Prunus microcarpa: a potential rootstock for apricots

Remzi UĞUR*

East Mediterranean Transitional Zone Agricultural Research Institute, Kahramanmaraş, Turkey

*Corresponding author's e mail: remzibey@hotmail.com

Orcid id number: https://orcid.org/0000-0001-6717-1689

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ABSTRACT

One of the most important developments in the history of fruit growing is the discovery and use of dwarf rootstocks.Today, dwarf rootstock studies continue in different fruit species including apricot.The main goal of this study was to identify new dwarfing rootstocks for apricots that limit apricot tree height and size, without altering scion production or fruit characteristics. In this study, 'Hacıhaliloğlu', 'Hasanbey', 'Kabaaşı', and 'Roxana' apricot cultivars grafted on *Prunus microcarpa* -a potential rootstock for apricot- were investigated. Phenological, morphological, yield and quality traits of apricot (*Prunus armeniaca* L.) cultivars grafted on *Prunus microcarpa* seedlings and apricot (*P. armeniaca*) seedlings and Pixy (*Prunus institia*) were exemined. The study was carried out between 2011-2016 years in the field and laboratories of the Kahramanmaraş East Mediterranean Transitional Zone Agricultural Research Institute. Phenologically, it was observed that apricot varieties grafted on P. microcarpa rootstock showed

2-5 days shorter blooming period than control rootstocks.Furthermore, the average flowering time was completed in a shorter time in this rootstock compared to the control rootstocks. *P. microcarpa*gave lower rooststock diameter (68.80 mm) based on average of four cultivars while the highest seedling diameter was obtained from *P. armeniaca*seedlings (109.27 mm). The apricot cultivars grafted on *P. microcarpa*in general showed a remarkable dwarf growing with an average shoot length of 83.65 cm, an average crown volume of 3.26 $m^3$and a average trunk cross-section of 37.32 cm^2, respectively. In addition, the yield was found to be significantly higher in trees grafted on *P. microcarpa* with a value of 0.20 $kgcm^{-2}$ compared to the other two control rootstocks (equally 0.16 $kgcm^{-2}$). It was determined that total soluble solid content values did not differ statistically among rootstocks, and Pixy (*P. institia*) rootstock gave the higher fruit weight than the others (42.44 g).

Key words: Apricot, P*runus*, *prunus microcarpa*, rootstock,yield.

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1. Introduction

Turkey is one of the most important countries in the world in terms of fruit production. In addition to the temperate zone, the cultivation of subtropical and even tropical fruit species in some areas makes the country important for fruit production.In recent years, a better understanding of the importance of fruits in terms of human health and nutrition has increased fruit cultivation and consumption in Turkey. In the face of increasing interest, the sector is developing very rapidly in the light of technological developments (Engin and Mert, 2020;Sulu et al., 2020, Gundesli et al., 2021; Okatan et al., 2021).

Although Turkey is not the homeland of apricots, it has a very special place in the world in terms of apricot cultivation. Turkey has one of the most favorable climate and soil characteristics in the world for both fresh and dried apricot cultivation. In some regions, both table and dried apricot cultivation can be done together (Gecer et al., 2020; Karatas and Sengul, 2020).

The increase in the interest in both fresh and dry apricot cultivation in Turkey and the increased of export-oriented studies in recent years and the expansion to different markets have increased both the apricot area and amount of production(Ozdoğru et al., 2015). Thus, fresh and dried apricot production of Turkey is continuously increasing. For example fresh apricot production was 75.800 tons in 1963 year and increased to 143.000 tons, 245.000 tons, 280.000 tons, 499.000 tons and 811.609 tons in 1973, 1983, 1993, 2003, and 2013 , respectively. However due to spring frosts, fluctations on production amount was evident on apricot in Turkey and in 2018 the total apricot production of Turkey was 685.000 tons (FAO, 2020).Depending on the years, Turkey provides 22-28% of the world's fresh apricot production.Turkey's share in world exports of fresh apricots is 13.6% while it is 79.7% in the dried apricots.

Prunus is one of the biggest and diverse genus in horticulture and consist of more than 250 different species in tree and bush form and many of them was not botanically defined yet. It is known that there are many unidentified wild species in this genus. In general *Prunus* species widely distributed in the northern hemisphere and most of the wild species occur in arid and semi arid climates. The taxonomy of the genus is complicated because of the polymorphism, natural hybridization, wide ecological tolerance of the species, as well as the presence of numerous openpollinated genotypes. Cultivated species such as apricot, peach and nectarine, sweet and sour cherries, almond and plum of the genus are high economic value and found under varying ecological conditions. Cultivars of *Prunus* species are very prone to modern fruit growing practices and offer a wide alternative for growers and consumers with their cultivars that mature in different periods(Gundogdu, 2019; Guney, 2019;Gecer, 2020).

Each region in Turkey has different climatic and soil conditions. Thus, each region has its own suitable apricot cultivars. Since apricot has a weak adaptability as a species, problems arise in interregional transportation of cultivars within the country (Ercisli, 2009). Therefore, several factors should be considered when selecting an apricot cultivar, including local climate, desired market (fresh or processed), ripening date, and fruit characteristics. In addition to selecting cultivars that tolerate local climatic conditions, growers also tend to plant multiple cultivars with a range of ripening dates to reduce labor demand at one time during the season and to take advantage of different niches within the fresh market.

Anatolia shows great ecological diversity from subtropic climate to temperate climate. For that reason, a large number of native *Prunus* species include *P. domestica*, *P. cerasifera*, *P. divaricata*, *P. spinosa*, *P. microcarpa*, *P. scoparia*, *P. amygdalus*, *P. arabica* etc.widely found in the country and represented by a large number of genotypes. Recently, new studies have been carried out on the possibility of using wild Prunus species as clonal rootstocks. (Bolat et al., 2017).

One of the modern applications in fruit science is the use of dwarf rootstock. Rootstocks have several advantages to provide resistance to climate and soil conditions, shorten the flowering period, early fruit formation, increase fruit yield and quality (Darikova et al., 2011). *Prunus* species can be use as rootstocks each other makes it possible to grow different species in different soil conditions. For that reason different rootstocks belongs to *Prunus* species is widely used in apricots (Milosevic et al., 2014). Rootstock breeding studies have been carried out for apricots in different parts of the world in apricot growing countries and important findings have been revealed by examining the tree growth (Nicolae et al., 2017), yield(Sosna,and Malanczuk, 2012), quality (Hernandez et al., 2010) and fruit biochemical properties (Gundogdu, 2019). However, since the rootstock and scion relationship has a complex structure in apricot, discussions about the use of suitable rootstocks are still ongoing and a perfect rootstock for apricot has not yet been found(Sharma at al.,2020). With the onset of global warming in recent years, breeding of rootstocks that grow in different soil and climatic conditions, easily propagated, control of tree vigor, increase the yield and fruit quality, and have good anchorage has become increasingly important (Ugur and Gundesli, 2020).

Apricot cultivation is intensively carried out in Turkey, Poland, Romania, Russia, Serbia, Czechia, France, Hungary and Switzerland. Myrobolan rootstocks (*P. cerasifera*) are commonly used in these countries. Although this rootstock is resistant to hard soil conditions and groundwater, it is not suitable for high density planting due to its strong development in suitable soil conditions (Sitarek and Bartosiewicz, 2011; Milosevic et al., 2014). In addition, some of the apricot cultivars grafted on Myrobolan rootstocks also reveal grafting incompatibility (Licznar and Sosna, 2005). The use of dwarf clonal rootstocks is of great importance for modern intensive apricot orchards consisting of more homogeneous plants (Ercisli, 2009).

P. microcarpa is a wild *Prunus* species that has dwarf growing characteristics, which grows naturally in the region including Northern Iraq and Western Iran from the eastern, southern and southeastern regions of Anatolia (Nas et al., 2011a), is genetically close to the cherries (Nas et al., 2011a,b) and it is one of the *Prunus* that has a small carpel structure. It has an average fruit width of 7 mm and a fruit length of 8 mm (Sevgin, 2018). Plants of this species have white or pink flowers and red, black or yellow fruits (Ugur, 2020). The trees of the specie has bush height of 3 meters at maximum, being able to grow at an altitude of 300-1500 m, has shorter vegetation period compared to other *Prunus* species, exhibit better adaptation capacity to hot-cold-dry climate conditions with salinity resistance properties (Nas et al., 2011a,b;Mohammadi et al.,2019). Although *P. microcarpa*, has spread widely in Anatolia, the number of researches on rootstock properties is insufficient. For these reasons the main objective of this study was to investigate the influence of *P. microcarpa* rootstock on vegetative growth, vigor, phenological changes, productivity, fruit quality parameters in four apricot varieties under East Mediterranean conditions.

2. Materials And Methods

The research was carried out between 2011–2016 in the field and laboratories conditions of the Kahramanmaras East Mediterranean Transitional Zone Agricultural Research Institute, Turkey. The experiment was established at a range of 4 × 3 m and a total of 180 trees were used. Along with *Prunus microcarpa* seedlings,apricot seedlings (*P. armeniaca* L.) and Pixy (*P. institia*) clone were used as control rootstock. The apricot cultivars‘Hacıhaliloğlu’, ‘Hasanbey’, ‘Kabaaşı’ and ‘Roxana’ were grafted on those three rootstocks.

Phenological features: The phenological observation results (bud swelling, first flowering, full flowering and end of flowering) were determined. Fruit-flower formation were evaluated on annual shoots according to the scale of 0-3: 0-no fruit-flowerformation, 1-less than 1/10, 2-more than 2/10, 3-more than 3/20 flowers and/or fruit (Donadio at al., 2018). Flowering phenology (Gur, 2008)were determined in 2014-2016 years.

Tree growth: Crown volume was calculated according to the formula $V= (\pi r^2 h)/2$ (Tekintas, 2006). Rootstock diameter was measured 4 cm above soil level with 0.01 mm sensitive digital caliper (Tekintas, 2006). The diameter and length of the annual shoots on the main branches were measured and the average value was calculated at the end of the 6th year (Milosevic at al., 2014).

Fruit yield and quality measurements: Fruits were harvested at full maturation stage in 2014-2016 years from 3 tree for each repetitionsand they were weighed in electronic scales (PCS 572 Dinar 4948). Averages tree yields were calculated. Furthermore, weight values of approximately 50 ripe fruits that represent each plant were weighed on sensitive scale. Afterwards, TSS (Total Solible Solid) content was measured by using 30 fruits with hand refractometer (0-20 Brix ATC Refractometer) (Gundogdu, 2019).

Statistical analysis: In this study, randomized block design was used with 3 blocks and 4 trees in each repeat. The data were analyzed according to the factorial design in the package program JMP (7.0).LSD multiple comparison test with %5 significance level in application groups where the difference is important. In addition, correlation analyzes were made with same statistic program between the parameters examined.

3. Result and Discussion

The phenological observation results (bud swelling, first flowering, full flowering and, end of flowering) regarding rootstock/scion combinations in apricot are given in Table 1. It was observed that bud swelling started earlier in apricot cultivars grafted on P.microcarpa rootstock than control rootstocks (Table 1). The earliest full flowering was encountered in the *P. microcarpa*/Roxana combinations and the latest full flowering encountered in *P. armeniaca*/Hasanbey combination. It was also observed that the average flowering period was completed in a shorter period in all grafted apricot cultivars on *P. microcarpa* rootstock than the other rootstocks (Table 1).Flowering period were ranged from as short as 24 days in *P. microcarpa*/Roxana, while the longest flowering period was observed in *P. armeniaca*/Kabaaşı combination as 35 days (Table 1). Previously, cultivars grafted on *P. microcarpa* are reported to be shorter in vegetation period (Nas et al., 2011a,b; Mohammadi et al., 2019). This short flowering period may provide an advantage in early and table apricot varieties. In apricot varieties grafted on *P.microcarpa*, flowering is completed in a shorter time compared to other rootstocks, and early completion of the flowering period can reduce flower/fruit losses caused by late spring frosts. This short flowering period could have a positive effect on the yield. It could affect the pheneology of the grafted variety as it has different chilling and winter dormant periods on rootstocks. Eremin (2012) calculated the flowering times of Zard, Orangevy, Krasny, Kakalinski, Shlor and Vynoslvy local apricot cultivars grafted on different *prunus* rootstocks. In his study, the researcher reported that a similar situation occurred in apricots grafted on *P.microcarpa* due to the low chilling requrietment. However, in the same study, this investigator reported that although the chilling requirement of *P.microcarpa* rootstocks was low, flowering started late compared to other rootstocks. The results obtained by the researcher are generally consistent with the present study, on the contrary, the flowering date of apricot varieties grafted on *P.microcarpa* rootstock was started and completed later then the present study. High chilling requirement in rootstocks could cause similar problems in table apricot cultivation especially in subtropical regions. In these regions, it would be beneficial to use rootstocks with low chilling needs such as *P.microcarpa*.

Results on tree growth parameters of apricot cultivars grafted on *Prunus microcarpa* and control rootstocks are shown in Table 2, 3, 4 and 5. It was found that the difference between rootstocks, cultivars and their interactions was statistically significant in all tree growth parameters examined.

Among tree growth parameters, rootstock and scion diameters are given in Table 2. Based on 4 apricot cultivar averages, *P. microcarpa* rootstock gave the lowest (68.80 mm) whereas *P. armeniaca* seedlinggave the highest rootstock diameter (109.27 mm). Rootstocks exhibited statistically significant differences each other for rootstock diameter at p ≤ 0.01level. Pixy rootstock placed between those two rootstocks with a average value of 75.68 mm (Table 2). Considering rootstock/scion combinations, the lowest rootstock diameter was obtained from *P. microcarpa*/Kabaaşı combination with 62.28 mm, followed by *P. microcarpa*/Hasanbey combination (68.82 mm), *P. microcarpa*/Roxana (71.25 mm) and Pixy (*P.institia*)/Hasanbey (71.95 mm), respectively (Table 2). Another result is that all apricot cultivars grafted on apricot seedlings showed vigorous growth. In this context, the highest rootstock diameter was determined as 111.86 mm in the combination of *P. armeniaca*/Kabaaşı. The scions of four cultivars grafted on *P. microcarpa* rootstock showed the most dwarf growth with average of 59.85 mm. Pixy had 67.67 mm and the apricot seedlinghad 106.47 mm scion diameter (Table 2). The relationship between rootstock growth and scion diameter is a desired traits for compatible grafting combinations in fruit species. Otherwise, the risk of graft incompatibility may occure during time (Reig et al., 2018).

Table 3 indicate rootstock/scion homogenity and annual shoot length. According to the data obtained from the study, there was generally a homogeneous growth in all rootstock/scion combinations, although the level of homogenity among rootstock/scion combinations based on averages of 4 cultivars were statistically important (p ≤ 0.01). The most homogeneous combinations were observed in the *P. armeniaca* seedling (0.97), while the scion showed weaker growing compared to the rootstock in those who were grafted on *P. microcarpa* rootstock (0.86). The most homogeneous growth was observed in *P. armeniaca*/Hacıhaliloğlu with 1.0 while the most heterogeneous growth was seen in *P. microcarpa*/Kabaaşı with 0.77 (Table 3).

When the growth of rootstock and scion is analyzed in general, it is noteworthy that both rootstock and scion showed a dwarf development in those who were grafted on *P. microcarpa* (Table 2-5). Dimitrova and Marinov (2002) reported that the average rootstock diameter values varied between 15.30 and 16.20 cm in 7-years-old apricot cultivars grafted on Myrobolan rootstocks. Similar values were also obtained in the tree growth values of Novosadskarodna apricot variety grafted on *Prunus spinosa* L. interstock and Myrobolan 29C rootstocks (Miodragovic et al., 2019). Dimitrova and Marinov (2002) found that rootstock diameter of 'Hungarian Best' apricot cultivar varied between 11.94 and 18.56 cm when it grafted on Uhrepga, Greeggage, Damas GF 1869, Marianna GF-8-1, GF 655/2, Dzhanka and Alfred rootstocks. Similar results have been obtained from recent studies. Duval et al. (2012) reported that the average diameter values of some Bergarouge and Flavorcot apricot cultivars grafted on rootstocks were 15.47 cm for dwarf ones and 20.91 cm for strong ones at the end of 10 years. Comparing the data obtained from present study, it is clear that the apricot cultivars grafted on *P. microcarpa* showed dwarf development in terms of growth strength.

Annual shoot is very important organ for fruit trees for the formation of fruit buds. There was strong correlation between quality fruit buds and formation of quality shoots (Sitarek and Bartosiewicz, 2011). In present study, annual shoot formation in apricot cultivars grafted on *P. microcarpa* rootstock exhibited high degree of dwarf development than control rootstocks at $p \leq 0.01$ level. When consider 4 cultivars together,average annual shoot length as 83.65 cm was observed on *P. microcarpa* rootstock, while it was measured as 96.73 cm in Pixy and 139.21 cm in *P. armeniaca* seedlings. In terms of rootstock/scion combinations, the shortest shoot length was obtained from *P. microcarpa*/Kabaaşı combination (51.97 cm) while the longest shoot length was seen in the *P. armeniaca* seedling/Roxana combination with 225.75 cm (Table 3). Sosna and Malanczuk (2012) examined the shoot growth of some apricot cultivars grafted on different rootstocks and reported that annual shoot length values varied between 65 and 170 cm.It was seen that these values are compatible with previous studies. Atli et al. (2019) reported that annual shoot lengths of apricots grafted onto *P.microcarpa* seedlings obtained from different regions varied between 43 and 85 cm. Researchers also grafted almond and cherry on *P.microcarpa* and obtained similar shoot growth values. In the present study, it was determined that annual shoot length values varying between 76.12-128.10 cm according to the cultivars were obtained. According to Atlı et al. (2019), it is seen that annual shoot length largely coincides with the results of the present study.

Another tree growth parameters were annual shoot diameter and tree height which were shown in Table 4. Parralel to shoot length, apricot cultivars grafted on *P. microcarpa* rootstock showed lower average shoot diameter (9.44 mm) compared to Pixy (10.51 mm) and *P.armeniaca* seedling (11.30 mm), respectively. Shoot diameter significantly varied among rootstocks used in this trial ($p \leq 0.01$). It was determined that the average annual shoot values of apricot cultivars grafted on *P.microcarpa* rootstocks varied between 8.74-11.44 mm (Table 4). The average annual shoot values reported by Atlı et al. (2019) were 6.10-8.00 mm, which is seen that it is relatively high. This small difference might be due to the different soil and environment conditions of the studies.

It was revealed that the rootstocks strongly affected tree height and statistically significant differences among rootstocks are evident at $p \leq 0.01$ level (Table 4). The average tree length averages of 4 apricot cultivars grafted on *P. microcarpa* rootstock was 242.73 cm, while it was 345.05 cm on Pixy and 410.02 cm in*P. armeniaca* seedling, respectively (Table 4). According to rootstock/scion combinations, it was found that the lowest tree height value was 221.55 cm in *P. microcarpa*/Kabaaşı combination and the highest value was 443.80 mm in *P. armeniaca* seedling/Kabaaşı combination. Malanczuk and Sosna (2013) found that tree length values varied between 240-300 cm in some apricot cultivars grafted on Pumiselect rootstock. It is remarkable that the plant height values of apricot cultivars grafted on *P. microcarpa* (221-264cm) in present study were found to be promising in terms of dwarf growth compared to value of dwarf apricot rootstock, Pumiselect (240-300 cm).

Table 5 shows tree width and crown volume of rootstock/scion combinations. The rootstocks greatly varied each other statistically ($p \leq 0.01$) in terms of tree width (Table 5). Based on four cultivars average, the lowest tree width was seen on *P. microcarpa* rootstock as 179.94 cm and followed by Pixy as 193.72 and *P. armeniaca* seedling as 322.45 cm, respectively (Table 5).

In rootstock breeding studies, crown volume values give researchers an idea about yield per decare, dwarf growth and how many trees per decare will be planted (Sosna and Malanczuk, 2012). According to the data of this study, crown volume values of all rootstocks were different from each other at $p \leq 0.01$ level. According to 4 cultivars average, the lowest crown volume value was obtained from *P. microcarpa* rootstock with 3.26 m^3, while Pixy rootstock had 5.18 m^3 and *P. armeniaca* seedling had 16.97 m^3 crown volume (Table 5). Among combinations, *P. microcarpa*/Kabaaşı (1.67 m^3) was the lowest crown volume while the highest crown volume was obtained from *P. armeniaca* /Hacıhaliloğlu (23.63 m^3) combinations. In the study of Malanczuk and Sosna (2013) on Pumiselect® rootstock, it was found that average crown volume were between 14.2–49.7 m^3 contrary to their expectation.These values are significantly different from the values of the present study.In their similar study, Sosna and Malanczuk (2012) observed the most dwarf tree crown volume as 9.6 m^3.

Fruit bud formation and trunk cross-section of rootstock/cultivar are given in Table 6. The dwarf rootstocks, Pixy and *P. microcarpa* displayed significantly higher bud formation ($p \leq 0.01$) as 2.16 and 2.08 based on four cultivars averages when compared to the seeedling (*P. armeniaca*), respectively (Table 6). The lowest trunk cross-section in the rootstocks was 37.32 cm^2 for *P. microcarpa*, 45.05 cm^2 for Pixy and 93.81 cm^2 for *P. armeniaca* seedling ($p \leq 0.01$). In rootstock combinations, the average trunk cross-section ranged between 30.49 (*P.microcarpa*/Kabaaşı) and

98.25 cm^2 (*P. armeniaca* seedling/Kabaaşı). Previously, in apricot rootstock breeding studies, average trunk cross-section was found to be 188-343 cm^2 in 10-years trees (Duval et al., 2012); 53.70 and 106.40 cm^2 in 5-years trees (Hernandez et al., 2010); 55.29-108.68 cm^2 in 6-years trees (Sosna and Malanczuk,2012); 51.66-84.68 cm^2 in 6-years trees (Milosevic et al., 2014); 29.30-80.70 cm^2 in 4-years trees (Malanczuk and Sosna, 2012). When the above studies were analyzed in general, although the rootstocks and growing locations are different, it was seen that there were a great differences on average rootstock trunk cross-section areas which varied between 29.30-343 cm^2. Cultivars grafted on *P. microcarpa* gave the high bud formation but the same ootstock tended to gave the lowest trunk-cross-section area (Table 6). Negative relationship between the trunk cross-section area and fruit formation as well as yield efficiency could be explained with dwarf growth (Milosevic et al., 2014). When compared with the results of the other studies, it could be said that there were similarities between present and the other studies.

Yield and cumulative yield data are given in Table 7 and it was clear that cultivar yields and cumulative yields strongly affected by used rootstocks. Yield data was obtained in 2016 year as kg/tree and cumulative yield data were obtained from 2014-2016. The dwarf rootstocks Pixy (*P. insititia*) gave the lowest yield per tree as 7.36 kg and followed by *P. microcarpa* as 7.65 kg/tree and *P. armeniaca* seedling gave 2 times higher yield per tree (14.62 kg) than dwarf rootstocks. Dwarf rootstocks were in the same statistical group but differed from *P. armeniaca* at $p \leq 0.01$ level (Table 7).

The cumulative yield per tree on *P. armeniaca* seedling was 21.97 kg/tree.In trees grafted on *P. microcarpa*and Pixy (*P. insititia*) it was 10.90 kg/tree 11.43 kg/tree, respectively. It was clear that as seen in yield data, dwarf rootstocks were placed in the same statistical group but differed from *P. armeniaca* at $p \leq 0.01$ level (Table 7). Milosevic ve ark (2014) in their study conducted that Biljana, Vera, Roxana and Harcot apricot varieties grafted on Myrobolan 29C rootstock and

Myrobolan/Blackthorn (*P.spinosa*) interstock average yield 52.24-69.41 kg/tree at the end of the 6th year. Duval et al. (2012) showed that the yield values of Bargaruoge and Flavorcot apricots varieties grafted on Torinel Avifel rootstock were 18.8-33.2 kg/tree. On the other hand, Hernandez et al. (2010) indicated that cumulative yield of E101 and E404 aprioct vaireties grafted different PADAC series rootstocks were 12.3-35.1 kg/tree. Considering all three studies on rootstock breeding, it could be said that the rootstocks are more vigorous than *P.microcarpa* in terms of growth. For appropriate planting densities, the data obtained from the present study can be considered promising to establish high density orchards. As given in Table 8, yield efficiency, fruit weight and TSS values were strongly affected by rootstocks at $p \leq 0.01$ level. The yield efficiency values were found to vary between 0.09-0.40 kg cm^{-2}. The highest yield efficiency was obtained from trees grafted on *P. microcarpa* (0.20 kg cm^{-2}), and it was found to be 0.16 kg cm^{-2} in the both control rootstocks (Table 8). In this study, where *P. microcarpa* gave promising results, the yield efficiency values were low compared to the literature. It is thought that the reasons for the yield values to be lower than expected are due to high the average wind speed during the flowering period, the late-spring-frost in 2014 and dried apricots in case of low chilling period (Table 8). In previous studies, yield efficiency values varied between 0.13-1.10 kg cm^{-2} depending to age and growing conditionsin apricot (Duval et al., 2012; Milosevic et al., 2014).

The average fruit weight was the highest in four cultivars grafted on Pixy (*P. insititia*) as 42.44 g, and followed by apricot seedling (41.44 g) and *P. microcarpa* as 40.11 g, respectively. There were statistically significant differences between rootstocks in terms of fruit weight ($p \leq 0.01$). Pixy (*P. institia*)/Roxana combination exhibited the highest fruit weight as 80.27 g. In fruit weight parameter, *P. microcarpa* was somewhat lower than control rootstocks. All rootstocks/Roxana combinations gave slightly higher fruit weight values (74.42-80.27 g) than

Milosevic et al. (2014) that reported Roxana cultivar between 73.85-77.50 g on different rootstocks in Serbia. In addition, average fruit weight values of used dried apricot cultivars in this study were similar with the literature (Karabulut et al., 2017; Karaat and Serçe, 2019).

4. Conclusion

In present study the rootstock characteristics of *P. microcarpa* were detaliedly investigated and promising results were found. It was thought that *P. microcarpa* could be a candidate rootstock for apricot cultivars. It was observed that quality fruit buds were formed in the second year in apricot cultivars grafted on *P. microcarpa* rootstock, and the flowering started earlier in this rootstock than the control group.It has been determined that *P. microcarpa* has significantly reduced the growth of grafted apricot cultivars. Hereby, it could be an important rootstock for modern highly-dense apricot orchards establishment and greenhouse apricot cultivation as well. Although preliminary studies of *P. microcarpa* have been envisaged to be durable or tolerant to nematode, it will be useful to carry out larger studies on this subject. However, the possibilities of clonal propagation of *P. microcarpa* should be investigated.

It is normal for the yield per tree to be lower due to dwarfing in apricot varieties grafted on *P. microcarpa* rootstock. However, due to the high yield efficiency of *P. microcarpa* rootstock, it should be known that higher yields will be obtained from the per unit area with the appropriate planting spacing. Atli et al. (2019) reported that cherry, almond and apricot varieties grafted on *P. microcarpa* rootstock showed dwarf growing. Because, it could be recommended to examine the properties of the rootstock for not only for apricots but also for plum, almond and peach cultivars. As a result, it is important to conduct comprehensive rootstock selection breeding studies about *P. microcarpa*, which is naturally spread in eastern, southern and southeastern regions of Turkey, to find promising rootstock candidates for the Mediterranean coastal and semi arid regions as well as to preserve them as rootstock genetic resources for some economically important *Prunus* species .

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Table 1. Phenological features of apricot cultivars grafted on *P.microcarpa*, Pixy and apricot seedlings

Rootstock	Cultivar	Bud Swelling	First Flowering	Full Flowering	End of Flowering	Flowering Period (days)
P.microcarpa	Hacıhaliloğlu	24.02	16.03	19.03	24.03	28
	Hasanbey	27.02	18.03	22.03	27.03	28
	Kabaaşı	22.02	15.03	19.03	24.03	30
	Roxana	20.02	11.02	14.02	18.03	24
Pixy (*P.institia*)	Hacıhaliloğlu	25.02	18.03	22.03	28.03	31
	Hasanbey	27.02	20.03	26.03	31.03	32
	Kabaaşı	23.02	17.03	21.03	26.03	31
	Roxana	20.02	12.02	16.02	20.03	28
Apricot Seedling (*P.armeniaca*)	Hacıhaliloğlu	26.02	21.03	25.03	01.04	33
	Hasanbey	01.03	21.03	27.03	02.04	32
	Kabaaşı	24.02	19.03	24.03	30.03	35
	Roxana	21.02	13.03	18.03	23.03	30

The differences between the means are shown in separate letters.**: $p < 0.01$; *: $p < 0.05$.

Table 2. Rootstock and scion growth in apricot cultivars grafted on different rootstocks

Rootstock	Cultivar	Rootstock Diameter (mm)		Scion Diameter (mm)	
P.microcarpa	Hacıhaliloğlu	72.87 ± 2.27 def	68.80 ±4.48 A	71.17 ± 1.56 e	59.85 ± 8.27 A
	Hasanbey	68.82 ± 1.44 b		61.58 ± 1.36 c	
	Kabaaşı	62.28 ± 2.20 a		48.43 ± 1.78 a	
	Roxana	71.25 ± 1.75 bc		58.23 ± 1.43 b	
Pixy (*P.institia*)	Hacıhaliloğlu	75.71 ± 1.19 f	75.68 ± 3.18 B	64.58 ± 1.58 cd	67.67 ± 3.84 B
	Hasanbey	71.97 ± 1.76 bcd		66.87 ± 1.64 d	
	Kabaaşı	75.51 ± 1.85 ef		65.73 ± 1.61 d	
	Roxana	79.55 ± 1.95 g		73.50 ± 1.80 e	
Apricot Seedling (*P.armeniaca*)	Hacıhaliloğlu	110.51 ± 2.04 i	109.27 ±3.04 C	112.02 ± 1.79 h	106.47 ± 3.70 C
	Hasanbey	109.71 ± 1.04 i		104.51 ± 1.75 fg	
	Kabaaşı	111.86 ± 1.21 i		106.52 ± 0.33 g	
	Roxana	105.01 ± 1.92 h		102.85 ± 0.82 f	
LSD		**3.62****	**1.81****	**3.11****	**1.79****

The differences between the means are shown in separate letters.**: $p < 0.01$; *: $p < 0.05$.

Table 3. Scion/Rootstock homogenity and annual shoot length in apricot cultivars grafted on different rootstocks

Rootstock	Cultivar	Scion/Rootstock Homogenity		Annual Shoot Lenght (cm)	
P.microcarpa	Hacıhaliloğlu	0.97 ± 0.01 ab	0.86 ± 0.08 C	76.12 ± 3.74 b	83.65 ± 27.81 A
	Hasanbey	0.89 ± 0.04 de		78.40 ± 1.53 bc	
	Kabaaşı	0.77 ± 0.06 g		51.97 ± 2.10 a	
	Roxana	0.81 ± 0.00 fg		128.10 ± 3.14 f	
Pixy (*P.institia*)	Hacıhaliloğlu	0.85 ± 0.03 ef	0.89 ± 0.04 B	96.60 ± 2.37 d	96.73 ± 20.98 B
	Hasanbey	0.92 ± 0.00 cd		74.55 ± 1.83 b	
	Kabaaşı	0.87 ± 0.00 e		85.57 ± 2.10 c	
	Roxana	0.92 ± 0.00 cd		130.28 ± 3.19 f	
Apricot Seedling (*P.armeniaca*)	Hacıhaliloğlu	1.01 ± 0.01 a	0.97 ± 0.03 A	112.35 ± 4.77 e	139.21 ± 50.33 C
	Hasanbey	0.95 ± 0.01 bc		111.65 ± 4.33 e	
	Kabaaşı	0.95 ± 0.01 bc		107.10 ± 8.20 e	
	Roxana	0.97 ± 0.02 ab		225.75 ± 4.62 g	
LSD		**0.04****		**8.05****	**4.01****

The differences between the means are shown in separate letters.**: $p < 0.01$; *: $p < 0.05$.

Table 4. Annual shoot diameter and tree height in apricot cultivars grafted on different rootstocks

Rootstock	Cultivar	Annual Shoot Diameter (mm)		Tree Height (cm)	
P.microcarpa	Hacıhaliloğlu	8.74 ± 0.84 ab	9.44 ±1.45 A	264.60 ± 2.94 c	242.73 ± 16.06 A
	Hasanbey	9.07 ± 0.93 abc		245.38 ± 4.60 b	
	Kabaaşı	8.53 ± 1.13 a		221.55 ± 4.16 a	
	Roxana	11.44 ± 0.28 e		239.40 ± 6.26 b	
Pixy (*P.institia*)	Hacıhaliloğlu	12.26 ± 0.28 de	10.51 ±0.57 B	348.60 ± 1.85 e	345.05 ± 14.74 B
	Hasanbey	9.83 ± 0.24 a-e		355.95 ± 8.72 e	
	Kabaaşı	10.55 ± 0.26 cde		352.97 ± 8.63 e	
	Roxana	10.40 ± 0.25 b-e		323.40 ±7.92 d	
Apricot Seedling (*P.armeniaca*)	Hacıhaliloğlu	9.60 ± 0.97 a-d	11.30 ±2.83 B	388.85 ± 6.40 f	410.02 ± 21.95 C
	Hasanbey	10.18 ± 0.48 a-e		397.93 ± 8.44 fg	
	Kabaaşı	9.66 ± 0.96 a-d		443.80 ±7.26 h	
	Roxana	15.77 ± 1.78 f		409.50 ± 5.07 g	
LSD		**0.84****	**1.71****	**13.20****	**6.59****

The differences between the means are shown in separate letters.**: $p < 0.01$; *: $p < 0.05$.

Table 5. Tree width and crown volume in apricot cultivars grafted on different rootstocks

Rootstock	Cultivar	Tree Width (cm)		Crown Volume (m^3)	
P.microcarpa	Hacıhaliloğlu	232.57 ± 4.07 cd	179.94 ± 34.43 A	5.61 ± 0.14 e	3.26 ± 1.46 A
	Hasanbey	182.70 ± 2.30 c		3.21 ± 0.04 bc	
	Kabaaşı	138.60 ± 4.37 a		1.67 0.07 a	
	Roxana	165.90 ± 4.06 b		2.58 ± 0.08 ab	
Pixy (*P.institia*)	Hacıhaliloğlu	179.55 ± 4.40 c	193.72 ± 36.07 B	4.41 ± 0.23 d	5.18 ± 1.84 B
	Hasanbey	166.95 ± 4.09 b		3.89 ± 0.29 cd	
	Kabaaşı	173.25 ± 4.24 bc		4.15 0.31 cd	
	Roxana	255.15 ± 6.25 d		8.27 ± 0.61 f	
Apricot Seedling (*P.armeniaca*)	Hacıhaliloğlu	393.40 ± 6.06 f	322.45 ± 46.50 C	23.62 ± 0.82 j	16.97 ± 4.56 C
	Hasanbey	312.20 ± 7.00 e		15.22 ± 0.76 h	
	Kabaaşı	319.11 ± 8.70 e		17.76 ± 1.23 ı	
	Roxana	265.10 ± 6.97 d		11.29 ± 0.48 g	
LSD		**11.28****	**5.64****	**1.11****	**0.55****

The differences between the means are shown in separate letters.**: $p < 0.01$; *: $p < 0.05$.

Table 6. Fruit bud formation and trunk cross-section of apricot cultivars grafted on different rootstocks

Rootstock	Cultivar	Fruit Bud Formation (1-3)		Trunk Cross-Section (cm^2)	
P.microcarpa	Hacıhaliloğlu	1.66 ± 0.47 cde	2.08 ± 0.64 A	41.72 ± 2.60 e	37.32 ± 4.75 A
	Hasanbey	2.00 ± 0.46 bcd		37.19 ± 1.56 bc	
	Kabaaşı	1.66 ± 0.46 cde		30.49 ± 2.15 a	
	Roxana	3.00 ± 0.47 a		39.87 ± 1.95 ab	
Pixy (*P.institia*)	Hacıhaliloğlu	1.66 ± 0.47 cde	2.16 ± 0.64 A	45.00 ± 1.40 d	45.05 ± 3.79 B
	Hasanbey	2.33 ± 0.47 abc		40.69 ± 1.99 cd	
	Kabaaşı	2.00 ± 0.46 bcd		44.78 ± 2.19 cd	
	Roxana	2.66 ± 0.47 ab		49.71 ± 2.43 f	
Apricot Seedling (*P.armeniaca*)	Hacıhaliloğlu	1.66 ± 0.47 cde	1.58 ± 0.64 B	95.09 ± 3.52 j	93.81± 5.17 C
	Hasanbey	1.33 ± 0.46 de		94.50 ± 1.79 h	
	Kabaaşı	1.00 ± 0.47 e		98.25 ± 2.12 ı	
	Roxana	2.33 ± 0.47 abc		86.60 ± 3.18 g	
LSD		**0.78****	**0.39****	**4.75****	**2.37****

The differences between the means are shown in separate letters.**: $p < 0.01$; *: $p < 0.05$.

Table 7. Fruit yield and cumulative yield in apricot cultivars grafted on different rootstocks

Rootstock	Cultivar	Yield (kg/tree)		Cumulative Yield (kg/tree)	
P.microcarpa	Hacıhaliloğlu	4.50 ± 0.31 d	7.65 ± 4.88 B	6.85 ± 0.75 d	10.90 ± 7.22 B
	Hasanbey	5.25 ± 0.31 d		7.83 ± 0.45 d	
	Kabaaşı	4.87 ± 0.31 d		7.24 ± 0.63 d	
	Roxana	16.00 ± 1.41 b		23.76 ± 1.94 a	
Pixy (*P.institia*)	Hacıhaliloğlu	4.50 ± 0.31 d	7.36 ± 4.62 B	6.75 ± 0.46 d	11.42 ± 6.69 B
	Hasanbey	4.87 ± 0.31 d		7.30 ± 0.42 d	
	Kabaaşı	4.75 ± 0.18 d		7.13 ± 0.18 d	
	Roxana	15.33 ± 0.62 b		22.41 ± 1.23 b	
Apricot Seedling (*P.armeniaca*)	Hacıhaliloğlu	8.87 ± 0.64 c	14.62 ± 10.34 A	13.29 ± 0.92 c	21.97 ± 15.53 A
	Hasanbey	8.75 ± 0.64 c		13.15 ± 0.93 c	
	Kabaaşı	8.37 ± 0.47 c		12.61 ± 0.72 c	
	Roxana	32.49 ± 0.70 a		48.33 ± 0.98 a	
LSD		**1.23****	**0.80****	**1.87****	**0.92****

The differences between the means are shown in separate letters.**: p < 0.01; *: p < 0.05.

Table 8. Fruit yield and quality parameters depending on tree growth of apricot cultivars grafted on different rootstocks (2011-2016).

Rootstock	Cultivar	Yield efficiency ($kg\ cm^{-2}$)		Fruit weight (g)		TSS	
P.microcarpa	Hacıhaliloğlu	0.10 ± 0.01 de		26.07 ± 0.58 d		24.05 ± 0.54	
	Hasanbey	0.14 ± 0.01 cd		33.07 ± 1.10 c		17.63 ± 0.47	
	Kabaaşı	0.16 ± 0.02 c	0.20 ± 0.1 A	26.89 ± 0.40 d	40.11 ± 2.01 C	22.20 ± 0.63	19.45 ± 4.28
	Roxana	0.40 ± 0.05 a		74.42 ± 0.56 b		13.48 ± 0.37	
Pixy (*P.institia*)	Hacıhaliloğlu	0.09 ± 0.00 e		26.95 ± 0.46 d		24.39 ± 0.57	
	Hasanbey	0.11 ± 0.00 de		34.86 ± 1.19 c		17.12 ± 0.17	
	Kabaaşı	0.10 ± 0.00 de	0.16 ± 0.0 B	27.69 ± 0.29 d	42.44 ± 2.07 A	21.72 ± 0.91	19.09 ± 4.34
	Roxana	0.30 ± 0.02 b		80.27 ± 0.92 a		13.15 ± 0.09	
Apricot Seedling (*P.armeniaca*)	Hacıhaliloğlu	0.09 ± 0.01 e		27.37 ± 0.60 d		24.03 ± 0.67	
	Hasanbey	0.09 ± 0.01 e		34.72 ± 1.15 c		16.99 ± 0.22	
	Kabaaşı	0.08 ± 0.00 e	0.16 ± 0.1 B	27.60 ± 0.52 d	41.44 ± 2.24 B	22.68 ± 0.65	19.31 ± 4.28
	Roxana	0.37 ± 0.02 a		76.06 ± 1.76 b		13.56 ± 0.44	
LSD		**0.03****	**0.01****	**1.83****	**0.90****	**N.S.**	**N.S.**

The differences between the means are shown in separate letters. N.S.: Not Significant, **: $p < 0.01$; *: $p < 0.05$.