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Yerel Zeytin Çeşitlerindeki Pomolojik Değişimlerin Farklı Hasat Zamanlarında Belirlenmesi

Nesrin GÜLCEMAL[1], Sercan ÖNDER[1], Muhammet TONGUÇ[1*]

ÖZET: Zeytin (*Olea europaea* L.) yağ üretiminde kullanılan önemli bir meyve türüdür ve antik çağlardan bu yana tarımı yapılmaktadır. Türkiye yerel zeytin çeşitleri bakımından zengindir ve yerel zeytinlerin özelliklerinin belirlenmesi gerekmektedir. Mevcut çalışmada beş zeytin çeşidinin (Çekişte, Memecik, Yamalak sarısı, Eşek zeytini, Gemlik) meyve gelişimi boyunca 5 farklı hasat dönemindeki (H1-H5) pomolojik özelliklerinin belirlenmesi amaçlanmıştır. Zeytin çeşitlerine ait meyveler, Aydın'daki bir meyve bahçesinden 2019 yılının Temmuz-Kasım tarihleri arasında birer aylık aralıklarla toplanmıştır. Meyve gelişimi ve olgunlaşması boyunca 10 pomolojik özellik (meyve eni ve boyu, çekirdek eni ve boyu, meyve ve çekirdek ağırlığı, meyve eti ağırlığı, et/çekirdek oranı, meyve eti sertliği ve meyve nem içeriği) incelenmiştir. Tüm pomolojik özellikler hasat dönemleri ve çeşitler arasında önemli farklılıklar göstermiştir. Çeşitlerin meyve olgunlaşma indeksleri zamanla artmış fakat çeşitler arasındaki değişim seviyeleri farklı olmuştur. Zeytin çeşitlerinin meyve gelişim dönemleri boyunca meyve boyu ve eni, meyve ağırlığı, çekirdek boyu ve eni, meyve eti ağırlığı ve et/çekirdek oranı önemli ölçüde artarken, meyve eti sertliği ve meyve su içerikleri ise azalmıştır. Çekirdek ağırlığı H1-H3 hasat dönemlerinde artmış ancak meyve gelişiminin sonraki aşamalarında önemli bir değişim göstermemiştir. Zeytin çeşitlerinin çekirdek sertleşme döneminden başlayarak meyve gelişim ve olgunlaşma dönemleri boyunca devam eden önemli fizyolojik değişikliklerin meydana geldiğini göstermektedir.

Anahtar Kelimeler: Meyve kalitesi, *Olea europea*, zeytin meyvesi, zeytin çekirdeği

Determination of Pomological Changes in Local Olive Varieties at Different Harvest Times

ABSTRACT: Olive (*Olea europaea* L.) is an important oil producing fruit species and it has been cultivated since ancient times. Turkey is rich in local olive varieties and it is necessary to determine their pomological parameters. The aim of the present study was to determine the pomological characteristics of five olive varieties (Çekişte, Memecik, Yamalak sarısı, Eşek zeytini, Gemlik) at five harvest periods (H1-H5) throughout the fruit development period. Olives were collected from an orchard in Aydın at monthly intervals between July and November 2019. During fruit development and ripening, 10 pomological variables (fruit width and length, seed width and length, fruit and seed weight, flesh weight, flesh/seed ratio, flesh firmness and fruit moisture content) were measured. All pomological variables exhibited significant differences between harvest periods and varieties. While fruit ripening indices of the varieties increased over time, level of change differed among the varieties. During fruit ripening of olive varieties, fruit length and width, fruit weight, seed length and width, fruit flesh weight and flesh/seed ratio increased significantly, while flesh firmness and fruit water contents decreased. Seed weight increased between H1-H3 periods, but it did not show a significant change at the later stages of fruit development. These results show that important physiological changes occur starting from the pit hardening of the olive varieties and continue throughout the fruit growth and ripening.

Keywords: Fruit quality, *Olea europea*, olive fruit, olive seed

[1]Nesrin GÜLCEMAL (**Orcid ID:** 0000-0002-3543-5165), Sercan ÖNDER (**Orcid ID:** 0000-0002-8065-288X), Muhammet TONGUÇ (**Orcid ID:** 0000-0003-1292-2910), Isparta University of Applied Science, Faculty of Agriculture, Department of Agricultural Biotechnology, Isparta, Turkey

Sorumlu Yazar / *Corresponding Author: Muhammet TONGUÇ, e-mail: muhammettonguc@isparta.edu.tr

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INTRODUCTION

Olive (*Olea europea* L.) has been grown since antiquity for its fruits and oil. The Oleacea family has 25 genera and contains 600 species in the world. The *Olea* genus has 30 species including *O. europaea* with 2n=46 chromosomes (Kailis, 2017). Olive is grown commercially in 37 countries throughout the world between 30°- 45° north and south latitudes (Toscano et al., 2015), but 95% of the production takes place around the Mediterranean basin (Özaltaş et al., 2016).

Olive is an evergreen tree species blooming between May and June and produces dark green drupe type fruits. Fruits continue to develop throughout summer and fall, and drupes weights and dimensions increase, color change from dark green to black, water content and fruit firmness decrease during the maturation period (Therios, 2009; Kutlu and Şen, 2011). Fruit size and shape is largely genotype dependent, but fruit development and quality influenced by tree age, crop load, environmental factors and production methods (Criado et al., 2004; Di Vaio et al., 2012; Küçükyaşar and Pazır, 2019).

Olive production is a very important economic activity in Turkey with over 180 million olive trees planted in 37 provinces. The majority of production takes place in the Aegean region and Aydın has the largest production area and the highest olive production among the olive growing provinces (Anonymous, 2021). Turkey ranks as the fourth largest producer of olives in the world (FAOSTAT, 2021) with over 1.3 million tons of production in 2020, and approximately 513 thousand tons are used as table olives (TUIK, 2021). Turkey is the third largest producer and consumer of table olives in the world with 4.3 kg per capita consumption annually. The majority (85%) is used as black and the rest (15%) is used as green table olives (Çolak and Çulha, 2020). Olive and olive oil production directly contributes livelihoods of 2 million and indirectly to 8 million people in Turkey (Özaltaş et al., 2016). Many local varieties of olive exist in Turkey and 119 of them were characterized and registered as olive varieties in recent years (Arsel and Sefer, 2010; Öztürk et al., 2021), Gemlik, Ayvalık, Memecik and Domat cultivars constitute over 90% of the production area in Turkey. The other varieties grown mainly as local varieties suited to ecological conditions of different regions (Savran and Kaya, 2018). Studies that examine local varieties are scarce and mainly deal with olive and oil quality at the harvest stage. Therefore, the purpose of the present study was to evaluate changes in pomological features of five olive varieties from the fruit setting period to the fruit development period.

MATERIALS AND METHODS

Fruits of five olive varieties (Gemlik, Memecik, Çekişte, Yamalak sarısı and Eşek zeytini) were evaluated in the study. After pit hardening took place in July, fruits were harvested from an olive orchard in Yenice village (37° 49′ N, 28° 34′ E), Karacasu, Aydın at five different harvest periods (H1-H5) between July-November 2019 with monthly intervals (Figure 1). The olives in the orchard were watered with flood irrigation during the summer. The meteorological data were obtained from the State Meteorological Service (MGM) for Aydın province and is presented in Table 1.

Table 1. Long term (1941-2019) and monthly average temperatures (°C) and rainfall (mm) for 2019 of Aydın province

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avr.
Mean temperature	8.1	9.3	11.8	15.9	20.8	25.6	28.2	27.6	23.7	18.6	13.5	9.5	17.7
Mean rainfall	119	93.5	70.6	49.2	36.3	16.2	7.6	5.8	17.4	44.1	81.5	126.2	667.4
Monthly temperature	8.5	10.6	13.3	16.0	21.6	26.9	28.4	29.3	24.4	21.4	16.5	10.5	18.9
Monthly rainfall	206	58.3	28.6	56.9	11.9	26.9	1.2	0.0	16.6	29.4	65.1	117.7	618.0

Figure 1. Fruits of olive varieties evaluated at five different harvest times in 2019

The ripening index (RI) of olives was calculated according to Karagöz et al. (2017). Ten measurements were taken from different development periods of fruits to assess pomological changes during the fruit development period of olives. Fruit length and width were measured with an electronic caliper and fruit weights were recorded with a scale from each harvest period. Fruit flesh was peeled with a knife and fruit flesh weights were recorded. Seed length, width and weights were measured as described above. The flesh/seed ratio was calculated by dividing flesh weight to seed weight. Flesh firmness was measured along the equatorial circumference at each harvest period with PCE-PTR 200 digital penetrometer equipped with a 6 mm sensor (PCE Instruments, UK) and the results are given in Newtons (N). The water content of fruits was calculated as described by Uylaşer and Başoğlu (2016). Peeled and homogenized pulps (5 g) were oven dried at 105 °C until they reached a constant weight. After allowing samples to cool in a desiccator, dry weights of the samples were measured and water contents of the samples (%) were calculated with the following formula (1).

$$\%\text{water} = \frac{(\text{Fresh weight of samples}) - (\text{Dry weight of samples})}{\text{Fresh weight of samples}} * 100 \quad (1)$$

All measurements were taken with three replications and each replication contained 30 olive fruits. Data was subjected to analysis of variance (ANOVA) using IBM SPSS Statistics 22.0 software (SPSS Inc., Chicago, IL, USA). Mean separations were calculated using least significant differences (LSD) at $p \leq 0.05$ significance level.

RESULTS

Changes in fruit size and color of olive varieties during the study period was presented in Figure 1. Memecik and Gemlik fruits started to turn pink at the H3 period and continued to change color. Eşek zeytini and Yamalak sarısı turned purple-black at H5 period, yet Çekişte turned to pale green at the last harvest stage. To evaluate the maturity stages of olives at harvest periods, RI values were calculated. At H1 period, all olives were dark green and RI values were close to 0 and were below 1 at the H2 period. After H3 period, rapid increases in RI values for Gemlik, Yamalak sarısı and Memecik was observed and RI increase continued at H4 and H5 periods (Table 2). Çekişte and Eşek zeytini reached to RI values between 1 and 2 at H4, but Çekişte RI values remained between 2 and 3 at H5.

Table 2. Changes in ripening index of olives during the different harvest periods

	H1	H2	H3	H4	H5
Gemlik	0.15±0.03d	0.38±0.04d	1.78±0.07c	3.03±0.09b	4.35±0.11a
Eşek zeytini	0.02±0.00c	0.30±0.02c	0.82±0.04bc	1.85±0.06b	3.62±0.09a
Memecik	0.13±0.03c	0.68±0.09c	1.85±0.12b	3.13±0.10a	4.09±0.14a
Yamalak sarısı	0.07±0.00c	0.40±0.01c	1.55±0.06b	2.30±0.06b	3.85±0.08a
Çekişte	0.10±0.00b	0.18±0.03b	0.45±0.06b	1.43±0.07a	2.29±0.09a

Fruit lengths of olive varieties varied at H1 and the lengths continued to increase throughout the development period. Initially, Eşek zeytini had the highest fruit length (3.07 cm) and Gemlik had the shortest (1.91 cm) at H1. At H5 period, both Eşek zeytini (3.39 cm) and Gemlik (2.17 cm) still had the highest and the shortest fruit lengths. Even though Memecik and Çekişte had shorter fruit lengths than Eşek zeytini, the highest length gains were observed in Memecik (43%) and Çekişte (24%) during the fruit development period (Figure 2A).

Fruit widths also varied among the varieties and harvest stages. Fruit widths ranged from 1.40 cm for Memecik to 1.82 cm for Eşek zeytini at H1 (Figure 2B). Fruit widths increased for all varieties and Eşek zeytini had the largest fruit width and had the second largest enlargement of fruits (43%) after Memecik (54%) at H5. Gemlik had both the smallest fruit diameter (1.73 cm) and diameter increase (13%) among the olive varieties.

Although there was an increase in fruit weights for all olive varieties, Çekişte, Eşek zeytini and Gemlik's fruit weights did not significantly increase until the H4 (Figure 2C). Memecik and Yamalak sarısı rapidly increased their fruit weights at the H2 period and their fruit weights did not significantly increase between H3 and H4 periods and later significantly increased at H5. Memecik had the lowest (2.25 g) and Eşek zeytini (5.49 g) had the highest fruit weights at H1. Eşek zeytini had the highest (12.35 g) and Gemlik had the lowest (3.75 g) average fruit weights at H5. While fruit weight increased by more than 300% in Memecik, Çekişte, Yamalak sarısı; Eşek zeytini's fruit weight increase was around 200%. Gemlik had 145% fruit weight increase throughout the fruit development period.

Changes in fruit flesh weights of varieties followed similar patterns to fruit weights. Çekişte, Eşek zeytini and Gemlik flesh weights were not significantly different between H1-H3 periods but significantly increased at H4 and H5 periods. Memecik and Yamalak sarısı flesh weights significantly increased at H2. While Yamalak sarısı flesh weight increase was not significant between H2- H4 periods, Memecik flesh weight increase was significant at H4. The highest flesh weight increases were recorded in Memecik (430%) and Çekişte (300%) and the lowest in Gemlik (172%) between H1 and H5 periods (Figure 2D).

Seed lengths of Gemlik and Yamalak sarısı did not significantly increase between H1-H4 periods (Figure 2E). Eşek zeytini and Memecik seed lengths increased significantly at H3. Seed length increase was not significant at H4 and H5 periods for Eşek zeytini, but was significant for Memecik at H5. Çekişte seed length increased significantly at H2 and but no significant changes were not detected between H3-H5 periods. Overall, the highest seed length increases were observed in Memecik (28%) and Eşek zeytini (25%); and the lowest was in Gemlik (10%).

Seed widths of olive varieties were 0.77-0.88 cm at H1 and reached 0.89-0.99 cm at H5. Çekişte seed width increased 5% from H1 to H5 periods, and seed width increase was not significant between H1 to H5 periods. Similarly, seed width increase from H1 to H4 periods for Gemlik and Eşek zeytini was not significant. The highest seed width increase was recorded for Gemlik with a 19% increase and a significant seed width increase took place at the H5 (Figure 2F).

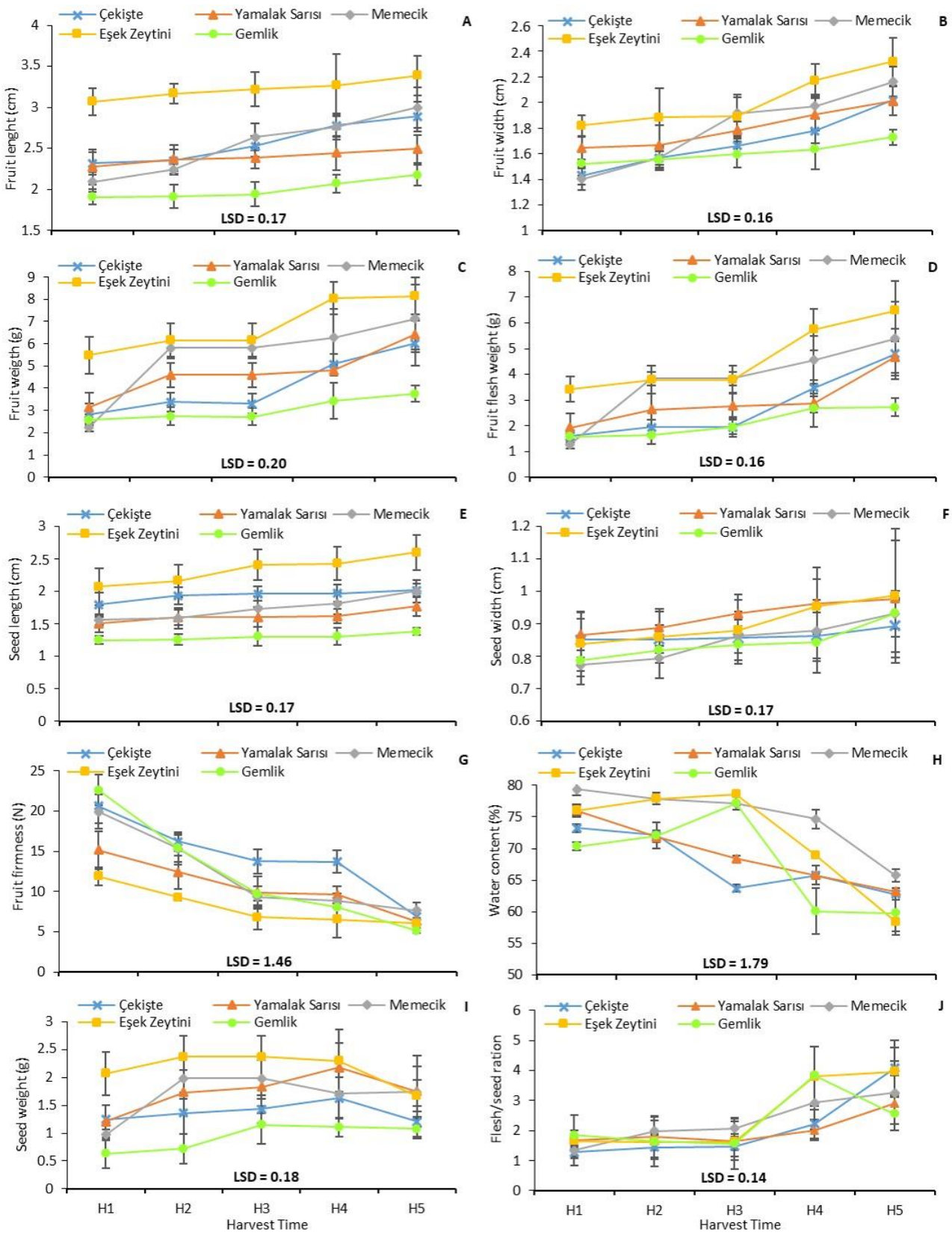

Figure 2. Changes of pomological parameters in olive varieties at different harvest periods during the study period

Fruit flesh firmness of olives was highest at H1. The lowest flesh firmness was observed in Eşek zeytini (11.89 N) and the highest was found in Gemlik (22.63 N) at H1 (Figure 2G). Fruit flesh firmness decreased steadily as fruit development progressed. Çekişte, Memecik and Gemlik flesh firmness

decreased significantly at H2. The level of decrease between H2-H4 periods for Çekişte, H3-H5 periods for Memecik, Eşek zeytini, Yamalak sarısı and Gemlik was not significant. Fruit flesh firmness values varied from 5.14 N for Gemlik to 7.64 N for Memecik at H5.

The water content of olive fruits varied among the varieties and harvest periods (Figure 2H). The water content of Yamalak sarısı significantly decreased between the harvest periods, from 76.3% at H1 to 63.2% at H5. Similar to Yamalak sarısı, Memecik's water content decreased from 79.4% at H1 to 65.8% at H5, and it was significant between H3 to H5 periods. Gemlik's water content significantly increased from 70.4% at H1 to 77.1% at H3 afterward decreased to 60.1% at H4 and remained almost the same at H5. Eşek zeytini's water content increased until H3 and reached 78.6%, later dropped to 58.4% at H5. Çekişte's water content dropped from 73.2% at H1 to 62.9% at H5.

Seed weight increased with harvest period at the early stages of fruit development and started to decrease after H4 for all varieties, but it was only significant for Çekişte and Eşek zeytini between H4 and H5 periods. Gemlik (0.63 g) and Memecik (0.97 g) had the lowest seed weights at H1, and Çekişte (1.21 g) and Gemlik (1.08 g) had the lowest seed weights at H5. Eşek zeytini, Yamalak sarısı and Memecik had similar seed weights (1.64-1.74 g) at H5. Çekişte and Eşek zeytini lost 3% and 23% of their initial seed weights at H5; respectively.

Çekişte had the lowest flesh/seed ratio (1.28) and Gemlik had the highest (1.85) at H1. The flesh/seed ratio did not increase significantly between H1-H3 periods and it significantly increased at H4 for all varieties. A significant increase was observed for Çekişte at H5, while a significant decrease for the flesh/seed ratio was observed for Gemlik and its flesh/seed ratio dropped to 2.56 at H5 from 3.85 at H4. Gemlik had the lowest flesh/seed ratio increase during the study (138%) while the highest increase was found for Çekişte (318%).

DISCUSSION

Gemlik is the most widely cultivated olive variety in Turkey (Savran and Kaya, 2018) and Memecik is the most commonly cultivated olive variety in the Aegean region (Nergiz and Engez, 2000). Gemlik and Memecik have dual uses as table and oil olives with high oil contents. Çekişte, Eşek zeytini and Yamalak sarısı are local varieties from İzmir and Aydın provinces, and used as table olives with low to moderate oil contents (Kaya et al., 2015).

Pomological properties of olive varieties are influenced significantly by climatic conditions, especially rainfall and temperature (Efe et al., 2009; Ocakoğlu et al., 2009), location (Criado et al., 2004) and elevation (Arslan et al., 2013). Even though olive varieties were grown in the same orchard, their maturity levels were different as reflected by their RI values, which were close to 0 at H1 and was between 2.29 to 4.35 at H5 (Table 2). Gemlik and Memecik had the highest RI values at H5 and most of their fruits still had black epicarp with green flesh. Çekişte had the lowest RI value at the end of the harvest period. Efe et al. (2013) reported that color change in the fruit happens in a short time while the ripening process takes a long time in olives. In addition, growing methods affect pomological properties of fruits (Küçükyaşar and Pazır, 2019). According to Kaya et al. (2015), Yamalak sarısı and Memecik are early, Gemlik and Çekişte are mid, and Eşek zeytini is late maturing varieties. In the present study, Gemlik, Memecik and Yamalak sarısı were found to be early maturing varieties. While Çekişte was classified as a mid-maturing variety, its RI value was lower than the other varieties, suggesting that growth location and conditions may affect fruit development and maturation levels.

Fruit length, width and weights increased during the development period of olives. Fruit weights were significantly different from each other at H5. Fruit weights were given as 2-4 g for Gemlik, 4-6 g for Çekişte and Memecik and over 6 g for Yamalak sarısı and Eşek zeytini (Kaya et al., 2015). In the

present study, Memecik's reported fruit weight was higher; the fruit weight of other varieties was within the reported ranges. Fruit weight, length and width also show similar development pattern for other olive varieties, as reported for Memecik (Uğurlu and Özkan, 2011; Yıldırım et al., 2017), Gemlik (Gümüşoğlu et al., 2006; Çevik et al., 2013; Keçeli, 2013), Edremit (Yorulmaz et al., 2013), Ayvalık and Topakaşı (Yıldırım et al., 2017), Domat (Gümüşoğlu et al., 2006), Adana topağı (Keçeli, 2013), Kargaburun, Erkence, Saurani and Halhalı (Arslan, 2012) and 6 foreign olive varieties grown in Turkey (Gündoğdu et al., 2016; Kaleci et al., 2016). However, fruit weight, length and width could decrease with increased maturity level (Uğurlu and Özkan, 2011; Yıldırım et al., 2017) or remain the same (Arslan, 2012). In the present study, fruit weight, length and width did not decrease indicating the fruits were not fully ripened at the end of the study period as noted for their RI values.

Seed size is an important quality factor for olives as it influences flesh/seed ratio, especially for table olives. Seed development largely takes place before the fruit development between June and July, later mesocarp growth accelerates (Therios, 2009). Although seed widths steadily increased, statistically important seed width increases were observed only for Memecik at H3, Eşek zeytini at H4, and Gemlik at H5 periods. For seed length, significant increases were observed at H1 for Çekişte, at H3 for Memecik and Eşek zeytini, at H4 for Yamalak sarısı. Seed weights increased till H3 and started to decrease and important seed weight losses were observed for Çekişte, Yamalak sarısı and Eşek zeytini at H5. Seed weights of four local olive varieties from Hatay province did not show any significant change at three different harvest times (Arslan, 2012). Seed length and width increases and decreases were reported both for local (Uğurlu and Özkan, 2011; Yıldırım et al., 2017) and foreign olive varieties (Gündoğdu et al., 2016; Kaleci et al., 2016) during the development period of olives.

The olives are harvested at different periods depending on their uses. Table olives are harvested when they turn yellow-green or red-black. Fruits should reach their normal size and mesocarp tissue should lose its stiffness (Caran, 2004). Significant changes in fruit firmness, water content, and flesh/seed ratios were observed in the study. Fruit firmness was highest at H1 and significant decreases was observed beginning from H2 for all varieties and continued throughout the development period. The lowest fruit firmness values were observed at H5 for all varieties. Decrease in fruit flesh firmness is an indication of fruit growth and maturity (Gümüşoğlu et al., 2006; Özdemir et al., 2011). Even though significant water content increase was not measured for H1 and H2 periods, reduction of fruit firmness at these early stages of development indicates mesocarp growth and loosening of cell walls starts at the early periods when all varieties had RI value less than 1.

The water content increased rapidly during the early periods of olive ripening, as dry matter and oil accumulation increase, flesh/seed ratio and water content began to decrease at maturity (Theiros, 2009). Water contents of varieties decreased from H1 to H5 periods and the highest decrease from H3 to H5 was observed in Eşek zeytini and Gemlik. Flesh/seed ratio did not increase between H1-H3 periods and a significant decrease was observed for Gemlik between H4 and H5 periods. Gemlik fruits had the highest water contents up to RI values 4-5 and overripe fruits started to lose water (Çevik et al., 2013; Özdemir et al., 2011). Similarly, Memecik water content and flesh/seed ratio also decreased with increased maturity (Nergiz and Engez, 2000; Uğurlu and Özkan, 2011).

CONCLUSION

The aim of the present study was to determine changes in pomological properties of five olive varieties, and pomological measuruments were taken at monthly intervals during the fruit development. All examined parameters had significant changes during the fruit ripening period. While fruit firmness and fruit water contents decreased, the other pomological properties increased at the end of the study

period. These results show that significant pomological and physiological changes occur starting from pit hardening and continue during the fruit development period. While Gemlik and Memecik were the early maturing, Çekişte was the latest maturing variety. Eşek zeytini had both the highest fruit and seed measurements, and Gemlik had the smallest fruit and seed meaurements.

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Conflict of Interest

The article authors declare that there is no conflict of interest between them.

Author's Contributions

The authors declare that they have contributed equally to the article.

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