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Aronya'nın Sistematiği ve Yetiştiriciliği İle İlgili Güncel Bilgiler

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Özet

Ülkemiz için yeni bir meyve türü olan aronya, gen merkezi Kuzey Amerika olan siyah aronya türü "*Aronia melanocarpa*" ile diğer bir tür "*Sorbus aucuparia*" arasında 130 yıl önce Rusya'da başlatılan melezleme çalışmaları sonucunda cinsler arası bir hibrit tür olarak (*Aronia mitschurinii*) geliştirilmiş ve dünyaya yayılmıştır. İlk küçük ölçekli bahçelerin 10 yıl önce Yalova ve Kırklareli'nde kurulduğu ülkemizde aronya bugün Marmara Bölgesi başta olmak üzere İç Anadolu, Ege, Karadeniz, Doğu ve Güneydoğu Anadolu Bölgelerinde ticari boyutta yetiştirilen ve üreticisinin yüzünü güldüren bir meyve türü haline gelmiştir. Yüksek adaptasyon yeteneği ve kârlılığı nedeniyle tüm bölgelerde giderek yaygınlaşmakta olan aronya yetiştiriciliğinden üreticilerin gelecekte de en yüksek faydayı sağlayabilmesi için türün ekolojik istekleri ile birlikte küresel ısınma ve iklim değişikliğinin bölgelerdeki olası sonuçları dikkate alınarak illerde bu türün yetiştiriciliği için uygun yerleri işaret edecek bir üretim planlamasının yapılması gerekmektedir. Bu derlemede aronya ve bu meyve türünün ekonomik anlamda yetiştiriciliği için önemli faktörler ve uygulamalar güncel bilimsel yaklaşımlar esas alınarak anlatılmıştır.
Anahtar Kelimeler: *Aronia melanocarpa*, *Aronia mitschurinii*, Fidan, Bahçe Tesisi, Kültürel Uygulamalar

Current Knowledge on Aronia Systematics and Cultivation

Abstract

Aronia, a new fruit species for Türkiye, was developed as an intergeneric hybrid species (*Aronia mitschurinii*) as a result of the hybridization studies initiated in Russia 130 years ago between the black aronia "*Aronia melanocarpa*", whose gene center is in North America, and "*Sorbus aucuparia*", and spread throughout the world. In Türkiye, where the first small-scale orchards were established in Yalova and Kırklareli 10 years ago, aronia has become a fruit species that is grown commercially and satisfies the producers, especially in the Marmara Region, Central Anatolia, Aegean, Black Sea, Eastern and Southeastern Anatolia Regions. In order for producers to obtain the most benefit in the future from aronia cultivation, which is becoming widespread in all regions every day due to its high adaptability and profitability, a production planning should first be made to indicate suitable areas for the cultivation of this species in the provinces by taking into account the ecological requirements of this species along with the possible consequences of global warming and climate change in the regions. In this review, aronia and the important factors and practices for the economic cultivation of this fruit species are explained based on current scientific approaches.
Keywords: *Aronia melanocarpa*, *Aronia mitschurinii*, Sapling, Orchard establishment, Cultural practices

Giriş

Güçlü antioksidan özelliğinden dolayı ORAC değeri (Oksijen Radikal Absorbans Kapasitesi) çok yüksek olan aronya meyveleri insan sağlığı üzerine olumlu birçok etkiye sahiptir (Özdemir ve Eroğlu Özkan, 2020; Green vd. 2023; Shi vd. 2024). Fonksiyonel gıda olarak bu meyveye talebin giderek artması ve pazarlama sorununun bulunmaması, bitkilerinin erken meyveye yatması, üretim maliyetinin yüksek olmaması ve yatırımın mali rantabilitesinin %299 olması nedenleriyle kârlı bir tarımsal faaliyet olarak tanımlanan aronya yetiştiriciliğinin ülkemizde ve dünyada popülaritesi her geçen gün yükselmektedir (Anonim, 2022; Mahoney vd. 2023). Bu meyve türü organik tarımda da değerlidir ve endüstriyel bir ürün olarak meyveleri yüksek düzeyde pazarlanabilir niteliktedir (Green vd. 2023; Dragomir vd. 2023). Her ne kadar aronya ülkemizin her bölgesinde çok sayıda üretici tarafından yetiştirilmek istense de yeterince kaliteli fidan sağlanamaması, bahçe yerinin seçiminde bitkinin fizyolojik ve ekolojik isteklerinin yeterince dikkate alınmaması, özellikle tesisin ilk yıllarında yabancı ot kontrolüne önem verilmemesi ve diğer kültürel uygulamalarda yapılan hatalar bitki gelişimini ve verimliliği doğrudan etkilemektedir. Bu derlemede, güncel bilimsel verilere dayalı olarak aronya yetiştiriciliği mercek altına alındığı gibi aronya kültür çeşitlerinin sistematiği ve biyolojik özellikleri konularında yeni bilimsel yaklaşımlar da sunulmuştur.

Aronya Kültür Çeşitlerinin Sistematiği ve Biyolojik Özellikleri İle İlgili Güncel Bilgiler

Viking ve Nero gibi aronya kültür çeşitleri birçok kaynakta yaygın olarak *A. melanocarpa* türü içerisinde tanımlanmakta ise de son yıllardaki moleküler çalışmalar bu çeşitlerin cinsler arası bir

hibrit tür olan "*A. mitschurinii*"'nin üyeleri olduğunu göstermiştir (Leonard vd. 2013; Brand vd. 2022; Mahoney vd. 2019, 2023; Sharma vd. 2025). Aslında aronya, türler arasındaki sınırların belirsiz olduğu taksonomik bakımdan çok karışık bir bitki grubu olarak kabul edilmektedir (Brand vd. 2022). Bu meyve türlerinin dâhil olduğu *Aronia* cinsi Kuzey Amerika'ya özgü siyah aronya (*A. melanocarpa* (Michx.) Elliott), kırmızı aronya (*A. arbutifolia* (L.) Pers.) ve mor aronya (*A. prunifolia* (Marshall) Rehder) ile Rusya'da geliştirilmiş hibrit takson "*A. mitschurinii* A.K. Skvortsov and Maitul." türlerini kapsamaktadır. Morfolojik olarak *Aronia* cinsinin türleri çok gövdeli çalı formunda odunsu bitkilerdir. Yaprakları yumurta şeklinde, parlak yeşil, kenarları ince dişli ve sürgün üzerindeki dizilişi almaşıktır. Salkım şeklinde olan çiçeklerde beş adet beyaz veya pembemsi beyaz taç yapraklar, çok sayıda erkek organ ve bir dişi organ bulunmaktadır. Böceklerle tozlanan bu meyve türü kendine verimlidir. Meyve yapısı elma, armut gibi yumuşak çekirdeklidir. Meyvedeki çekirdek sayısı 1-5 adet arasındadır. Bir salkımda 30'dan fazla meyve bulunabilmektedir. Aronya pomolojik olarak üzümsü meyveler grubunda yer almaktadır. Kuzey Amerika orijinli üç aronya türü rizomatöz kök yapısına sahipken ebeveynlerinden birisinin *Sorbus* olmasından dolayı *A. mitschurinii* rizomatöz bir tür değildir (Ekiert vd. 2021; Brand vd. 2022). Aronya türleri, Rosales takımı, Rosaceae familyasının üyeleridir. Alt familya olarak Maloideae bildirilmekte ise de Rosaceae familyasının alt familyaları Spiraeoideae ve Maloideae, Amygdaloideae olarak birleştirildiği için kimi kaynaklarda aronyalar Amygdaloideae alt familyasında gösterilmektedir (Ristvey ve Mathew, 2011; Sun vd. 2018). Alt familyanın altında tribus (oymak), Pyrodea yerine Maleae, alt tribus (alt oymak) ise elma, armut, yenidünya, aronya gibi yumuşak çekirdekli türlerin girdiği Malinae (Pyrinae hatalıdır) olarak tanımlanmıştır. Bunlar yeni sınıflandırmada en çarpıcı değişiklikler arasında gösterilmiştir. Maleae tribusunda basal kromozom sayısı x=17'dir (Sun vd., 2018). *A. mitschurinii* türünün ebeveynlerinden birisi olan Kuzey Amerika'ya özgü siyah aronya *A. melanocarpa* doğada diploid (*A. melanocarpa*-2x) ve tetraploid (*A. melanocarpa*-4x) olarak bulunabilmekte, eşeyli ve diplospori apomiksis yoluyla eşeysiz olarak üreyebilmektedir (Brand, 2010; Leonard vd. 2013; Sun vd. 2018; Mahoney vd. 2019). Bu aronya türü ile *Sorbus aucuparia* (dişbudak yapraklı kuş üvezi) türü arasında 20. yüzyılın başlarında Rus meyve bilimci Ivan Michurin tarafından gerçekleştirilen melezleme çalışmaları sonucunda geliştirilmiş olan *A. mitschurinii* türü (Leonard vd. 2013) ise cinsler arası hibrit olan tetraploid bir aronya türüdür. *A. mitschurinii*, 'Viking', 'Nero' ve diğer ticari kültür çeşitlerinin dâhil olduğu tür olarak belirtilmiştir (Leonard vd. 2013; Mahoney vd. 2019, 2023). Ancak moleküler çalışmalar ve fenotipik verilere göre bu tür içerisindeki çeşitlerin tamamına yakınının genetik olarak aynı olduğu, farklılığın büyük olasılıkla aynı genotipin yeniden adlandırılmasından kaynaklandığı, aronyada meyve üretiminin esas olarak 'Viking' çeşidi ile gerçekleştiği bildirilmiştir (Leonard vd. 2013; Mahoney vd. 2019). Viking ve Nero, dünyada en fazla yetiştirilen iki ticari aronya çeşididir (Jurikova vd. 2017). Bu çeşitlerin bitkileri türün özelliği olarak çok gövdeli ve çalı formundadır. Meyvelerin olgunlaşması için tam çiçeklenmeden hasada kadar geçen gün sayısı 140 gün civarındadır. Meyveler, 1-1.5 g ağırlıkta, yuvarlak-hafif basık, morumsu siyah-siyah, tanen içeriği yüksek, tadı buruk, hafif tüylüdür ve her birisinde 12-30 meyve bulunabilen salkım şeklindedir. Hasat zamanında suda çözünebilir kuru madde miktarı %16-18 civarında, titre edilebilir asitlik %0.6-0.7'dir (Poyraz Engin, 2020).

Aronya Yetiştiriciliği İle İlgili Güncel Bilgiler

Günümüzde aronyanın en fazla yetiştirildiği ülke, dünya üretiminin %75'ini karşılayan Polonya'dır. Bu ülkeyi Almanya, ABD, Finlandiya, Norveç ve Rusya izlemektedir (Şahin ve Erdoğan 2022, Coşkun 2024). Aronya meyveleri yüksek tanen içeriğinden dolayı taze tüketimde ağızda buruk bir tat bırakmakta ve bu nedenle işlenmiş ürün olarak tüketimi tercih edilmektedir (Everhart, 2009). Meyvelerinin taşınma sırasında mekanik hasara dayanıklı olması ve düşük pektin içeriğinden dolayı endüstriyel işlemeye son derece uygundur (Brand, 2010; Ochmian vd. 2012). Rusya, Danimarka ve Doğu Avrupa ülkelerinde meyve suyu ve şarap üretiminde yaygın olarak kullanılan aronya (Knudson, 2009), özellikle Polonya'da meyve suyu konsantresi üretimi için yetiştirilmekte ve üretimin %90'ı ihraç edilmektedir (Ochmian vd. 2012). ABD'de diğer meyve türlerinin sularıyla karıştırılarak tüketilmektedir (Brand, 2010). Gıda endüstrisinde reçel, sos, meyve çayı, yoğurt, likör, enerji verici içecekler, sirke, sakız, sağlıklı atıştırmalıklar, dondurma ve yüksek antosiyanin içeriğinden dolayı doğal gıda boyası olarak kullanılmaktadır (Everhart, 2009; Jurikova vd. 2017; Zhang vd. 2021). Aynı zamanda gıda takviyesi olarak da değerlendirilmektedir (Ekiert vd. 2021). Dünyada aronya yetiştiriciliği farklı çeşitler ile gerçekleştirilmektedir. Önemli aronya çeşitleri 'Nero' (Çekya), 'Viking' (Finlandiya), 'Aron' (Danimarka), 'Hugin' (İsveç), 'Galicjanka', 'Albigowa', 'Dabrowice', 'Egerta', 'Kutno' ve 'Nowa Wies' (Polonya), 'Amit' (Rusya), 'Fertödi' (Macaristan), 'Rubina' (hibrit çeşit) (Rusya ve Finlandiya), 'Autumn Magic', 'McKenzie' ve 'Morton' (ABD)'dur (Ristvey ve Mathew, 2011; Ochmian vd. 2012; Ekiert vd. 2021). Geçmişte Amerika'nın yerli halkı Kızılderili kabileler tarafından bağışıklığı

güçlendirmek amacıyla kullanılmış olan aronya özellikle 1950'li yıllardan bu yana Kuzey, Orta ve Doğu Avrupa'da, ABD'de ve dünyanın farklı ülkelerinde ticari olarak yetiştirilmektedir. Türkiye'de aronya ile ilgili ilk çalışmalar 2012 yılında Yalova'da Atatürk Bahçe Kültürleri Araştırma Enstitüsü'nde başlatılmıştır. Daha sonra Yalova, Tokat, Edirne ve Malatya illerinde bu meyve türü ile ilgili TAGEM (Tarımsal Araştırmalar ve Politikalar Genel Müdürlüğü) projeleri yürütülmüştür. İlk küçük ölçekli aronya bahçeleri 2014 yılında Yalova ve Kırklareli'nde kurulmuş, büyük ölçekli bahçeler ise 2017 yılında Kırklareli'nde 60 da ve Manisa'da 50 da olarak tesis edilmiştir (Poyraz Engin, 2020). Bugün ülkemizin pek çok bölgesinde aronya yetiştiriciliği yapılmaktadır. Tarım ve Orman Bakanlığı İl Müdürlüklerinin çizelge 1'de sunulan verilerine göre aronya tarımının en yoğun yapıldığı il 2023 yılında 1.370 da ile Kırklareli'dir (Çizelge 1) (Coşkun 2024).

Çizelge 1. Türkiye'de aronya yetiştiriciliğinde öne çıkan iller ve üretim alanları (Coşkun, 2024)
Table 1. Prominent provinces and production areas in aronia cultivation in Türkiye (Coşkun, 2024)

İller	Üretim Alanı (da)	Veri Yılı
Kırklareli	1.370	2023
Bursa	1.273	2022
Yalova	471	2024
Tekirdağ	450	2023
Balıkesir	297	2022
Çanakkale	246	2022
Edirne	220	2023
Ankara	197	2024
Manisa	178	2023
Samsun	100	2022
Gümüşhane	71	2023
Ordu	60	2022
Kocaeli	10	2022

Bir ılıman iklim meyve türü olan aronyanın bitkileri kış dinlenme döneminde -35 °C düşük sıcaklıklara dayanabilmektedir. İçsel dinlenmenin kırılarak ilkbaharda gelişmenin başlayabilmesi için dinlenme döneminde +7 °C'nin altında soğuklama isteğinin karşılanması gerekmektedir. Bu ihtiyaç yetiştiricilikte başarıyı doğrudan etkileyen önemli bir faktördür. Aronyanın kültür çeşitlerinin minimum soğuklama süresinin 900 saat olduğu, 1200 saat soğuklamanın ise tomurcukların dinlenmeden çıkmasında ve sürgün gelişiminde etkili olduğu belirtilerek, aronya bahçelerinin dinlenme döneminde 1000 saatten fazla soğuklama süresine sahip yerlerde kurulması önerilmektedir (Mahoney vd. 2023). Aronyada çiçeklenme, meyve tutumu ve kalitesinin iyileştirilmesi için güneşlenme süresi fazla, aydınlık, bitkilerin gölgesinde kalmayan yerler tercih edilmelidir. Bahçeler don kuşağında bulunmayan, taban suyu seviyesi düşük, su baskınlarının yaşanmadığı yerlerde kurulmalıdır. Aronya yüzlek kök sistemine sahiptir. Kurak ya da aşırı nemli, farklı topraklara uyumlu olduğu bildirilmekte ise de (Ekiert vd. 2021; Dinu vd. 2022; Gerasimov vd. 2023; Mahoney vd. 2023) verimli, organik madde kapsamı yüksek, kohezyon kuvveti orta, geçirgen, besin maddelerince zengin topraklarda en iyi gelişmektedir. Bahçe kurulmadan önce toprak derin olarak işlenmelidir (Ekiert vd. 2021). Aronya yıllık 600-800 mm suya ihtiyaç duymaktadır ve özellikle yaz aylarında sulamaya özen gösterilmelidir (Şahin ve Erdoğan, 2022; Chiorean vd. 2023).

Aronya, generatif ve vejetatif yöntemler ile çoğaltılabilmektedir. Generatif olarak tohumla çoğaltım, bitkilerin homojen olmaması, gençlik kısırlığının uzun sürmesi ve kuvvetli taç yapısı nedeniyle önerilmemektedir (Litwinczuk, 2013). Bununla birlikte tetraploid aronyalarda apomiktik tohum üretimi yoluyla homojen bitki çoğaltımının sağlanabileceği bildirilmektedir (Mahoney vd. 2019). Tohumlarda içsel dinlenmenin ortadan kaldırılabilmesi için en az 60 günlük soğukta katlama uygulamasına ihtiyaç bulunmaktadır (Brand, 2017). Vejetatif olarak çelikle çoğaltımda yeşil (Mckay, 2001; Brand, 2017), odun (Brand, 2017) ve yarı odun çelikleri (McKay, 2001; Shahin vd. 2019) kullanılabilmektedir. Kök oluşumu için IBA (indol-3-bütirik asit) ve yaralama uygulamalarının yapılması önerilmektedir (Brand, 2017; Yıldırım, 2023). Vejetasyon döneminde alınan, dip ısıtma ve mist sistemi olan seralarda köklendirilen çelikler, odun çeliklerine göre daha kolay ve yüksek oranlarda köklenmekte (%100) ve üretimde daha fazla tercih edilmektedir (Brand, 2017). Bununla birlikte aronyada yüksek fidan talebini karşılayacak en etkili vejetatif çoğaltım yöntemi doku kültürleri kapsamında mikro çoğaltımdır (Brand ve Cullina, 1992; Brand, 2017; Ekiert, 2021). Alt kültürlerde çoğaltılan mikro sürgünler köklendirme aşamasında in vitro veya ex vitro koşullarda köklendirilebilmektedir (Brand, 2017). Yeni bir çalışmada aronyanın mikro çoğaltımında oksin vb. maddeler kullanılmadan mikro çeliklerin ex vitro koşullarda yüzen perlit yatağında köklendirildiği ve aynı zamanda bitkiciklerin dış koşullara alıştırıldığı, kolay, ucuz ve etkili bir mikro çoğaltım protokolü geliştirilmiştir (Coşkun, 2024). Bu yolla üretilen bitkiciklerin fidanlık koşullarında geliştirilerek bahçelerin kaliteli fidanlarla kurulması büyük öneme sahiptir. İyi bir aronya fidanı en az 50 cm boyda, 2-3 yan dala sahip, kök boğazı çapı 1 cm kalınlıkta, 20 cm uzunlukta bol köklü olmalıdır (Ekiert, 2021).

Aronya bahçelerinde dikime başlamadan önce toprak derin sürülmeli, yabancı ot temizliği ile birlikte çok iyi bir toprak hazırlığı yapılmalıdır.

Dikim sonrasında da yabancı ot kontrolü sürdürülmelidir. Genç aronya fidanları yabancı otlarla mücadele edecek kadar gelişmiş bir kök sistemine sahip bulunmamaktadır, bitkiler 4-5 yaşlarında yabancı otları bastırabilecek kuvvete gelebilmektedir. Yabancı otları önlemek için başlangıçta plastik malç kullanılabilmekte ise de sonraki yıllarda dip sürgünü oluşumu nedeniyle malcın kaldırılması gerekmektedir (McKay, 2001). Aronya bahçelerinde dikim mesafesi 4-4.5 m sıralar arası ve 1-1.5 m sıra üzeri olarak uygulanabilmektedir. Makinalı hasadın ve geniş alanlarda yoğun üretimin yapıldığı bahçelerde sıra üzeri mesafe 0.6-0.8 m'ye kadar inebilmektedir (Hornig, 2020). Ocak şeklinde yetiştiricilik yapılacaksa sıra arası 2-2.5 m ve sıra üzeri 1.5-2 m olarak belirlenebilmektedir (Anonim, 2022). Fidan dikimi bütün meyve türlerinde olduğu gibi kök budaması ve her fidan çukuruna organik gübre verilerek elle ya da fidan dikim makinaları ile yapılabilmektedir (Hornig, 2020). Dikimden sonra fidanda geriye doğru 5-10 cm kalacak şekilde tepe vurma işlemi bir sonraki yıl bitkinin daha fazla sürgün oluşturmasını ve kuvvetli şekilde gelişmesini sağlanmaktadır. Boyu 40 cm'den kısa olan fidanlarda kesim işlemi yapılmamalı ve fidanın gelişmesi beklenmelidir (Hornig, 2020; Anonymous, 2024). Aronya bitkisi 5-6 yaşına ulaştığında taç içerisinde sıklık yaşanabilmekte ve ışık girişi engellenebilmektedir. Bu durum verimliliği ve meyve kalitesini düşürmekte, kültürel işlemlerin yürütülmesine engel olmaktadır. Budama ile tacın içindeki zayıf, kırılmış, yaşlı dallar uzaklaştırılmalı ve sık sürgünler seyreltilmelidir. Böylece tacın içinin güneş ışığı alması sağlanmalıdır. Kuvvetli ve dik yönde büyüyen sürgünler 20-25 cm'ye kadar kısaltılmalıdır (Popescu, 2018). Hornig (2020), budama maliyetini düşürücü alternatif bir yol olarak "radikal gençleştirme" işlemini önermekte ve bitkiler makine yardımı ile toprak seviyesinden kesilmektedir. Bu durum ilk yıl üretimde kayba neden olsa da daha sonraki yıllarda bitkinin rejenerasyon yeteneği sayesinde verimde artış sağlamaktadır. Lentz vd. (2023) de 10 yaşlı aronya bitkilerine tüm sürgünler 10 cm kalacak şekilde yaptıkları gençleştirme budaması sonrasında iki sezon boyunca meyve üretiminde kayıp yaşamış olsalar da 4-6 yılda, aynı zaman diliminde yeni kurulan bir aronya bahçesine eşdeğer meyve üretimine ulaşmışlardır.

Aronya hastalık ve zararlılara karşı genel olarak dirençli bir bitkidir (Dinu vd. 2022). İlaçlama, zarar, ekonomik eşiğe ulaştığında yapılmaktadır (McKay, 2001; Hornig, 2020). Bu meyve türünün yetiştiriciliğinde ateş yanıklığı (*Erwinia amylovora*) (McKay, 2001), külleme (*Erysiphaceae*) (Brand, 2010), pas hastalığı (*Gymnosporangium* sp.), yaprak biti (*Aphis pomi*), pamuklu bit (*Eriosoma lanigerum*), armut yaprak uyuzu (*Eriophyes piri*) (Ekiert, 2021), kiraz meyve kurdu (*Grapholita packardi*), kahverengi kokarca böceği (*Halyomorpha halys*) zararlılarına rastlanılmıştır (Ristvey ve Mathew, 2011). Kiraz sirkesineği de (*Drosophila suzukii*) potansiyel zararlısıdır (Hornig, 2020). Aronyada bakla zınnı (*Tropinota hirta*) da çiçeklenme döneminde yaptığı zarar ile verim düşüklüğüne neden olmaktadır.

Aronya bitkileri 2-3 yaşından itibaren meyve vermeye başlamaktadır. Dikimden sonra 3. yılda dekara 750 kg, 4. yılda 1.500 kg ve 5. yılda 1.800 kg meyve alınabilmektedir (Anonim, 2022).

Hasat, meyveler tam rengini aldığında, kuru madde oranı %14-20'ye ulaştığında Ağustos sonu ve Eylül ayında el ile ya da mekanik olarak yapılabilmektedir (Poyraz Engin, 2020; Anonim, 2022; Coşkun, 2024).

Sonuç

Ülkemizde konvansiyonel ya da organik aronya tarımında başlangıçtan itibaren iyi bir planlama ve bahçe yönetimi ile üretimin en üst seviyeye çıkartılması mümkündür. Bu derlemede aronya yetiştiriciliğinde sürdürülebilirlik için ilk olarak üretim planlamasının önemi vurgulanmıştır. Bu kapsamda türün fizyolojik ve ekolojik ihtiyaçlarının uzun süreli karşılanabilmesi için bölgelerimizin geleceğe yönelik iklim değişikliği senaryolarının incelenerek illerimizde aronya yetiştiriciliğine uygun yerlerin belirlenmesi önerilmiştir. Daha sonra bahçelerin kaliteli üretim materyali ile kurulması gerektiği ve kaliteli fidan üretimi için ülkemizde aronya fidan standardının hazırlanmasının önemi dile getirilmiştir. Fidan üretiminde etkin mikro çoğaltım protokolleri kullanılarak farklı çeşitlerde standarda uygun sertifikalı fidanların yerli imkânlarla elde edilerek üreticilerin bu yöndeki talebinin, ithalata gerek kalmadan karşılanmasına dikkat çekilmiştir. Bahçe kurulması aşamasında ise toprak hazırlığı, plantasyonun ilk yıllarında kök ve sürgün gelişimini teşvik etmek üzere yabancı ot kontrolü, sonraki yıllarda verimi artıracak budama ve terbiye teknikleri ve diğer kültürel uygulamalara önem verilmesinin başarılı bir aronya yetiştiriciliği için gerekli diğer unsurlar olduğu ifade edilmiştir. Tüm bu konulara güncel yaklaşımlarla çözüm önerileri sunulmuştur. Derlememizde ayrıca taksonomik bakımdan çok karışık bir bitki grubu olan aronyanın sistematiği ve biyolojik özellikleri konusundaki çalışmaların en son bulguları paylaşılmıştır.

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Some Morphological Characteristics of *Contarinia pruniflorum* Coutin & Rambier (Diptera: Cecidomyiidae)

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Abstract

The Apricot flower midge (*Contarinia pruniflorum*) is a pest of stone fruit trees and lays its eggs in the flower buds before the pink bud stage of the apricot. It is a pest that has a direct impact on the yield of the tree. This study was conducted in 2017-2018 in Malatya province of Türkiye to determine the morphological characteristics of certain biological stages of *Contarinia pruniflorum*. In the morphological examinations, the morphological characteristics of the adult female, adult male, mature larva, and pupa were described and measurements were made on some body parts. The average body width of the adult female is 0.43 mm, with a length without antennae of 1.81 mm. The average antenna length is 0.91 mm and consists of 12 segments. The average body width of the adult male is 0.34 mm and the body length excluding antennae is 1.68 mm. The mature larva has an average width of 0.49 mm and a length of 2.17 mm. The pupa has an average width of 1.09 mm and a length of 2.22 mm. The study contributed to population monitoring by introducing the pest to growers and researchers.

Key words: *Contarinia pruniflorum,* Apricot pest, Morphological characteristics

Contarinia pruniflorum Coutin & Rambier (Diptera: Cecidomyiidae)'un Bazı Morfolojik Özellikleri

Özet

Sert çekirdekli meyve ağaçlarının bir zararlısı olan Kayısı çiçek sineği (*Contarinia pruniflorum*) kayısının pembe tomurcuk döneminden önce çiçek tomurcuklarına yumurtasını bırakır. Meyve ağacının ürün miktarına direk etki eden bir zararlıdır. Çalışma, *Contarinia pruniflorum*'un bazı biyolojik dönemlerindeki morfolojik özelliklerinin belirlenmesi için 2017-2018 yıllarında Malatya (Türkiye)'da yürütülmüştür. Morfolojik incelemelerde, ergin dişi, ergin erkek, olgun larva ve pupanın morfolojik özellikleri tanımlanarak zararlının bazı vücut bölümlerinde ölçümler yapılmıştır. Ergin dişinin ortalama vücut genişliği 0.43 mm, anten hariç uzunluğu 1.81 mm'dir. Anten 12 segmentten oluşmuş olup uzunluğu 0.91 mm'dir. Ergin erkeğin ortalama vücut genişliği 0.34 mm, anten hariç vücut uzunluğu 1.68 mm'dir. Olgun larvanın ortalama genişliği 0.49 mm olup uzunluğu 2.17 mm'dir. Pupa genişliği 1.09 mm ve uzunluğu 2.22 mm'dir. Çalışma ile yetiştiricilere ve araştırmacılara zararlıyı tanıtarak popülasyon takibi yapılmasına katkı sağlanmıştır.

Anahtar Kelimeler: *Contarinia pruniflorum*, Kayısı zararlısı, Morfolojik özellikler

Introduction

Contarinia pruniflorum Coutin & Rambier (Diptera: Cecidomyiidae) (Apricot flower midge) adults lay their eggs on the flower buds of trees belonging to stone fruit species. The hatching larvae feed through the bud wall and the genital organs of the flower. The damaged flower does not bear fruit (Yiğit and Tunaz, 2021). The pest overwinters in the soil in the pupal stage and produces one generation per year (Pollini and Bariselli, 1996; Yiğit and Tunaz, 2023). Successful results have been achieved in the chemical control against adult stage of the pest (Yiğit and Tunaz, 2021). In addition, *Gastrancistrus pacillus*, *Synopeas* sp., and *Gastrancistrus pruniflorumus* have been identified as larval parasitoids of the pest (Rambier and Coitin, 1955; Doğanlar and Yiğit, 2019). The pest was first detected in *Prunus* species and some biological characteristics were identified (Rambier and Coitin, 1955). Then it was detected on *Prunus* cultivars in Czechoslovakia, Italy, Greece, and Türkiye. Some studies have been conducted such as determination of some biological terms, pest control, and cultivar preferences (Pollini and Bariselli, 1996; Gagne, 20014; 2017; Montuschi et al. 2004; Tsagarakis and Mitsopoulus, 2007; Doğanlar et al. 2014; Yiğit and Tunaz, 2021; 2023). It was first identified morphologically by molecular characterization using the COI gene sequence (Kaplan and İnal, 2021). For the first time in Türkiye, apricot was found to be damaged by the pest in Malatya province (Doğanlar et al. 2014; Kaplan, 2014). In addition, assessments were made on the prevalence areas and damage rates of the pest in Malatya province

and its bioecology was evaluated (Yiğit and Tunaz, 2021; 2023). The pest spends much of its life cycle as a mature larva and pupa in the soil. The adult stage of the pest is very short. The time when the pests lay their eggs is in the late winter months when gardening is minimal. Therefore, it is difficult to recognise and identify the pest. This study aims to contribute to growers and researchers by providing morphological descriptions of some biological stages of the Apricot flower midge.

Material and Method

The material of the study consists of the adults, larvae, and pupae of *C. pruniflorum* as well as laboratory equipment and materials.

Collecting *Contarinia pruniflorum*

In the apricot orchard of Hacıhaliloğlu variety in Yeşilyurt district of Malatya province, a 2 m^2 area was designated in 2017 where a considerable number of mature larvae were released. Square prism cages measuring 25x40 cm were placed in the area for biological monitoring of the pest. Over a year, observations were made and pupae and adults were collected. They were then taken to the laboratory for measurements.

During the observations after the pest had laid its eggs in apricot buds, the larva in the buds in which the eggs were laid were classified according to their biological stages. They were then taken to the laboratory for measurements.

Measurements

The body length and width, antenna length, wingspan, and length-width measurements of the mature females and males were measured, as well as the length and width of the mature larva and the length, width, and circumference of the pupa. The measurements and photos were taken with a Nikon e200 microscope.

RESULTS

Morphological studies

Measurements have been made on some biological stages of the pest and photos of some body parts are shown below.

Adult female

The adult female has an average body width of 0.43 mm and a length, excluding antennae, of 1.81 mm, with an orange-red body color. The head, thorax, and legs are black. The palp has four segments, the first of which is very short and the following segments are twice as long as the previous one. The antenna of the adult female is about 0.91 mm long and consists of 12 segments. It has a cylindrical shape and the flagellum consists of two fused parts. There are irregular and long sensory hairs on the segments. The legs are blackish and the tarsal claws are oblique. The empodium is only weakly developed and corresponds to the length of the claw. It has a long ovipositor, which can grow up to 2 mm long when laying eggs. The wings of the adult female are transparent, about 0.74 mm wide and 2 mm long and have only a few veins. Some body parts of the adult female are shown in Figure 1 and the morphological measurements are listed in Table 1.

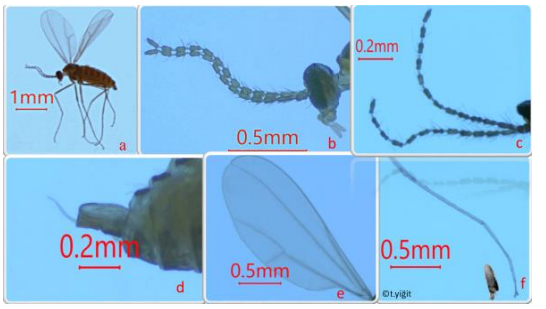

Figure 1. Adult female of *Contarinia pruniflorum* a- general appearance, b- head and antennae, c- general view of antennae, d- posterior segments of abdomen and ovipositor, e- wings, f- tarsus and pretarsus

Şekil 1. *Contarinia pruniflorum*'un ergin dişisinin a- genel görünümü b- baş ve anten c- antenin genel görünümü, d abdomen sonu ve oviporizatör, e- kanat, f- tarsus ve pretarsus

Adult male

The average body width of the adult male is 0.34 mm and its length without antennae is 1.68 mm, with an orange-red body color. The head, thorax and legs are black. At the end of the abdomen there is a pair of hook-shaped holders that help with mating. The male's antenna is about 1.95 mm long and consists of 24 segments. The antennal segments are rounded and the flagellum consists of two fused parts. There are irregular and long hairs on the segments. The wings of the adult male are about 0.69 mm wide and 1.93 mm long, transparent and sparsely veined. Some body parts of the adult male are shown in Figure 2, and the morphological measurements are given in Table 1.

Larva

Mature larvae hatched from the bud after feeding were collected and measured in the laboratory. The results are shown in Table 2 and Figure 3. The hatched legless larva is initially transparent and whitish. Later it becomes lemon yellow. The average width of the mature larva is 0.49 mm and its length is 2.41 mm.

Pupa

The pupa is barrel-shaped, with an average width of 1.09 mm and a length of 2.22 mm. The larva transforms into a pupa in the course of the summer.

In the pupal stage it remains in the soil until the end of February, the end of the following winter. With the warming of the weather and the soil, the adult insect emerges from the pupa and begins its adult activities. The morphological measurements of the pupae are shown in Table 3 and its general appearance can be seen in Figure 4.

Table 1. Morphological measurements of adult females and males of *Contarinia pruniflorum* (mm)
Çizelge 1. *Contarinia pruniflorum*'un ergin dişi ve erkeğinin morfolojik ölçümleri (mm)

	Width	Length	Antenna Length	Wing Width	Wing Length
Adult female (n 15, average)	0.43±0,047	1.82±0,160	0.91±0,109	0.74±0,072	2.00±0,116
Adult male (n 12, average)	0.34±0.113	1.68±0.301	1.95±0.255	0.69±0.072	1.93±0.105

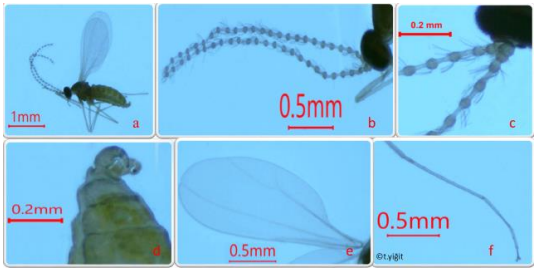

Figure 2. Adult male of *Contarinia pruniflorum* a- general appearance, b- general view of the antennae, c- antennal base and first segments, d- posterior segments of the abdomen and genital tip, e- wings, f- tarsus
Şekil 2. *Contarinia pruniflorum*'un ergin erkeğinin a- genel görünümü b- antenin genel görünümü, c- anten kaidesi ve ilk segmentleri, d- abdomen son segmentleri ve genital uç, e- kanat, f- tarsus

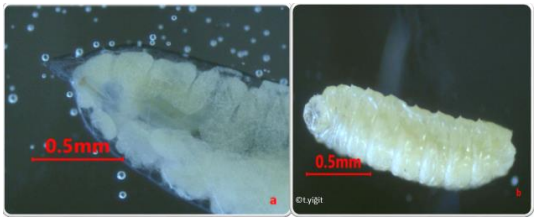

Figure 3. Mature larva of *Contarinia pruniflorum* a- head, sternal spatula, and first segments b- general appearance
Şekil 3. *Contarinia pruniflorum*'un olgun larvasının a- baş, sternal spatula ve ilk segmentleri b- genel görünüm

Table 2. Morphological measurements of the mature larva of *Contarinia pruniflorum* (mm)
Çizelge 2. *Contarinia pruniflorum*'un olgun larvasının morfolojik ölçümleri (mm)

	Width	Length
n 15, average	0.49±0.067	2.41±0.279

Figure 4. General appearance of the pupa of *Contarinia pruniflorum*
Şekil 4. *Contarinia pruniflorum*'un pupasının genel görünümü

Table 3. Morphological measurements of the pupa of *Contarinia pruniflorum* (mm)
Çizelge 3. *Contarinia pruniflorum*'un pupasının morfolojik ölçümleri (mm)

	Width	Length	Circumference
n 15, average	1.09±0.91	2.22±0.158	5.36±0.268

Discussion and Conclusion

Limited studies have been carried out to determine the morphological characteristics of the apricot flower midge (Rambier and Coitin, 1955; Kaplan and İnal, 2021). This study contributed to the literature by making a detailed study on the pest.
The apricot flower midge is a pest that is not recognised by growers due to its small distribution area in the world. To date, it has been detected in a few regions in Europe (Pollini and Bariselli, 1996; Gagne, 20014; 2017; Montuschi et al. 2004; Tsagarakis and Mitsopoulus, 2007; Doğanlar et al. 2014). Apricot growers in Türkiye have recently been confronted with this pest. The first point of view regarding the reason for the new occurrence of the pest could be the expansion or change of the distribution areas of the pest with the climatic

changes. The second point of view is that the pest was already present in the growing areas but was not noticed because the adult period of the pest is short, the period of adult emergence in nature is in the winter months and the population density is low and does not cause significant damage to the products. Yiğit and Tunaz (2021), in their study conducted in the Eastern Anatolia Region of Türkiye, detected the pest at different altitudes, but it caused damage to the crop only at low altitudes. Although the second approach seems more logical, more research on the distribution areas of the pest is needed to explain this issue.

The apricot flower midge has a direct impact on crop yields due to the damage it causes. Pest control measures should be started as soon as the adults emerge from the pupae (Yiğit and Tunaz, 2021). This is because when the damage is noticed at the end of the flowering period, it is too late for pest control. The pest should be controlled during the adult period. It is therefore very important to know the morphology of the adults. As the pest causes damage during the flowering period, control methods other than chemical control must be developed to protect both the existence of the pollinators and the natural balance.

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Malatya İli Yeşilyurt İlçesinde Deprem Sonrası Kiraz Üretiminin Sosyo-Ekonomik Analizi ve Depremin Üreticiler Üzerine Etkileri

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Özet

Bu çalışma ile Malatya ili Yeşilyurt ilçesinde deprem sonrasında kiraz üretiminin sosyo-ekonomik analizinin yapılması amaçlanmıştır. Araştırma, kiraz üreticilerinden toplanan birincil veriler ile farklı kaynaklardan elde edilen ikincil verilerin değerlendirilmesi ve yorumlanmasıyla kiraz üretiminin çeşitli yönlerinin incelenmesini hedeflemiştir. Çalışmada, ilçe genelinde kapama kiraz bahçesi bulunan kiraz üreticilerinden oransal örnekleme yöntemi kullanılarak 53 işletme örnek olarak belirlenmiştir. Hazırlanan anketler işletmeler ile yüz yüze görüşülerek 2022-2023 üretim sezonunu için doldurulmuştur. Çalışma kapsamında, işletmelerin yıllık faaliyet sonuçlarından brüt, mutlak ve nispi karlar hesaplanmıştır. Bölgede kirazların ortalama satış fiyatı 32.06 TL/kg olarak belirlenmiştir. İşletmelerin kiraz üretimi neticesinde dekara brüt kar 8 605.37 TL/da, mutlak kar 5 817.54 TL/da ve nispi kar 1.75 olarak belirlenmiştir. Sabit ve değişen masraflar ile toplam üretim masrafları hesaplanmıştır. 6 Şubat 2023 tarihli Kahramanmaraş depremlerinden en çok etkilenen bölgelerden biri olan araştırma sahasında üretim yapan üreticilerin deprem döneminde karşılaştığı problemler belirlenmiş ve çözüm önerileri sunulmuş ve politika önerilerinde bulunulmuştur.
Anahtar kelimeler: Kiraz, Sosyo-ekonomik analiz, Maliyet, Deprem, Malatya.

Socio-Economic Analysis of Cherry Production After the Earthquake in Yeşilyurt District of Malatya Province and the Effects of the Earthquake on Producers

Abstract

This study aims to conduct a socio-economic analysis of cherry production in the Yeşilyurt district of Malatya province following the earthquake. The research evaluates various aspects of cherry production by analyzing primary data collected from cherry producers and secondary data obtained from different sources. In the study, 53 farmers were selected as a sample by using the proportional sampling method from the cherry producers. Surveys were conducted through face-to-face interviews with the enterprises for the 2022-2023 production season. The annual operational results of the enterprises were analyzed to calculate gross, absolute, and relative profits. The average sales price of cherries in the region was determined as 32.06 TL/kg. The analysis revealed a gross profit of 8 605.37 TL/da, an absolute profit of 5 817.54 TL/da, and a relative profit 1.75. Fixed and variable costs, as well as total production costs, were calculated. Furthermore, the challenges faced by producers during the February 6, 2023, Kahramanmaraş earthquake, one of the most impactful natural disasters in the region, were identified. Solutions and policy recommendations were proposed to address these issues and enhance the resilience of the agricultural sector in the area.
Keywords: Cherry, Socio-economic analysis, Cost, Earthquake, Malatya.

Giriş

Depremler, doğrudan insan hayatını etkilediği kadar ekonomik ve sosyal yapıları da derinden sarsan olaylardır. Türkiye, jeolojik konumu itibariyle sık sık büyük depremlere maruz kalan bir ülkedir. Bu doğal afetler, özellikle tarım sektöründe ciddi etkilere yol açmakla birlikte üretim faaliyetlerinin aksamasından ürün kaybına, pazarlama sorunlarından üretici gelirlerinde düşüşe kadar geniş bir yelpazede sonuçlar doğurmaktadır. Tarım, kırsal ekonominin temelini oluştururken, kiraz gibi yüksek katma değerli ürünlerin üretimi, üreticiler ve ülke ekonomisi için büyük önem taşır. Türkiye'nin ekonomisinde önemli bir paya sahip olan kiraz, Hazar Denizi, Güney Kafkasya ve Kuzey Anadolu'ya özgü bir üründür ve Mayıs ayının ortalarından itibaren piyasada bulunmaktadır (Bolsu, 2007). Kiraz, dünya genelinde birçok ülkede yetiştirilmekle birlikte, yayılımı zorunlu iklim koşullarına bağlı olarak şekillenmiştir. Genellikle, üretimin yapıldığı bölgeler ılıman iklim kuşağında yer almaktadır (Öztürk vd. 2005). Türkiye, dünya kiraz üretiminde lider konumunda olup, 2022 yılında dünya genelinde gerçekleştirilen 2.7 milyon tonluk üretimin yaklaşık %24'ünü karşılamaktadır (FAO, 2024).

Ülke genelinde birçok bölgede kiraz yetiştirilmekle birlikte, en yoğun üretim Ege Bölgesi'nde gerçekleşmektedir ve bu bölge, Türkiye'nin kiraz üretiminin en çok yapıldığı bölgesidir. Ayrıca Türkiye kiraz üretiminde dünyada ilk sırada yer almaktadır. Malatya ili Yeşilyurt ilçesinde kiraz üretimi ekonomik olarak yapılmakta ve Yeşilyurt kirazı bölgede tercih edilen ürün olarak ön plana çıkmaktadır. Ancak, 6 Şubat 2023 tarihinde Kahramanmaraş merkezli gerçekleşen depremler, kiraz üretiminin önemli bir merkezi olan Malatya ilini de ciddi şekilde etkilemiştir. Bu çalışmada,

Malatya'nın Yeşilyurt ilçesinde deprem sonrası kiraz üretiminde yaşanan sosyo-ekonomik etkiler analiz edilmiştir. Çalışmada hem birincil hem de ikincil veriler kullanılarak üreticilerin yaşadığı sorunlar tespit edilmiş ve bölgedeki üretim faaliyetlerinin mevcut durumu değerlendirilmiştir. Deprem gibi beklenmedik krizlerin tarım sektöründe nasıl etkiler doğurduğunu anlamak, benzer durumlar için uygun politika ve stratejilerin geliştirilmesine katkı sağlayacaktır. Bu bağlamda, çalışmanın temel hedefi, üreticilerin deprem sonrası karşılaştığı zorlukları ve ihtiyaçlarını tespit ederek, bu zorluklara yönelik öneriler sunmaktır.

Materyal ve Yöntem

Materyal

Çalışmanın ana materyalini; Yeşilyurt ilçesinde ikamet eden ve tarımsal üretim faaliyetlerinde bulunan kiraz üreticileri ile yüz yüze görüşmeler yapılarak doldurulan anketlerden elde edilen veriler oluşturmaktadır. Ayrıca konu ile ilgili hazırlanmış istatistiki veriler, raporlar makaleler gibi ikincil kaynaklar da çalışmanın materyalleri arasında yer almaktadır.

Verilerin analizinde kullanılan yöntemler

Malatya İl Tarım ve Orman Müdürlüğü'nden ilçede Çiftçi Kayıt Sistemi'nde 246 kiraz üreticisi olduğu bilgisi alınmış ancak üretici bazlı veriler temin edilememiştir. Çiftçi Kayıt Sistemi verileri elde edilemediğinden örnek hacminin belirlenmesinde oransal örnekleme yöntemi kullanılmıştır. Oransal örnekleme, bir araştırmada ana kütlenin belirli bir oranını yansıtan bir örnekleme yöntemidir. Bu yöntemde, ana kütleye ilişkin bir oran (örneğin, bir özelliğe sahip olan bireylerin yüzdesi) bilinir ve bu oran doğrultusunda örnek büyüklüğü hesaplanır. Özellikle tarım ekonomisi çalışmaları gibi geniş popülasyonların analiz edildiği durumlarda sıkça kullanılan bir yöntemdir. Oransal örnekleme aşağıdaki şekilde formüle (Eşitlik 1) edilmiştir (Newbold vd. 2013; Çiçek ve Erkan, 1996).

$$\boldsymbol{n} = \frac{\boldsymbol{N.p.(1-p)}}{\boldsymbol{(N-1).\left(\frac{d^2}{z^2}\right)+p.(1-p)}} \qquad (1)$$

n: Gerekli örnek büyüklüğü ,**N**: Ana kütle büyüklüğü, **p**: Ana kütlede araştırılan özelliğin oranı, **d**: Kabul edilebilir hata payı, **z**: İstatistiksel güven düzeyi için Z-tablosu değeri.

Çalışmada %90 güven aralığı ve %10 hata payı ile oransal örnekleme formülünü aşağıdaki şekilde hesaplanarak örnekleme yapılacak üretici sayısı 53 olarak belirlenmiştir.

Anket yapılan mahalle isimleri ve üretici sayıları Çizelge 1.' de gösterilmiştir.

$$\mathrm{n} = \frac{246.\,0{,}5\,.\,(1-0{,}5)}{(246-1).\left(\frac{0{,}10^2}{1{,}645^2}\right)+0{,}5.\,(1-0{,}5)} = 53{,}16 = 53$$

n: 246 (ana kütle büyüklüğü), p: 0.5 (depremden etkilenme bilinmediği için muhafazakâr tahmin), d: 0.10 (hata payı), z: 1.645 (%90 güven aralığına karşılık gelen Z değeri).

Çizelge 1. Yeşilyurt ilçesi anket yapılan köy/mahalleler ve üretici sayısı.
Table 1. Surveyed Villages in Yeşilyurt District and Number of Producers.

Sıra No	Köy/Mahalle	Üretici Sayısı (Adet)
1	Gündüzbey	40
2	Bostanbaşı	6
3	Yeşilyurt Merkez	4
4	Hıroğlu	3
Toplam		53

Araştırmada veri toplama aracı olarak, Malatya Turgut Özal Üniversitesinden etik belgesi alınmış çoktan seçmeli ve açık uçlu sorulardan oluşan anket formu kullanılmıştır. Anket formunda, kiraz üreticilerin sosyo-ekonomik özellikleri ile depremin etkisi nedeniyle yaşanan problemler ve çözümü konusundaki düşünceleri gibi bilgileri belirlemeye yönelik 31 soru yer almıştır.
Tarım ekonomisi alanında yaygın olarak kullanılan yıllık faaliyet sonuçlarının elde edilmesinde;

Brüt kâr = Gayrisafi Üretim Değeri – Değişen Masraflar (2)
Mutlak (Net) kâr = Gayrisafi Üretim Değeri – Üretim Masrafları (3)
Nispi kâr = Gayrisafi Üretim Değeri / Üretim Masrafları (4)
eşitlikleri kullanılmıştır (Açıl ve Demirci, 1984; Erkuş vd. 1995; Kıral vd. 1999; Karagölge, 2001).

Kiraz üreten işletmelerin üretim masrafları hesaplanmıştır. Üretim faaliyetinde gerçekleşen masrafların hesaplanmasında 2022/2023 üretim sezonu fiyatları dikkate alınmıştır. Bölgedeki makine ve arazi kirası fiyatları çiftçi beyanı dikkate alınarak hesaplanmıştır. Aile işgücü ücret karşılığı hesaplamasında ise bölgede yabancı işgücü ücretleri esas alınmıştır. Döner sermaye faizi T.C. Ziraat Bankası'nın 2023 yılı bitkisel üretim kredi faizi oranının yarısı dikkate alınarak hesaplanmıştır. Genel idari giderler değişen masrafların %5'i alınarak hesaplanmıştır. Üretim değerinin hesaplanmasında üreticilerin çiftlik avlusu satış fiyatı baz alınmıştır.

Bulgular ve Tartışma

Dünya kiraz üretimi

2023 yılında dünya genelinde 2 milyon 964 bin ton kiraz üretimi yapılmıştır. Kiraz üretiminin yoğunlaştığı ülkeler; Türkiye, Şili, Özbekistan, Amerika Birleşik Devletleri (ABD) ve İran İ.C. olup ülkelere göre dünya kiraz üretimi Çizelge 2'de gösterilmiştir (FAO, 2024). Türkiye 2019-2023 yılları arasındaki beş yıllık üretim döneminde yıllık ortalama 694 bin ton kiraz üretim miktarı ile dünya kiraz üretiminin %25,22 sini tek başına karşılayarak dünyanın en önemli kiraz üreticisi konumunda bulunmaktadır. Bayav (2023) yaptığı çalışmada 2021 yılında dünya kiraz üretiminde önde gelen ilk on ülkenin üretim miktarlarının toplam kiraz üretimin %77.05'ini karşıladığını hesaplamıştır. 2019 yılı baz alındığında 2019-2023 yıları arasında Dünya kiraz üretim miktarı %12,62 oranında artış göstermiştir. Bu süreçte üretim miktarını Şili %72.85 oranında, Yunanistan %39.19 ve Özbekistan %24.45 oranında arttırırken Türkiye'nin artış oranı %10.93 olarak gerçekleşmiştir. Bu süreçte İspanya ve İtalya gibi önemli kiraz üreticisi ülkelerde %11 seviyesinde üretim azalışı söz konusudur. Şili özellikle coğrafi konumu nedeni ile kuzey yarım kürede üretimin olmadığı dönemlerde kiraz üreterek özellikle kuzey yarım küredeki pazarlar için önemli üretici konumuna gelmiştir.

Çizelge 2. Kiraz üretiminde lider ülkelerin yıllara göre üretim miktarları (ton).
Table 2. Production Quantities (tons) of the Leading Countries in Cherry Production by Years

Ülkeler	2019	2020	2021	2022	2023	2019/23 Arası Ort	Ortalama Üretim %	5 Yıllık Değişim %
Türkiye	664224	724944	689834	656041	736791	694367	25.22	10.93
Şili	269999	275999	392001	465001	465349	373670	13.57	72.35
ABD*	319870	294930	333210	202570	321420	294400	10.69	0.48
Özbekistan	175861	185068	213600	216867	218867	202053	7.34	24.45
İran İ.C.	128354	153745	119779	105390	144877	130429	4.74	12.87
İspanya	118380	82130	125810	116070	104470	109372	3.97	-11.75
İtalya	98600	104380	93030	107910	87710	98326	3.57	-11.04
Yunanistan	81600	93740	80970	85070	113580	90992	3.30	39.19
Diğer Ülkeler	774679	709342	708036	837793	770717	760114	27.60	-0.51
Dünya	2631566	2624279	2756270	2792712	2963781	2753722	100.00	12.62

*Amerika Birleşik Devletleri
Kaynak: FAO 2024

Türkiye kiraz üretimi

Türkiye Dünya kiraz üretiminde lider konumundadır. Ülkenin kiraz üretiminin son 5 yılı incelendiğinde; toplam üretimin 650 ile 750 bin ton arasında değiştiği görülmektedir. Bununla birlikte depremin gerçekleştiği 2023 yılında üretim miktarı 736 bin ton olarak gerçekleşmiştir (TÜİK, 2024).

Türkiye'de kiraz üretiminde önde gelen illerin son 5 yıl üretim değerleri incelendiğinde İzmir, Konya, Bursa ve Manisa illeri önemli üretim bölgeleri olarak ön plana çıkmaktadır. İzmir ili 2019-2023 yılları arasında yıllık ortalama 89 bin 502 ton kiraz üretim miktarı ile Türkiye kiraz üretiminin %12.89'luk kısmını oluşturmaktadır. İzmir ilini Konya %8.34, Bursa %7.73, Manisa %6.98 ve Amasya %5.83 oranı ile takip etmektedir. Kiraz üretim miktarı 2019-2023 yılları arasında 2019 yılına göre Türkiye genelinde %10.93 oranında artarken İzmir İlinde bu oran %53.97 olarak gerçekleşmiştir. İzmir'in dışındaki önemli kiraz üreticisi illerde ise bir azalış söz konusudur. Bu azalış Bursa için %26.97 Konya için %13.98, Manisa için %7.54 ve Amasya için %6.09 oranında belirlenmiştir. Malatya ilinde ise 2023 yılında 3 731 ton üretim gerçekleştirmiş olup ilin son beş yıllık ortalaması 3663 ton seviyesindedir. Malatya ili Türkiye kiraz üretim miktarının binde 5.3 lük kısmını oluştururken ildeki son beş yıllık üretim miktarındaki değişim %1.75 oranında artmıştır. (Çizelge 3) (TUİK, 2024).

Malatya ili kiraz üretimi

Malatya ilinde kiraz üretiminin en yoğun olarak yapıldığı ilçeler sırasıyla; Yeşilyurt, Hekimhan, Doğanşehir, Arapgir ve Akçadağ ilçeleridir (TUİK, 2024). Bu araştırmaya konu olan Malatya ili Yeşilyurt ilçesi, Doğu Anadolu Bölgesi'nin Yukarı Fırat Havzası Bölümü'nde yer alan Malatya ilinin iki merkez ilçesinden biridir. Yeşilyurt'ta, başta Malatya ekonomisinin itici gücü olan kayısı olmak üzere kiraz, üzüm, ceviz ve elma yetiştiriciliği yapılmaktadır. Yeşilyurt ilçesi Malatya ilinde en fazla kiraz üretiminin yapıldığı ilçedir. Malatya kiraz üretim alanının %59'u Yeşilyurt ilçesinde bulunurken Malatya kiraz üretim miktarının %43'ünü karşılamaktadır. 2023 üretim sezonunda 2 740 dekar alanda 1 595 ton kiraz üretimi gerçekleştirilmiştir (TUİK, 2024).

Çizelge 3. Türkiye'de kiraz üretiminde önde gelen iller (ton).
Table 3. Leading Provinces in Cherry Production (tons) in Türkiye

İller	2019	2020	2021	2022	2023	2019/23 Arası Ort	Ortalama Üretim %	5 Yıllık Değişim %
İzmir	66136	108495	87667	83383	101830	89502	12.89	53.97
Konya	68213	64086	51942	46750	58680	57934	8.34	-13.98
Manisa	48465	50934	49343	48832	44809	48477	6.98	-7.54
Bursa	60854	55652	52971	54485	44443	53681	7.73	-26.97
Amasya	38542	34926	41084	51524	36194	40454	5.83	-6.09
……..								
Malatya	3667	3675	3613	3628	3731	3663	0.53	1.75
Diğer iller	378347	407176	403214	367439	447104	400656	57.70	18.17
Toplam	664224	724944	689834	656041	736791	694367	100.00	10.93

Kaynak: TÜİK 2024

Kiraz üreten işletmelerin sosyo-ekonomik özellikleri

Bölgede anket yapılan kiraz üreticilerinin yaş ortalaması 56.32 olarak belirlenmiştir. Üreticilerin yaş aralığının 61 yaş üstü grubunda (%37.74) yoğunlaştığı ve bu gurubu 51-60 yaş grubu (%33.96), 41-50 yaş grubu (%16.98) ve 40 yaş ve altı grubu (%11.32) takip etmiştir. Malatya ilinde kiraz üreticilerinin sosyo-ekonomik yapılarına yönelik bir çalışmaya rastlanmamıştır. Atay vd. (2015) yılında Malatya ilinde kiraz yetiştiriciliğinde organik ve konvansiyonel üretimi karşılaştırmalı olarak analiz etmiş fakat üretici boyutunu incelememişlerdir. Bu nedenle bölgedeki kiraz üreticilerinin sosyo-ekonomik özellikleri üzerindeki bu çalışmada elde edilen veriler önemlidir.

Nalinci ve Kızılaslan (2019) Amasya ilinde kiraz üreticileri ile yapmış olduğu bir çalışmada üreticilerin ortalama yaşını 41.12 olarak bulmuştur. Namdar vd. (2023) Doğu Akdeniz Bölgesinde yapmış oldukları bir çalışmada üreticilerin ortalama yaşını 57.8 olarak belirlemişlerdir. Bölgeler itibari ile bu tür farklılaşmaların yaşanması normal bir sonuç olarak değerlendirilmektedir.

Kiraz üreticilerinin eğitim durumları incelendiğinde üreticilerin %45.28'inin lise, %20.75'inin yüksekokul, %16.98'inin lisans ve lisansüstü %15.09'unun ortaokul ve %1.89'unun ilkokul mezunu oldukları belirlenmiştir. Yeşilyurt ilçesi Malatya ilinin merkez ilçelerinden biri olması ve kiraz yetiştirilen alanların şehir merkezine oldukça yakın alanlarda yer alması, bölgede okullaşma oranını ve üreticilerin eğitim ortalamasını yükseltmiştir.

Yeşilyurt ilçesi kiraz üreticilerinin üreticilik deneyimi incelendiğinde ortalama deneyim süresi 32 yıl olarak belirlenmiştir. İşletmelerde ortalama deneyim süresi, üretim dalının bölgede uzun yıllardır yapıldığını ve kiraz yetiştiriciliğinin bölgede ekonomik bir üretim faaliyeti olduğunun göstergesi olarak kabul edilebilir. Doğan ve Saner (2017) İzmir ilinde yapmış oldukları bir çalışmada üreticilerin kiraz üretimindeki deneyim sürelerini ortalama 29.55 yıl olarak belirlemişlerdir.

İşletmelerin kiraz üretimi yaptığı parsel sayısı 1 ile 4 adet arasında değişmiş ve ortalama parsel sayısı 1.51 olarak hesaplanmıştır. Araştırma alanında ortalama kiraz üretim alanı 5.90 dekar , dekara ağaç sayısı 21.18 ve ortalama ağaç yaşı 19 yıl olarak belirlenmiştir. İşletmelerde yetiştirilen çeşitler incelendiğinde %68 ile Dalbastı çeşidi en fazla üretilen çeşit olurken, 0900 Ziraat çeşidinin %27 ve Napolyon çeşidinin %5 oranında yetiştirildiği tespit edilmiştir. Nalinci ve Kızılaslan (2019) Amasya ilinde kiraz üreticileri ile yapmış olduğu çalışmada işletmelerin ortalama arazi büyüklüğünün 15.90 dekar olduğunu belirtmiştir. Namdar vd.'nin (2023) yılında Doğu Akdeniz Bölgesinde yapmış oldukları bir çalışmada ortalama kiraz işletme arazi büyüklüğünü 8.1 dekar olarak bildirmişlerdir.

İncelenen işletmelerden 26'sının işletme içerisinde ev olarak kullandıkları bina varlığı bulunduğu tespit edilmiş olup bunların; 14 tanesi betonarme yapı, 8 tanesi ahşap, 3 tanesi konteyner ve 1 tanesi taş yapıdır. Ortalama bina yaşı 22 olarak belirlenirken deprem nedeniyle 6 çiftçinin işletme içerisindeki evinin hasara bağlı olarak yıkıldığı tespit edilmiştir.

İncelenen işletmelerin %32'si traktöre sahip olup traktörlerin 10 yaşından 25 yaşına kadar değiştiği ve ortalama traktör yaşı 18 yıl olarak hesaplanmıştır. İşletmelerin % 40'ında ilaçlama tankı ve %36'sında ise ot makinesi mevcuttur. Deprem nedeni ile işletmelerin alet ve makinelerinde bir kayıp yaşanmamıştır. İşletmelerin küçük ölçekte olması makineleşmenin düşük oranda kalmasına neden olmuştur.

İncelenen işletmelerde kiraz üretiminin ekonomik analizi

İşletmelerin kiraz üretiminde hasat sonrası işçilik giderleri ve arazi kirası en önemli iki üretim masrafı olarak belirlenmiştir. Üretim masraflarına ait veriler

Çizelge 4'te verilmiştir. 1 dekar alandan kiraz üretimi için değişen masraflar ortalama 5 001.21 ₺ da^{-1} ve toplam masraflar 7 789.04 ₺ da^{-1} olarak hesaplanmıştır.

Çizelge 4. Yeşilyurt İlçesinde Kiraz Üretim Masrafları.
Table 4. Cherry Production Costs in Yeşilyurt District.

Masraf Unsuru	₺ da^{-1}	%
Toprak İşleme	642.00	8.24
Budama	359.20	4.61
Gübreleme	438.04	5.62
Sulama	292.40	3.75
İlaçlama	1075.60	13.81
Nakliye	156.69	2.01
Hasat	2037.28	26.16
Toplam Değişen Masraflar	5001.21	64.21
Döner Sermaye Faizi %9,75	487.62	6.26
Genel İdari Giderler %5	250.06	3.21
Arazi kirası	1525.00	19.58
Tesis masrafları amortisman payı	525.15	6.74
Toplam Sabit Masraflar	2787.83	35.79
Toplam Üretim Masrafları	7789.04	100.00

₺=Türk Lirası, da=dekar

Bu çalışma kapsamında incelenen işletmelerde değişen masrafların toplam masraflar içerisindeki payı %64.21 olarak bulunmuştur. Kiraz üretimine ait farklı bölgelerde yapılan çalışmalarda değişen masrafların toplam masraflar içindeki oranın değiştiği görülmektedir. Bu oran; Isparta'da %65.44 (Demircan ve Aktaş, 2004), İzmir-Kemalpaşa'da %55 (Adanacıoğlu, 2012), Tokat'ta %72.19 (Balcı vd., 2016), Çanakkale'de ise %62.24 (Aydın vd. 2016), (Bilgili vd. 2019) İzmir-Kemalpaşa'da %48.24 olarak hesapladığı görülmektedir. Elde edilen sonuçların bölgeler arasında farklılığa rağmen yakın olduğu kabul edilebilir. İşletmelerin dekara ortalama son 5 yıllık verimleri incelendiğinde en yüksek verim alınan yılda ortalama 548 kg da^{-1}, en düşük verim alınan yılda 105 kg da^{-1} olduğu belirlenirken üreticilerin son beş yıllık ortalama verim değeri 361 kg da^{-1}, olarak hesaplanmıştır. Üreticilerin 2023 yılında ortalama kiraz üretimi 2 504 kg olup dekara verim 424.41 kg da^{-1}'dır. Üretilen kirazların %98'i gelir elde etmek için satılırken %2 oranında hane halkı tüketiminde ve hediye edildiği tespit edilmiştir. Bölgede kirazların ortalama satış fiyatı 32.06 ₺ kg^{-1} olarak belirlenmiştir. İşletmelerin kiraz üretimi neticesinde dekara brüt karı 8 605.37 ₺ da^{-1}, mutlak karı 5 817.54 ₺ da^{-1} ve Nispi Karı 1.75 olarak belirlenmiştir (Çizelge 5).

İşletmelerin ürünlerini pazarladıkları pazar yerine uzaklığı ortalama 4.9 km'dir. Üreticilerin %68'i pazarlama aşamasında depremin etkilerini yaşamış ve depremden etkilendiğini belirtmiştir.

Üreticilerin deprem nedeniyle yaşadığı problemler

Üreticilerin deprem nedeni ile yaşadıkları problemler incelenmiştir. Kiraz üreticilerinin yaşadıkları en önemli problemler sırasıyla; deprem nedeniyle ikametgahların hasar alması (%33.96), üreticilerin deprem nedeniyle psikolojik rahatsızlık geçirmesi (%22.64), üreticinin üretim aşamasında geçici işgücü bulamaması (%15.09), elektrik, su, doğal gaz gibi hizmetlerin aksaması (%13.21), ve ulaşım kaynaklı pazarlama sorunları (%11.32) gibi sorunlar üreticilerin deprem nedeniyle yaşanan en önemli problemleridir (Çizelge 6).

Çizelge 5. Üreticilerin Dekara Brüt, Mutlak ve Nispi Karları
Table 5. Producers' Gross, Absolute, and Relative Profits per Decare

Verim (kg da^{-1}) (1)	424.41
Satış Fiyatı (₺)(2)	32.06
Brüt Üretim Değeri (₺ da^{-1}) (3= 1*2)	13 606.58
Değişen Masraflar (₺ da^{-1}) (4)	5 001.21
Brüt Kar (marj) (5=3-4)	8 605.37
Üretim Masrafları (₺ da^{-1}) (6)	7 789.04
Birim Kiraz Maliyeti (₺ kg^{-1}) (7= 6/1)	18.35
Mutlak Kar (TL/da) (8= 3-6)	5 817.54
Nispi Kar (9=3/6)	1.75

₺=Türk Lirası, da=dekar, kg=kilogram

Çizelge 6. Üreticilerin Deprem Nedeni İle Yaşadığı Problemler
Table 6. Problems Faced by Producers Due to the Earthquake

Deprem Nedeni İle Yaşanan Problemler	%
Deprem nedeniyle ikametgahların hasar alması	33.96
Depremin psikolojik etkisi	22.64
Geçici işgücü bulunamaması	15.09
Elektrik, Su, Doğalgaz gibi hizmetlerin aksaması	13.21
Ulaşım kaynaklı pazarlama sorunları	11.32
Kurtarma ve enkaz kaldırma faaliyetlerinin yavaş ilerlemesi	3.78
Toplam	100.00

Üreticilerin deprem nedeni ile yaşadıkları bu problemlerin çözümü konusundaki düşünceleri incelenmiştir. Üreticilerin %26.42'si evlerini kaybeden üreticilere bir an önce ev temin edilmesini, %18.87'si geçici işgücü temini için yerel

yönetimlerin önlemler almasını, %16.98'i mazot, gübre, tarım ilaçları, sulama suyu gibi girdilerin deprem bölgesinde sübvanse oranının arttırılmasını ve iş gücü ücretlerinin standartlaştırılmasını, %13.21.2'i sulama ve elektrik gibi problemlerin giderilmesini ve %7.55'i depremden etkilenen üreticilere psikolojik destek sağlanması mevcut sorunlara çözüm önerileri olarak belitmişlerdir (Çizelge 7).

Çizelge 7. Üreticilerin Deprem Nedeniyle Yaşanan Sorunlara Çözüm Düşünceleri
Table 7. Producers' Thoughts on Solutions to Problems Caused by the Earthquake

Üreticilerin Çözüm Konusundaki Düşünceleri	%
Evlerini kaybeden üreticilere bir an önce ev temin edilmesi	26.42
Geçici işgücü temini için yerel yönetimlerin önlemler alması	18.87
İş gücü ücretlerinin standartlaştırılması	16.98
Mazot, gübre, tarım ilaçları, sulama suyu gibi girdilerin deprem bölgesinde sübvanse oranı arttırılmalı	16.98
Sulama, elektrik gibi alt yapı problemlerinin giderilmesi	13.21
Depremden etkilenen üreticilere psikolojik destek sağlanması	7.55
Toplam	100.00

Sonuç

Bu çalışma, Malatya'nın Yeşilyurt ilçesinde kiraz üreticilerinin 6 Şubat 2023 Kahramanmaraş depremlerinden nasıl etkilendiğini ortaya koyarak önemli bulgular sunmuştur. Elde edilen veriler, üreticilerin büyük bir kısmının deprem sonrası ekonomik, sosyal ve psikolojik sorunlarla mücadele etmek zorunda kaldığını göstermektedir. Yaşanan bu deprem ile üreticilerde ulaşım ve maddi sıkıntılar oluşmuş, elektrik, su, doğal gaz ve araç yakıtı gibi hizmetlerin aksadığı görülmüştür. Ayrıca işçi ücretlerinin yükselmesi ile çalıştırılacak işçilerin bulunmaması gibi problemlerin ortaya çıktığı görülmüştür. Özellikle ulaşım, pazarlama, iş gücü eksikliği ve artan üretim maliyetleri, bölgedeki kiraz üretimini olumsuz yönde etkilemiştir. Ancak, üretim miktarının genel olarak büyük bir düşüş yaşanmadığı, aksine 2023 yılında son yıllardaki ortalama üretim miktarından fazla üretim miktarı tespit edilmiştir. Çalışmada, deprem nedeniyle üreticilerin yaşadığı en büyük sorunların başında konut hasarları, psikolojik etkiler, işgücü teminde sıkıntılar ve alt yapı kaynaklı sıkıntılar nedeni ile elektrik, su, doğalgaz gibi hizmetlerin aksaması ve ulaşım kaynaklı pazarlama zorlukları gelmektedir. Üreticilerin deprem sonrası ihtiyaçlarının karşılanması ve zararlarının en aza indirilmesi sürecinde, devlet desteklerinin artırılması gerektiği ortaya çıkmıştır. Örneğin, tarımsal girdi maliyetlerini azaltacak sübvansiyonların sağlanması, pazarlama altyapısının geliştirilmesi ve üreticilere yönelik psikolojik destek programlarının oluşturulması gibi önlemler, hem mevcut sorunları hafifletmek hem de gelecekte olası benzer krizlere hazırlıklı olmak adına büyük önem taşımaktadır. Deprem gibi afetlerin tarım sektörüne etkilerini azaltmaya yönelik stratejilerin geliştirilmesi, üreticilerin ekonomik ve sosyal refahını artıracak ve tarımın ülke ekonomisindeki stratejik önemini korumasını sağlayacaktır.

Teşekkür

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Phenotypic Diversity of The Chestnut Genotypes in Yağlıdere District (Giresun, Türkiye)

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Abstract

Phenotypic diversity and population relationships of chestnut genotypes (*Castanea sativa* Mill.) growing spontaneously in forested areas of Yağlıdere district (Giresun, Türkiye) were investigated according to fruit traits. In 7 different populations where chestnut trees are dense in the region, 15 healthy genotypes and 105 genotypes in total were evaluated for 14 fruit traits. It was determined that the coefficient of variation was less than 20% except for nut and kernel weight. Correlation analysis revealed that 56 out of 91 relationships were significant and 51 of them were positive. The highest positive relationships were found between nut weight, kernel weight, kernel percentage, nut height and nut length. Only nut height/nut length ratio and stalk base length showed significant variation among populations. In within-population principal component analysis, the first four principal components explained 77.38% of the total variance. The relationships between the first principal component and nut width, nut length, nut height, the distance from the base to the largest section of the nut, nut weight and kernel weight were found to be high and positive. In the principal component analysis between populations, the first four principal components explained 88.98% of the total variance. The highest positive correlation was shown by scar length/scar width and nut height in the first principal component, nut length and distance from the base to the largest section of the nut in the second principal component, scar length and scar length/nut length in the third component and nut width in the fourth component, respectively. Cluster analysis divided genotypes into 12 clusters and populations into 2 clusters. In conclusion, principal component and clustering analysis explained the phenotypic diversity of 105 chestnut genotypes in the natural population in Yağlıdere district according to fruit traits and population relationships explained the whole phenotypic variation among genotypes.

Keywords: *Castanea sativa*, Clustering, Correlation, Population, Principal component, Variation.

Yağlıdere İlçesindeki (Giresun, Türkiye) Kestane Genotiplerinin Fenotipik Çeşitliliği

Özet

Yağlıdere ilçesi (Giresun, Türkiye) ormanlık alanlarda kendiliğinden yetişen kestane genotiplerinin (*Castanea sativa* Mill.) meyve özelliklerine göre fenotipik çeşitliliği ve populasyon ilişkileri araştırılmıştır. Yörede kestane ağaçlarının yoğun olduğu 7 farklı populasyonda sağlıklı durumda olan 15'er genotip ve toplamda 105 genotip 14 meyve özelliği yönünden değerlendirilmiştir. Kabuklu ve iç meyve ağırlığı dışındakilerin %20'nin altında varyasyon katsayısına sahip olduğu belirlenmiştir. Korelasyon analizi toplam 91 ilişkiden 56 tanesinin önemli olduğunu ve bunların da 51 tanesinin pozitif yönlü olduğunu ortaya koymuştur. En yüksek pozitif ilişkiler meyve ağırlığı, iç ağırlığı, iç oranı, meyve yüksekliği ve boyu arasında ortaya çıkmıştır. Sadece meyve yüksekliği/meyve boyu oranı ve sap tabanı uzunluğu populasyonlar arasında önemli değişim göstermiştir. Populasyon içi temel bileşen analizinde ilk dört temel bileşen toplam varyansın %77.38'ini açıklamıştır. Birinci temel bileşenle meyve eni, meyve boyu, meyve yüksekliği, meyve tabanı ile en geniş yeri arasındaki mesafe, meyve ağırlığı ve iç ağırlığı arasındaki ilişkilerin yüksek ve pozitif yönde bulunmuştur. Populasyonlar arası temel bileşen analizinde ilk dört temel bileşen toplam varyansın %88.98'ini açıklamıştır. En yüksek pozitif ilişkiyi, sırasıyla, birinci temel bileşende meyve tabanı boyu/meyve tabanı eni ve meyve yüksekliği, 2. temel bileşende meyve boyu ve meyve tabanı ile en geniş yeri arasındaki mesafe, üçüncü bileşende meyve tabanı boyu ve meyve tabanı boyu/meyve boyu ve dördüncü bileşende meyve eni göstermiştir. Kümeleme analizi genotipleri 12 kümeye, popülasyonları da 2 kümeye ayırmıştır. Sonuç olarak, temel bileşen ve kümeleme analizi ile Yağlıdere ilçesindeki doğal populasyondaki 105 kestane genotipinin meyve özelliklerine göre fenotipik çeşitliliği ve populasyon ilişkileri genotipler arasındaki fenotipik varyasyonun tamamını açıklamıştır.

Anahtar Kelimeler: *Castanea sativa*, Kümeleme, Korelasyon, Populasyon, Temel bileşen, Varyasyon.

Introduction

Chestnuts belong to the same order (*Fagales*) as hazelnuts and to the same family (*Fagaceae*) as oaks and beeches. Within the genus Castanea, several culturally important species have emerged in different parts of the world. The most widely distributed species, *Castanea sativa*, known as European chestnuts, is native to the Mediterranean countries and its homeland is not known for certain, but it is highly probable that it is Anatolia. According to some authors, this species is named after the city of Kastanis (Kastamonu, Northern Türkiye), its first distribution center. Although it is found at elevations up to 1800 m in the Caucasus, it can reach up to 1200 m in the region starting from the entire Black Sea coast in Anatolia, from Marmara and Western Anatolia to the Mediterranean coast (Soylu, 1984; Özçağıran et al. 2014).

Chestnut is a temperate climate fruit species that generally prefers acidic, deep and well-drained soils and does not grow in lowlands where it is too humid and cold, or in high mountainous areas with large differences in daily and annual temperatures (Poljak et al. 2022). *Castanea sativa* has long been recognized as a multipurpose species (Aravanopoulos, 2005), as it is widely cultivated for timber and nut production and represents an integral part of the economy in many areas, especially in rural areas (Diamandis and Perlerou, 1996).

European chestnut has been cultivated in Anatolia since ancient times, many chestnut genotypes with different fruit quality and tree characteristics have emerged. The nearly 2.5 million chestnut trees in Anatolia are highly variable. Within these rich European chestnut populations, there are species

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with large fruits with bright and striking colors, as well as species with low quality and small fruits. Although plant breeders in Türkiye have made chestnut selections from natural populations, European chestnut varieties are still restricted to individual chestnut regions. Genotypes with important characteristics such as good fruit quality, earliness and high yield capacity were selected by local breeders and propagated by grafting. There are significant differences in each region in terms of the mentioned characteristics (Ertan, 2007).

Natural populations of *Castanea sativa* are facing extreme degradation for timber utilization. Therefore, conservation and management of these natural areas is necessary (Aravanopoulos et al. 2001). Assessment of the genetic diversity and population structure of natural Chestnut areas is crucial for good management strategies and conservation strategy and sustainable use of this natural resource (Lang and Huang, 1999). The magnitude and structure of genetic variation in natural populations should also be known when determining gene conservation strategies (Zarafshar et al. 2010).

Varieties belonging to species of the genus *Castanea* possess many traits that are desirable for breeding (Huang et al. 1995; Huang, 1998). Morphological traits have often served as tools for studying genetic diversity (Neophytou et al. 2007), especially because they are easy to use and are clear traits (Cousens, 1963; Olsson, 1975; Kremer et al. 2002). In general, the study of morphological traits constitutes an important component in the study of species with population relationships and diversity (Aravanopoulos, 2005). Morphological and phenological traits are used to develop quantitative estimates of genetic similarities and relationships. MacKey (1988) emphasized the importance of morphological traits in taxonomic studies of cultivated plants. Morphological characterization is an accepted formal method for the registration and conservation of new varieties (Pereira-Lorenzo et al. 1996). Varieties have traditionally been characterized by morphological traits, which in turn are influenced by developmental status and environmental and cultural factors. In order to reduce the influence of environmental factors, these studies should be repeated in different years and regions (Pereira-Lorenzo et al. 1996; Oraguzie et al. 1998).

On the other hand, multivariate analysis, and in particular principal component and cluster analysis, has been used for the evaluation of germplasm when studying several traits and many genotypes (Cruz and Regazzi, 1994). The use of multivariate methods is an important strategy for the characterization, evaluation and classification of plant genetic resources when many genotypes are to be evaluated for several characters (Peeters and Martinelli, 1989).

Traditionally, leaf morphological traits have been used by scientists to study phenotypic diversity. It is widely accepted that leaves are the most important organs for photosynthesis and transpiration in plants and the arrangement, size, shape and anatomy of leaves vary greatly in different environments (Bruschi et al. 2003) and are also easy to measure (Neophytou et al. 2007).

In this study, statistical analyses were carried out using morphological traits with multivariate methods to determine phenotypic diversity and population relationships according to fruit traits in seven natural chestnut populations in Yağlıdere district of Giresun province (Türkiye).

Material and Methods

Experimental Site and Plant Material

This research was conducted in 2020 and 2021 in Yağlıdere district of Giresun province (Türkiye). Yağlıdere district is located between 40 ° 51′ 43″ North latitude and 38 ° 37′ 24″ East longitude, 50 meters above sea level and 14 km from the coast (Figure 1). There is a dense chestnut population in the forest area in the district, and all trees in the chestnut population were grown from seed and each of them is a separate gene source.

The climate of the district is typical Black Sea climate with cool summers and mild and rainy winters. Precipitation is distributed over four seasons. The average annual precipitation is 1300 m^3. The coldest month is february and the lowest air temperature is -3 °C. The hottest month is august, and the average temperature is 24 °C. The average annual temperature is 14 °C. The average humidity is 70% (Anonymous, 2022).

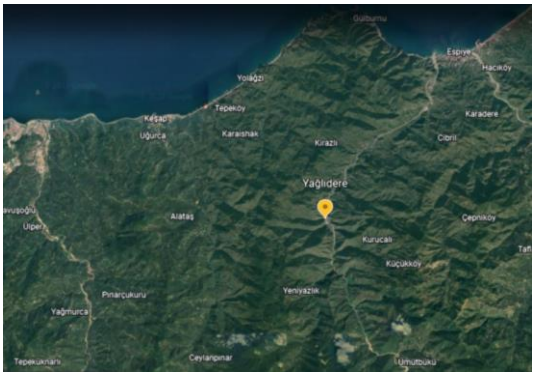

Figure 1. Google Earth view of Yağlıdere district
Şekil 1. Yağlıdere ilçesinin Google Earth görünümü

Chestnut genotypes are found in the population together with alder, beech, hornbeam, oak species and spruce forest species. According to the stand map, seven populations with a high density of

chestnut trees and in different locations were identified (Figure 2).

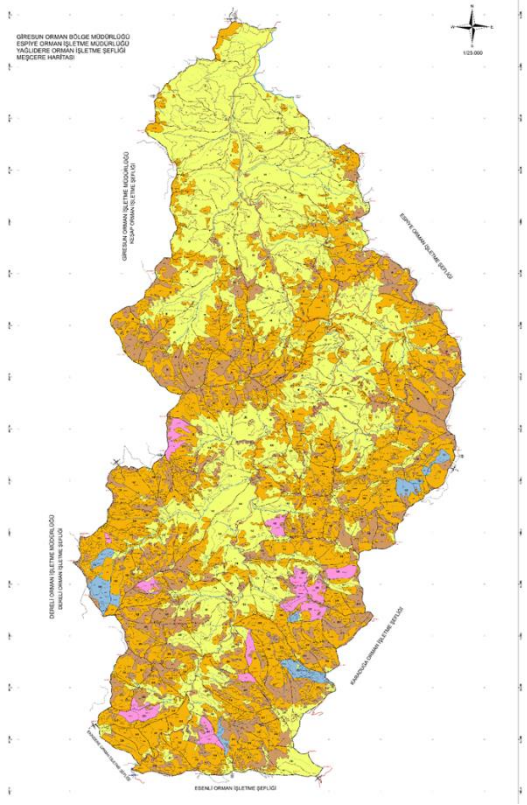

Figure 2. Stand Map of Yağlıdere District
Şekil 2. Yağlıdere İlçesi Meşcere Haritası

Nut Parameters

Fifteen genotypes were selected from each population and the genotypes were selected since they were at least 50 m away from each other to ensure that the genotypes were of productive age, healthy and unaffected by pollination and fertilization. When taking nut samples, care was taken to take them from the middle part of the shoots and from all four sides of the tree. Ten burs were sampled from 105 genotypes and brought to the measurement site on the same day in bags with air inlets.

Nut height, nut length, nut width, nut height/ nut length, width of the scar, length of the scar, length of the scar/width of the scar, length of the scar/ nut length, distance from the base to the largest section of the nut, length of the stalk's base, nut weight, kernel weight, kernel percentage and shell thickness were measured in ten nut samples (Figure 3).

Şahin (1989), Pigliucci et al. (1991), Pereira-Lorenzo et al. (1996), Oraguzie et al. (1998), Bolvansky et al. (2001), Alizoti and Aravanopoulos (2005), Aravanopoulos (2005), Solar et al. (2005), Ertan (2007), Soylu and Serdar (2009), Zarafshar et al, (2010), Serdar and Kurt (2011), Mujagić-Pašić and Ballian (2012), Serdar et al. (2014), Grygorieva et al. (2017), UPOV (International Union for the Protection of New Varieties of Plants) (2017), Atar and Turna (2018), Bostan et al. (2018), Grygorieva et al. (2018) and Serdar et al. (2018) were used to determine fruit parameters.

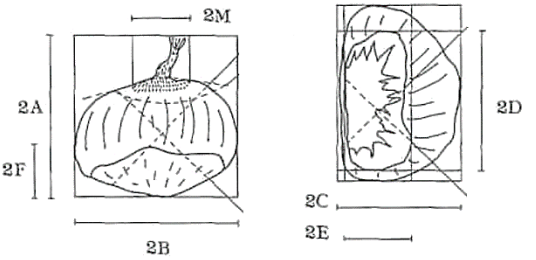

Figure 3. Nut height (2A), length (2B), width (2C), length of the scar (2D), width of the scar (2E), distance from the base to the largest section of the nut (2F) and length of the stalk's base (2M) measurements (Pigliucci et al., 1991)
Şekil 3. Meyvede yükseklik (2A), uzunluk (2B), en (2C), meyve tabanı uzunluğu (2D), meyve taban genişliği (2E), meyve tabanı ile en geniş yeri arası mesafe (2F) ve meyve sap tabanı uzunluğu (2M) ölçümleri (Pigliucci ve ark., 1991).

Statistical analysis

Statistical analyses were performed on 2-year average data. Descriptive statistics, correlation analysis, analysis of variance, principal component analysis and cluster analysis of fruit traits of the genotypes were performed using SAS JMP 13.2.0 statistical program.

Quantitative data were analyzed by ANOVA and means were compared using LSD (0.05) significance test.

Results and Discussion

Descriptive statistics

Among 105 chestnut genotypes, intrapopulational coefficient of variation was highest in kernel weight (27.30%) and nut weight (21.03%) and lowest in nut height/nut length ratio (6.81%) (Table 1).

The coefficients of variation of 10 genotypes from 10 different locations in Nazilli district (Aydın, Türkiye) were determined as 1.23-14.42% for nut weight, 2.94-8.90% for shell thickness, 0.84-7.74% for nut width, 0.28-4.55% for nut height, 0.47-3.39% for nut length and 0.14-2.85% for kernel percentage (Ertan, 2007). Although the coefficients of variation determined in our study were slightly higher, the order from high to low was the same as in the previous study. The high coefficients in our study may be due to the high number of genotypes.

Table 1. Minimum, maximum, mean, standard deviation (SD) and coefficient of variation (CV) values of 14 nut parameters of 105 chestnut genotypes intrapopulational

Çizelge 1. 105 Kestane genotipinin 14 meyve özelliğine ait populasyon içindeki minimum, maksimum, ortalama, standart sapma (SD) ve varyasyon katsayısı (CV) değerleri

Fruit parameters	Abbreviation	Min.	Max.	Mean	SD	CV (%)
1. Nut width (mm)	NWI	10.56	18.97	13.35	1.75	13.12
2. Nut length (mm)	NL	15.91	23.90	20.18	1.94	9.59
3. Nut height (mm)	NH	14.34	23.55	19.21	1.91	9.92
4. NH/NL	-	0.80	1.15	0.96	0.07	6.81
5. Scar width (mm)	SW	6.69	13.30	9.53	1.43	15.02
6. Scar length (mm)	SL	10.44	20.23	15.57	2.04	13.08
7. SL/SW	-	1.05	2.41	1.71	0.23	13.18
8. SL/NL	-	0.59	0.92	0.77	0.08	10.11
9. Distance from the base to the largest section of the nut (mm)	DBLS	6.15	12.92	10.09	1.27	12.54
10. Length of the stalk's base (mm)	LSB	3.28	9.65	6.01	1.03	17.06
11. Nut weight (g)	NW	2.25	7.00	4.13	0.87	21.03
12. Kernel weight (g)	KW	1.33	6.00	3.06	0.84	27.30
13. Kernel percentage (%)	KP	55.00	85.71	72.23	5.95	8.23
14. Shell thickness (mm)	ST	0.61	1.64	1.00	0.19	18.66

In many previous studies, the rate of within-population variation was found to be very significant for many parameters (Pigliucci et al., 1991; Pereira-Lorenzo et al., 1996; Oraguzie et al., 1998; Lang and Huang, 1999; Aravanopoulos et al., 2001; Alizoti and Aravanopoulos, 2005; Qin et al., 2005; Queijeiro et al., 2005; Beccaro et al., 2005; Ormeci et al., 2016; Grygorieva et al., 2017; Bilgen and Bostan, 2018; Bostan et al., 2018; Zenginbal et al., 2018; Poljak et al., 2021; Poljak et al., 2022). In addition, it has been reported that intrapopulational variation is moderate compared to interpopulational variation (Peterson et al., 1992); the most variation is observed between populations, within populations and within genotypes (individuals), respectively (Glushkova, 2007), and similarities within populations can also be seen (Solar et al., 2001). As can be understood from the studies, the variation within the population may vary according to the size of the population, heterogeneity of the genotypes, parameters studied and environmental conditions.

Among the 7 chestnut populations, the coefficient of variation was 9.32% (5th population)-17.38% (3rd population) for NWI, 6.81% (6th population)-11.16% (4th population) for NL, 6.40% (5th population)-11.69% (3rd population) for NH, 4.51% (7th population)-8.68% (1st population) for NH/NL, 9.80% (1st population)-9.80% (SW) for SW. population), 4.51% (7th population)-8.68% (1st population) for NH/NL, 9.80% (1st population)-18.46% (6th population) for SW, 10.17% (5th population)-16.34% (7th population) for SL, 7.70% (4th population)-19.21% (6th population), 7.11% (3rd population)-13.94% (1st population) for SL/NL, 9.84% (6th population)-15.82% (1st population) for DBLS, 9.13% (6th population)-21.31% (2nd population) for LSB, 18.33% (5th population)-26. 71% (3rd population), 22.07% (1st population)-35.73% (3rd population) for KW, 4.40% (1st population)-9.88% (4th population) for KP and 12.21% (3rd population)-24.39% (5th population) for ST (Table 2).

On the other hand, within the populations, the coefficient of variation was 4.40% (KP)-22.07% (KW) in population 1, 5.09% (NH/NL)-25.59% (KW) in population 2, 7.11% (NH/NL)-35.73% (KW) in population 3, 5. 61% (NH/NL)-26.12% (KW), 6.40% (NH)-24.87% (KW) in population 5, 5.77% (KP)-26.48% (KW) in population 6, 4.51% (NH/NL)-26.77% (KW) in population 7 (Table 2).

In previous studies, the coefficient of variation was 5.1-9.6% for nut height, 5.4-10.9% for nut width, 6.6-12.2% for nut thickness, 11.2-32.4% for nut weight, 9.5-20.3% for scar length and 9.6-18.1% for scar width in 6 subpopulations in Slovenia (Solar et al, 2001); 7.4-12.5% for nut height, 6.8-12.4% for nut width, 7.7-14.4% for nut thickness, 17.3-38.6% for nut weight, 12.7-17.8% for scar length and 10.0-17.9% for scar width in a population of 3 locations in the same country (Solar et al., 2005); 32.18% for nut weight and 10.14% for nut size in 3 different locations in Srinagar district (Kashmir) (Pandit et al., 2013); 10.42% for nut height, 10.82% for nut width, 16.68% for nut thickness, 25.71% for nut weight, 17.76% for scar length and 19.65% for scar width at 3 locations in Bosnia and Herzegovina (Skender et al., 2013); 13.74% in nut height, 14.98%

in nut width, 20.57% in fruit thickness, 45.92% in nut weight, 19.58% in scar length and 20.66% in scar width in Forest-Steppe regions of Ukraine (Grygorieva et al., 2017); 24.59-35.85% in nut weight, 7.97-13.03% in nut height, 10.34-14.40% in nut width, 11.22-15.82% in DBLS, 13.78-17.37% in nut thickness, 13.69-21.07% in scar length, 16.66-24.78% in scar width, 7.25-10.28% in NH/NL, 6.15-10.50% in SL/FL in eight populations in Italy (Poljak et al., 2022). It has also been reported that there are significant differences in fruit characteristics among 8 chestnut populations in Türkiye (Atar and Turna, 2018) and that the nuts of different plantations in Sicily vary most in height, width, thickness and weight (Cutino et al., 2010). As in previous studies, the highest coefficient of variation among populations in our study was determined in nut weight, and it can be said that nut and scar sizes also have significant coefficients.

Table 2. Interpopulations coefficients of variation (%) of 14 nut parameters of 105 chestnut genotypes
Çizelge 2. 105 kestane genotipinin 14 meyve özelliğinin populasyonlararası varyasyon katsayıları (%)

Fruit parameters	Populations						
	1	2	3	4	5	6	7
Nut width	11.84	9.58	17.38	12.57	9.32	9.84	14.15
Nut length	7.57	9.90	10.44	11.16	9.81	6.81	10.80
Nut height	6.48	9.77	11.69	10.58	6.40	6.63	11.66
NH/NL	8.68	5.09	7.44	5.61	7.83	4.84	4.51
Scar width	9.80	17.76	11.71	13.41	14.20	18.46	15.97
Scar length	11.09	11.73	10.38	14.17	10.17	13.06	16.34
SL/SW	11.34	10.67	10.21	7.70	9.38	19.21	14.71
SL/NL	13.94	8.08	7.11	11.78	8.74	9.26	9.65
DBLS	15.82	11.91	13.32	15.64	12.36	9.84	10.29
LSB	17.70	21.31	14.90	13.12	12.60	9.13	13.43
Nut weight	19.74	19.51	26.71	18.67	18.33	22.45	20.33
Kernel weight	22.07	25.59	35.73	26.12	24.87	26.48	26.77
Kernel percentage	4.40	8.60	9.53	9.88	9.49	5.77	8.51
Shell thickness	22.01	20.52	12.21	19.82	24.39	18.33	15.63

In previous studies, the coefficient of variation was 5.1-9.6% for nut height, 5.4-10.9% for nut width, 6.6-12.2% for nut thickness, 11.2-32.4% for nut weight, 9.5-20.3% for scar length and 9.6-18.1% for scar width in 6 subpopulations in Slovenia (Solar et al, 2001); 7.4-12.5% for nut height, 6.8-12.4% for nut width, 7.7-14.4% for nut thickness, 17.3-38.6% for nut weight, 12.7-17.8% for scar length and 10.0-17.9% for scar width in a population of 3 locations in the same country (Solar et al., 2005); 32.18% for nut weight and 10.14% for nut size in 3 different locations in Srinagar district (Kashmir) (Pandit et al., 2013); 10.42% for nut height, 10.82% for nut width, 16.68% for nut thickness, 25.71% for nut weight, 17.76% for scar length and 19.65% for scar width at 3 locations in Bosnia and Herzegovina (Skender et al., 2013); 13.74% in nut height, 14.98% in nut width, 20.57% in fruit thickness, 45.92% in nut weight, 19.58% in scar length and 20.66% in scar width in Forest-Steppe regions of Ukraine (Grygorieva et al., 2017); 24.59-35.85% in nut weight, 7.97-13.03% in nut height, 10.34-14.40% in nut width, 11.22-15.82% in DBLS, 13.78-17.37% in nut thickness, 13.69-21.07% in scar length, 16.66-24.78% in scar width, 7.25-10.28% in NH/NL, 6.15-10.50% in SL/FL in eight populations in Italy (Poljak et al., 2022). It has also been reported that there are significant differences in fruit characteristics among 8 chestnut populations in Türkiye (Atar and Turna, 2018) and that the nuts of different plantations in Sicily vary most in height, width, thickness and weight (Cutino et al., 2010). As in previous studies, the highest coefficient of variation among populations in our study was determined in nut weight, and it can be said that nut and scar sizes also have significant coefficients.

Correlations

Correlation analysis revealed that there were many significant relationships among the fruit traits of chestnut genotypes (Table 3).

The 14 parameters had correlation coefficient values ranging from (-) 0.001 (NW-SL/SF) to 0.982 (KW-NW). Out of a total of 91 relationships, 56 (61.54%) were significant, of which 51 were positive (91.07%) and 5 were negative (8.93%). Out of 56 significant relationships, 75% (42) were significant at 1‰ ($P<0.001$), 17.86% (10) at 1% ($P<0.01$) and 7.14% (4) at 5% level. The highest positive relationship was found between kernel weight and nut weight (0.982). This was followed by kernel percentage-kernel weight (0.868), kernel percentage-nut weight (0.780), nut height-nut length (0.773), DBLS- nut length (0.706).

Table 3. Pairwise correlation coefficients between fruit traits
Çizelge 3. Meyve özellikleri arasındaki Pairwise korelasyon katsayıları

Variable	by Variable	Corr.	Sign Prob	Variable	by Variable	Corr.	Sign Prob
KW	NW	0.982	<.0001*	SL/SW	NWI	-0.305	0.0015*
KP	KW	0.868	<.0001*	LSB	NH	0.291	0.0026*
KP	NW	0.780	<.0001*	ST	SL	0.287	0.0030*
NH	NL	0.773	<.0001*	ST	NWI	0.257	0.0080*
DBLS	NH	0.706	<.0001*	DBLS	SL/NL	0.255	0.0086*
NL	NWI	0.687	<.0001*	ST	NW	0.251	0.0098*
SL/NL	SL	0.677	<.0001*	ST	DBLS	0.244	0.0122*
NW	NL	0.674	<.0001*	ST	SW	0.242	0.0128*
KW	NL	0.665	<.0001*	KP	NH/NL	-0.233	0.0170*
DBLS	SL	0.648	<.0001*	LSB	NL	0.211	0.0308*
SL	NL	0.647	<.0001*	ST	KW	0.188	0.0542
SL	NH	0.642	<.0001*	ST	LSB	0.179	0.0671
KW	NWI	0.631	<.0001*	NW	LSB	0.169	0.0857
SW	NL	0.628	<.0001*	DBLS	NH/NL	0.167	0.0885
NW	NWI	0.623	<.0001*	KW	LSB	0.166	0.0910
SW	NWI	0.618	<.0001*	LSB	DBLS	0.165	0.0917
SL/NL	SL/SW	0.618	<.0001*	KP	LSB	0.164	0.0946
DBLS	NL	0.591	<.0001*	LSB	SW	0.146	0.1381
KP	NL	0.590	<.0001*	LSB	NWI	0.130	0.1878
SL/SW	SW	-0.574	<.0001*	LSB	NH/NL	0.119	0.2286
SW	NH	0.585	<.0001*	ST	SL/NL	0.116	0.2389
DBLS	SW	0.564	<.0001*	SL/SW	NH/NL	0.109	0.2688
NW	SW	0.553	<.0001*	SL/NL	NH	0.105	0.2846
NW	NH	0.551	<.0001*	ST	KP	0.078	0.4285
KW	SW	0.534	<.0001*	ST	NH/NL	0.068	0.4932
KW	NH	0.527	<.0001*	SL	NH/NL	0.014	0.8894
KP	NWI	0.522	<.0001*	LSB	SL	0.011	0.9137
NW	SL	0.495	<.0001*	NW	SL/NL	-0.001	0.9953
SL	SW	0.473	<.0001*	SL/NL	SW	-0.003	0.9738
NH	NWI	0.462	<.0001*	ST	SL/SW	-0.014	0.8880
NW	DBLS	0.448	<.0001*	DBLS	SL/SW	-0.014	0.8849
KW	SL	0.448	<.0001*	SL/SW	NH	-0.036	0.7156
KP	NH	0.430	<.0001*	KW	SL/NL	-0.053	0.5908
KW	DBLS	0.425	<.0001*	SL/SW	NL	-0.082	0.4048
SL	NWI	0.424	<.0001*	SW	NH/NL	-0.088	0.3741
KP	SW	0.418	<.0001*	SL/NL	NWI	-0.099	0.3166
DBLS	NWI	0.411	<.0001*	SL/NL	NL	-0.116	0.2384
SL/SW	SL	0.401	<.0001*	LSB	SL/SW	-0.145	0.1399
SL/NL	NH/NL	0.349	0.0003*	KP	SL/SW	-0.161	0.1013
KP	DBLS	0.344	0.0003*	NW	SL/SW	-0.164	0.0955
NH/NL	NH	0.343	0.0003*	KP	SL/NL	-0.165	0.0922
NH/NL	NL	-0.323	0.0008*	NW	NH/NL	-0.169	0.0849
NH/NL	NWI	-0.317	0.0010*	KW	SL/SW	-0.180	0.0662
KP	SL	0.310	0.0013*	LSB	SL/NL	-0.182	0.0625
ST	NH	0.308	0.0014*	KW	NH/NL	-0.191	0.0514
ST	NL	0.256	0.0084*				

In previous studies, Alizoti and Aravanopoulos (2005) found that the correlation coefficients between 7 nut traits ranged between 0.000-0.874. In the study, high positive correlations were found between nut weight- nut width and nut width- nut length; moderate positive correlations were found between nut weight- nut thickness, nut width-scar length, nut weight- nut height, nut weight- nut length, nut width- nut height and nut weight-scar length. Ertan (2007) examined the correlations among 11 nut traits. The correlation coefficients between nut weight, nut width, nut length, nut height, kernel percentage and shell thickness ranged between 0.026-0.947; the highest correlations were

found between nut weight-fruit width (0.947), nut weight- nut width (0.910), nut length- nut height (0.910), nut length- nut height (0.871), nut width-nut height (0.871), nut width- nut thickness (0.947) and nut weight- nut width (0.947), respectively. 947), nut weight- nut height (0.910), nut length- nut height (0.871), nut width- nut height (0.855), nut weight- nut height (0.832) and nut width- nut height (0.828), respectively. Soylu and Serdar (2009) reported that the highest relationships between nut width, nut length, nut height and nut weight were nut weight- nut length (0.961), nut width- nut length (0.925), nut width-nut weight (0.890), nut width-nut height (0.865), nut height- nut height (0.825) and nut height-nut weight (0.824), respectively. Pandit et al. (2013) reported that nut size and nut weight were highly correlated (0.855). Bostan et al. (2018) found that the relationship between nut weight and nut size was positive and significant (0.860). Tuğ et al. (2022) found that the correlation coefficients between 11 nut traits ranged between (-) 0.006-0.923 and 43 (78.18%) out of 55 correlations were significant. The highest correlations between nut weight, nut length, nut height, nut width, nut height, scar width and scar length were found between nut width and nut weight (0.877), nut height and nut weight (0.796), nut height and nut weight (0.794) and nut height and nut width (0.766), respectively. Atar and Turna (2018) determined that the correlation coefficients between nut height, nut width, nut thickness and 1000 nut weight varied between 0.914-0.965. As in previous studies, especially NW-NWI, NW-NH, NW-NL, NW-NL, NW-SL, NWI-FL, NWI-SL, NWI-NH and NH-NL correlations were positive and high in our study.

Variance Analysis

Analysis of variance revealed that only NH/NL ratio and LSB were significant among the populations. The highest NH/NL ratio (1.00) was observed in population 2, while the lowest was observed in populations 3 (0.91) and 6 (0.93). The highest LSB was observed in population 1 (6.89), while the lowest was observed in populations 3 (5.44) and 2 (5.50) (Table 4).

Table 4. Mean and standard deviation (second rows) values of 14 fruit traits of 105 chestnut genotypes interpopulations
Çizelge 4. 105 kestane genotipinin 14 meyve özelliğinin populasyonlararası ortalama ve standart sapma (ikinci satırlar) değerleri

Nut traits	Populations							Prob > F
	1	2	3	4	5	6	7	
NWI	13.77	12.48	14.03	14.11	13.16	13.13	13.17	ns
	1.63	*1.19*	*2.44*	*1.77*	*1.23*	*1.29*	*1.86*	
NL	20.33	19.96	20.14	20.52	20.58	20.46	19.84	ns
	1.54	*1.97*	*2.10*	*2.29*	*2.02*	*1.39*	*2.14*	
NH	19.69	19.82	18.32	19.27	20.22	18.90	18.71	ns
	1.28	*1.94*	*2.14*	*2.04*	*1.30*	*1.25*	*2.18*	
NH/NL	0.98 abc	1.00 a	0.91 d	0.95 bcd	0.99 ab	0.93 d	0.95 cd	0.0004***
	0.09	*0.05*	*0.07*	*0.05*	*0.08*	*0.04*	*0.04*	
SW	9.63	9.32	9.99	9.07	9.68	9.77	9.39	ns
	0.94	*1.65*	*1.17*	*1.22*	*1.38*	*1.80*	*1.50*	
SH	15.73	16.01	15.69	15.96	15.67	15.91	14.68	ns
	1.75	*1.88*	*1.63*	*2.26*	*1.59*	*2.08*	*2.40*	
SL/SW	1.68	1.81	1.63	1.80	1.73	1.74	1.63	ns
	0.19	*0.19*	*0.17*	*0.14*	*0.16*	*0.33*	*0.24*	
SL/NL	0.78	0.80	0.78	0.78	0.77	0.78	0.74	ns
	0.11	*0.07*	*0.05*	*0.09*	*0.07*	*0.07*	*0.07*	
DBLS	10.08	10.23	9.87	10.10	10.46	10.47	9.73	ns
	1.60	*1.22*	*1.32*	*1.58*	*1.29*	*1.03*	*1.00*	
LSB	6.89 a	5.50 c	5.44 c	5.74 c	6.16 bc	6.62 ab	5.96 c	<.0001***
	1.17	*1.16*	*0.81*	*0.75*	*0.78*	*0.60*	*0.80*	
NW	4.13	3.92	4.41	3.95	4.09	4.12	4.21	ns
	0.82	*0.76*	*1.18*	*0.74*	*0.75*	*0.93*	*0.86*	
KW	2.99	2.84	3.36	2.95	3.03	3.01	3.17	ns
	0.66	*0.73*	*1.20*	*0.77*	*0.75*	*0.80*	*0.85*	
KP	70.61	70.58	73.90	72.79	72.63	71.29	73.50	ns
	3.11	*6.07*	*7.05*	*7.19*	*6.89*	*4.11*	*6.25*	
ST	0.96	1.04	0.96	1.01	0.99	1.01	0.99	ns
	0.21	*0.21*	*0.12*	*0.20*	*0.24*	*0.19*	*0.15*	

Significant level, ***: 1‰, ns: nonsignificant, Önemlilik düzeyi: ***: ‰1, ns: önemli değil

Previous studies have shown that although intra-population variation in chestnut is moderate, inter-population variation, including fixed differences between populations, is high (Peterson et al. 1992); chestnut species and genotypes can be separated along geographical lines (Oraguzie et al., 1998); the level of variability can vary significantly between species and regions (Lang and Huang, 1999); the studied nut traits vary more between regions than between populations (Aravanopoulos et al., 2001); that the variance between populations was greater than that within a population and within a genotype, respectively (Glushkova, 2007); and that all nut traits examined varied significantly among populations (Skender et al., 2013; Atefe et al., 2015; Atar and Turna, 2018; Poljak et al., 2022). As can be seen from previous studies, the differences among populations may vary according to the degree of heterozygosity in genotypes, parameters studied, size and density of populations and geographical distance.

Principal Component Analysis

As a result of the principal components analysis for intrapopulational relationships, the first four components with eigenvalues above 1 explained 77.38% of the variation. Nut size and weight were the most important variables in component 1, which accounted for 41.69% of the total variance in terms of the traits analyzed. In the second component, which accounted for 17.80% of the variation, scar traits (except scar width) were the most important variables. All 14 fruit traits explained 100% of the phenotypic variation among genotypes (Table 5).

Table 5. Eigenvalues, total variability and correlation between the original variables and the three principal components intrapopulational

Çizelge 5. Populasyon içindeki özdeğerler, toplam değişkenlik oranı ve orijinal değişkenler ile incelenen kestane genotiplerindeki üç temel bileşen arasındaki korelasyon

Fruit traits	PCA1	PCA2	PCA3	PCA4
Nut width	0.318	-0.144	-0.084	-0.232
Nut length	0.366	-0.026	-0.074	-0.066
Nut height	0.327	0.185	0.295	0.072
NH/NL	-0.054	0.329	0.528	0.229
Scar width	0.317	-0.091	0.211	-0.432
Scar length	0.284	0.410	-0.170	-0.142
SL/SW	-0.082	0.474	-0.371	0.314
SL/FL	0.018	0.564	-0.151	-0.101
DBLS	0.291	0.226	0.190	-0.144
LSB	0.105	-0.076	0.437	0.518
Nut weight	0.359	-0.076	-0.165	0.232
Kernel weight	0.357	-0.115	-0.192	0.280
Kernel percentage	0.307	-0.170	-0.218	0.366
Shell thickness	0.146	0.118	0.223	-0.112
Eigenvalue	5.84	2.49	1.48	1.03
Variance (%)	41.69	17.80	10.55	7.34
Total variance (%)	41.69	59.49	70.04	77.38

As a result of the principal component analysis for interpopulational relationships, 48.93% of the total variance for the traits examined could be explained by the first component, 66.88% by the first two components, 79.83% by the first three components and 88.98% by the first four components. All 14 nut traits explained 100% of the phenotypic variation among the populations (Table 6).

SL/SW and NH in the first principal component, NL and DBLS in the second principal component, SL and SL/NL in the third component and NWI in the fourth component showed the highest positive relationship, respectively.

Table 6. Eigenvalues, total variability and correlation between the original variables and the three principal components interpopulations
Çizelge 6. Populasyonlar arasındaki özdeğerler, toplam değişkenlik oranı ve orijinal değişkenler ile üç temel bileşen arasındaki korelasyon

Fruit traits	PCA1	PCA2	PCA3	PCA4
Nut width	-0.192	0.285	0.247	0.504
Nut length	0.126	0.482	0.037	0.417
Nut height	0.300	0.047	-0.289	0.121
NH/NL	0.279	-0.155	-0.338	0.012
Scar width	-0.188	0.392	-0.110	-0.494
Scar length	0.246	0.343	0.371	-0.121
SL/SW	0.350	-0.032	0.268	0.110
SL/NL	0.239	0.221	0.360	-0.332
DBLS	0.276	0.317	-0.063	-0.109
LSB	0.051	0.330	-0.534	0.115
Nut weight	-0.354	0.159	-0.034	-0.234
Kernel weight	-0.368	0.070	0.083	-0.097
Kernel percentage	-0.293	-0.110	0.217	0.272
Shell thickness	0.280	-0.297	0.212	-0.115
Eigenvalue	6.85	2.51	1.81	1.28
Variance (%)	48.93	17.95	12.96	9.14
Total variance (%)	48.93	66.88	79.83	88.98

In our study, similar to the results of previous studies (Pereira-Lorenzo et al., 1996; Ertan, 2007; Bostan et al., 2018; Poljak et al., 2021; Poljak et al., 2022), it was found that component 1 had a significant share in total variation and traits such as nut size and weight represented component 1. Atefe et al. (2015) also reported that the first three principal components represented the highest cumulative variance, and that nut weight and size traits were prominent.

Cluster Analysis

Cluster analysis for intrapopulational relationships revealed that genotypes were divided into 2 main groups and these groups were divided into 2 subgroups and branching occurred and a total of 12 clusters were formed (Figure 2).

The most genotypes were in cluster 1 (19) and the least in cluster 9 (3). Genotypes 62 and 67 were the most similar to each other in terms of fruit characteristics.

Genotypes 31, 32 and 37 in cluster 9 had the highest values in terms of fruit width, NH/NL, nut weight, kernel weight and kernel percentage, which were significantly different from the other clusters (Table 7).

Table 7. Number of genotypes and averages of the traits of the clusters intrapopulational
Çizelge 7. Populasyon içi kümelerin genotip sayısı ve incelenen özelliklerinin ortalamaları

Cluster	Count	NWI	NL	NH	FH/FL	SW	SL	SL/SW	SL/NL	DBLS	LSB	NW	KW	KP	ST
1	19	12.44	18.91	18.25	0.97	9.10	15.18	1.75	0.80	9.43	5.79	4.02	2.90	71.45	1.08
2	13	12.25	20.15	18.58	0.93	8.48	14.56	1.79	0.72	9.57	6.16	3.78	2.81	72.67	0.83
3	5	12.27	17.70	16.13	0.92	8.51	10.82	1.29	0.62	8.82	5.77	3.29	2.30	67.60	0.86
4	12	11.73	17.30	17.13	1.00	7.79	13.91	1.86	0.81	8.54	5.40	2.89	1.87	62.97	0.92
5	8	15.03	22.66	22.53	1.00	11.32	18.31	1.66	0.81	12.06	6.40	4.93	3.59	72.32	1.30
6	6	16.36	23.03	21.49	0.94	10.34	15.77	1.59	0.69	10.35	7.62	4.92	3.90	78.03	1.20
7	5	14.03	20.96	19.54	0.93	11.96	13.91	1.30	0.66	9.87	7.26	4.28	3.20	73.64	0.92
8	9	13.85	21.54	20.46	0.95	10.29	15.72	1.59	0.73	10.82	5.24	4.27	3.27	75.57	0.89
9	3	17.32	21.68	17.52	0.81	10.89	15.52	1.45	0.72	9.99	4.41	5.83	4.85	81.91	1.05
10	6	12.77	19.13	20.03	1.05	9.29	15.97	1.78	0.84	10.93	6.50	4.12	3.05	71.64	0.82
11	12	13.76	21.18	20.42	0.97	10.37	18.14	1.81	0.86	11.17	6.26	4.86	3.78	76.21	0.96
12	7	13.91	21.34	19.09	0.90	9.06	17.67	1.98	0.83	10.52	5.68	3.92	2.85	71.92	1.16

In previous studies on this subject, it was reported that different clusters were formed in genotypes in terms of similar nut characteristics (Oraguzie et al., 1998; Serdar et al., 2014; Bostan et al., 2018; Stojanović and Magazin, 2020; Poljak et al., 2022); it has been reported that traits such as nut weight, nut size, shape and scar size are important distinguishing characteristics of clusters (Pereira-Lorenzo et al., 1996; Solar et al., 2001; Ertan, 2007; Cutino et al., 2010; Atefe et al., 2015; Grygorieva et al., 2017).

Cluster analysis for interpopulational relationships revealed that the populations formed 2 main groups, with 5 populations in group 1 and 2 populations in group 2 (Figure 4).

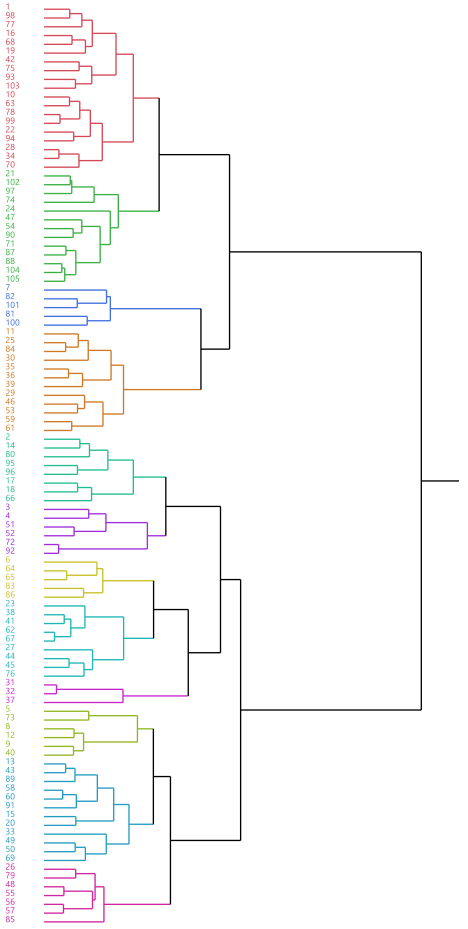

Figure 3. Dendrogram of chestnut genotypes according to fruit characteristics determined by cluster analysis

Şekil 3. Kestane genotiplerinin meyve özelliklerine göre kümeleme analizi ile belirlenen dendrogramı

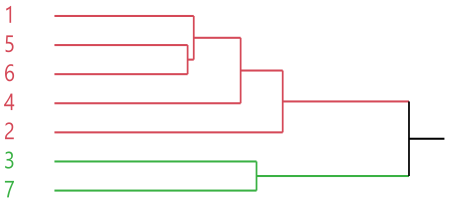

Figure 4. Dendrogram of chestnut populations according to fruit characteristics determined by cluster analysis

Şekil 4. Kestane populasyonlarının meyve özelliklerine göre kümeleme analizi ile belirlenen dendrogramı

Populations 5 and 6 were the most similar to each other in terms of nut characteristics, while populations 1 and 3 were the most distant.

Populations 3 and 7 in cluster 2 had the highest values in terms of nut width, scar width, nut weight, kernel weight and kernel percentage and were significantly different from cluster 1 (Table 8).

Table 8. Number of genotypes and averages of the traits studied in interpopulation clusters

Çizelge 8. Populasyonlararası kümelerde genotip sayısı ve incelenen özelliklerinin ortalamaları

Variables	**Cluster**	1	2
	Count	5	2
NWI		13.33	13.60
NL		20.37	20.00
NH		19.58	18.52
NH/NL		0.97	0.93
SW		9.49	9.69
SL		15.85	15.19
SL/SW		1.75	1.63
SL/NL		0.78	0.76
DBSL		10.27	9.80
LSB		6.18	5.70
NW		4.04	4.31
KW		2.96	3.27
KP		71.58	73.70
ST		1.00	0.98

Similar results were obtained from previous studies. In Slovenia, significant genetic differences were found among 6 subpopulations within 4 main regions (Solar et al., 2001); in Greece, two distant regions showed significant variation in almost all nut traits and Mount Paiko region had higher mean values for nut weight, nut length, nut width, nut height, nut length to the widest point (DBSL) and nut weight (Alizoti and Aravanopoulos, 2005); It was reported that populations consisting of 15-20 genotypes selected from 8 provinces in different

parts of Türkiye and from each province formed 3 groups and nut length, 1000 nut weight, nut height and nut width were the traits with the highest discrimination power among the groups (Atar and Turna, 2018) and a total of 8 populations (160 genotypes), 5 from Croatia, 1 each from Italy, Slovenia and Bosnia-Herzegovina, were divided into two groups in terms of 10 fruit morphometric traits (Poljak et al., 2022).

Conclusions

As a result, principal component and clustering analyses explained the phenotypic variation of 105 chestnut genotypes in the natural population in Yağlıdere district according to nut traits and population relationships explained all the phenotypic variation among genotypes. Since the variation of the nut traits examined among both genotypes and populations is significant, it can be said that these variations of nut traits can be used in further genetic studies. Among the parameters examined in the whole population, especially nut and kernel weight had high coefficient of variation.

It can be said that the sizes of chestnut genotypes of Yağlıdere region are generally small and therefore have the potential to be used for secondary food products.

This study is preliminary research, and it can be said that expanding it based on years and populations can contribute to future breeding studies.

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Orta Kelkit Vadisi Ceviz (*Juglans regia* L.) Genotiplerinde Meyve Özelliklerine Dayalı Çeşitliliğin Çok Değişkenli Analizlerle İncelenmesi

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Özet

Bu çalışmada, Orta Kelkit Vadisinde tohumdan yetişen ceviz genotiplerinin meyve ve yaprakçık özellikleri çok değişkenli analizler ile değerlendirilmiştir. Genotiplerin meyve ve yaprakçık özellikleri geniş bir varyasyon göstermiştir. Ceviz ıslahında önemli kalite kriterlerinden olan özelliklerden, kabuklu meyve ağırlığı 5.57-16.73 g arasında, kabuk kalınlığı 1.02-2.04 mm arasında, iç meyve ağırlığı 2.64-8.16 g arasında ve iç meyve oranı %40.46-%64.33 arasında belirlenmiştir. Genotiplerin çeşitliliğini ortaya koymak için kullanılan temel bileşen analizi (TBA) ve heatmap hiyerarşik kümeleme analizi, genotipleri meyve özelliklerine göre ayırt etmede etkili olmuştur. TBA'ne göre, üç temel bileşen (eigen değeri ≥ 1,00) toplam varyasyonun %66,82'sini açıklamıştır. Heatmap hiyerarşik kümeleme analizi sonuçlarına göre genotipler iki ana gruba ayrılmıştır. Ceviz genotiplerine ait çalışma sonuçları gelecekte yapılacak çalışmalara yol gösterici niteliktedir.
Anahtar kelimeler: *Juglans regia L.,* Temel bileşen analizi, Heatmap analizi, Genetik çeşitlilik, Morfolojik özellikler.

Investigation of Diversity Based on Fruit Characteristics in Middle Kelkit Valley Walnut (*Juglans regia* L.) Genotypes with Multivariate Analysis

Abstract

In this study, fruit and leaflet characteristics of walnut genotypes grown from seed at the Middle Kelkit Valley were evaluated with multivariate analysis. Fruit and leaflet characteristics of genotypes showed wide variation. Among the important quality criteria in walnut breeding, nut weight ranged from 5.57 to 16.73 g, shell thickness ranged from 1.02 to 2.04 mm, kernel weight ranged from 2.64 to 8.16 g and kernel ratio ranged from 40.46% to 64.33%. Principal component analysis (PCA) and heatmap hierarchical clustering analysis, used to reveal the diversity of genotypes, were effective in distinguishing genotypes according to fruit characteristics. According to PCA, three principal components (eigen value ≥ 1.00) explained 66.82% of the total variation. According to the results of heatmap hierarchical clustering analysis, genotypes were divided into two main groups. The study results on walnut genotypes provide guidance for future studies.
Key words: *Juglans regia L.,* Principal component analysis, Heatmap analysis, Genetic diversity, Morphological characteristics.

Giriş

Türkiye, dünyadaki biyoçeşitlilik merkezlerinin (İran-Turan, Akdeniz ve Avrupa-Sibirya) kesişim noktasında bulunduğu için bitki genetik kaynakları açısından dünyada özel bir konuma sahiptir ve birçok meyve türünün anavatanıdır (Sümbül vd. 2023). Bu meyve türlerinden biride *Juglans* cinsi içerisinde yer alan cevizdir (*Juglans spp.*)'dir. Dünya üzerinde bilinen 21 ceviz türü vardır. Anadolu cevizi, İran cevizi ve İngiliz cevizi olarak tanımlanan *Juglans regia* L., dünya üzerinde en çok üretimi yapılan ceviz türüdür (Şen, 1986). Ceviz, ağacı, meyvesi, yaprağı ve kerestesi ile hem çeşitli sektörlere ham madde sağlamakta hem de çeşitli şekillerde işlenerek gıda sektöründe kullanılmasıyla insan beslenmesinde önemli bir yere sahiptir.

Monoik çiçek yapısına sahip olan cevizlerde dikogami görülmektedir. Bu nedenle cevizlerde görülen açık tozlaşma, ceviz ıslahında yeni çeşitler elde etmek için uygun fırsatlar sağlayan önemli bir genetik çeşitlilik kaynağı meydana getirmektedir (Cosmulescu ve Botu, 2012). Tür içindeki zengin çeşitlilik üstün özelliklere sahip bireylerin seçilmesinde kolaylıklar sağlamaktadır. Ceviz germplazm kaynaklarının araştırılması ve değerlendirilmesi gelecekte yapılacak ıslah programları için önemlidir. Farklı coğrafi bölgelerdeki geniş genetik çeşitlilik, ıslah programlarında kullanılabilecek genotipleri seçme fırsatı sunarak genetik erozyonu önler (Rezaei vd., 2018). Germplazm kaynaklarının farklı özelliklerinin belirlenmesi ıslah açısından yararlı genetik kaynakların seçilmesinde fayda sağlar (Uzun vd., 2017).

Genetik çeşitlilik içeren germplazmalarının tanımlanması ve korunması, istenen özelliklere

sahip bir gen havuzunun oluşturulmasını sağlayabilir. Bu durum araştırmacıların gelecekte daha hassas ve hızlı bir ıslah süreci yürütmesine olanak tanıyabilir (Vahdati vd., 2019). Islah programlarında zamandan tasarruf sağlamak ve istenilen özelliklerde yeni çeşitler elde etmek için uygulanan en önemli strateji, çeşitlilik ve orijin merkezlerindeki germplazmalarının taranmasıdır. Nitekim ceviz germplazmaları üzerine Hindistan (Shah vd., 2021), Türkiye (Gerçekcioğlu vd., 2020; Bayazit vd., 2024), İran (Einollahi ve Khadivi, 2024) ve Pakistan (Hussain vd., 2016) ve İtalya (Poggetti vd., 2017) gibi birçok ülkede çalışmalar yürütülmüştür.

Ceviz yetiştiriciliğinde genetik materyalin orijinal olması ve bu materyallerin genetik ilişkilerinin ortaya konulması oldukça önemlidir (Yildiz vd., 2021). Morfolojik tanımlayıcılar genellikle germplazm çeşitliliğini değerlendirmek için faydalıdır. Genetik kaynakları değerlendirme ve tanımlamadaki ilk adım, farklı büyüme koşulları için üstün genotiplerin seçilebilmesi için morfolojik tanımlayıcılar kullanmaktır (Shah vd., 2023). Bu nedenle morfolojik karakterler, ümitvar genotiplerin seçilmesi ve sınıflandırılması için bir seçenek olarak düşünülmektedir (Skender vd., 2020).

Ülkemizde, cevizlerde açık tozlaşmanın yaygın olarak görülmesinden ve tohumdan yetiştirilmesinden (Orhan vd., 2020) kaynaklı olarak geniş bir genetik zenginlik vardır. Türkiye'nin sahip olduğu bu genetik zenginlik ıslah çalışmaları için büyük önem taşımaktadır. Bu çalışmada, Orta Kelkit Vadisinde (Suşehri, Akıncılar, Koyulhisar ve Şebinkarahisar) tohumdan yetişen ceviz popülasyonu içerisinde meyve kalitesi bakımından üreticiler tarafından tercih edilen ceviz genotiplerinin çeşitliliği çok değişkenli analizler ile açıklanmıştır.

Materyal ve Yöntem

Bitki materyali

Çalışmanın materyalini Orta Kelkit Vadisinde (Koyulhisar, Suşehri, Şebinkarahisar ve Akıncılar ilçeleri) tohumdan yetişen ceviz popülasyonu içerisinden meyve kalite özellikleri bakımından bölge halkı tarafından tercih edilen genotipler oluşturmuştur. Çalışmada, Koyulhisar (G1, G2, G3, G4, G5 ve G6), Suşehri (G7, G8, G9, G10, G11, G12, G13 ve G14), Şebinkarahisar (G15, G16, G17, G18, G19, G20, G21, G22 ve G23) ve Akıncılar (G24, G25, G26, G27, G28 ve G29) yörelerinden toplanan toplam 29 adet ceviz genotipi değerlendirmeye alınmıştır.

Meyve analizleri

Çalışma kapsamında, yöre halkı ile görüşmeler neticesinde verimlilik, meyve iriliği, meyve tadı ve kabuk kalınlığı açısından üstün ve farklı olan 29 adet ceviz genotipinden meyve örnekleri alınmıştır. Hasat kriteri olarak meyvelerin yeşil kabuklarının büyük oranda kabuktan ayrılması kabul edilmiştir. Analizler üç tekerrürlü olarak planlanmış ve analizler her tekerrürde 30 adet meyvede gerçekleştirilmiştir. Çalışma sırasında, meyve örnekleri ağacın farklı yönlerinden alınmıştır. Toplanan meyve örnekleri hızla dış kabuklarından ayrılmıştır. Bu örnekler doğal kuruma sağlanması amacıyla gölgede saklanmıştır. Kurutma işlemi tamamlanan meyvelerde gerekli ölçümler yapılmıştır. Kabuklu meyve ve iç meyve ağırlığı ölçümleri ± 0.01 gr hassasiyetli hassas terazi kullanılarak yapılmıştır. Kabuklu meyve eni, kabuklu meyve boyu, kabuklu meyve yüksekliği ve kabuk kalınlığı değerleri 0.01 mm hassasiyetli dijital kumpas kullanılarak ölçülmüştür. İç meyve oranı, iç meyve ağırlığının kabuklu meyve ağırlığına oranlanması ile % olarak hesaplanmıştır. Cevizlerin kabuk ve iç renk ölçümleri (L*, a* ve b*) el tipi renkölçer ile yapılmıştır.

Yaprak analizleri

Genotiperin yaprak özelliklerini belirlemek için üç tekerrürlü ve her tekerrürde 30 adet yaprak olacak şekilde örnekleme yapılmıştır. Yapraklar büyümesini tam olarak tamamladığı eylül ayının başında rastgele olarak toplanmıştır. Genotiplerin yaprak eni ve yaprak boyu yaprakçıklarda cetvel yardımıyla belirlenmiştir.

Verilerin analizi

Genotiplere ait verilerin istatistiksel analizi tek yönlü varyans analizi (ANOVA) yöntemi ile gerçekleştirilmiştir. Ortalamalar arasındaki farklılıklar Tukey Testi ile karşılaştırılmıştır. Ayrıca çalışmada incelenen özelliklerin etkinliğini ve genotiplerin çeşitliliğini ortaya koyabilmek için TBA ve heatmap hiyerarşik kümeleme analizi JMP Pro 17 istatistiksel paket programı kullanılarak gerçekleştirilmiştir. Heatmap hiyerarşik kümeleme analizi Öklid uzaklık katsayılarına dayalı Ward yöntemine göre gerçekleştirilmiştir.

Bulgular ve Tartışma

Meyve özellikleri

Varyans analizi sonuçlarına göre, ceviz genotiplerinin meyve özellikleri önemli farklılıklar göstermiş ve bu farklılıklar istatistiksel olarak önemli bulunmuştur (Çizelge 1). Ceviz genotiplerinin kabuklu meyve ağırlığı 5.57 g (G2) - 16.73 g (G13) arasında değişiklik göstermiştir. Kabuklu meyve ağırlığı bakımından G14 (15.12 g), G23 (14.59 g), G9 (13.87 g) ve G3 (13.51 g) ön plana çıkan diğer genotipler olmuştur. İç meyve ağırlığı 2.64 g (G2) - 8.16 g (G3) arasında değişiklik göstermiştir. G23 (8.10 g) ve G13 (7.97 g) diğer en yüksek iç meyve ağırlığına sahip genotiplerdir. İç meyve oranı %40.46 (G8) - %64.33 (G27) arasında

değişmiştir. G28 (%63.28), G22 (%62.04), G29 (%60.48), G3 (%60.41) ve G15 (%60.16) genotipleri iç meyve oranı ile ön plana çıkan diğer genotipler olmuştur.

Çizelge 1. Ceviz genotiplerinin meyve ve yaprak özellikleri
Table 1. Fruit and leaf characteristics of walnut genotypes

Genotip	Kabuklu Meyve Ağırlığı (g)	Kabuklu Meye Eni (mm)	Kabuklu Meye Boyu (mm)	Kabuklu Meye Yüksekliği (mm)	Kabuk Kalınlığı (mm)	İç Meyve Ağırlığı (g)	İç Meyve Oranı (%)	Yaprakçık Eni (cm)	Yaprakçık Boyu (cm)
G1	8.48±0.35 l	28.11±1.10 ı-k	30.95±1.13 k	31.70±0.40 gh	1.33±0.03 h-k	4.68±0.40 kl	55.14±2.41 e-g	5.16±0.47 k	12.25±0.58 lm
G2	5.57±0.33 n	24.16±0.05 p	33.07±0.52 h-j	26.33±0.52 o	1.37±0.09 g-k	2.64±0.31 q	47.35±2.66 m	5.95±0.10 c-e	12.11±0.35 m
G3	13.51±0.24 c	34.08±0.93 a	39.20±1.50 ab	35.29±0.61 d	1.26±0.06 j-m	8.16±0.27 a	60.41±0.91 b-d	5.17±0.10 jk	12.44±0.49 k-m
G4	7.59±0.23 m	26.08±0.64 m-o	31.20±1.13 k	27.87±0.40 n	1.46±0.01 e-h	3.72±0.28 op	49.03±2.23 k-m	5.77±0.21 e-g	13.44±0.38 g-ı
G5	10.73±0.72 f	28.36±0.56 ıj	31.87±0.42 ı-k	32.65±0.83 fg	1.71±0.10 bc	5.76±0.13 g-ı	53.77±2.88 f-ı	6.54±0.12 b	14.49±0.50 c-f
G6	8.79±0.36 kl	28.76±0.61 h-j	34.38±1.08 f-h	30.46±0.12 ıj	1.61±0.03 cd	4.28±0.15 l-n	48.68±0.38 lm	6.35±0.09 b	12.46±0.26 j-m
G7	12.05±0.49 e	32.15±0.67 cd	36.14±0.77 de	33.14±0.57 ef	1.37±0.05 g-k	6.79±0.29 cd	56.33±0.66 ef	5.90±0.06 c-f	12.59±0.47 j-m
G8	10.36±0.85 f-h	32.69±1.18 bc	31.87±1.12 ı-k	35.38±0.74 cd	1.70±0.17 bc	4.19±0.38 l-o	40.46±0.96 n	5.69±0.48 e-h	13.24±0.60 h-j
G9	13.87±0.40 c	34.14±1.64 a	39.97±2.11 a	38.75±1.18 a	1.55±0.07 d-f	7.44±0.40 b	53.68±2.43 f-ı	5.63±0.10 e-ı	14.11±0.23 e-g
G10	7.65±0.19 m	26.76±0.32 l-n	29.18±0.12 l	28.36±0.47 mn	1.38±0.03 g-j	3.96±0.24 n-p	51.77±2.28 h-k	7.38±0.35 a	15.00±0.41 bc
G11	7.55±0.16 m	24.93±0.33 op	28.20±1.18 lm	28.18±0.12 mn	1.52±0.02 d-g	3.57±0.17 p	47.33±1.39 m	5.66±0.22 e-ı	10.64±0.14 n
G12	9.49±0.66 ı-k	29.06±1.00 g-ı	31.06±2.09 k	32.39±0.60 fg	1.22±0.08 k-m	5.28±0.41 ıj	55.64±0.48 ef	5.54±0.17 f-ı	10.97±0.29 n
G13	16.73±0.13 a	33.40±1.12 ab	40.81±0.75 a	36.74±0.84 b	2.04±0.16 a	7.97±0.12 a	47.65±0.53 m	5.53±0.05 g-j	11.93±0.53 m
G14	15.12±0.72 b	32.66±0.26 bc	37.88±0.62 bc	36.26±0.35 bc	1.76±0.06 b	7.88±0.53 ab	52.12±1.08 g-j	6.38±0.16 b	12.22±0.62 lm
G15	9.41±0.31 ı-k	28.32±0.11 ıj	33.95±1.03 gh	30.04±0.33 jk	1.16±0.04 l-n	5.66±0.13 g-ı	60.16±1.62 cd	5.16±0.31 k	14.12±1.55 d-g
G16	12.77±0.18 d	32.07±0.49 cd	36.42±0.45 c-e	31.31±0.07 h	2.03±0.17 a	6.31±0.20 d-f	49.45±1.23 j-m	6.23±0.24 bc	14.86±0.31 b-e
G17	7.18±0.34 m	27.10±0.59 k-m	27.44±0.61 m	29.42±1.27 kl	1.15±0.08 l-n	4.13±0.22 m-o	57.44±0.65 de	5.88±0.32 c-g	12.03±0.25 m
G18	8.85±0.18 kl	27.78±0.08 j-l	31.66±0.74 jk	30.02±0.55 jk	1.27±0.09 ı-l	4.98±0.26 jk	56.28±2.33 ef	6.56±0.04 b	14.28±0.10 c-f
G19	7.56±0.38 m	25.86±0.14 no	28.85±0.50 lm	26.36±0.16 o	1.60±0.04 c-e	3.86±0.07 n-p	51.20±3.58 ı-l	5.31±0.35 ı-k	13.17±0.47 h-k
G20	9.66±0.25 h-j	31.90±0.80 cd	37.28±1.49 cd	33.92±0.52 e	1.48±0.07 d-g	4.99±0.24 jk	51.65±1.24 h-l	6.39±0.17 b	13.22±0.45 h-k
G21	11.63±0.40 e	30.26±0.36 e-g	36.94±0.82 cd	30.78±0.86 h-j	1.42±0.13 f-ı	6.44±0.27 de	55.44±3.45 ef	5.40±0.15 h-k	13.87±0.29 f-h
G22	9.76±0.40 g-j	31.01±0.78 de	33.64±0.87 gh	33.21±0.60 ef	1.14±0.04 l-n	6.06±0.55 e-g	62.04±3.21 a-c	5.68±0.24 e-h	13.23±0.49 h-k
G23	14.59±0.13 b	33.81±0.47 ab	40.17±0.15 a	33.63±0.40 e	1.50±0.03 d-g	8.10±0.18 a	55.54±0.76 ef	5.81±0.04 e-g	14.21±0.62 c-g
G24	12.32±0.21 de	31.92±0.36 cd	34.93±0.97 e-g	32.49±0.35 fg	1.61±0.06 cd	6.94±0.21 c	56.34±0.78 ef	6.21±0.14 b-d	14.50±0.32 c-f
G25	10.46±0.33 fg	30.47±0.17 ef	34.15±0.31 gh	31.34±0.25 hı	1.47±0.11 d-h	5.78±0.19 gh	55.28±2.05 ef	5.94±0.31 c-e	13.01±0.36 ı-l
G26	9.86±0.46 g-ı	26.39±0.61 mn	35.86±1.11 d-f	27.55±0.56 n	1.62±0.22 b-d	5.36±0.17 h-j	54.35±0.89 f-h	5.81±0.10 e-g	16.43±0.23 a
G27	9.08±0.73 j-l	29.59±0.32 f-h	33.33±0.42 g-ı	30.43±0.31 ıj	1.02±0.06 n	5.85±0.62 f-h	64.33±1.86 a	5.72±0.04 e-h	14.92±0.35 b-d
G28	8.82±0.69 kl	29.13±1.33 g-ı	33.31±1.13 g-j	30.06±0.31 jk	1.04±0.08 n	5.57±0.33 g-ı	63.28±1.27 ab	5.93±0.15 c-e	15.43±0.08 b
G29	7.62±0.24 m	26.76±0.94 l-n	31.23±0.88 k	28.98±0.71 lm	1.12±0.07 mn	4.61±0.18 k-m	60.48±1.45 b-d	5.86±0.19 d-g	15.00±0.36 bc
LSD	0.71	1.21	1.66	0.96	0.15	0.50	3.08	0.37	0.80

*Aynı sütunda ve satırda farklı harflerle gösterilen değerler arasındaki farklar istatistiksel olarak önemlidir (Tukey çoklu karşılaştırma testi, $p<0.05$).

Ceviz ıslah programında meyve ağırlığı ve boyutları bakımından yüksek değerlere sahip genotiplere yoğun bir ilgi vardır. Türkiye'nin farklı bölgelerinde yapılan çalışmalarda meyve ağırlığı, iç meyve ağırlığı ve meyve oranı sırasıyla 5.10 - 20.08 g, 3.56 - 8.97 g ve %34.48 - %63.20 arasında değişiklik göstermiştir (Yaviç vd., 2017; İpek vd., 2019; Sütyemez vd., 2019; Varol vd., 2020; Gerçekcioğlu vd., 2020; Çiçek vd., 2020; Ünver vd., 2023; Bayazit vd., 2024). Ceviz genotiplerin kabuklu meyve

ağırlığı, iç meyve ağırlığı ve iç meyve oranı sırasıyla İran'da yapılan çalışmada 6.19 - 16.06 g, 2.84 - 7.97 g ve %34.41 - %59.18 (Einollahi ve Khadivi, 2024), Pakistan'da yapılan çalışmada 6.93 - 18.12 g, 3.37 - 5.68 g ve %27.28 - %56.88 (Hussain vd., 2016), Bosna-Hersek'de yapılan çalışmada 5.86 - 16.25 g, 1.66 - 5.07 g ve %26.96 - %48.25 (Skender vd., 2020) ve Kazakistan'da yapılan çalışmada 6.21 - 15.18 g, 2.36 - 6.64 g ve %33.55 - %71.01 (Akça vd., 2020) arasında değişiklik göstermiştir. Ceviz ıslahında meyve özellikleri ticari anlamda önemli bir parametredir. Ceviz için ideal kabuklu meyve ağırlığı 12.00 - 18.00 g, iç meyve ağırlığı 6.00 - 10.00 g ve iç meyve oranı e az %50.00 olarak kabul edilmektedir (Khadivi-Khub, 2014). İç meyve oranı cevizlerde ekonomik performansının bir göstergesi olarak kabul edildiği (Bayazit ve Sümbül, 2012) için iç meyve oranı ıslah çalışmalarında ön plana çıkan kriterdir. Çalışma kapsamında incelenen genotiplerin yaklaşık %76'sının iç meyve oranı %50'den fazladır. Bu sonuç çalışma alanındaki genotiplerin ıslah çalışmalarında kullanılabilecek genetik zenginliğe sahip olduğunu göstermektedir.

Çalışmadaki genotiplerin kabuklu meyve eni 24.16 mm (G2) - 34.14 mm (G9) arasında, kabuklu meyve boyu 27.44 mm (G17) - 40.81 (G13) arasında ve kabuklu meyve yüksekliği 26.33 mm (G2) - 38.75 mm (G9) arasında değişim göstermiştir. Çalışma kapsamında elde edilen bulgular önceki çalışmalar ile benzerlik göstermektedir. Ceviz genotiplerinde kabuklu meyve eni, kabuklu meyve boyu ve kabuklu meyve yüksekliği sırasıyla Yaviç vd. (2017) tarafından 26.53 - 32.57 mm, 32.01 - 41.45 mm ve 25.02 - 31.10 mm arasında, Öztürk ve Öztürk (2019) tarafından 24.02 - 31.07 mm, 27.85 - 55.52 mm ve 23.43 - 28.84 mm arasında, Gerçekcioğlu vd. (2020) tarafından 30.18 - 42.14 mm, 37.91 - 45.95 mm ve 31.42 - 38.90 mm arasında ve Ünver vd. (2023) tarafından 31.84 - 34.06 mm, 36.70 - 46.36 mm ve 32.95 - 37.21 mm arasında belirlenmiştir.

Genotiplerin kabuk kalınlıkları 1.02 mm (G27) - 2.04 mm (G13) arasında değişim gösterirken G28 (1.04 mm) diğer en düşük kabuk kalınlığına sahip genotip olmuştur. Önemli bir seleksiyon kriteri olan kabuk kalınlığı önceki çalışmalar ile benzerlik göstermektedir. Ülkemizde yapılan çalışmalarda Sütyemez vd. (2019) tarafından 0.85 - 1.85 mm, Varol vd. (2020) tarafından 2.00 - 4.53 mm Başak vd. (2022) tarafından 1.04 - 1.59 mm ve Ünver vd. (2023) tarafından 1.03 - 2.22 mm olarak belirlenmiştir. Ceviz genotiplerinin kabuk kalınlığı İran'da Einollahi ve Khadvi (2024) tarafından 0.88 - 2.60 mm arasında, İtalya'da Poggetti vd. (2017) tarafından 0.40 - 2.30 mm arasında ve Macaristan'da Bujdoso ve Cseke (2021) tarafından 1.37 - 1.89 mm arasında tespit edilmiştir. Kabuk kalınlığı, kabuğun iç meyveden ayrılmasının kolaylığını etkiler ve kabuğun ayrılması ne kadar kolay olursa cevizin ticari kalitesi de o kadar iyi olur (Sharma ve Sharma, 2001). Cevizlerde 0.70 - 1.50 mm arasındaki kabuk kalınlığı aranan bir özelliktir (Arzani vd. 2008). Bu açıdan çalışmadaki genotiplerin %62'si kabuk kalınlık özelliği bakımından ıslah kriterlerine uymaktadır.

Çalışma kapsamında incelenen genotiplerin kabuk ve iç meyve renkleri arasında geniş varyasyonlar tespit edilmiştir (Çizelge 2). Genotiplerin kabuk renk değerlerinden L değeri 50.46 (G21) - 63.40 (G27), a* değeri 4.22 (G17) - 27.25 (G20) ve b* değeri 14.83 (G29) - 36.69 (G8) arasında değişim göstermiştir. İç meyve renk değerlerinden L değeri 37.42 (G8) - 61.24 (G26), a* değeri 2.76 (G24) - 45.21 (G8) ve b* değeri 27.27 (G8) - 42.92 (G12) arasında değişim göstermiştir. Ceviz renginin parlaklığı, cevizin kalitesini ve pazar değerini belirleyen önemli kriterlerden biri olarak ıslah çalışmalarında kullanılan önemli bir özelliktir (Rezaei vd., 2018). İç ceviz renginin açık olması önemli kalite kriterlerindendir. Cevizlerin iç meyve renkleri genotip ve çevrenin etkisine göre değişiklik göstermektedir. Cevizlerin iç meyve renkleri genetik faktörlerin etkisinde olsa da havanın bağıl neminin ve sıcaklığın yüksek oluşu iç meyve renginin koyulaşmasına yol açmaktadır (Şen, 2011; Bayazit vd., 2024).

Çalışma kapsamında ceviz genotiplerinin meyve özellikleri ile literatürde bildirilen sonuçlar arasında benzerlikler olduğu gibi farklılıklarda gözlemlenmiştir. Cevizlerde meyve özelliklerinin ağaç yaşından etkilenmediği bilinse de (Sharma ve Sharma, 2001) genotip, çevre ve bunların etkileşimleri cevizlerde meyve kalitesini güçlü bir şekilde etkilemektedir (McGranahan ve Leslie, 1991).

Yaprak özellikleri

Ceviz genotiplerinin yaprakçık özellikleri önemli farklılıklar göstermiş ve bu farklılıklar istatistiksel olarak önemli bulunmuştur (Çizelge 1). Genotiplerin yaprakçık eni 5.16 cm (G1) - 7.38 cm (G10) ve yaprakçık boyu 10.64 cm (G11) - 16.43 cm (G26) arasında değişim göstermiştir. Yapılan bir çalışmada yaprak eni 20.41 - 32.90 cm ve yaprak boyu 29.20 - 49.60 cm arasında belirlenmiştir (Einollahi ve Khadivi, 2024). Başka bir çalışmada yaprak eni 19.30 - 40.60 cm ve yapak boyu 25.70 - 61.80 cm (Kavosi ve Khadivi, 2021) arasında belirlenirken diğer bir çalışmada yaprak eni 15.00 - 34.33 cm ve yaprak boyu 29.75 - 42.00 cm (Skender vd., 2020) arasında belirlenmiştir.

Çizelge 2. Ceviz genotiplerinin kabuk ve iç meyve renk değerleri
Table 2. Nut and kernel fruit color values of walnut genotypes

Genotip	Kabuk L değeri	Kabuk a değeri	Kabuk b değeri	İç Meyve L değeri	İç Meyve a değeri	İç Meyve b değeri
G1	61.63±1.51 bc	20.88±3.79 d-f	31.67±1.58 b	51.35±0.97 c-e	20.97±0.44 b-d	33.18±1.33 f-h
G2	51.15±0.29 ıj	13.55±1.95 j-l	20.15±0.34 n	50.38±0.32 e-h	14.10±1.05 lm	31.29±2.41 h-m
G3	50.92±0.10 j	24.00±1.14 bc	27.85±0.48 d-f	50.69±0.17 d-g	16.18±0.62 j-l	31.40±1.01 h-m
G4	61.40±0.99 bc	11.18±2.15 lm	31.69±2.36 b	50.91±0.02 d-g	21.98±0.17 bc	30.62±0.36 ı-n
G5	51.58±0.81 ıj	20.18±2.84 e-g	24.97±1.62 ı-l	50.40±0.05 e-h	18.01±1.93 f-j	32.66±1.74 g-j
G6	52.45±0.21 ı	17.63±0.50 g-ı	23.21±0.49 lm	51.43±0.75 cd	22.08±1.67 b	29.98±1.56 k-n
G7	57.47±0.08 de	18.71±2.78 f-h	31.34±0.23 b	50.88±0.14 d-g	20.17±1.55 b-e	29.37±1.59 m-o
G8	60.57±0.95 c	23.18±2.65 b-d	36.69±1.60 a	37.42±0.42 ı	45.21±1.50 a	27.27±0.53 o
G9	51.66±0.77 ıj	22.08±0.93 c-e	27.16±0.53 d-h	50.20±0.26 f-h	14.68±1.95 k-m	35.03±2.79 c-f
G10	51.05±0.03 j	24.77±0.60 ab	26.55±0.53 e-j	50.87±0.09 d-g	19.19±0.34 d-h	31.54±0.98 h-l
G11	57.90±1.05 d	18.36±1.65 f-h	31.44±1.42 b	56.78±0.54 b	4.46±0.30 qr	33.25±1.81 f-h
G12	56.40±1.10 ed	9.89±1.22 mn	30.97±2.03 bc	49.49±0.10 h	5.60±0.13 q	42.92±1.10 a
G13	51.03±0.23 j	20.06±0.97 e-h	25.95±0.81 f-k	50.22±0.10 f-h	11.58±1.55 no	35.44±1.74 c-e
G14	50.94±0.19 j	22.41±1.66 b-e	27.02±1.01 d-ı	50.89±0.11 d-g	18.67±0.81 e-ı	30.55±0.87 j-n
G15	54.32±0.65 h	12.29±0.17 k-m	25.51±1.24 g-k	50.10±0.14 gh	10.97±1.16 o	35.08±0.88 c-f
G16	50.65±0.23 j	15.61±1.43 ıj	26.85±1.32 d-j	50.78±0.14 d-g	17.62±1.00 g-j	29.54±0.48 l-n
G17	56.01±0.67 fg	4.22±1.05 o	25.69±0.24 f-k	50.80±0.57 d-g	16.10±0.58 j-l	32.70±1.28 g-ı
G18	51.65±0.49 ıj	20.76±1.13 d-f	24.78±2.33 j-l	51.62±0.93 cd	17.49±1.19 h-j	28.97±0.93 no
G19	61.82±0.74 bc	13.40±0.22 j-l	24.33±1.28 kl	51.95±1.04 c	19.93±1.18 c-f	32.27±0.63 g-j
G20	51.11±0.13 ıj	27.25±0.59 a	28.38±0.96 de	51.60±0.91 cd	13.29±1.68 mn	29.47±1.15 l-n
G21	50.46±0.05 j	15.12±1.54 ıj	27.60±1.67 d-g	50.40±0.05 e-h	16.71±1.53 ı-k	34.00±1.20 d-g
G22	58.62±0.39 d	14.65±1.03 jk	31.46±1.15 b	50.22±0.05 f-h	14.13±1.10 lm	36.46±0.95 bc
G23	54.93±0.83 gh	15.51±0.66 ıj	29.00±0.81 cd	51.17±0.57 c-f	19.69±1.91 d-g	28.80±1.27 no
G24	58.74±1.00 d	17.57±1.37 hı	31.39±1.13 b	60.44±2.20 a	2.76±1.48 r	35.93±1.00 cd
G25	61.05±1.54 bc	13.97±0.56 jk	25.16±2.07 h-l	50.69±0.06 d-g	18.66±1.04 e-ı	32.68±0.76 g-j
G26	58.58±1.60 d	4.34±0.82 o	21.84±1.24 mn	61.24±0.65 a	8.47±1.61 p	38.21±0.43 b
G27	63.40±1.41 a	7.43±0.69 n	14.87±1.49 o	50.71±0.12 d-g	17.43±1.04 h-j	31.97±0.68 g-k
G28	61.31±0.53 bc	14.08±1.42 jk	16.72±1.17 o	50.80±0.14 d-g	20.50±1.78 b-e	33.74±0.25 e-g
G29	62.03±1.01 b	13.60±1.27 j-l	14.83±1.57 o	50.28±0.24 f-h	14.85±1.46 k-m	35.53±2.07 c-e
LSD	1.35	2.57	2.18	1.01	2.09	2.14

*Aynı sütunda ve satırda farklı harflerle gösterilen değerler arasındaki farklar istatistiksel olarak önemlidir (Tukey çoklu karşılaştırma testi, $p<0.05$).

Temel bileşen analizi (TBA)

TBA, incelenen özellikler arasındaki değişimi ve ilişkileri ortaya çıkarmak için kullanılan etkili bir istatistiksel yöntemdir. Çok değişkenli istatistiksel yöntemlerden biri olan TBA, veri setindeki en önemli nitelikleri belirlemek için ve çeşitli bitki türlerinin çeşitliliğini değerlendirmek için yaygın olarak kullanılmaktadır. TBA'nın sahip olduğu üstün özelliği nedeniyle ıslah ve popülasyon genetiği çalışmalarında sıklıkla kullanılmaktadır. Ceviz genotiplerinin meyve ve yaprak özelliklerinin TBA sonuçlarına göre on beş temel bileşen oluşmuş ve dört temel bileşende eigen değeri 1'den büyük olarak tespit edilmiştir. İlk üç temel bileşen toplam varyansın %66.82'sini açıklamıştır. Bu sonuç ilk üç temel bileşende önemli olan özelliklerin ceviz genotipleri arasında en fazla çeşitliliğe sahip olduğunu ve ceviz genotiplerinin farklılaşması üzerinde en büyük etkiye sahip olduğunu göstermektedir. İlk üç temel bileşende incelenen özelliklerin etkileri farklılık göstermiştir. Toplam varyansın %34.43'ünü açıklayan birinci temel bileşende meye özellikleri (meyve ağırlığı, meyve eni, meyve boyu, meyve yüksekliği ve iç meyve ağırlığı) yüksek etki göstermiştir. Toplam varyansın %20.08'ini açıklayan ikinci temel bileşene iç meyve ağırlığı, iç meyve oranı ve iç meyve renk değerleri (L, a* ve b*) yüksek etki göstermiştir. Toplam varyansın %12.31'ini açıklayan üçüncü temel bileşene ise kabuk kalınlığı, kabuk L renk değeri, iç meyve L ve a* renk değerleri ve yaprak eni yüksek etkiye sahip olmuştur (Çizelge 3, Şekil 1). TBA ceviz genotiplerinin çeşitliliği ve morfolojik özellikler arasındaki ilişkiyi belirlemek amacıyla yaygın olarak kullanılıştır. Ceviz üzerine yapılan çalışmalarda ilk üç temel bileşenin toplam varyansın Rezaei vd. (2018) % 42.90'nını, Skender vd. (2020) %78.20'sini, Kavosi ve Khadivi (2021) %35.67'sini, Soveili ve Khadivi (2023) %48.41'ini ve Einollahi ve Khadivi (2024) %28.25'ini açıkladığını bildirmişlerdir. Çalışma sonuçları arasındaki farklılıklar genotiplerin ve çalışmalarda incelenen parametrelerin farklılığından kaynaklanabilir.

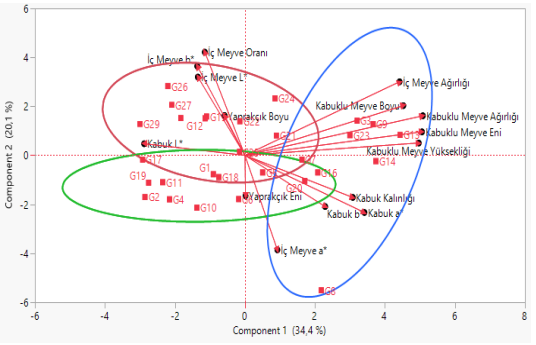
Heatmap hiyerarşik kümeleme analizi

Heatmap hiyerarşik kümeleme analizi, çalışma kapsamında incelenen parametrelerin ve genotiplerin birlikte değerlendirilerek çeşitliliği ortaya koyan çok değişkenli istatistiksel yöntemlerden biridir. İncelenen ceviz genotiplerinin meyve ve yaprak özelliklerine göre sınıflandırılması için heatmap hiyerarşik kümeleme analizi yapılmıştır (Şekil 2). Heatmap hiyerarşik kümeleme analizinde maviden kırmızıya doğru değişen renk yoğunluğu genotiplere ait özelliklerin değerlerinde ki yüksekliği göstermektedir. Heatmap hiyerarşik kümeleme analizi sonucunda genotipler iki ana gruba ve her grup iki alt gruba ayrılmıştır. G8

genotipi diğer genotiplerden ayrı bir şekilde A1 grubunu oluşturmuştur. G3, G7, G9, G13, G14, G16 ve G23 genotipi ise A2 grubunu oluşturmuştur. A1 grubunda tek başına bulunan G8 genotipi kabuklu meyve eni, kabuklu meyve yüksekliği, kabuk kalınlığı, kabuk renk değerleri (L, a* ve b*) ve iç meyve a* renk değeri özellikleri yönünden yüksek değerlere sahip olmuştur. B grubunda yer alan genotipler ise incelenen özellikler açısından farklı etkiler göstermiştir. İncelenen özellikler iki ana gruba ve her grup kendi içerisinde iki alt gruba ayrılmıştır. A grubunda iç meyve oranı, yaprak boyu, iç meyve L ve iç meyve b* renk değerleri yer alırken diğer özellikler B grubunda yer almıştır.

Çizelge 3. Ceviz genotiplerine ait özelliklerin temel bileşen analizi
Table 3. Principal component analysis of the characteristics of walnut genotypes

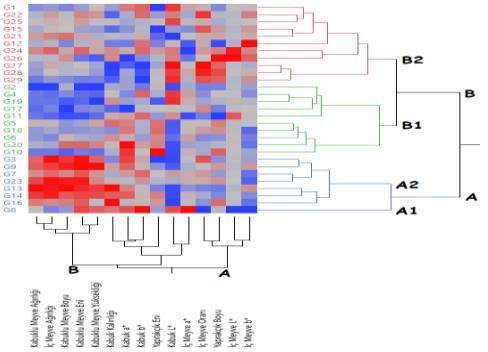
Özellikler	TBA1	% Cont.	TBA2	% Cont.	TBA3	% Cont.	TBA4
Kabuklu Meyve Ağırlığı	0.41	16.47	0.17	2.86	0.02	0.03	-0.01
Kabuklu Meyve Eni	0.40	16.30	0.10	1.01	-0.18	3.38	0.07
Kabuklu Meyve Boyu	0.36	13.04	0.21	4.51	0.04	0.19	0.10
Kabuklu Meyve Yüksekliği	0.40	15.71	0.05	0.28	-0.17	2.98	-0.05
Kabuk Kalınlığı	0.25	6.05	-0.18	3.22	0.37	13.45	-0.13
İç Meyve Ağırlığı	0.35	12.43	0.31	9.89	-0.07	0.42	0.07
İç Meyve Oranı	-0.09	0.84	0.44	19.42	-0.25	6.19	0.24
Kabuk L*	-0.23	5.29	0.05	0.25	-0.41	16.41	-0.03
Kabuk a*	0.27	7.43	-0.24	5.95	0.11	1.22	0.06
Kabuk b*	0.18	3.34	-0.22	4.78	-0.07	0.46	-0.43
İç Meyve L*	-0.11	1.15	0.33	11.19	0.45	20.59	-0.11
İç Meyve a*	0.07	0.55	-0.40	16.27	-0.37	13.72	0.29
İç Meyve b*	-0.11	1.18	0.38	14.52	0.02	0.02	-0.34
Yaprakçık Eni	0.00	0.00	-0.17	2.97	0.45	20.25	0.39
Yaprakçık Boyu	-0.05	0.22	0.17	2.89	0.08	0.67	0.59
Eigen değeri	5.16		3.01		1.85		1.74
Varyans	34.43		20.08		12.31		11.57
Toplam Varyans	34.43		54.51		66.82		78.39



Şekil 1. Ceviz genotiplerinde incelenen özelliklere ait iki boyutlu temel bileşen analizi grafiği
Figure 1. Two-dimensional principal component analysis chart of the characteristics examined in walnut genotypes

Sonuç

Bu çalışma, zengin ceviz popülasyonuna sahip Orta Kelkit Vadisinde tohumdan yetişen ceviz genotiplerinin çeşitliliğini çok değişkenli analizler ile değerlendirmek amacıyla gerçekleştirilmiştir. Elde edilen veriler ışığında meyve ve yaprak özellikleri bakımından ceviz genotiplerinin geniş varyasyon gösterdiği tespit edilmiştir. Çalışma sonuçları ceviz genotipleri arasındaki çeşitliliğin ıslah çalışmalarında kullanılabilecek düzeyde olduğunu göstermiştir. Ceviz ıslah programlarında önemli ticari özelliklerden olan kabuklu meyve ağırlığı, iç meyve ağırlığı, iç meyve oranı, iç meyve rengi ve kabuk kalınlığı bakımından G3, G7, G9, G14, G15, G21, G22, G23, G24, G27, G28 ve G29 genotiplerinin üstün olduğu ve ıslahçılar tarafından kullanılabileceği belirlenmiştir. Çalışmada genotiplerin çeşitliliğini ortaya koymak için kullanılan TBA ve heatmap hiyerarşik kümeleme analizi hem türleri hem de genotipleri özelliklerine göre ayırt etmede etkili olmuş ve gelecek çalışmalarda başarılı şekilde kullanılabileceği ortaya konulmuştur.



Şekil 2. Ceviz genotiplerinde incelenen özelliklere ait heatmap hiyerarşik kümeleme analizi
Figure 2. Heatmap hierarchical clustering analysis of the traits examined in walnut genotypes

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Rootstock and Variety Effect on Mineral Nutrition in Vineyard

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Abstract

This study was conducted to determine the effect of rootstock, variety, and rootstock-variety interaction on the mineral nutrition of the vine. Plant nutrient concentrations of Merlot, Cabernet Franc, Cabernet Sauvignon, and Syrah cultivars grafted on Fercal and 140 Ruggeri rootstocks were investigated. To compare the nutritional status of vineyard, N, P, K, Ca, Mg, Fe, Cu, Mn, and Zn analyses were performed on leaf and fruit samples. Among rootstocks, while the 140 Ruggeri rootstock leaves K, Mg, Ca, Cu, and Mn concentrations were higher, the Fercal rootstock leaves N, P, Fe, and Zn concentrations were higher. While the nutrient concentrations of the cultivars were examined, the Cabernet Sauvignon cultivar leaves had the highest N, P, K, Ca, Fe, and Mn concentrations, while Cabernet Franc Mg, Syrah Zn, and Cu were at high levels in terms of nutritional concentrations. As a result of the study, it was seen that the rootstock, cultivar, and rootstock-variety interaction of the vine had an important effect in terms of mineral nutrition. It had been revealed that the rootstock and cultivar characteristics of that region should be taken into consideration and a fertilizing program should be prepared in terms of fertilizing the vine.
Key words: Fruit, Mineral nutrition, Rootstock, Variety, Vineyard.

Anaç ve Çeşitlerin Bağda Mineral Beslenmesine Etkisi

Özet

Bu çalışma, asmanın mineral beslenmesi üzerinde anaç, çeşit ve anaç-çeşit etkileşiminin etkisini belirlemek amacıyla yürütülmüştür. Fercal ve 140 Ruggeri anaçlarına üzerine aşılanmış Merlot, Cabernet Franc, Cabernet Sauvignon ve Syrah çeşitlerinin bitki besin konsantrasyonları araştırılmıştır. Asmanın beslenme durumunu karşılaştırmak için yaprak ve meyve örneklerinde N, P, K, Ca, Mg, Fe, Cu, Mn ve Zn analizleri yapılmıştır. Anaçlar arasında, 140 Ruggeri anaç yapraklarında K, Mg, Ca, Cu ve Mn konsantrasyonları daha yüksek iken, Fercal anaç yapraklarında N, P, Fe ve Zn konsantrasyonları daha yüksek bulunmuştur. Çeşitlerin besin konsantrasyonları incelendiğinde, Cabernet Sauvignon çeşidinin yaprakları en yüksek N, P, K, Ca, Fe ve Mn konsantrasyonlarına sahipken, Cabernet Franc Mg, Syrah Zn ve Cu besin konsantrasyonları açısından yüksek seviyelerde bulunmuştur. Çalışma sonucunda, asmanın anaç, çeşit ve anaç-çeşit etkileşiminin mineral beslenmesi açısından önemli bir etkiye sahip olduğu görülmüştür. Asmanın gübrelenmesi açısından o bölgenin anaç ve çeşit özelliklerinin dikkate alınması ve gübreleme programının hazırlanması gerektiği ortaya çıkmıştır.
Anahtar kelimeler: Meyve, Mineral besin, Anaç, Çeşit, Bağ

Introduction

Grape is the most produced temperate climate fruit and is the oldest cultivated plant. Viticulture in the world consists of a large cultivation area. According to FAO 2020 data, the first 6 countries in the world in grape production are Spain, France, China, Italy, Turkey, and the USA respectively (Anonymous, 2020). Grapes contain carbohydrates, minerals, proteins, and vitamins. The difference between grapes and other agricultural products is that they contain useful compounds such as flavanol, anthocyanin, caffeic acid, phenolic acid, quercetin, and catechin (Xia et al., 2010).

The amount of nutrient concentrations that plants uptake from the soil is controlled by various factors. These factors are; soil, environment, and plant factors can be included in a basic classification. Different soil properties such as soil pH, lime content, organic matter, and nutrient concentration, as well as factors such as precipitation, temperature, and cultural treatments, affect the nutrient uptake of plants (Erdal et al., 2005). The amount of nutrients taken from the soil can vary from plant to plant, as well as between different genotypes of the same plant. These differences can affect plant growth, yield, and quality at different levels. Therefore, the nutrient uptake and transport capabilities of plant species and varieties should be considered to prepare a good fertilizing program. Selecting appropriate variety and rootstocks is momentous for orchard establishment. To have better yield and quality growing conditions, the transport of nutrients of cultivars and rootstocks should be taken into consideration (Tsipouridis et al., 1990; Kucukyumuk and Erdal, 2011).

In studies, it was determined that varietal differences were effective on nutrient concentrations. The effect of different grape

cultivars on the nutrient content was investigated and it was determined that the nutrient concentrations of the plant showed significant differences according to the cultivars. Determining nutrient concentrations has received special attention since it can provide information on fruit quality based on previously known adequate and critical nutrient levels (Suzuki and Argenta, 1994, Nachtigall and Dechen, 2006, Ibacache and Sierra, 2009). For better quality grapefruits, the producers should take into consideration the mineral nutrient concentration of the grape.

In this study, it was aimed to examine the effect of rootstock and variety on the nutritional status of grapes leaves and fruits. This study aimed to investigate differences in nutrient concentrations among rootstocks and cultivars even if they are grown in the same conditions.

Materials and Method

In the study, five-year-old Cabernet Franc, Cabernet Sauvignon, Merlot, and Syrah varieties grafted on Fercal and 140 Ruggeri rootstocks were used as plant material. Varieties and rootstocks were used and all rootstocks were the same age to compare nutrient concentrations. Planting distances of rootstocks were 2x1 m in Fercal rootstock and 2.5x1 m in 140 Ruggeri rootstock. The reason for the distance difference is the different root growth.

All the rootstocks and varieties were in the same area and soil. The study was carried out on the land belonging to Kavaklıdere Winery Inc. 140 Ruggeri Rootstock (Berlandieri x Rupestris hybrids) is strong and delays the maturation of grafted varieties. The shoots of 140 Ruggerie rootstock are striped, purplish pink, and slightly hairy. Fercal rootstock (Vinifera x American hybrid) was obtained by crossing *Vitis vinifera* L. x *Vitis berlanderi* L. hybrid with 333 EM by Pont de la Maye, Bordeaux in 1983 at INRA Viticulture Research Station in France, by Pouget and Ottenwaelter in Bordeaux. Spread around the World. It is sensitive to Mg deficiency and does not need much K. It has a good affinity with most other grape cultivars, but drying and wilting of the cluster skeleton have been reported in some cultivars. Fercal's growth and fruit set speed is good. Fercal is balanced in terms of efficiency and yield, and its vaccines produce quality products. It is particularly well suited for Syrah (Anonymous, 2022).

Cabernet Sauvignon has a small round grain, black-colored grain structure with blue-gray haze. Cabernet Franc grains are round in shape, blue-black, seeded, and have a typical aromatic odor. Cabernet Franc clusters are small-medium sized and their appearance is conical (Çelik, 2002). Merlot grains are round-shaped, blue-black in color, with a slight aromatic odor. Merlot clusters are medium-sized, plump, and conical in shape. The clusters mature mid-early (Çelik, 2002).

The soils of the study area (0-30 and 30-60 cm) are clay loam textured, slightly alkaline (pH 8.27-8.29) (Thomas, 1996), excessive calcareous (46%-66% $CaCO_3$) (Loeppert and Suarez, 1996), salt-free - slightly salty (0.13-0.17) (Rhodes 1996), and organic matter content is low (1.9-1.6%) (Walkley and Black 1934), N (0.06%), P (4.4-3.2 mg kg^{-1})(Olsen, 1954), Ca (5278 mg kg^{-1}), Mg (60 mg kg^{-1}) Carson, 1980), Fe (4.3-3.4 mg kg^{-1}) and Cu (1.1-0.5 mg kg^{-1}) concentrations are sufficient for Zn (0.18-0.08 mg kg^{-1}) and Mn (2.8-1.6 mg kg^{-1}) concentrations (Lindsay and Norvell, 1978). The soils of the study area have clay loam texture, slightly alkaline, very calcareous, and non-saline character, organic matter content is low, N, Zn, P, Mn, and Mg concentrations are low, K and Cu concentrations are sufficient, Fe concentrations medium, high in terms of Ca.

Samples were collected from 2 rootstocks, 4 varieties, 4 replications, and 10 rootstocks for each replication. Sampling started from young and mature leaves corresponding to the first bunch of grapes from fruiting shoots. Leaves were taken from all four sides of the shoot during the flowering period (Moyer et al., 2018). The number of leaf samples was between 50-100 and sampled on 10.07.2021 (Flynn et al., 2004).

Leaf samples were ground and 0.5 g sample were digested in microwave (Temminghoff and Houba, 2004). N, P, K, Ca, Mg, Fe, Cu, Mn, and Zn analyses were carried out to determine the nutrient content of the vine leaves. The N contents of the plant leaves were determined according to the Kjeldahl method. In addition, after the dried and ground leaf samples were wet digested, P, K, Mg, Ca, Fe, Zn, Cu, and Mn were determined by ICP-OES (Temminghoff and Houba, 2004). Grapefruits in the same field were harvested in September (01.09.2021) and brought to the laboratory for analysis. Tillage, irrigation, fertilization, pruning and disease, pest, and weed control were carried out in the study area. 25 tons of compost (thyme stalk + animal manure) per hectare was applied in November with a farm manure-spreading machine.

The statistical analysis results were made through the MINITAB 16 package program. The relationships between rootstock and cultivar were compared with the TUKEY multiple comparison test.

Results and Discussion

Nutrient Concentrations of Grape Leaves on Different Rootstocks and Varieties

N, P, K, Mg, Ca concentrations of rootstockxvariety interaction, rootstock, and variety leaves were given in Table 1. Limit values determined by Jones et al. (1991) were used in the evaluation of leaf

nutritional status. Rootstock*variety interaction of different cultivars grafted on different rootstocks was determined to be significant. While there were 2.1% (Syrah), 2.21% (Merlot), 2.34% (C.Franc), and 2.34% (C.Sauvignon) N concentrations in varieties grafted on Fercal rootstock, in varieties grafted on 140 Ruggeri rootstocks, 1.8% (C.Franc, 1.96 (Merlot), 2.18% C.Sauvignon, and 2.31% (Syrah) values were determined. In terms of rootstocks, Fercal rootstock had 2.25% N concentration, while 140 Ruggeri rootstock had 2.06% N concentration. The highest N concentration in leaves was determined in C. Sauvignon (2.26%), Syrah (2.21%), Merlot (2.09%), and C. Franc (2.07%) cultivars. Leaf N nutrient of Flame Seedless, Thompson Seedless, Superior Seedless, and Red Globe varieties grafted on 10 different rootstocks (Freedom, Harmony, Saint George, Salt Creek, SO4, 1613C, 1103P, 99R, 110R, 140Ru) was between 0.72-1.29% (Ibacache and Sierra, 2009). In another study, the N concentrations of the leaves of Xinomavro and Chardonnay grape varieties grafted on 41B,1103P,110 R, and 140 Ru rootstocks were reported to be 2.9% (Assimakopoulou et al., 2016). The values reported by other researchers were; 1.5-2.4%; 2.3-2.8% (Bergmann, 1992), 2.25% (Levy, 1968); and 2.0-2.3% (Mills and Jones, 1996), it was determined that there was no problem in terms of nitrogen nutrition. According to Jones et al. (1991), the N concentration was sufficient in all of the leaf samples of C. Franc, C. Sauvignon, Merlot, and Syrah cultivars.

P concentration content of rootstock x variety interaction of cultivars grafted on rootstocks was statistically significant. While the leaves of the C.Sauvignon variety grafted on Fercal rootstock had the highest P content (0.33%), the lowest P concentration, Syrah and C.Franc varieties grafted on 140 Ruggeri rootstocks (0.17%). While the varieties P concentrations for Fercal rootstock were 0.33% (C. Sauvignon), 0.25% (Syrah), 0.23% (Merlot), 0.22% (C. Franc); 140 Ruggeri rootstock were 0.17% (C. Franc and Syrah), 0.19% C. Sauvignon, 0.21% (Merlot) results were determined. According to the mean values, Fercal rootstock leaf P content had 0.26% P content, while 140 Ruggeri rootstock had 0.19% P content. Among the cultivars, in C. Sauvignon (0.26%), Merlot (0.22%), Syrah (0.21%) and C.Franc (0.20%) leaf P contents were determined respectively. In a study, P concentration of the leaves of Xinomavro and Chardonnay grape varieties grafted on 41B,1103P,110 R, and 140 Ru rootstocks was reported as 0.29% (Assimakopoulou et al., 2016). In a 3-year study, it was reported that the amount of P in Cabernet Sauvignon, Sauvignon Blanc, and Merlot grape varieties varied between 0.14-0.24% and 0.13-0.43% (Klein, 2000).

K concentration of rootstock x variety interaction was not statistically significant. Fercal rootstock leaf K content had 0.99% K content, while 140 Ruggeri rootstock had 1.12% K concentration. As in rootstocks, variety interaction was statistically significant. The potassium content of cultivars in grape leaves was C. Sauvignon (1.31%), Merlot (1.01%), C. Franc (0.96%) and Syrah (0.94%) respectively. Leaf K concentration of Flame Seedless, Thompson Seedless, Superior Seedless, and Red Globe varieties grafted on 10 different rootstocks (Freedom, Harmony, Saint George, Salt Creek, SO4, 1613C, 1103P, 99R, 110R, 140Ru) reported to be between 0.99-3.37% (Ibacache and Sierra, 2009). In studies, different wine grape cultivars on leaves had 1.06%-1.34% K concentration; Bobal, Tempranillo, Cabernet Sauvignon, and Crujidera cultivars had 0.89-1.34% leaf K concentration (Fregoni, 1984; Fallahi, 2005, Navarro et al., 2008). In our study, all leaf samples of C.Franc, C. Sauvignon, Merlot, Syrah cultivars, K were found to be sufficient (Jones et al., 1991). Mg concentration of rootstock*variety interaction of different cultivars grafted on different rootstocks was found to be statistically significant. While it was determined that the leaves of C. Franc variety grafted on 140 Ruggeri rootstock had the highest Mg content (0.50%), and the lowest Mg concentration was observed in the Syrah variety grafted on 140 Ruggeri rootstock (0.16%). Fercal rootstock had 0.25% leaf Mg concentration, while 140 Ruggeri rootstock had 0.37% Mg content. As in rootstocks, in terms of Mg concentration in grape leaves, the highest leaf Mg concentration among varieties was C. Franc (0.36%), C. Sauvignon (0.36%), followed by Merlot (0.32%) and Syrah (0.21%). followed sequentially. Mg was sufficient in all leaf samples (Jones et al. 1991). In terms of Ca concentration, rootstock x variety interaction was statistically significant. While the C.Franc variety grafted on 140 Ruggeri rootstock leaf concentration had the highest Ca concentration (3.56%), and the lowest Ca concentration was found in the Syrah variety grafted on 140 Ruggeri rootstock (1.22%). Among the rootstocks, Fercal rootstock had 2.15% Ca concentration, while 140 Ruggeri rootstock had 2.71% Ca concentration. The highest leaf Ca concentration among the cultivars was determined as C. Franc (2.90%), followed by Merlot (2.82%) C. Sauvignon (2.71%), and Syrah (1.29%), respectively. Ca was sufficient in all leaf samples according to Jones et al. (1991).

Table 1. The concentrations of N, P, K, Ca, Mg of rootstocks and cultivars leaves (%)
Çizelge 1. Anaç ve çeşitlerin yapraklarında N, P, K, Ca, Mg konsantrasyonları (%)

Varieties					
N					
Rootstocks	C.Franc	C.Sauvignon	Merlot	Syrah	Mean
Fercal	2.34A**	2.34AB	2.21ABC	2.1CD	2.25
140 Ruggeri	1.8E	2.18BC	1.96DE	2.31AB	2.06
Mean	2.07	2.26	2.09	2.21	
P					
	C.Franc	C.Sauvignon	Merlot	Syrah	Mean
Fercal	0.22BC**	0.33A	0.23 B	0.25 B	0.26
140 Ruggeri	0.17D	0.19CD	0.21BC	0.17D	0.19
Mean	0.20	0.26	0.22	0.21	
K					
	C.Franc	C.Sauvignon	Merlot	Syrah	Mean
Fercal	0.83^{ns}	1.28	0.96	0.88	0.99b**
140 Ruggeri	1.08	1.33	1.06	1.00	1.12a
Mean	0.96b**	1.31a	1.01b	0.94b	
Mg					
	C.Franc	C.Sauvignon	Merlot	Syrah	Mean
Fercal	0.22CD**	0.37B	0.26C	0.16D	0.25
140 Ruggeri	0.50A	0.35B	0.38B	0.26C	0.37
Mean	0.36	0.36	0.32	0.21	
Ca					
	C.Franc	C.Sauvignon	Merlot	Syrah	Mean
Fercal	2.24E**	2.57D	2.41DE	1.35F	2.15
140 Ruggeri	3.56A	2.84C	3.22B	1.22F	2.71
Mean	2.90	2.71	2.82	1.29	

*: Capital letters showed the difference between rootstock x cultivar interaction. *: lowercase letters showed the difference between rootstocks (vertical order); *: lowercase letters showed the difference between varieties (horizontal order). *: $p<0.05$ **: $p<0.001$
*: Büyük harfler anaç x çeşit interaksiyonu arasındaki farkı göstermektedir. *: Küçük harfler anaçlar arasındaki farkı göstermektedir (dikey sıra); *: Küçük harfler çeşitler arasındaki farkı göstermektedir (yatay sıra). *: $p<0,05$ **: $p<0,001$

The Fe, Zn, Cu, and Mn concentrations of rootstock x variety, rootstock, and variety interaction in vine leaves were given in Table 2. The Fe content of rootstock x variety interaction was statistically significant. While it was determined that the leaves of the C. Sauvignon variety grafted on 140 Ruggeri rootstock had the highest Fe concentration (267 mg kg^{-1}), the lowest Fe concentration was observed in C.Franc variety grafted on 140 Ruggeri rootstock (120 mg kg^{-1}). Fercal rootstock leaf Fe content had 191 mg kg^{-1} Fe concentration, while 140 Ruggeri rootstock had 170 mg kg^{-1}Fe concentrations. When the leaf Fe content was examined among the cultivars, the values varied between 146 and 265 mg kg^{-1}. The Zn concentration of rootstock*variety interaction was statistically significant. While the leaf of Syrah variety grafted on Fercal had the highest Zn concentration (39 mg kg^{-1}), the lowest Zn concentration was observed in C.Franc variety grafted on 140 Ruggeri rootstock (22 mg kg^{-1}). While Fercal rootstock had 32 mg kg^{-1} Zn concentration, 140 Ruggeri rootstock had 24 mg kg^{-1} Zn concentration. Among the varieties in terms of zinc concentration in vine leaves, leaf concentrations were between 25-31 mg kg^{-1}. In a study, the Zn concentration of the leaves of Xinomavro and Chardonnay grape varieties grafted on 41B,1103P,110 R, and 140 Ru rootstocks was reported as 95.3 mg kg^{-1} (Assimakopoulou et al., 2016). The Cu concentrations of rootstock*variety interaction of different cultivars grafted on different rootstocks statistically significant. While it was determined that the leaf of the Syrah variety grafted on 140 Ruggeri rootstock had the highest Cu concentration (10.5 mg kg^{-1}), the lowest Cu concentration was observed in C.Franc variety grafted on Fercal rootstock (1.4 mg kg^{-1}). Fercal rootstock leaf Cu concentration had 4.2 mg kg^{-1} Cu concentration, while 140 Ruggeri rootstock had 6.0 mg kg^{-1} Cu concentration. Among the cultivars, the Cu concentration varied between 1.7-9.5 mg kg^{-1}, and the Cu concentrations of Syrah, Merlot, C. Sauvignon, and C. Franc grape varieties were 9.5, 5.5, 3.5, and 1.7 mg kg^{-1}, respectively. As reported by other researchers, between 5 to 20 mg kg^{-1} for leaf (Fregoni, 1984) 3-6 mg kg^{-1} (Reuter and Robinson, 1986); 6-12 mg kg^{-1} (Bergman, 1986), and 10-15 mg kg^{-1} (Cahoon, 1970), our samples were found to be sufficient in terms of Cu.

Mn concentration of different varieties grafted on different rootstocks rootstock x variety interaction was statistically significant. While the C. Sauvignon variety grafted on Fercal rootstock leaves had the highest Mn concentration (202 mg kg^{-1}), the lowest Mn concentration was observed in the Syrah variety grafted on 140 Ruggeri rootstock (54 mg kg^{-1}). When the rootstocks were compared Fercal rootstock leaf had 152 mg kg^{-1} Mn concentration, and 140 Ruggeri rootstock had 136 mg kg^{-1} Mn concentration. According to the varieties, C. Sauvignon had the highest Mn concentration (197 mg kg^{-1}), followed by C. Franc (176 mg kg^{-1}), Merlot (131 mg kg^{-1}), and Syrah (73 mg kg^{-1}), respectively. In a study of the Anab-e-Shahi grape variety, Mn values were determined between 16-160 mg kg^{-1} during budding and 10-225 mg kg^{-1} during the blooming period (Bhargava and Raghupathi, 1999).

Table 2. The concentrations of leaves Fe, Zn, Cu, Mn on rootstocks and cultivars leaves (mg kg^{-1})
Çizelge 2. Anaç ve çeşitlerin yapraklarındaki Fe, Zn, Cu, Mn konsantrasyonları (mg kg^{-1})

Varieties					
Fe					
Rootstocks	C.Franc	C.Sauvignon	Merlot	Syrah	Mean
Fercal	200 AB*	264 A	131 B	169 B	191
140 Ruggeri	120 B	267 A	162 B	130 B	170
Mean	160	265	146	149	
Zn					
	C.Franc	C.Sauvignon	Merlot	Syrah	Mean
Fercal	29BC**	29B	30 B	39A	32
140 Ruggeri	22D	27BCD	23CD	23D	24
Mean	25	28	27	31	
Cu					
	C.Franc	C.Sauvignon	Merlot	Syrah	Mean
Fercal	1.4F**	4.1C	2.6DE	8.5B	4.2
140 Ruggeri	2.0EF	3.0D	8.4B	10.5A	6.0
Mean	1.7	3.5	5.5	9.5	
Mn					
	C.Franc	C.Sauvignon	Merlot	Syrah	Mean
Fercal	191A**	202A	122C	92D	152
140 Ruggeri	160B	192A	139BC	54E	136
Mean	176	197	131	73	

*: Capital letters showed the difference between rootstock x cultivar interaction. *: $p<0.05$ **: $p<0.001$
*: Büyük harfler anaç x çeşit etkileşimi arasındaki farkı göstermektedir. *: $p<0,05$ **: $p<0,001$

Nutrient Concentration of Grape Fruits on Different Rootstocks and Varieties

N, P, K, Mg, and Ca concentrations of rootstock x variety, rootstock, and variety interaction in grapes were given in Table 3. N concentrations of rootstock x variety interaction were statistically significant. While the fruit of the Merlot variety grafted on Fercal rootstock had the highest N concentration (0.24%), the lowest N concentration was seen in the Syrah variety grafted on 140 Ruggeri rootstock (0.08%). While Fercal rootstock fruit N concentration had 0.16% N content, 140 Ruggeri rootstock had 0.13% N concentration. Among varieties in terms of fruit nitrogen concentrations, Merlot had the highest variety with 0.19%, followed by C. Franc (0.18%), C. Sauvignon (0.13%), and Syrah (0.09%). In a study, the N concentration in fruit was reported between 0.54-0.56% in 2005/06 and 0.61-0.66% in 2006/07 (Bonomelli et al., 2010). As a result of a study examining the effect of table grapes on mineral nutrition, 0.40% N concentration was reported (Bavaresco et al., 2003), our results were low when compared to the studies.

Rootstock x variety interaction of grapefruit was not found statistically significant in terms of P concentration. The P concentration of the rootstock x cultivar interaction varied between 115-206 mg kg^{-1}. As seen in Table 3, the effect on fruit P content was found as 149 mg kg^{-1} in Fercal rootstock fruit and 155 mg kg^{-1} in 140 Ruggeri rootstock fruit. In terms of phosphorus concentration in grapefruit varieties, it was statistically significant, C. Sauvignon (186 mg kg^{-1}), and Merlot (160 mg kg^{-1}) varieties had higher P concentration than C. Franc (123 mg kg^{-1}) and Syrah (139 mg kg^{-1}) varieties. In a study conducted by Bonomelli and Ruiz (2010), P concentration in grapefruit was determined between 0.12-0.13% in 2005/06 and 0.12-0.13% in 2006/07. In another study, P was determined at 67 mg kg^{-1} in grape juice of Kavaklıdere and Elit varieties (Aras, 2006). The P results obtained from the study area were sufficient. K concentration of

rootstock x variety and interaction of grapefruit were not statistically significant.

Rootstock x variety interaction K concentration was found in the range of 2083-2782 mg kg^{-1}. Rootstocks K concentrations were found to be significant statistically. While the K concentration of Fercal rootstock was 2142 mg kg^{-1}, 140 Ruggeri rootstock K content concentration in terms of potassium concentration in cultivars, which is statistically significant. While Merlot (2697 mg kg^{-1}) cultivar had the highest K concentration, C. Franc had 2432 mg kg^{-1}, C. Sauvignon had 2259 mg kg^{-1} and Syrah had 2032 mg kg^{-1} K concentration. In a study, K values of 767 mg kg^{-1} were determined in the grape juice of Kavaklıdere and Elit varieties (Aras, 2006).

Mg and calcium concentration of rootstock x variety interaction of grapefruit was not found significant statistically. Mg concentration of rootstock x cultivar interaction varied between 86-132 mg kg^{-1}. Rootstocks and cultivars were statistically significant in terms of magnesium and calcium concentrations. While C. Sauvignon (115 mg kg^{-1}) variety had the highest Mg concentration, C. Franc had 105 mg kg-1, Merlot had 95 mg kg^{-1} and Syrah had 92 mg kg^{-1} Mg concentration. While the Mg content of Fercal rootstock was 91 mg kg^{-1}, the Mg concentration of 140 Ruggeri rootstock was determined as 113 mg kg^{-1}. While the Ca content of Fercal rootstock was 406 mg kg^{-1}, the Ca concentration of 140 Ruggeri rootstock was determined as 322 mg kg^{-1}. While C. Sauvignon (442mg kg^{-1}) variety had the highest Ca concentration, C. Franc had 384 mg kg^{-1}, Merlot had 365mg kg-1 and Syrah had 265mg kg^{-1} Ca concentrations. In a study, Thompson grape variety had between 0.05-0.07% Ca and 0.04-0.05 % Mg concentration in fruit (Bonomelli and Ruiz, 2010). In another study, 0.20% Ca concentration was reported in grapes (Bavaresco and Poni, 2003). In a study, 89 mg kg^{-1} Ca was found in Kavaklıdere and Elit grape varieties (Aras, 2006).

Table 3. The concentrations of N, P, K, Ca, Mg of rootstocks and cultivars fruits
Çizelge 3. Anaç ve çeşit meyvelerinin Anaç ve çeşit meyvelerinin N, P, K, Ca, Mg konsantrasyonları

Varieties					
N*(%)*					
Rootstocks	C.Franc	C.Sauvignon	Merlot	Syrah	Mean
Fercal	0.19B**	0.12DE	0.24A	0.09E	0.16
140 Ruggeri	0.16BC	0.14CD	0.14CD	0.08E	0.13
Mean	0.18	0.13	0.19	0.09	
P *(mg kg^{-1})*					
	C.Franc	C.Sauvignon	Merlot	Syrah	Mean
Fercal	131^{ns}	167	160	138	149
140 Ruggeri	115	206	160	140	155
Mean	123 b*	186 a	160 ab	139 ab	
K(*mg kg^{-1})*					
	C.Franc	C.Sauvignon	Merlot	Syrah	Mean
Fercal	2083^{ns}	2253	2444	1789	2142 b*
140 Ruggeri	2782	2265	2951	2275	2568 a
Mean	2432 ab*	2259 ab	2697 a	2032 b	
Mg*(mg kg^{-1})*					
	C.Franc	C.Sauvignon	Merlot	Syrah	Mean
Fercal	91^{ns}	98	90	86	91b*
140 Ruggeri	120	132	101	99	113a
Mean	105 a*	115 a	95 a	92 a	
Ca*(mg kg^{-1})*					
	C.Franc	C.Sauvignon	Merlot	Syrah	Mean
Fercal	432^{ns}	461	462	269	406 a*
140 Ruggeri	336	424	268	261	322 b
Mean	384 a*	442 a	365 ab	265 b	

*: Capital letters showed the difference between rootstock x cultivar interaction. *: lowercase letters showed the difference between rootstocks (vertical order); * :lowercase letters showed the difference between varieties (horizontal order). *: $p<0.05$ **: $p<0.001$ ns:not significant

Results showed that the grapefruits were at a sufficient level in terms of Ca concentration. Our studies of grapefruit Mg concentrations were high when compared to other studies. Fe, Zn, Cu, and Mn concentrations of rootstock x variety, rootstock, and variety interaction in grapes were given in Table 4. Fe concentrations of rootstock x cultivar interaction varied between 2.8-9.4mg kg^{-1}. While Fe concentrations of varieties grafted on Fercal rootstocks had 2.8 mg kg^{-1} (Syrah), 5.9 mg kg^{-1} (C.Sauvignon), 6.0 mg kg^{-1} (C.Franc), 9.4 mg kg^{-1} (Merlot), 140 Ruggeri rootstocks had 3.7 mg kg^{-1} (Syrah), 4.6 mg kg^{-1} (C.Franc), 5.1 mg kg^{-1} C.Souvignon, 7.8 mg kg^{-1} (Merlot). While the Fe concentration of Fercal rootstock was 6.0 mg kg^{-1}, the Fe concentration of 140 Ruggeri rootstock was determined as 5.3 mg kg^{-1}. Varieties of fruits were statistically significant. Among the varieties, while Merlot (8.6 mg kg^{-1}) had the highest Fe concentration, C. Sauvignon had 5.5 mg kg^{-1}, C. Franc had 5.3 mg kg^{-1} and Syrah had 3.3 mg kg^{-1}. Rootstock x variety and rootstock interaction of grapefruit was not found statistically significant in terms of zinc concentration. The Zn concentrations of the rootstock x cultivar interaction varied between 0.64-1.41 mg kg^{-1}. Fercal rootstock fruit Zn concentration was 0.82 mg kg^{-1}, while 140 Ruggeri rootstock fruit Zn content was 0.98 mg kg^{-1}. While C. Sauvignon (1.26 mg kg^{-1}) variety had the highest Zn concentration, Marlot had 0.86 mg kg^{-1}, C.Franc had 0.80 mg kg^{-1} and Syrah had 0.68 mg kg^{-1}. Cu concentrations of rootstock x variety interaction of different cultivars grafted on different rootstocks were significant statistically. While the C. Sauvignon cultivar grafted on Fercal rootstock had the highest Cu concentration (0.37 mg kg^{-1}), the lowest Cu concentration was found in the Syrah cultivar (0.08 mg kg^{-1}) grafted on 140 Ruggeri rootstock. Fercal rootstock had 0.18 mg kg^{-1} Cu concentration, while the 140 Ruggeri rootstock had 0.26 mg kg^{-1}. Mn concentration of rootstock x variety interaction was found statistically significant. While the Merlot variety grafted on Fercal rootstock had the highest Mn concentration (2.28 mg kg^{-1}), the lowest Mn concentration was observed in the Syrah variety grafted on Fercal rootstock (0.95 mg kg^{-1}).

Table 4. The concentrations of Fe, Zn, K, Cu, Mn rootstocks and cultivars fruits (mg kg^{-1})
Çizelge 4. Anaç ve çeşitlerin meyvelerindeki Fe, Zn, K, Cu, Mn konsantrasyonları (mg kg^{-1})

Varieties					
Fe					
Rootstocks	C.Franc	C.Sauvignon	Merlot	Syrah	Mean
Fercal	6.0 ^{ns}	5.9	9.4	2.8	6.0 ^{ns}
140 Ruggeri	4.6	5.1	7.8	3.7	5.3
Mean	5.3 b**	5.5 b	8.6 a	3.3 b	
Zn					
	C.Franc	C.Sauvignon	Merlot	Syrah	Mean
Fercal	0.64^{ns}	1.10	0.88	0.66	0.82^{ns}
140 Ruggeri	0.96	1.41	0.84	0.69	0.98
Mean	0.80 b*	1.26 a	0.86 ab	0.68 b	
Cu					
	C.Franc	C.Sauvignon	Merlot	Syrah	Mean
Fercal	0.28AB*	0.37A	0.31AB	0.09D	0.26
140 Ruggeri	0.15CD	0.22BC	0.29AB	0.08D	0.18
Mean	0.21	0.30	0.30	0.08	
Mn					
	C.Franc	C.Sauvignon	Merlot	Syrah	Mean
Fercal	1.49AB*	1.43B	2.28A	0.95B	1.54
140 Ruggeri	1.13B	1.33B	1.13B	1.16B	1.19
Mean	1.31	1.38	1.71	1.05	

*: Capital letters showed the difference between rootstock x cultivar interaction. *: lowercase letters showed the difference between rootstocks (vertical order); *: lowercase letters showed the difference between varieties (horizontal order). *: $p<0.05$ **: $p<0.001$ ns:not significant.

Conclusions

Factors such as soil pH, organic matter amount, lime content, moisture level, texture, soil nutrient level, type, and variety of the plant grown are factors that affect both the mineral nutrition of the plants and the nutritional level of the plant. Plants grown in the same environment and conditions benefit from plant nutrients in the soil and nutrients given by fertilization in different amounts.

When the results of the study were evaluated, the varieties and rootstocks were statistically significant in nutritional status. These results

showed the nutrient concentration of the rootstock and variety should be taken into account when making fertilization programs. While yield losses will be prevented with insufficient fertilization, economic and environmental damages will be prevented with excessive fertilization. In addition, suitable rootstocks and varieties should be determined in viticulture, which is intensive in the region, and appropriate fertilization studies should be continued.

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Evaluating the Fatty Acid, Sterol and Erythrodiol+Uvaol Contents of Turkish Olive Oil under Different Maturity Index and Storage Conditions with Chemometric Approaches

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Abstract

The objective of this study was to utilize unsupervised classification and clustering techniques, such as hierarchical (HCA) and principal component analyses (PCA), to assess the impact of maturity index and storage conditions on the composition of fatty acids, sterols, and erythrodiol+uvaol in Ayvalık and Memecik Turkish extra virgin olive oils. For a period of 15 months, the oils were maintained at ambient temperature, under daylight conditions, and in darkness within two transparent glass bottles. The chemometric analysis yielded the revelation that both Memecik and Ayvalık could be classified into two distinct subgroups. The findings indicated that oleic, behenic, arachidic, gadoleic, and MUFA (Monounsaturated Fatty Acid) acids were pivotal in distinguishing the initial harvest year for both oils. The second year's characterization process involved the analysis of palmitic, palmitoleic, heptadecanoic, heptadecenoic, trans fatty acids, SFA (Saturated Fatty Acids), and MUFA in the Ayvalık olive oil; and miristic, linolenic, and PUFA (Polyunsaturated Fatty Acids) in the Memecik olive oil. The results of the PCA indicate that Memecik oils contain β-sitosterol, stigmasterol, cholesterol, clerosterol, brassicasterol, and erythrodiol+uvaol, while Ayvalık oils contain campestanol, sitosterol, campestanol, Δ7-avenasterol, Δ5-avenasterol, total sterol, Δ5-7 stigmastadienol, and total β-sitosterol.
Key words: PCA, HCA, Sterol, Fatty acid, Storage conditions.

Farklı Olgunluk İndeksi ve Depolama Koşullarında Türk Zeytinyağlarının Yağ Asidi, Sterol ve Eritrodiol+Uvaol İçeriklerinin Kemometrik Yaklaşımlarla Değerlendirilmesi

Özet

Bu çalışmanın amacı, Ayvalık ve Memecik Türk sızma zeytinyağında olgunluk indeksi ve saklama koşullarının yağ asitleri, steroller ve eritrodiol+uvaol bileşimi üzerindeki etkisini değerlendirmek için hiyerarşik (HCA) ve temel bileşen analizleri (PCA) gibi denetimsiz sınıflandırma ve kümeleme tekniklerinden yararlanmaktır. Yağlar 15 ay süreyle oda sıcaklığında, gün ışığı koşullarında ve karanlıkta iki şeffaf cam şişe içerisinde muhafaza edildi. Kemometrik analiz, Memecik ve Ayvalık'ın iki ayrı alt gruba ayrılabileceğini ortaya çıkardı. Bulgular, oleik, behenik, araşidik, gadoleik ve MUFA asitlerinin, her iki yağ için de ilk hasat yılını ayırt etmede çok önemli olduğunu gösterdi. İkinci yılın karakterizasyon sürecinde Ayvalık zeytinyağında palmitik, palmitoleik, heptadekanoik, heptadekenoik, trans yağ asitleri, SFA ve MUFA analizleri; Memecik zeytinyağında miristik, linolenik ve PUFA bulunur. PCA sonuçları Memecik yağlarının β-sitosterol, stigmasterol, kolesterol, klerosterol, brassikasterol ve eritrodiol+uvaol içerdiğini, Ayvalık yağlarının ise kampestanol, sitosterol, kampestanol, Δ7-avenasterol, Δ5-avenasterol, toplam sterol, Δ5-7 stigmastadienol ve toplam β-sitosterol içerdiğini göstermektedir.
Anahtar kelimeler: PCA, HCA, Sterol, Yağ asidi, Depolama koşulları.

Introduction

An economic and social perspective places great importance on olive farming and the olive oil industry, particularly in Spain, Italy, Türkiye, Portugal and Greece (López-Salas et al., 2024). In Türkiye, the majority of olive production is concentrated in a small number of varieties (well known local olive fruits include Ayvalık, Memecik, Gemlik, Domat, Erkence, Nizip Yaglık etc.), although the Turkish National Germplasm Bank has registered 95 distinct endemic varieties (Yıldırım et al., 2023). In the context of Turkish olive cultivation, Ayvalık and Memecik cultivars have emerged as predominant, economically significant, and widely adopted varieties. These cultivars collectively contribute to a substantial proportion of the nation's total olive oil production, accounting for approximately 75-80% of the total output (Sevim and Tuncay, 2013).

A substantial body of research has been conducted on the dietary and medicinal qualities of olive oil, and the results of these studies have been thoroughly documented. Historically, the primary benefits of oil consumption have been ascribed to its abundant presence of monounsaturated fatty acids (MUFAs) (Peres et al., 2024). Olive oil is food that works well for preventing of cardiovascular, hypertension, cancer and digestive system diseases due to its monounsaturated fatty acids and antioxidant substances (López-Salas et al., 2024). A comprehensive analysis reveals that 98% of olive oil is composed of glycerides and fatty acids, which are predominant components, while 2% consists of minor components (IOC, 2022). An 3 of olive oil quality is conducted by means of a multifaceted

approach, incorporating a range of assessment techniques. Among these methods are organoleptic tests, which are utilized to identify and evaluate characteristics related to the sensory perception of the oil. Additionally, analyses of fatty acid composition are employed to ascertain the nutritional value and chemical profile of the olive oil. Furthermore, physicochemical parameters are measured to provide a comprehensive assessment of the oil's physical and chemical properties. To ensure the dietary value, authenticity, and purity of olive oils sold, it is imperative that monitoring be carried out in an effective and continuous manner. A comprehensive understanding of the fatty acid composition is imperative. The composition of fatty acids of olive oils serves as a crucial quality parameter and a reliable indicator of their authenticity. The composition of fatty acids of oil is influenced by numerous factors, including variety, maturity, and climate (Bechar et al., 2024; Köseoğlu et al., 2016). Palmitic, oleic, linoleic and stearic are major fatty acids, palmitoleic, linolenic and arachidonic are minor fatty acids. The oleic acid content of olive oil is 55-85%, linoleic acid content is 2.5-21% and linolenic acid content is below ≤1% (IOC, 2022). The surrounding conditions have been demonstrated to exert an influence on the content of oleic and linoleic acids (Rodrigues et al., 2021). Olive oil is regarded as a stable and healthful fat, and due to the its high proportion of monounsaturated fatty acids and low content of saturated fatty acids, it is an ideal fat source that can lower cardiovascular disease risk (Mousavi et al., 2019; Gagour et al., 2024). Vegetable oils' shelf life is shortened by oxidation, a significant process that alters their organoleptic characteristics. Oxidation alters various physiological properties as well as causing a loss of nutritional value (Bouaziz et al., 2008). Changes in the composition of fatty acids and the loss of smaller components are the main factors affecting the shelf life of olive oils. According to reports, about 24% of Rancimat stability is attributed to the composition of fatty acids (Mateos et al., 2003). The level of unsaturation of fatty acids and the existence of antioxidants such as phenolic compounds and carotenoids, among other factors, have an impact on the structure of olive oil and its ability to prevent autooxidation and photooxidation during storage (Bechar et al., 2024). Previous studies found that the content of palmitic acid in olive oils remained unchanged, while the content of unsaturated and saturated fatty acids decreased, increased, and oleic acid decreased due to oxidation (Mendez and Falque, 2007). Moreover, the content of stearic acid increased (Morello et al. 2004; Mendez and Falque, 2007), oleic acid increased, linoleic and linolenic acid decreased, and oleic acid increased because of the decrease in polyunsaturated fatty acids like linoleic and linolenic acid due to degradation and preservation of the content of saturated fatty acids (Morello et al., 2004). According to Gomez-Alonso et al. (2007), linolenic acid content decreased more during the storage period than linoleic acid content. This was because, under the same oxidation conditions, the antioxidants in extra virgin olive oil protected linoleic acid greater than linolenic acid.

Sterols are essential for human nutrition and health. The majority of the unsaponifiable material in olive oil is made up of phytosterols, which are sterols that are present in vegetables and plant oils. Plant species are characterized by their sterol profiles. Understanding the makeup of sterols is crucial for determining the nutritional value and identity of olive oil. The composition and amount of sterols are important factors in determining the quality of extra virgin olive oil. These substances are some of the most important criteria for trade standards that are used to confirm the legitimacy of olive oil and identify counterfeiting (Piravi-Vanak et al., 2012). Sterols, on the other hand, show a lot of promise as practical chemical markers to guarantee the variety, traceability, and geographic origin of olive oil (Lukić et al., 2021; Sevim et al., 2023). Olive oil's primary sterols are β-sitosterol, delta-5-avenasterol, and campesterol. Others include stigmasterol, cholesterol, and related compounds. β-Sitosterol makes up most (75-90%) of the total sterols in olive oil. The percentage of delta-5-avenasterol ranges between 5-20%, while campesterol and stigmasterol are between 1-4% and 0.5-2%, respectively. 24-methylene-cholesterol, which is found in low levels in the structure of olive oil, is an intermediate product in campesterol synthesis and is a characteristic component of olive pulp and is the only sterol in which significant differences can be clearly observed between varieties and ripening stages (Şahin et al., 2008). High levels of stigmasterol are an indication of high acidity and low sensory properties (Bıyıklı, 2009). Sterols are heat stable, odourless and tasteless compounds. The quantitative sterol profiles of olive fruits are recognized to be impacted by several factors. Genetics of fruit (Navas–Lopez et al., 2019), environment (soil, location, climate, water) (Hamze et al., 2022), fruit ripening stage (Giuffrè et al., 2013), harvest year (Rey-Giménez et al., 2022), the oils' storage conditions or technological factors (Guillaume et al., 2012) all have an impact on the composition of sterols. And also, recently it has been suggested to use sterol composition to categorize extra virgin olive oil based on fruit varieties (Rivera del A´ lamo et al., 2004).

The objectives of this study were to assess the impact of ripening index and storage conditions on the fatty acids, sterol, and erythrodiol+uvaol contents of Turkish virgin olive oil. To this end, unsupervised chemometrics classification and

clustering methods, such as PCA and HCA, were utilized. Ayvalık and Memecik olive oils were stored in two distinct transparent glass bottles at ambient temperature in conditions of both daylight and darkness for a period of 15 months. Fatty acid, sterol, and erythrodiol+uvaol content analyses were conducted at five-month intervals (0 (initial), 5, 10, and 15 months).

Materials and Method

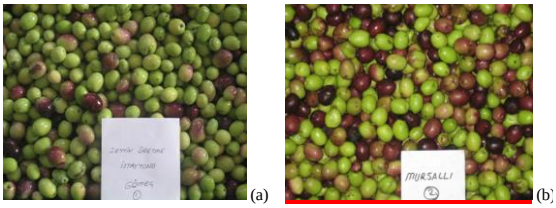
Material

The "Ayvalık" and "Memecik" varieties were harvested from orchards in Ayvalık and Aydın regions, respectively, in two consecutive harvest periods (Figure 1). The olives were harvested by hand at two different maturation indices and subsequently processed (without waiting) by an Abencor system at the Olive Research Institute of Turkish Ministry of Agriculture and Forestry in Izmir, Türkiye.

Method

Maturity index (MI)

Maturity index, which the International Olive Council's suggested approach (IOC, 1991), according to the olive skin's color and is determined by gathering about one kilogram of olives.



(a) (b)

Figure 1. Ayvalık (a) and Memecik (b) cultivars
Şekil 1. Ayvalık (a) ve Memecik (b) çeşitleri

Oil extraction

The olives of the "Ayvalık" and "Memecik" were harvested manually. The fruits were thoroughly cleaned with tap water, followed by mechanical crushing using an Abencor System (MC2, Spain). The instrument is outfitted with apparatus designed for the compression of fruit, as well as mechanisms that facilitate the process of malaxating and centrifugal separation. Cold pressing was used in the process (25°C) and the olives were malaxing for approximately 30 minutes. The extracted oils were then separated into two distinct fractions. The objective of this step was to conduct a comprehensive investigation into the storage effects of daylight and darkness, as well as ambient temperature, over a period of 15 months. Fatty acid composition analysis was conducted at five-month intervals (0, 5, 10, and 15 months).

Fatty acid composition

According to IOC methods, the fatty acid composition was assessed, COI/T.20/Doc.No.33.Rev1 (IOC, 2017). Fatty acid methyl esters (FAMEs) were examined using chromatography of gas with a flame ionization detector and an Agilent DB-23 capillary column. The temperature of the oven was kept constant between 170°C and 210°C for ten minutes at a 2 C min^{-1} increase, the detector temperatures at 250 °C, the carrier gas at 0.5 ml min^{-1}, the injection volume at 0.2 µL, and the split ratio at 1:100. A standard FAME reference mixture (Sigma-Aldrich Chemicals 189-19) was used for reference. The area percentages of all fatty acids were determined and recorded using ChemStation software.

Sterol composition

Sterol and diol amounts were determined using the IOC method, COI/T.20/Doc. No 26 (IOC, 2020). The sterol fraction was analyzed with a Hewlett-Packard 6890 with a split injector and flame-ionization detector. 2 N ethanolic potassium hydroxide was used to saponify the olive oil after adding α-cholestanol. The unsaponifiable was extracted with ethyl ether. The analytical column was an HP-5 with a 5% phenyl, methyl, siloxane stationary phase (30m×0.32mm×0.25µm). The chromatographic conditions were as follows: temperature of an inlet: 280°C; temperature of an oven: 260°C; temperature of detector: 290°C; split ratio: 1:50; amount injected: 1µL. As a carrier gas, helium was utilized at a flow rate of 0.7 to 0.8 ml min^{-1}. Cholestanol served as an internal standard for the measurement of sterols. Outcomes for individual sterols were stated as percentages of total sterols. Total sterols were stated as percentages of total sterols and diols.

Statistical analysis

The olive oil samples were subjected to unsupervised chemometrics techniques, specifically PCA and HCA, to achieve multivariate classification and clustering. Using Minitab Statistical software version 15, multivariate analysis was carried out.

Results and Discussion

Figure 2 shows the maturity index of Ayvalık and Memecik olives. In the first harvest year, 1st MI of Ayvalık olives was 2.02 and 2nd MI was 2.33; in 2010, 1st MI of Ayvalık olives was 1.5 and 2nd MI was 2.2. In 2009, 1st MI of Memecik olives was 1.97 and 2nd MI was 2.83; in 2010, 1st MI of Memecik olives was 1.6 and 2nd MI was 2.3.

Ayvalık extra virgin olive oil, oleic acid varied between 68.13-69.22% and 66.24-67.20%, linoleic acid varied between 10.86-11.47% and 11.89-12.37%, linolenic acid varied between 0.64-0.72% and 0.70-0.74% was determined after 15 months of storage in the daylight conditions at the 1st MI, in

the first and the second harvest year, respectively. Also oleic acid varied between 68.13-69.73% and 66.65-67.20%, linoleic acid varied between 11.06-11.47% and 11.87-12.37%, linolenic acid varied between 0.65-0.72% and 0.69-0.74% was determined after 15 months of storage in the dark conditions at the 1st MI, in the first and the second harvest year, respectively.

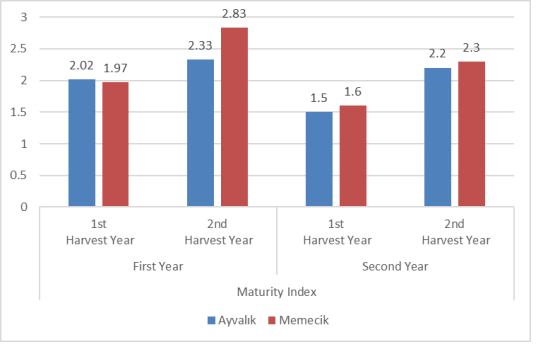


Figure 2. Maturity index of Ayvalık and Memecik cultivars
Şekil 2. Ayvalık ve Memecil çeşitlerinde olgunluk indeksi

When looked at the 2nd MI oleic acid varied between 69.29-69.99% and 65.98-66.65%, linoleic acid varied between 10.47-11.42% and 12.71-12.99 %, linolenic acid varied between 0.62-0.74% and 0.71-0.77% was determined after 15 months of storage in the daylight conditions, in the first and the second harvest year, respectively. Also oleic acid varied between 69.07-69.73% and 66.05-66.46%, linoleic acid varied between 10.89-11.42% and 12.85-12.96%, linolenic acid varied between 0.66-0.74% and 0.74-0.77% was determined after 15 months of storage in the dark conditions at the 2nd MI, in the first and the second harvest year, respectively. Memecik extra virgin olive oil, oleic acid varied between 71.43-72.70% and 65.21-65.70%, linoleic acid varied between 9.14-9.83% and 13.21-13.66%, linolenic acid varied between 0.80-0.89% and 0.92-0.95% was determined after 15 months of storage in the daylight conditions at the 1st MI, in 2009 and 2010, respectively. Also oleic acid varied between 71.43-72.33% and 65.39-66.16%, linoleic acid varied between 9.14-9.71% and 12.91-13.40%, linolenic acid varied between 0.81-0.89% and 0.85-0.94% was determined after 15 months of storage in the dark conditions at the 1st MI, in the first and the second harvest year, respectively. When looked at the 2nd MI oleic acid varied between 69.81-70.33% and 67.27-67.57%, linoleic acid varied between 10.81-11.00% and 13.08-13.28%, linolenic acid varied between 0.80-0.91% and 0.85-0.86% was determined after 15 months of storage in the daylight conditions, in the first and the second harvest year, respectively. Also oleic acid varied between 69.47-70.74% and 67.14-67.70%, linoleic acid varied between 10.70-11.09% and 12.94-13.22%, linolenic acid varied between 0.83-0.91% and 0.81-0.88% was determined after 15 months of storage in the dark conditions at the 2nd MI, in the first and the second harvest year, respectively.

The primary elements of extra virgin olive oil's stability are its antioxidants and composition of fatty acid. Oxidation of fats, particularly when trace metals are present, is one of the main storage degradations. Lipid peroxide is formed when unsaturated fatty acid double bonds are attacked by reactive oxygen radicals. In the study, no significant change was detected in the fatty acid composition during 15 months of storage in both daylight and dark conditions, and it followed an uneven course. The fatty acid composition of Ayvalık and Memecik oils remained within the limits set by the IOC trading standard (IOC, 2022) throughout the shelf life and was determined as virgin olive oil. Similar outcomes were attained in different studies. Gagour et al. (2024) reported that extra virgin olive oil can be stored for up to two years without losing its sensory qualities if it is kept in appropriate and well-made packaging. Mendez and Falque (2007) reported that the unsaturated fatty acid content of olive oils and the oleic acid content decreased due to oxidation during storage, Morello et al. (2004) reported that the oleic acid content increased due to the decrease in polyunsaturated fatty acids such as linoleic acid and linolenic acid due to deterioration and the preservation of the saturated fatty acid content, Gomez-Alonso et al. (2007) reported that the decrease in linolenic acid content during storage was greater than the linoleic acid content, and this was due to the antioxidants of virgin olive oil protecting linoleic acid more than linolenic acid under the same oxidation conditions. It was determined that heptadecanoic acid, heptadecenoic acid, linoleic acid, SFA and PUFA contents were lower in Memecik olive oil than in Ayvalık olive oil, while oleic acid, linolenic acid and MUFA contents were higher. The findings concerning the fatty acid composition of Memecik and Ayvalık olive oils were discovered to be in agreement with previous research (Andjelkovic et al., 2009; İlyasoğlu and Özçelik, 2011; Köseoğlu et al., 2016) reached similar conclusions in their studies.

Table 1. The composition of fatty acids (%) in Ayvalık (A) and Memecik (M) olive oils at different MI in daylight and dark, in the first harvest year during 15 months storage

Çizelge 1. Ayvalık (A) ve Memecik (M) zeytinyağlarının farklı MI değerlerinde, birinci hasat yılında, gün ışığında ve karanlıkta, 15 aylık depolama süresince yağ asitleri kompozisyonları (%)

MI	V	ST	STP	C14:0	C16:0	C16:1	C17:0	C17:1	C18:0	C18:1	C18:2T	C18:2	18:3T	C18:3	C20:0	C20:1	C22:0	C24:0	SFA	MUFA	PUFA
1	A	DL	0	0.02	14.35±0.01	1.06	0.14	0.25	2.24	68.13±0.01	0.02	11.47±0.01	0.05	0.72	0.47	0.35	0.16	0.08	17.46	69.53±0.03	12.19
			5	0.02	13.93±0.02	1.04	0.14	0.25	2.25	69.23±0.00	0.01	11.38±0.01	0.04	0.71	0.47	0.35	0.15	0.08	17.04	70.87±0.04	12.08
			10	0.02	14.64±0.00	1.09	0.14	0.25	2.24	68.41±0.04	0.02	11.44±0.00	0.04	0.72	0.44	0.32	0.14	0.07	17.70	70.08±0.05	12.15
			15	0.02	14.50±0.01	1.00	0.14	0.24	2.30	69.22±0.02	0.00	10.86±0.01	0.00	0.64	0.47	0.35	0.16	0.08	17.67	70.80±0.04	11.50
1	A	D	0	0.02	14.35±0.03	1.06	0.14	0.25	2.24	68.13±0.02	0.02	11.47±0.02	0.05	0.72	0.47	0.35	0.16	0.08	17.46	69.53±0.03	12.19
			5	0.02	13.95±0.01	1.07	0.14	0.25	2.24	69.31±0.01	0.02	11.34±0.03	0.04	0.70	0.47	0.35	0.16	0.08	17.06	70.98±0.03	12.04
			10	0.02	14.81±0.02	1.09	0.14	0.25	2.23	68.36±0.01	0.01	11.31±0.04	0.04	0.71	0.45	0.33	0.14	0.07	17.86	70.04±0.04	12.02
			15	0.02	14.22±0.02	1.02	0.14	0.24	2.35	69.16±0.00	0.00	11.06±0.00	0.00	0.65	0.49	0.36	0.16	0.08	17.46	70.79±0.03	11.70
2	A	DL	0	0.02	13.04±0.01	0.96	0.14	0.24	2.37	69.73±0.01	0.01	11.42±0.02	0.05	0.74	0.52	0.38	0.20	0.11	16.40	71.04±0.04	12.16
			5	0.02	13.69±0.01	0.99	0.14	0.25	2.33	69.40±0.04	0.01	11.33±0.01	0.05	0.72	0.47	0.34	0.16	0.08	16.88	70.98±0.03	12.06
			10	0.02	13.73±0.02	1.00	0.15	0.25	2.33	69.29±0.02	0.01	11.37±0.01	0.05	0.74	0.47	0.34	0.16	0.07	16.92	70.88±0.03	9.78
			15	0.02	13.85±0.02	0.94	0.16	0.24	2.53	69.99±0.03	0.00	10.47±0.01	0.00	0.62	0.53	0.37	0.18	0.08	17.36	71.54±0.04	11.09
2	A	D	0	0.02	13.04±0.01	0.96	0.14	0.24	2.37	69.73±0.01	0.01	11.42±0.02	0.05	0.74	0.52	0.38	0.20	0.11	16.40	71.04±0.04	12.16
			5	0.02	13.72±0.01	0.99	0.15	0.25	2.33	69.27±0.02	0.01	11.30±0.02	0.05	0.72	0.48	0.34	0.16	0.08	16.94	70.85±0.04	12.01
			10	0.02	14.07±0.03	1.01	0.15	0.25	2.33	69.07±0.01	0.01	11.25±0.01	0.05	0.72	0.47	0.34	0.15	0.07	17.27	70.66±0.03	9.86
			15	0.02	13.95±0.01	0.97	0.15	0.25	2.43	69.58±0.01	0.00	10.89±0.00	0.00	0.66	0.49	0.35	0.16	0.07	17.28	71.15±0.04	11.55

MI: Maturity Index, V: Variety, ST: Storage Type, STP: Storage Period (Month), Myristic (C14:0), Palmitic (C16:0), palmitoleic (C16:1), Margaric (C17:0), Margoleic (C17:1), Stearic (C18:0), Oleic (C18:1), Linoleic (C18:2), Linolenic (C18:3), Arachidic (C20:0), Gadoleic (C20:0), Behenic (C22:0), Lignoceric (C24:0), Saturated Fatty Acids (SFA), Monounsaturated fatty acids (MUFA), Polyunsaturated fatty acids (PUFA).

MI: Olgunluk İndeksi, V: Çeşit, ST: Depolama Tipi, STP: Depolama Süresi (Ay), Miristik (C14:0), Palmitik (C16:0), Palmitoleik (C16:1), Margarik (C17:0), Margoleik (C17:1), Stearik (C18:0), Oleik (C18:1), Linoleik (C18:2), Linolenik (C18:3), Arakidik (C20:0), Gadoleik (C20:0), Behenik (C22:0), Lignoserik (C24:0), Doymuş Yağ Asitleri (SFA), Tekli Doymamış Yağ Asitleri (MUFA), Çoklu Doymamış Yağ Asitleri (PUFA).

Table 1 The composition of fatty acids (%) in Ayvalık (A) and Memecik (M) olive oils at different MI in daylight and dark, in the first harvest year during 15 months storage (continued)

Çizelge 1. Ayvalık (A) ve Memecik (M) zeytinyağlarının farklı MI değerlerinde, birinci hasat yılında, gün ışığında ve karanlıkta, 15 aylık depolama süresince yağ asitleri kompozisyonları (%) (devamı)

MI	V	ST	STP	C14:0	C16:0	C16:1	C17:0	C17:1	C18:0	C18:1	C18:2T	C18:2	18:3T	C18:3	C20:0	C20:1	C22:0	C24:0	SFA	MUFA	PUFA
1	M	DL	0	0.02	13.33±0.01	1.02	0.04	0.07	2.09	71.43±0.01	0.02	9.14±0.02	0.01	0.88	0.44	0.36	0.15	0.07	16.15	72.94±0.04	10.02
			5	0.02	12.36±0.01	1.01	0.04	0.07	2.05	72.70±0.01	0.01	9.83±0.00	0.01	0.89	0.43	0.36	0.14	0.07	15.11	74.15±0.03	10.73
			10	0.02	13.68±0.02	1.02	0.05	0.07	2.09	71.44±0.00	0.02	9.69±0.01	0.01	0.88	0.43	0.35	0.14	0.07	16.47	72.89±0.03	11.01
			15	0.02	13.02±0.00	0.96	0.04	0.07	2.15	72.41±0.01	0.00	9.46±0.01	0.00	0.80	0.46	0.37	0.14	0.08	15.90	73.82±0.04	10.26
1	M	D	0	0.02	13.33±0.01	1.02	0.04	0.07	2.09	71.43±0.02	0.02	9.14±0.02	0.01	0.88	0.44	0.36	0.15	0.07	16.15	72.94±0.04	10.02
			5	0.02	12.84±0.03	1.00	0.04	0.07	2.08	72.33±0.03	0.01	9.62±0.02	0.01	0.88	0.45	0.37	0.14	0.08	15.65	74.08±0.05	10.50
			10	0.02	13.43±0.01	1.02	0.04	0.07	2.10	71.60±0.00	0.02	9.71±0.03	0.01	0.89	0.44	0.36	0.14	0.07	16.25	73.05±0.04	10.87
			15	0.02	13.32±0.01	0.98	0.04	0.07	2.18	72.08±0.01	0.00	9.41±0.01	0.00	0.81	0.46	0.37	0.15	0.07	16.25	73.50±0.03	10.22
2	M	DL	0	0.02	12.94±0.00	1.03	0.05	0.07	2.54	70.33±0.01	0.02	11.00±0.00	0.01	0.89	0.50	0.36	0.15	0.07	16.27	71.50±0.04	11.89
			5	0.02	13.26±0.01	1.06	0.05	0.07	2.48	70.02±0.00	0.02	11.09±0.02	0.01	0.90	0.47	0.33	0.14	0.06	16.48	71.49±0.03	11.99
			10	0.02	13.49±0.02	1.07	0.05	0.07	2.49	69.81±0.01	0.02	11.04±0.02	0.01	0.91	0.46	0.33	0.13	0.06	16.70	71.28±0.04	11.95
			15	0.02	13.34±0.03	1.02	0.05	0.07	2.59	70.23±0.02	0.00	10.81±0.01	0.00	0.80	0.50	0.36	0.15	0.07	16.71	71.67±0.03	11.61
2	M	D	0	0.02	12.94±0.01	1.03	0.05	0.07	2.54	70.33±0.01	0.02	11.00±0.01	0.01	0.89	0.50	0.36	0.15	0.07	16.27	71.50±0.04	11.89
			5	0.02	12.54±0.02	1.05	0.04	0.07	2.39	70.74±0.00	0.01	11.08±0.01	0.01	0.90	0.46	0.34	0.13	0.06	15.65	72.19±0.04	11.98
			10	0.03	13.78±0.01	1.11	0.05	0.07	2.47	69.47±0.01	0.02	11.09±0.00	0.01	0.91	0.45	0.32	0.13	0.06	16.95	70.98±0.05	12.00
			15	0.02	13.31±0.02	1.02	0.05	0.07	2.61	70.31±0.02	0.00	10.70±0.00	0.00	0.83	0.50	0.36	0.15	0.07	16.69	71.77±0.05	11.53

MI: Maturity lndex, V: Variety, ST: Storage Type, STP: Storage Period (Month), Myristic (C14:0), Palmitic (C16:0), palmitoleic (C16:1), Margaric (C17:0), Margoleic (C17:1), Stearic (C18:0), Oleic (C18:1), Linoleic (C18:2), Linolenic (C18:3), Arachidic (C20:0), Gadoleic (C20:0), Behenic (C22:0), Lignoceric (C24:0), Saturated Fatty Acids (SFA), Monounsaturated fatty acids (MUFA), Polyunsaturated fatty acids (PUFA).
MI: Olgunluk İndeksi, V: Çeşit, ST: Depolama Tipi, STP: Depolama Süresi (Ay), Miristik (C14:0), Palmitik (C16:0), Palmitoleik (C16:1), Margarik (C17:0), Margoleik (C17:1), Stearik (C18:0), Oleik (C18:1), Linoleik (C18:2), Linolenik (C18:3), Arakidik (C20:0), Gadoleik (C20:0), Behenik (C22:0), Lignoserik (C24:0), Doymuş Yağ Asitleri (SFA), Tekli Doymamış Yağ Asitleri (MUFA), Çoklu Doymamış Yağ Asitleri (PUFA).

Table 2. The composition of fatty acids (%) in Ayvalık (A) and Memecik (M) olive oils at different MI in daylight and dark, in the second harvest year during 15 months storage

Çizelge 2. İkinci hasat yılında 15 aylık depolama süresince, farklı MI değerlerinde, gün ışığında ve karanlıkta, Ayvalık (A) ve Memecik (M) zeytinyağlarındaki yağ asitlerinin kompozisyonları (%)

MI	V	ST	STP	C14:0	C16:0	C16:1	C17:0	C17:1	C18:0	C18:1	C18:2T	C18:2	18:3T	C18:3	C20:0	C20:1	C22:0	C24:0	SFA	MUFA	PUFA
1	A	DL	0	0.02	14.83±0.01	1.28	0.13	0.24	2.18	67.20±0.01	0.01	12.37±0.01	0.00	0.74	0.44	0.33	0.14	0.07	17.82	69.06±0.03	13.11
			5	0.02	16.37±0.01	1.21	0.13	0.23	2.18	66.24±0.01	0.02	11.89±0.01	0.00	0.70	0.44	0.33	0.14	0.07	19.36	68.01±0.04	12.60
			10	0.02	16.04±0.00	1.23	0.13	0.23	2.13	66.75±0.02	0.02	11.92±0.02	0.03	0.70	0.42	0.31	0.13	0.07	18.94	68.52±0.04	12.62
			15	0.02	15.06±0.02	1.19	0.13	0.23	2.16	67.18±0.02	0.02	12.23±0.02	0.03	0.74	0.44	0.33	0.13	0.08	18.02	68.94±0.05	12.97
1	A	D	0	0.02	14.83±0.01	1.28	0.13	0.24	2.18	67.20±0.03	0.01	12.37±0.03	0.00	0.74	0.44	0.33	0.14	0.07	17.82	69.06±0.04	13.11
			5	0.02	15.38±0.01	1.23	0.13	0.23	2.16	67.04±0.04	0.02	12.01±0.02	0.00	0.70	0.44	0.33	0.13	0.07	18.33	68.82±0.03	12.71
			10	0.02	15.84±0.02	1.19	0.13	0.23	2.17	67.11±0.02	0.01	11.87±0.01	0.04	0.69	0.43	0.32	0.13	0.07	18.79	68.85±0.03	12.55
			15	0.02	15.71±0.00	1.25	0.13	0.24	2.12	66.65±0.03	0.02	12.16±0.01	0.03	0.72	0.42	0.31	0.12	0.07	18.58	68.45±0.04	12.89
2	A	DL	0	0.02	15.19±0.02	1.32	0.13	0.23	2.13	66.22±0.01	0.02	12.96±0.02	0.00	0.76	0.45	0.34	0.15	0.08	18.14	68.11±0.04	13.72
			5	0.02	15.47±0.02	1.33	0.12	0.23	2.06	65.98±0.02	0.02	12.99±0.03	0.04	0.77	0.42	0.32	0.13	0.07	18.30	67.86±0.03	13.76
			10	0.02	15.26±0.01	1.24	0.12	0.22	2.13	66.65±0.03	0.02	12.71±0.03	0.02	0.71	0.45	0.34	0.15	0.08	18.21	68.44±0.04	13.42
			15	0.02	15.49±0.01	1.27	0.12	0.23	2.08	66.03±0.02	0.02	12.92±0.02	0.03	0.77	0.43	0.32	0.14	0.07	18.36	67.86±0.03	15.99
2	A	D	0	0.02	15.19±0.01	1.32	0.13	0.23	2.13	66.22±0.01	0.02	12.96±0.03	0.00	0.76	0.45	0.34	0.15	0.08	18.14	68.11±0.04	13.72
			5	0.03	15.42±0.03	1.33	0.12	0.24	2.06	66.05±0.03	0.02	12.96±0.01	0.03	0.77	0.42	0.32	0.13	0.07	18.26	67.93±0.03	13.73
			10	0.02	15.17±0.03	1.25	0.12	0.22	2.11	66.46±0.02	0.01	12.85±0.01	0.02	0.74	0.45	0.34	0.14	0.08	18.09	68.28±0.04	13.59
			15	0.02	15.39±0.02	1.31	0.12	0.24	2.07	66.09±0.01	0.02	12.96±0.02	0.03	0.77	0.42	0.32	0.14	0.07	18.24	67.95±0.03	15.98

MI: Maturity lndex, V: Variety, ST: Storage Type, STP: Storage Period (Month), Myristic (C14:0), Palmitic (C16:0), palmitoleic (C16:1), Margaric (C17:0), Margoleic (C17:1), Stearic (C18:0), Oleic (C18:1), Linoleic (C18:2), Linolenic (C18:3), Arachidic (C20:0), Gadoleic (C20:0), Behenic (C22:0), Lignoceric (C24:0), Saturated Fatty Acids (SFA), Monounsaturated fatty acids (MUFA), Polyunsaturated fatty acids (PUFA).
MI: Olgunluk İndeksi, V: Çeşit, ST: Depolama Tipi, STP: Depolama Süresi (Ay), Miristik (C14:0), Palmitik (C16:0), Palmitoleik (C16:1), Margarik (C17:0), Margoleik (C17: 1), Stearik (C18:0), Oleik (C18:1), Linoleik (C18:2), Linolenik (C18:3), Arakidik (C20:0), Gadoleik (C20:0), Behenik (C22:0), Lignoserik (C24:0), Doymuş Yağ Asitleri (SFA), Tekli Doymamış Yağ Asitleri (MUFA), Çoklu Doymamış Yağ Asitleri (PUFA).

Table 2. The composition of fatty acids (%) in Ayvalık (A) and Memecik (M) olive oils at different MI in daylight and dark, in the second harvest year during 15 months storage (continued)

Çizelge 2. İkinci hasat yılında 15 aylık depolama süresince, farklı MI değerlerinde, gün ışığında ve karanlıkta, Ayvalık (A) ve Memecik (M) zeytinyağlarındaki yağ asitlerinin kompozisyonları (%) (devamı)

MI	V	ST	STP	C14:0	C16:0	C16:1	C17:0	C17:1	C18:0	C18:1	C18:2T	C18:2	18:3T	C18:3	C20:0	C20:1	C22:0	C24:0	SFA	MUFA	PUFA
1	M	DL	0	0.03	15.36±0.00	1.29	0.04	0.07	2.21	65.63±0.01	0.02	13.40±0.01	0.00	0.94	0.45	0.32	0.14	0.08	18.31	67.32±0.03	14.34
			5	0.02	16.07±0.01	1.25	0.04	0.07	2.20	65.21±0.03	0.02	13.21±0.01	0.00	0.92	0.45	0.32	0.13	0.08	18.99	66.85±0.04	14.12
			10	0.03	15.77±0.02	1.25	0.04	0.06	2.14	65.70±0.02	0.02	13.66±0.01	0.00	0.92	0.45	0.32	0.13	0.08	18.63	67.33±0.04	14.58
			15	0.02	15.55±0.00	1.25	0.04	0.07	2.18	65.55±0.01	0.02	13.37±0.02	0.01	0.95	0.45	0.32	0.13	0.08	18.45	67.19±0.05	13.59
1	M	D	0	0.03	15.36±0.03	1.29	0.04	0.07	2.21	65.63±0.02	0.02	13.40±0.03	0.00	0.94	0.45	0.32	0.14	0.08	18.31	67.32±0.03	14.34
			5	0.02	15.75±0.01	1.24	0.04	0.07	2.22	65.39±0.02	0.02	13.10±0.02	0.00	0.90	0.46	0.32	0.14	0.08	18.71	67.17±0.04	14.00
			10	0.03	15.47±0.01	1.14	0.04	0.06	2.27	66.16±0.03	0.02	12.91±0.00	0.00	0.85	0.48	0.33	0.15	0.08	18.53	67.69±0.04	13.76
			15	0.02	15.57±0.02	1.24	0.04	0.07	2.16	65.54±0.01	0.02	13.38±0.01	0.01	0.94	0.45	0.32	0.13	0.08	18.45	67.16±0.04	13.70
2	M	DL	0	0.02	14.32±0.01	1.09	0.04	0.07	2.17	67.34±0.01	0.02	13.08±0.02	0.00	0.85	0.44	0.35	0.13	0.07	17.19	68.85±0.04	13.93
			5	0.02	14.25±0.02	1.11	0.04	0.07	2.10	67.27±0.01	0.03	13.28±0.03	0.01	0.88	0.41	0.32	0.12	0.06	17.00	68.77±0.03	14.16
			10	0.02	14.18±0.02	1.06	0.04	0.06	2.15	67.57±0.02	0.02	13.09±0.01	0.00	0.86	0.44	0.35	0.13	0.07	17.02	69.03±0.05	13.95
			15	0.02	13.97±0.02	1.06	0.04	0.06	2.16	67.48±0.02	0.02	13.28±0.01	0.01	0.88	0.43	0.33	0.13	0.07	16.82	68.93±0.04	14.16
2	M	D	0	0.02	14.32±0.03	1.09	0.04	0.07	2.17	67.34±0.02	0.02	13.08±0.00	0.00	0.85	0.44	0.35	0.13	0.07	17.19	68.85±0.03	13.93
			5	0.02	14.41±0.01	1.09	0.04	0.06	2.13	67.14±0.03	0.02	13.22±0.01	0.01	0.88	0.42	0.33	0.12	0.07	17.21	68.63±0.04	14.10
			10	0.02	14.22±0.00	1.04	0.04	0.06	2.16	67.70±0.03	0.01	12.94±0.01	0.00	0.81	0.44	0.34	0.13	0.07	17.08	69.15±0.04	13.76
			15	0.02	14.16±0.01	1.06	0.04	0.07	2.11	67.42±0.01	0.02	13.22±0.03	0.01	0.87	0.43	0.33	0.13	0.08	16.96	68.88±0.03	14.09

MI: Maturity lndex, V: Variety, ST: Storage Type, STP: Storage Period (Month), Myristic (C14:0), Palmitic (C16:0), palmitoleic (C16:1), Margaric (C17:0), Margoleic (C17:1), Stearic (C18:0), Oleic (C18:1), Linoleic (C18:2), Linolenic (C18:3), Arachidic (C20:0), Gadoleic (C20:0), Behenic (C22:0), Lignoceric (C24:0), Saturated Fatty Acids (SFA), Monounsaturated fatty acids (MUFA), Polyunsaturated fatty acids (PUFA).
MI: Olgunluk İndeksi, V: Çeşit, ST: Depolama Tipi, STP: Depolama Süresi (Ay), Miristik (C14:0), Palmitik (C16:0), Palmitoleik (C16:1), Margarik (C17:0), Margoleik (C17:1), Stearik (C18:0), Oleik (C18:1), Linoleik (C18:2), Linolenik (C18:3), Arakidik (C20:0), Gadoleik (C20:0), Behenik (C22:0), Lignoserik (C24:0), Doymuş Yağ Asitleri (SFA), Tekli Doymamış Yağ Asitleri (MUFA), Çoklu Doymamış Yağ Asitleri (PUFA)

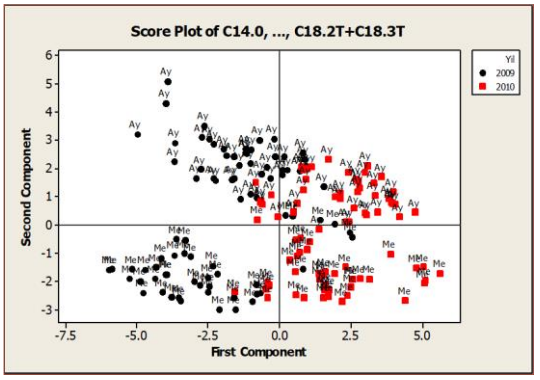


Figure 3. PCA score plot of Ayvalık (Ay) and Memecik (Me) olive oils fatty acid composition in the first and the second harvest years.
Şekil 3. Ayvalık (Ay) ve Memecik (Me) zeytinyağlarının birinci ve ikinci hasat yıllarındaki yağ asidi kompozisyonunun PCA skor çizelgesi

As illustrated in Figure 3, the PCA score plot of Ayvalık and Memecik oils in the initial and secondary harvest years is presented. According to the results of PCA, the score plot of the first (PC1) and second (PC2) principal component demonstrated that the samples were classified into two primary groups with respect to the harvest years. Furthermore, a successful clustering of the samples into two sub-groups was achieved based on their cultivars (Ayvalık and Memecik), which underscores the influence of both genetic factors and environmental conditions during fruit development on the observed outcomes.

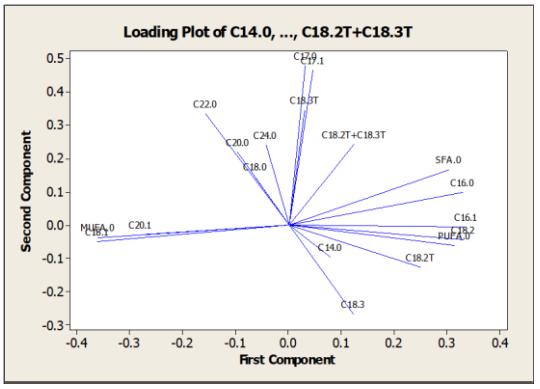


Figure 4. PCA loading plot of fatty acid composition of Ayvalık and Memecik olive oils.
Şekil 4. Ayvalık ve Memecik zeytinyağlarının yağ asidi kompozisyonunun PCA yükleme grafiği.

As illustrated in Figure 4, the PCA loading plot of the fatty acid composition of Ayvalık and Memecik olive oil is shown. The PCA results indicated that the variables C18:0, C20:0, C22:0, C24:0 and C18:1, C20:1, MUFA had a significant impact in the characterization of the olive oil samples obtained in the first harvest years, Ayvalık and Memecik, respectively. Furthermore, the analysis of the olive oils revealed that they were predominantly characterized by the presence of certain fatty acids, including C16:0, C16:1, C17:0, C17:1, C18:3T, C18:2T+C18:3T, SFA, and C14:0, C18:2, C18:2T, C18:3, and PUFA, as obtained in the second harvest years of Ayvalık and Memecik, respectively.

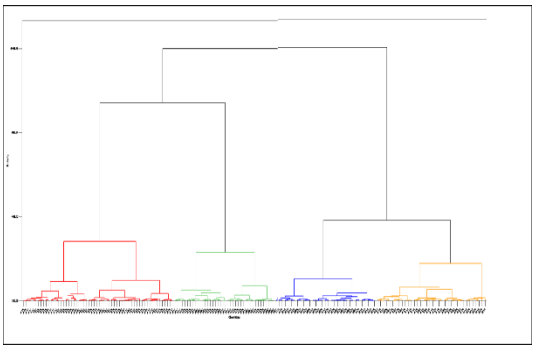


Figure 5. The HCA dendrogram of Ayvalık and Memecik olive oils at first and second maturation index in 2009 and 2010 harvest years.
Şekil 5. 2009 ve 2010 hasat yıllarında birinci ve ikinci olgunlaşma indeksindeki Ayvalık ve Memecik zeytinyağlarının HCA dendrogramı.

According to the HCA results the oils obtained from Ayvalık and Memecik olives are separated into four groups; A, B, C and D (Figure 5). The clustering was observed in Ayvalık ve Memecik varieties but the differences were not observed in clusters according to the MI. Ayvalık and Memecik olive oils showed differences according to years. Memecik olive oils were clustered at B group in the first harvest year and at C group in the second harvest year. Ayvalık olive oils were clustered at A group in the first harvest year and at D group in the second harvest year. There was no difference observed between the 1th and 2nd harvest. In our research, there was not a significant difference of fatty acid composition of olive oils with maturation. This can be caused by close MI. The MI values are near the each other.

Sterol and Erythrodiol+Uvaol Contents

The findings pertaining to the sterol and triterpenic dialcohol contents (in percent) of the olive oil samples are documented in Table 3 and Table 4. The results indicated that β-sitosterol, Δ5-avenasterol and campesterol were the most predominant sterols. In addition, the presence of cholesterol, brassicasterol, 24-metilen cholesterol, campestanol, stigmasterol, Δ7-campesterol, clerosterol, sitostanol, Δ5-24-stigmastadienol, Δ7-stigmastenol, Δ7-avenasterol, eritrodiol, and uvaol was confirmed in all samples, albeit in lower concentrations. Memecik olive oil has higher levels of certain

nutrients, including brassicasterol, stigmasterol, and uvaol, compared to Ayvalık olive oil, which has higher levels of campesterol, Δ5-avenasterol, and total sterol.

Sterol oxidation increases during extra virgin olive oil storage as a result of reactions with light, high temperatures, and oxygen; the degree of unsaturation determines this increase (El Bernoussi et al., 2020). Generally, a increasing tendency was observed along the ripenesss in the values of Δ5-avenasterol. β-sitosterol values of the oils decreased, while erythrodiol+uvaol, values increased during 15 months storage. During the storage period every result fell within the IOC's bounds (2022) aside from delta-7-stigmastenol and brassicasterol. The delta-7-stigmastenol value varied between 0.51 and 0.63%, varied between 0.51 and 0.94%, in the first and the second harvest year, respectively. For brassicasterol only in the first harvest year, it was determined to be 0.15% in the 15th month of storage. β-sitosterol level in olive oil decreased during storage period. Thanh et al. (2006) reported that olive oil's β-sitosterol level declined 16.5% after 6 months of storage at room temperature. Abu-Alruz et al. (2011) reported an increase in Δ7-stigmastenol after 6 months of storage in different containers. Lukić et al. (2013) reported a decrease in stigmasterol, campesterol, Δ5,24-stigmastadienol, and uvaol, and a significant increase in β-sitosterol, and in campestanol levels after 12 months of storage of extra virgin olive oils at different temperatures. Our study yielded similar results. Rey-Giménez et al. (2022) stated that the degree of olive maturity was important only for Δ7-sterols, and the harvest year played an important role in correctly classifying 94.9% of the oils. According to studies, the total sterol loss in oils that are kept closed for the duration of storage is minimal at low temperatures (+4°C and -18°C). According to studies, EVOO is able to be kept at low temperatures for up to 36 months, as long as it stays within the legal bounds created by the present EU regulations that apply to the majority of compounds (Mousavi et al., 2021).

PCA score plots for the first (PC1) and second (PC2) principal components were used to analyze the sterol composition of the samples. The results of this analysis revealed that the samples could be classified into two main groups, based on their cultivar, Ayvalık and Memecik (Figure 6). The PCA analysis revealed that the sterol composition of oils extracted from different MI, harvest years, and storage conditions remained relatively constant and did not exhibit significant variation.

Figure 7 shows the PCA loading plot of sterol composition of Ayvalık and Memecik olive oil. The results of the PCA indicated that the following compounds were important for the description of the Memecik olive oil samples: β-sitosterol, stigmasterol, cholesterol, clerosterol, brassikasterol, and eritrodiol+uvaol. In addition, Ayvalık olive oils were essentially characterized with campestanol, sitosterol, campestanol, Δ7-avenasterol, Δ5-avenasterol, total sterol, Δ5-7 stigmastadienol and total β-sitosterol.

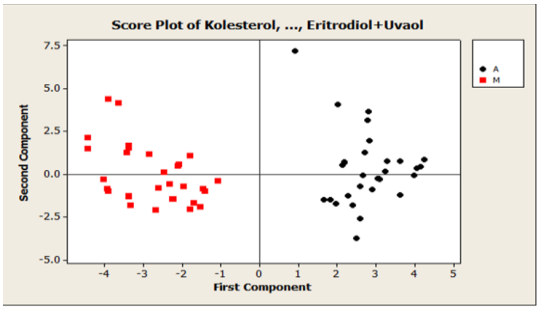


Figure 6. Score plot of PCA results of Ayvalık (A) and Memecik (M) olive oils based on the sterol composition data in daylight and dark storage conditions in 2009 and 2010 harvest years.

Şekil 6. 2009 ve 2010 hasat yıllarında gün ışığında ve karanlıkta depolama koşullarında Ayvalık (A) ve Memecik (M) zeytinyağlarının sterol kompozisyon verilerine göre PCA sonuçlarının puan grafiği.

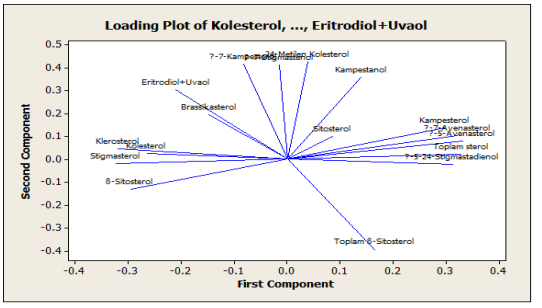


Figure 7. Loading plot of PCA based on the sterol composition results of Ayvalık and Memecik olive oils in 2009 and 2010 harvest years.

Şekil 7. 2009 ve 2010 hasat yıllarında Ayvalık ve Memecik zeytinyağlarının sterol kompozisyon sonuçlarına dayalı PCA yükleme grafiği.

As indicated by the results of the HCA, the oils obtained from the Ayvalık and Memecik olive oils were separated into two distinct groups, as illustrated in Figure 8. The clustering was observed in Ayvalık ve Memecik varieties but the differences were not observed in clusters according to the MI, harvest years and also storage conditions. This can be caused by close MI.

Table 3. Evaluation of Sterol Composition of Ayvalık (A) and Memecik (M) olive oils at different MI in daylight and dark, in the first harvest year during15 months storage.
Çizelge 3. Ayvalık (A) ve Memecik (M) zeytinyağlarının farklı MI değerlerinde, gün ışığında ve karanlıkta, ilk hasat yılında 15 aylık depolama süresince sterol kompozisyonlarının değerlendirilmesi

MI	V	ST	STP	Chole sterol (%)	Brassica sterol (%)	24-Mehylene Chole sterol (%)	Campe sterol (%)	Campe stanol (%)	Stigma stenol (%)	Δ-7-Campe sterol (%)	Clero sterol (%)	β-Sitosterol (%)	Sito stanol (%)	Δ-5-Avena sterol (%)	Δ-5-24-Stigma stadienol (%)	Δ-7-Stigma stenol (%)	Δ-7-Avena sterol (%)	Total Sterol (mg kg^{-1})	Total β-Sitosterol*	Erytrodiol +Uvaol (%)
1	A	DL	0	0.15	0.02	0.01	3.47	0.06	0.54	0.06	0.92	85.57±0.05	0.40	6.80±0.01	0.98	0.25	0.65	2404±0.14	94.68±0.04	0.68
			5	0.17	0.06	0.11	3.53	0.06	0.56	0.08	0.95	85.91±0.04	0.45	6.27±0.00	0.97	0.31	0.55	2377±0.15	94.55±0.05	0.92
			10	0.18	0.04	0.10	3.45	0.05	0.56	0.09	0.95	85.93±0.03	0.43	6.21±0.01	1.02	0.39	0.59	2291±0.17	94.54±0.04	1.04
			15	0.14	0.01	0.10	3.45	0.10	0.57	0.08	0.81	84.55±0.05	0.69	7.38±0.01	1.03	0.42	0.65	2198±0.12	94.47±0.07	1.18
1	A	D	0	0.15	0.02	0.10	3.47	0.06	0.54	0.06	0.92	85.57±0.06	0.40	6.80±0.02	0.98	0.25	0.65	2404±0.17	94.68±0.05	0.68
			5	0.20	0.04	0.09	3.52	0.06	0.57	0.09	0.96	85.24±0.05	0.43	6.89±0.02	0.94	0.28	0.68	2260±0.18	94.46±0.07	0.79
			10	0.17	0.05	0.09	3.50	0.08	0.55	0.12	0.91	84.70±0.04	0.57	6.84±0.01	1.11	0.61	0.70	2345±0.25	94.13±0.08	1.31
			15	0.12	0.02	0.12	3.43	0.08	0.61	0.09	0.87	83.93±0.05	0.59	8.00±0.00	0.95	0.48	0.70	2250±0.14	94.34±0.09	1.43
2	A	DL	0	0.15	0.02	0.12	3.58	0.07	0.48	0.08	0.91	85.68±0.04	0.38	6.99±0.01	0.59	0.27	0.66	2333±0.18	94.55±0.10	0.58
			5	0.21	0.02	0.12	3.59	0.08	0.49	0.09	0.92	85.34±0.06	0.54	6.96±0.02	0.65	0.29	0.70	2340±0.19	94.40±0.08	0.66
			10	0.21	0.04	0.14	3.64	0.10	0.49	0.10	0.90	84.81±0.07	0.46	7.15±0.03	0.70	0.51	0.73	2396±0.24	94.04±0.09	0.99
			15	0.19	0.02	0.11	3.56	0.14	0.45	0.08	0.82	84.09±0.04	0.84	7.88±0.01	0.72	0.37	0.70	2348±0.13	94.36±0.07	0.95
2	A	D	0	0.15	0.02	0.12	3.58	0.07	0.48	0.08	0.91	85.68±0.04	0.38	6.99±0.00	0.59	0.27	0.66	2333±0.11	94.55±0.11	0.58
			5	0.21	0.02	0.13	3.60	0.09	0.50	0.08	0.92	84.84±0.03	0.56	7.20±0.00	0.72	0.35	0.77	2346±0.17	94.25±0.05	0.69
			10	0.22	0.02	0.11	3.60	0.10	0.49	0.10	0.86	84.70±0.05	0.58	7.14±0.01	0.78	0.63	0.66	2374±0.19	94.07±0.07	1.18
			15	0.14	0.01	0.13	3.65	0.14	0.47	0.10	0.90	83.90±0.06	0.86	7.92±0.03	0.77	0.28	0.73	2315±0.14	94.34±0.08	1.22

MI: Maturity Index, V: Variety, ST: Storage Type, STP: Storage Period (Month).
MI: Olgunluk Endeksi, V: Çeşit, ST: Depolama Tipi, STP: Depolama Süresi (Ay).

Table 3. Evaluation of Sterol Composition of Ayvalık (A) and Memecik (M) olive oils at different MI in daylight and dark, in the first harvest year during15 months storage (continued)

Çizelge 3. Ayvalık (A) ve Memecik (M) zeytinyağlarının farklı MI değerlerinde, gün ışığında ve karanlıkta, ilk hasat yılında 15 aylık depolama süresince sterol kompozisyonlarının değerlendirilmesi (devamı)

MI	V	ST	STP	Chole sterol (%)	Brassica sterol(%)	24-Mehylene Cholesterol(%)	Campe sterol(%)	Campe stanol(%)	Stigma stenol(%)	Δ-7-Campe sterol(%)	Clero sterol(%)	β-Sito sterol (%)	Sito stanol(%)	Δ-5-Avena sterol (%)	Δ-5-24-Stigma stadienol (%)	Δ-7-Stigma stenol (%)	Δ-7-Avena sterol(%)	Total Sterol (mg kg^{-1})	Total β-Sitos terol*	Erytrodiol +Uvaol (%)
1	M	DL	0	0.31	0.05	0.09	3.08	0.05	1.79	0.08	1.08	84.22±0.05	0.32	3.28±0.01	0.23	0.27	0.31	1337±0.14	93.70±0.10	1.35
			5	0.25	0.03	0.10	3.26	0.06	1.92	0.12	1.17	88.96±0.05	0.43	2.93±0.00	0.20	0.30	0.25	1281±0.12	93.70±0.09	1.26
			10	0.34	0.04	0.12	3.27	0.12	1.89	0.14	1.22	88.05±0.05	0.38	3.42±0.02	0.26	0.37	0.35	1272±0.17	93.34±0.11	2.06
			15	0.25	0.08	0.13	3.24	0.17	1.83	0.13	1.17	87.46±0.04	0.61	3.65±0.02	0.36	0.32	0.31	1347±0.19	93.54±0.11	1.69
1	M	D	0	0.31	0.05	0.09	3.08	0.05	1.79	0.08	1.08	84.22±0.07	0.32	3.28±0.01	0.23	0.27	0.31	1337±0.15	93.70±0.13	1.35
			5	0.23	0.04	0.10	3.23	0.06	1.92	0.11	1.19	88.94±0.03	0.43	3.03±0.01	0.18	0.28	0.25	1270±0.14	93.77±0.10	1.29
			10	0.22	0.06	0.10	3.22	0.09	1.94	0.08	1.22	88.50±0.05	0.30	3.38±0.01	0.24	0.32	0.33	1330±0.20	93.64±0.14	1.87
			15	0.20	0.10	0.13	3.21	0.20	2.00	0.08	1.12	87.74±0.04	0.66	3.56±0.02	0.30	0.41	0.29	1273±0.18	93.38±0.15	1.78
2	M	DL	0	0.27	0.02	0.12	3.42	0.04	1.42	0.09	1.20	87.61±0.05	0.37	4.50±0.00	0.27	0.22	0.40	1578±0.11	94.00±0.10	1.06
			5	0.30	0.02	0.13	3.41	0.04	1.43	0.14	1.12	87.52±0.04	0.58	4.45±0.02	0.26	0.24	0.34	1608±0.14	93.95±0.08	1.07
			10	0.24	0.05	0.12	3.46	0.06	1.49	0.12	1.18	87.43±0.02	0.35	4.47±0.01	0.27	0.35	0.40	1634±0.12	93.71±0.12	1.46
			15	0.17	0.00	0.15	3.37	0.11	1.40	0.17	1.12	87.52±0.04	0.61	4.33±0.01	0.33	0.36	0.35	1479±0.17	93.91±0.13	1.49
2	M	D	0	0.27	0.02	0.12	3.42	0.04	1.42	0.09	1.20	87.61±0.06	0.37	4.55±0.02	0.27	0.22	0.40	1578±0.18	94.00±0.10	1.06
			5	0.29	0.04	0.11	3.38	0.05	1.45	0.10	1.14	87.86±0.05	0.46	4.18±0.00	0.24	0.25	0.42	1597±0.18	93.78±0.11	1.24
			10	0.24	0.06	0.12	3.46	0.08	1.49	0.14	1.20	87.31±0.04	0.36	4.43±0.03	0.25	0.45	0.39	1550±0.17	93.57±0.12	1.65
			15	0.18	0.00	0.11	3.40	0.11	1.40	0.12	1.06	87.04±0.04	0.84	4.64±0.01	0.45	0.25	0.38	1575±0.14	94.05±0.10	1.49

MI: Maturity Index, V: Variety, ST: Storage Type, STP: Storage Period (Month)

MI: Olgunluk Endeksi, V: Çeşit, ST: Depolama Tipi, STP: Depolama Süresi (Ay).

Table 4. Evaluation of Sterol Composition of Ayvalık (A) and Memecik (M) olive oils at different MI in daylight and dark, in the second harvest year during 15 months storage
Çizelge 4. İkinci hasat yılında 15 aylık depolama süresince, farklı MI değerlerinde, gün ışığında ve karanlıkta, Ayvalık (A) ve Memecik (M) zeytinyağlarının sterol kompozisyonunun değerlendirilmesi

MI	V	ST	STP	Cholesterol (%)	Brassicasterol (%)	24-Mehylene Cholesterol (%)	Campesterol (%)	Campestanol (%)	Stigmastenol (%)	Δ-7-Campesterol (%)	Clerosterol (%)	β-Sitosterol (%)	Sitostanol (%)	Δ-5-Avenasterol (%)	Δ-5-24-Stigmastadienol (%)	Δ-7-Stigmastenol (%)	Δ-7-Avenasterol (%)	Total Sterol (mg kg^{-1})	Total β-Sitosterol	Erytrodiol +Uvaol (%)
1	A	DL	0	0.14	0.04	0.09	3.70	0.10	0.59	0.09	0.90	83.78±0.05	0.44	7.87±0.01	1.06	0.34	0.86	2170±0.14	94.06±0.09	1.30
			5	0.10	0.00	0.10	3.75	0.16	0.59	0.11	0.89	83.20±0.07	0.62	8.27±0.02	1.06	0.32	0.83	2434±0.18	94.04±0.10	1.16
			10	0.12	0.00	0.11	3.74	0.16	0.57	0.11	0.88	82.84±0.04	0.92	8.57±0.02	0.88	0.35	0.78	2416±0.15	94.01±0.07	0.78
			15	0.16	0.04	0.14	3.77	0.19	0.65	0.16	0.99	82.79±0.03	0.81	8.27±0.02	0.71	0.56	0.76	2293±0.14	93.57±0.07	1.02
1	A	D	0	0.14	0.04	0.09	3.70	0.10	0.59	0.09	0.90	83.78±0.05	0.44	7.87±0.00	1.06	0.34	0.86	2170±0.13	94.06±0.08	1.30
			5	0.10	0.00	0.12	3.70	0.12	0.65	0.12	0.96	83.39±0.05	0.65	8.13±0.00	0.88	0.38	0.79	2433±0.18	94.02±0.11	1.33
			10	0.14	0.00	0.11	3.82	0.16	0.57	0.12	0.91	82.46±0.06	1.07	8.54±0.03	0.98	0.34	0.76	2426±0.17	93.98±0.12	0.80
			15	0.14	0.07	0.14	3.74	0.11	0.58	0.12	0.94	83.41±0.07	0.60	7.89±0.01	0.92	0.47	0.86	2352±0.19	93.76±0.09	1.32
2	A	DL	0	0.10	0.01	0.10	3.72	0.12	0.51	0.08	0.85	84.57±0.06	0.35	7.59±0.02	0.96	0.27	0.76	2212±0.20	94.33±0.10	0.85
			5	0.17	0.00	0.14	3.65	0.13	0.58	0.13	0.96	83.59±0.05	0.85	7.77±0.01	0.90	0.38	0.73	2298±0.19	94.09±0.09	1.52
			10	0.11	0.00	0.12	3.67	0.17	0.60	0.16	0.95	83.60±0.05	0.72	7.85±0.01	1.01	0.29	0.75	2320±0.18	94.13±0.09	0.70
			15	0.14	0.02	0.18	3.74	0.16	0.62	0.18	0.94	83.68±0.06	0.60	7.85±0.01	0.59	0.56	0.73	2183±0.17	93.67±0.08	1.96
2	A	D	0	0.10	0.01	0.10	3.72	0.12	0.51	0.08	0.85	84.57±0.07	0.35	7.60±0.02	0.96	0.27	0.76	2212±0.19	94.33±0.07	0.85
			5	0.22	0.00	0.16	3.72	0.24	0.59	0.17	0.99	82.93±0.08	1.01	7.98±0.00	0.89	0.46	0.73	2344±0.17	93.80±0.08	1.62
			10	0.13	0.00	0.13	3.74	0.15	0.51	0.09	0.89	83.62±0.07	0.67	8.03±0.00	0.98	0.30	0.75	2432±0.18	94.20±0.10	0.84
			15	0.20	0.15	0.24	3.68	0.20	0.57	0.22	1.04	83.50±0.05	0.74	7.34±0.01	0.65	0.71	0.75	2248±0.19	93.27±0.11	1.86

MI: Maturity Index, V: Variety, ST: Storage Type, STP: Storage Period (Month)
MI: Olgunluk Endeksi, V: Çeşit, ST: Depolama Türü, STP: Depolama Süresi (Ay)

Table 4. Evaluation of Sterol Composition of Ayvalık (A) and Memecik (M) olive oils at different MI in daylight and dark, in the second harvest year during 15 months storage (continued)

Çizelge 4. İkinci hasat yılında 15 aylık depolama süresince, farklı MI değerlerinde, gün ışığında ve karanlıkta, Ayvalık (A) ve Memecik (M) zeytinyağlarının sterol kompozisyonunun değerlendirilmesi (devamı)

MI	V	ST	STP	Chole sterol (%)	Brassica sterol (%)	24-Mehylene Chole sterol (%)	Campe sterol (%)	Campe stanol (%)	Stigma stenol (%)	Δ-7-Campe sterol (%)	Clero sterol (%)	β-Sito sterol (%)	Sito stanol (%)	Δ-5-Avena sterol (%)	Δ-5-24-Stigma stadienol (%)	Δ-7-Stigma stenol (%)	Δ-7-Avena sterol (%)	Total Sterol (mg kg^{-1})	Total β-Sito sterol*	Erytrodiol +Uvaol (%)
1	M	DL	0	0.23	0.07	0.06	3.32	0.04	1.36	0.11	1.20	89.54±0.07	0.39	2.66±0.01	0.45	0.28	0.27	1453±0.14	94.26±0.07	1.54
			5	0.14	0.01	0.11	3.21	0.09	1.32	0.13	1.20	88.36±0.09	0.86	3.43±0.02	0.50	0.33	0.28	1525±0.12	94.37±0.08	1.48
			10	0.15	0.01	0.07	3.24	0.14	1.35	0.14	1.12	87.91±0.05	1.29	3.57±0.00	0.44	0.28	0.28	1480±0.17	94.34±0.05	1.24
			15	0.22	0.06	0.15	3.32	0.07	1.36	0.13	1.21	88.98±0.05	0.31	2.94±0.01	0.40	0.51	0.33	1472±0.12	93.85±0.05	2.02
1	M	D	0	0.23	0.07	0.06	3.32	0.04	1.36	0.11	1.20	89.54±0.07	0.39	2.66±0.02	0.45	0.28	0.27	1453±0.17	94.26±0.06	1.54
			5	0.13	0.00	0.09	3.23	0.10	1.33	0.12	1.14	88.00±0.06	1.13	3.57±0.00	0.48	0.36	0.30	1565±0.18	94.34±0.05	1.35
			10	0.17	0.00	0.06	3.35	0.08	1.34	0.14	1.15	88.09±0.04	0.75	3.89±0.01	0.36	0.29	0.33	1474±0.16	94.24±0.07	1.00
			15	0.27	0.10	0.14	3.38	0.04	1.40	0.14	1.26	89.04±0.05	0.31	2.63±0.02	0.35	0.59	0.34	1456±0.15	93.59±0.05	2.35
2	M	DL	0	0.23	0.07	0.06	3.32	0.03	1.35	0.10	1.10	88.62±0.08	0.61	3.56±0.01	0.42	0.23	0.32	1358±0.17	94.30±0.05	1.45
			5	0.28	0.00	0.08	3.26	0.11	1.39	0.14	1.13	86.52±0.09	0.65	5.00±0.00	0.46	0.57	0.40	1387±0.18	93.77±0.07	1.40
			10	0.25	0.00	0.07	3.18	0.08	1.33	0.12	1.08	87.67±0.07	0.77	4.49±0.02	0.40	0.22	0.34	1472±0.15	94.41±0.08	1.09
			15	0.24	0.09	0.17	3.32	0.11	1.37	0.20	1.25	87.84±0.05	0.56	3.46±0.02	0.23	0.79	0.35	1314±0.14	93.34±0.09	1.88
2	M	D	0	0.23	0.07	0.06	3.32	0.03	1.35	0.10	1.10	88.62±0.04	0.61	3.56±0.00	0.42	0.23	0.32	1358±0.19	94.30±0.11	1.45
			5	0.26	0.00	0.10	3.31	0.10	1.40	0.11	1.16	87.02±0.04	0.63	4.39±0.03	0.45	0.62	0.45	1438±0.16	93.63±0.07	1.34
			10	0.21	0.00	0.08	3.23	0.07	1.34	0.12	1.08	87.52±0.07	1.02	4.37±0.01	0.40	0.21	0.34	1423±0.14	94.39±0.09	1.12
			15	0.27	0.06	0.13	3.25	0.13	1.36	0.20	1.11	87.98±0.08	0.47	3.43±0.02	0.25	0.94	0.42	1289±0.17	93.23±0.07	1.90

MI: Maturity Index, V: Variety, ST: Storage Type, STP: Storage Period (Month)
MI: Olgunluk Endeksi, V: Çeşit, ST: Depolama Türü, STP: Depolama Süresi (Ay)

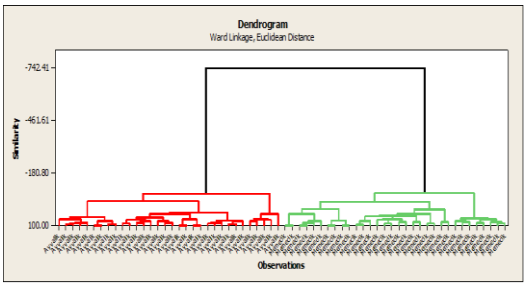


Figure 8. The dendrogram on HCA results of Ayvalık and Memecik olive oils in daylight and dark conditions at 1th and 2nd MI in 2009 and 2010 harvest years.

Şekil 8. 2009 ve 2010 hasat yıllarında 1. ve 2. MI'da gün ışığı ve karanlık koşullarında Ayvalık ve Memecik zeytinyağlarının HCA sonuçlarına ilişkin dendrogram.

Conclusion

Many variables influence olive oil composition and quality. These include ripening and storage of olives, as well as agricultural practices, raw material quality, harvest time, fruit storage conditions, and oil extraction technology.

In the study, it was determined that Memecik olive oil had higher oleic acid (C18:1) (71-72.7%) and MUFA content than Ayvalık olive oil in terms of fatty acid composition. High oleic acid is advantageous for cardiovascular health and is more resistant to oxidation. A comparative analysis revealed that Ayvalık olive oil exhibited a higher content of SFA and PUFA compared to Memecik olive oil. The palmitic acid (C16:0) and linoleic acid (C18:2) ratios are higher than those observed in Memecik. The presence of high levels of SFA has been demonstrated to impart heat resistance and shelf life stability.

In regard to the sterol and triterpenic components, a higher content of β-sitosterol, stigmasterol, brassicasterol, and erythrodiol+uvaol was observed in Memecik olive oil compared to Ayvalık olive oil. As is widely recognized, β-sitosterol, a phytosterol, has been demonstrated to reduce cholesterol absorption. The amount of erythrodiol+uvaol increased during storage (1.35-2.35%), which contributed to the antioxidant capacity. A comparative analysis of the olive oils from Ayvalık and Memecik revealed that Ayvalık olive oil exhibited higher concentrations of campestanol, Δ5-avenasterol, and total sterol compared to Memecik olive oil. Notably, Δ5-avenasterol, a sterol known for its role in enhancing oxidative stability, was found to be a distinguishing component in the Ayvalık olive oil. The total sterol content (2.404–2.198 mg kg^{-1}) is higher than that of Memecik (1.337–1.579 mg kg^{-1}). With respect to storage stability, both varieties satisfied the IOC criteria over a 15-month storage period. Memecik olive oil demonstrates enhanced resistance to oxidation, attributable to its elevated MUFA content, Linoleic acid loss is reduced (and tends to be protected by antioxidants). Ayvalık olive oil sterol oxidation, particularly the increase in Δ7-stigmastenol, is more pronounced, yet total sterol loss remains limited.

PCA and HCA analyses were performed to differentiate between the Memecik and Ayvalık varieties. These analyses revealed clear distinctions in the fatty acid and sterol profiles of the two varieties. Memecik was characterized by the presence of β-sitosterol and erythrodiol+uvaol, while Ayvalık was distinguished by the presence of campestanol and Δ5-avenasterol. The two varieties were grouped in different clusters according to harvest year, and the effect of maturity index was found to be limited.

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Determination of Morphological and Biochemical Properties of Almond (*Prunus amygdalus*) Genotypes in Denizli-Çivril

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Abstract

In this study, morphological and biochemical properties of 22 almond genotypes and 'Nonpareil' cultivar were examined. Nut weight, kernel weight, kernel ratio, shell thickness, nut and kernel dimensions, as well as oil, protein, ash, moisture, and total carbohydrate contents were determined. Nut weight ranged from 2.54 to 4.61 g, kernel weight from 0.67 to 1.38 g, kernel ratio from 19.69% to 32.26%, and shell thickness from 2.43 to 3.41 mm. Biochemical analyses revealed oil content between 45.40-55.65%, protein content between 17.22-19.50%, ash content between 2.90-3.69%, moisture content between 3.59-4.55%, and total carbohydrate content between 16.67-30.06%. Principal Component Analysis (PCA) showed a strong negative correlation (r=-0.970) between oil content and carbohydrate in the first two components, which explained 57.27% of the total variance. The 20CVRL22 genotype had the highest kernel ratio (32.26%), 20CVRL13 and 20CVRL18 genotypes had the highest oil content (51.47% and 51.60%, respectively), and the 20CVRL15 genotype had the highest protein content (19.50%). The results reveal the richness of almond genetic resources in the Çivril region while providing important information for genotype selection and breeding studies for different usage purposes.

Key words: Morphological properties, Biochemical properties, PCA analysis, Correlation, Variance analysis

Denizli-Çivril'deki Badem (*Prunus amygdalus*) Genotiplerinin Morfolojik ve Biyokimyasal Özelliklerinin Belirlenmesi

Özet

Bu çalışmada, 22 badem genotipi ve 'Nonpareil' çeşidinin morfolojik ve biyokimyasal özellikleri incelenmiştir. Meyve ağırlığı, iç ağırlığı, iç oranı, kabuk kalınlığı, kabuklu ve iç meyve boyutları ile yağ, protein, kül, nem ve toplam karbonhidrat içerikleri belirlenmiştir. Meyve ağırlığı 2.54-4.61 g, iç ağırlığı 0.67-1.38 g, iç oranı %19.69-32.26 ve kabuk kalınlığı 2.43-3.41 mm arasında değişmiştir. Biyokimyasal analizlerde yağ içeriği %45.40-55.65, protein içeriği %17.22-19.50, kül içeriği %2.90-3.69, nem içeriği %3.59-4.55 ve toplam karbonhidrat içeriği %16.67-30.06 arasında tespit edilmiştir. Temel Bileşenler Analizi (PCA), toplam varyansın %57.27'sini açıklayan ilk iki bileşende, yağ içeriği ile karbonhidrat arasında güçlü negatif korelasyon (*r*=-0.970) göstermiştir. 20CVRL22 genotipi en yüksek iç oranına (%32.26), 20CVRL13 ve 20CVRL18 genotipleri en yüksek yağ içeriğine (sırasıyla %51.47 ve %51.60), 20CVRL15 genotipi en yüksek protein içeriğine (%19.50) sahip olmuştur. Sonuçlar, Çivril yöresindeki badem genetik kaynaklarının zenginliğini ortaya koyarken, farklı kullanım amaçlarına yönelik genotip seçimi ve ıslah çalışmaları için önemli bilgiler sunmaktadır.

Anahtar Kelimeler: Morfolojik özellikler, Biyokimyasal özellikler, PCA analizi, Korelasyon, Varyans analizi

Introduction

Almond (*Prunus amygdalus*) is a significant fruit species belonging to the genus Amygdalus of the Prunoideae subfamily within the Rosaceae family, order Rosales. It originates from western and central Asia, with a wide geographical distribution encompassing the Mediterranean region, Türkiye, Northern Iran, India, and China. Its sensitivity to low temperatures and heavy precipitation during the flowering period limits its cultivation distribution worldwide (Kester et al. 1990; Kester and Gradziel, 1996). Currently, major almond-producing countries include the United States, Australia, and Mediterranean countries with suitable ecological conditions such as Spain, Türkiye, Morocco, and Italy.

Türkiye holds special significance due to its location within the Mediterranean and Near East gene centers, which are among the eight gene centers identified worldwide (Demir, 1990; Ağaoğlu et al., 1995), and it serves as the homeland of almond along with many other cultivated plants. The suitability of Türkiye's ecological conditions for horticultural crop cultivation, its position on migration routes, and its history as a region inhabited by numerous civilizations since ancient times are the most important factors contributing to its rich diversity of species and cultivars. Almond cultivation has gained particular importance especially in the Aegean Region (Kırca, 2024).

Almond kernels are rich in protein, monounsaturated and polyunsaturated fatty acids, vitamin E, ash, riboflavin, phytosterols, and polyphenols, which are considered valuable for human health and nutrition. Additionally, they are important for health due to their ability to reduce cholesterol absorption and lower LDL-cholesterol levels in the blood. This information has increased

interest in almond consumption (Richardson et al., 2009; Kırca and Karadeniz, 2022; Özcan, 2023).

Morphological characterization is highly useful for preliminary evaluation of almond and other fruit species genetic resources due to its rapidity and ease of assessment, and it can also be used to reveal genetic variation among morphologically distinguishable accessions. For this purpose, morphological traits combined with multivariate analyses such as principal component analysis (PCA) and cluster analysis are frequently used to screen accessions in different fruit species (Čolić et al., 2012; Sepahvand et al., 2015; Bak and Karadeniz, 2021; Güler et al., 2021; Kırca et al., 2023; Gürcan et al., 2024; Şenlik and Mertoğlu, 2024; Bak et al., 2024). Morphological characteristics of almond genotypes such as fruit weight, fruit width, fruit length, fruit thickness, shell thickness, kernel weight, width, length, thickness, kernel ratio, kernel width index, and kernel thickness index are important parameters for identification and classification of genotypes.

The biochemical properties of almond, particularly its fat, protein, ash, moisture, and total carbohydrate content, are of great importance for both nutritional value and industrial applications. High fat content is a significant factor in the confectionery industry, as higher fat content causes almond paste to absorb less water (Sze-Tao and Sathe, 2000; Gomez et al., 2008; Kırca and Karadeniz, 2022). In this context, the strategic role of high fat content in confectionery production contributes to improving production processes and consumer satisfaction. Protein content is an important factor determining the nutritional value of almonds and can show significant variations among cultivars (Kodad et al., 2023).

Almond genetic resources propagated from seeds show great variation in terms of resistance to diseases and pests, adaptation to ecological conditions, and tree and fruit characteristics (Čolić et al., 2012; Batlle et al., 2017). The presence of numerous seed-propagated almond trees in Türkiye provides significant advantages to almond breeders in selecting genotypes with desired traits. The conservation and characterization of local almond genotypes are important to prevent the loss of genetic diversity and to serve as a potential source of genetic diversity for future almond breeding programs.

In Türkiye, many researchers have conducted selection studies to identify almond genotypes with superior characteristics (Kalyoncu, 1990; Aslantas, 1993; Karadeniz and Erman, 1996; Karadeniz et al., 1996; Balta, 2002; Ağlar, 2005; Yıldırım, 2007; Şimşek, 2008; Sümbül, 2009; Şimşek, 2011; Köse, 2013; Bozkurt, 2017; Acar et al., 2018; Genç, 2024; Işık, 2025). In these selection studies, many promising genotypes have been selected that possess the qualities desired by almond breeding programs, particularly those that flower late and show superior characteristics in terms of fruit and tree properties. In this study, the morphological (fruit weight, fruit width, fruit length, fruit thickness, shell thickness, kernel weight, width, length, thickness, kernel ratio, kernel width index, kernel thickness index) and biochemical (fat, protein, ash, moisture, total carbohydrate) characteristics of 22 almond genotypes grown in the Çivril district of Denizli and the 'Nonpareil' almond cultivar were examined. The aim of the research is to determine the pomological, morphological, and biochemical characteristics of these genotypes and to reveal their potential for commercial production and as genetic resources.

Materials and Methods

Plant material and characteristics of the region

The study was conducted in 2023 on 22 almond genotypes grown from seed without any irrigation, fertilization, or other cultural practices, along with the 'Nonpareil' almond cultivar in the Çivril district of Denizli province. Çivril is a district located in the northeast of Denizli province with an area of 1,570 km^2. Situated at an altitude of 840 meters above sea level, Çivril has a transitional climate between the Aegean Region and the Central Anatolia Region. It is characterized by hot and dry summers, and cold and rainy winters (Anonymous, 2025).

When examining the 15-year climate data for monthly average relative humidity, precipitation, temperature, and wind speed in Çivril district between 2009-2023 (Figure 1), continental climate characteristics with distinct seasonal variations are observed. Temperature values reach an average of 25°C during summer months (July-August), while dropping to around 3-5°C during winter months (January-February). This indicates a temperature difference of approximately 22°C throughout the year. Analysis of the region's precipitation regime shows that the annual total precipitation is approximately 442 mm with significant differences in seasonal distribution. The rainiest period occurs during winter and spring months (January-May), while summer months (especially July-September) are distinctly dry. July stands out as the month with the least precipitation, averaging 4.91 mm. Relative humidity levels reach 74-75% during winter months (December-January) and drop to 42-43% during summer months (July-August). This pattern parallels the low precipitation amounts during summer months. Wind speed data varies between 1.96-2.67 m sec^{-1} throughout the year without showing significant seasonal differences (TSMS, 2025).

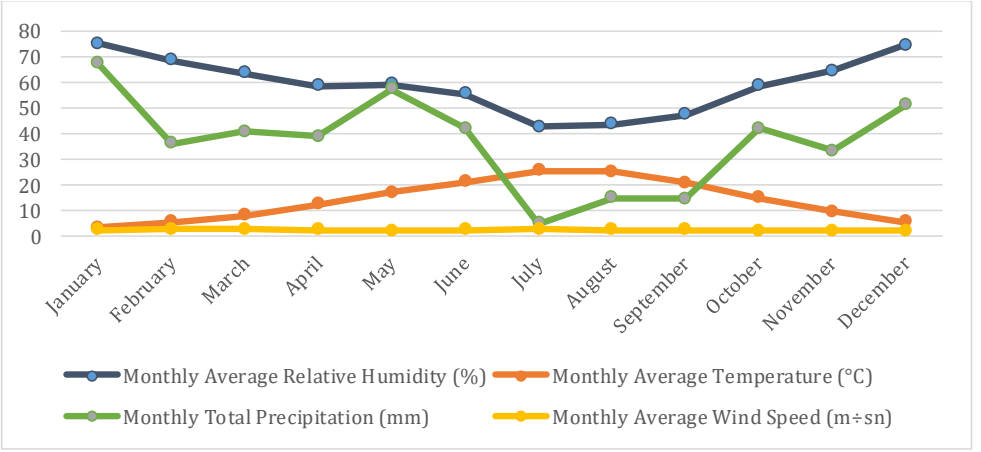

Figure 1. Distribution of monthly average temperature (°C), relative humidity (%), total precipitation (mm), and wind speed (m sec^{-1}) values in Çivril district between 2009-2023
Şekil 1. 2009-2023 yılları arasında Çivril ilçesinde aylık ortalama sıcaklık (°C), bağıl nem (%), toplam yağış (mm) ve rüzgar hızı (m sn^{-1}) değerlerinin dağılımı

Morphological and biochemical analyses

Morphological and biochemical measurements were performed on 20 randomly selected fruits from each genotype. Fruit analyses were conducted at Pamukkale University Tavas Vocational School, Department of Plant and Animal Production. Fruit weight and kernel weight were measured using an electronic scale with 0.0001 g sensitivity, while the dimensional properties of the fruit with shell and kernel, as well as shell thickness, were measured using a digital caliper with 0.01 mm sensitivity. Kernel ratio was calculated as a percentage. Kernel width index was calculated as the percentage ratio of kernel width to kernel length; kernel thickness index was calculated as the percentage ratio of kernel thickness to kernel width.

Protein content was determined using the micro Kjeldahl method, with total nitrogen amount multiplied by a factor of 6.38 (Cemeroğlu, 2015). Moisture content was determined by the weight loss method after drying ground samples in an oven at 105°C (Uylaşer and Başoğlu, 2016). Fat analysis was performed using the Soxhlet extraction method with Hexane solvent using a behr EF Solvent Extractors device (Cemeroğlu, 2015). Ash content was determined by incinerating samples in an ash furnace at 550°C. Total carbohydrate value was calculated by subtracting the sum of ash, moisture, fat, and protein amounts from 100 (Gibson, 1990).

Statistical analysis

Descriptive statistics (minimum, maximum, mean) of the data obtained in the study were calculated. Analysis of variance (ANOVA) was applied for statistical evaluation, and differences between means were determined using Tukey's multiple comparison test at $p<0.05$ significance level. These analyses were performed using R statistical software (version 4.4.1) (R Core Team, 2024) with the 'agricolae' package (de Mendiburu, 2023) and the 'psych' package (Revelle, 2025) for descriptive statistics. Pearson correlation analysis was conducted to determine relationships between variables, and correlation coefficients were evaluated at $p<0.05$, $p<0.01$, and $p<0.001$ significance levels. The correlation matrix was visualized using the "corrplot" package (Wei and Simko, 2021). Principal Component Analysis (PCA) was used for multivariate analysis of morphological and biochemical characteristics of genotypes. PCA analysis and biplot graph were created using 'FactoMineR' (Lê et al., 2008) and 'factoextra' (Kassambara and Mundt, 2020) packages. The correlation table was prepared using the "ggcorrplot" package (Kassambara, 2023). All graphs were arranged using the "ggplot2" package (Wickham, 2016).

Results and Discussion

Analysis of variance

Morphological characteristics

When examining the fruit weight, kernel weight, kernel ratio, and shell thickness characteristics of almond genotypes, significant differences were detected (Table 1). In terms of fruit weight, genotypes 20CVRL16 (4.47 g), 20CVRL14 (4.36 g), and 20CVRL08 (4.34 g) stood out with high values and were in the same statistical group as the commercial cultivar 'Nonpareil' (4.61 g). The lowest fruit weight was recorded in genotype 20CVRL04 (2.54 g). These values show similarity with the fruit weights of 'Ferragnes' (4.53 g) and 'Ferraduel' (4.83

g) cultivars grown in Yeşilyurt district of Malatya (910 m) as reported by Yıldırım et al. (2023). Additionally, they are consistent with the fruit weights ranging from 3.38-5.24 g in 'Umutlu' almond types selected by Kalyoncu (1990) in Konya and the values reported to range from 1.57-5.26 g in almond types selected from Çınar district by Şimşek (2011). In Parlakçı's (2008) study, the fruit weight of the 'Bertina' cultivar (6.66 g) was found to be higher than other cultivars.

Table 1. Results regarding fruit weight, kernel weight, kernel ratio and shell thickness traits of almond genotypes
Çizelge 1. Badem genotiplerinin meyve ağırlığı, çekirdek ağırlığı, çekirdek oranı ve kabuk kalınlığı özelliklerine ilişkin sonuçlar

Genotype	Nut weight (g)	Kernel weight (g)	Kernel rate (%)	Shell thickness (mm)
20CVRL01	3.90±0.09 c-e	1.08±0.01 bc	27.61±0.47 a-d	3.41±0.03 a
20CVRL02	3.92±0.13 cd	1.02±0.01 b-e	26.07±0.89 b-e	3.03±0.08 c-g
20CVRL03	3.55±0.11 e-g	0.85±0.03 e-ı	23.95±0.04 c-f	2.86±0.11 d-h
20CVRL04	2.54±0.02 j	0.67±0.03 ı	26.44±1.34 b-e	3.21±0.11 a-d
20CVRL05	3.88±0.06 c-e	0.94±0.01 b-h	24.26±0.04 c-f	3.03±0.11 b-g
20CVRL06	3.56±0.1 e-g	1.01±0.04 b-f	28.23±0.21 a-c	2.43±0.12 j
20CVRL07	3.87±0.16 c-e	0.90±0.07 c-h	23.27±0.85 c-f	2.81±0.05 f-h
20CVRL08	4.34±0.03 a	1.01±0.05 b-f	23.16±1.29 d-f	2.78±0.02 f-ı
20CVRL09	4.31±0.04 ab	1.12±0.06 b	25.90±1.27 b-e	3.40±0.10 a
20CVRL10	4.27±0.03 ab	0.98±0.11 b-g	22.95±2.50 d-f	3.24±0.10 a-c
20CVRL11	3.61±0.11 d-f	0.83±0.05 f-ı	22.88±0.70 d-f	2.85±0.11 e-h
20CVRL12	3.97±0.13 bc	0.95±0.10 b-h	23.98±3.27 c-f	2.83±0.06 f-h
20CVRL13	2.88±0.01 ıj	0.77±0.04 hı	26.61±1.17 b-e	3.38±0.12 ab
20CVRL14	4.36±0.07 a	0.97±0.01 b-g	22.25±0.04 ef	3.08±0.06 a-f
20CVRL15	3.42±0.06 f-h	0.95±0.02 b-h	27.68±0.11 a-d	2.46±0.09 ıj
20CVRL16	4.47±0.06 a	0.88±0.01 d-h	19.69±0.06 f	2.84±0.07 e-h
20CVRL17	3.76±0.16 c-f	0.94±0.01 b-h	24.89±1.22 c-e	3.18±0.04 a-e
20CVRL18	3.12±0.12 hı	0.85±0.01 e-ı	27.15±1.27 b-e	3.18±0.10 a-e
20CVRL19	2.89±0.06 ı	0.77±0.07 hı	26.63±1.93 b-e	2.60±0.08 h-j
20CVRL20	3.85±0.01 c-e	1.05±0.01 b-d	27.31±0.32 a-d	2.61±0.10 h-j
20CVRL21	3.25±0.05 gh	0.80±0.03 g-ı	24.67±1.25 c-f	3.01±0.10 c-g
20CVRL22	3.44±0.06 f-h	1.11±0.04 b	32.26±0.71 a	2.83±0.04 f-h
Nonpareil	4.61±0.05 a	1.38±0.01 a	29.97±0.01 ab	2.72±0.04 g-j
Minimum	2.54	0.67	19.69	2.43
Maximum	4.61	1.38	32.26	3.41
Mean	3.73	0.95	25.56	2.95

When evaluating kernel weight, the 'Nonpareil' cultivar (1.38 g) was found to be significantly higher than all genotypes. Among the examined genotypes, 20CVRL09 (1.12 g) and 20CVRL22 (1.11 g) were determined to have the highest kernel weights. The lowest kernel weight was observed in genotype 20CVRL04 (0.67 g). These findings are consistent with kernel weights ranging from 0.66-1.34 g in almond types selected from Kahramanmaraş by Beyhan and Şimşek (2007). Additionally, in another study mentioned by Şimşek (2011), kernel weight in selected almond types was reported to vary between 1.01 g and 1.80 g. In Parlakçı's (2008) study, the kernel weight of the 'Bertina' cultivar (1.79 g) was found to be higher than other cultivars. Gülsoy and Balta (2014) reported that kernel weight in almond genotypes in Aydın province varied between 0.67-1.56 g.

In terms of kernel ratio, genotype 20CVRL22 reached the highest value with 32.26% and was in a statistically similar group with 'Nonpareil' (29.97%). Genotypes 20CVRL06 (28.23%), 20CVRL15 (27.68%), and 20CVRL01 (27.61%) also stood out with high kernel ratios. The lowest kernel ratio was determined in genotype 20CVRL16 (19.69%). These values are consistent with previous studies. Indeed, they align with the kernel ratio (30.24-32.49%) of the 'Ferragnes' cultivar reported

by Yıldırım et al. (2023). However, in the same study, it was noted that as altitude increased, the kernel ratio of the 'Ferraduel' cultivar decreased (from 26.59% to 23.56%). Types selected from Çınar district reported by Şimşek (2011) showed a wider range of kernel ratios varying between 23.52-48.30%. In Parlakçı's (2008) study, while the 'Felisia' cultivar (38.09%) had the highest kernel ratio, the 'Bertina' cultivar (24.46%) showed the lowest value.

When examining shell thickness, genotypes 20CVRL01 (3.41 mm) and 20CVRL09 (3.40 mm) were identified as having the thickest shells. The thinnest shells were measured in genotypes 20CVRL06 (2.43 mm) and 20CVRL15 (2.46 mm). The 'Nonpareil' cultivar (2.72 mm) was in the medium-low shell thickness group. Gülsoy and Balta (2014) reported that shell thickness in almond genotypes in Aydın province varied between 2.08-4.79 mm.

When examining fruit and kernel dimensions of almond genotypes, significant differences were observed between genotypes (Table 2). In terms of fruit width, genotypes 20CVRL18 (23.85 mm), 20CVRL13 (23.78 mm), and 20CVRL22 (23.49 mm) had the highest values and were in the same statistical group as the 'Nonpareil' cultivar (23.41 mm). The lowest fruit widths were recorded in genotypes 20CVRL21 (18.01 mm) and 20CVRL19 (18.37 mm). These values are consistent with the range of in-shell fruit width (17.25-27.14 mm) reported by Gülsoy and Balta (2014) in almond genotypes in Aydın province.

When evaluating fruit length, the 'Nonpareil' cultivar (36.01 mm) was found to be significantly higher than all genotypes. Among the examined genotypes, 20CVRL10 (34.88 mm) and 20CVRL04 (33.55 mm) were identified as having the longest fruits. The shortest fruits were measured in genotype 20CVRL12 (19.62 mm). These results show similarity with the fruit length values of the 'Ferragnes' cultivar at 910 m altitude reported by Yıldırım et al. (2023). Additionally, they are consistent with the fruit dimensions reported by Pérez-Sánchez and Morales-Corts (2021) in traditional almond cultivars in the Iberian Peninsula.

In terms of fruit thickness, the 'Nonpareil' cultivar (15.15 mm) and genotype 20CVRL11 (14.80 mm) reached the highest values and were in the same statistical group. Genotype 20CVRL18 (14.07 mm) also stood out with high fruit thickness. The lowest fruit thickness was determined in genotypes 20CVRL08 (12.17 mm) and 20CVRL10 (12.28 mm). The findings of the present study are consistent with the range reported by Gülsoy and Balta (2014), who reported in-shell fruit thickness between 13.42 mm (AYD-124) and 18.68 mm (AYD-49).

When examining kernel width, genotype 20CVRL13 (13.32 mm) was determined to have a similar value to 'Nonpareil' (13.12 mm). Genotypes 20CVRL01 (12.85 mm) and 20CVRL17 (12.41 mm) also stood out with large kernel measurements. The narrowest kernel measurements were observed in genotypes 20CVRL10 (9.55 mm) and 20CVRL03 (9.99 mm). These values fall within the kernel width range (8.19-14.81 mm) reported by Gerçekçioğlu and Güneş (1999) in a study conducted in Tokat. These values, which are consistent with the kernel length range (16.41-28.20 mm) reported by Kaşka et al. (1993), demonstrate the commercial potential of the examined genotypes.

In terms of kernel length, the 'Nonpareil' cultivar (27.75 mm) was found to be significantly longer than all genotypes. Genotypes 20CVRL04 (25.33 mm) and 20CVRL07 (25.23 mm) were recorded as having the longest kernel measurements. The shortest kernels were measured in genotypes 20CVRL11 (15.16 mm) and 20CVRL12 (15.18 mm). The findings of the present study are consistent with the kernel fruit length range (19.52-28.80 mm) reported by Gülsoy and Balta (2014) in almond genotypes.

When evaluating kernel thickness, the 'Nonpareil' cultivar (7.15 mm) was found to have the highest value. Genotypes 20CVRL19 (6.66 mm) and 20CVRL01 (6.60 mm) stood out with thick kernel measurements. The thinnest kernels were detected in genotypes 20CVRL05 (5.38 mm) and 20CVRL04 (5.44 mm). Gülsoy and Balta (2014), in their study with almond genotypes, reported kernel thickness between 5.18 mm (AYD-122) and 9.04 mm.

When examining the shape indices of almond genotypes, significant differences were detected between genotypes (Table 2). Significant differences were observed among genotypes in terms of kernel width and thickness indices. The highest values for kernel width index were recorded in genotypes 20CVRL12 (81.06%) and 20CVRL17 (80.63%). These genotypes were followed by 20CVRL11 (70.64%), 20CVRL18 (69.86%), 20CVRL09 (69.07%), 20CVRL13 (67.52%), and 20CVRL19 (67.46%). The lowest kernel width index value was determined in genotype 20CVRL10 (38.31%). In terms of kernel thickness index, genotypes 20CVRL19 (43.32%) and 20CVRL11 (43.16%) had the highest values, followed by genotypes 20CVRL12 (40.19%) and 20CVRL18 (36.74%). The lowest kernel thickness index was detected in genotype 20CVRL04 (21.49%). The 'Nonpareil' cultivar used as a standard (47.27%; 25.76%) has medium-low values for both indices. These results indicate a wide variation in kernel shape among the examined almond genotypes. Genotypes with high index values have a more rounded and plump kernel structure, while genotypes with low index values exhibit a longer

and thinner kernel structure. Bayazit and Çalışkan (2021), in their study with *Amygdalus orientalis* and *Amygdalus turcomanica* species, reported kernel width index as 42.44-80.16% and kernel thickness index as 34.81-66.02%. Şimşek and Küden (2007), in their study in Hilvan, reported that the width index varied between 52.05-60.30%. Shape indices are important parameters in morphological characterization of almond fruits and determination of marketing categories (Gradziel, 2008).

Table 2. Results regarding dimensional properties (width, length, thickness) and shape indices of in-shell and kernel almonds
Çizelge 2. Kabuklu ve iç bademlerin boyutsal özellikleri (en, boy, kalınlık) ve şekil indekslerine ilişkin sonuçlar

Genotype	Nut width (mm)	Nut length (mm)	Nut thickness (mm)	Kernel width (mm)	Kernel length (mm)	Kernel thickness (mm)	Kernel width index	Kernel thickness index
20CVRL01	22.12±0.34bc	32.96±0.28cd	13.55±0.10c-f	12.85±0.11ab	23.48±0.44cd	6.60±0.04ab	54.74±1.50de	28.09±0.68e-j
20CVRL02	20.87±0.16d-f	29.87±0.08g	12.90±0.06g	11.69±0.08d-f	23.06±0.26d	6.12±0.21a	50.68±0.24ef	26.55±1.22e-j
20CVRL03	19.37±0.18gh	22.64±0.23l	13.54±0.06c-f	9.99±0.01jk	17.24±0.45hk	5.72±0.24b	57.97±1.60cd	33.17±0.52b-f
20CVRL04	22.30±0.13bc	33.55±0.18c	13.17±0.01e-g	11.34±0.24f-h	25.33±0.50b	5.44±0.01b	44.80±1.84g-ı	21.49±0.48j
20CVRL05	22.44±0.25b	31.42±0.13ef	12.39±0.08h	11.53±0.17e-g	23.39±0.25d	5.38±0.59b	49.29±0.19f	22.97±2.26ıj
20CVRL06	21.72±0.12b-d	32.20±0.23de	13.23±0.18c-g	10.90±0.03g-ı	24.56±0.40bc	6.09±0.30ab	44.39±0.83hı	24.79±1.64g-j
20CVRL07	19.06±0.18hı	31.69±0.06e	13.69±0.08bc	10.78±0.3hı	25.23±0.09b	5.92±0.17ab	42.72±1.36ı	23.47±0.76h-j
20CVRL08	19.50±0.20gh	24.31±0.21jk	12.17±0.04h	11.24±0.29f-h	18.38±0.05g	5.76±0.26b	61.14±1.41c	31.32±1.34c-g
20CVRL09	21.90±0.28bc	24.22±0.10jk	13.59±0.15c-e	12.25±0.25b-d	17.74±0.32gh	5.92±0.20ab	69.07±0.20b	33.38±0.52b-e
20CVRL10	19.12±0.06hı	34.88±0.14b	12.28±0.17h	9.55±0.08k	24.93±0.07bk	5.74±0.38b	38.31±0.45j	23.03±1.60ıj
20CVRL11	20.72±0.08ef	21.43±0.01m	14.80±0.14a	10.71±0.27hı	15.16±0.17ı	6.54±0.58ab	70.64±0.98b	43.16±4.31a
20CVRL12	20.84±0.11ef	19.62±0.33n	12.90±0.08g	12.31±0.04b-d	15.18±0.13ı	6.10±0.20ab	81.06±0.91a	40.19±1.64ab
20CVRL13	23.78±0.15a	27.67±0.32h	13.62±0.18b-e	13.32±0.19a	19.72±0.06f	6.05±0.03ab	67.52±0.77b	30.68±0.06c-h
20CVRL14	21.52±0.07c-e	26.30±0.17ı	13.40±0.01c-f	11.34±0.25f-h	20.74±0.25ef	5.54±0.01b	54.69±1.90de	26.71±0.26e-j
20CVRL15	21.97±0.13bc	28.13±0.35h	13.11±0.13fg	11.29±0.08f-h	20.59±0.13ef	6.10±0.52ab	54.85±0.77d	29.63±2.35c-ı
20CVRL16	20.02±0.34fg	24.52±0.03j	12.91±0.14g	10.94±0.03g-ı	18.21±0.23gh	5.85±0.50ab	60.10±0.93c	32.09±2.35c-g
20CVRL17	20.78±0.19ef	21.63±0.30m	13.60±0.05c-e	12.41±0.06bc	15.39±0.09ı	5.48±0.01b	80.63±0.07a	35.62±0.30b-d
20CVRL18	23.85±0.02a	23.60±0.23k	14.07±0.15b	12.13±0.06c-e	17.37±0.25gh	6.38±0.66ab	69.86±0.67b	36.74±4.31a-c
20CVRL19	18.37±0.25ıj	21.15±0.13m	13.64±0.13b-d	10.38±0.20ıj	15.39±0.48ı	6.66±0.21ab	67.46±0.82b	43.32±2.73a
20CVRL20	22.47±0.32b	26.00±0.18 ı	13.49±0.19c-f	12.40±0.11bc	20.48±0.29ef	5.83±0.01b	60.56±0.30c	28.45±0.37d-j
20CVRL21	18.01±0.18j	30.64±0.24fg	13.22±0.05d-g	10.49±0.16ıj	21.59±0.21e	5.62±0.42b	48.56±0.28fg	26.00±1.68e-j
20CVRL22	23.49±0.19a	27.97±0.06h	12.94±0.01g	12.09±0.11c-e	20.17±0.08f	5.91±0.04ab	59.93±0.76c	29.31±0.10c-ı
Nonpareil	23.41±0.40a	36.01±0.16a	15.15±0.04a	13.12±0.11a	27.75±0.26a	7.15±0.16a	47.27±0.83f-h	25.76±0.83f-j
Minimum	18.01	19.62	12.17	9.55	15.16	5.38	38.31	21.49
Maximum	23.85	36.01	15.15	13.32	27.75	7.15	81.06	43.32
Mean	21.20	27.50	13.36	11.52	20.48	6.00	58.10	30.26

Biochemical characteristics

When examining the biochemical composition of almond genotypes, significant variations emerged in terms of nutritional components (Table 3). Regarding fat content, the 'Nonpareil' cultivar (55.65%) was determined to have a significantly higher fat ratio than all genotypes. Among the genotypes, 20CVRL18 (51.60%) and 20CVRL13 (51.47%) stood out with the highest fat content. These genotypes can be evaluated as valuable raw material sources for fat-based products. The lowest fat content was detected in genotypes 20CVRL22 (45.40%) and 20CVRL06 (45.46%). These values are consistent with the range of 45.2-57.8% determined by Parlakçı (2008) in different almond cultivars. Additionally, the 55.30% fat ratio reported by Ayadi et al. (2006) in the 'Nonpareil' cultivar is almost identical to the result in our study.

When evaluating the protein profile, genotype 20CVRL15 (19.50%) stood out as having similar protein content to the 'Nonpareil' cultivar (19.46%). Genotypes 20CVRL21 (18.60%) and 20CVRL12 (18.55%) also showed superiority in nutritional value with their high protein contents. The genotypes with the lowest protein content were determined to be 20CVRL22 (17.22%) and 20CVRL18 (17.25%). Kester and Asay (1975) reported that 100 g of fresh almonds contain 19 g of

protein, which aligns with the results in our study. Similarly, Özdemir (2022) determined that protein content varied between 19.36-30.00% in a study with almond fruits. Ahrens et al. (2005) stated that the protein content of 'Carmel', 'Mission', and 'Nonpareil' cultivars grown in California, USA was 20.6%, 23.3%, and 21%, respectively. Erdoğmuş (2018), in a study conducted in the Eğil district of Diyarbakır, determined the protein content in 'Ferragnes' and 'Ferradual' cultivars as 25.31% and 31.38%, respectively. Gülsoy and Balta (2014) identified the protein range in 'Texas' and 'Ferragnes' cultivars in Aydın province as 22.08-33.01%.

In terms of ash content, which is an indicator of mineral matter, the 'Nonpareil' cultivar (3.69%) and genotype 20CVRL13 (3.67%) were determined to have the richest composition. Genotypes 20CVRL18 (3.54%) and 20CVRL10 (3.53%) were also found to be rich in mineral matter. The lowest ash content was detected in genotypes 20CVRL11 (2.90%) and 20CVRL03 (2.91%). Özdemir (2022), in a study conducted in Mardin and Diyarbakır provinces, reported ash content as 2.83-3.69%. Similarly, Erdoğmuş (2018) determined the ash content in 'Ferragnes' and 'Ferradual' cultivars from Diyarbakır Eğil district as 2.86% and 4.20%, respectively. Pérez-Sánchez and Morales-Corts (2021) reported that the ash content of Spanish almond cultivars varied between 3.05-3.45%; the values in our study are at the upper limit of this range or slightly above it.

When examining moisture content, the highest moisture content was detected in the 'Nonpareil' cultivar (4.55%). Genotypes 20CVRL13 (4.34%) and 20CVRL18 (4.27%) also stood out with high moisture content. This characteristic is important in terms of storage stability and texture properties. The lowest moisture content was recorded in genotypes 20CVRL03 (3.59%) and 20CVRL08 (3.60%). In terms of total carbohydrate content, genotypes 20CVRL17 (30.06%), 20CVRL04 (30.02%), and 20CVRL03 (29.90%) were found to have the highest values. These genotypes are thought to offer different characteristic features in terms of energy value and flavor profile. The 'Nonpareil' cultivar (16.67%) was determined to have significantly lower carbohydrate content than all genotypes. Özdemir (2022) reported that the total carbohydrate value was between 14.51% and 19.95%; Erdoğmuş (2018) reported it as 10.91% and 25.21% in 'Ferragnes' and 'Ferradual' cultivars, respectively.

Table 3. Results regarding biochemical composition (oil, protein, ash, moisture and total carbohydrate) of almond genotypes

Çizelge 3. Badem genotiplerinin biyokimyasal bileşimlerine (yağ, protein, kül, nem ve toplam karbonhidrat) ilişkin sonuçlar

Genotype	Oil (%)	Protein (%)	Ash (%)	Humidity (%)	Total Carbohydrate (%)
20CVRL01	48.37±0.35 e-g	17.40±0.24 ef	3.15±0.04 f-h	3.87±0.05 f-ı	27.22±0.2 e-g
20CVRL02	50.33±0.76 bc	18.34±0.08 c-e	3.30±0.06 d-f	3.82±0.06 f-j	24.23±0.56 j-l
20CVRL03	46.25±0 hı	17.36±0.15 ef	2.91±0.08 j	3.59±0.05 k	29.9±0.01 ab
20CVRL04	45.7±0.33 ı	17.70±0.40 c-f	2.94±0.02 ıj	3.66±0.05 ı-k	30.02±0.01 a
20CVRL05	50.24±0.6 b-d	18.47±0.41 b-d	3.33±0.04 c-f	4.00±0.06 d-f	23.98±0.29 kl
20CVRL06	45.46±0.42 ı	18.51±0.20 a-d	3.20±0.03 e-h	3.88±0.06 f-h	28.95±0.31 a-d
20CVRL07	46.68±0.03 g-ı	18.23±0.21 c-f	3.08±0.04 g-j	3.74±0.06 g-k	28.28±0.09 b-f
20CVRL08	46.46±0.01 hı	17.27±0.22 f	3.04±0.12 g-j	3.60±0.05 k	29.65±0.4 a-c
20CVRL09	49.32±0.16 c-f	17.60±0.18 c-f	3.44±0.01 b-d	4.16±0.05 b-e	25.5±0.37 h-k
20CVRL10	48.4±0.09 e-g	18.51±0.06 a-d	3.53±0.04 a-c	4.22±0.06 bc	25.35±0.06 ı-k
20CVRL11	46.51±0.54 hı	18.38±0.26 c-e	2.90±0.03 j	3.69±0.06 h-k	28.53±0.72 a-e
20CVRL12	47.64±0.42 f-h	18.55±0.11 a-d	3.00±0.03 h-j	3.74±0.04 g-k	27.08±0.38 e-h
20CVRL13	51.47±0.26 b	18.51±0.24 a-d	3.67±0.03 a	4.34±0.06 ab	22.02±0.01 m
20CVRL14	46.36±0.35 hı	17.27±0.07 f	3.13±0.04 f-ı	3.83±0.06 f-j	29.43±0.32 a-c
20CVRL15	45.56±0.26 ı	19.50±0.63 a	3.23±0.03 e-g	3.94±0.06 e-g	27.79±0.8 d-f
20CVRL16	49.61±0.35 c-e	17.41±0.04 ef	3.21±0.08 e-h	3.93±0.06 fg	25.85±0.18 g-j
20CVRL17	45.56±0.05 ı	17.54±0.13 d-f	3.08±0.04 g-j	3.77±0.04 g-k	30.06±0 a
20CVRL18	51.6±0.18 b	17.25±0.27 f	3.54±0.02 ab	4.27±0.06 b	23.35±0.17 lm
20CVRL19	47.61±0.24 f-h	17.71±0.26 c-f	2.93±0.03 ıj	3.63±0.06 jk	28.13±0.06 c-f
20CVRL20	48.50±0.04 d-f	17.31±0.23 f	3.31±0.08 d-f	4.01±0.04 c-f	26.88±0.06 f-ı
20CVRL21	45.98±0.01 hı	18.60±0.08 a-c	3.04±0.01 g-j	3.70±0.05 h-k	28.7±0.13 a-e
20CVRL22	45.4±0.16 ı	17.22±0.23 f	3.39±0.06 b-e	4.17±0.08 b-d	29.83±0.07 ab
Nonpareil	55.65±1.45 a	19.46±0.25 ab	3.69±0.05 a	4.55±0.02 a	16.67±1.17 n
Minimum	45.40	17.12	2.90	3.59	16.67
Maximum	55.65	19.50	3.69	4.55	30.06
Mean	48.03	18.00	3.22	3.92	26.84

PCA analysis

Multivariate analysis of morphological and biochemical characteristics of almond genotypes is critically important in breeding programs and cultivar development. The Principal Component Analysis (PCA) Biplot graph presented in Figure 2 visualizes the complex relationships between physical and chemical properties of 22 almond genotypes and the 'Nonpareil' (23) cultivar. The first two components (Dim1 and Dim2) explain 57.27% of the total variance. Dim1 (35.3%) is positively correlated with characteristics such as fat, moisture, ash, and kernel dimensions, while negatively correlated with total carbohydrate. Dim2 (21.9%) shows strong positive correlation with kernel thickness and width indices. These findings parallel the study by Güney and Genç (2025) on almond genotypes grown in Yozgat province; their research also identified similar relationships between fatty acid profile and morphological characteristics. Genotypes positioned on the right side of the figure have high fat content and kernel dimensions, while those on the left have higher carbohydrate content. Genotypes in the upper part show superiority in terms of kernel thickness and width indices, while those in the lower part are characterized by kernel and fruit length. Similarly, in the genetic diversity assessment conducted by Bayazit et al. (2025) in the Eastern Mediterranean Region, phenotypic and morpho-physicochemical properties were emphasized as determinants for almond breeding programs. When examining the relationship of genotypes with characteristics, 'Nonpareil' (23) stands out with high fat, moisture, and ash content, while 20CVRL13 and 20CVRL18 are superior in terms of kernel width and thickness. This is consistent with the fatty acid profiling study by Kumawat et al. (2024) in almond germplasm in the Western Himalaya region; they also showed that genotypes with high fat content are associated with certain morphological characteristics. 20CVRL11, 20CVRL12, 20CVRL17, and 20CVRL19 show strong correlation with kernel thickness and width indices. 20CVRL3, 20CVRL14, 20CVRL16, and 20CVRL21, located on the left side, stand out with high carbohydrate content. 20CVRL4, 20CVRL5, 20CVRL6, 20CVRL7, and 20CVRL10, located in the lower part, are characterized by kernel and fruit length properties. 20CVRL02 and 20CVRL15 are associated with protein content, while 20CVRL08, 20CVRL20, and 20CVRL22 are related to fruit thickness and shell thickness properties. As stated in the genomic study by Khojand et al. (2024) in Iranian almond germplasm, such multivariate analyses are critically important in selecting genotypes with targeted characteristics in almond breeding programs and in preserving genetic diversity.

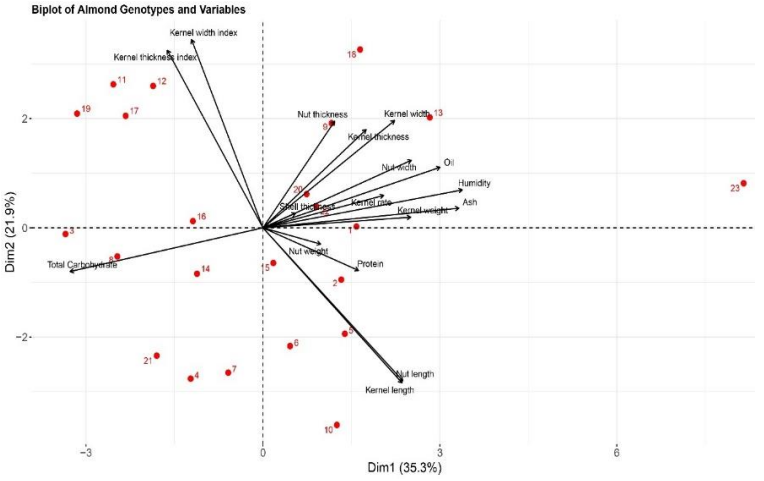

Figure 2. PCA Biplot graph of morphological and biochemical characteristics of almond genotypes. Numbers shown in red in the graph represent genotypes.

Şekil 2. Badem genotiplerinin Badem genotiplerinin morfolojik ve biyokimyasal özelliklerinin PCA Biplot grafiği. Grafikte kırmızı ile gösterilen sayılar genotipleri temsil etmektedir.

1:20CVRL01, 2:20CVRL02, 3:20CVRL03, 4:20CVRL04, 5:20CVRL05, 6:20CVRL06 22:20CVRL22, 23:Nonpareil

Correlation analysis

The correlation matrix presented in Figure 3 shows the relationships between morphological and biochemical characteristics of almond genotypes. The strong positive correlation between kernel weight and fruit weight (r=0.711, p<0.001) indicates

that fruit weight largely derives from kernel weight. Similarly, a strong positive correlation was observed between kernel width and fruit width (r=0.768, p<0.001). The very high correlation between fruit length and kernel length (r=0.977, p<0.001) shows that these two characteristics change almost completely together. These findings are consistent with the relationships between morphological characteristics identified by Güney and Genç (2025) in almond genotypes grown in Yozgat province; similar correlations between fruit and kernel dimensions were also observed in their study. A significant positive correlation was also found between fruit thickness and kernel thickness (r=0.664, p<0.001). While a strong positive correlation was observed between kernel width index and kernel thickness index (r=0.862, p<0.001), strong negative correlations were detected between these indices and fruit length and kernel length (r=-0.881, p<0.001; r=-0.882, p<0.001; r=-0.896, p<0.001; r=-0.903, p<0.001). These results show that, as emphasized by Bayazit and Alaz (2022), in-shell fruit dimensions can provide important clues about kernel characteristics.

In terms of chemical properties, strong positive correlations were observed between fat content and ash and moisture (r=0.734, p<0.001; r=0.729, p<0.001), while a very strong negative correlation was found between fat and total carbohydrate (r=-0.970, p<0.001). These findings parallel the study by Kumawat et al. (2024) in almond germplasm in the Western Himalaya region; they also identified similar relationships between fat content and other biochemical parameters. Similarly, a very strong positive correlation between moisture and ash (r=0.967, p<0.001) and strong negative correlations of both with total carbohydrate (r=-0.794, p<0.001) were detected. Kernel width showed positive correlation with fat content, moisture, and ash (r=0.498, p=0.016; r=0.522, p=0.011; r=0.497, p=0.016), while showing negative correlation with total carbohydrate (r=-0.477, p=0.021).

Gouta et al. (2021) identified significant relationships between the physical properties and chemical composition of almond kernels. The researchers reported negative correlations between kernel length and weight and oleic/linoleic ratio and oleic acid content (r=-0.37), and positive correlation with linoleic acid content (r=-0.40). Additionally, they found that fruit thickness and weight showed positive correlation with protein content (r=0.32) and linoleic acid (r=0.26), while showing negative correlation with fat content (r=-0.27) and oleic acid (r=-0.25). These findings partially differ from the positive correlation between kernel width and fat content (r=0.498, p=0.016) detected in the present study. This difference may result from differences in the genetic structures of the studied genotypes and the ecological conditions in which they were grown.

The results of the correlation analysis are consistent with the observation noted by Kodad et al. (2023) in their research on almond genotypes in Spain, that genotypes with high fat content generally have larger kernel dimensions. Additionally, the relationships between morphological and biochemical characteristics detected by Bayazit et al. (2025) in almond genotypes in the Eastern Mediterranean Region support our findings. As stated by Gülcan (1976) and Özbek (1978), the kernel ratio is low in thick-shelled almonds and high in thin-shelled almonds. This observation was also confirmed in the genomic study by Khojand et al. (2024) in Iranian almond germplasm; the negative relationship between shell thickness and kernel ratio is consistently observed in almond populations with different genetic structures. In the study by Göksu and Yıldız (2024), as a result of principal component analysis, it was reported that genotypes with high kernel ratio had thinner shells.

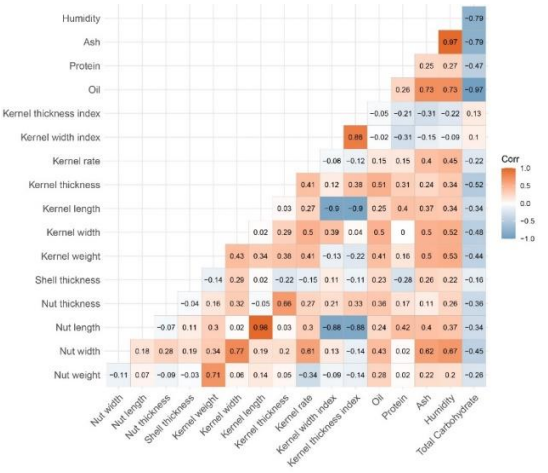

Figure 3. Pearson correlation coefficients and significance levels between morphological and biochemical characteristics of almond genotypes.
Şekil 3. Badem genotiplerinin morfolojik ve biyokimyasal özellikleri arasındaki Pearson korelasyon katsayıları ve anlamlılık düzeyleri.

Conclusion

As a result of the research, genotype 20CVRL22 had the highest kernel ratio with 32.26%, while genotypes 20CVRL13 and 20CVRL18 stood out with fat contents of 51.47% and 51.60%, respectively. Genotype 20CVRL15 drew attention with 19.50% protein content, and genotypes 20CVRL06 and 20CVRL15 with the thinnest shell thickness values of 2.43 mm and 2.46 mm, respectively. Principal Component Analysis showed a strong negative correlation between fat content and carbohydrate. In correlation analysis, strong positive relationships were detected between fruit and kernel dimensions. In conclusion, genotype 20CVRL22 was found

valuable for breeding studies with its high kernel ratio and kernel weight, while genotype 20CVRL13 showed versatile usage potential with high fat, ash, and moisture content similar to 'Nonpareil'. Genotype 20CVRL15 was found suitable for products with high nutritional value due to its high protein content, and genotypes 20CVRL06 and 20CVRL15 were found suitable for in-shell consumption with their thin shell characteristics. These findings reveal the richness of almond genetic resources in the Çivril region while providing valuable information for genotype selection for different usage purposes and future breeding programs.

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Hasat Öncesi Putresin Uygulamalarının Angeleno Eriğinin Bazı Kalite Parametreleri Üzerine Etkileri

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Özet

Bu araştırma Angeleno erik çeşidinin bazı pomolojik ve fizyolojik özellikleri üzerine hasat öncesi putresin uygulamalarının etkilerini belirlenmek amacıyla yürütülmüştür. Bu amaçla, *Prunus cerasifera* anacına aşılı tam verim çağındaki ağaçlara PUT uygulamaları hasat zamanından 28 gün önce tek seferde (10mM PUT) ve toplam doz ikiye bölünerek 14 gün ara ile iki tekrarlamalı (5mM+5mM PUT) uygulama şeklinde gerçekleştirilmiştir. Genel olarak PUT uygulamaları meyve boyutları ve ağırlığı üzerine istatistik olarak anlamlı etkilere sahip olmuştur. 10 mM PUT uygulaması kontrole göre %5.5'lik bir meyve eni artışı sağlamıştır. Uygulama yapılmış Angeleno meyvelerinde yaklaşık %9 (10 mM PUT) oranında ağırlık artışı görülmüştür. Meyve eti sertliği üzerine tüm uygulamaların etkili olduğu ve sertliğin kontrole göre yaklaşık %8 (PUT 10 mM) oranında arttığı belirlenmiştir. Putresinin meyve olgunlaşmasını geciktirici etkisine paralel olarak meyve renklenmesi de gecikmiştir. Çalışmamızda PUT uygulaması meyvelerin hem etilen üretim hızını hem de solunum hızını azaltmıştır. PUT uygulamaları askorbik asit miktarı üzerine olan etkiler arasındaki farklar genel olarak istatistiksel olarak önemsiz bulunmuştur.
Anahtar kelimeler: Poliamin, PUT, Pomoloji, *Prunus salicina* L.

Effects of Pre-harvest Putrescine Applications on Angeleno Plum some Quality Parameters

Abstract

This research was conducted to determine the consequence of pre-harvest applications of putrescine on some pomological and physiological characteristics of the Angeleno plum. For this purpose, PUT was applied to full-bearing trees grafted on *Prunus cerasifera* rootstock as a single application (10 mM PUT) 28 days before harvest and as a repeated application (5mM + 5mM PUT) which was divided into two parts with an interval of 14 days. Generally, there were statistically significant effects on fruit weight and dimensions. The 10 mM PUT application resulted in a %5.5 increase in the fruit width compared to the control. PUT applications increased fruit weight by about % 9 (PUT 10 mM). It was found that dose of PUT 10 mM was the most effective treatment on fruit flesh firmness and resulted in a about %8 increase. Fruit colouring was delayed in parallel with the delaying effect of PUT applications on fruit ripening. In our study, applying PUT reduced both the rate of ethylene production and the rate of respiration of the fruit. The differences between the result of PUT treatments on ascorbic acid content was generally found to be statistically insignificant.
Keywords: Poliamine, PUT, Pomology, *Prunus salicina* L.

Giriş

Japon erikleri (*Prunus salicina* L.), Rosaceae familyasına ait oldukça önemli bir meyvedir. Asya, Avrupa ve Kuzey Amerika dahil olmak üzere dünya çapında yaygın olarak yetiştirilmekte (Du vd., 2024) olan eriklerin anavatan toprakları arasında Anadolu da yer almaktadır (Bilgü ve Seferoğlu, 2005). Farklı ekolojik koşullara uyum sağlayabilen çok sayıda yenebilir türü olan erikler, dünyada değişik coğrafyalarda ekonomik olarak yetiştirilmektedir. Erikler içerdikleri vitamin, mineral ve biyoaktif bileşikler sebebiyle taze tüketimde aranan meyvelerdir. Zengin besin değeri bakımından hastalıkları önlemede ve sağlıklı yaşamı sürdürmede önemli rol oynar (Kim vd., 2003; Balık, 2005; Manganaris vd., 2008). Taze olarak tüketilen diğer meyvelerde olduğu gibi eriklerin pazarlanabilirliklerini ve tüketici cazibesini oluşturan başlıca kalite parametreleri; renk, irilik, kuru madde içeriği, asitlik ve meyve eti sertliği olarak öne çıkmaktadır (Crisosto ve Kader, 2000; Bal ve Çelik, 2008).

Yetiştiricilik açısından ise birim alandan elde edilen verim dışında ürünün kalitesi de oldukça önemlidir. Birinci sınıf kalitede meyve üretimi genetik faktörlerin yanında birçok kültürel uygulamadan (sulama, gübreleme, seyreltme ve budama gibi) etkilenir. Bu amaçla üreticiler rutin bakım işleri yanında, elde edecekleri üründe ekstra kalite meyve oranını artırmaya yönelik uygulamalara yönelmişlerdir. Son yıllarda meyve kalitesini artırmaya yönelik olarak derim öncesi veya derim sonrası yapılan kimyasal uygulamalarının çevre dostu ve insan sağlığına zararsız hatta faydalı sekonder metabolitleri artırıcı etkilere sahip olanlardan seçilmesi büyük önem arzetmektedir. Hasattan önce uygulanan bazı bitki büyüme düzenleyici maddeler eriklerde

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hasat zamanını geciktirmiş ve kalite özelliklerini iyileştirmiştir (Khan vd., 2008; Khan ve Singh. 2010).

Poliaminler (PA), tüm canlı hücrelerde bulunan (Yang vd., 2024) bitki büyümesi ve gelişiminin modülatörleri olarak bildirilen organik maddelerdir (Onursal vd., 2013). Amino asit türevleri olan PA'ların kadaverin, putresin (PUT), spermidin ve spermin olmak üzere dört ayrı tipi vardır (Eti, 2006; Kireçci, 2006; Cao vd., 2022). Poliaminlerin hücre bölünmesi ve farklılaşması, protein sentezi, DNA replikasyonu, embriyogenezis, köklenme, çiçeklenmenin başlaması, çiçek gelişimi, polen tüpünün büyümesi, bitkinin abiyotik strese tepkisi ve hücrenin hayatta kalması gibi önemli hücresel süreçlerde etkili oldukları pek çok araştırma ile bildirilmiştir (Alcázar vd., 2020; Şahin ve Örgeç, 2022; Yang vd., 2024). Ayrıca PA uygulamarının, hücre duvarı parçalanmasından sorumlu enzimlerin aktivitesini engelleyerek meyve yumuşamasını azalttığı (Sing vd., 2019), etilen biyosentezini etkilediği (Sing vd., 2022) ve birçok metabolik süreçlerde de rol oynadığı yürütülen çalışmalarla ortaya konulmuştur. Farklı bahçe ürünlerinde (mango, elma, nektarin, kayısı, şeftali, kiraz ve armut) yapılan çalışmalarda, ekzojen PUT uygulamasının meyve eti sertliğini koruduğu, etilen üretimini baskıladığı, olgunlaşmayı geciktirdiği ve birçok fiziksel ve kimyasal kalite özelliğini etkilediği, dolayısıyla meyve kalitesinin korunmasında önemli etkilere sahip olduğu bildirilmiştir (Khan vd., 2007; Khan ve Singh, 2010; Ali vd., 2010; Wannabussapawich ve Seraypheap, 2018; Shaaban vd., 2020). Bu çalışma, hasat öncesi farklı putresin (PUT) uygulamalarının Angeleno Japon eriği çeşidinde meyve kalite parametreleri üzerine olan etkisini araştırmak amacıyla planlanmıştır.

Materyal ve Yöntem

Materyal

Prunus cerasifera L. anacına aşılı 9 yaşlı Angeleno eriği çalışmamızda materyal olarak kullanılmıştır. Meyveler Isparta ili Çünür Mahallesinde bulunan, 4mX4m dikim mesafesine sahip; budama, gübreleme, sulama gibi kültürel işlemlerin düzenli yapıldığı kapama erik bahçesinden temin edilmiştir. PUT uygulamaları, sağlıklı ağaçlara sırt pompası ile püskürtülerek ve solüsyonun tüm ağacı tamamen kaplaması sağlanacak şekilde yapılmıştır. Tween 20 (%1) yayıcı yapıştırıcı olarak bütün çözeltilere eklenmiştir. Araştırma 5 tekerrürlü ve her tekerrürde 1 ağaç olacak şekilde tesadüf blokları deneme desenine göre planlanmıştır. Ağaçlara PUT uygulamaları tek seferde ve toplam doz ikiye bölünerek iki hafta ara ile tekrarlamalı uygulama şeklinde gerçekleştirilmiştir. Tek doz olarak 10mM PUT öngörülen hasat zamanından 28 gün önce uygulanmıştır. Bölünmüş doz olarak 5 mM+5 mM PUT uygulaması ise hasat zamanından 28 gün önce (5 mM) ve 14 gün önce (5 mM) ikili uygulama şeklinde yapılmıştır. Kontrol grubu ağaçlara %1'lik Tween 20 içeren su püskürtülmüştür. Optimum derim tarihinde derilen meyve örnekleri Isparta Uygulamalı Bilimler Üniversitesi, Derim Sonu Fizyolojisi Laboratuvarına getirilerek aşağıda belirtilen pomolojik ve fizyolojik bazı analizler yapılmıştır.

Meyve ağırlığı ve meyve boyutları

Meyve ağırlığı, 0.01 g hassasiyette elektronik terazi (CPA 16001S, Sartorius, Göttingen, Almanya) ile, meyvelerin eni ve boyu ise 0.01 mm hassasiyetli dijital kumpas ile belirlenmiştir.

Meyve eti sertliği

Meyve eti sertliği ölçümleri, meyvenin iki tarafından ince bir kabuk tabakası çıkarıldıktan sonra 8 mm çapındaki uç ile Lloyd Instruments LF Plus marka tekstür cihazı kullanılarak gerçekleştirilmiştir. Sertlik ölçümlerinde elde edilen maksimum güç newton (N) biriminden verilmiştir.

Suda çözünebilir kuru madde miktarı (SÇKM) ve titre edilebilir asitlik (TA)

SÇKM meyve suyunda dijital refraktometre (Atago Pocket PAL-1) ile okunmuş ve yüzde (%) değer şeklinde verilmiştir. Seyreltilmiş meyve suyunun (10 ml) 0.1 N NaOH ile pH 8.1'e kadar titrasyonu yoluyla bir WTW Inolab Ph-Level 2 kullanılarak belirlenen TA malik asit eşdeğeri olarak ifade edilmiştir.

Meyve kabuk rengi

Renk ölçümlerinde Minolta kalibrasyon plakası ile kalibre edilmiş Minolta CR-300 model renk cihazı kullanılmıştır. Ölçümler meyvelerin her iki meyve yanağından yapılmış ve meyve kabuk rengi CIE L*, a*, b* cinsinden belirlenmiştir.

Solunum hızı ve etilen üretimi

Etilen üretimi (µL $kg.h^{-1}$) ve solunum hızı (mL CO2 kg^{-1} s^{-1}) ölçümleri için 1 kg meyve 4L hacmindeki sızdırmaz cam kavanozlarda oda sıcaklığında (20±1 °C) yaklaşık 2- 3saat boyunca bekletilmiştir. Bekletme sonrası gaz sızdırmaz enjektör ile kavanozlardan gaz örneği alınmış ve Agilent GC-6890N marka gaz kromotografisine enjekte edilmiştir. Erbaş ve Koyuncu (2016) tarafından kullanılan protokole göre etilen üretim miktarı ve solunum hızı tek bir gaz örneğinde ölçülmüştür.

Askorbik asit tayini

L-Askorbik asit (C vitamini) miktarı Hışıl (1997) ve Özkan'ın (2007) daha önce bildirdikleri yöntem

esas alınarak T80 UV/VIS spektrofotometre kullanılarak belirlenmiş ve mg 100 ml^{-1} olarak ifade edilmiştir.

İstatistiksel analizler

Tesadüf blokları deneme desenine göre 5 tekerrürlü ve her tekerrürde 1 ağaç olacak şekilde planlanan araştırmada elde dilen veriler ile varyans analizi yapılmış (ANOVA, JMP7) ve ortalamalar LSD testi ile ayrılmıştır.

Bulgular ve Tartışma

PUT uygulamalarının Angeleno meyvelerinin fiziksel özellikleri üzerine olan etkilerinin sonuçları Çizelge 1'de verilmiştir. PUT uygulamalarının meyve eni, meyve boyu ve meyve ağırlığı üzerine etkileri istatistiksel olarak önemli bulunmuştur ($p<0.05$). En düşük meyve eni (54.65 mm) kontrol meyvelerinden elde edilirken, en yüksek meyve eni (57.66 mm) 10 mM PUT ile uygulama yapılan meyvelerden elde edilmiştir. Bu uygulama meyve eninde kontrole göre %5.5 oranında artış sağlamıştır. Meyve boyu üzerine bölünmüş doz olarak 5mM+5 mM PUT uygulamasının diğer uygulamalara göre daha etkili olduğu ve meyve boyunu %4.3 oranında artırdığı gözlenmiştir. Genel olarak PUT uygulamasının meyve ağırlığını artırdığı belirlenmiştir. Meyve ağırlık değeri 93.79g (kontrol)-102.09gr (10 mM PUT) arasında değişmiştir (Çizelge 1). Uygulama yapılmış meyvelerde yaklaşık %4 (5+5 mM PUT) - %9 (10 mM PUT) oranında ağırlık artışı görülmüştür. Meyve fiziksel özellikleri bakımından değerlendirildiğinde PUT uygulamalarının meyve boyutları ve ağırlığı üzerine istatistiksel olarak önemli etkileri olduğu görülmektedir. Çalışmamıza benzer şekilde Ali vd. (2010), Canino kayısı çeşidinde putresin ve sipermin uygulamışlar ve elde edilen verilere göre poliamin uygulamasının meyve ağırlığı üzerine olumlu etkileri olduğu belirtilmiştir. Yine Asadi vd. (2013) ve Alebidi vd. (2023), PUT uygulamasının meyve çapını, uzunluğunu ve ağırlığını artırdığını bildirmişlerdir.

PUT uygulamalarının Angeleno erik çeşidinin meyve eti sertliğine olan etkileri istatistiksel anlamda önemli bulunmuştur ve sonuçlar Çizelge 2'de sunulmuştur. PUT uygulanmış meyvelerde en yüksek meyve eti sertliği değeri (33.72 N) 10 mM PUT'un tek uygulamasından elde edilirken, en düşük değer (31.30 N) ise kontrol meyvelerinden elde edilmiştir. Her iki PUT uygulamasına ait meyveler, kontrol meyvelerinden önemli ölçüde daha sert olmuş ve 10 mM PUT, kontrole göre meyve eti sertliğini yaklaşık %8 oranında artırmıştır. PUT uygulamaları meyve eti sertliğini artırarak meyvenin yumuşamasını geciktirmede de etkili olmuştur. PUT'un etkiyi pektin metilesteraz (PME) ve poli-galakturonaz (PG) enzimlerinin aktivitesini azaltılmasında ve böylece hücre duvarının daha az bozulması yolağında yer alarak gerçekleştirdiği düşülmektedir (Singh vd., 2022).

Çizelge 1. PUT uygulamalarının meyve boyutları ve meyve ağırlığı üzerine etkileri
Table 1. Effects of PUT treatments on fruit dimensions and fruit weight of Angeleno plums

Uygulamalar	Meyve eni (mm)	Meyve boyu (mm)	Meyve ağırlığı (g)
Kontrol	54.65 b	50.67 b	93.79 b
PUT (10 mM)	57.66 a	51.06 b	102.09 a
PUT (5+5 mM)	55.79 b	52.85 a	97.45 ab

* Aynı sütundaki farklı harfli ortalamalar arasındaki fark önemlidir (LSD test) ($P<0.05$).
* The difference between means with different letters in the same column is significant (LSD test) ($P<0.05$).

Torrigiani vd. (2004) bulgularımızla paralel olarak PUT uygulamarının meyvenin sertliğini korumada etkili olduğunu ve özellikle 5mM ve 10 mM PUT dozlarının meyvenin yumuşamasını önemli ölçüde geciktirdiğini belirlemişlerdir. Yine yürütülen çalışmalarda erik (Khan ve Singh, 2010; Archana vd., 2019), armut (Hosseini vd., 2017; Singh vd. 2019) ve mango (Ali vd., 2017; Hans vd., 2025) gibi türlerde de PUT uygulamasıyla meyve et sertliğinin korunduğu araştırıcılar tarafından bildirilmiştir.

Çizelge 2. PUT uygulamalarının Angeleno erik çeşidinde sertlik, SÇKM, ve TA üzerine etkileri
Table 2. Effects of PUT treatments on fruit flesh firmness, SCC and TA of Angeleno plums

Uygulamalar	Meyve eti sertliği (N)	SÇKM (%)	TA (%)
Kontrol	31.30 b	14.29 b	1.37 ÖD
PUT (10 mM)	33.72 a	15.14 a	1.30
PUT (5+5 mM)	32.08 ab	14.76 a	1.26

* Aynı sütundaki farklı harfli ortalamalar arasındaki fark önemlidir (LSD test) ($P<0.05$). ÖD: Önemli değildir (LSD test) ($P<0.05$).
* The difference between means with different letters in the same column is significant (LSD test) ($P<0.05$). ÖD: Not significant (LSD test) ($P<0.05$).

Çalışmada tüm uygulamalar kontrol ile karşılaştırıldığında SÇKM içeriğinin artırma yönünde olumlu etki gösterdiği ve uygulamalar arası farkların istatistiksel olarak önemli olduğu saptanmıştır ($p<0.05$). En yüksek SÇKM değeri (%15.14) 10 mM PUT ile muamele edilen meyvelerden elde edilmiştir. Bulgularımıza parelel, kayısı (Ali vd. 2010) ve erikte (Khan ve Singh, 2010) yapılan çalışmalarda SÇKM miktarının PUT uygulamasıyla arttığı bildirilmiştir. Meyvelerde TA ve SÇKM

olgunlaşmayı gösteren pomolojik karakterlerdir. Meyve olgunlaştıkça SÇKM değeri artarken tersine TA ise azalmaktadır. En düşük TA (%1.26) tekrarlamalı uygulama meyvelerinden elde edilmiş ancak TA değerleri bakımından PUT uygulamaları arasındaki farklar istatistiksel anlamda önemsiz bulunmuştur (Çizelge 2).

Yapılan uygulamalarının meyve kabuk rengi parametrelerinden L* ve a* değeri üzerine etkisi istatistiksel olarak önemli bulunurken, b* değeri üzerine etkisi ise önemsiz bulunmuştur ($p<0.05$) (Çizelge 3). En yüksek L*(31.26), ve a*(9.49) değerleri kontrol meyvelerinden elde edilmiştir. En düşük L* (29.86) ve a* (8.52) değerleri ise 5+5 mM PUT dozundan elde edilmiştir. L* değeri kabuktaki parlaklığı belirtirken a* değeri ise kırmızı renklenmeyi göstermektedir. PUT uygulamasının kırmızı üst rengin oluşumunu geciktirerek meyve olgunlaşmasını da geciktirdiği düşünülmektedir.

Çizelge 3. PUT uygulamaların Angeleno erik çeşidinin meyve kabuk üzerine etkisi
Table 3. Effects of PUT on skin color of Angeleno plums

Uygulamalar	L*	a*	b*
Kontrol	31.26 a	9.49 a	0.06 ÖD
PUT (10 mM)	30.99 a	7.16 b	-0.51
PUT (5+5 mM)	29.86 b	8.52 a	0.23

* Aynı sütundaki farklı harfli ortalamalar arasındaki fark önemlidir (LSD test) ($P<0.05$). ÖD: Önemli değildir (LSD test) ($P<0.05$).

Çizelge 4. Uygulamaların Angeleno erik çeşidinin solunum hızı ve etilen üretimi üzerine olan etkisi
Table 4. Effects of PUT on respiration rate, ethylene production and ascorbic acid value of Angeleno plums

Uygulamalar	Solunum hızı (mL.C02 kg.h^{-1})	Etilen üretimi (µL kg.h^{-1})	Askorbik asit (%)
Kontrol	0.066 a	0.073 a	14.91ÖD
PUT (10 mM)	0.003 b	0.052 ab	18.16
PUT (5+5 mM)	0.003 b	0.035 b	17.47

* Aynı sütundaki farklı harfli ortalamalar arasındaki fark önemlidir (LSD test) ($P<0.05$). ÖD: Önemli değildir (LSD test) ($P<0.05$).
* The difference between means with different letters in the same column is significant (LSD test) ($P<0.05$). ÖD: Not significant (LSD test) ($P<0.05$).

Çalışmamızda, eriklerde tüketici albenisi ve kalite göstergesi bakımından oldukça önemli olan meyve kabuk rengi üzerine PUT uygulamasının olumlu etkilerde bulunduğu ve renklenmeyi geciktirdiği belirlenmiştir. Sonuçlarımıza paralel olarak putresin uygulamasının Japon eriklerinde meyve kalitesi ve olgunlaşmasına etkisinin araştırıldığı bir çalışmada, PUT uygulamasının meyve renklenmesindeki değişimi geciktirdiğini saptanmıştır (Khan ve Singh, 2010). Yine poliamin uygulamasının mango meyvesinde renk gelişimini geciktirdiğini Vaka vd. (2020) tarafından bildirilmiştir.

PUT'un solunum hızı ve etilen üretimi üzerine etkileri istatistiksel olarak anlamlı bulunmuştur ($p<0.05$) (Çizelge 4). Kontrol grubu meyvelerin solunum değeri (0.066 mL CO_2 kg.h^{-1}) en yüksek iken, her iki PUT uygulaması meyvelerinin solunum hızı (0.003 mL CO_2 kg.h^{-1}) en düşük değer olarak elde edilmiştir. En düşük etilen üretimi (0.035 µL kg.h^{-1}) tekrarlamalı uygulama ile elde edilirken, en yüksek değer (0.073 µL kg.h^{-1}) uygulama yapılmamış meyvelerden elde edilmiştir (Çizelge 4). Olgunlaşmaya parelel meyvede artan metabolik aktivite solunum hızında artışa yol açmaktadır. Olgunluğu teşvik eden etilen üretiminin baskılanması ile solunum yavaşlar dolayısıyla olgunlaşma da yavaşlar (Türk vd., 2017). Çalışmamızda PUT uygulaması meyvelerin hem etilen üretim hızını hemde solunum hızını azaltmıştır. PUT uygulanmış meyvelerdeki daha düşük etilen üretiminin düşük metabolik aktiviteden kaynaklanıyor olabileceği düşünülmektedir (Singh vd., 2022). Poliaminler ile etilen üretimi birbirleriyle ilişkilidir, çünkü S-AdoMET (SAM) ortak öncülleridir. Bu yolakta PA'lar etilen ile rakebete girer ve meyve olgunlaşma süreci üzerine etkili olurlar (Vaka vd., 2020). Hem hasattan önce hem de sonra uygulanan PUT'un Angeleno erik çeşidinde etilen üretimini azalttığı önceki çalışmada bildirilmiştir (Khan vd., 2007). PA'ların solunum hızı ve etilen üretimi üzerindeki baskılayıcı etkisinden dolayı derim sonrası meyve çürümesini de geciktirdiği yönünde sonuçlar bulunmaktadır (Torrigiani vd., 2004). Çeşitli PA'lar arasında PUT etilen için rekabet ettiğinden, etilen üretimini azaltarak meyvede solunumu azalttığı bildirilmiştir (Singh vd., 2022). Bulgularımıza benzer şekilde Erbaş ve Koyuncu (2019) ve Archana vd. (2019) PUT uygulamasının solunum hızını ve etilen üretimini azaltma etkilerinin daha belirgin olduğunu bildirmişlerdir.

PUT ile muamele edilen meyvelerde askorbik asit miktarının (%18.16, PUT10 mM) kontrol meyvelerine (%14.91) göre daha yüksek olduğu bulunmuştur. Ancak askorbik asit miktarı bakımından uygulamalar arasındaki farklar istatistiksel açıdan önemsiz bulunmuştur (Çizelge 4). Japon eriklerinde yürütülen önceki bir araştırmada ise PUT uygulamasının Askorbik asit içeriğini azalttığını bildirilmiştir (Khan ve Singh, 2010). Askorbik asit içeriği ile ilgili oluşan bu farklılıkların askorbat oksidaz enziminin aktivitesini etkileyen diğer faktörler ile ilişkili olabileceği düşünmektedir.

Sonuç olarak, derim öncesi PUT uygulaması, Angeleno Japon erik çeşidi meyvelerinde, etilen

üretimini ve solunum hızını azaltığı; meyve boyutları, ağırlık, sertlik ve SÇKM gibi çok önemli kalite parametrelerini artırdığı belirlenmiştir. Bununla beraber azalan endojen etilen üretimi nedeniyle olgunlaşma süreci de gecikmiştir. Bu verilerden haraketle, eriklerde meyve kalitesini artırmak ve olgunluğu geciktirmek bakımından PUT uygulamalarının önerilebileceği düşünülmektedir.

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Assessment of Nut Quality Traits in Almond Cultivars Grown in Karaman

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Abstract

This trial was conducted in a commercial almond orchard belonging to a grower in Dereköy, Karaman. In this study, the nut characteristics of Ferragnes, Ferraduel, and Bertina cultivars grafted onto Nemaguard rootstock were examined. According to the two-year data obtained, full bloom was observed to occur in the third week of April for the Ferragnes cultivar and in the second week of April for the Ferraduel and Bertina varieties. In terms of nut quality traits, the shell thickness of Ferragnes, Ferraduel, and Bertina almond varieties was determined as 24.73 mm, 24.58 mm, and 24,42 mm, respectively; shell width as 31.49 mm, 31.83 mm, and 35.55 mm; shell height as 37.89 mm, 46.62 mm, and 51.27 mm; shell weight as 3.59 g, 5.07 g, and 11.65 g; and kernel weight as 1.27 g, 1.20 g, and 2.90 g. Kernel ratios were identified as 35.17%, 28.37%, and 25.09%, respectively.

Key words: Almond, Adaptation, Yield, Cultivar

Karaman'da Yetiştirilen Badem Çeşitlerinde Kalite Özelliklerinin Değerlendirilmesi

Özet

Bu deneme, Karaman Dereköy'de bir üreticiye ait ticari badem bahçesinde yürütülmüştür. Bu çalışmada, Nemaguard anacı üzerine aşılı Ferragnes, Ferraduel ve Bertina çeşitlerinin meyve özellikleri incelenmiştir. Elde edilen iki yıllık verilere göre, Ferragnes çeşidinde tam çiçeklenmenin nisan ayının üçüncü haftasında, Ferraduel ve Bertina çeşitlerinde ise nisan ayının ikinci haftasında gerçekleştiği görülmüştür. Meyve kalite özellikleri bakımından ise, Ferragnes, Ferraduel ve Bertina badem çeşitlerinde kabuk kalınlığı sırasıyla 24,73 mm, 24,58 mm ve 24,42 mm; kabuk genişliği 31,49 mm, 31,83 mm ve 35,55 mm; kabuk yüksekliği 37,89 mm, 46,62 mm ve 51,27 mm; kabuk ağırlığı 3,59 g, 5,07 g ve 11,65 g olarak tespit edilmiştir. ve çekirdek ağırlığı 1,27 g, 1,20 g ve 2,90 g olarak belirlendi. Çekirdek oranları sırasıyla %35,17, %28,37 ve %25,09 olarak belirlendi.

Anahtar kelimeler: Badem, Adaptasyon, Verim, Çeşit

Introduction

Almond (*Prunus amygdalus* Batsch) is an important member of the *Rosaceae* family and is cultivated widely around the world. Turkey, with its suitable climate conditions and broad genetic diversity, has significant potential in almond production. However, determining the phenological and fruit quality characteristics of almond cultivars grown in different ecological regions is of great importance for yield and quality.

Phenological traits describe the growth and development stages of plants, while Nut characteristics include the physical and chemical properties of the fruit. Understanding these characteristics plays a critical role in the selection of suitable cultivars, determination of harvest time, and optimization of cultivation techniques.

Various studies on almond cultivation in Turkey have focused on the adaptation abilities and characteristics of almond cultivars in different regions. For example, a study conducted in Gaziantep examined the nut characteristics of 21 almond cultivars and 6 species. In this study, the flowering times, fruit characteristics, and yield potentials of different cultivars were evaluated (Atlı, 2019).

In another study conducted in the Elazığ region, the soil properties and nutrient element contents of local almond trees were examined. This research reveals the relationship between the growth conditions and soil characteristics of almond trees in the region (Akgün et al., 2019).

These studies contribute to determining the most suitable cultivars for specific ecological conditions, revealing the performance of different almond cultivars. However, given Turkey's vast

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geography and microclimatic diversity, specific studies are needed for each region.
In this context, the aim of this study is to identify the nut characteristics of different almond cultivars in Karaman, contributing to the identification of regionally suitable cultivars and the development of almond cultivation in the area.

Material and Methods
This research was conducted during 2020–2021 in an orchard located in Dereköy, Karaman province, where 6-year-old 'Ferragnes', 'Ferraduel', and 'Bertina' almond cultivars grafted on Nemaguard rootstock were planted at a spacing of 5x5 meters. The geographical coordinates of the orchard are 37.12 latitude and 33.29 longitude, with an altitude of 1218 meters. The cultivation was carried out under the prevailing ecological conditions without irrigation.

Physical and nut quality traits
Fruit samples were collected from the almond orchard to evaluate physical and nut quality traits. A total of 100 fruits-25 fruits per replicate with 4 replicates per cultivar were randomly selected and evaluated. The samples were evaluated based on the methods of Şimşek (1996), Kuzdere (1999), Balta (2002), Yıldırım (2007), and Gülsoy (2012). The width, thickness, and height of the shelled fruit (mm) were measured using a digital caliper.

Kernel weight (g): The inner kernel weights of randomly selected fruits were determined using a precision balance with 0.001 g sensitivity.

Kernel ratio: The kernel ratio was calculated for randomly selected fruits from each tree using the following formula:

Kernel Ratio (%) = (Average kernel weight / Average shelled fruit weight) x 100

Statistical analysis
The data obtained in the study were evaluated using the JMP 8.0 statistical software based on a randomized plot design. The differences between the means were analyzed using the Least Significant Difference (LSD) test at a significance level of $P<0.05$.

Results
Fruit width
According to the fruit size measurements in 2019, Ferragnes measured 29.91 mm, Ferraduel 32.46 mm, and Bertina 36.44 mm. Among these, Ferragnes had the smallest fruit width, while Bertina had the largest. In 2020, the widths were 33.07 mm for Ferragnes, 31.20 mm for Ferraduel, and 34.66 mm for Bertina. These results showed that Bertina had the highest fruit width in both years, while the lowest values were recorded for Ferragnes in 2019 and Ferraduel in 2020 (Table 1).
Variance analysis for fruit width showed that the effects of year, replicate, and year × variety interaction were not significant. However, the variety factor was significant at the 5% level.

Table 1. 2019–2020 Fruit width (mm)
Çizelge 1. 2019–2020 Meyve genişliği (mm)

Years	2019	2020
Ferragnes	29.91 ± 3.04 b	33.07 ± 1.31 **
Ferraduel	32.46 ± 0.40 b	31.20 ± 2.14 **
Bertina	36.44 ± 1.65 a	34.66 ± 1.91 **
Average	32.93	32.98
P-value	0.0081	0.0917

*Different letters in the same column indicate statistically significant differences (LSD, P<0.05).
*Aynı sütundaki farklı harfler istatistiksel olarak anlamlı farklılıkları göstermektedir (LSD, P<0,05).

Fruit thickness
In 2019, the measured fruit thickness values were 26.70 mm for Ferragnes, 28.23 mm for Ferraduel, and 24.81 mm for Bertina. In 2020, the measurements were 22.77 mm, 20.94 mm, and 24.03 mm, respectively. The highest fruit thickness was observed in Ferragnes in 2019 and in Bertina in 2020, whereas the lowest values were recorded for Bertina in 2019 and for Ferraduel in 2020 (Table 2).
Variance analysis revealed that differences in replicate and variety were not significant for fruit thickness, but the effects of year and year × variety interaction were significant at the 1% level.

Table 2. 2019–2020 Fruit thickness (mm)
Çizelge 2. 2019–2020 Meyve kalınlığı (mm)

Years	2019	2020
Ferragnes	26.70 ± 1.41 ab	22.77 ± 0.35 b
Ferraduel	28.23 ± 0.69 a	20.94 ± 1.05 c
Bertina	24.81 ± 0.71 b	24.03 ± 0.99 a
Average	26.58	22.58
P-value	0.0143	0.0016

*Different letters in the same column indicate statistically significant differences (LSD, P<0.05).
*Aynı sütundaki farklı harfler istatistiksel olarak anlamlı farklılıkları göstermektedir (LSD, P<0,05).

Fruit height
In 2019, the fruit height values were 39.44 mm for Ferragnes, 47.35 mm for Ferraduel, and 51.96 mm for Bertina. In 2020, the values were 36.34 mm, 45.89 mm, and 59.59 mm, respectively. Bertina

had the highest fruit height in both years, while Ferragnes had the lowest (Table 3).
According to variance analysis, differences in replicate and year × variety interaction were not significant, while the year effect was significant at the 5% level and variety differences were significant at the 1% level.

Table 3. 2019–2020 Fruit height (mm)
Çizelge 3. 2019-2020 Meyve yüksekliği (mm)

Years	2019	2020
Ferragnes	39.44 ± 1.17 c	36.34 ± 0.48 c
Ferraduel	47.35 ± 1.21 b	45.89 ± 1.36 b
Bertina	51.96 ± 1.25 a	50.59 ± 3.63 a
Average	46.25	42.27
P-value	0.0001	0.0004

*Different letters in the same column indicate statistically significant differences (LSD, P<0.05).
*Aynı sütundaki farklı harfler istatistiksel olarak anlamlı farklılıkları göstermektedir (LSD, P<0.05).

Kernel weight
Kernel weight measurements in 2019 were 1.97 g for Ferragnes, 1.14 g for Ferraduel, and 2.94 g for Bertina. In 2020, Ferragnes had 1.27 g, Ferraduel 1.60 g, and Bertina 2.92 g. The lowest kernel weight was observed in Ferraduel in 2019 and Ferragnes in 2020, while Bertina had the highest in both years (Table 4).
According to variance analysis, year and replicate effects were not significant, but variety and year × variety interactions were significant at the 1% level.
Statistical analysis of kernel weight by variety showed that, in 2019, the varieties formed three different groups, while in 2020, Ferragnes and Ferraduel were in the same group and Bertina was in a separate group.

Table 4. 2019–2020 Kernel weight (g)
Çizelge 4. 2019-2020 Meyve iç ağırlığı (g)

Years	2019	2020
Ferragnes	1.97 ± 0.14 b	1.27 ± 0.25 b
Ferraduel	1.14 ± 0.24 c	1.60 ± 0.21 b
Bertina	2.94 ± 0.16 a	2.92 ± 0.13 a
Average	2.02	1.93
P-value	0.0001	0.0001

*Different letters in the same column indicate statistically significant differences (LSD, P<0.05).
*Aynı sütundaki farklı harfler istatistiksel olarak anlamlı farklılıkları göstermektedir (LSD, P<0,05).

Kernel ratio
According to the kernel ratio measurements in 2019, Ferragnes had 36.19%, Ferraduel 27.87%, and Bertina 25.02%. In 2020, the values were 34.16%, 28.87%, and 25.16%, respectively. The lowest kernel ratio in both years belonged to Bertina, while the highest was found in Ferragnes (Table 5).
No significant differences were found for year, replicate, or year × variety interaction. However, the variety factor was significant at the 1% level.

Table 5. 2019–2020 Kernel Ratio (%)
Çizelge 5. 2019-2020 Meyve iç oranı (%)

Years	2019	2020
Ferragnes	36.19 ± 1.76 a	34.16 ± 3.79 a
Ferraduel	27.87 ± 0.75 b	28.87 ± 0.79 b
Bertina	25.02 ± 0.92 c	25.16 ± 0.29 c
Average	29.69	29.39
P-value	0.0001	0.0019

*Different letters in the same column indicate statistically significant differences (LSD, P<0.05).
*Aynı sütundaki farklı harfler istatistiksel olarak anlamlı farklılıkları göstermektedir (LSD, P<0.05).

Discussion and Conclusion
Almond is an important fruit species for Turkey, and there is a need for production planning and increased cultivation. In recent years, scientific studies aiming to achieve this goal have continued. Among these studies, the most critical aspect is adaptation trials to determine suitable cultivars for each region. However, there is still insufficient information about which cultivar should be grown where. Various adaptation and fruit quality studies are ongoing with different almond cultivars in different regions.
With this study, it is aimed to identify suitable almond cultivars for the Karaman ecology, integrate them into production, and thereby contribute economically and scientifically. The fruit physical and quality characteristics of selected almond cultivars were identified during this research.
Nut quality analyses showed that in Karaman's ecology, the shelled fruit weight was Ferragnes (3.59 g), Ferraduel (5.07 g), and Bertina (11.65 g); fruit width: Ferragnes (31.49 mm), Ferraduel (31.83 mm), Bertina (35.55 mm); fruit thickness: Ferragnes (24.73 mm), Ferraduel (24.58 mm), Bertina (24.42 mm); fruit height: Ferragnes (37.89 mm), Ferraduel (46.62 mm), Bertina (51.27 mm); kernel weight: Ferragnes (1.27 g), Ferraduel (1.20 g), Bertina (2.90 g); kernel ratio: Ferragnes (35.17%), Ferraduel (28.37%), Bertina (25.09%).
In comparison, in Şanlıurfa, the shelled fruit weight was Ferragnes (3.76 g), Ferraduel (3.85 g), Bertina (7.11 g); kernel weight: Ferragnes (3.76 g), Ferraduel (3.85 g), Bertina (7.11 g); kernel ratio: Ferragnes (31.11%), Ferraduel (31.01%), Bertina (24.46%). In Gaziantep, Ferragnes was

4.15 g, Ferraduel 4.21 g, and Bertina 6.29 g for shelled fruit weight (Parlakçı, 2008).

In other regions such as Diyarbakır, Manisa, and Uşak, fruit and kernel weights, fruit dimensions, and kernel ratios varied depending on ecological and cultivation conditions. For instance, in Diyarbakır, the shelled fruit weight ranged from 1.99 to 3.59 g, and kernel ratio from 22.93% to 56.20%.

When the current study is compared with those conducted in other regions, the differences observed in shelled fruit weight and kernel ratios are believed to be due to climatic and cultivation conditions, as well as the use of dry farming in the research area. Nevertheless, the findings are largely consistent with previous studies, especially those from Central and Southeastern Anatolia.

It is considered beneficial to conduct further research in the region regarding rootstock, cultivar, and cultivation practices. Particularly, the adaptation of new late-blooming almond cultivars may be advantageous. Additionally, testing drought-resistant or intensive cultivation-suitable almond rootstocks in regions of Karaman with Mediterranean climate characteristics may yield positive results.

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Apricot Plant Disease and Pest Detection from Field Images Using Fine-Tuned CNNs and Symptom–Organ Level Labeling

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Abstract

Early and accurate detection of plant diseases and pests is critical to preventing yield and quality losses, supporting sustainable agriculture, and ensuring food security. In this study, a novel dataset of 6,081 field images showing disease and pest symptoms on apricot (*Prunus armeniaca*) plants was created. Three pre-trained convolutional neural networks (CNNs), namely AlexNet, GoogLeNet, and ResNet-50, were fine-tuned for the classification task. Instead of a standard labeling strategy, a detailed labeling method was proposed, which considers both symptom type and the affected plant organ. The CNNs were trained on two datasets: a traditional 7-class version and a 13-class version generated using the proposed method. All models were evaluated using 5-fold cross-validation. Among all model and dataset combinations, the highest accuracy of 93.9% was achieved by the ResNet-50 model on the 7-class dataset. Although the proposed labeling method resulted in a slight decrease in classification accuracy, the performance difference remained small even with more classes. These findings indicate that the method is dependable and suitable for practical applications.

Key Words: Apricot (*Prunus armeniaca*), Plant disease and pest detection, Convolutional neural networks (CNNs), Transfer learning, Detailed labeling

İnce Ayarlanmış CNN'ler ve Belirti-Organ Düzeyinde Etiketleme ile Arazi Görüntülerinden Kayısı Bitkisi Hastalık ve Zararlılarının Tespiti

Özet

Bitki hastalık ve zararlılarının erken ve doğru tespiti, verim ve kalite kayıplarının önlenmesi, sürdürülebilir tarımın desteklenmesi ve gıda güvenliğinin sağlanması açısından kritik öneme sahiptir. Bu çalışmada, kayısı (*Prunus armeniaca*) bitkilerinde hastalık ve zararlı semptomlarını gösteren 6.081 adet arazi görüntüsünden oluşan özgün bir veri seti oluşturulmuştur. Ön-eğitimli evrişimsel sinir ağı (CNN) modelleri AlexNet, GoogLeNet ve ResNet-50 sınıflandırma görevi için ince-ayarlanmıştır. Standart bir veri etiketleme stratejisi yerine, hem belirti türünü hem de etkilenen bitki organını dikkate alan ayrıntılı bir etiketleme yöntemi önerilmiştir. CNN modelleri, biri geleneksel 7-sınıflı, diğeri ise önerilen yöntemle oluşturulan 13-sınıflı olmak üzere iki ayrı veri seti üzerinde eğitilmiştir. Tüm modeller beş-katlı çapraz-doğrulama yöntemi ile değerlendirilmiştir. Tüm model ve veri seti kombinasyonları arasında en yüksek doğruluk oranı olan %93,9'a, ResNet-50 modelinin 7-sınıflı veri seti üzerinde elde ettiği sonuçla ulaşılmıştır. Önerilen etiketleme yöntemi sınıflandırma doğruluğunda küçük bir düşüşe neden olsa da, sınıf sayısının artmasına rağmen performans farkı düşük kalmıştır. Bu bulgular, yöntemin güvenilir olduğunu ve pratik uygulamalar için uygunluğunu göstermektedir.

Anahtar kelimeler: Kayısı (*Prunus armeniaca*), Bitki hastalık ve zararlı tespiti, Evrişimsel sinir ağları (CNN), Transfer öğrenme, Ayrıntılı etiketleme.

Introduction

Plant diseases and pests cause significant yield and quality losses in agricultural production. These losses vary depending on the spread and stage of the diseases and the population of the pests, and can reach up to 100%, even resulting in plant deaths. Furthermore, due to the damage they inflict on various plant organs, they can negatively impact the productivity of subsequent years, not just the current year's yield. Preventing these losses and increasing the success of agricultural pest and disease management can be achieved by accurately diagnosing diseases in their early stages or before the pest population exceeds the economic threshold for damage (Mohanty et al., 2016).

Diagnosing plant diseases and pests is a task that requires both time and expertise. The symptoms may vary depending on the plant's phenological stage and environmental conditions. This further complicates the diagnosis of plant diseases and pests. Diagnoses made by plant protection experts are not always accurate. This situation can lead to delayed or incorrect treatments, which may result in more severe crop damage. Due to these challenges, artificial intelligence (AI) solutions have become a necessity to support fast and accurate diagnoses. AI-powered plant disease and pest diagnosis systems support sustainable agriculture and contribute to food security in the long term.

In this study, the aim is to detect diseases and pests on apricot (*Prunus armeniaca*) plants using deep learning methods with images obtained under field conditions. In this regard, a novel image dataset has been created, which includes

disease symptoms at different stages, the levels of damage caused by pests, and the effects on various plant organs. As prediction models, commonly used pre-trained CNN architectures such as AlexNet (Krizhevsky et al., 2017), GoogLeNet (Szegedy et al., 2015), and ResNet-50 (He et al., 2016) were fine-tuned and adapted to the problem. Additionally, an alternative labeling strategy based on combinations of diseases/pests and plant organs has been proposed, and the effects of this detailed labeling structure on classification performance have been evaluated.

In recent years, the number of deep learning-based approaches for detecting plant diseases and pests has been increasing (Ahmad et al., 2023; Liu and Wang, 2021; Shoaib et al., 2025; Tugrul et al., 2022). Deep learning-based models, which are widely used in this field, exhibit superior performance in image classification and object detection tasks. In particular, adapting CNN-based architectures to different datasets with transfer learning enables working with limited examples and increases the overall performance of the model (Altuntaş et al., 2019; Turkoglu et al., 2022; Yao et al., 2024).

Ferentinos (2018) classified various plant diseases using different CNN architectures and achieved very successful results on the PlantVillage dataset. Similarly, Mohanty et al. (2016) demonstrated the advantages of transfer learning by retraining pre-trained networks instead of training CNN models directly.

Turkoglu et al. (2020) proposed a CNN model for apricot disease detection. They examined how different convolution filter sizes affected classification performance. The highest accuracy, 98.20%, was achieved using a 9×9 kernel. Falaschetti et al. (2022) developed a lightweight CNN-based plant disease detection system running on a low-cost, low-power embedded device. The system was tested on both binary and multi-class classification tasks. It achieved accuracy rates of 98.10% and 95.24%, respectively. Yao et al. (2024) utilized data augmentation and transfer learning in their work on tea leaf blight detection. They particularly stressed that under conditions of limited samples, relying solely on data augmentation might prove inadequate, and that transfer learning offers notable advantages. Shafik et al. (2024) introduced a pair of new models for detection plant diseases. They put to use fine-tuned CNN models for extracting deep features. Their trials, carried out on PlantVillage dataset, uncovered that both the early fusion and ensemble learning models demonstrated strong predictive performance, achieving 96.74% and 97.79% accuracy rates. In their study, Ashurov et al. (2024) introduce a modified depthwise CNN architecture that incorporates squeeze-and-excitation blocks along with improved residual skip connections for plant disease detection. According to the authors, the model achieves 98% accuracy across diverse plant species and disease types. Perumal et al. (2024) proposed an CNN-based approach for detecting plant diseases. They optimized model parameters and used visual interpretation techniques to better understand the network's decisions. The method achieved strong classification performance and showed promise for real-time use in agriculture.

Within the scope of transfer learning, fine-tuned CNN models have been successfully applied on different datasets. However, in addition to using these models directly for classification, their use as feature extractors has also found a response in the literature. For example, Too et al. (2019) combined deep features with traditional methods by classifying the intermediate layer features extracted from various CNN architectures with Support Vector Machines (SVM). Altuntaş and Kocamaz, (2021) combined the deep features obtained from 3 CNN models and classified them with SVM and managed to detect tomato diseases and pests with high performance.

However, a significant portion of existing studies has been conducted with limited datasets and mostly under controlled laboratory conditions (Moupojou et al., 2023). This study aims to analyze apricot diseases and pests in a more realistic scenario using a unique dataset created from images obtained under field conditions.

In this context, the study makes the following original contributions: (i) A novel image dataset of apricot diseases and pests obtained under field conditions has been created. (ii) The impact of detailed class labels based on disease/pest and plant organ combinations on classification performance has been investigated. (iii) AlexNet, GoogLeNet, and ResNet-50 CNN models have been fine-tuned and adapted to the apricot plant disease and pest detection problem, and their performance has been evaluated.

The remaining sections of this paper are organized as follows. The technical details of the proposed model are presented in the *Materials and Methods* section. The experimental results are reported in the *Results* section. Discussion, general conclusions and recommendations for future work are provided in the *Discussion and Conclusion* section.

Materials and Methods

Dataset collection

The study was conducted during the 2021–2022 period through fieldwork in producer orchards located in the Malatya, Kayseri, and Aksaray provinces of Türkiye, primarily in the trial and

production orchards of the Apricot Research Institute Directorate. The objective was to create a unique image dataset for use in disease and pest detection studies. Healthy and disease or pest infected apricot orchards were surveyed, and images of visible disease symptoms and pest damage on various plant organs were collected.

Images were captured under natural field conditions using digital cameras and smartphones of different brands and models, resulting in variations in lighting, framing, and distance. Care was taken to ensure that disease symptoms and pest damage were clearly visible and, where possible, centered in the frame. All collected images were labeled by a subject expert through visual diagnosis.

The dataset comprises images showing disease symptoms and pest damage on apricot leaves, fruits, shoots, branches, and stones. It includes examples from different developmental stages of three diseases (shot hole, monilia, and sharka) and three pest types (aphids, plum scale, and leaf blister mite). In total, the dataset contains 6,081 images. The detailed distribution of images across diseases, pests, plant organs, and classes is provided in Table 1, offering an overview of the dataset's structure and balance.

Table 1. Detailed information of the dataset, including class and organ-specific image counts
Çizelge 1. Sınıf ve organ bazlı görüntü sayılarını içeren veri setine ait ayrıntılı bilgiler

Class Name	Scientific Name	Leaf	Fruit	Shoot / Branch	Stone	Total Images
Aphid	*Myzus persicae*	420	0	0	0	420
Healthy	-	449	665	86	204	1,404
Leaf Blister Mite	*Acalitus phloeocoptes*	515	0	0	0	515
Monilia	*Monilinia laxa*	0	0	336	0	336
Plum Scale	*Parthenolecanium corni*	0	0	739	0	739
Sharka	*Plum pox virus (PPV)*	398	375	0	143	916
Shot Hole	*Wilsonomyces carpophilus*	974	777	0	0	1,751
Total Images		2,756	1,817	1,161	347	6,081

The leaf images consist of samples of shot hole and sharka diseases, as well as aphid and leaf blister mite pests, along with healthy ones. Shot hole disease presents as round, red lesions surrounded by a light-colored halo on young leaves. These lesions gradually turn brownish-centered, reddish-brown spots, and after 5-10 days, they fall off, creating holes in the leaf. Sharka disease causes scattered line and halo-shaped symptoms around the secondary veins of the leaves. Aphids cause the leaves they feed on to curl and form red spots. Leaf blister mites form round or oval horn-like galls on the undersurface of the leaves. The gall tissue on the underside of the leaf causes irregular, raised, yellowish-green to reddish spots on the upper side (Tarım ve Orman Bakanlığı, 2022). Example images of the relevant classes are presented in Figure 1.

The fruit images consist of samples of shot hole and sharka diseases, along with healthy ones. Shot hole disease creates depressions on the fruit surface, accompanied by lesions with a light-colored halo around them. The symptoms of sharka disease on fruits are bright yellow rings or deep wounds extending to the stone (Tarım ve Orman Bakanlığı, 2022). Example fruit images from the dataset are presented in Figure 2.

Shoot and branch images include samples of monilia disease and plum scale pest, along with healthy individuals. Shoots infected with monilia disease turn brown; thin shoots dry completely, while thicker ones develop sunken, elliptical or elongated cracks. The plum scale pest forms visible colonies on the trunks and thicker branches (Tarım ve Orman Bakanlığı, 2022). Example shoot/branch images from the dataset are presented in Figure 3.

Stone images consist of samples of sharka disease, along with healthy ones. Dark spots surrounded by yellow or cream-colored rings on the stone are typical symptoms of sharka disease (Tarım ve Orman Bakanlığı, 2022). Healthy stones have smooth and uniform surfaces. Example stone images from the dataset are presented in Figure 4.

Data preprocessing

Among the pre-trained CNN models used in this study, AlexNet requires input images of 227×227 pixels, whereas GoogLeNet and ResNet-50 require 224×224 pixels. Therefore, the original images in the dataset, which had varying resolutions, were first cropped to a square format while preserving their aspect ratio. During cropping, equal portions were removed from both ends of the longer side, based on the difference in length between the two dimensions. Subsequently, the cropped images were resized to meet the input requirements of the respective models.

Figure 1. Images of sample leaves from the dataset, visually depicting symptoms and damage caused by aphids (top-left), leaf blister mites (top-right), shot hole (bottom-left), and sharka (bottom-middle). A healthy one is also presented (bottom-right).
Şekil 1. Yaprak biti (sol-üst), yaprak uyuzu (sağ-üst), çil (sol-alt) ve şarka (orta-alt) hastalık ve zararlılarının sebep olduğu simptom ve belirtileri gösteren veri setine ait örnek yaprak görüntüleri. Sağlıklı bir yaprak da sunulmuştur (sağ-alt).

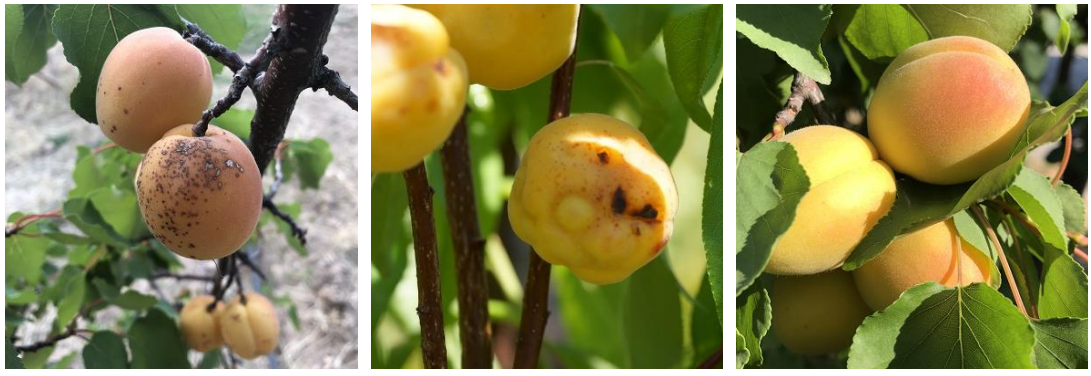

Figure 2. Sample fruit images. These display symptoms of shot hole (left) and sharka (middle) diseases, alongside a healthy one (right).
Şekil 2. Örnek meyve görüntüleri. Bu görsellerde çil (sol) ve şarka (orta) hastalıklarına ait simptomlar ile birlikte sağlıklı bir meyve (sağ) gösterilmektedir.

Figure 3. Shoot and branch images illustrating symptoms of monilia disease (left) and plum scale pest infestation (middle), plus a healthy sample (right).
Şekil 3. Monilya hastalığına ait semptomları (sol) ve erik koşnili zararlısı belirtilerini (orta) gösteren sürgün ve dal görüntülerinin yanı sıra sağlıklı bir örnek (sağ).

Figure 4. Apricot stone images. Symptoms of sharka disease are visible on the left, shown with a healthy stone on the right.
Şekil 4. Kayısı çekirdeği görüntüleri. Şarka hastalığına ait simptomlar sol tarafta görülmekte, sağda ise sağlıklı bir çekirdek gösterilmektedir.

CNN Architectures and fine-tuning approach

Convolutional Neural Network (CNN) architectures, which demonstrate superior performance in solving computer vision problems such as image classification, object recognition, and object tracking, differ from traditional neural networks by incorporating convolutional blocks, where features are discovered, and pooling layers, which reduce the dimensionality of the data (Lecun et al., 2015).

In CNN architectures, feature extraction is performed through convolution, activation functions, and pooling layers. This process enables the extraction of meaningful features from raw data. In the convolutional layer, the image is processed using specific filters, resulting in visual features such as horizontal, vertical, and angular edges, as well as smoothed and sharpened versions of the image. The pooling operation, on the other hand, reduces the image size using functions like average or maximum value pooling. This process increases the computational efficiency of the network, thereby improving overall performance.

The extracted features are then transformed into vector form and classified through the fully connected layer. In the final stage, the error value calculated at the network's output is used in the backpropagation algorithm to update the convolutional filters and the weights of the fully connected layer. Through this process, the model gains the ability to make more accurate predictions during the learning process.

CNN models require large amounts of data as they automatically learn the representation of the data (He et al., 2019). Additionally, training these models requires high computational costs (Kornblith et al., 2019). To overcome these disadvantages, transfer learning techniques have been developed. Transfer learning is a machine learning method in which the knowledge gained by solving one problem is reused as a starting point to solve a different problem. Pre-trained CNN models are used as starting points for solving

different problems, allowing high classification performance to be achieved on smaller datasets with lower computational costs (Altuntaş and Kocamaz, 2021; Kornblith et al., 2019).

A brief overview of the CNNs employed in this study is presented below: AlexNet considered one of the foundational architectures in deep learning. It consists of a total of eight layers, including five convolutional layers for feature extraction and three fully connected layers for classification. Its relatively simple structure laid the groundwork for later CNN advancements.

GoogLeNet introduced the innovative Inception module, which enables the network to capture multi-scale features within a single layer by combining multiple convolutional operations. Although it comprises 22 layers, GoogLeNet maintains efficiency through the strategic use of 1×1 convolutions for dimensionality reduction.

ResNet-50 is a deep residual network with 50 layers, specifically designed to overcome the vanishing gradient problem often encountered in very deep architectures. By employing residual connections, it facilitates more effective gradient flow and faster convergence. ResNet-50 is widely adopted in transfer learning due to its balance of depth, performance, and computational efficiency.

Data labeling approach

The image data obtained in this study were diagnosed by the subject matter expert within our research team. During the data labeling phase, each image was labeled according to the disease symptoms or pest indications it showed. Disease and pest names were used as class labels, resulting in a dataset with 7 classes: 3 diseases, 3 pests, and 1 healthy class.

Diseases and pests can cause symptoms and damage on multiple plant organs. These symptoms and damages may visually differ significantly depending on the plant organ. To ensure that the dataset aligns with real-world conditions, images were collected from different plant organs. Therefore, each image was categorized based on which plant organ the primary feature belonged to. The dataset consists of images obtained from 4 main plant organs: leaf, fruit, shoot/branch, and stone.

Since some diseases and pests cause symptoms and damage on multiple plant organs, visual differences appear between these symptoms and damages. This results in high intra-class variance. High intra-class variance can make it challenging for the model to make accurate predictions (Wei et al., 2022). Therefore, to improve the classification performance of the deep learning-based prediction models (fine-tuned CNN), a second data labeling approach was proposed with detailed data labeling. In the first dataset, 7 classes were created using disease and pest names, while in the second dataset, 13 classes were formed by combining disease and pest names with plant organs (disease-pest x plant organ). This data labeling strategy aims to increase inter-class variance while reducing intra-class variance.

Experimental setup

To measure the classification performance of the CNN models used in the study, the k-fold cross-validation procedure was applied. In the hold-out validation procedure, performance evaluation based on a single training-test split can be either fortunate or unfortunate. k-fold cross-validation reduces the variance caused by data splitting by including all the samples in the test set once. In addition, results may vary even on the same data split due to factors such as dropout layers in CNN architectures, random weight initialization, or the order of mini-batches. Evaluating the models with different folds creates random training conditions, allowing the changes resulting from the stochastic nature of deep learning to be reflected in the average. The results are presented as mean and standard deviation values. In this way, a more reliable performance evaluation can be made. In this study, the number of folds was set to 5, considering the number of samples and their class distribution.

An evaluation framework is proposed to compare the predictive performance of CNN models and to fairly evaluate the effects under different data labeling approaches. This evaluation framework ensures that all models are trained with the same training, validation and test samples on different data labeling approaches. In this framework, the 13-class labeled dataset is divided into 5 folds. In order to prevent underrepresented classes from being left out by chance, the partitioning process is carried out by taking into account the class ratios in each fold. Then, each fold is divided into two subsets, 75% of the samples in the fold are for training and 25% of the samples in the fold are for validation. First, the entire first fold was used as the test set, while the training subsets of the remaining four folds were combined to form the training set, and their validation subsets were merged to form the validation set. The training process was then carried out using these sets. Then, the entire second fold was used as the test set, while the training subsets of the remaining four folds were merged to create the training set, and their validation subsets were combined to form the validation set. The training process was then carried out using these sets. This process is repeated five times, each time using a different fold for testing. Thus, it is guaranteed that each model is trained with the same training, validation and test sets.

After the training of all CNN models used in the study was completed on the 13-class labeled dataset, the five folds created for the 13-class dataset were converted into folds for the 7-class version. The detailed class labels within each fold were mapped back to their original categories. For example, SharkaXFruit, SharkaXLeaf, and SharkaXStone classes were converted to Sharka class. The same process was applied to other detailed classes. Model trainings were repeated for each fold as explained above. Thus, not only CNN models but also data labeling approaches were partitioned with the same training, validation and test sets.

Training models for a fixed number of epochs may lead to overfitting or, conversely, underfitting. Therefore, an early stopping procedure was adopted as a regularization technique. Models were evaluated on the validation set in each epoch. Training was stopped if no improvement in validation accuracy was observed during five consecutive epochs.

Evaluation metrics

In this study, accuracy (Acc.), precision (Pre.), recall (also known as sensitivity), and F1 score performance metrics were used to evaluate and compare the classification performances of the fine-tuned CNN models. These metrics are calculated using the values of True Positive (TP), False Positive (FP), False Negative (FN), and True Negative (TN) obtained from the confusion matrix. The confusion matrix summarizes the number of correct and incorrect predictions made by the model on the test set.

In multi-class classification problems, performance metrics are calculated separately for each class. For the class under evaluation, correct predictions are considered as TP, while incorrect predictions for that class are counted as FN. All other classes are treated as negative. Among these, instances that do not belong to the positive class and are correctly not predicted as such are classified as TN. Conversely, instances from negative classes that are incorrectly predicted as positive are counted as FP.

The mathematical formulas for the performance metrics used in this study are given below.

$$Acc.= \frac{TP + TN}{TP + FP + FN + TN} \quad (1)$$

$$Pre.= \frac{TP}{TP + FP} \quad (2)$$

$$Recall = \frac{TP}{TP + FN} \quad (3)$$

$$F1\ score = \frac{2 * TP}{2 * TP + FP + FN} \quad (4)$$

In addition, the overall performance of the model is assessed using the overall accuracy metric, whose formula is also provided below.

$$Overall\ Acc.= \frac{\sum_{i=1}^{N} TP_i}{\sum_{i=1}^{N}(TP_i + FP_i)} \quad (5)$$

Here, N refers to the number of classes, while TP_i and FP_i represent the number of correct and incorrect positive predictions for the i^{th} class, respectively.

Results

All procedures in this study were conducted using MATLAB© R2020b. The computer used for the study was equipped with a 2.6 GHz i5 processor, a 512 GB SSD hard drive, 8 GB DDR4 system memory, and a 4 GB graphics card.

This study aimed to accurately detect apricot diseases and pests from images of different plant organs captured under field conditions using fine-tuned CNN models. To support this goal, two different labeling strategies were employed: a conventional 7-class structure and a more detailed 13-class structure that incorporates both disease-pest types and affected plant organs. The dataset was evaluated using stratified 5-fold cross-validation. Each model was evaluated using the same data partitions across folds, ensuring a fair basis for comparison between models and labeling methods. The results are reported as the mean and standard deviation of performance metrics across all folds.

Stochastic Gradient Descent with Momentum (SGDM) was used as the optimization method for fine-tuning the CNN architectures (Murphy, 2012). The hyperparameters were set as follows: The final fully connected layers of the models were replaced with fully connected layers having output sizes of 7 and 13, respectively, to match the number of classes in each dataset. The maximum number of epochs was set to 100, the mini-batch size to 32, and the learning rate to 10^{-4}.

The validation procedure was performed once at the end of each epoch. If no improvement in validation performance was observed for five consecutive validation runs, training was terminated early. Table 2 summarizes the total training time and total number of epochs spent across the five folds, along with the mean and standard deviation of validation accuracy for each model and dataset.

Table 2. Total training time, total number of epochs, and validation accuracy (mean ± standart deviation) obtained from the models after fine-tuning procedure
Çizelge 2. Modellerin ince-ayarlama işlemi sonrasında elde edilen toplam eğitim süresi, toplam eğitim döngüsü sayısı ve doğrulama başarımı (ortalama ± standart sapma)

Model	Dataset	Total Training Time	Total Epochs	Val. Accuracy (%, Mean ± SD)
AlexNet	7-class	3 hr 28 min 59 sec	91	88.28±0.63
	13-class	3 hr 16 min 23 sec	85	87.48±0.81
GoogLeNet	7-class	11 hr 48 min 24 sec	105	91.87±0.60
	13-class	10 hr 48 min 36 sec	102	91.60±0.83
ResNet-50	7-class	36 hr 37 min 22 sec	133	94.35±0.34
	13-class	32 hr 31 min 28 sec	128	93.51±0.64

Table 3. Classification results of the fine-tuned AlexNet model
Çizelge 3. İnce-ayarlanmış AlexNet modeline ait sınıflandırma sonuçları

DataSet	Class Name	TP	FP	FN	TN	Acc. (%)	Pre. (%)	Recall (%)	F1 scr (%)	Overall Acc. (%)
7-class	Aphid	361	30	59	5,631	98.54 ±0.48	92.48 ±4.67	85.95 ±4.64	89.02 ±3.60	88.80±0.66
	Healthy	1,211	179	193	4,498	93.88 ±0.55	87.14 ±1.41	86.25 ±1.94	86.68 ±1.24	
	Leaf Blister Mite	423	81	92	5,485	97.16 ±0.31	83.95 ±2.31	82.13 ±1.48	83.03 ±1.76	
	Monilia	304	38	32	5,707	98.85 ±0.16	89.00 ±2.55	90.48 ±3.88	89.66 ±1.48	
	Plum Scale	705	60	34	5,282	98.45 ±0.29	92.18 ±1.32	95.40 ±2.11	93.75 ±1.25	
	Sharka	775	137	141	5,028	95.43 ±0.32	85.02 ±2.04	84.61 ±1.92	84.79 ±1.05	
	Shot Hole	1,621	156	130	4,174	95.30 ±0.65	91.22 ±1.06	92.58 ±1.53	91.89 ±1.14	
13-class	Aphid	358	38	62	5,623	98.36 ±0.38	90.49 ±3.63	85.24 ±3.53	87.74 ±2.84	88.18±0.64
	HealthyXBranch	59	8	27	5,987	99.42 ±0.15	89.76 ±10.50	68.56 ±10.80	76.93 ±6.68	
	HealthyXFruit	592	90	73	5,326	97.32 ±0.41	86.90 ±3.06	89.02 ±2.16	87.91 ±1.76	
	HealthyXLeaf	334	86	115	5,546	96.70 ±0.46	79.69 ±4.23	74.37 ±5.70	76.81 ±3.59	
	HealthyXStone	196	3	8	5,874	99.82 ±0.07	98.56 ±2.14	96.07 ±2.20	97.27 ±1.03	
	Leaf Blister Mite	439	75	76	5,491	97.52 ±0.31	85.56 ±3.54	85.24 ±2.70	85.34 ±1.72	
	Monilia	303	23	33	5,722	99.08 ±0.27	93.00 ±3.16	90.18 ±2.70	91.55 ±2.45	
	Plum Scale	713	56	26	5,286	98.65 ±0.35	92.73 ±1.15	96.48 ±2.54	94.55 ±1.47	
	SharkaXFruit	318	58	57	5,648	98.11 ±0.54	85.17 ±7.05	84.80 ±3.48	84.79 ±3.63	
	SharkaXLeaf	317	94	81	5,589	97.12 ±0.46	77.18 ±3.97	79.64 ±2.80	78.38 ±3.30	
	SharkaXStone	138	8	5	5,930	99.78 ±0.05	94.65 ±2.62	96.53 ±3.45	95.51 ±0.91	
	Shot HoleXFruit	695	71	82	5,233	97.48 ±0.24	90.85 ±2.33	89.45 ±3.86	90.06 ±1.17	
	Shot HoleXLeaf	900	109	74	4,998	96.99 ±0.42	89.38 ±3.61	92.40 ±2.49	90.79 ±1.02	

Table 4. Classification results of the fine-tuned GoogLeNet model
Çizelge 4. İnce-ayarlanmış GoogLeNet modeline ait sınıflandırma sonuçları

DataSet	Class Name	TP	FP	FN	TN	Acc. (%)	Pre. (%)	Recall (%)	F1 scr (%)	Overall Acc. (%)
7-class	Aphid	388	33	32	5,628	98.93 ±0.33	92.28 ±3.55	92.38 ±3.33	92.27 ±2.36	91.43±0.74
	Healthy	1,245	127	159	4,550	95.30 ±0.51	90.76 ±0.77	88.67 ±2.79	89.68 ±1.29	
	Leaf Blister Mite	456	69	59	5,497	97.89 ±0.52	86.93 ±3.36	88.54 ±4.63	87.67 ±3.16	
	Monilia	307	24	29	5,721	99.13 ±0.30	92.74 ±2.34	91.37 ±3.58	92.03 ±2.84	
	Plum Scale	714	35	25	5,307	99.02 ±0.28	95.35 ±1.15	96.62 ±2.48	95.96 ±1.21	
	Sharka	788	142	128	5,023	95.56 ±0.73	84.88 ±3.79	86.03 ±2.01	85.40 ±2.09	
	Shot Hole	1,662	91	89	4,239	97.04 ±0.54	94.83 ±1.53	94.92 ±0.74	94.87 ±0.92	
13-class	Aphid	391	27	29	5,634	99.08 ±0.34	93.58 ±2.77	93.10 ±3.08	93.32 ±2.45	91.30±0.67
	HealthyXBranch	71	12	15	5,983	99.56 ±0.11	87.34 ±9.90	82.49 ±10.29	83.94 ±4.00	
	HealthyXFruit	620	78	45	5,338	97.98 ±0.34	88.92 ±2.31	93.23 ±4.01	90.95 ±1.64	
	HealthyXLeaf	387	89	62	5,543	97.52 ±0.50	81.49 ±4.73	86.19 ±1.33	83.73 ±2.90	
	HealthyXStone	199	5	5	5,872	99.84 ±0.10	97.58 ±1.65	97.56 ±2.99	97.54 ±1.54	
	Leaf Blister Mite	444	49	71	5,517	98.03 ±0.44	90.23 ±3.87	86.21 ±3.78	88.10 ±2.54	
	Monilia	307	22	29	5,723	99.16 ±0.07	93.34 ±1.18	91.36 ±1.97	92.32 ±0.71	
	Plum Scale	711	36	28	5,306	98.95 ±0.28	95.27 ±2.42	96.21 ±2.73	95.69 ±1.18	
	SharkaXFruit	318	35	57	5,671	98.49 ±0.11	90.17 ±1.76	84.80 ±3.60	87.34 ±1.21	
	SharkaXLeaf	322	72	76	5,611	97.56 ±0.41	82.07 ±5.53	80.91 ±1.53	81.38 ±2.40	
	SharkaXStone	139	6	4	5,932	99.84 ±0.10	95.99 ±3.51	97.24 ±2.89	96.56 ±2.01	
	Shot HoleXFruit	730	38	47	5,266	98.60 ±0.37	95.10 ±2.22	93.95 ±1.96	94.50 ±1.45	
	Shot HoleXLeaf	913	60	61	5,047	98.01 ±0.11	93.92 ±2.23	93.74 ±2.57	93.78 ±0.40	

Table 3 presents the classification outcomes of the fine-tuned AlexNet model on the 7-class and 13-class datasets. Confusion matrix values are shown as totals across all five folds, while the performance metrics are summarized using mean and standard deviation.

Table 4 summarizes the results obtained with the fine-tuned GoogLeNet model for both labeling approaches. The confusion matrices reflect total counts across the five folds, and the performance values are reported as averages with standard deviations.

Table 5 provides the classification performance of the ResNet-50 model using the two labeling schemes. Confusion matrix totals are based on all five folds, and the associated metrics are expressed as mean and standard deviation.

Discussion and Conclusion

This study aimed to accurately detect apricot diseases and pests from images of different plant organs captured under field conditions using fine-tuned CNN models. For this purpose, our research team constructed an original dataset consisting of 6,081 images including healthy samples and samples affected by three diseases and three pests. In addition to the 7-class dataset, a second 13-class dataset was created by combining disease-pest types with plant organ labels through a detailed labeling approach.

Table 5. Classification results of the fine-tuned ResNet-50 model
Çizelge 5. İnce-ayarlanmış ResNet-50 modeline ait sınıflandırma sonuçları

DataSet	Class Name	TP	FP	FN	TN	Acc. (%)	Pre. (%)	Recall (%)	F1 scr (%)	Overall Acc. (%)
7-class	Aphid	402	19	18	5,642	99.39 ±0.44	95.60 ±4.45	95.72 ±2.74	95.63 ±3.15	93.90±0.39
	Healthy	1,312	125	92	4,552	96.43 ±0.43	91.32 ±1.26	93.45 ±1.31	92.36 ±0.94	
	Leaf Blister Mite	463	28	52	5,538	98.68 ±0.25	94.39 ±2.74	89.90 ±2.79	92.05 ±1.54	
	Monilia	304	21	32	5,724	99.13 ±0.29	93.62 ±3.88	90.46 ±2.30	91.99 ±2.60	
	Plum Scale	717	40	22	5,302	98.98 ±0.23	94.76 ±1.93	97.02 ±1.77	95.86 ±0.93	
	Sharka	831	94	85	5,071	97.06 ±0.45	90.02 ±3.74	90.72 ±2.22	90.30 ±1.26	
	Shot Hole	1,681	44	70	4,286	98.12 ±0.24	97.46 ±1.11	96.00 ±0.71	96.72 ±0.40	
13-class	Aphid	403	21	17	5640	99.37 ±0.37	95.17 ±3.84	95.95 ±3.22	95.51 ±2.65	93.27±1.18
	HealthyXBranch	64	13	22	5982	99.42 ±0.19	83.01 ±2.54	74.38 ±14.83	77.89 ±9.08	
	HealthyXFruit	628	69	37	5347	98.25 ±0.60	90.33 ±4.82	94.43 ±2.17	92.26 ±2.49	
	HealthyXLeaf	401	61	48	5571	98.21 ±0.52	86.84 ±4.06	89.30 ±3.47	88.03 ±3.50	
	HealthyXStone	198	6	6	5871	99.80 ±0.13	97.10 ±2.53	97.05 ±2.07	97.06 ±1.84	
	Leaf Blister Mite	465	27	50	5539	98.73 ±0.22	94.62 ±2.57	90.29 ±3.29	92.34 ±1.34	
	Monilia	305	24	31	5721	99.10 ±0.17	92.79 ±2.81	90.77 ±1.97	91.74 ±1.52	
	Plum Scale	711	39	28	5303	98.90 ±0.12	94.82 ±1.11	96.21 ±1.77	95.50 ±0.55	
	SharkaXFruit	338	25	37	5681	98.98 ±0.24	93.13 ±2.08	90.13 ±2.60	91.59 ±1.99	
	SharkaXLeaf	358	42	40	5641	98.65 ±0.27	89.54 ±2.61	89.94 ±2.83	89.71 ±2.10	
	SharkaXStone	137	6	6	5932	99.80 ±0.15	95.79 ±2.94	95.79 ±4.53	95.75 ±3.25	
	Shot HoleXFruit	737	30	40	5274	98.85 ±0.36	96.10 ±1.62	94.85 ±1.98	95.46 ±1.44	
	Shot HoleXLeaf	927	46	47	5061	98.47 ±0.24	95.31 ±1.77	95.17 ±1.18	95.23 ±0.71	

The motivation behind this detailed labeling was to reduce intra-class variance and increase inter-class variance, thereby improving classification performance. Accordingly, the AlexNet, GoogLeNet, and ResNet-50 CNN architectures were fine-tuned and adapted to the problem, and their performances were compared. The results showed that these three models achieved overall accuracy rates of 88.80%, 91.43%, and 93.90%, respectively, on the 7-class dataset. On the 13-class dataset, the models achieved 88.18%, 91.30%, and 93.27% accuracy, respectively. All three models produced highly successful results. A trend was observed where deeper architectures outperformed shallower ones in terms of classification accuracy, suggesting a potential advantage of increased representational capacity. However, when tested on the 13-class labeled dataset created through detailed labeling, each model exhibited a slight, statistically insignificant drop in classification performance. One potential reason for this decline is the increased visibility of class imbalance as the number of classes increased. Furthermore, although the images were labeled based on plant organs, they were captured under real field conditions, often containing multiple plant parts in a single image. The background complexity and the presence of different plant organs together may be other contributing factors to the performance drop.

In future studies, it is planned to create a more balanced dataset by incorporating additional images or applying data augmentation techniques. To improve the classification performance of the detailed 13-class dataset, the use of attention mechanisms or hierarchical classification approaches will be considered. Additionally, hybrid or ensemble learning methods that combine the feature extraction capabilities of different CNN architectures will be explored to further enhance classification success.

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Data Availability
The dataset used in this study was created during the completed TAGEM project and is currently being reused and further expanded within the scope of a broader, ongoing research project that includes additional fruit species and vineyards.
At this stage, due to class imbalance and the dataset's active use in ongoing analyses and model development, the data is not publicly available. However, we support open science and plan to make the dataset publicly available once it becomes sufficiently complete and balanced.
Until then, the dataset may be shared with researchers upon reasonable request, provided that the request meets relevant ethical standards and institutional requirements.

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