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Research Article/Araştırma Makalesi

Determination of fruit growth and fruit peel and aril colors in different pomegranate genotypes

Farklı nar genotiplerinde meyve büyümesi ile meyve kabuk ve dane renklerinin belirlenmesi

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ABSTRACT

This study examines the growth of "Kışnarı" type with "Hicaznar" and "Kirli Hanım" pomegranate varieties in fruit length and width as well as the fruit peel and aril colors. It was found that the relationship between these type and varieties in terms of growth in fruit length and width were positive and significant and that the "Hicaznar" variety grew more robustly than the other variety and type. In addition, it was determined that width and length of the varieties and types of the fruit increased in direct proportion from the full flowering stage to the harvest period; and the fruit width growth was higher than the fruit height development. The peel L* value was determined in the range between 47.15 and 94.88 and varies by year, variety and type. The Kışnarı variety had the highest a* value (45.00) in terms of peel color while the highest b* value (41.88) was registered in the Kirli Hanım variety. The fruit peel chroma (C*) values varied between 36.99 and 63.51. It was found that the peel Hue (H°) values of the Kirli Hanım (44.88) and Kışnarı (41.59) varieties were significantly higher than those of the Hicaznar (35.14) variety. According to aril L* values, the highest brightness was ascribed to the Kirli Hanım (73.68) while the lowest to the Hicaznar (39.80). According to a two-year average, the a* values of the aril color of the type and variety varied between 39.73 and 47.66. The aril of Hicaznar (18.25) variety had the lowest b* value aril while the Kirli Hanım (22.02) had the highest. The aril color C* values of the type and varieties varied between 43.73 and 53.99. The two-year average aril color H° value of the type and varieties varied between 24.48 (Kışnarı) and 25.95 (Kirli Hanım).

Key Words: Fruit growth, Peel, Aril, Color properties, Pomegranate

ÖZ

Bu çalışmada, Kışnarı tipi ile Hicaznar ve Kirli Hanım çeşitlerinin meyvelerinde en-boy gelişimleri ile meyve kabuk ve dane renkleri incelenmiştir. Araştırma sonucu tip ve çeşitlerin meyve en-boy büyüme ilişkilerinin pozitif ve önemli olduğu, Hicaznar çeşidinin diğer çeşit ve tipe göre daha fazla gelişme gösterdiği tespit edilmiştir. Ayrıca, çeşit ve tiplerin meyve en ve boyunun, tam çiçeklenme evresinden hasat zamanına kadarki süreçte doğru orantılı olarak arttığı, meyve eni büyümesinin meyve boyu gelişiminden daha fazla olduğu saptanmıştır. Kabuk L* değeri yıllara, tip ve çeşitlere göre değişmekle beraber, 47.15-94.88 arasında belirlenmiştir. Kabuk renginde en yüksek a* değeri Kışnarı'nda (45.00), b* değeri ise Kirli Hanım'da (41.88) belirlenmiştir. Meyve kabuk rengi kroma (C*) değerleri 36.99 ile 63.51 arasında değişim göstermiştir. Kirli Hanım (44.88) ve Kışnarı'nın (41.59) kabuk Hue değerlerinin, Hicaznar (35.14) çeşidinden anlamlı olarak daha yüksek olduğu tespit edilmiştir. Dane L* değerlerine göre en yüksek parlaklığın Kirli Hanım (73.68), en az parlaklığın ise Hicaznar'da (39.80) olduğu tespit edilmiştir. İki yıllık ortalamaya göre tip ve çeşitlerin meyve dane rengi a* değeri 39.73 ile 47.66 arasında değişmiştir. En düşük dane rengi b* değeri

Hicaznar çeşidinde (18.25), en yüksek ise Kirli Hanım çeşidinde (22.02) belirlenmiştir. Tip ve çeşitlerin dane rengi kroma değerleri 43.73 ile 53.99 arasında değişim göstermiştir. Tip ve çeşitlerin iki yıllık ortalama dane rengi H° değeri, 24.48 (Kış Narı) ile 25.95 (Kirli Hanım) arasında ölçülmüştür.

Anahtar Kelimeler: Meyve büyümesi, Kabuk, Dane, Renk özellikleri, Nar

Introduction

Pomegranate (*Punica granatum* L.) is a perennial plant belonging to the Punicaceae family and can be grown anywhere in tropical and subtropical regions (Schubert et al., 1999) up to an altitude of 1000 m (Özgüven and Yılmaz, 2000).

Pomegranates have been grown in Turkey over many years. Since Turkey is one of the gene centers of pomegranate, it is very rich in the genetic resources of pomegranate. Almost fifty varieties of pomegranates have been registered in Turkey to date. These include various pomegranate varieties from sweet to sour, red to yellow, small fruits to large fruits and hard arils to soft arils. (Yılmaz, 2007).

Pomegranate peel color is an important quality parameter in terms of creating allure. Generally, consumers prefer fruits with red peels (Holland et al., 2009). Nuncio-Jáuregui et al., (2014) measured the fruit peel a* value in Spain as between 12.31 and 24.26; Yaman et al., (2015) measured the b* value of Hicaznar grown fruit peel color as 29.0-37.6 in different locations in Hatay Region. Selcuk and Erkan (2014) determined the peel chroma value of the Hicrannar variety as 47.52. It is reported that the fruit aril color a* values of pomegranates are determined between 0.31 and 34.10 (Legua et al., 2000; Yılmaz, 2005; Gölükçü and Tokgöz, 2008; Al-Said et al., 2009; Borochov-Neori et al., 2009; Gündoğdu et al., 2011; Calişkan and Beyazit, 2012; Fawole and Opara, 2013b,c; Nuncio-Jáuregui et al., 2014; Yaman et al., 2015).

Özden et al., (2017) in the study they conducted in Şanlıurfa on pomegranate, reported that the Hue (H^o) angle values of the varieties in the peel were between 16.23- 98.96, and in fruit, the values are between 31.36-179.02. Peña et al., (2013) stated that the peel Hue angle value of the "Mollar de Elche" pomegranate variety in Spain as 60.3; Yaman et al., (2015) stated that the peel Hue angle value of Hicaznar as 37.21-49.82. Various researchers (Peña et al., 2013; Fawole and Opara, 2013b; Fawole and Opara, 2013c; Selcuk and Erkan, 2014; Yaman et al., 2015) determined the L* value, which expresses the fruit peel brightness, in the range of 43.82-68.80.

In their studies, they stated that the width of pomegranate fruit varied between 44.1 and 100.68 mm (Laribi et al., 2013; El-Sayed et al., 2014; Parvizi et al., 2014; Gündoğdu et al., 2015; Davarpanah et al., 2016; Dandachi et al., 2017; Cicek et al., 2019). Various researchers (Korkmaz, 2013; Yaman et al., 2015; Davarpanah et al., 2016; Dandachi et al., 2017; Cicek et al., 2019) measured fruit size as 39.00-93.28 in their studies on different pomegranate varieties and genotypes in different ecologies.

This study examines the growth of the “Kışnarı” type with “Hicaznar” and “Kirli Hanım” pomegranate varieties grown in the province of Gaziantep, Turkey in fruit length and width as well as the changes in the fruit peel and aril color.

Material and Methods

Plant material and field trial

This study was carried out at the research station of the Pistachio Research Institute (Gaziantep, Turkey). (36° 56´N latitude; 37° 28´E longitude; 705 m altitude). The trees have 3-4 trunks on average and have the shape of a shrub. During the test period, the pomegranate plants were irrigated with a drip irrigation system and the annual upkeep of the orchard was undertaken on a regular basis.

To determine fruit growth in length and width, five plants were selected and measurements were taken from two pieces of fruit randomly selected from the four sides of each plant.

Measurements were taken using a digital caliper with a precision up to 0.01 mm at two-week intervals from fruit set time to harvest time and a growth chart was prepared based on these measurements. The fruit peel and aril measurements were undertaken in a repeated three-trial-sequence in each of which there would be five trees according to the Completely Randomized Design.

Fruit peel and aril color

Color measurements of the fruit peel and arils were made according to the C.I.E. L* a* b* (Commission Internationale de l'Eclairage-) method with a Hunter Lab colorimeter (A 60-1010-615 Model Colorimeter, Hunter Lab and Reston VA; Zerbini and Polesollo, 1984). An average of six measurements, four of which from the equator area of the fruit and two of which from the calyx area and the stalk area, were accepted as representing the peel color of the fruit. Color measurements of the arils were undertaken on the arils about 2 to 3 cm thick placed in Petri cups. In the samples, chroma indicates color intensity and the hue, indicates the hue angle (0°; red-purple, 90°; yellow, 180°; bluish-green, 270°; blue) (Zerbini and Polesollo, 1984). The L* value is an indicator of blackness-whiteness that ranges between 0 (black) to 100 (white), the value a* is an indicator of greenness-redness that ranges between -60 (green) to +60 (red) and the value b* is an indicator of blueness-yellowness that ranges between -60 (blue) to +60 (yellow), as with value a (Özdemir, 2001). Besides, Chroma shows the intensity of the color while the hue indicates the angular value of the color (0°; red-lilac, 90°; yellow, 180°; bluish-green, 270°; blue) (McGuire, 1992).

$$[C = (a^2+b^2)^{1/2})] \quad (1)$$

$$[h^{\circ} = arctan\ (b^*/a^*)] \quad (2)$$

Statistical analyses

An evaluation of the average data over two years was performed in a repeated three-trial sequence according to the Completely Randomized Design, and the question of whether there was any difference between the averages tested by one-way variance analysis (ANOVA). If there was a significant difference after the analysis of variance, the Tukey HSD test (Honest Significant Difference) was used for multiple comparisons between groups. The SPSS 16 (Inc, Chicago, IL) packaged software was utilized in data analysis and the statistical significance level was taken as 0.05. Using peel and aril color values, the properties of the genotypes were classified by PCA (Principal Component) analysis. PCA analysis is a multivariate statistical technique that attempts to explain a large number of variables with fewer components.

Results and Discussion

Fruit growth in fruit length and width

It was found that the width and length of the genotypes in the study increased proportionally from full blossom to harvest time and that growth in width was greater than growth in length (Figures 1 and 2).

The growth of the genotypes in the study in terms of length and width was investigated within the timeframe of six different periods. The fastest growth was recorded in the second period (25 July). From this period until 5 October, when the latest data was collected, a proportional but slow growth process occurred. The width and height of the Hicaznar variety was higher than the growth values of the other variety and type (Figures 1 and 2). The relationship between fruit width and length and the growth period were positive and significant for all genotypes. Therefore, it was established that over a specific growth period all genotypes grew more in width and length. Yılmaz (2005) showed in his study conducted in Adana that fruit growth and width increased linearly from June to September. Fawole and Opera (2013a) conducted a study in South Africa on the varieties 'Ruby' and 'Bhagwa' and found that there was a constant increase in the width and length of both varieties from bloom to harvest time. They also mentioned that growth in width exceeded growth in length. This study also revealed similar results.

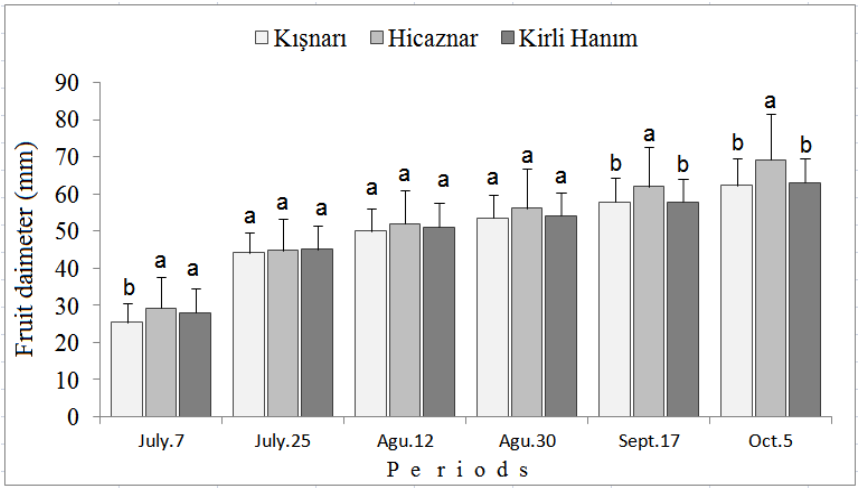

Figure 1. Variation of fruit width values by variety/type and periods (mm) (The differences between the averages indicated by different letters during the periods are significant (Anova F Test, followed by Tukey HSD,α= 0.05)

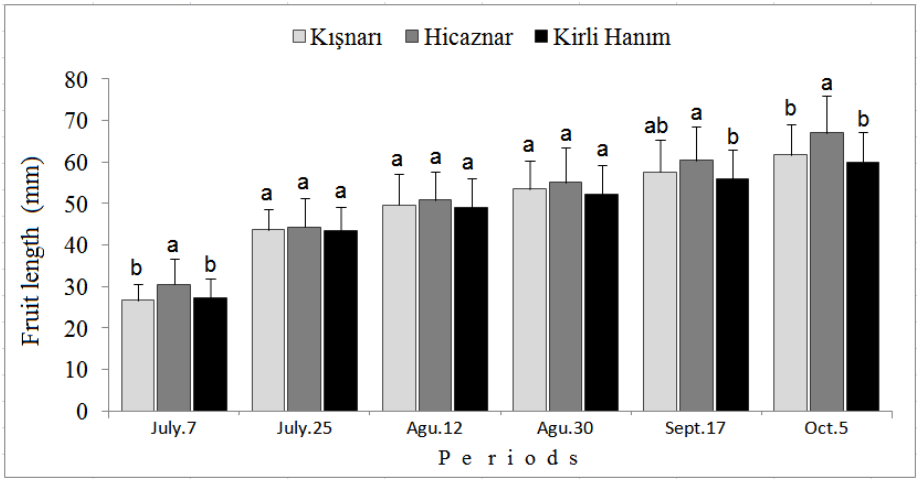

Figure 2. Variation of fruit length values by variety/type and period (mm) (The differences between the averages indicated by different letters during the periods are significant (Anova F Test, followed by Tukey HSD,α= 0.05)

Fruit peel color

The L* value that represents the brightness of the peel of the fruit varied between 47.15 (Hicaznar) and 94.88 (Kirli Hanım) (Table 1). In various other studies, the fruit peel L* value ranged between 32.76 and 87.35 (Yılmaz, 2005; Toplu et al., 2007; Al-Said et al., 2009; Caliskan and Bayazit, 2013; Peña et al., 2013; Selcuk and Erkan, 2014; Nuncio-Jáuregui et al., 2014; Yaman et al., 2015; Boussaa et al, 2019). It was found that the value L* for fruit peel color obtained in this study corresponds to values for the Kışnarı type and Hicaznar variety when compared to previous studies and that the value for the Kirli Hanım variety with the brightest peel (94.88) was higher than the values cited in the literature.

Table 1. Fruit peel color values of some pomegranate variety and types

	Kışnarı	Hicaznar	Kirli Hanım	ANOVA F test
L*	72.31±4.50 b[1]	47.15±4.69 c	94.88±11.14 a	308.595**
a*	45.00±19.72 a	30.17±3.90 b	44.03±15.89 a	9.428**
b*	35.38±4.27 b	20.70±2.30 c	41.88±10.49 a	79.311**
Chroma	59.36±13.69 a	36.99±3.12 b	63.51±6.61 a	76.041**
Hue	41.59±15.11ab	35.14±5.33 b	44.88±16.15 a	4.265*

([1]): The difference between the averages indicated by different letters in the same line is statistically significant (Tukey HSD α = 0.05). The values cover a period of two years and are expressed in terms of Mean±SD (*: p<0,05; **: p<0.01).

According to the two-year average, value a* for fruit peel color was the lowest for the Hicaznar variety with 30.17 and the highest for the Kışnarı type with 45.00. In various studies (Toplu et al., 2007; Nuncio-Jáuregui et al., 2014; Yaman et al., 2015; Boussaa et al., 2019), value a* for fruit peel color was reported as varying between 3.22-48.73. The results in the current study with regard to the a* values for peel color of the fruit, which indicate a color change from green to red, show similarities with the results obtained by many other researchers.

According to two-year average values, the difference between the b* values of the type and varieties for peel color of the fruit was statistically significant. The lowest value was registered for the Hicaznar variety with 20.70 and the highest value was registered for the Kirli Hanım variety with 41.88. Various researchers (Toplu et al., 2007; Nuncio-Jáuregui et al., 2014; Yaman et al., 2015; Boussaa et al., 2019) have found the fruit peel color b* value to be 17.11-45.69. It can be seen that the b* values for fruit peel color obtained in the current study are consistent with those found in other studies.

According to the two-year average values, chroma values for fruit peel color (low values highlighted in a dark color, high values highlighted in a light color) varied between 36.99 and 63.51 according to the type and varieties. The highest chroma value for fruit peel color was registered for the Kirli Hanım variety. The literature shows that the chroma values of pomegranates for fruit peel color (C*) vary between 27.21 and 55.80 (Yıldız et al., 2009; Peña et al., 2013; Nuncio-Jáuregui et al., 2014; Selcuk and Erkan, 2014; Yaman et al., 2015; Boussaa et al., 2019). The values obtained in this study are slightly higher than those determined by other researchers (36.99-63.51), and the peel color of the Kirli Hanım variety (63.51) was found to be lighter.

Color angle value Hue (H^o) refers to the transition from red to yellow from 0° to 90° and from yellow to green from 90° to 180°. On the basis of the two-year averages, it was found that the fruit peel Hue values of the Kışnarı type and Kirli Hanım variety (41.59 and 44.88 respectively) were significantly higher than those of the Hicaznar (35.14) variety. Accordingly, it can be argued that the fruit peel color of the Hicaznar variety has more red than other variety and type. Various researchers (Yıldız et al., 2009; Caliskan and Bayazit, 2013; Peña et al., 2013; Yaman et al., 2015; Boussaa et al., 2019) have found the peel Hue angle value to range between 17.05 and 103.2.

Fruit aril color

The aril color L* value of the type and varieties was found to vary between 39.80 (Hicaznar) and 73.68 (Kirli Hanım) (Table 2). In many studies conducted in Turkey or abroad (Yılmaz, 2005; Gölükçü and Tokgöz, 2008; Al-Said et al., 2009; Gündoğdu et al., 2011; Caliskan and Beyazit, 2012; O'Grady, 2012; Fawole and Opara 2013a, Fawole and Opara 2013b; Nuncio-Jáuregui et al., 2014; Yaman et al., 2015; Boussaa et al., 2019), the L* values for fruit aril color showed variations on a large scale ranging from 9.9 to 103.4. L* values for aril color found in this study show similarities to those cited in other studies.

Table 2. Fruit aril color values of some pomegranate variety and types

	Kışnarı	Hicaznar	Kirli Hanım	ANOVA F test
L*	72.82±4.87 a[1]	39.80±6.71 b	73.68±9.26 a	217.428**
a*	47.66±13.44 a	39.73±7.50 b	46.48±14.27 ab	3.747*
b*	19.44±6.77 a	18.25±3.89 a	22.02±13.57 a	1.364
Chroma*	52.72±9.77 a	43.73±8.40 b	53.99±10.00 a	10.588**
Hue	24.48±12.89 a	24.55±1.29 a	25.95±16.09 a	0.145

([1]): The difference between the averages indicated by different letters in the same line is statistically significant (Tukey HSD α = 0.05). The values cover a period of two years and are expressed in terms of Mean±SD (*: p<0,05; **: p<0.01).

The aril color a* value of the type and varieties ranged between 39.73 (Hicaznar) and 47.66 (Kışnarı). The fruit aril color a* values of the pomegranates vary significantly by country, region, and ecology where the research is conducted, and particularly varies by the studied varieties. As a matter of fact, the fruit aril color a* values of pomegranates are reported to range between 0.31 and 34.10 (Legua et al., 2000; Yılmaz, 2005; Gölükçü and Tokgöz, 2008; Al-Said et al., 2009; Borochov-Neori et al., 2009; Gündoğdu et al., 2011; Caliskan and Beyazit, 2012; Fawole and Opara, 2013a; Fawole and Opara, 2013b; Nuncio-Jáuregui et al., 2014; Yaman et al., 2015; Boussaa et al., 2019).

The aril color b* value of the type and varieties was highest for the Kirli Hanım variety with 22.02 and the lowest was for the Hicaznar with 18.25. In many studies conducted in different ecological environments (Legua et al., 2000; Yılmaz, 2005; Gölükçü and Tokgöz, 2008; Al-Said et al., 2009; Gündoğdu et al., 2011; O'Grady, 2012; Fawole and Opara, 2013b; Nuncio-Jáuregui et al., 2014; Yaman et al., 2015; Boussaa et al., 2019), pomegranate fruit aril b* values were reported to range between -1.90 and 30.02. The results in this study on the b* values of the aril indicating the change from yellow to blue seem to agree with the findings in the literature.

The lowest chroma value for aril color was registered for the Hicaznar (43.73) and the highest for the Kirli Hanım (53.99). The literature shows that the chroma values of pomegranates for aril color (C*) vary between 0.39 and 33.24 (Legua et al., 2000; Yılmaz, 2005; Gölükçü and Tokgöz, 2008; Özgen et al., 2008; Gündoğdu et al., 2011; Caliskan and Bayazit, 2012; O'Grady ,2012; Fawole and Opara, 2013b; Nuncio-Jáuregui et al., 2014; Yaman et al., 2015; Boussaa et al., 2019). According to the aril color chroma values obtained in the study (low values are highlighted in dark colors, high values are highlighted in lighter colors), the Kirli Hanım was found to have the lightest aril color while the Hicaznar variety was found to have the darkest aril color.

The average aril color H° value of the type and varieties varied between 24.48 (Kış Narı) and 25.95 (Kirli Hanım). Caliskan and Bayazit (2012) found it to vary between 33.6-65.8 for sourish pomegranates and between 26.5-64.1 for sweet pomegranates and between 34.3-68.9 for sour pomegranates; O'Grady (2012) found it to vary between 17.3 (Ruby) and 22.1 (Arakta) in South Africa; Fawole and Opara (2013a, 2013b) found the hue value for the variety "Ruby" to vary between 32.09-47.18 in South Africa; Yaman et al. (2015) were value of 30.42 for the Hicaznar variety in the region of Hatay. The findings are consistent with the current literature.

Fruit peel and aril color PCA analysis

The results of measurement for fruit peel and aril color are given in Tables 1 and 2. A Principal Component Analysis (PCA) was performed where fruit peel and aril color properties were assumed based on varieties. In this way, pomegranate type and varieties were classified according to latent variables. When the classification of pomegranate type and varieties with PCA was examined on the basis of color properties, it became evident that type and varieties have been very accurately classified (Figure 3). The total variance ratio accounted for by the first two components was 87.27%. Although only color characteristics were used in PCA analysis, the rate of variance explained is quite high. The rate of variance explained by the first component was 46.14%, and the rate of variance explained by the second component was 41.13 %. In the PCA analysis, aril a*, aril b* and aril H^{o} are the most important properties of the first component. On the other hand, peel L*, aril L* and peel C* are the most important properties of the second component (Table 3).

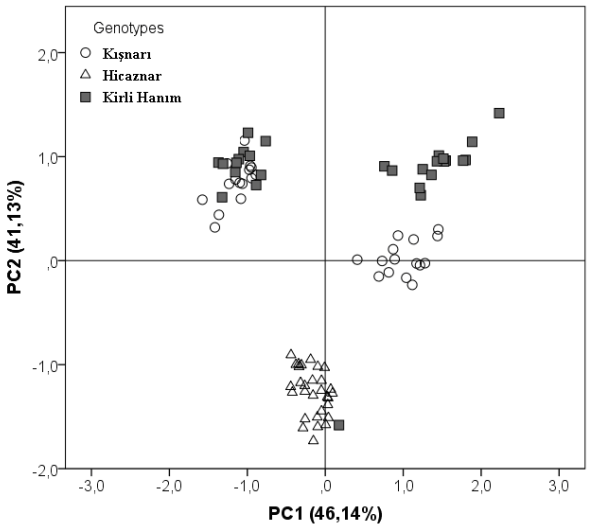

Figure 3. Classification of variety and types according to color characteristics (Principal Component Analysis)

Table 3. PCA factor load values (Component Matrix[1])

Peel and Aril Color Properties		PC1	PC2
Peel	L*	.060	.893
	a*	-.796	.548
	b*	.581	.770
	C*	-.344	.895
	Hue	.952	.152
Aril	L*	.068	.942
	a*	-.815	.472
	b*	.846	.157
	C*	-.532	.677
	Hue	.973	-.067

(1: Extraction Method, Principal Component Analysis)

Conclusions

It has been established that the type and varieties grow fastest in fruit width and length in the second period (25 July) when the data was taken during the period from full blossom to harvest and that they maintain a proportional and steady growth from this period until the period when the final data was recorded (October 5). However, it was found that fruit growth in width was greater than fruit growth in fruit length and also that there was a significant and highly positive relationship between fruit width in the growth period as well as the fruit length in the growth period. In this study, it was found that the fruit width and height of the Hicaznar variety were higher than the growth values of the other two genotypes.

According to the results of the research, the brightest peel structure was found in the Kirli Hanım variety (L*: 94.88), and the darkest red peel (a* = 30.17, C* = 36.99, H^0 = 35.14) and aril (a* = 39.73, C* = 43.73, H^0 = 24.55) color was determined in the Hicaznar variety.

In the pomegranate market, varieties with large fruit sizes, dark and red colored varieties are preferred. According to these results, particularly the Hicaznar variety, which was brought to Gaziantep from outside, yielded larger and darker fruits than other local types and varieties in this study reveals that this variety should be considered both in the new pomegranate garden establishment studies and in the breeding studies. However, in order to reach a definite conclusion, values obtained for many years are still required.

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Contribution: AAP conceived and designed the experiments. ST performed the experiments. ST and RB analyzed the data. ST wrote and revised the paper. All authors read and approved the final version of the manuscript (AAP: A. Aytekin POLAT; ST: Serdar TURKER; RB: Recep BİNDAK)

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