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Physico-Chemical Characterization of Some Naturally Grown Apricot Genotypes

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Abstract

The degradation of natural ecosystems under global climate change, coupled with increasing population pressures, results in a narrowing of genetic resources while exacerbating biotic and abiotic stress factors, thereby limiting plant production. In this context, the thorough exploration, comprehensive characterization, and effective conservation of genetic resources have gained significant importance, serving as crucial steps in preserving biodiversity and supporting sustainable utilization strategies. In this study, twelve apricot genotypes of seed origin from various provinces were characterized in terms of several physico-chemical properties in 2023 and 2024. The traits examined showed significant differences among the genotypes, with variation coefficients ranging from 11.18% (fruit length) to 52.78% (ripening index). The fruit width, length, and weight varied from 24.01 to 39.99 mm, from 27.41 to 40.36 mm, and from 9.58 to 33.01 g, respectively. Seed adhesion was not observed in the ten genotypes, while the a* value of the upper skin color ranged from 4.66 to 14.17. Seed weight positively contributed to the improvement of pomological characteristics, while reducing biochemical accumulation. Genotypes 1 and 3, which are prominent for their large fruit size and relatively low soluble solid content, seem promising for fresh consumption. In contrast, Genotypes 2, 4, and 5, with their high acidity, may be suitable for industrial applications.

Keywords: Diversity, selection, principal component analysis, wild apricot, *Prunus armeniaca* L.

Doğal Olarak Yetişen Bazı Kayısı Genotiplerinin Fiziko-Kimyasal Karakterizasyonu

Özet

Doğal ekosistemin, küresel iklim değişikliği altında artan nüfusla tahribatı, gen havuzunda daralmalara sebep olurken, biyotik ve abiyotik stres faktörlerinde artışa sebep olarak, bitkisel üretimi sınırlandırmaktadır. Bu bağlamda, genetik materyalin derinleştirilmesi, karakterize edilmesi ve korunması oldukça kıymetli hale gelmektedir. Bu çalışma kapsamında, 2023 ve 2024 yıllarında farklı illeri kapsayan tohum kökenli on iki kayısı genotipi bazı fiziko-kimyasal özellikler yönüyle karakterize edilmiştir. İncelenen özellikler genotipler arasında önemli farklılıklar gösteriken, varyasyon katsayıları %11,18 (meyve uzunluğu) ile %52,78 (olgunluk indisi) arasında değişim göstermiştir. Genotiplerde, meyve eni, meyve boyu ve meyve ağırlığı özellikleri sırası ile 24,01–39,99 mm, 27,41–40,36 mm ve 9,58–33,01 g aralıklarında değişim göstermiştir. On genotipte çekirdek bağlılığı gözlemlenmezken, üst kabuk rengine ait a* değeri 4,66 ile 14,17 sınırları içerisinde bulunmuştur. Çekirdek ağırlığı, meyve pomolojik özelliklerinin iyileşmesine pozitif katkılar sağlarken, biyokimyasal birikimi azaltmaktadır. Yüksek meyve iriliği ve nispeten düşük kuru madde birikimi yönleriyle ön plana çıkan 1 ve 3 numaralı Genotipler taze tüketime yönelik ümitvar görülürken; 2, 4 ve 5 numaralı Genotipler ise sahip oldukları yüksek asitlik sayesinde, sanayiye uygunluk taşıyor olabilirler.

Anahtar kelimeler: Çeşitlilik, seleksiyon, temel bileşen analizi, zerdali, *Prunus armeniaca* L.

Introduction

The apricot, classified within the Rosaceae family and the *Prunus* genus, is predominantly cultivated as the species *Prunus armeniaca*, which represents the most widely grown type. Renowned for its unique aroma, the apricot is not only consumed fresh but also extensively utilized in various industrial applications, with its fruit and other parts integrated into a wide range of products (Al-Soufi et al., 2022; Karadağ and Omarova, 2024). In contemporary societies, increasing awareness of health and nutrition has led to a rising interest in nutrient-rich foods. Apricot is distinguished among these products by its high concentrations of bioactive compounds, including vitamins, minerals, polyphenols, and organic acids, all of which exhibit significant antioxidant properties (Doğan et al., 2023; Sarıdaş et al., 2024). This potent antioxidant activity has been linked to a reduced risk of numerous chronic diseases, including microbial infections, cancer, and cardiovascular disorders (Erdogan-Orhan and Kartal, 2011; Siddiqui et al., 2023; Aydın et al., 2024). Thus, the apricot holds considerable importance not only as a nutritional resource but also for its potential contributions to health protection.

Apricot has witnessed increasing global demand, positioning Turkey as the world's largest producer (803,000 tons) and the leading exporter (Fresh: 97,000 tons; Dried: 74,500 tons) (FAO, 2022). Despite this prominence, the desired export potential for table apricot cultivation has not been fully achieved. This limitation is primarily attributed to factors such as the predominance of dried apricot varieties, adaptation challenges of foreign cultivars, short postharvest shelf life, self-incompatibility in local cultivars, high chilling, and constraints in achieving desired quality standards (Özen and Gül, 2020; Poyraz and Gül, 2022).

Turkey, owing to its geographical location, geomorphological structure, and the influence of diverse climatic conditions, is one of the world's richest countries in terms of plant diversity. Although Turkey is not the primary center of origin for apricot, it is recognized as a secondary center of origin due to its location within the boundaries of the Asian and Mediterranean gene centers (Vavilov, 1951). Apricot cultivation is economically viable across most regions of the country, with the exception of the Eastern Black Sea Region, characterized by high humidity, and the high altitudes of Eastern Anatolia, where harsh winter conditions prevail. Furthermore, Turkey's genetic diversity in apricot is remarkably high. To harness this diversity, selection studies have been conducted in various regions, leading to the detailed characterization of local apricot genotypes (Balta et al., 2002; Çetinbaş et al., 2016; Dumanoglu et al., 2019).

Global challenges, particularly those linked to climate change, have reaffirmed the critical importance and value of genetic resources. Projections suggest that in the near future, 20% of global biodiversity could be lost due to pollution resulting from human activities and the persistent, improper exploitation of natural resources (Çepel, 2002). Within this framework, the identification, characterization, and conservation of existing genetic resources are paramount. The development of genotypes with high adaptability that fulfill both producer and consumer demands is contingent upon the integration of genetically diverse genotypes into breeding programs. Such programs are designed to cross promising genotypes, characterized alongside existing cultivars, with the goal of developing new varieties exhibiting superior traits tailored to diverse objectives (Bilgin et al., 2016; Asma et al., 2017; Bircan et al., 2023).

This study investigated the pomological and chemical characteristics of fruits harvested from ten seed-originated genotypes collected from diverse regions. The primary objective was to evaluate their potential for various applications, including fresh consumption and industrial processing.

Material and Methods

The current study was conducted in 2023 and 2024 using seed-originated apricot genotypes grown in Senirce (three genotypes in 2023, two genotypes in 2024) and Baladız (one genotype in 2023 and two genotypes in 2024) villages of Isparta, and in Karayakuplu (two genotypes in 2024) village of Usak. The fruits were harvested at commercial maturity, with taste and color development serving as the harvest criteria (Zhebentyayeva et al., 2012). The harvested fruits were transported to the laboratory without delay using portable coolers.

Determination of some pomological characteristics

To determine the fruit weight, the harvested fruits were individually weighed using a sensitive balance with a precision of 0.01 g, and the average fruit weight was calculated. The fruit's length and width were measured using a digital caliper with a sensitivity of 0.01 mm, and average values were recorded (Aydın, 2019; Altan, 2019). The fruit length-to-width ratio was calculated by dividing the measured length by the width, and the average of all measurements was taken (Doğru Çokran, 2020). Fruit flesh firmness was determined using an 8 mm-tipped handheld penetrometer, and the average of the values obtained from two opposite points on each fruit was calculated, and the results obtained were expressed in kg cm^{-2}. Subsequently, the seeds were removed from the fruits, and both the seed and fruit flesh were weighed separately, with the seed-to-flesh ratio calculated (Aydın, 2019). The upper skin color of the fruits was determined by a colorimeter, with readings recorded in terms of L*, a*, and b* (Karaçalı, 1990). The separation of the seed from the fruit flesh was identified during fruit dissection and classified as freestone, semi-freestone, or clingstone according to Aydın (2019).

Determination of some chemical characteristics

The remaining fruits after the pomological measurements were converted into fruit juice using a hydraulic fruit juice press and filtered through Whatman filter paper for chemical analysis. The soluble solid content (SSC) was measured using a digital refractometer, and the results were expressed as percentages (%) (Aydın, 2019). A portion of the filtered fruit juice was placed in a beaker, and the electrode of a pH meter was immersed in the juice. The stabilized value was recorded as the pH (Karaçalı, 1990). To determine the fruit's titratable acidity content (TA), 3-4 drops of phenolphthalein were added as an indicator to 10 ml of fruit juice. During titration, the total acidity was calculated by noting the consumption amount at the point where the color change became permanent, and the result was expressed as a percentage, based on the calculation of malic acid according to Karaçalı (1990). The ripening index was calculated by dividing the total SSC in the fruit juice by the total acid content (Ahı, 2017).

Statistical analysis

The research was conducted using a randomized design. Pomological measurements were performed on twenty-five fruits taken from each of the four directions of the tree (a total of one hundred fruits per genotype). For chemical analyses, all fruits from each genotype were separately converted into fruit juice, and the results were obtained. For the traits examined, a one-way analysis of variance (ANOVA) was conducted using the Minitab-17 software, and Tukey's multiple comparison test was applied to evaluate the differences. Bi-plot and correlation plots were generated using the R statistical software (Zar, 2013).

Results and Discussion

Fruit weight, dimensions, and firmness

Fruit weight varies between 9.58 g and 33.01 g, with a mean of 18.33 g (Table 1). This indicates significant weight variation within the sample, suggesting diversity in fruit size. Fruit dimensions, including fruit width (ranging from 24.01 mm to 39.99 mm) and fruit length (ranging from 27.41 mm to 40.36 mm), further highlight morphological variability. The mean fruit width is 32.61 mm, and the average length is 32.3 mm (Table 1). Fruit flesh firmness is crucial for consumption characteristics and processability. It ranges from 1.81 kg cm^{-2} to 3.62 kg cm^{-2}, with a mean of 2.65 kg cm^{-2} (Table 1).

Table 1. Descriptive statistics for physco-chemical characteristics investigated
Tablo 1. İncelenen fiziko-kimyasal özelliklere ilişkin tanımlayıcı istatistikler

	Unit	Minimum	Maximum	Mean$^{\pm StDev}$	CV (%)
Fruit Weight	g	9,58	33,01	18,33±6,68*	36,44
Fruit Width	mm	24,01	39,99	32,61±5,92*	18,14
Fruit Length	mm	27,41	40,36	32,30±3,61*	11,18
Stone Weight	g	0,84	2,86	1,64±0,65*	39,82
Pulp/Stone Ratio	%	8,72	17,97	11,53±2,56*	22,18
Endocarp adhesion	-	Freestone	Clingstone	Mostly freestone	
SSC	%	14,40	24,10	17,96±3,03*	16,87
TA	%	0,53	2,43	1,39±0,54*	38,97
pH	-	3,16	4,50	3,80±0,44*	11,65
Ripening Index	-	6,41	31,29	15,44±8,15*	52,78
Fruit Flesh Firmness	kg cm^{-2}	1,81	3,62	2,65±0,58*	21,86
L*	-	44,42	70,73	58,52±8,15*	13,93
a*	-	4,66	14,17	8,13±2,49*	30,56
b*	-	32,47	51,05	40,07±5,56*	13,87

StDev: Standart deviation; CV: Coefficient of variation; *Means statistical difference among genotypes, ns: non-significant
StDev: Standart sapma; CV: Değişim katsayısı; *Genotipler arasındaki istatistiksel fark anlamına gelir, ns: anlamlı değil.

This indicates significant weight variation within the sample, suggesting diversity in fruit size. Fruit dimensions, including fruit width (ranging from 24.01 mm to 39.99 mm) and fruit length (ranging from 27.41 mm to 40.36 mm), further highlight morphological variability. The mean fruit width is 32.61 mm, and the average length is 32.3 mm (Table 1). Fruit flesh firmness is crucial for consumption characteristics and processability. It ranges from 1.81 kg/cm^2 to 3.62 kg/cm^2, with a mean of 2.65 kg/cm^2 (Table 1).

Stone weight and flesh-to-seed ratio

Seed weight varies between 0.84 g and 2.86 g, with an average of 1.64 g. The variability in seed weight suggests differences in seed structure and size across fruits of genotypes. Additionally, the flesh-to-seed ratio ranges from 8.72% to 17.97%, with an average of 11.53% (Table 1). A higher flesh-to-seed ratio is indicative of greater edible content in the fruit, which is an important factor in determining fruit productivity and consumer preference. Fruits with higher flesh-to-seed ratios are generally considered more desirable due to their higher market value and more usable parts.

Soluble solid content (SSC), pH, and ripening index

The SSC, which is a key indicator of sweetness and organoleptic properties, ranges from 14.4% to 24.1%, with an average of 17.96%. This range suggests that the fruits exhibit significant variation in sweetness, which may be influenced by genetic factors. The coefficient of variation (CV) for SSC is 16.87%, indicating moderate variability. TA ranges from 0.53% to 2.43%, with an average of 1.39%, and a CV of 38.97%, indicating high variability in fruit acidity. This variation plays a significant role in the fruit's flavor profile, as the acidity directly influences the balance between sweetness and tartness. The pH value ranges from 3.16 to 4.50, with an average of 3.80. This pH level reflects the fruit's acidic nature, an important characteristic for flavor and storage. The ripening index, which characterizes the degree of fruit ripeness, varies from 6.41 to 31.29, with an average of 15.44. The ripening index's high coefficient of variation (52.78%) suggests significant variation in the ripening stages within the sample, highlighting the influence of genetic differences in ripening patterns.

Color characteristics

Fruit color parameters are important determinants of consumer preference, as they directly affect the fruit's aesthetic appeal. The L* value (lightness) ranges from 44.42 to 70.73, with an average of 58.52, indicating significant variation in the brightness of the fruits. The a* value (red-green spectrum) ranges from 4.66 to 14.17, averaging 8.13, suggesting variability in the fruits' red and green tones. This variability could be attributed to both genetic traits and environmental conditions. The b* value (yellow-blue spectrum) ranges from 32.47 to 51.05, with an average of 40.07. This parameter reflects the degree of yellowing in the fruits, which typically increases as the fruit ripens. The b* value suggests that the fruits in the sample display various degrees of ripeness, with a noticeable yellowing trend.

Endocarp adhesion

The sample predominantly consists of freestone fruits, but some fruits exhibit clingstone characteristics. Endocarp adhesion is an important factor for processing and consumption, as it affects the ease with which the stone can be separated from the flesh. Freestone fruits are generally more desirable for both industrial processing and direct consumption, as they facilitate easier extraction of the seed. In contrast, clingstone fruits require more effort to remove the stone, which can be a disadvantage for both consumer preference and industrial use.

In a study conducted by Aydın (2019) on 37 apricot genotypes in Antakya, fruit weights were found to range between 18.36 g and 66.64 g, while TSS (total soluble solids) values varied from 10.57% to 25.56%. Seed weights were determined to be between 1.60 g and 3.92 g (Aydın, 2019). Similarly, in a study by Doğru Çokran (2020) conducted in Iğdır and Kars, fruit weight ranged from 28.60 g to 81.30 g, fruit length from 44.45 mm to 63.04 mm, fruit width from 34.54 mm to 54.01 mm, seed weight from 1.80 g to 3.5 g, and fruit flesh firmness from 1.22 kg cm^{-2} to 4.25 kg cm^{-2}. TSS was measured between 9.90% and 17.00%, while pH and TA were found to range from 3.79 to 5.36 and 0.33% to 0.94%, respectively. In a study conducted by Bircan et al. (2023) on the apricot collection plot at the Alata Horticultural Research Institute, fruit weight ranged between 20.33 g and 51.60 g, kernel weight between 2.47 g and 4.57 g, fruit width between 28.08 mm and 44.94 mm, and fruit length between 27.92 mm and 49.74 mm. The fruit flesh/kernel ratio was calculated to range from 6.39 to 16.49, while fruit flesh firmness varied between 0.24 kg cm^{-2} and 2.8 kg cm^{-2}. Among the chemical properties, TSS and TA values varied from 9.4% to 17.3% and 0.82% to 1.76%, respectively.

The findings of the present study align with the previously reported bioactive profiles of apricot varieties/genotypes. While the observed variations are primarily attributed to genetic differences among the examined genotypes, several additional factors significantly influence the final physico-chemical characteristics of the fruits. These include methodological discrepancies in analytical procedures, ecological variations in the selection area, differences in harvest time and technique, and the stage of fruit maturity (Kulaitiene et al., 2020; Kırca et al., 2023; Kurnaz et al., 2024; Mertoğlu et al., 2024).

In the study, the distribution of physico-chemical properties across genotypes was analyzed using principal component analysis, and the bi-plot graph, drawn based on the first two components, is presented in Figure 1. This method is widely employed in agricultural studies for purposes such as assessing the effects of cultivation practices, adaptation, and selection breeding (Kırca et al., 2023; Erbas et al., 2024; Mertoğlu et al., 2024). Based on the results, it was determined that apricot genotypes have the potential for use in various applications. Genotypes 1 and 3, characterized by their larger fruit size and relatively low SSC, appear promising for fresh consumption. In contrast, Genotypes 2, 4, and 5, with their high acidity, may be more suitable for industrial applications.

As is well known, organic acids aid in preserving product stability by inhibiting microbial activity (Tejero-Sarinena et al., 2012). Additionally, acidic environments enhance the synthesis of phenolic compounds, which have high antioxidant activity (Mertoğlu and Evrenosoğlu, 2019). This group also stands out for its superior pigment accumulation. All genotypes, due to their advantageous traits, could serve as potential parents in breeding programs aimed at developing new superior cultivars for specific traits.

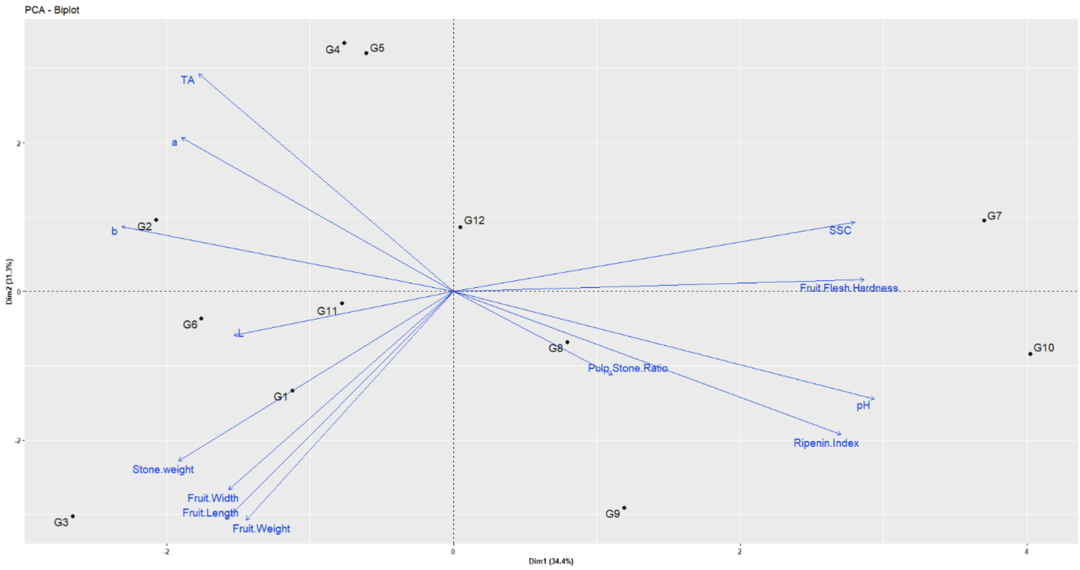

Figure 1. Distribution of Genotypes (G) Based on the Investigated Traits
Şekil 1. Araştırılan Özelliklere Göre Genotiplerin (G) Dağılımı

Understanding the relationships between different traits is crucial, especially for estimating unknown characteristics using known correlations. Such knowledge significantly benefits cultivation and breeding programs, offering opportunities to save time and resources. In this context, the correlation coefficients among the evaluated traits are presented in Figure 2. A strong positive correlation was observed between fruit width and length (r = 0.74). In plants, post-fertilization development typically involves an initial increase in cell number, followed by cell enlargement. During this phase, the simultaneous expansion of cells in both directions width and length accounts for the strong association between these two traits. Cell volume growth within the fruit structure also directly influences fruit weight. Accordingly, strong positive correlations were identified between fruit weight and fruit width (r = 0.69) and between fruit weight and fruit length (r = 0.96). These findings align with previous studies on apricots and other species, which consistently reported strong associations among fruit weight, width, and length (Caliskan et al., 2012; Kırca and Aygün, 2024; Mertoğlu et al., 2024; Kurnaz et al., 2024). Seeds serve as a major source of growth hormones, such as auxins, cytokinins, and gibberellins, which play a critical role in fruit development. These hormones promote cell division and expansion, thereby positively influencing fruit size. Additionally, they enhance the transport of essential nutrients into the fruit, further contributing to its growth (Ozga and Reinecke, 2003). In this study, an increase in seed weight was strongly associated with increases in fruit width (r = 0.64), fruit length (r = 0.78), and fruit weight (r = 0.82). Similar results were reported by Asma and Ozturk (2005), who noted that pomological traits in apricots tend to align closely with variations in seed weight. These findings emphasize the significant role of seeds in determining fruit morphology and quality.

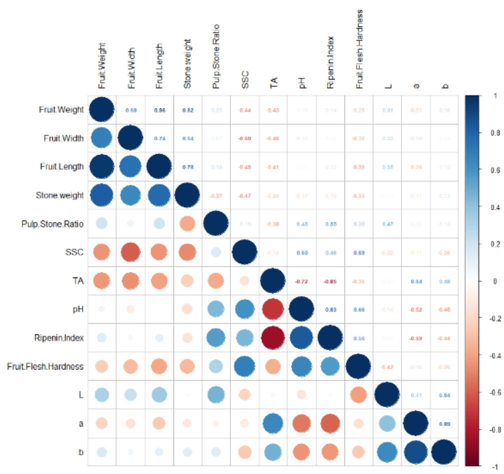

Figure 2. Correlation Coefficients Among the Investigated Traits
Şekil 2. İncelenen Özellikler Arasındaki Korelasyon Katsayıları

Increases in fruit volume and weight result in greater intercellular space, thereby reducing the concentration of accumulated substances per unit area (Eskimez et al., 2020). Consequently, the pomological and chemical traits of fruits are often reported to exhibit inverse relationships (Radunic et al., 2015). The findings of this study support this observation, revealing negative correlations between fruit weight, width, and length with both SSC (r = -0.44, r = -0.60, and r = -0.45, respectively) and fruit flesh firmness (r = -0.25, r = -0.32, and r = -0.39, respectively). Similarly, the a* value, which indicates the accumulation of pigmentation, was negatively associated with fruit width (r = -0.15), length (r = -0.26), weight (r = -0.21), and firmness (r = -0.16). These inverse relationships are likely due to the simultaneous synthesis of pigments and the enhancement of physical fruit traits during the photosynthetic process (Eskimez et al., 2020). The results align with existing literature (Saridaş et al., 2016; Kurnaz et al., 2024).

The breakdown of organic acids, which release H+ ions, leads to an increase in pH values. In this study, a strong negative correlation was observed between pH and TA (r = -0.72), consistent with this phenomenon. This negative relationship between pH and TA has been consistently reported across various fruit species (Serçe et al., 2011; Mertoğlu and Evrenosoğlu, 2019; Kırca and Aygün, 2024).

Conclusion and Reccomendation

This study revealed the physicochemical properties of some naturally grown apricot genotypes, emphasizing the importance of evaluating and preserving genetic diversity. The findings demonstrated significant variation among the examined genotypes. Notably, genotypes 1 and 3, characterized by large fruit size and low dry matter accumulation, were identified as suitable for fresh consumption, while genotypes 2, 4, and 5, with high acidity values, were deemed promising for industrial use. In the future, these genotypes will be further characterized with additional traits, and promising genotypes are planned to be preserved for evaluation as genetic resources.

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