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Research Article

Morphometric Properties Comparison of Some Turkish and Foreign Apricot Variety Grown at High Altitude

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Abstract: Apricots are becoming more preferred because of their usage in the fresh, dried, and processing industries and are appreciated by consumers for their pleasant flavor, aroma, and high nutritional value. Apricot cultivation is mostly performed by native varieties in Turkey, and there is insufficient knowledge about the characteristics of foreign varieties. In this study, important Turkish and foreign varieties were evaluated according to their morphological properties using multivariate analyses. The highest fruit weight was detected as 31.90 g (Sakıt-2) in the Turkish varieties and detected 22.36 g (Precoce de Colomer) in the foreign varieties. The highest fruit height, thickness, stone height, and weight were detected in 'Alyanak' and 'Sakıt-2' the Turkish apricot varieties. The 'Soğancı' and 'Sakıt-2' were characterized by the highest stone thickness, pH, fruit height, and weight in Turkish varieties, whereas 'Precoce de Tyrinthe' had the highest total soluble solids in the foreign varieties. The correlation analysis demonstrated significant positive correlations between examined features in Turkish and foreign varieties. In the principal component analysis, the first five components elucidated 93.59% of the total variance. Examined traits were separated into three groups, and 'Sakıt-2', 'Alyanak', 'Hasanbey', and 'Hacihaliloğlu' at the Turkish varieties were placed in the first two groups and characterized by fruit and stone traits, while the foreign varieties formed the other group and were characterize by pH, TSS, and colorimetric traits. The study put forward useful information for the comparison of morphometric traits between Turkish and foreign varieties, and the results can be used in future apricot breeding programs.

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1. Introduction

The market value of fruits is related to their quality characteristics, and pomological traits are basic commercial attention, while they are closely related to the yield of regular high fruit sets, and low drops (Balta et al., 2007; Muradoğlu et al., 2007). Costumers' acceptance is determined by fruit color, visual characteristics, firmness, maturity index (Total Soluble Solids/Titratable Acidity), appealing smell, taste, and eating quality for fresh consumption (Ruiz and Egea, 2008; Krška et al., 2009; Mikulic-

Petkovsek et al., 2016; Suszek et al., 2017). Additionally, the apricot fruit is fantastically approved by consumers due to its richness in nutrients, vitamins, minerals, fibers, sugars, and bioactive phytochemicals (Karabulut, et al., 2007; Leccese et al., 2011; Ali et al., 2011; Kan et al 2014; Fan et al., 2017).

Apricot (*P. armeniaca* L.) kernel is a rich source of protein, fiber, oil, fatty acids, carotenoids, phenolics, antioxidants, and several minerals such as K, Ca, and Mg (Özcan, 2000; Silem et al., 2006; Şeker et al., 2009; Muradoğlu et al. 2011). Because apricot is a climacteric fruit, it cannot be stored for a long time as fresh. While it is mostly consumed fresh, different preservation methods are used to prolong shelf life, such as dried, marmalade, juice, jam, puree, freezing, extrusion products, or packing in a controlled atmosphere (Yıldız, 1994; Haciseferogullari et al., 2007). The main reason for the preference for the apricot fruit is its high flavor, aroma, and sugar content which makes it one of the most popular fruits in the world. The greatest amount of cultivation of apricot is in Mediterranean countries such as Turkey, Spain, Italy, France, and Greece (Greger and Schieberle, 2007). Turkey is the leading country in the world's apricot production, with 833.398 tons. Following Turkey, Uzbekistan, Iran, İtaly, Algeria, and Spain are the main apricot producer countries (FAO, 2020). The apricot tree greatly adapted to Anatolia and many important cultivars such as Kabaaşı, Hasanbey, Hacıhaliloğlu, Soğancı, and Sakıt-2 have been economically cultivated since the centuries (Akın, et al., 2008; Hacıseferoğulları, et al 2007; Karataş and Songül, 2020). Fruit quality is strongly affected by genotypes or cultivars and environmental conditions. Therefore, fruit properties and quality may considerably change among different varieties or the same varieties cultivated in different regions.

Many studies were performed on the characterization of some apricot genotypes or cultivars. But, to our knowledge, there have been no comparative studies on morphometric properties of the Turkish and foreign apricot varieties grown under the same ecological conditions or orchards. With the present study, we aim to compare some Turkish and foreign apricot varieties cultivated in the same orchard based on their fruit, stone, colorimetric, and chemical properties. Additionally, multivariate analyses were used first time in the comparison of Turkish and foreign apricot varieties.

2. Material and Methods

2.1. Plant Material

The ten Apricot varieties which six Turkish varieties ('Alyanak', 'Hacıhaliloğlu', 'Hasanbey', 'Kabaaşı', 'Sakıt-2', and 'Soğancı') and four foreign varieties ('Bebeco', 'Paviot', 'Precoce de Colomer', and 'Precoce de Tyrinthe') were collected from collection orchards of Yuzuncu Yıl University in Van province (Figure 1) at the commercial ripening period and the morphometric traits were evaluated through two consecutive years (2013 and 2014). The cultivars grown at 1730 m altitude are fifteen years old and grafted on 'Zerdali' (wild apricot) rootstock. Orchard was regularly fertigated, and pest and disease control were performed properly. No nutritional deficiency was observed on trees, and all cultural practices were done properly during the study.

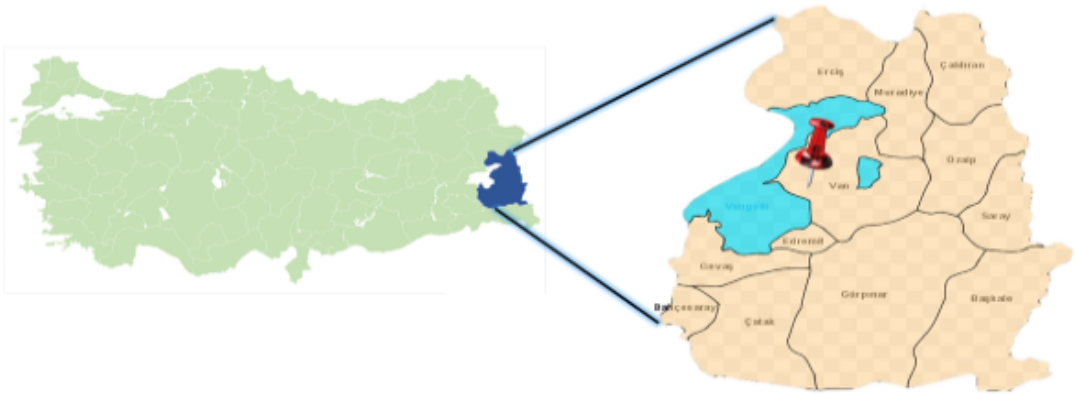

Figure 1: The location of the collection orchard and sampling region.

2.2. Method

About 40 similar fruits were harvested uniformly from five different trees. The fruit quality traits: fruit width (FWD), fruit thickness (FT), fruit height (FH), stone width (SWD), stone thickness (ST), and stone height (SH) were measured using a caliper with an accuracy of 0.1 mm. Fruit weight (FWT) and stone weight (SW) were measured with an electronic scale that has a 0.01 g precision. The color parameters (L*, a*, b* Chrome*, and Hue^{o}) were determined by using a hand-type colorimeter (Minolta Co., model CR-400, Tokyo, Japan). pH was determined by a table-type pH meter (Thermo Science, Orion star A 111). Total soluble solids (TSS) were determined using a hand refractometer (ATC, NTRM01). TA was measured by titration method by adding 0.1 N NaOH to fruit juice (5 ml) until the final pH reaches 8.1. (Ruiz et al., 2008; Muradoğlu et al., 2011)

2.3. Climate Description of Research Area

Climatic data belonging to the research area, as shown in Figure 2, obtained from the Turkish State Meteorological Service are presented as the monthly average of two years (2013 and 2014). The range of monthly minimum, maximum, and average temperatures were 7.6-14.7 °C, 1.9-28.0 °C, and -3.4 °C - 22.2 °C, respectively. The minimum, maximum, and average temperatures during the vegetative period (from March to November) ranged between -2.7-5.7 °C, 6.6-17.1 °C, and 1.4-10.7°C, respectively. January and February were characterized by the lowest temperatures, whereas July and August had the highest temperatures. The monthly precipitation varied between 3.4 and 56.0 kg/m^2. The highest precipitation occurred in the winter months, and the summer months were the lowest in the research area.

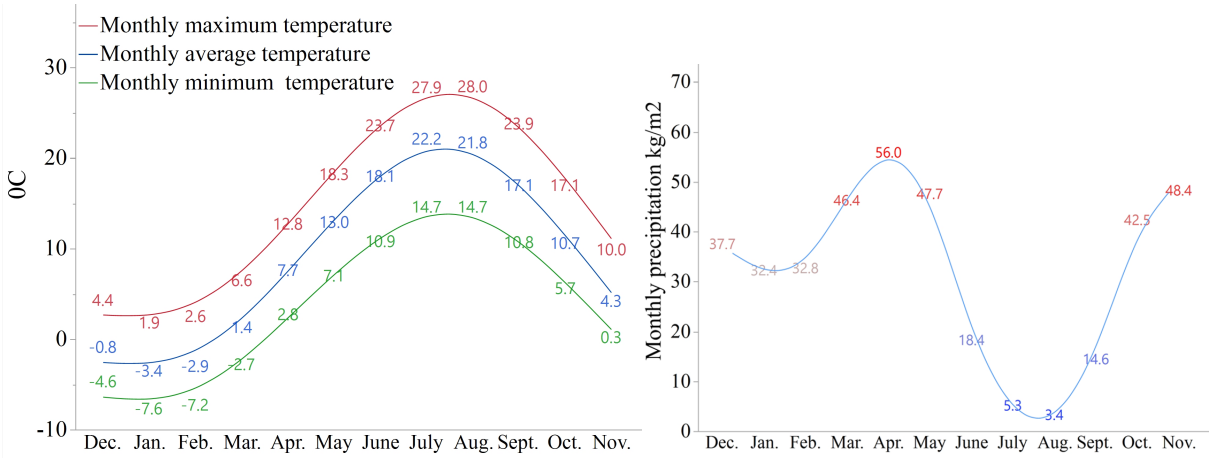

Figure 2. Climatic data belong to the research area.

2.4 Statistical Analysis

The average data from two years (2013-2014) were subjected to analysis of variance using SPSS 23.0 statistical software. Data were presented as the mean and standard error. One-way ANOVA and Duncan multiple range tests were used to compare the varieties, and the statistical significance level was taken as 5% in the calculations. Moreover, the correlations matrix was determined by Pearson's correlation analysis using R Studio software with the package 'Corrplot' (Wei et al., 2017) and the cluster dendrogram was created according to Ward's method. The principal component analysis (PCA) was performed to clarify the relationships of features with each other and varieties using R Studio software with the package of 'ggplot2' (Wickham, 2016).

3. Results and Discussions

The sixteen morphological characters that average for two years (2013-2014) belong to Turkish and foreign apricot varieties were determined. Morphological characters include fruit (width, thickness, height, and weight), stone (width, thickness, height, and weight), color (lightness, green/redness,

blueness/yellowness, chroma, lightness's angle), total soluble solids, pH, and titratable acidity were evaluated.

3.1. Morphometric Traits of Turkish and Foreign Varieties

The apricot fruit is also consumed fresh, and consumers primarily prefer the fruit in terms of visual appearance, and minorly defected or low-quality fruits could be used for processing. Therefore, fruit dimensions are an important description factor of fruit quality and are one of the crucial criteria for consumers' preferences. The fruit dimensions, FWD, FT, FH, and FWT, were detected between 27.29-39.42 mm, 31.72-39.45 mm, 24.34-38.42 mm, and 10.68-31.9 g, respectively in the Turkish varieties, while they ranged from 29.06 to 35.95 mm, 34.01 to 35.28 mm, 30.68 to 33.9 mm, and 19.42 to 22.36 g, respectively in the foreign varieties.

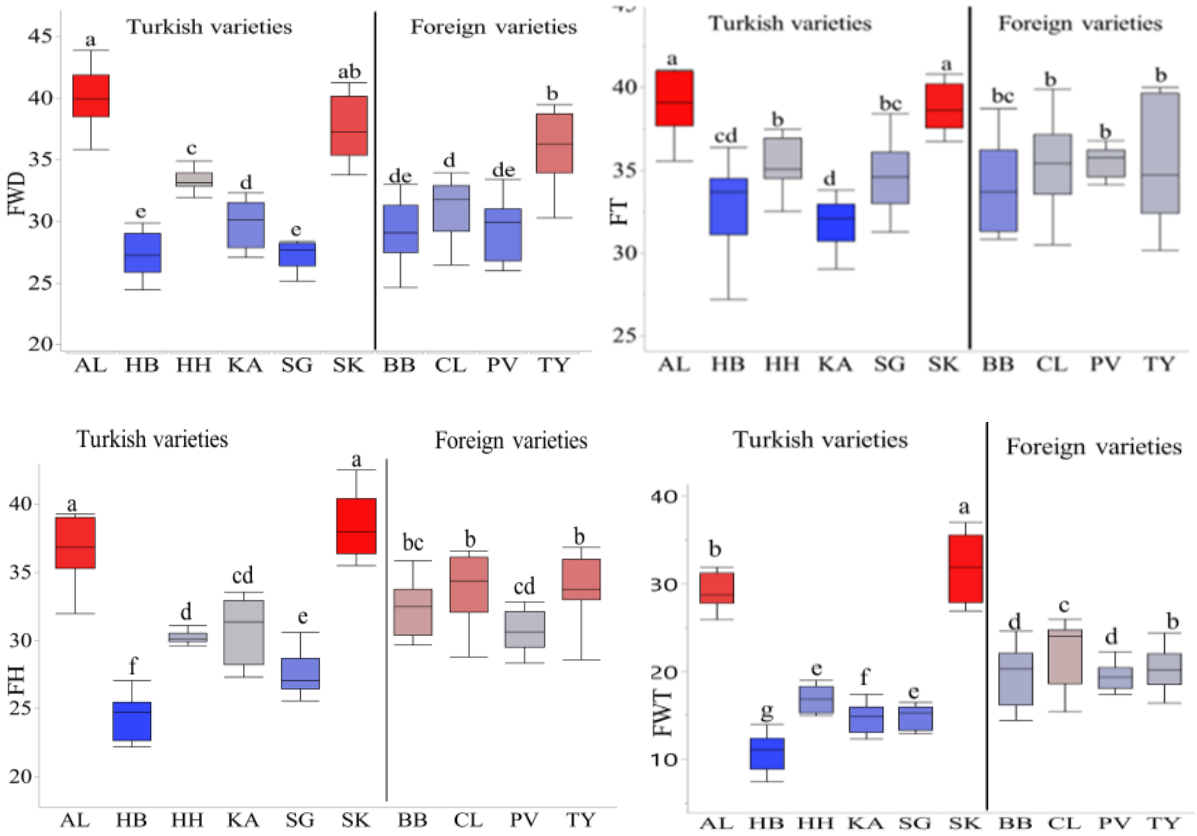

Figure 3. Fruit dimension features of Turkish and foreign varieties. AL; Alyanak, HH; Hacıhaliloğlu, HB; Hasanbey, KA; Kabaaşı, SK; Sakıt-2, SG; Soğancı, BB; Bebeco, PV; Paviot, CL; Precoce de Colomer, TY; Precoce de Tyrinthe.

The fruit dimensions were highest in Turkish varieties 'Alyanak' and 'Sakıt-2' compared to foreign varieties (Figure 3). Krichen et al. (2014) reported that fruit dimensions of 112 Tunisian apricot accessions ranged from 2.0 to 10 g for fruit weight and from 1.0 to 1.8 g for stone weight. Studies on fruit height, width, thickness, and 100 kernel weight were previously reported to vary from 14.0 to 19.17 mm, from 9.99 to 10.20 mm, from 3.3 to 6.27 mm, and from 28.7 to 65.1 g, respectively (Gezer et al., 2003; Vursavuş and Özgüven, 2004). Velardo-Micharet, et al. (2021) declared fruit height, diameter, and weight as varying from 46.6 to 53.9 mm, 48.4 to 57.5 mm, and 58.0 to 97.4 g, respectively. Another study was carried out in the Iğdır region on six apricot cultivars, fruit and stone weights were recorded as 27.88-52.9 g and 1.96-2.94 g, respectively (Muradoğlu et al., 2011). The fruit pomological data were in line with the previous findings; nevertheless, the differences are related to cultivar, yield (high and low fruit set up), maturity, soil types, nutritional status, and climatic conditions. The fruit set and pomological characters are seriously affected by climatological events. As shown in Figure 2. the research area where Located in eastern Turkey at a high altitude is show suitable climate conditions for

apricot growing. Besides in some years, extreme temperature fluctuations including late spring frost that occur in late April-early May can be causing an important threat to fruit sets and the yield of apricot varieties. Because apricot is a sensitive species and is seriously affected by climatological conditions.

Apricot stones (kernel) are generally by products in the fruit processing industry and thinking as discarded material. Apricot, a very important commercial fruit, is in the world and numerous apricot stones are exposed in food processing. Recent studies showed that apricot stones are rich in unsaturated fatty acids (Özkal, 2004), minerals such as K, Ca, and Mg (Muradoğlu et al. 2011), contains dietary fiber (Dwivedi and Ram, 2006), and several biological activities by its antioxidant, anticarcinogenic and, antimicrobial properties (Mandalari et al., 2010; Yiğit et al., 2009). For these reasons, apricot stones have been used in many foods and industrial areas in recent years.

Significant statistical differences were observed in terms of stone dimensions between the Turkish and the foreign apricot varieties (Figure 4). The SWD, ST, SH, and SWT of Turkish varieties changed from 9.31 to 17.04 mm, from 21.05 to 25.24 mm, from 10.15 to 18.81 mm, and from 1.23 to 2.13 g, respectively. These values changed to 8.40-9.68 mm, 19.93-22.60 mm, 14.14-16.51 mm, and 1.36-1.35 g, respectively for foreign varieties. Turkish varieties had higher stone dimensions than foreign varieties. Mratinic et al., (2011) reported that the stone weight of twenty Macedonia wild apricot ranged from 1.81 to 4.85 g. The stone length and width were previously reported by Velardo-Micharet, et al., (2021) as from 26.4 to 28.2 mm and between 21.6 and 23.4 mm from apricot cultivars, respectively. Our results were in a close relationship with previous studies and minor differences are due to varieties or high altitudes that are affected by climatic factors and fruit characters.

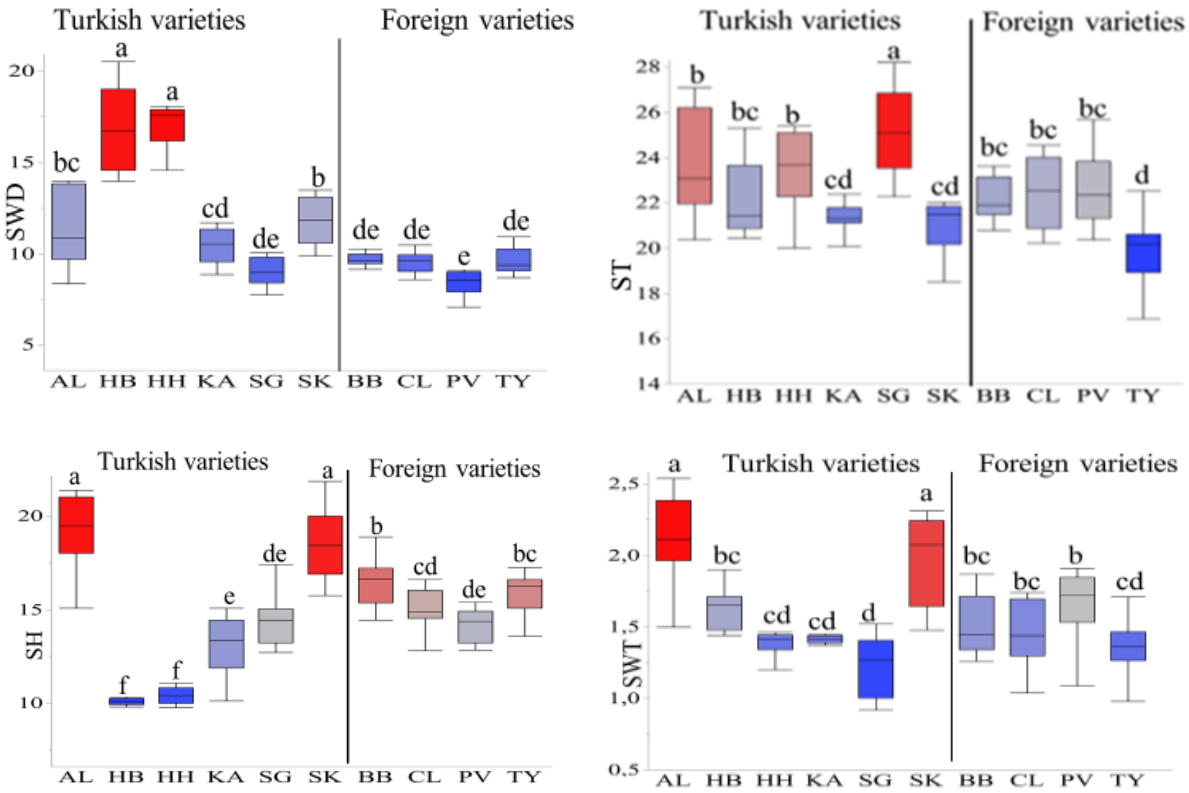

Figure 4. Stone dimension features of Turkish and foreign varieties. AL; Alyanak, HH; Hacıhaliloğlu, HB; Hasanbey, KA; Kabaaşı, SK; Sakıt-2, SG; Soğancı, BB; Bebeco, PV; Paviot, CL; Precoce de Colomer, TY; Precoce de Tyrinthe.

Apricot fruit color is very important commercially and customer prefers acceptable fruit color should be skin color ranging from yellow to deep orange, with a distinct red blush in many modern cultivars. According to Callahan (1995) and Moreau-Rio (2006), shiny, yellow, and orange apricot genotypes with a high red-blush ratio are very desirable to customers. Therefore, chromatic parameters such as l*, a*, b*, C*, and hue^{o}* are crucial and have been widely used to describe fruit quality. In

addition, the color variables have been connected to the cultivars and presence of phenolic compounds, anthocyanins, and antioxidant capacity in fruits (Akin et al., 2008; Christiensen, 2000; Cömert et al., 2020). Therefore, numerous researches were performed on chromatic parameters by Akın et al., (2008); Fan et al., (2017) and Velardo-Micharet, et al (2021) to determine the fruit quality of apricot. In this study, the fruit color of Turkish apricot varieties was detected 50.39-55.75 for L*, 15.77-30.02 for a*, 33.9-42.34 for b*, 27.75-49.06 for C*, and 32.15-66.39 for hue°. In foreign verities, fruit color was observed as 52.39-62.14 for L*, 17.98-27.66 for a*, 37.99-48.40 for b*, 45.84-55.67 for C*, and 55.66-62.34 for hue° respectively. The color of apricot varieties was higher in foreign varieties except for a* and hue° than Turkish varieties (Figure 5). Moreover, color is the most important maturity indicator for many fruit species and chromatic traits are affected by a sequence of agents such as cultivar, lighting, cultivation management, and maturity stage.

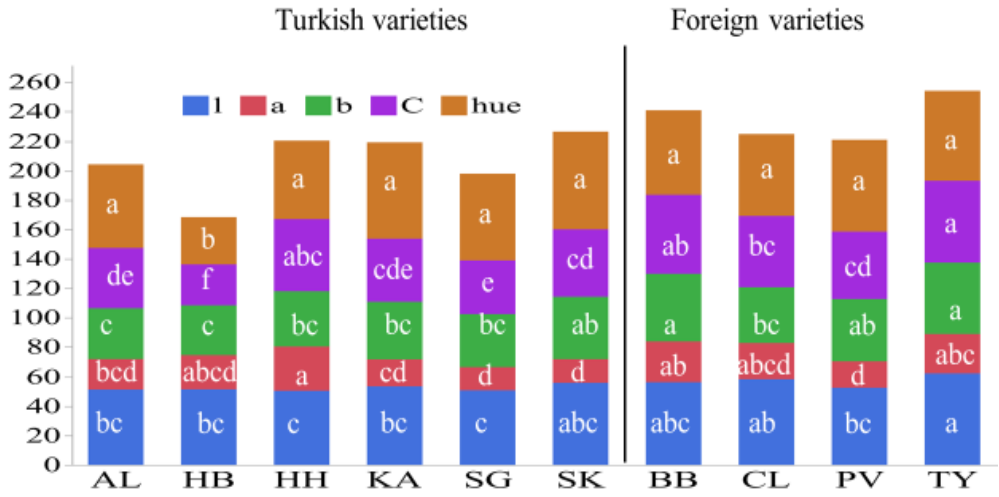

Figure 5. Chromatic features of Turkish and foreign varieties. AL; Alyanak, HH; Hacıhaliloğlu, HB; Hasanbey, KA; Kabaaşı, SK; Sakıt-2, SG; Soğancı, BB; Bebeco, PV; Paviot, CL; Precoce de Colomer, TY; Precoce de Tyrinthe,

Apricot quality is generally characterized by parameters of soluble solids content, sugars, titratable acidity, flesh firmness, and peel color (Génard et al., 1994). Fruit taste contributing to fruit quality was determined by sweetness and acidity, which is related to the content of soluble sugars and types of organic acids (Mikulic-Petkovsek et al., 2016). TSS and pH for Turkish varieties ranged from 3.05-4.20 % to 3.66-5.42 and for foreign varieties ranged from 3.55-5.00% to 3.95-5.14 respectively. TA varied from 0.37 to 3.18% in Turkish varieties and 0.60-2.39 % in foreign varieties (Figure 6). In a study conducted on 13 Turkish apricot cultivars, pH and titratable acids varied between 3.68-5.04 and 0.22-1.40% respectively (Karataş and Şengül, 2020). In another study, the pH and total acid values were reported as 3.83–6.61 and 0.08% and 0.28% as malic acid (Akin et al., 2008). In the studies conducted on some apricot cultivars, total acidity, pH, and soluble solid contents were found 0.14-0.68%, 4.81-5.45 and 12.50-24.00% by Muradoğlu et al., (2011) and 0.96-1.89%, 3.90-4.70, and 11.70-14.40 Brix, respectively by Mratinic, et al., (2011). According to the researchers, soluble solids contents of over 10% and titratable acidity of 0.7–1.0% are critical for consumer acceptance. Our titratable acidity amounts were in the range of acceptance threshold, but soluble solids contents were below. The main reasons were variety differentiation, environmental conditions, and harvest date such as early harvest.

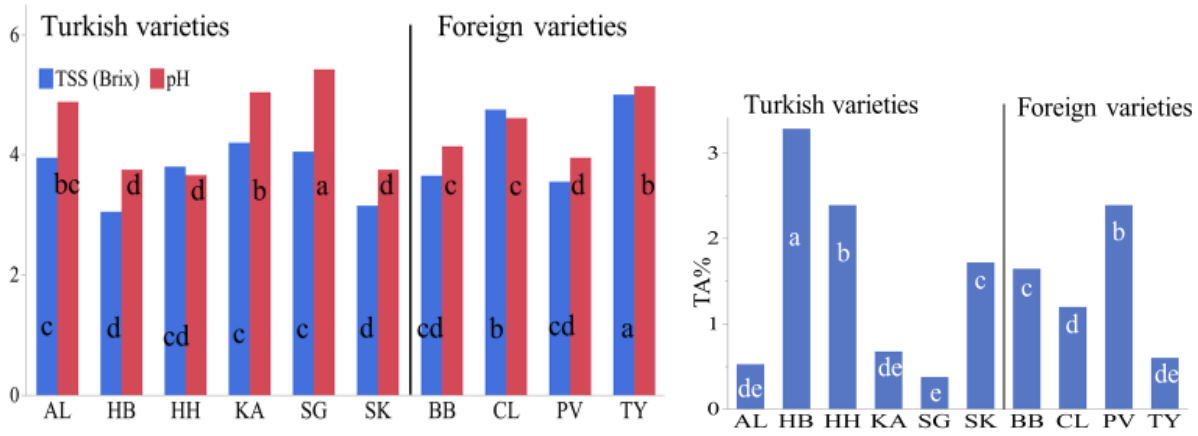

Figure 6. Chromatic features of Turkish and foreign varieties. AL; Alyanak, HH; Hacıhaliloğlu, HB; Hasanbey, KA; Kabaaşı, SK; Sakıt-2, SG; Soğancı, BB; Bebeco, PV; Paviot, CL; Precoce de Colomer, TY; Precoce de Tyrinthe.

3.2. Morphological Distribution in Turkish Apricot Varieties

The studied morphological characters in Turkish varieties were grouped into four categories depending on the correlation matrix and the clustering analyses (Figure 7A). These analyses were successfully used in the previous studies by Liu et al., (2021) in the comparison of relationships.

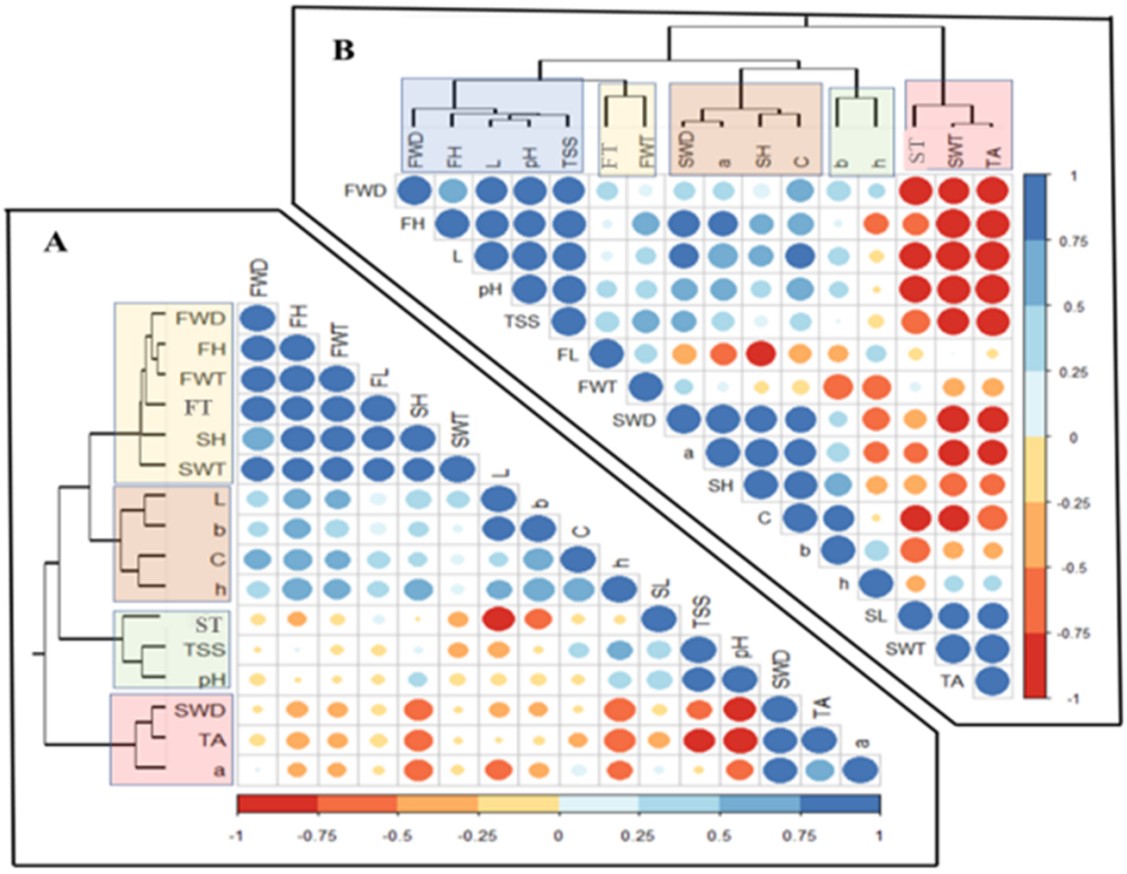

Figure 7. Correlation matrix and cluster dendrogram of morphological characters in Turkish (A) and foreign (B) varieties. FWD: fruit width, FT: fruit thickness, FH: fruit height, FWT: fruit weight, SWD: stone width, ST: stone thickness, SH: stone height, SWT: stone weight, L: lightness, a: green/redness, b: blueness/yellowness, C: chroma, hue°: lightness's angle, TSS: total soluble solids, and TA: titratable acidity.

Six morphological characters (Fruit width, fruit thickness, fruit height, fruit weight, stone height, and stone weight) were grouped in the first category (Fig 7A). The highest FWD, FT, SH, and SWT were determined in the 'Alyanak' variety, while the highest FH and FWT were determined in the 'Sakıt-2' variety (Figure 3)

Some calorimetric parameters such as L, b, C, and hue^{o} were grouped in the second category (Figure 7A). The highest L*, b*, and hue^{o} were detected in the 'Sakıt-2' variety, while the highest C* was detected in the 'Hacıhaliloğlu' variety (Figure 5).

Morphological characters in the third group were separated into two clusters. Maximum ST and pH were detected in 'Sakıt-2' and the highest TSS was detected in the 'Kabaaşı variety (Figures 4 and 6)

SWD, TA, and a* were grouped into four categories: The maximum SWD and a* were observed in 'Hacıhaliloğlu', while the maximum TA was observed in 'Hasanbey' (Figures 4, 5, and 6).

3.3. Morphological Distribution in Foreign Apricot Varieties

The studied morphological characters in foreign varieties were grouped into five categories depending on the correlation matrix and clustering analyses (Figure 7B).

FWD; FH, L*, pH, and TSS parameters were formalized in the first group. In this cluster, all examined morphological characters were the highest in 'Precoce de Tyrinthe' (Figures 3, 5, and 6)

Two characters, FT and FWT, were placed in the second group. The highest FL was determined in 'Paviot', while the maximum FWT was in 'Precoce de Colomer' (Figure 3).

The third group consisted of four characters SWD, a*, SH, and C*. The maximum a*, and SH were determined in 'Bebeco', while maximum SWT and C* were determined in 'Paviot' and 'Precoce de Tyrinthe' (Figures 4 and 5).

From the colorimetric parameter, b* and hue^{o} were composed of the fourth group. The highest b* was detected in the 'Precoce de Tyrinthe', while the highest hue^{o} was in 'Paviot' (Figure 5).

ST, SWT, and TA parameters were grouped in the fifth cluster. The maximum ST, SWT, and TA were detected in 'Paviot' (Figures 4 and 6).

3.4. Differences in Morphological Characters Between Turkish and Foreign Apricot Varieties

Relationships between morphological characters of Turkish and foreign varieties were detected by creating a correlation matrix. Significant positive correlations were observed among fruit and stone characters in the Turkish varieties. On the contrary, TA with pH and a* with SWD had a significant negative correlation in both Turkish and foreign varieties (Figure 7). These results agree with previous findings by Krichen et al., (2014) and Cömert et al., (2020). PCA was used to determine critical characters and to minimize the number of effective factors. Therefore, PCA has been used intensely by researchers to define critical characteristics of fruit species for the last decade (Mratinic, et al., 2011; Güler et al., 2021; Muradoğlu et al., 2021). In this study, PCA was conducted to characterize morphological characters of Turkish and foreign varieties. The PCA showed that 93.59% of the observed total variability was described by the first five components. PC1 and PC2 identified 40.1%, and 23.2% of total variations, respectively, and the first two components described 63.32% of the total variability. Turkish and foreign varieties were separated into three groups. The first group was associated with the 'Alyanak', and 'Sakıt-2' variety that was related to FWD, FH, FWT, FT, SH, SWT, and hue^{o}*. The second group was formed mostly of foreign varieties as 'Precoce de Colomer', 'Bebeco', 'Paviot', 'Precoce de Tyrinthe', 'Soğancı', and 'Kabaaşı' linked with colorimetric data such as L*, b*, c*, TSS, and pH characters. 'Hasanbey' and 'Hacıhaliloğlu' varieties formed the third group, and these varieties were characterized by ST, SWD, TA, and a*. Relationships among varieties were shown on a biplot (Figure 8). In a similar study on local apricot genotypes, Mratinic, et al., (2011) reported that the first three components represented 70.85% of the total variance.

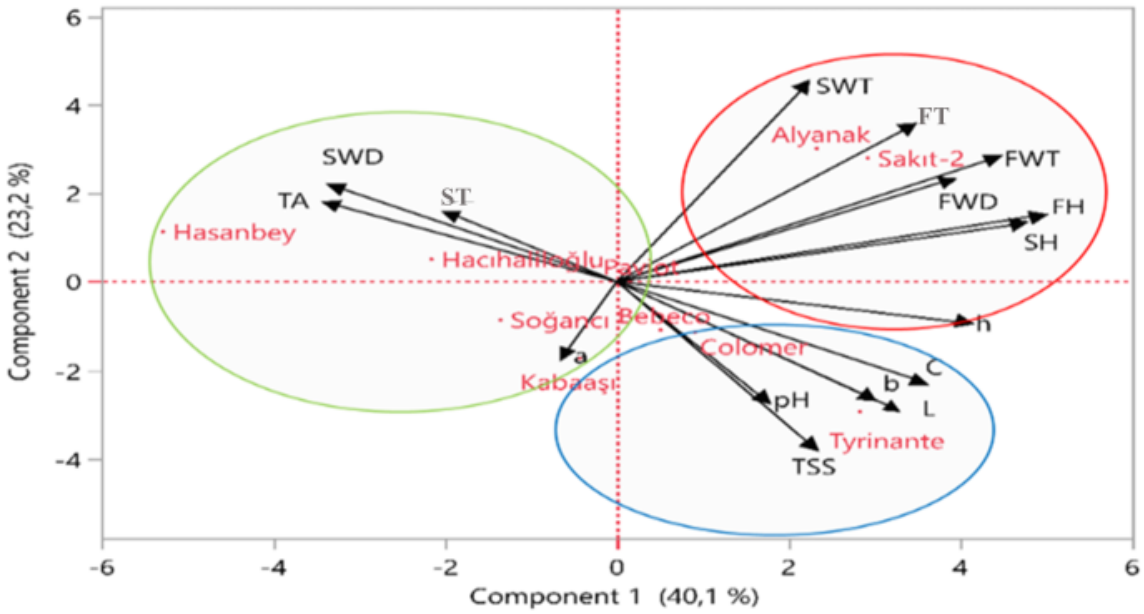

Figure 8. The principal component analysis (PCA) shows the interrelation of Turkish and foreign apricot variety and morphological characters.

4. Conclusions

The morphological properties of varieties are major indicators in determining fruit quality. That's why it is important to investigate fruit quality related to consumer preferences. In the present study, significant differences were observed in Turkish and foreign varieties according to their morphometric properties.

The fruit dimensions (FWD, FT, FH, and FWT) of varieties were the highest in 'Alyanak' and 'Sakıt-2' in the Turkish varieties. The highest values regarding stone width were recorded from the 'Hasanbey' and 'Hacıhaliloğlu' varieties, length from the 'Soğancı' variety, while 'Alyanak' and 'Sakıt-2' varieties have the biggest fruit height and weight. Fruit stone features were the highest in Turkish varieties compared to foreign varieties. The color was higher in foreign varieties except for a* and hue°. The highest soluble solid contents were recorded from the 'Precoce de Tyrinthe' in foreign varieties. Contrarily, pH and total titratable acids were higher recorded from 'Soğancı' and 'Hasanbey' in Turkish varieties.

The results showed that Turkish varieties have higher morphometric characters and these varieties had better performance in the ecological conditions of the study.

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