bulgulara benzer şekilde (Liu vd., 2010; Ma vd., 2015; Qaswar vd., 2020). Bu çalışmada da KHG ve KG (20-20-0)'nin diğer gübre kaynaklarına kıyasla verimi ve verim ögelerini artırdığı bulunmuştur (Çizelge 5 ve 6). Bunun nedeni, KHG'nin gübreleme karakteristiğini tam olarak kullanması, yetiştirme sezonu boyunca besin maddesi teminini sağlaması ve besin maddesi kaybını önlemesi, dolayısıyla da bitki besin maddesi alımını teşvik ederek verimi ve bitki besin elementi kullanım etkinliğini artırmasıdır (Wang vd., 2020).

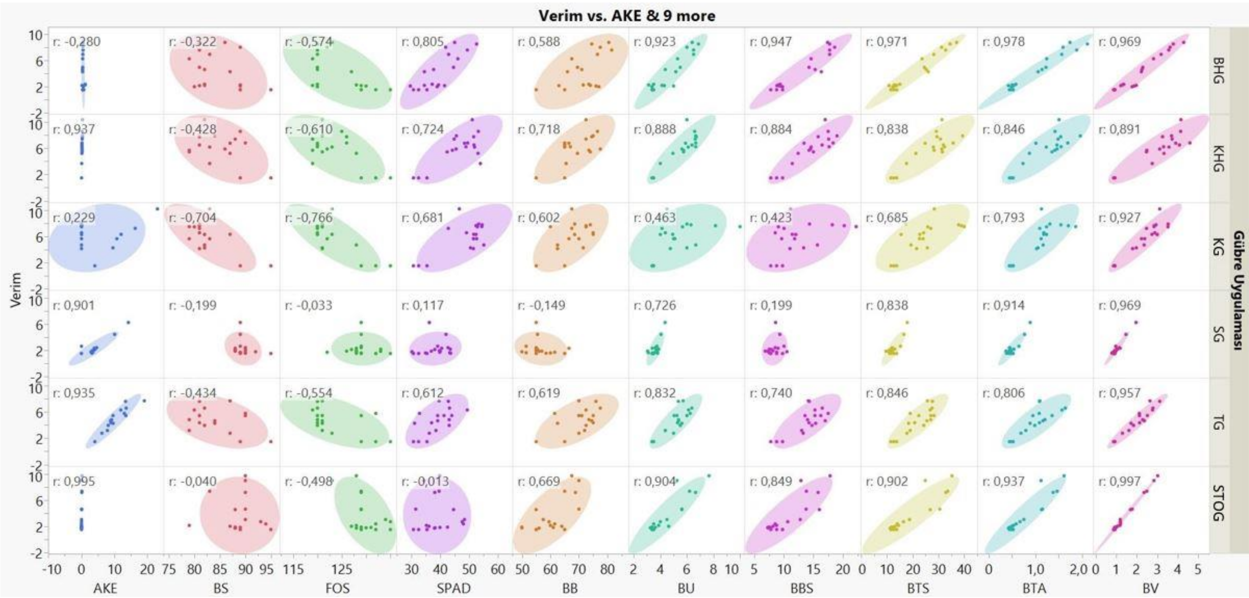
Çizelge 6. Gübrelerin ve dozlarının incelenen özellikler üzerine etkisi ve azot kullanım etkinliği değerleri
Table 6. Effect of fertilizers and doses on the examined traits and nitrogen use efficiency values.

	Gübreler	Gübre Dozları													
		N_0		N_1		N_2		N_3		N_4		N_5		Ortalama	
Tane Verimi (g)	BHG	0.37	k	0.55	k	0.51	k	1.14	g-j	1.72	a-f	2.10	a	1.09	bc
	KHG	0.37	k	1.58	b-h	1.99	ab	1.84	a-c	1.30	e-ı	1.62	a-g	1.47	a
	SG	0.37	k	1.10	h-j	0.39	k	0.52	k	0.48	k	0.49	k	0.58	d
	TG	0.37	k	1.36	c-ı	1.07	ıj	1.24	f-ı	1.31	d-ı	1.54	b-ı	1.17	b
	STOG (Seleda)	0.37	k	0.44	k	0.49	k	1.74	a-e	1.79	a-e	0.67	jk	0.93	c
	KG (20-20-0)	0.37	k	1.80	a-d	1.34	d-ı	1.90	ab	1.63	a-g	1.57	b-h	1.45	a
	Doz Ortalama	0.37	d	1.14	bc	0.97	c	1.40	a	1.37	a	1.33	ab	1.11	
	DK (%)	**11.88**													
	AÖF (0.05)	**G: 0.28**, D: 0.19**, G*D: 0.46****													
Biyolojik Verim (g)	BHG	0.90	mn	1.29	k-n	1.87	ı-k	2.25	h-j	3.18	c-e	3.89	ab	2.23	bc
	KHG	0.90	mn	2.88	e-g	3.51	a-d	3.72	a-c	3.32	b-e	4.07	a	3.07	a
	SG	0.90	mn	1.47	k-m	0.80	n	1.04	mn	0.94	mn	1.03	mn	1.03	e
	TG	0.90	mn	2.13	h-j	1.71	k-l	2.25	h-j	2.47	f-ı	2.72	e-h	2.03	c
	STOG (Seleda)	0.90	mn	0.94	mn	1.06	mn	2.34	g-ı	2.38	f-ı	1.20	l-n	1.47	d
	KG (20-20-0)	0.90	mn	2.52	f-h	2.25	h-j	2.87	e-g	2.93	d-g	2.96	d-f	2.41	b
	Doz Ortalama	0.90	c	1.87	b	1.87	b	2.41	a	2.54	a	2.64	a	2.03	
	DK (%)	**8.02**													
	AÖF (0.05)	**G: 0.35**, D: 0.22**, G*D: 0.56****													
Azot Kullanım Etkinliği (AKE) (g saksı$^{-1}$)	BHG	4.11	h-k	1.17	jk	0.6	k	0.93	jk	1.06	jk	1.05	jk	1.49	c
	KHG	4.11	h-k	2.69	ı-k	1.84	ı-k	1.16	jk	0.63	k	0.63	k	1.84	c
	SG	4.11	h-k	4.54	h-j	5.08	g-ı	17.54	a	17.79	a	6.56	f-h	9.27	a
	TG	4.11	h-k	10.13	c-f	3.3	h-k	4.1	h-k	3.48	h-k	3.34	h-k	4.74	b
	STOG (Seleda)	4.11	h-k	13.54	bc	9.65	d-f	10.27	c-e	10.03	c-f	10.91	c-e	9.75	a
	KG (20-20-0)	4.11	h-k	16.37	ab	10.27	c-e	12.68	cd	9.6	d-f	8.25	e-g	10.22	a
	Doz Ortalama	4.11	b	8.07	a	7.78	a	7.1	a	5.12	b	5.12	b	6.22	
	DK (%)	**7.76**													
	AÖF (0.05)	**G: 2.55**, D: 1.48**, G*D: 3.63****													

**: P≤0.01 düzeyinde önemli, DK: Düzeltme Katsayısı, AÖF: Asgari Önemli Farklılık, G: Gübre, D: Doz, BHG: Büyükbaş Hayvan Gübresi, KHG: Küçükbaş Hayvan Gübresi, SG: Solucan Gübresi, TG: Tavuk Gübresi, STOG: Sertifikalı Ticari Organik Gübre (Seleda), KG: Kompoze Gübre (20-20-0)

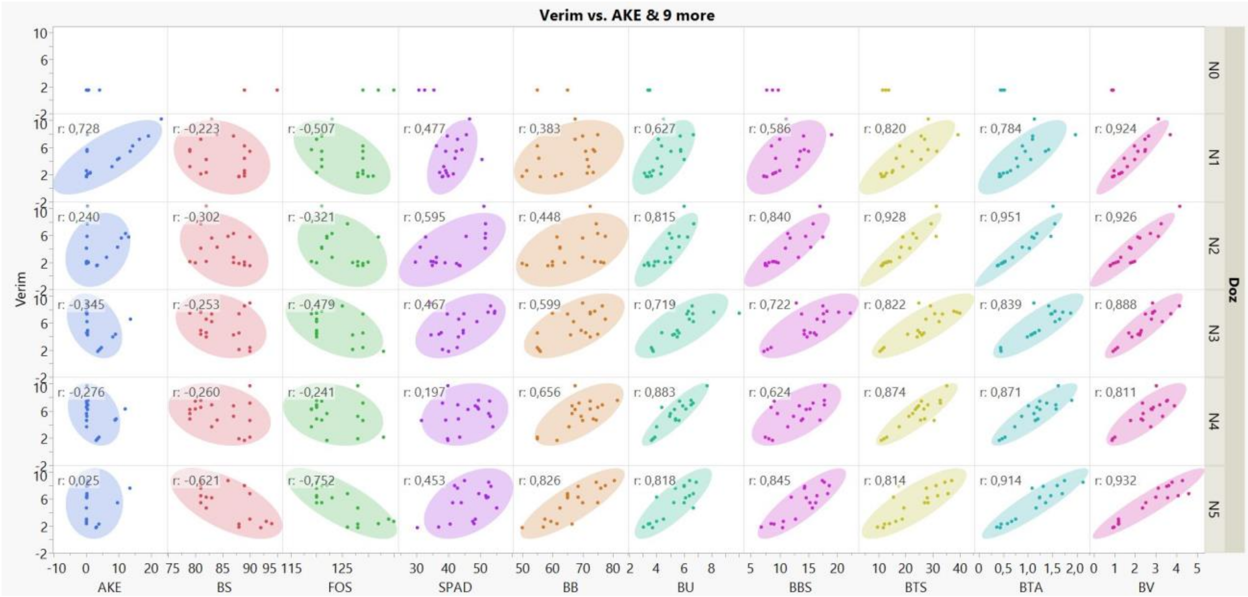
Farklı gübre uygulamaları arasında en yüksek azot kullanım etkinliği KG (20-20-0), STOG (Seleda) ve SG kaynaklarında elde edilirken, en düşük azot kullanım etkinliği ise BHG ve KHG kaynaklarında elde edilmiştir. Uygulanan dozlara göre ise en yüksek AKE N_1 dozunda elde edilirken, en düşük değer ise N_0 dozunda elde edilmiştir. Gübre uygulama*doz interaksiyonu bakımından en yüksek değerler SG kaynağının N_3 ve N_4 dozlarında elde edilirken, en düşük değer ise BHG kaynağının N_2 dozunda tespit edilmiştir (Çizelge 6). Kimyasal gübre kullanımının azaltılmasıyla bitki besin elementi kullanım etkinliğinin artırılması, verimin korunması ve toprak besin elementi kaybının azaltılmasında kilit bir faktördür (Geng vd., 2019; Yang vd., 2020; Zhang vd., 2016).

Özellikler arası korelasyon ilişkileri bakımından STOG (Seleda), TG, SG, KHG gübre kaynaklarında AKE ile tane verimi arasında pozitif ilişkiler saptanmıştır. Ayrıca uygulanan tüm gübre kaynaklarında verim ile verim öğeleri (SG de BBS hariç) arasında; STOG (Seleda), ile SG hariç diğer gübre kaynaklarında SPAD ile verim arasında pozitif korelasyonlar tespit edilmiştir. Gübre dozlarında ise N_1 dozunda verim ile AKE arasında pozitif korelasyon saptanırken, diğer dozlarda önemli korelasyon tespit edilmemiştir. İncelenen tüm dozlar bakımında verim ile verim öğeleri ve SPAD arasında önemli ilişkiler saptanmıştır (Şekil 2). Tarımsal üretimde kimyasal gübre azaltma yöntemlerinin uygulanmasında, verim artışı ve toprak verimliliğinin iyileştirilmesi etkilerinin kapsamlı bir şekilde dikkate alınması gerekmektedir. Kimyasal ve organik gübrelerin birlikte uygulanması, organik gübreden besin salınımını teşvik eder ve toprak verimliliğini artırmak için besin kayıplarını azaltır (Liu vd., 2021; Ning vd., 2017; Zhang vd., 2016). Toprak özellikleri toprak verimliliğini yansıtır ve bitki büyümesi ile verim artışının temel göstergeleridir (Du vd., 2020).



Şekil 2. Gübre kaynaklarına göre verim ile diğer özellikler arası korelasyon ilişkisi.
Figure 2. Correlation relationship between yield and other traits according to fertilizer sources.

BHG: Büyükbaş Hayvan Gübresi, KHG: Küçükbaş Hayvan Gübresi, KG: Kompoze Gübre (20-20-0), SG: Solucan Gübresi, TG: Tavuk Gübresi, STOG: Sertifikalı Ticari Organik Gübre (Seleda), AKE: Azot Kullanım Etkinliği, BS: Başaklanma Süresi, FOS: Fizyolojik Olum Süresi, BB: Bitki Boyu, BU: Başak Uzunluğu, BBS: Başakta Başakçık Sayısı, BTS: Başakta Tane Sayısı, BTA: Başakta Tane Ağırlığı, BV: Biyolojik Verim.



Şekil 3. Gübre dozlarına göre verim ile diğer özellikler arası korelasyon ilişkisi.
Figure 3. Correlation relationship between yield and other traits according to fertiliser doses.

AKE: Azot Kullanım Etkinliği, BS: Başaklanma Süresi, FOS: Fizyolojik Olum Süresi, BB: Bitki Boyu, BU: Başak Uzunluğu, BBS: Başakta Başakçık Sayısı, BTS: Başakta Tane Sayısı, BTA: Başakta Tane Ağırlığı, BV: Biyolojik Verim.

SONUÇ

Bu çalışmada, buğdayda verim ve verim bileşenleri üzerine farklı gübrelerin ve dozlarının etkileri ortaya konmaya çalışılmıştır. Özellikle küçükbaş hayvan gübresi kompoze gübre ile rekabet etmiş ve başarılı sonuçlar vermiştir. Buna ek olarak, tavuk gübresi de çok yüksek olmasa da diğer gübrelere kıyasla olumlu bir artış göstermiştir. Konvansiyonel üretim sisteminin bir parçası olan kompoze gübre uygulamasının, bitki tarafından hızlı bir şekilde alınması ve kullanılması nedeniyle etkili bir gübre kaynağı olduğu ve organik gübre uygulamasının bitki gelişimi üzerinde olumlu bir etkiye sahip olduğu sonucuna varılmıştır. AKE bakımından ise en yüksek değerler solucan gübresinin N_3 ve N_4 dozlarında elde edilmiştir. Ayrıca, geleneksel gübre ile karşılaştırılabilir sonuçlar veren koyun ve tavuk gübrelerinin buğday üretimi için önerilebileceği sonucuna varılmıştır.

Dünya nüfusundaki hızlı artıştan dolayı, başta buğday olmak üzere gıda üretiminde de bir artış gerektirmektedir. Çevreyi ve mevcut doğal kaynakları korumak için, buğday üretiminde daha fazla artış sağlamak ancak uygun bir gübreleme yönetimi ve programı ile mümkündür.

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Yazarlar bu makale ile ilgili herhangi bir çıkar çatışması olmadığını beyan ederler.

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Research Article / Araştırma Makalesi

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Tuzluluk Stresinin Topraksız Kültürde Yetiştirilen Domates Bitkisinde Bazı Gelişme ve Fizyolojik Parametreleri ile Makro Bitki Besin Elementi Kapsamına Etkileri

Effects of Salinity Stress on Some Growth and Pysiological Parameters and Macronutrient Content of Tomato Plants Grown in Soilless Culture

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Öz: Domates (*Lycopersicon esculentum* L.) yaygın bir şekilde yetiştirilen sebze ürünlerinden biri olup, büyüme ve gelişme dönemi boyunca tuzluluğa orta derecede duyarlı bir bitkidir. Bu çalışmada, topraksız kültürde farklı tuz seviyelerinde yetiştirilen domates bitkisinde gelişmenin, makrobesin kapsamının ve fotosentetik pigmentlerin değişimi incelenmiştir. Denemede 2:1 torf: perlit (v/v) karışımından her saksı için 1500 gram alınıp 3 litrelik saksılara konulmuştur. Her saksıya bir domates fidesi dikilmiştir. Denemede besin solüsyonuna sodyum klorür (NaCl) artan konsantrasyonlarda [0 (T_0), 14.4 mM (T_1), 44.4 mM (T_2) ve 70.4 mM (T_3)] ilave edilmiştir. Besin çözeltisinde artan NaCl konsantrasyonu yaprak sayısını ve kök kuru ağırlığını önemli derecede azaltmıştır. Fakat bitki boyuna, gövde çapına, gövde ve yaprak kuru ağırlığına NaCl ilavesinin etkisi önemsiz bulunmuştur. Bununla birlikte, besin çözeltisindeki NaCl konsantrasyonundaki artışın, domates bitkisi yaprağında fotosentetik pigmentler üzerine etkisi anlamlı bulunmuştur. Besin çözeltisine T_2 düzeyinde NaCl ilavesi kontrole (T_0) göre yaprakta klorofil-b, toplam klorofil ve karotenoid kapsamını önemli derecede arttırmıştır. Besin çözeltisinde NaCl konsantrasyonu arttıkça yaprakta N ve P kapsamı artış gösterirken; K, Ca, Mg ve S kapsamı azalma göstermiştir. Ayrıca besin çözeltine NaCl ilavesi hasat sonu yaprak analizlerine göre yaprakta N, P, K, Ca, Mg ve S noksanlıklarına sebebiyet vermemiştir. Domates bitkilerinin tuzluluk stresine karşı adaptasyonunu arttırmak amacıyla, besin çözeltilerinde kontrollü NaCl uygulamaları ve etkin makro besin yönetimi stratejileri geliştirilmelidir.

Anahtar Kelimeler: Domates, topraksız kültür, tuz stresi, makro besin elementi, fotosentetik pigmentler

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Abstract: The tomato (*Lycopersicon esculentum* L.) is one of the most commonly grown vegetable crops and is moderately sensitive to salinity during the growth and development period. This study investigated the changes in growth, macronutrients and photosynthetic pigments in tomato plants grown in soilless culture under different salinity levels. One thousand five hundred grammes (1500 g) of substrate (2:1 peat: perlite (v/v) mixture) was added to each 3-litre pot. A tomato seedling (Kardelen F1 variety) was planted in each pot. In the experiment, sodium chloride (NaCl) was added to the nutrient solution at increasing concentrations [0 (T_0), 14.4 mM (T_1), 44.4 mM (T_2) and 70.4 mM (T_3)]. Increasing the NaCl concentration in the nutrient solution significantly reduced the number of leaves and the dry weight of the roots. However, the effect of NaCl addition on plant height, stem diameter, stem and leaf dry weight was found to be insignificant. Conversely, it was observed that an increase in the NaCl concentration in the nutrient solution had a significant effect on the content of photosynthetic pigments in the leaves of the tomato plants. The addition of NaCl to the nutrient solution at T_2 level significantly increased the chlorophyll-b, total chlorophyll and carotenoid content in the leaf compared to the control (T_0). With increasing NaCl concentration in the nutrient solution, N and P in the leaf increased, while K, Ca, Mg and S decreased. Furthermore, post-harvest leaf analysis revealed that the addition of NaCl to the nutrient solution did not result in deficiencies of N, P, K, Ca, Mg, and S in the leaves. In order to increase the adaptation of tomato plants to salinity stress, controlled NaCl applications in nutrient solutions and effective macronutrient management strategies should be developed.

Keywords: Tomato, soilless culture, salt stress, macronutrients, photosynthetic pigments

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GİRİŞ

Tuzluluk, halihazırda sulanan alanların üçte birinden fazlasını etkilemekte ve 2050 yılına kadar dünyadaki ekili alanların yarısından fazlasının tuzlanması beklenmektedir (FAO, 2011; Zhao vd., 2020). Toprak tuzlanması arazi kullanımını ciddi şekilde sınırlandırmakta ve ürün verimini önemli ölçüde etkilemektedir (van Zelm vd., 2020).

Bitki kök bölgesindeki yüksek tuz konsantrasyonu, ozmotik stres, iyon (Na^+) toksisitesi, hormonal ve besinsel dengesizlik, oksidatif stres ve hücre içi potasyum (K^+) homeostazının bozulması gibi bir dizi zararlı etki yaratır (Liang vd., 2018). Tuz stresi, reaktif oksijen türleri birikimine neden olur (Achard vd., 2008; Miller vd., 2010), bu da ikincil olarak indüklenen oksidatif hasarın redoks homeostazisini engelleyerek fotosentetik etkinliğin azalmasına (Miller vd., 2010; Xie vd., 2011; Khan vd., 2014) neden olmakla birlikte nitrojen ve osmolit metabolizmasını (Ahanger ve Agarwal, 2017; Ahanger vd., 2020), mineral asimilasyonunu, fitohormon profilini ve genlerin ifadesini de değiştirir (Fallah vd., 2017; Ma vd., 2018). Ayrıca, tuz stresinin kök anatomisini ve kök morfolojik parametrelerini etkilediği de rapor edilmiştir (Rivero vd., 2014; Robin vd., 2016).

Tuzluluk stresine yanıt olarak morfolojik görünümde meydana gelen değişiklikler, etkiyi belirleme ve ardından yönetim stratejilerini geliştirmek için yeterli değildir (Loudari vd., 2020). Bu nedenle, bitkilerin tuzluluk toleransını iyileştirmek için temel fizyolojik ve biyokimyasal faktörleri belirlemek önemlidir (Munns ve Tester, 2008; Ahanger ve Agarwal, 2017; Ahanger vd., 2020).

Tuzluluğun olumsuz etkilerini önlemek için bitkilerde antioksidan sistem, ozmotik düzenleme, kök ve vakuol seviyesinde etkili tuz uzaklaştırması gibi mevcut mekanizmalar bulunmaktadır (Horie vd., 2012; Deinlein vd., 2014; Ahanger vd., 2020). Bununla birlikte, bitkilerin dokularındaki yüksek tuz seviyelerini tolere etme ve biriktirme kapasitelerinin farklılık gösterdiği bilinmektedir. Bu nedenle, deneysel koşullara ve araştırmada seçilen bitki türüne bağlı olarak farklı sonuçlar elde edilebilir (Loudari vd., 2020).

Tuzluluğun bitki dokularındaki fosfor (P) gibi besin maddelerinin konsantrasyonlarını değiştirdiğini gösteren çalışmaların çoğu toprakta gerçekleştirilmiştir (Loudari vd., 2020). Öte yandan, topraksız yetiştiricilikte de tuz uygulamalarının domatesin bazı kalite özelliklerini arttırması sebebiyle bu çalışmada domatesin tuz stresine vereceği cevabı, toleransını görmek gerekmektedir. Özellikle seracılığın yaygın olduğu ülkelerde topraksız tarım oldukça popülerdir ve bunun birçok nedeni vardır. Bunlar arasında ilk sırada, yetiştiricilikte toprağa bağımlılığı ortadan kaldırması gelmektedir. Topraksız tarım teknikleri, kök ortamı olarak yalnızca besin çözeltisine sahip su kültürü sistemlerinde yapılan yetiştiriciliğin yanı sıra, bitki büyümesi için uygun oranlarda hem havayı hem de suyu tutabilen bir matris oluşturan gözenekli bir yetiştirme ortamında yapılan yetiştiriciliği de ifade etmektedir (Akınoğlu vd., 2021). Topraksız tarımın verimli olabilmesi için besin solüsyonlarının tuz içeriği dikkatle izlenmeli ve kontrol edilmelidir. Doğru tuz seviyesinin korunması, bitki köklerinin optimum beslenmesini sağlayarak sağlıklı bitki gelişimini destekler.

Tuzluluk ile bitkilerin beslenmesi arasındaki etkileşim büyük ölçüde bitki türü ve gelişim yaşına, tuzluluğun bileşimi ve düzeyine, substrattaki makro ve mikro elementlerin konsantrasyonuna bağlıdır (Loupassaki vd., 2002; Shahriaripour vd., 2011). Tuz stresi koşulları altında Na^+ gibi bazı iyonların yüksek konsantrasyonu nedeniyle, temel besin maddelerinin bitkiler tarafından absorpsiyonu azalır (Flowers ve Flowers, 2005). Saneoka vd. (2001), tuzun bitki kök ve sapındaki K^+ ve Ca^{+2} akümülasyonunu engellediğini, K^+, Ca^{+2} ve Mg^{+2} iyonlarının yapraklara taşınımı üzerine sodyum klorürün olumsuz etkisinin bir sonucu olarak bu elementlerin noksanlığına sebebiyet verdiğini bildirmişlerdir. Öte yandan, domates yapraklarındaki K, Ca ve Mg içeriğinin tuz stresi altında arttığını gösteren çalışmalar da mevcuttur (Costan vd., 2020; Javeed vd., 2021).

En önemli sebze ürünlerinden biri olan domates (*Lycopersicon esculentum* L.) dünya çapında yetiştirilmektedir (Guo vd., 2022). Meyveleri gıda olarak yaygın bir şekilde kullanılmaktadır ve aynı zamanda meyve gelişimi, genetik ve stres toleransı araştırmaları için model bir bitkidir (Rothan vd., 2019).

Bu çalışmada, topraksız kültürde farklı tuz seviyelerinde yetiştirilen domates bitkisinde gelişmenin, makro-besin kapsamının ve fotosentetik pigmentlerin değişimi incelenmiştir.

MATERYAL VE METOT

Denemede sırık domates çeşidi (*Lycopersicon esculentum* L. cv. Kardelen F1) fideleri her saksıya bir bitki gelecek şekilde dikilmiştir. Domates fideleri Antalya'da fide üretimi yapan firma tarafından tedarik edilmiştir. Deneyde, yetiştirme ortamı için torf ve perlit 2:1 (v/v) oranında karıştırılmıştır. Turba yosunu (Klasmann) Sphagnum cinsine ait, su tutma kapasitesi yüksek, pH değeri 5.5 ile 6.0 arasında olan bir yosundur. Genleşmiş mineral perlit, nötr pH'ya ve yüksek havalandırma kapasitesine sahip, inert, tuz içermeyen bir substrattır. 3 L kapasiteli, 16.5 cm çapında ve 19.0 cm derinliğindeki her bir saksıya bin beş yüz gram (1500 g) substrat konuldu. Drenaj için saksıların dibine delikler açılmıştır.

Deneme, besin çözeltisine NaCl artan dozlarda, T_0 = 0, T_1=14.1 mM, T_2= 44.4 mM ve T_3= 70.4 mM, üç tekerrürlü olarak uygulanmıştır. Besin çözeltisine ilave edilen tuzun dozları Korkmaz vd. (2018)'ne göre belirlenmiştir.

Domates bitkisine (Kardelen F1 çeşidi) Alpaslan vd. (1998) tarafından önerilen besin çözeltisi formülü uygulanmıştır (Çizelge 1).

Çizelge 1. Besin çözeltisinin kimyasal bileşimi (Alpaslan vd., 1998).
Table 1. Chemical composition of the nutrient solution (Alpaslan et al., 1998).

Makro besinler (mM)							Mikro besinler (µM)					
NO_3^--N	NH_4^+-N	P	K	Ca	Mg	SO_4^{-2}-S	Fe	Mn	Cu	Zn	B	Mo
12.0	0.5	1.25	5.25	2.75	1.125	0.125	40	5	0.75	4	30	0.5

Farklı deneme konularını içeren besin çözeltisi uygulamaları dikimle beraber başlatılmış, her saksıya yaklaşık 30 gün her gün 150 mL besin çözeltisi uygulanmıştır. Çiçeklenmeden veya meyve tutumu başlangıcından sonra ise bitki başına her saksıya günde 300 mL besin çözeltisi uygulanmıştır. Deneme süresince saksılardaki drenaj kontrol edilerek saksıların nem içeriği tarla kapasitesi civarında tutulmuştur. İlk dönemlerde saksılar sürekli tartılarak kaybolan su miktarı tarla kapasitesindeki ağırlığa kadar ilave edilmiştir. Denemenin başlangıcından itibaren meyve oluşumuna kadar geçen süre boyunca günlük ortalama kaybolan su miktarı belirlenmiştir. Bu günlük kaybolan su miktarı bitkinin meyveli dönemlerinde tartım işlemi yapılmaksızın ilave edilmiştir. Deneme 90 gün sürmüştür.

Domates Bitkilerinde Yapılan Ölçüm, Gözlem ve Analizler

Yaprak Sayısı, Bitki Boyu (cm) ve Gövde Çapı (mm)

Hasattan hemen önce, gözlem bitkisinde yaprak sayıları tespit edilmiş, bitki boyu ölçümleri yapılmıştır. Bitkilerde kök boğazı ile büyüme ucu arasındaki mesafe şerit metre ile bitki boyu olarak ölçülmüştür. Substrat yüzeyinin 5 cm yukarısından 0.01 mm'ye duyarlı dijital kumpas ile gövde çapı ölçümleri yapılmıştır.

Kök, Gövde ve Yaprak Vejetatif Kuru Ağırlıkları (g)

Hasat dönemine ulaşmış domates bitkisi, bıçak ile kök boğazı kısmından kesilerek ayrılmıştır. Domates bitkisinin topraküstü aksamlarına (gövde+yaprak) ek olarak, kökleri de substrat ortamından temizlenerek çıkartılmıştır. Bitkilerin kökleri, musluk suyu altında, kayıp olmayacak şekilde yıkanarak temizlenmiş ve daha sonra bu köklerin kurutma kağıdı ile nemi alınmış ve oda koşullarında 15 dakika süreyle bekletilmiştir. Son olarak kısımlarına ayrılmış domates bitkileri, kese kâğıtlarına koyulmuş ve 65-80 °C'ye ayarlı etüvde (Nüve, ES-500, Türkiye) sabit ağırlığa gelinceye kadar kurutulmuştur. Daha sonra 0.001 g'a duyarlı dijital hassas terazide (Precisa, XB-620M, Switzerland) tartılarak, kök, gövde ve yaprak vejetatif kuru ağırlıkları tespit edilmiştir.

Bitkinin Taze Yaprağında Klorofil ve Karotenoid Konsantrasyonunun Belirlenmesi

Klorofil-a, klorofil-b, toplam klorofil ve karotenoid konsantrasyonunu belirlemek amacıyla domates bitkisinin tam gelişmiş, sağlıklı yapraklarından hasattan 1 hafta önce taze yaprak örnekleri alınmıştır. Bu örneklerde klorofil ve karotenoid analizi aşağıdaki yönteme göre yapılmış ve hesaplanmıştır.

0.2 g taze yaprak örneği hassas bir terazide tartılarak, porselen bir havana alınmıştır. Üzerine 0.1 g magnezyum oksit ve 0.25 g ince kum ilave edilmiştir. Daha sonra karışım, doğrudan güneş ışığı gelmeyen loş bir yerde, soğuk ortam eşliğinde %80'lik (v/v) aseton içerisinde homojenize edilip, filtre edildikten sonra ekstrakt aseton ile 25 mL'ye tamamlanmıştır. Bu şekilde elde edilecek ekstrakt örneklerinin UV-Visible spektrofotometre (Shimadzu Corporation, Kyoto, Japonya) cihazında 645, 663 ve 480 nanometre dalga boylarında absorbansları ölçülmüştür. Taze yapraklarda klorofil-a, klorofil-b, toplam klorofil ve karotenoid miktarları aşağıdaki formüllerde belirtildiği şekilde hesaplanmış ve analiz sonuçları bitkide mg g^{-1} taze madde (TM) olarak ifade edilmiştir (Arnon, 1949; Witham vd., 1971).

$$\text{Klorofil a, mg x } g^{-1} \text{ TM} = [(12.70 \times A_{663}) - (2.69 \times A_{645})] \times V \times (1000 \times w)^{-1} \quad (1)$$

$$\text{Klorofil b, mg x } g^{-1} \text{ TM} = [(22.90 \times A_{645}) - (4.68 \times A_{663})] \times V \times (1000 \times w)^{-1} \quad (2)$$

$$\text{Toplam klorofil, mg x } g^{-1} \text{ TM} = [(20.2 \times A_{645}) + (8.02 \times A_{663})] \times V \times (1000 \times w)^{-1} \quad (3)$$

$$\text{Karotenoid, mg x } g^{-1} \text{ TM} = (A_{480} \times V) \times (250 \times w)^{-1} \quad (4)$$

A_{663} = 663 nm'deki absorbans okuma değeri
A_{645} = 645 nm'deki absorbans okuma değeri
V = Son hacim, mL
w = Örnek miktarı, g TM

Kuru Yaprakta Makro Element (N, P, K, Ca, Mg, SO_4^{-2}-S) Tayinleri

Kurutulmuş ve öğütülmüş domates bitkisinin yaprak numuneleri hacimce (% v/v) 4:1'lik nitrik : perklorik asit karışımı içerisinde ve hot plate üzerinde yaklaşık bir saat 200 ºC'de yakılma işlemine maruz bırakılmıştır. Yakma işleminin ardından örneklerin son hacmi 100 mL olacak şekilde saf su ile tamamlanmıştır. Böylece elde edilen bitki ekstraklarındaki toplam potasyum, fosfor, kalsiyum, magnezyum ve kükürt tayinleri, Kacar ve İnal (2008)'e göre belirlenmiştir. Kurutulmuş ve öğütülmüş domates bitkisinin yaprak numunelerinde toplam azot (N) kapsamı ise modifiye Kjeldahl yaş yakma yöntemiyle tayin edilmiştir (Bremner ve Mulvaney, 1982).

İstatistiksel Analizler

Deneme, tesadüf parselleri deneme desenine göre her uygulamada 3 tekerrür olacak şekilde kurulmuştur. Verilerin varyans analizi ile incelenmesinde, SPSS 17.0 paket programından yararlanılarak Fisher LSD çoklu karşılaştırma testi yapılmıştır ve farklılık dereceleri, % 5 düzeyinde harflendirme yoluyla gösterilmiştir.

BULGULAR VE TARTIŞMA

Morfolojik Gelişme Üzerine Etkisi

Katı ortama uygulanan besin çözeltisinde artan NaCl konsantrasyonlarının domates bitkisinde morfolojik gelişme üzerine etkileri Çizelge 2'de verilmiştir.

Besin çözeltisindeki artan tuz konsantrasyonunun bitkide yaprak sayısı ve kök kuru ağırlığı üzerine etkileri sırasıyla $p < 0.01$ ve $p < 0.05$ seviyesinde önemli bulunmuş; fakat bitki boyu ve gövde çapı ile gövde ve yaprak kuru ağırlığı üzerine etkisi önemsiz bulunmuştur (Çizelge 2). Besin çözeltisine NaCl ilavesi bitkide yaprak sayısını ve kök kuru ağırlığını önemli derecede azaltmıştır. Fakat dozlara göre bu azalmaların trendi dalgalı bir değişim göstermiştir (Çizelge 2). Tuzluluğun bitki morfolojisi üzerindeki etkileriyle ilgili olarak, gelişimin tüm aşamalarında bitki boyunu, kök/sürgün oranını, yaprak alanını, dal sayısını veya bitki başına yaprak/çiçek sayısını etkileyen değişiklikler ortaya çıkabilir (Roşca vd., 2023). Domates bitkileri üzerindeki tuzluluk etkilerine odaklanan çalışmalar, bitki morfolojisindeki değişikliklerin yoğunluğunun yetiştirme ortamındaki tuz seviyesine bağlı olduğunu göstermiştir. Birçok çalışma, yetiştirme ortamındaki tuz değişiminin taze biyokütle, bitki boyu, kök/sürgün oranı, yaprak alanı, dal sayısı ve bitki başına yaprak/çiçek sayısında negatif veya pozitif değişikliklere neden olduğunu göstermiştir. Ek olarak, her çeşit/hibrit tuz stresine farklı tepki verir (Roşca vd., 2023). Yapılan araştırmalar, tuzluluk konsantrasyonu arttıkça yaprak alanı, yaprak sayısı ve yaprak uzunluğu üzerindeki zararlı etkilerin arttığını göstermiştir (Hossain vd., 2012; Abdelaziz ve Abdeldaym, 2019; Maeda vd., 2020). Diğer yandan, Prazeres vd. (2013) sulama suyundaki NaCl konsantrasyonunun 3.22 dS m^{-1} seviyelerine kadar arttırılmasının, Roma domates çeşidinin yapraklarının taze ağırlığında bir artışa (bitki başına 84.7 g) yol açtığını; ancak daha yüksek NaCl konsantrasyonunda ise yaprak ağırlığının düşüşe geçtiğini bildirmiştir. Bununla birlikte, Rio Grande domates çeşidinde ise 1.75 dS m^{-1} seviyesinin üzerindeki sulama suyunun bitkinin kök, sürgün ve yaprak taze ağırlığı, yaprak alanı, gövde başına boğum sayısı, birincil kök ve gövde uzunluğu üzerinde olumlu bir etkiye sahip olduğu aynı araştırmacı tarafından rapor edilmiştir.

Çizelge 2. NaCl konsantrasyonlarının domates bitkisinde morfolojik gelişme üzerine etkisi.
Table 2. Effect of NaCl concentrations on the morphological development of tomato plants.

NaCl (mM)	Bitki boyu (cm)	Bitki gövde çapı (mm)	Bitkide yaprak sayısı (adet bitki^{-1})	Kök kuru ağırlığı (g bitki^{-1})	Gövde kuru ağırlığı (g bitki^{-1})	Yaprak kuru ağırlığı (g bitki^{-1})
T_0 (Kontrol)	165.66	15.48	18.33 a	6.6 a	32.1	42.6
T_1	175.00	15.61	14.66 b	6.1 b	34.7	43.2
T_2	169.33	14.92	16.33 b	6.1 b	31.4	43.2
T_3	164.33	14.29	16.33 b	6.2 b	28.9	44.0
$LSD_{0.05}$	-	-	1.71	0.33	-	-
Önemlilik seviyesi	ns	ns	**	*	ns	ns

Aynı harflerle gösterilen ortalamalar arasında 0.05 düzeyinde anlamlı bir fark yoktur; ns; Anlamlı değil; *;%5 düzeyinde anlamlı, **;%1 düzeyinde anlamlı. T_0 = 0, T_1=14.1 mM, T_2= 44.4 mM ve T_3= 70.4 mM NaCl.

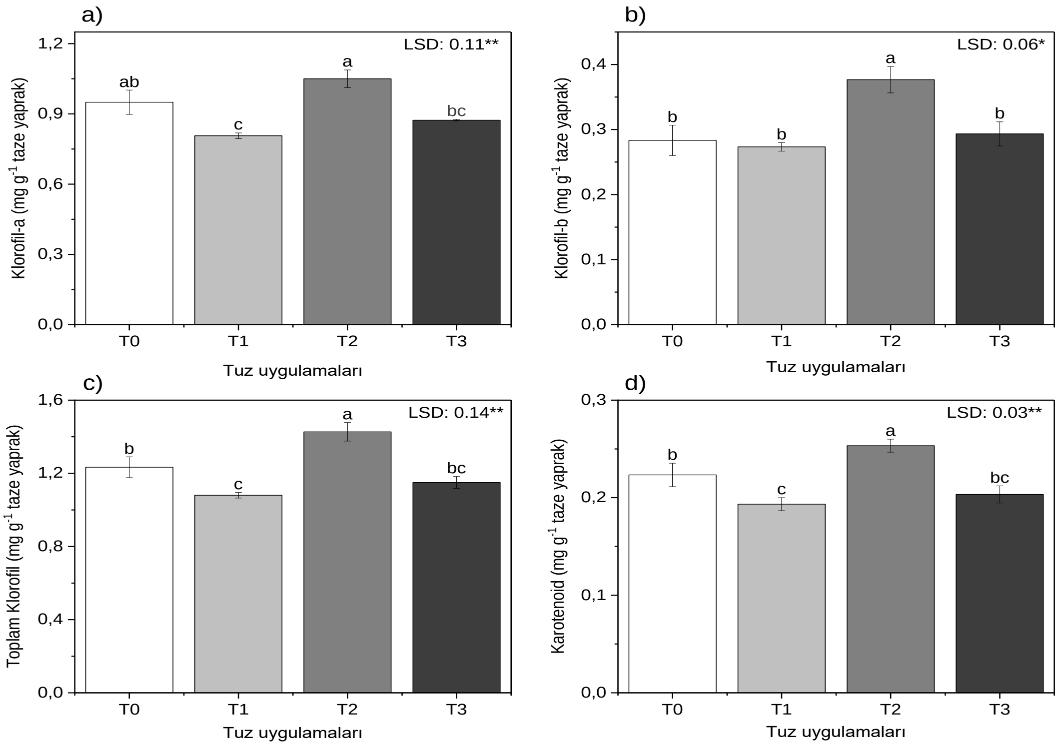
Birçok çalışma, tuz konsantrasyonu ile fotosentez arasında güçlü bir negatif korelasyon olduğunu göstermiştir (Chartzoulakis vd., 2002; Lovelli vd., 2012; Paranychianakis ve Chartzoulakis, 2005). Tuzluluk, fotosentezi etkileyen ilk süreçtir. Tuz stresi, yaprak su potansiyelinde azalmaya ve stomatal direnç ile birlikte gaz akışına karşı mezofil direncin artmasına neden olur, bu da sonrasında fotosentetik aktivitenin kısıtlanmasına yol açar (Bethke ve Drew, 1992; Flexas vd., 2004). Tuz stresi altında stoma iletkenliğinin ve fotosentezin azalması, yaprak gelişimi ve kuru madde üretimini azaltır (Rivelli vd., 2002). Düşük tuz konsantrasyonları halofitik olmayan bitkilerde büyüme geriliğine neden olabilirken, yüksek konsantrasyonlar bitkinin ölümüyle bile sonuçlanabilmektedir (Short ve Colmer, 1999; Suwa vd., 2006; Chen vd., 2009). Tuzluluğa verilen tepki, bitkinin türüne, büyüme aşamasına ve tuzluluk seviyesine göre değişmektedir (Alzahib vd., 2021). Örneğin, buğday, çeltik ve mısır gibi tahıl ürünlerinde bitki biyokütlesinin 100 ila 150 mM NaCl seviyelerinde azalma gösterdiği; ayçiçeği ve domates bitkilerinde ise 50 mM NaCl seviyelerinde biyokütlede azalma göstediği bildirilmiştir (Alzahib vd., 2021). Ancak, 200-300 mM tuz (NaCl) seviyelerinde tüm bitkilerin gelişimlerinin olumsuz etkilendiği rapor edilmiştir (Soltabayeva vd., 2021).

Fotosentetik Pigmentler Üzerine Etkisi

Katı ortama uygulanan besin çözeltisinde artan NaCl konsantrasyonlarının domates bitkisi yapraklarında fotosentetik pigmentler üzerine etkileri Şekil 1'de verilmiştir.

Besin çözeltisindeki NaCl konsantrasyonunun artışın, domates bitkisi yaprağında klorofil-a, toplam klorofil ve karotenoid kapsamına etkisi $p<0.01$ düzeyinde, klorofil-b kapsamına etkisi de $p<0.05$ düzeyinde anlamlı bulunmuştur (Şekil 1a-d).

Besin çözeltisindeki tuz konsantrasyonu klorofil-a kapsamını kontrole göre T_1 tuz seviyesinde önemli derecede azalttığı halde; T_2 ve T_3 tuz konsantrasyonlarında etkilememiştir (Şekil 1a). Tuz konsantrasyonu, yaprakta klorofil-b kapsamını kontrole göre T_1 ve T_3 seviyelerinde etkilememiş; fakat T_2 tuz konsantrasyonunda klorofil-b kapsamında önemli derecede artış görülmüştür (Şekil 1b).



Şekil 1. NaCl konsantrasyonlarının domates bitkisi yapraklarında fotosentetik pigmentler üzerine etkisi.

(Aynı harflerle gösterilen ortalamalar arasında 0.05 düzeyinde anlamlı bir fark yoktur; *: %5, **: %1 düzeyinde anlamlı farkı ifade eder. $T_0 = 0$, T_1=14.1 mM, T_2= 44.4 mM ve T_3= 70.4 mM NaCl).

Figure 1. Effect of NaCl concentration on photosynthetic pigments in tomato plant leaves.

(There is no significant difference at the 0.05 level between the mean values shown with the same letters; *; indicates a significant difference at the 5% level, **; indicates a significant difference at the 1% level. $T_0 = 0$, T_1=14.1 mM, T_2= 44.4 mM ve T_3= 70.4 mM NaCl).

Toplam klorofil kapsamı kontrole göre T_1 tuz düzeyinde azalma göstermiş; buna karşın, T_2 tuz düzeyinde artmıştır. Bununla birlikte, T_3 tuz seviyesinde toplam klorofil kapsamı kontrole ve T_1 tuz konsantrasyonuna göre etkilenmemiştir (Şekil 1c). Yaprakta karotenoid kapsamı kontrole göre T_1 tuz içeren besin çözeltisi uygulamasıyla azalma göstermiş; buna karşın, T_2 tuz içeren besin çözeltisi uygulamasıyla artış göstermiştir. Fakat dozlara göre bu artışların trendi dalgalı bir değişim göstermiştir. Bu durum bitki örneklemesi ve yapılan analiz hatalarından kaynaklanmış olabilir. T_3 tuz içeren besin çözeltisi uygulamasının yaprakta karotenoid kapsamına etkisi kontrole göre önemsiz bulunmuştur (Şekil 1d).

Yaprak klorofil içeriği fotosentetik kapasitenin önemli bir göstergesidir (Houborg vd., 2015; Cannella vd., 2016). Bununla birlikte, karotenoidler ise karotenler ve ksantofillerden oluşur ve bir diğer önemli fotosentetik pigment grubunu temsil eder (Shah vd., 2017). Domates bitkisinin yapraklarındaki klorofil sentezi, yüksek tuz seviyelerine maruz kalmaktan olumsuz etkilenebilir (Giannakoula ve Ilias, 2013; Taheri vd., 2020). Bu, kloroplast aktivitesinin ve fotosentezin azalmasına, klorofilaz enzim aktivitesinin ve solunumun artmasına ve ardından klorofil içeriğinin azalmasına neden olan metabolik bozukluklardan kaynaklanabilir (Taheri vd., 2020). Singh vd. (2016), topraksız yetiştiricilikte NaCl düzeyinin 0'dan 0.5 g kg^{-1}'a çıktığında ''Lakshmi'' domates çeşidinin yapraklarındaki klorofil içeriğinin 0.996 mg g^{-1} 'dan 0.751 mg g^{-1} 'a düştüğünü bildirmişler ve aynı eğilimi, içeriği kontrole göre %27.73 oranında azalan klorofil b sentezinde de gözlemlemişlerdir. Başka bir çalışmada, tuz stresi altında (120 mM NaCl) hidroponik sistemde yetiştirilen Super Chef domates çeşidinde toplam klorofil içeriği kontrole (0 mM NaCl) kıyasla %40.93 oranında azalmıştır (Taheri vd., 2020). Diğer yandan, önceki çalışmalar, tuzluluk stresinin tuza toleranslı bitkilerde yaprak alanı başına toplam klorofil içeriğini arttırdığını (Higbie vd., 2010) ve tuz stresi altında toplam klorofil kapsamındaki artışın bitkilerde tuz toleransının biyokimyasal bir göstergesi olarak kullanılabileceğini göstermiştir (Stefanov vd., 2016; Jiang vd., 2017). Orta derecede tuz stresinin, fotosentetik sistemin düzgün işleyişini sürdürmek için toplam klorofil ve karotenoid biyosentezini arttırabildiği bildirilmiştir (Shah vd., 2017).

Makro Besin Kapsamı Üzerine Etkisi

Katı ortama uygulanan besin çözeltisinde artan NaCl konsantrasyonlarının domates bitkisinin yaprağında makro besin element kapsamı üzerine etkileri Çizelge 3'te verilmiştir.

Çizelge 3. NaCl konsantrasyonlarının domates bitkisi yaprağında makro element kapsamı üzerine etkisi.
Table 3. Effect of NaCl concentration on the content of macroelements in tomato leaves.

NaCl (mM)	N, %	P, %	K, %	Ca, %	Mg, %	S, %
T_0 (Kontrol)	3.47 d	0.24 bc	2.65 a	1.70 a	0.85 a	0.57 a
T_1	3.55 c	0.23 c	2.61 a	1.60 b	0.76 b	0.49 b
T_2	3.61 b	0.25 ab	2.27 b	1.37 c	0.60 c	0.38 c
T_3	3.94 a	0.27 a	2.22 c	1.11 d	0.49 d	0.33 d
$LSD_{0.05}$	0.05	0.01	0.04	0.03	0.04	0.03
Önemlilik seviyesi	**	*	**	**	**	**

Aynı harflerle gösterilen ortalamalar arasında 0.05 düzeyinde anlamlı bir fark yoktur; *;%5 düzeyinde anlamlı, **;%1 düzeyinde anlamlı. T_0 = 0, T_1=14.1 mM, T_2= 44.4 mM ve T_3= 70.4 mM NaCl.

Besin çözeltisindeki artan tuz konsantrasyonunun yaprakta toplam N, K, Ca, Mg ve S kapsamlarına etkisi $p < 0.01$ seviyelerinde önemli iken; P kapsamına etkisi $p <0.05$ düzeyinde önemli bulunmuştur (Çizelge 3).

Artan tuz konsantrasyonu kontrole göre yaprakta N kapsamını önemli derecede arttırmıştır. Kontrole göre T_1 ve T_2 tuz konsantrasyonlarında yaprakta P kapsamı önemli derecede etkilenmemiş; fakat T3 konsantrasyonunda tuz uygulaması yaprakta P kapsamını önemli derecede arttırmıştır. Na^+ iyonunu yüksek miktarda içeren ortamlarda fosforun çözünürlüğü artacağından bitkideki konsantrasyonunun yükselmesine sebep olmuş olabilir. Besin çözeltisinde NaCl konsantrasyonu arttıkça yaprakta K, Ca, Mg ve S kapsamı azalma göstermiş; fakat K besinindeki azalma T_1 tuz konsantrasyonunda önemsiz bulunmuştur (Çizelge 3). Yüksek tuz konsantrasyonunun K, Ca, Mg kapsamını azaltmadaki sebebi Na ile K, Ca ve Mg arasındaki antagonistik etkileşimdir. Aynı şekilde, yüksek tuz konsantrasyonunun yaprakta kükürt kapsamını azaltmadaki sebebi Cl^- ve SO_4^{-2} arasındaki antagonistik etkileşimdir. Topraksız ortamda yetiştirilen domates bitkisinin temel mineral alımı tuzluluk stresinden önemli ölçüde etkilenir (Sánchez vd., 2012; Nebauer vd., 2013). Bitki yetişme ortamındaki yüksek tuz seviyeleri Ca, K ve bazen de Mg iyonlarının daha az alınmasına neden olabilir (Sánchez vd., 2012; Nebauer vd., 2013; Assimakopoulou vd., 2015; Parvin vd., 2016). Öte yandan, mevcut çalışmada hasat zamanı alınan domates bitkisi yaprak örneklerinde azotun yüksek, fosforun yeterli, potasyumun yeterli ve yüksek, kalsiyumun yeterli, magnezyumun yeterli ve yüksek, kükürdün yeterli seviyelerde oldukları tespit edilmiştir (Hochmuth vd., 2012). Diğer bir ifadeyle, yetiştirilen domates bitkilerinin artan tuz konsantrasyonunda besin çözeltisi ile beslenmelerine rağmen yapraklarında makro-element noksanlığı tespit edilmemiştir.

SONUÇ

Besin çözeltisinde artan NaCl konsantrasyonu yaprak sayısını ve kök kuru ağırlığını önemli derecede azaltmıştır. Fakat bitki boyuna, gövde çapına, gövde ve yaprak kuru ağırlığına NaCl ilavesinin etkisi önemsiz bulunmuştur. Bununla birlikte, besin çözeltisindeki NaCl konsantrasyonundaki artışın, domates bitkisi yaprağında fotosentetik pigmentler üzerine etkisi anlamlı bulunmuştur. Besin çözeltisine T_2 düzeyinde NaCl ilavesi yaprakta klorofil-b, toplam klorofil ve karotenoid kapsamını önemli derecede arttırmıştır. Besin çözeltisinde NaCl konsantrasyonu arttıkça yaprakta N ve P kapsamı artış gösterirken; K, Ca, Mg ve S kapsamı azalma göstermiştir. Ayrıca, besin çözeltine NaCl ilavesi hasat sonu yaprak analizlerine göre yaprakta N, P, K, Ca, Mg ve S noksanlıklarına sebebiyet vermemiştir. Bu çalışma, belirli NaCl konsantrasyonlarının dikkatli yönetimi ile domates bitkilerinde fotosentetik pigmentlerin artırılabileceğini ve besin dengesi korunarak tuz stresine karşı optimal büyüme stratejilerinin geliştirilebileceğini göstermektedir.

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Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi

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Effects of Doses and Different Applications of Salicylic Acid on Salinity Stress and Plant Growth in Broad Beans (*Vicia faba* L.)

Salisilik Asitin Farklı Uygulama Şekli ve Dozlarının Bakla (*Vicia faba* L.)'da Tuzluluk Stresi ve Bitki Gelişimi Üzerine Etkisi

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DÜZELTME

Bu düzeltme metni, **Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi**'nin **2024** yılı **10**. cilt, **2**. sayısında **10.24180/ijaws.1436876** DOI numarasıyla yayımlanan Uçar, Ö., Soysal, S., Erman, M., Çığ, F., Önder S.' in "**Salisilik Asitin Farklı Uygulama Şekli ve Dozlarının Bakla (*Vicia faba* L.)'da Tuzluluk Stresi ve Bitki Gelişimi Üzerine Etkisi**" başlıklı makalede, Teşekkür bölümünde yer alan "**Proje Numarası"**nın yazarlar tarafından sehven hatalı olması nedeniyle yazılmıştır.

ERRATUM

This correction was written because the "**Project Number**" in the Acknowledgement section of the article titled "**Effects of Doses and Different Applications of Salicylic Acid on Salinity Stress and Plant Growth in Broad Beans (*Vicia faba* L.)**" by Uçar, Ö., Soysal, S., Erman, M., Çığ, F., Önder S., published in the **10th** volume, **2nd** issue of the **International Journal of Agricultural and Wildlife Sciences** in **2024** with the DOI number **10.24180/ijaws.1436876**, was inadvertently written incorrectly by the authors.

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