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Phenological and pomological characterization of promising loquat (*Eriobotrya japonica*) cultivars suitable for the Mediterranean climate

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ABSTRACT

This study was conducted during the 2017 and 2018 growing seasons to determine the yield performances, phenological and pomological characteristics of ten 21-year-old loquat cultivars grown under Mediterranean conditions at Dörtyol, Hatay, Turkey. The flowering of the cultivars was observed in detail and the earliest flowering was found in 'Akko XIII' and the latest in 'Ottaviani' cultivars. Among the tested cultivars, the highest yield was found in 'Champion' (168 kg tree^{-1}, 387.36 g cm^{-2}) whereas the earliest and latest ripening cultivars were found as 'Akko XIII' and 'Lapta M', respectively. The highest values in terms of fruit weight, seed weight and seed number were obtained from 'Baduna 5' variety as 50.60 g, 9.59 g and 4.50 fruits, respectively. In terms of fruit flesh/seed ratio, 'Hafif Çukurgöbek' (5.33) had the highest value, while 'Lapta M' (3.29) had the lowest. The highest total soluble solids, pH and acidity values were measured in 'Hafif Çukurgöbek' (13.70%), 'Lapta B2' (3.85) and 'Lapta M' (1.15), respectively. The cultivars used in the study were compared using the Weighted-Rankit Method according to their important characteristics and the cultivar 'Hafif Cukurgöbek' got the highest score. However, the results showed that most of the cultivars used in the experiment, except 'Lapta M', could be grown economically in the Mediterranean climate.

1. Introduction

Loquat (*Eriobotrya japonica* (Thunb.) Lindl) is an evergreen subtropical fruit, which unlike most fruit trees, blooms in autumn and winter. As it blooms in autumn and winter, pollination, fertilization, and therefore yield can be adversely affected (Eti et al. 1990). When the ecological conditions are taken into account, it can be easily grown in the coastal areas of the Mediterranean Region and some regions of Turkey with microclimate characteristics. (Polat 1996). However, almost all of the loquat cultivation in Turkey is carried out in the Mediterranean Region (Çelikyurt et al. 2011; Tepe 2013).

Considering the climatic conditions and location in the Mediterranean region, Hatay should be in a much better situation than other provinces but unfortunately has lagged behind in terms of the number of loquat trees and the amount of production. Achieving early ripening in the period when fresh fruits are limited in the market, could provide a satisfactory income for the producers (Durgac et al. 2006). In addition, Hatay, being very close to the Middle Eastern countries, has an advantage of marketing loquat in both domestic and foreign markets (Kızıl 2019).

This study aimed to determine the most suitable loquat varieties for the Dörtyol region, which is under the influence of the Mediterranean climate, and thus to contribute to loquat cultivation both in our country and in other countries with similar ecologies.

2. Materials and Methods

The study was carried out on 21-year-old loquat plants planted at a distance of 6x6 m in Dörtyol (Hatay), located in the Mediterranean climate zone, in the 2016-2017 and 2017-2018 vegetation periods. The vegetative growth, yield, phenological and pomological characteristics of the cultivars ('Akko XIII', 'Baduna 5', 'Gold Nugget', 'Güzelyurt 1', 'Hafif Çukurgöbek', 'Lapta B2', 'Lapta M', 'Ottaviani', 'Sayda' and 'Champion') were determined through the methods outlined below with five replications.

Phenological observations were made in detail from the beginning of flowering to the ripening period. The results were evaluated according to Durgac et al (2006) i.e. the period in which 5% of the flowers blossomed was assumed to be "beginning of blossoming", the period in which 70% of the flowers blossomed was assumed to be "full bloom", and the period in which the flowers drop 70% of their petals after pollination was assumed to be "end of blossoming". The first stage in which the receptacle swells and turns into fruit after the flowers have dropped their petals was assumed to be "fruit set", and after that, the stage in which the formed fruits reach the size of a hazelnut was assumed to be "small fruit". The fruits were harvested in the period in which cultivars obtain their specific properties such as color and taste.

To determine the relationship between vegetative growths and yield components, the trunk circumference of the trees were measured 10 cm above from the grafting point using a tape measure. With the help of the values obtained, the cross-sectional areas were calculated. After determining the tree yield (kg tree^{-1}), the yields per unit trunk cross-sectional area (g cm^{-2}) were calculated.

Within the scope of the pomological analysis, 50 fruit samples were picked randomly as five replications, which each tree being one replication (10 fruits per tree), at harvest time (the period when 70% of the fruits mature). Pomological characteristics of these fruit samples such as fruit weight, fruit width, fruit length, width/length index, number of seeds, seed weight, flesh/seed ratio, fruit skin color, fruit flesh color, total soluble solids (TSS), pH and titratable acidity were determined.

The experiment was planned as five replications, with one plant per replicate. The data were analyzed by ANOVA with a completely randomized design and the mean comparison with the 'Duncan Test' (Steel and Torrie 1980). Statistical analyses of the obtained data were performed using the SPSS Statistics program. The data obtained at the end of all these calculations were evaluated using the 'Weighted-Rankit Method' (Yazgan 1979), taking into account the most desired features in loquats.

3. Results and Discussion

3.1. Phenological observations

According to the phenological observations, flowering periods of the cultivars took place between 2 November 2017 and 25 February 2018 (Fig. 1). 'Akko XIII' was the earliest and 'Ottaviani' was the latest blooming cultivar. Due to the characteristics of the varieties and the effect of ecological conditions, some annual differences were observed in the flowering period of plants. Akkuş and Polat (2022) found the flowering period of the 'Hafif Çukurgöbek' cultivar between 11 December and 31 January in Antakya. The same cultivar flowered between 26 November 2017 and 22 January 2018 in our study. The flowering of 'Hafif Çukurgöbek' cultivar started and ended earlier in our study. This difference is probably due to the fact that the study site location was very close to the sea, while the study site of Akkuş and Polat (2022) was approximately 30 km further away from the sea. Polat and Çalişkan (2011a) found the flowering period between November 14 and February 17 in a previous study on the same field and on the same plants as in this study. Durgac et al. (2006) found the flowering period between 26 November and 3 February. Our findings were similar to those of Polat and Çalışkan (2011a), and differed from those of Durgac et al. (2006) and Akkuş and Polat (2022). The longest blooming period was found in 'Sayda' (36 days), the shortest in 'Ottaviani', 'Hafif Çukurgöbek' and 'Baduna 5' (17 days each). The observations in our study generally coincide with the observations made by Polat and Çalişkan (2011a).

As with many other fruit species, early maturing cultivars in loquats are usually sold at a higher price than mid-season ripening cultivars. For this reason, precocity is an important criterion in terms of marketing. In terms of precocity, 'Akko XIII' was the earliest to mature. This was followed by 'Hafif Çukurgöbek' and 'Champion' varieties, respectively. The latest maturing variety was 'Lapta M'. The first harvest of all varieties was between mid-April-early May, and the last harvest was between the end of May-early June. Previous studies under Hatay ecological conditions have shown that the average harvesting period was between mid of May and mid of June (Durgac et al. 2006; Polat and Çalişkan 2011a). These small differences between studies may be due to cultural practice conditions and climatic parameters that change over the years.

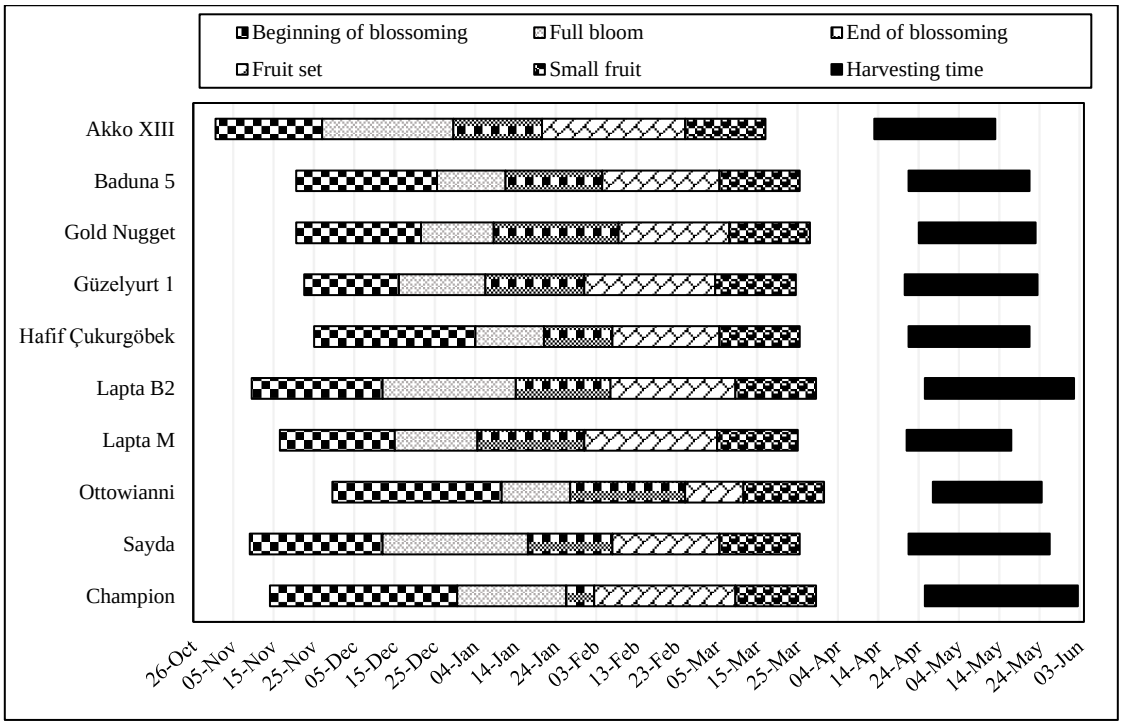

Figure 1. Phenological observations of cultivars (average of years 2017–2018).

3.2. Yield components

The differences in yield per tree and per unit trunk cross-sectional area of the cultivars were statistically significant ($P \leq 0.05$) (Table 1). In the study, yields per tree and per unit trunk cross-sectional area were found to be between 50.02-168.46 kg tree^{-1} and 96.94-387.36 g cm^{-2}, respectively. The highest yield per tree and unit trunk cross-sectional area was obtained from 'Champion' and the lowest yield was obtained from 'Lapta M' cultivars. In a previous study, the highest yield per tree from the 'Champion' cultivar with 56.80 kg tree^{-1}, and the lowest from 9.30 kg tree^{-1} from the 'Lapta 1' cultivar were reported (Polat and Çalışkan 2011a), respectively. In terms of yield per unit trunk cross-sectional area of 'Gold Nugget' cultivar, Razeto et al. (2003) found between 0.12 kg cm^{-2} and 0.64 kg cm^{-2}, and Durgac et al. (2006) obtained 44.15 g cm^{-2}. The yield values obtained in our study were found to be higher than those of Polat and Çalışkan (2011a) and Durgac et al. (2006) and close to the yield values of Razeto et al (2003). This difference between the studies may have resulted from both the age of the plants and cultural processes. The results in our study were obtained from 21-year-old trees, whereas Durgac et al. (2006) were obtained from 6-year-old trees.

Table 1. Yield parameters of cultivars (average of years 2017–2018)

Cultivars	kg tree^{-1}	g cm^{-2}
Akko XIII	143.00 ab*	297.39 b
Baduna 5	118.16 bcd	288.83 b
Gold Nugget	84.29 e	268.53 bc
Güzelyurt 1	128.69 bc	291.88 b
Hafif Çukurgöbek	104.39 cde	285.57 b
Lapta M	50.02 f	96.94 d
Lapta B2	133.13 bc	290.67 b
Ottaviani	143.74 ab	272.30 bc
Sayda	89.80 de	197.43 c
Champion	168.46 a	387.36 a

*Values in the same column with different letters are significantly different ($P \leq 0.05$).

3.3. Pomological analyses

The pomological analyses of loquat cultivars are depicted in Table 2. There were statistical differences ($P \leq 0.05$) among all the pomological characteristics of the cultivars. Fruit size, which varies due to genetics and environmental conditions (such as the age of the tree, the amount of fruit set and cultural practices), is an important factor in loquat marketing. Fruit weights of the cultivars ranged from 24.85 g ('Lapta M') to 50.60 g ('Baduna 5'). Previous studies reported that the highest fruit weight was found in 'Guzelyurt 1' with 37.80 g, and the lowest fruit weight was found in 'Akko XIII' with 20.20 g (Polat and Çalışkan 2011a). The average fruit weights reported in other studies, 50 g for 'Mogi', 60 g for 'Nakasakiwase' and 70 g for 'Tananka' in Japan; 70 g for 'Jiefangzhong', 60 g for 'Dawuxing' and 'Zaozhong No-6', in China; 65g for 'Algerie' in Spain (Lin et al. 1999). Llácer et al. (2003) reported that the average fruit weight of 'Ullera' cultivar is 90 g in Spain and this cultivar can produce fruit up to 250 g. Compared to the above studies, fruit size of our cultivars in the experiment was relatively small. In another study conducted in Adana, fruit weights of the cultivars ranged from 22.47 g ('Champagne de Grasse') to 39.14 g ('Dr. Trabut') (Paydaş et al. 1992). The fruit weights obtained in our study were found to be higher than similar cultivars used in both studies. The relationship between varieties in terms of fruit sizes (width, length) was found to be similar to fruit weight.

Caldeira and Crane (1999) reported that the fruit shape of loquats varied from pear shape to round generally. When the fruit index value (width/length) approaches 1.00, it is considered to be round. In our study, the width/length ratios of the loquat cultivars ranged from 0.92 to 0.81. These results showed similarities with the results of Polat et al. (2003) and Uzun et al. (2012) who reported 0.90-0.80 and 0.88 and 0.76, respectively.

When the seed weight and number of the experimental cultivars were considered, the highest values were found in 'Baduna 5' (9.59 g and 4.50 pieces fruit^{-1}) while the lowest seed weight (4.85 g) was found in 'Champion' and the lowest seed number (2.99 pieces fruit^{-1}) was found in 'Gold Nugget' cultivars. Özdemir and Topuz (1997) found the highest seed weight in 'Gold Nugget' cultivar with 3.22 g, and the lowest seed weight in 'Tanaka' cultivar with 0.73 g in a study they conducted in Antalya. The researchers determined the maximum number of seeds (3.30 pieces fruit^{-1}) in the 'Hafif Çukurgöbek' and the least (1.75 pieces fruit^{-1}) in the 'Seedling'.

As in many other fruit species, the fruit flesh/seed ratio is another important fruit quality factor in loquats. Flesh/seed ratio was highest in 'Hafif Çukurgöbek' (5.33), and lowest in 'Lapta M' (3.29). In different studies, flesh/seed ratio values of the loquat cultivars changed between the highest 6.03 and the lowest 3.42 (Erdogdu 1987; Yalcin and Paydaş 1995; Yilmaz et al. 1995; Polat et al. 2003; Tepe and Koyuncu 2020).

Table 2. Average pomological analyses of loquat (*Eriobotrya japonica* (Thunb.) Lindl) cultivars between 2017 and 2018

Cultivars	Fruit weight (g)	Fruit width (mm)	Fruit length (mm)	Width/length index	Seed weight (g)	Seed number (piece)	Flesh/seed ratio	Fruit skin color	Flesh color
Akko XIII	41.30 bc*	39.95 b	43.21 c	0.92 a	7.09 bc	3.69 b	4.78 abc	Orange	Orange
Baduna 5	50.60 a	42.34 a	50.63 a	0.84 cd	9.59 a	4.50 a	4.29 bc	Yellow	Cream
Gold Nugget	32.60 de	37.61 cd	42.56 c	0.88 abc	5.45 de	2.99 c	5.00 ab	Orange	Orange
Güzelyurt 1	44.49 bc	40.21 ab	48.07 b	0.84 cd	7.95 bc	3.64 b	4.62 abc	Yellow	Cream
Hafif Çukurgöbek	36.25 cd	39.19 bc	43.66 c	0.90 abc	5.81 de	3.32 bc	5.33 a	Orange	Orange
Lapta B2	31.87 de	36.61 de	42.96 c	0.85 bcd	6.04 de	3.42 bc	4.36 bc	Yellow	Cream
Lapta M	24.85 f	34.42 ef	39.44 d	0.87 bc	5.80 de	3.06 c	3.29 d	Yellow	Cream
Ottaviani	42.08 bc	40.50 ab	47.59 b	0.85 bcd	7.00 c	3.82 b	5.02 ab	Orange	Orange
Sayda	27.41 ef	34.55 ef	42.79 c	0.81 d	5.61 de	3.44 bc	4.05 c	Orange	Orange
Champion	26.80 ef	32.84 f	40.52 d	0.81 d	4.85 e	3.25 bc	4.65 abc	Yellow	Cream

*Values in the same column with different letters are significantly different by Duncan's test ($P \leq 0.05$).

The fruit skin colors of the cultivars were divided into two groups as orange and yellow. 'Akko XIII', 'Gold Nugget', Hafif Çukurgöbek', 'Ottaviani' and 'Sayda' cultivars were found to have orange fruit skin color, 'Baduna 5', 'Güzelyurt 1', 'Lapta M', 'Lapta B2' and 'Champion' cultivars had yellow fruit skin color. The flesh color of the cultivars with orange fruit skin color was also orange, while the fruit flesh color of the cultivars with yellow fruit skin color was determined as cream. The results of our study are similar to other studies (Paydaş et al. 1991; Durgac et al. 2006; Ferreres et al. 2009; Polat and Çalışkan 2011a; Tepe 2013; Balcı 2015; Tepe and Koyuncu 2020; Dhiman et al. 2021).

The total soluble solids contents of the loquat cultivars vary from 7 to 20% (Lin et al. 2007). In general, a high-quality loquat fruit has high Total Soluble Solids (TSS) content. In our study, TSS content was found to be over 11.5% in all loquat varieties except 'Ottaviani' and 'Gold Nugget'. 'Hafif Çukurgöbek' (13.70%) and 'Lapta B2' (13.68%) cultivars were found to have the highest TSS content, and 'Ottaviani' (9.82%) the lowest. In different studies, 'Gold Nugget' had 11.2 % in Italy (Insero et al. 2003), and 11.2% TSS content in Spain (Llácer et al. 2003). While pH values varied between 3.85 and 3.42, the highest and lowest values were obtained from 'Lapta B2' and 'Lapta M' cultivars, respectively. Malic acid is the predominant organic acid in loquats. It confers a tart taste to fruit, although the amount decreases with increasing fruit ripeness (Gurtler and Mai 2014). Acidity of the cultivars varied between 0.42% ('Güzelyurt 1') and 1.15% ('Lapta M'). There is generally an inverse relationship between the pH value of the fruits and their acidity. The acidity was low in cultivars with high pH value and high acidity was found in cultivars with low pH value (Figure 2).

3.4. "Weighed Rankit Method" of the cultivars

All the cultivars in the study were evaluated with the "Weighed Rankit Method", and the scores obtained from each characteristic of the cultivars and their total scores are given in Table 3. The "Weighed Rankit Method" score was highest in 'Hafif Çukurgöbek' (800 points) and lowest in 'Lapta M' (450 points). It is thought that not only 'Hafif Çukurgöbek' but also 'Akko XIII', 'Champion' and 'Güzelyurt 1' varieties with a score above 700 can be successfully grown in the Mediterranean climate.

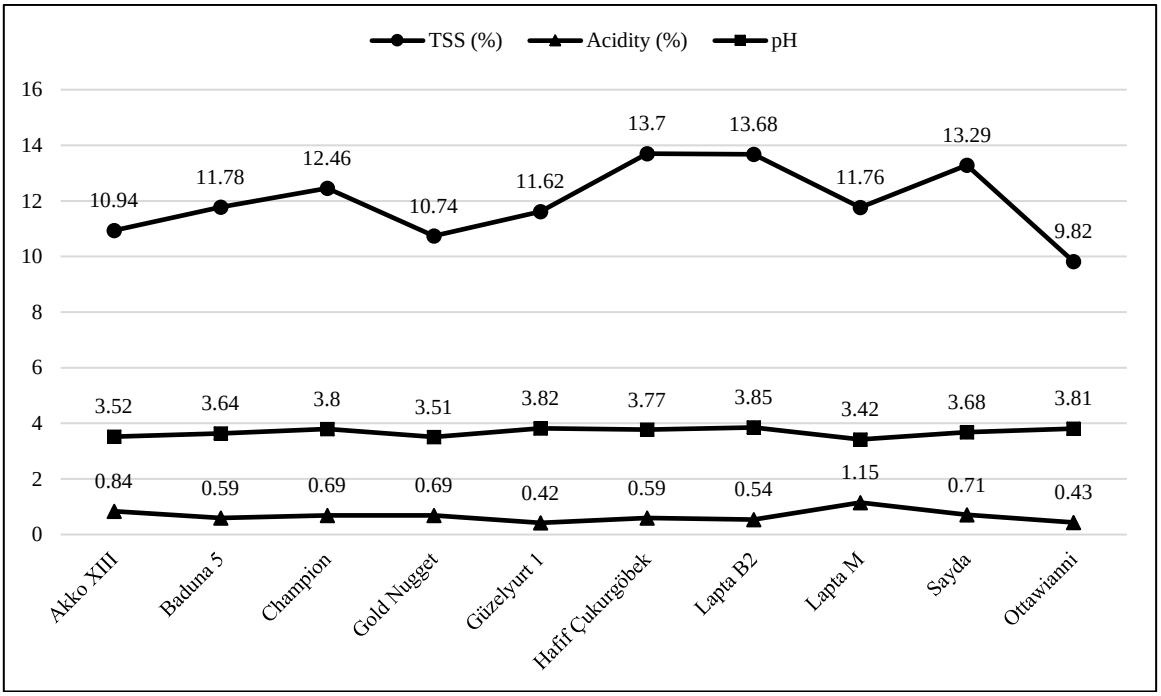

Figure 2. Total soluble Solids (TSS), pH and titratable acidity contents of loquat cultivars.

Table 3. Weighted-Rankit Method scores of the cultivars for some important commercial characteristics

Cultivar	Yield (Kg tree^{-1})	Fruit weight (g)	Seed number (piece)	TSS (Brix)	Flesh/seed ratio	Fruit skin color	Precocity	Total
Akko XIII	200	160	60	60	80	100	100	760
Baduna 5	150	200	40	90	60	50	40	630
Gold Nugget	100	120	100	60	80	100	80	640
Güzelyurt 1	200	160	60	90	80	50	60	700
Hafif Çukurgöbek	150	120	80	150	100	100	100	800
Lapta B2	200	40	80	150	60	50	80	660
Lapta M	50	120	80	90	20	50	40	450
Ottaviani	200	160	60	30	100	100	40	690
Sayda	100	80	80	150	60	100	80	650
Champion	250	80	80	120	80	50	100	760

4. Conclusions

The loquat is one of the most important species in minor fruit trees in Mediterranean countries. Under Mediterranean climatic conditions loquats bloom in autumn and winter, and fruits ripen mostly in spring. During this period, they are sold at high prices, as there are few competitive fruits on the market except for strawberry, green plum, and green almond. In addition, due to the limited loquat cultivation in the world, it can be sold at high prices in international markets. In our study, 'Akko XIII' was most suitable for its fruitfulness; 'Champion' for its productivity; 'Baduna 5' for its large fruits; 'Hafif Çukurgöbek' for its flesh/seed ratio, TSS and bright orange color. Our results revealed that all cultivars except 'Lapta M' were promising in terms of yield, plus various pomological and phenological characteristics. Nevertheless, 'Hafif Çukurgöbek' cultivar comes to the fore in the common expectations (fruit quality, suitability for transportation, attractiveness) of both producers and consumers.

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Appendix

The cultivars used in the experiment and their characteristics are given below.

'Akko XIII' is an attractive and delicious cultivar with dark pink fruits that ripen in mid-season. It is very resistant to transportation and Black Spot disease. TSS content and malic acid content are 25-40 g, 10-11% and 1-1.7%, respectively (Demir 1987; Polat and Çalışkan 2011b; Polat and Turunç 2015).

'Gold Nugget' is a dark orange, attractive, delicious and late maturing loquat cultivar originating from the USA, with an average fruit weight of 35-40 g. It is a self-fertile cultivar and begins to bloom in mid-November. TSS content is around 11-12% and pH value is between 3-3.5 (Demir 1987; Polat and Çalışkan 2011b; Polat and Turunç 2015).

'Güzelyurt 1' is a Cyprus origin cultivar and is sensitive to cold. It starts to bloom from the beginning of December and at the end of the same month, almost all of the flowers bloom. Fruit weight is around 40-45 g and seed weight is between 2-3 g (Polat and Çalışkan 2011b; Polat and Turunç 2015).

'Hafif Çukurgöbek' is an early maturing cultivar selected from Turkey. Its fruits are pink-orange, attractive, very tasty and sweet. It is a variety that is partially suitable for transportation, resistant to black spot disease and self-fertile. Average fruit weight, TSS content, pH value and malic acid content are between 45-50 g, 12-13%, 3-3.5 and 0.9-1%, respectively (Demir 1987; Polat and Çalışkan 2011b; Polat and Turunç 2015).

'Lapta B2' is a Cyprus origin cultivar and its flowering period continues from the beginning of December to the end of January. The average weight of the fruits is 30 g and usually contains 2-3 seeds. TSS content of its fruits is between 12-13%, pH value is 3.5-4, malic acid content is between 0.4-0.5 (Polat and Çalışkan 2011b; Polat and Turunç 2015).

'Lapta M' is a Cyprus origin cultivar and is sensitive to winter cold. It begins to bloom at the end of November and ends in the second half of January. The number of seeds in the fruits is generally low and the TSS content is 13-14% (Polat and Çalışkan 2011b; Polat and Turunç 2015).

'Ottaviani' is a delicious mid-season loquat cultivar with very large pear-shaped fruits. It is resistant to black spot diseases. Average fruit weight is 40-41 g, pH value is 3.5-4, TSS content is 8-9%, and malic acid content is around 0.4-0.5% (Demir 1987, Polat and Çalışkan 2011b; Polat and Turunç 2015).

'Sayda' is an early maturing cultivar with large, pink-orange colored, very sweet and delicious fruits. It is moderately resistant to transport and black spot disease. Average fruit weight is 32 g, TSS content is 13-14%, pH value is between 3-3.5, malic acid ratio is between 1-1.5% (Polat and Çalışkan 2011b; Polat and Turunç 2015).

'Champion' begins to bloom from the end of November and continues to bloom until the beginning of January. Average fruit weight is 33-34 g, TSS content is 12%, pH is 3.5-4, malic acid ratio is between 0.6-0.7%. (Polat and Çalışkan 2011b; Polat and Turunç 2015; Karabıyık and Eti 2015).

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