Turkish Journal of Agricultural and Natural Sciences 12 (2): 379–389, 2025
https://doi.org/10.30910/turkjans.1608381

TÜRK TARIM ve DOĞA BİLİMLERİ DERGİSİ

TURKISH JOURNAL of AGRICULTURAL and NATURAL SCIENCES

www.dergipark.gov.tr/turkjans

Original Article

Morphological and Chemical Characteristics of *Prunus spinosa* L. Genotypes from Denizli (Çivril)

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ABSTRACT

This study was conducted to characterize the physico-chemical properties of naturally occurring blackthorn (*Prunus spinosa* L.) genotypes in Çivril, Denizli, Türkiye. In this context, 13 different blackthorn genotypes originating from seeds were examined in terms of color parameters, physical, and chemical properties. Physical characteristics of the fruits revealed that fruit width ranged from 7.95 mm to 14.12 mm, fruit length from 10.49 mm to 14.63 mm, and fruit weight varied between 1.82 g and 2.71 g. Notably, genotypes G3 and G5 stood out with fruit weights of 2.71 g and 2.58 g, respectively. Regarding the fruit flesh-to-seed ratio, genotype G3 exhibited the highest value of 7.10. In terms of color parameters, the L^* value of the fruit skin ranged from 16.75 to 20.59, while the L^* value of the fruit flesh varied between 17.48 and 20.45. Biochemical characteristics showed that the soluble solids content ranged widely from 12.00% to 23.40%, while pH values remained stable between 3.60 and 3.90. PCA analysis revealed that the first two components explained 67.13% of the total variation in the examined traits. Correlation analysis found a strong positive relation between fruit flesh color L^* and b^* values (r=0.95), as well as between fruit length and shape index (r=0.89). Based on the biplot results, it can be inferred that the studied *P. spinosa* genotypes have the potential to be evaluated in different ways. In conclusion, it can be stated that this species has high adaptability to local ecosystems and that, in the short term, more efficient genotypes can be obtained through selection, and in the long term, through hybridization.

Key words: *Prunus spinosa* L., Genetic Resources, Phenotypic Variation, Principal Component Analysis, Selection

Denizli (Çivril) Bölgesinde *Prunus spinosa* L. Genotiplerinin Meyvelerinin Morfolojik ve Kimyasal Özellikleri

ÖZ

Bu çalışma, Türkiye'nin Denizli ili, Çivril ilçesinde doğal olarak yetişen çakal eriği (*Prunus spinosa* L.) genotiplerini, fiziko-kimyasal özellikler yönüyle karakterize etmek amacı ile gerçekleştirilmiştir. Bu bağlamda, tohum kökenli 13 farklı çakal eriği genotipi renk parametreleri, fiziksel ve kimyasal özellikleri yönüyle incelenmiştir. Meyvelerin fiziksel özellikleri incelendiğinde, meyve eni 7.95-14.12 mm, meyve boyu 10.49-14.63 mm ve meyve ağırlığı özelliklerinin 1.82 ile 2.71 g sınırları içerisinde değişim gösterdiği belirlenmiştir. Özellikle G3 ve G5 genotipleri, sırasıyla 2.71 g ve 2.58 g meyve ağırlıklarıyla dikkat çekmiştir. Meyve eti/çekirdek oranında G3 genotipi 7.10 ile en yüksek değere sahip olmuştur. Renk parametreleri açısından, meyve kabuğu L^* değeri 16.75-20.59, meyve eti L^* değeri ise 17.48-20.45 aralığında dağılım göstermiştir. Biyokimyasal özellikler değerlendirildiğinde, suda çözünür kuru madde içeriği %12.00 ile %23.40 arasında geniş bir varyasyon sergilemiş, pH değerleri ise 3.60-3.90 gibi dar bir aralıkta stabilite göstermiştir. PCA sonucunda, incelenen özelliklerin toplam varyasyonun %67.13'ü ilk iki bileşen tarafından açıklanmıştır. Korelasyon analizinde özellikle meyve eti rengi L^* ile b^* değerleri arasında (r=0.95) ve meyve uzunluğu ile şekil indeksi arasında (r=0.89) güçlü pozitif ilişkiler tespit edilmiştir. Bi-plot sonuçları doğrultusunda, incelenen *P. spinosa* genotiplerinin farklı şekillerde değerlendirilebilme potansiyellerinde olduğu söylenebilir. Sonuç olarak, bu türün yerel ekosistemdeki adaptasyon kapasitesinin yüksek olduğu ve kısa dönemde seleksiyonla, uzun vadede ise melezleme yoluyla daha verimli genotiplerin elde edilebileceği söylenebilir.

Anahtar kelimeler: *Prunus spinosa* L., Genetik Kaynaklar, Fenotipik Varyasyon, Temel Bileşen Analizi, Seleksiyon

INTRODUCTION

Plum (*Prunus* spp.) is a member of the Rosaceae and belongs to the *Prunus* genus, which includes a wide range of economically and ecologically important species. Among these, *Prunus spinosa* L., commonly known as blackthorn, is native to Europe-Asia gene center in where Türkiye takes place within a significant genetic center for wild plums (Başaran et al., 2024). This species exhibits remarkable drought tolerance and adaptability to diverse ecological conditions, positioning it as a promising rootstock candidate for stone fruit and nuts under the challenges posed by global climate change scenarios (Milosevic et al., 2015; Kirca and Karadeniz, 2024). Furthermore, its resilience makes it suitable for afforestation efforts in arid regions, landscape restoration, and carbon sequestration due to its phytoremediation potential (Özer et al., 2009; Gülay, 2023).

The fruits of *P. spinosa* are small, bluish-purple, and covered with a waxy coating. They are rich in bioactive compounds, including minerals, amino acids, vitamins, phytosterols, triterpenes, organic acids, and phenolic compounds (Bei et al., 2023). These phytochemicals, particularly those with high antioxidant activity, have been reported to mitigate the risk of chronic diseases such as cancer and cardiovascular conditions (Sabatini et al., 2020; Negrean et al., 2023; Kotsou et al., 2023; Başaran et al., 2024). For instance, studies have shown its efficacy in reducing viability in brain cancer cells (Karakas et al., 2019) and its potential use in diabetes treatment due to its antioxidant properties (Sarıkaya et al., 2010). Its antioxidant activity is further linked to enhanced collagen synthesis, contributing to wound healing (Ayla et al., 2017). In traditional medicine, the species has been valued for its hemostatic effects and its ability to improve intestinal functions (Baytop, 1999; Sezer et al., 2016). Additionally, the non-fruit parts of the plant are also abundant in bioactive components (Atik et al., 2022).

In recent years, there has been growing interest in the inclusion of products with superior phytochemical properties in daily diets, particularly in health-conscious societies (Demir and Aktaş, 2018). This increasing demand has underscored the need for more comprehensive studies on phytochemical compositions and the selection of wild genotypes with superior traits (Uzun et al., 2015; Dumanoglu et al., 2019; Delialioğlu et al., 2022; Kurnaz et al., 2024).

Despite the astringent taste of the fruit, which limits its fresh consumption, various parts of *P. spinosa* have long been processed into products such as jams, marmalades, and fruit juices due to their nutritional and medicinal benefits (Başkaya, et al., 2016; Başaran et al., 2024). Nevertheless, there remains a significant gap in the development of superior genotypes for broader cultivation and utilization. The selection of genotypes with enhanced phytochemical properties and superior fruit traits is critical for the species' potential expansion in both agricultural and industrial applications. This study aims to address these gaps by (1) investigating the natural genetic resources of *P. spinosa* for breeding purposes and (2) characterizing key fruit traits using multivariate analysis to identify genotypes with superior characteristics.

MATERIALS AND METHODS

The study was carried out in 2024 on thirteen seed-origin genotypes (G1, G2...G13) of *P. spinosa* (blackthorn) that grow naturally in the Çivril district of Denizli province (Türkiye). To verify the seed origin of the genotypes, local people and garden/field owners were consulted, and plants confirmed to have grown from seeds were included in the study. The genotypes used in this study grew spontaneously in nature without any cultural practices. Fruit sampling was carried out during the period when the genotypes reached their characteristic fruit color and physiological maturity. Analyses were performed using twenty randomly selected fruit samples from four different orientations of each genotype. After harvest, the fruit samples were immediately transferred to a laboratory in portable coolers to minimize time delays before starting the analyses.

Çivril is located at an average altitude of 832 meters above sea level. A visual representation of the study area is given in Figure 1. The district's topography consists of 30% mountainous terrain, 16% hilly areas, and 54% flat plains, reflecting its various geomorphological features. The region is characterized by a transitional climate between Mediterranean and continental climates. Geologically, the district is situated in an alluvial basin and is surrounded by significant mountainous features such as Mount Bulkaz (1990 m), Kocayaka Hill (1259 m), Bozdağı Hill (1350 m), and Mount Akdağ, which is the highest point in the region at 2449 m (Wikipedia, 2024). These features contribute to the region's unique microclimate, which is particularly suitable for the growth of drought-resistant and hardy species like *P. spinosa*.

When examining the 15-year (2009-2023) average climate data of Çivril district, it shows continental climate characteristics (Figure 2). Annual average temperature values range from 3.45°C (January) in winter months to 25.29°C (July) in summer months. The low temperatures during winter months are suitable for meeting the chilling requirements of *P. spinosa*. The fifteen-year average relative humidity values vary between 42.53% (July) and 74.81% (January), with particularly low humidity rates observed during summer months. The average annual total precipitation is 441.96 mm, with the highest average precipitation recorded in January (67.2 mm) and the lowest in July (4.91 mm). When examining the seasonal distribution of precipitation, it is concentrated in winter and spring months, while significantly decreasing during summer months. The average wind speed varies between 1.96-2.67 m/sec throughout the year, showing no extreme values (TSMS, 2024). These long-term climate parameters enable *P. spinosa* to grow naturally in the region.

The Çivril district's ecological characteristics, including its variable topography, transitional climate, and diverse soil properties, make it an ideal location for studying the genetic diversity and adaptability of *P. spinosa*. This study leverages these unique conditions to explore the genetic potential of this species for future breeding and cultivation strategies.

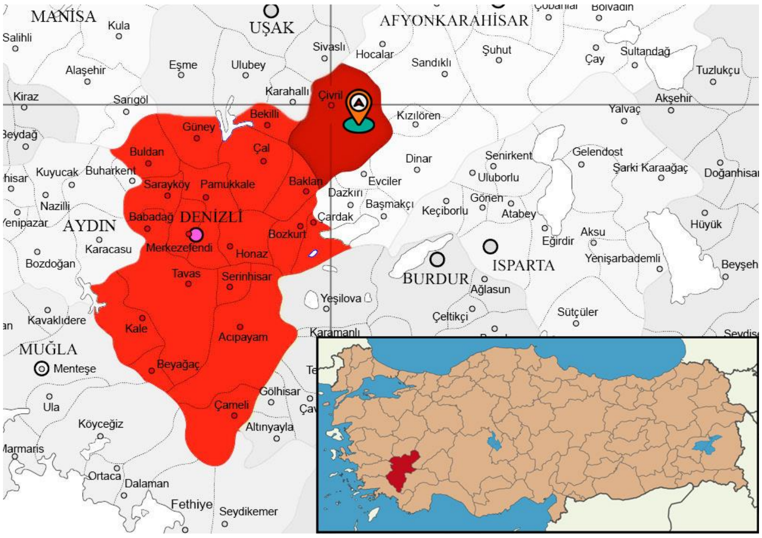

Figure 1. Map of the study area

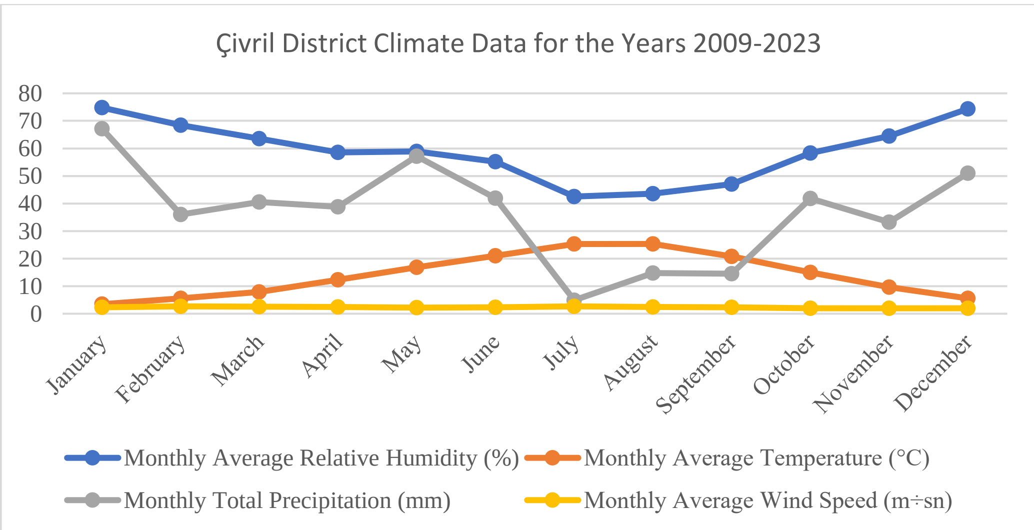

Figure 2. Average monthly average relative humidity (%), monthly average temperature (°C), monthly total precipitation (mm) and monthly average wind speed (m÷sn) of Çivril district between 2009-2023.

The traits examined in this study were grouped into three main categories: physical measurements (fruit width, length, weight, and flesh-to-stone ratio), color attributes (*L**, *a**, *b**, chroma, and hue°), and chemical analyses (TSS, pH, and TA).

Physical Measurements: Fruit width and length were measured in millimeters (mm) using a digital caliper, and fruit weight was recorded in grams (g) using a precision balance (Gülsoy et al., 2016; Başaran et al., 2024). To determine the fruit flesh-to-stone ratio, twenty fruits from each genotype were weighed, the stones were removed, and the weights of the flesh and stones were measured separately and then calculated as a ratio (Öncül and Aygün, 2021).

Color Measurements: Fruit skin and flesh color measurements were conducted using a PCE Instruments Colorimeter (model PCE-CSM 1, Manchester, UK). Measurements were taken from two opposing points on the skin and flesh of each fruit. The color attributes *L** (lightness), *a** (red-green), *b** (yellow-blue), chroma (color saturation), and hue° (color angle) values were determined (Başaran et al., 2024).

Chemical Analyses: Soluble solids content (SSC) was measured at 20°C using an Abbe refractometer (Atago, Japan) after filtering the juice obtained from pulped fruit samples through a muslin cloth. The pH was measured at 20°C using a digital pH meter (Eutech, Singapore). Titratable acidity (TA) was determined by extracting 10 g of fruit pulp with distilled water to a volume of 100 mL, storing it overnight in a refrigerator, and filtering the extract. A 10 mL aliquot of the filtrate was titrated with 0.1 M NaOH solution until reaching pH 8.1, and the results were expressed as citric acid equivalents. Chemical analyses followed the methods described by Karadeniz et al. (2007).

Various statistical methods were applied to evaluate the data obtained from the study. Descriptive statistics (mean, standard deviation, minimum, and maximum values) were calculated using the Minitab 17 software (Minitab Inc., State College, PA, USA). Analysis of variance (ANOVA) was performed to determine differences among genotypes, and means were compared using Fisher's Least Significant Difference (LSD) test at $p < 0.05$. Pairwise Pearson correlation analysis was conducted to determine the relationships between the studied pomological traits, and principal component analysis (PCA) was applied to visualize these relationships. The correlation and PCA analyses were performed in RStudio (Version 2024.12.0+467) using the 'ggplot2', 'factoextra', 'FactoMineR', and 'corrplot' packages. A significance level of $p < 0.05$ was adopted for all statistical analyses (Zar, 2013).

RESULTS AND DISCUSSION

The descriptive statistics for the physico-chemical properties of the blackthorn genotypes, including minimum, maximum, mean, standard deviation, and coefficient of variation (CV), are presented in Table 1. The average fruit width was 11.70 mm, ranging from 7.95 mm to 14.12 mm. The CV value of 17.60% indicated significant variation in fruit width, suggesting a heterogeneous structure in terms of width among the fruits. The average fruit length was 13.26 mm, with a range of 10.49–14.63 mm. A lower CV value of 9.76% was observed for fruit length compared to width, indicating that the fruits were more homogeneous in terms of length. This difference is thought to be due to the nearly spherical characteristic shape of the fruits (Başaran et al., 2024). The average fruit weight was 2.42 g, ranging from 1.82 to 2.71 g. In a study conducted on blackthorn genotypes, the fruit weight varied between 1.31 g and 2.67 g (Bükücü et al., 2024). The CV value of 11.38% suggested moderate variation in fruit weight among the genotypes. Fruit size and weight are significant due to their direct impact on consumer preferences (Gorynska-Goldmann et al., 2023). Therefore, the selection and breeding of genotypes with superior and standardized traits in these aspects are crucial.

The fruit flesh-to-stone ratio is important as it represents the edible portion, which is significant for both fresh consumption and the processing industry to enhance yield (Delialioğlu et al., 2022). The average value obtained in this study was 5.36, with a high CV of 22.84% observed among the genotypes.

The mean skin *L** value was 18.51, ranging from 16.75 to 20.59. A low CV value of 7.52% indicated that the lightness of the fruit skin was relatively stable among the genotypes. The skin *a** value, representing redness, ranged from 2.26 to 2.53, with a mean value of 2.42. The low CV of 4.02% suggested high stability in redness among the genotypes. The skin *b** value, representing yellowness, ranged from 0.28 to 0.60, with a mean value of 0.45. A high CV of 20.93% indicated considerable variability in yellowness among the genotypes. The mean chroma value for the skin was 2.46, with a range of 2.30–2.55. The very low CV of 3.44% suggested a high degree of stability in color saturation. The mean hue° value for the skin was 9.91, ranging from 1.10 to 14.67. The hue° parameter exhibited the highest CV of 36.21%, making it one of the most distinctive traits among the genotypes. In a study conducted on blackthorn genotypes, Bükücü et al. (2024) reported that the pericarp color measurements showed *L** values ranging from 18.36 to 19.42, *a** values between 2.23 and 2.40, and *b** values varying between 0.16 and 0.54. The chroma values for pericarp color were calculated between 2.63 and 2.97.

The mean flesh *L** value was 18.84, ranging from 17.48 to 20.45. The low CV of 5.86% indicated stability in flesh lightness among the genotypes. The flesh a value had a mean of 3.65, ranging from 3.30 to 3.88. The low CV of 4.64% showed that redness was consistent among the genotypes. The flesh b value, representing yellowness, ranged from 0.57 to 0.84, with an average of 0.69. A CV of 11.98% indicated moderate variability in yellowness among the samples. The chroma values, which express flesh color saturation, ranged from 3.36 to 3.97, with a mean of 3.72. A low CV of 4.56% indicated high homogeneity in color saturation. The hue° values, representing the basic color tone of the flesh, ranged from 9.32 to 13.31, with an average of 10.71. The CV of 11.66% indicated moderate variability in flesh color tone among the samples. For pulp color measurements, Bükücü et al. (2024) found *L** values between 17.65 and 18.91, *a** values ranging from 3.11 to 4.18, and *b** values between 0.54 and 0.81. The chroma values for pulp color were calculated between 5.16 and 8.90.

Chemical properties, which are critical in determining flavor profiles, offer insights into fruit tolerance to stress factors, post-harvest physiology, and overall quality (Kumar et al., 2023; Erbaş et al., 2024). The total soluble solids (TSS) content showed considerable variation among the samples, ranging from 12.00% to 23.40% with an average of 19.05%. The high CV of 18.00% indicates significant variability in sugar content among the genotypes. These values were notably higher than those reported in previous research, where "total soluble solids values were found between 11.9% and 13.2% in 5 different blackthorn genotypes" (Bükücü et al., 2024). This difference in TSS ranges suggests that our genotypes might have greater potential for selections targeting higher sugar content, which could be valuable for both fresh consumption and processing purposes.

The pH values of the fruit samples showed remarkable consistency, ranging from 3.60 to 3.90, with an average of 3.77. The lowest CV value (2.28%) among all measured parameters indicated highly stable and uniform acidity levels across the samples. While our findings showed a narrow pH range, the pH of the blackthorn genotypes were determined between 3.35 and 4.22 (Bükücü et al., 2024), indicating a broader range of acidity in their study. The high stability in our samples suggests that the acid-base balance of the fruits is under tight genetic control and minimally influenced by environmental factors, providing an advantage for product quality and processing technology. This consistency in pH levels could be particularly beneficial for standardizing processing procedures and ensuring consistent product quality. Similarly, the titratable acidity (TA) values, with a low CV of 5.90%, ranged from 0.66% to 0.82%. These values were notably lower compared to previous research where titratable acid values of 5 blackthorn genotypes were found to be between 0.83 and 1.30 (Bükücü et al., 2024). These results, consistent with the pH findings, further supported the idea that the acid composition of the fruits is likely under genetic control and harvested at similar maturity levels. The stability observed in acidity parameters suggests that the fruits can provide a predictable and standardized quality in terms of flavor profile, storage life, and processing characteristics. The lower TA values in our study compared to previous findings might indicate genotypes with potentially more favorable taste characteristics for fresh consumption.

Ozzengin et al. (2023) reported the fruit weight, width, and length of wild-grown *P. spinosa* genotypes as 2.40 g, 12.66 mm, and 13.25 mm, respectively, closely aligning with the results of this study. They also found significant variations in skin L, a, and b values, ranging from 15.47–27.58, 2.59–7.04, and 1.77–6.55, respectively. Similarly, flesh L, a, and b values were reported in the ranges of 19.34–31.28, 0.98–5.32, and 4.86–14.59, respectively. The fruit flesh-to-stone ratio was reported as 4.91. İlhan (2023) reported TSS content ranging from 18.40% to 21.07% in eight blackthorn genotypes and identified citric acid as the dominant acid. In a study evaluating a larger population, pH values ranged from 3.17 to 4.13, and acidity from 0.86% to 4.26% (Kuru Berk et al., 2020). Previous studies have consistently reported that blackthorn fruits are characterized by their small size, bluish skin, yellowish flesh color, high soluble solids content, and high acidity (Claudia et al., 2017; Başaran et al., 2024). The results of this study are consistent with the literature. Although genotype is a major factor influencing the traits examined, variations in analysis methods, ecological differences in the selection area, harvest time and type, maturity period, and other factors significantly impact the final phytochemical composition of the fruits (Çalışkan et al., 2012; Polat et al., 2020; Bakoğlu et al., 2024).

According to Principal Component Analysis (PCA) results, while the first five principal components explain 93.68% of the total variance, PC1 accounts for 44% and PC2 accounts for 23.14% (Table 2). This indicates that a significantly high proportion of the variability in the dataset is represented. This ratio is substantially higher than the 69.19% (for the first three components) reported by İlhan (2023) and 63.50% (for the first three components) reported by Kuru Berk et al. (2020).

When examining PC1, which explains 44% of the total variance in our study, flesh/stone ratio (0.335), fruit width (0.334), and soluble solids content (0.334) showed the highest positive loadings, while titratable acidity (-0.301) exhibited the highest negative loading. In İlhan's (2023) study, PC1 explained variance with a lower ratio (36.05%), and fruit weight and SSC were positively effective. The strong relationship of PC1 with fruit characteristics in both studies aligns with Mertoğlu's (2022) findings indicating distinct variations in pomological characteristics.

Table 1. Descriptive statistics of physical, morphological and biochemical characteristics of P. spinosa genotypes

Variable	Abbreviation	Unit	Min.	Max.	Mean	±StDev	CV%
Fruit width	FW	mm	7.95	14.12	11.70	2.06	17.60
Fruit length	FL	mm	10.49	14.63	13.26	1.30	9.76
Fruit weight	FW	g	1.82	2.71	2.42	0.28	11.38
Flesh/seed ratio ratio	FFS	%	2.53	7.10	5.36	1.22	22.84
Peel *L**	PL	-	16.75	20.59	18.51	1.39	7.52
Peel *a**	Pa*	-	2.26	2.53	2.42	0.10	4.02
Peel *b**	Pb*	-	0.28	0.60	0.45	0.09	20.93
Peel Chroma	PCh	-	2.30	2.55	2.46	0.08	3.44
Peel Hue°	PHue	-	1.10	14.67	9.91	3.59	36.21
Flesh *L**	FL	-	17.48	20.45	18.84	1.10	5.86
Flesh *a**	Fa*	-	3.30	3.88	3.65	0.17	4.64
Flesh *b**	Fb*	-	0.57	0.84	0.69	0.08	11.98
Flesh Chroma	FCh	-	3.36	3.97	3.72	0.17	4.56
Flesh Hue°	FHue	-	9.32	13.31	10.71	1.25	11.66
Soluble solids	SS	%	12.00	23.40	19.05	3.43	18.00
pH	pH	-	3.60	3.90	3.77	0.09	2.28
Titratable acidity	TA	%	0.66	0.82	0.72	0.04	5.90

Significant differences were observed in the structure of PC2. In our study, while PC2 explained 23.14% of the variance, flesh hue° value (0.404), fruit skin b* value (0.402), and fruit skin hue° value (0.342) showed the highest positive loadings; fruit skin a* value (-0.342) and fruit skin chroma value (-0.297) exhibited the highest negative loadings. In contrast, PC2 (25.27%) in İlhan's (2023) study was more associated with biochemical properties (vitamin C, total phenolics, total anthocyanins, and citric acid). This difference may result from the growth of examined genotypes under different ecological conditions and the evaluation of different characteristics.

Table 2. PCA results and component loadings of the studied features.

Variable	PC1	PC2	PC3	PC4	PC5
Fruit width	0.334	0.144	0.115	-0.046	-0.021
Fruit length	0.177	-0.167	0.549	0.038	0.056
Fruit weight	0.304	0.117	0.114	-0.070	-0.160
Fruit flesh/seed ratio	0.335	0.146	0.139	-0.107	0.022
Peel *L**	-0.205	0.184	0.051	-0.320	0.534
Peel *a**	0.175	-0.342	0.033	0.333	0.328
Peel *b**	-0.132	0.402	-0.113	0.258	-0.111
Peel Chroma	0.174	-0.297	0.027	0.410	0.358
Peel Hue	-0.150	0.342	-0.148	0.052	0.085
Flesh *L**	0.216	-0.156	-0.170	0.192	-0.578
Flesh *a**	0.258	-0.034	-0.501	0.006	0.168
Flesh *b**	0.135	0.393	-0.010	0.375	0.107
Flesh Chroma	0.264	0.007	-0.491	0.049	0.170
Flesh Hue	0.036	0.404	0.200	0.397	0.050
Soluble solids content	0.334	0.138	0.061	-0.167	0.149
pH	0.324	0.179	0.176	-0.111	-0.035
Titratable acidity	-0.301	-0.065	0.136	0.389	-0.026
Eigenvalue	7.48	3.93	1.77	1.55	1.19
% of Variance	44.00	23.14	10.42	9.13	6.99
Cumulative %	44.00	67.13	77.56	86.69	93.68

The separation of genotypes into four different groups (those with larger fruits, sweeter ones, and those with higher polyphenolic compounds and antioxidant capacity) in İlhan's (2023) study is important in demonstrating the genetic diversity of the species and supports the high variation ratio (93.68%) observed in our study. These results emphasize the importance of evaluating both pomological and biochemical properties together in the characterization of P. spinosa genotypes.

The distribution of the genotypes based on their traits has been visualized using a Biplot, with the results presented in Figure 3. Based on the findings, it appears that the studied genotypes hold potential for evaluation across different intended uses.

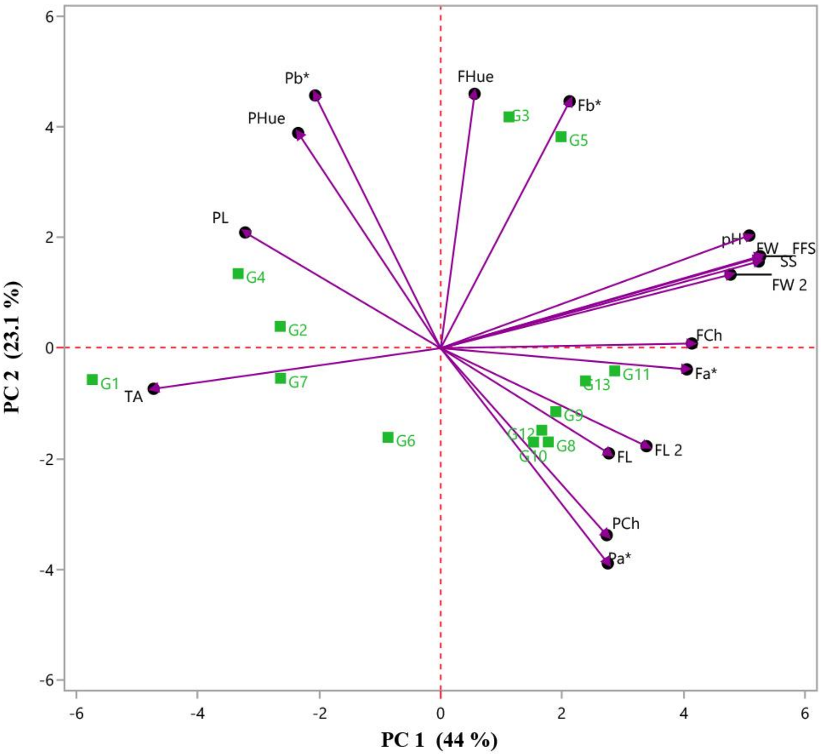

Figure 3. Biplot plot showing PCA results for studied fruit traits.

Genotype 1, characterized by its low pH (3.60) and high acidity (0.77%) (Table 3), is particularly suited for use in the processing industry. Acids that contribute to a low pH environment are known to inhibit the activity of harmful microorganisms responsible for spoilage, thereby aiding in the preservation of stability (Adamczak et al., 2019). Genotype 3, on the other hand, stands out for its large fruit size (13.88 g) and high fruit flesh-to-seed ratio (7.10) (Table 3), making it a potential parent for breeding programs aimed at developing new genotypes with larger fruit size and higher fruit flesh-to-seed ratios. Additionally, this genotype exhibits a high soluble solid content, rendering it particularly suitable for products such as marmalade and puree. An increase in soluble solids positively impacts product yield. One of the most significant advantages of selection studies is their potential to identify genotypes suitable for different purposes (Uzun et al., 2015; Dumanoglu et al., 2019).

The relationships among the traits investigated in blackthorn genotypes are presented in Figure 4. A positive correlation was identified between fruit width and length (r = 0.43). In plants, cell division increases following fertilization, which is subsequently followed by cell expansion. During the cell expansion phase, simultaneous transverse and longitudinal growth of the cells accounts for the strong correlation between these two traits (Sarıdas et al., 2017). The volumetric enlargement of cells that make up the fruit leads to an increase in fruit weight. In this context, strong positive correlations were observed between fruit weight and fruit width (r = 0.77) and length (r = 0.42), consistent with the literature (Eskimez et al., 2020).

The breakdown of organic acids in fruits results in an increase in pH values. Similarly, this study found a strong negative correlation (-0.80) between total titratable acidity (TEA) and pH, aligning with findings reported for apples by Mertoğlu and Evrenosoğlu (2019), who reported a similar relationship (-0.81).

The increase in pigments that impart color to fruits contributes to their darkening while simultaneously reducing their brightness. Therefore, a^* values of the fruit skin were found to be negatively correlated with L^* (-0.48) and b^* (-0.64) values. Positive correlations were identified between a^* values and fruit dimensions, as well as fruit weight, with correlation coefficients of 0.23, 0.52, and 0.15, respectively. A similar trend was observed for fruit flesh color. This relationship may be attributed to the ability of pigments to absorb higher levels of sunlight during photosynthesis.

Table 3. Fruit sizes, color values and chemical properties of fruit peel and flesh of *P. spinosa* genotypes.

Genotypes		G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	$LSD_{0.05}$
FW		8.12 ± 0.12 f	10.45 ± 0.14 e	13.88 ± 0.15 a	9.76 ± 0.13 e	14.12 ± 0.16 a	11.34 ± 0.14 d	7.95 ± 0.12 f	12.67 ± 0.15 b	12.85 ± 0.15 b	11.97 ± 0.14 cd	13.45 ± 0.15 ab	12.35 ± 0.14 bc	13.15 ± 0.15 ab	0.75
FL		11.23 ± 0.15 e	13.45 ± 0.16 c	14.63 ± 0.17 a	12.88 ± 0.15 d	10.49 ± 0.14 e	13.92 ± 0.16 bc	11.76 ± 0.15 e	14.15 ± 0.17 ab	13.95 ± 0.16 bc	14.23 ± 0.17 ab	13.75 ± 0.16 bc	14.15 ± 0.17 ab	13.85 ± 0.16 bc	0.52
FW		1.82 ± 0.08 e	2.45 ± 0.09 c	2.71 ± 0.10 a	2.15 ± 0.08 d	2.58 ± 0.09 ab	1.98 ± 0.08 de	2.33 ± 0.09 c	2.64 ± 0.10 a	2.55 ± 0.09 b	2.48 ± 0.09 bc	2.62 ± 0.10 ab	2.58 ± 0.09 ab	2.60 ± 0.09 ab	0.18
FFS		2.53 ± 0.11 g	4.86 ± 0.13 e	7.10 ± 0.15 a	3.92 ± 0.12 f	6.45 ± 0.14 b	5.23 ± 0.13 d	4.15 ± 0.12 ef	5.78 ± 0.13 c	5.95 ± 0.14 c	5.65 ± 0.13 cd	6.15 ± 0.14 bc	5.85 ± 0.13 c	6.05 ± 0.14 bc	0.45
Fruit peel color values	***L****	19.78 ± 0.25 bc	18.37 ± 0.24 cd	20.59 ± 0.26 ab	18.97 ± 0.24 c	18.59 ± 0.24 cd	20.12 ± 0.25 abc	19.96 ± 0.25 abc	19.31 ± 0.24 bc	17.25 ± 0.23 d	16.85 ± 0.22 d	16.95 ± 0.22 d	17.15 ± 0.23 d	16.75 ± 0.22 d	1.25
	a*	2.30 ± 0.08 d	2.26 ± 0.08 d	2.29 ± 0.08 d	2.46 ± 0.09 bc	2.31 ± 0.08 d	2.48 ± 0.09 bc	2.38 ± 0.08 cd	2.53 ± 0.09 ab	2.46 ± 0.09 bc	2.52 ± 0.09 ab	2.48 ± 0.09 bc	2.51 ± 0.09 ab	2.47 ± 0.09 bc	0.15
	b*	0.54 ± 0.05 bc	0.41 ± 0.04 cd	0.60 ± 0.05 ab	0.58 ± 0.05 ab	0.55 ± 0.05 bc	0.36 ± 0.04 d	0.47 ± 0.05 c	0.28 ± 0.04 e	0.44 ± 0.05 cd	0.38 ± 0.04 d	0.42 ± 0.05 cd	0.39 ± 0.04 d	0.43 ± 0.05 cd	0.12
	Chroma	2.36 ± 0.09 d	2.30 ± 0.08 d	2.37 ± 0.09 d	2.52 ± 0.09 bc	2.37 ± 0.09 d	2.51 ± 0.09 bc	2.42 ± 0.09 cd	2.54 ± 0.09 ab	2.49 ± 0.09 bc	2.55 ± 0.09 ab	2.52 ± 0.09 bc	2.53 ± 0.09 ab	2.51 ± 0.09 bc	0.14
	Hue°	13.20 ± 0.45 b	10.28 ± 0.38 c	14.67 ± 0.48 a	13.26 ± 0.45 b	13.39 ± 0.45 b	8.26 ± 0.32 d	11.17 ± 0.40 c	6.31 ± 0.28 e	1.10 ± 0.15 f	8.56 ± 0.32 d	9.62 ± 0.35 cd	9.10 ± 0.34 cd	9.85 ± 0.36 cd	1.85
Fruit flesh color values	***L****	18.32 ± 0.24 cd	18.37 ± 0.24 cd	17.96 ± 0.23 d	17.48 ± 0.23 d	18.67 ± 0.24 c	17.89 ± 0.23 d	18.16 ± 0.24 cd	17.51 ± 0.23 d	20.15 ± 0.26 a	19.85 ± 0.25 ab	20.45 ± 0.26 a	19.85 ± 0.25 ab	20.25 ± 0.26 a	1.15
	a*	3.47 ± 0.10 cd	3.30 ± 0.10 d	3.58 ± 0.10 bc	3.42 ± 0.10 cd	3.88 ± 0.11 a	3.62 ± 0.10 bc	3.78 ± 0.11 ab	3.70 ± 0.11 abc	3.66 ± 0.10 bc	3.75 ± 0.11 ab	3.82 ± 0.11 a	3.70 ± 0.11 abc	3.78 ± 0.11 ab	0.25
	b*	0.57 ± 0.05 e	0.62 ± 0.05 de	0.80 ± 0.06 ab	0.81 ± 0.06 ab	0.84 ± 0.06 a	0.62 ± 0.05 de	0.64 ± 0.05 de	0.63 ± 0.05 de	0.70 ± 0.06 cd	0.68 ± 0.06 cd	0.72 ± 0.06 bc	0.65 ± 0.05 de	0.69 ± 0.06 cd	0.12
	Chroma	3.52 ± 0.10 d	3.36 ± 0.10 d	3.67 ± 0.11 bc	3.52 ± 0.10 d	3.97 ± 0.11 a	3.67 ± 0.11 bc	3.83 ± 0.11 ab	3.75 ± 0.11 bc	3.72 ± 0.11 bc	3.81 ± 0.11 ab	3.89 ± 0.11 ab	3.76 ± 0.11 bc	3.85 ± 0.11 ab	0.24
	Hue°	9.32 ± 0.35 e	10.64 ± 0.38 de	12.60 ± 0.42 c	13.31 ± 0.43 bc	12.22 ± 0.41 cd	9.72 ± 0.36 e	9.61 ± 0.36 e	9.66 ± 0.36 e	10.85 ± 0.38 de	10.28 ± 0.37 de	10.65 ± 0.38 de	9.95 ± 0.36 e	10.42 ± 0.37 de	1.65
SS		12.0 ± 0.42 f	16.5 ± 0.48 cd	23.0 ± 0.58 a	14.8 ± 0.45 de	23.4 ± 0.58 a	19.7 ± 0.52 b	15.3 ± 0.46 de	21.8 ± 0.56 ab	20.51 ± 0.54 b	18.9 ± 0.51 bc	21.2 ± 0.55 ab	19.8 ± 0.52 b	20.8 ± 0.54 ab	2.85
pH		3.60 ± 0.08 e	3.75 ± 0.08 cd	3.90 ± 0.09 a	3.68 ± 0.08 de	3.85 ± 0.09 ab	3.72 ± 0.08 cd	3.65 ± 0.08 de	3.82 ± 0.09 abc	3.79 ± 0.08 bc	3.78 ± 0.08 bc	3.83 ± 0.09 abc	3.81 ± 0.09 abc	3.82 ± 0.09 abc	0.12
TA		0.77 ± 0.03 ab	0.75 ± 0.03 abc	0.70 ± 0.03 cd	0.82 ± 0.03 a	0.66 ± 0.03 d	0.72 ± 0.03 bcd	0.76 ± 0.03 abc	0.68 ± 0.03 d	0.71 ± 0.03 cd	0.73 ± 0.03 bcd	0.69 ± 0.03 d	0.72 ± 0.03 bcd	0.70 ± 0.03 cd	0.08

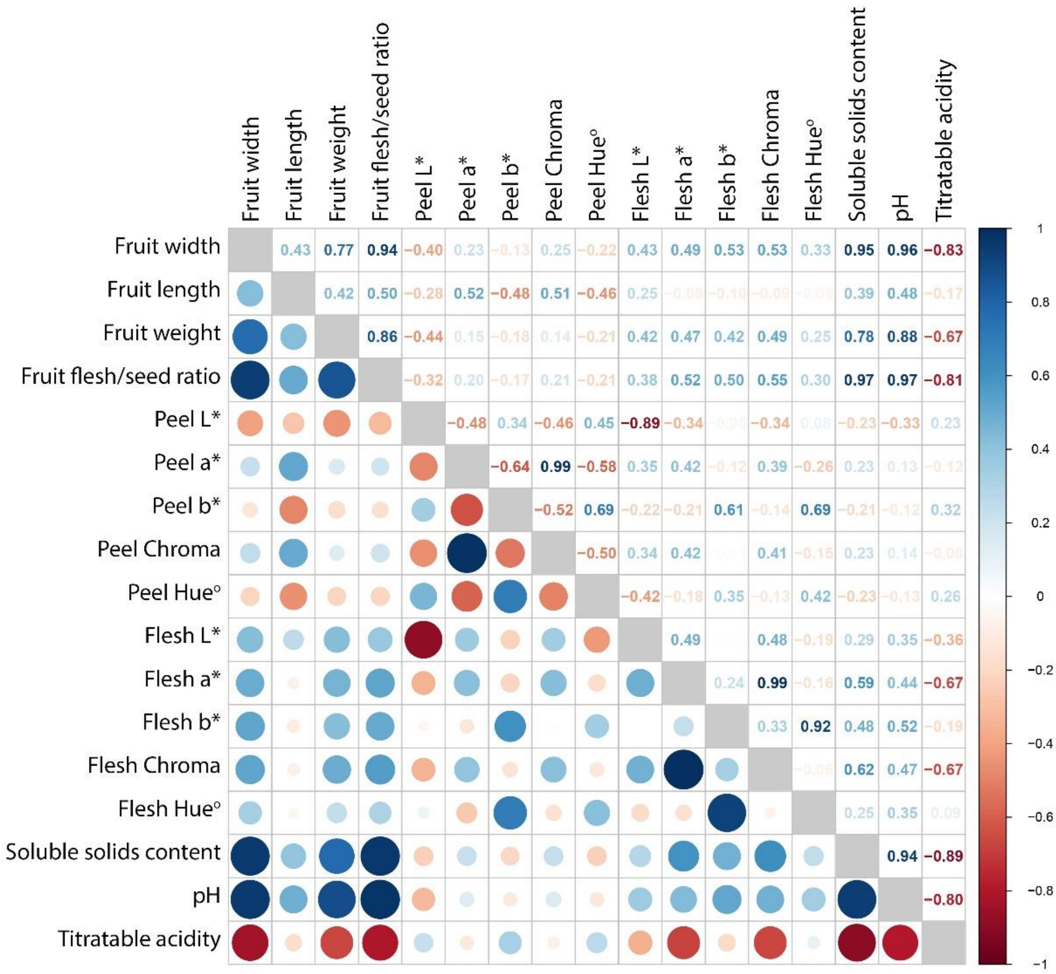

Figure 4. Correlation analysis of the examined features

CONCLUSION(S)

This study examined the physicochemical properties of *P. spinosa* L. genotypes from the Çivril district of Denizli province, revealing the diversity and potential of this species within the local ecosystem. Comprehensive analyses of the physical, morphological, and biochemical characteristics of the wild plum genotypes demonstrated that particularly the G3 and G5 genotypes stood out due to their high fruit pulp/seed ratio (7.10% and 6.45%, respectively), high soluble solid content (23.0% and 23.4%, respectively), and ideal fruit size (G3: 13.88×14.63 mm; G5: 14.12×10.49 mm). In the future, it is planned to protect these superior genotypes, subject them to further analyses, and transform them into value-added products. Furthermore, these genotypes are considered promising material for future commercial production and breeding studies.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author Contributions

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Article History	
Submission received:	27.12.2024
Received:	16.02.2025
Accepted:	19.12.2024

REFERENCES

Adamczak, A., Ożarowski, M., & Karpiński, T. M. (2019). Antibacterial activity of some flavonoids and organic acids widely distributed in plants. Journal of clinical medicine, 9(1), 109.

Atik, I., Karasu, S., & Sevik, R. (2022). Physicochemical and bioactive properties of cold press wild plum (*Prunus spinosa*) and sour cherry (*Prunus cerasus*) kernel oils: Fatty acid, sterol and phenolic profile. Riv. Ital. Sostanze Grasse, 991, 13-20.

Ayla, Ş., Günal, M. Y., Sayın Şakul, A. A., Biçeroğlu, Ö., Özdemir, E. M., Okur, M. E., ... & Bilgiç, B. E. (2017). Effects of *Prunus spinosa* L. fruits on experimental wound healing. Medeniyet medical journal, 32(3).

Bakoğlu, N., Tuna Gunes, N., & Akbulut, M. (2024). Some Physical and Chemical Changes in Kiwifruit During Two Different Growth and Development Seasons. Applied Fruit Science, 1-11.

Başaran, T., Gür, E., Yılmaz, N., & Gündoğdu, M. A. (2024). Çanakkale Doğal Florasında Yayılış Gösteren Güvem Eriği (*Prunus spinosa* L.)'nin Pomolojik Özelliklerinin Belirlenmesi. Bahçe, 53(Özel Sayı 1), 276-280.

Başkaya Sezer, D., Erdoğan Tokatlı, K., & Demirdöven, A. (2016). Çakal Eriği ve Yonuz Eriği Marmelatları. Journal of Agricultural Faculty of Gaziosmanpasa University/Gazi Osman Pasa Üniversitesi Ziraat Fakültesi Dergisi, 33(1).

Baytop, T. (1997). Türkçe Bitki Adları Sözlüğü, TDK yayınları 578 s.

Baytop, T. (1999). Türkiye'de Bitkiler ile Tedavi. 2. baskı. Nobel Tıp Kitabevleri, İstanbul, 340.

Bei, M. F., Apahidean, A. I., Budău, R., Rosan, C. A., Popovici, R., Memete, A. R., ... & Vicas, S. I. (2023). An Overview of the Phytochemical Composition of Different Organs of *Prunus spinosa* L., Their Health Benefits and Application in Food Industry. Horticulturae, 10(1), 29.

Bükücü, Ş. B., Süslüoğlu, Z., Özcan, A., Kafkas, N. E. Y., & Sütyemez, M. (2024). Determination of chemical composition of some blackthorn genotypes (*Prunus spinosa* L.). Journal of Agriculture Faculty of Ege University, 61(4), 401-412.

Caliskan, O., Bayazit, S., & Sumbul, A. (2012). Fruit quality and phytochemical attributes of some apricot (*Prunus armeniaca* L.) cultivars as affected by genotypes and seasons. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 40(2), 284-294.

Claudia, G.C.F., I.M. Elena & C.S. Niculina, 2017. Some fruit characteristics of blackthorn (*Prunus spinosa* L.). Annals of The University of Craiova, Vol. 22 (58): 129-136.

Delialioğlu, R. A., Dumanoğlu, H., Erdoğan, V., Dost, S. E., Kesik, A., & Kocabaş, Z. (2022). Multidimensional scaling analysis of sensory characteristics and quantitative traits inwild apricots. Turkish Journal of Agriculture and Forestry, 46(2), 160-172.

Dumanoglu, H., Erdogan, V., Kesik, A., Dost, S. E., Delialioglu, R. A., Kocabas, Z., ... & Bakir, M. (2019). Spring late frost resistance of selected wild apricot genotypes (*Prunus armeniaca* L.) from Cappadocia region, Turkey. Scientia Horticulturae, 246, 347-353.

Erbas, D., Mertoglu, K., Eskimez, I., Polat, M., Koyuncu, M. A., S. Durul, M., ... & Esatbeyoglu, T. (2024). Preharvest salicylic acid and oxalic acid decrease bioactive and quality loss in blackberry (cv. Chester) fruits during cold storage. Journal of Food Biochemistry, 2024(1), 4286507.

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

Gorynska-Goldmann, E., Murawska, A., & Balcerowska-Czerniak, G. (2023). Consumer profiles of sustainable fruit and vegetable consumption in the European Union. Sustainability, 15(21), 15512.

Gülay, M. (2023). Orijin, Ön İşlem ve Sıcaklığının Çakal Eriği (*Prunus spinosa*) Tohumlarının Çimlenmesine Etkisi. 3. Uluslararası Lisansüstü Çalışmalar Kongresi. s370-376

Gülsoy, E., Kaya, T., Pehluvan, M., Doğru Çokran, B. (2016). Textural and physicochemical characteristics of Şalak (Apricose) apricot cultivar. VII. International scientific agriculture symposium (AgroSim), Jahorina, Bosna and Herzegovina, 6-9 October 2016, 1092-1098.

İlhan, G. (2023). Sensory Evaluation, Biochemical, Bioactive and Antioxidant Properties in Fruits of Wild Blackthorn (*Prunus spinosa* L.) Genotypes from Northeastern Türkiye. Horticulturae, 9(9), 1052.

Karadeniz, T., Deligöz, H., Corumlu, M. S., Şenyurt, M., & Bak, T. (2007). Selection of native cornelian cherries grown in Çorum (Turkey). In I Balkan Symposium on Fruit Growing 825 (pp. 83-88).

Karakas, N., Okur, M. E., Ozturk, I., Ayla, S., Karadag, A. E., & Polat, D. Ç. (2019). Antioxidant activity of blackthorn (*Prunus spinosa* L.) fruit extract and cytotoxic effects on various cancer cell lines. Medeniyet Medical Journal, 34(3), 297.

Kirca, L., Karadeniz, T. Histological Investigation of the Compatibility of *Prunus spinosa* as Interstock with Almond Cultivars. Applied Fruit Science 66, 1305–1316 (2024). https://doi.org/10.1007/s10341-024-01123-7

Kotsou, K., Stoikou, M., Athanasiadis, V., Chatzimitakos, T., Mantiniotou, M., Sfougaris, A. I., & Lalas, S. I. (2023). Enhancing Antioxidant Properties of *Prunus spinosa* Fruit Extracts via Extraction Optimization. Horticulturae, 9(8), 942.

Kumar, S., Bhushan, B., Wakchaure, G. C., Dutta, R., Jat, B. S., Meena, K. K., ... & Pathak, H. (2023). Unveiling the impact of heat stress on seed biochemical composition of major cereal crops: Implications for crop resilience and nutritional value. Plant Stress, 9, 100183.

Kurnaz, O. C., Ozturk, A., Faizi, Z. A., Ates, U., & Ozturk, B. (2024). Pomological, bioactive compounds, and antioxidant activity of selected superior genotypes from a highly diversified loquat population. Genetic Resources and Crop Evolution, 71(4), 1507-1520.

Kuru Berk, S., Tas, A., Orman, E., Gundogdu, M., Necas, T., Ondrasek, I., Karatas, N., & Ercisli, S. (2020). Agro-morphological and biochemical characterization of wild *Prunus spinosa* L. subsp. *dasyphylla* (schur) domin genotypes naturally grown in western black sea region of Turkey. Agronomy, 10(11), 1748.

Mertoğlu, K. & Evrenosoğlu, Y. (2019). Bazı elma ve armut çeşitlerinde fitokimyasal özelliklerin belirlenmesi. Ziraat Fakültesi Dergisi, 14(1), 11-20.

Mertoğlu, K. (2022). Investigation of genetic parameters and phytochemical characteristics in plum under altitude change. Genetika, 54(1), 73-89.

Milosevic, T., Milošević, N., & Glišić, I. (2015). Einfluss einer Zwischenveredlung mit Schlehe (*Prunus spinosa* L.) auf das vegetative und generative Wachstum von Aprikosen. Erwerbs-Obstbau, 57, 77-91.

Negrean, O. R., Farcas, A. C., Pop, O. L., & Socaci, S. A. (2023). Blackthorn-A Valuable Source of Phenolic Antioxidants with Potential Health Benefits. Molecules, 28(8), 3456.

Ozzengin, B., Zannou, O., & Koca, I. (2023). Quality attributes and antioxidant activity of three wild plums from *Prunus spinosa* and *Prunus domestica* species. Measurement: Food, 10, 100079.

Öncül, C., & Aygün, A. (2021). Giresun ve ilçelerinde yetiştirilen yerel erik çeşitlerinin pomolojik ve morfolojik özeliklerinin belirlenmesi. Ziraat Mühendisliği, (372), 101-115.

Özer, S., Atabeyoğlu, Ö., & Zengin, M. (2009). "*Prunus spinosa* L." (Çakal Eriği)'nin Peyzaj Mimarlığı Çalışma Sahasında Kullanım Olanakları. Journal of Agricultural Faculty of Gaziosmanpaşa University (JAFAG), 2009(2), 1-7.

Polat, M., Mertoglu, K., Eskimez, I., & Okatan, V. (2020). Effects of the fruiting period and growing seasons on market quality in goji berry (L.). Folia Horticulturae, 32(2), 229-239.

Sabatini, L., Fraternale, D., Di Giacomo, B., Mari, M., Albertini, M. C., Gordillo, B., ... & Colomba, M. (2020). Chemical composition, antioxidant, antimicrobial and anti-inflammatory activity of *Prunus spinosa* L. fruit ethanol extract. Journal of Functional Foods, 67, 103885.

Sarıdas, M. A., Kapur, B., Çeliktopuz, E. & Kargı, S. P. (2017). Irrigation regimes and bio-stimulant application effects on fruit quality features at 'Rubygem' strawberry variety. Turkish Journal of Agriculture-Food Science and Technology, 5(10), 1221-1227.

Sarıkaya, S., Öner, H., & Harput, Ü.Ş. (2010). Türkiye Florasında Diyabet Tedavisinde Kullanılan Tıbbi Bitkiler. Ankara Ecz. Fak. Derg. 39 (4) 317-342, 2010

TSMS. (2024). Turkish State Meteorological Service. https://www.mgm.gov.tr/eng/forecast-cit-ies.aspx. Accessed November 25, 2024.

Uzun, A., Celik, B., Karadeniz, T., Yılmaz, K. U., & Altıntaş, C. (2015). Assessment of fruit characteristics and genetic variation among naturally growingwild fruit Elaeagnus angustifolia accessions. Turkish Journal of Agriculture and Forestry, 39(2), 286-294.

Wikipedi. (2024, 28 November). Çivril. https://tr.wikipedia.org/wiki/Çivril

Zar, J. H. (2013). Biostatistical Analysis. Pearson Higher Ed, UK.