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Phenological and Morphological Characteristics of Some Medlar Cultivars Grafted onto Quince Rootstocks*

Ayva Anaçları Üzerine Aşılı Bazı Muşmula Çeşitlerinin Fenolojik ve Morfolojik Özellikleri

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Abstract: This study was conducted to evaluate the phenological and morphological characteristics of 'Akçakoca77' and 'Istanbul' medlar cultivars grafted on three different quince clone rootstocks [Quince BA29 (BA29), Quince A (QA) and Quince C (MC)] during 2021 and 2022 years. The earliest flowering was observed in the 'Istanbul' grafted on the BA29 and the MC rootstock, the latest flowering was observed in the 'Akçakoca77' grafted on the MC rootstock, and the latest harvest was observed in 'Istanbul' grafted on the BA29 rootstock. The BA29 and the QA rootstocks had higher rootstock diameter, trunk diameter, and tree height than the MC rootstock. The 'Istanbul' medlar cultivar had a higher crown volume than the 'Akçakoca77' cultivar. The trunk cross-sectional area was lower on the MC rootstock (11.05 cm^2) than on the BA29 and the QA rootstocks in terms of rootstock averages and higher on the 'Istanbul' cultivar (28.58 cm^2) than the 'Akçakoca77' cultivar (20.43 cm^2) in terms of cultivars averages. Rootstock and cultivars had a significant effect on leaf area. The leaf area of the 'Akçakoca77'/QA combination was higher than the other combinations. Annual shoot length was higher in the QA rootstock (38.63 cm) than the MC rootstock (25.89 cm) in terms of rootstocks, and the 'Istanbul' (44.27 cm) was higher than 'Akçakoca77' cultivar (21.40 cm) in terms of cultivars. According to this research, the research needs to be continued for a more extended period to obtain more precise results and recommend the most appropriate cultivar/rootstock combination.

Keywords: *Mespilus germanica*, cultivar, flowering, quince rootstock, tree and leaf characteristic

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Öz: Bu çalışma, üç farklı ayva klon anacı [Quince BA29 (BA29), Quince A (QA) ve Quince C (MC)] üzerine aşılanmış 'Akçakoca77' ve 'İstanbul' muşmula çeşitlerinin 2021 ve 2022 yıllarında fenolojik ve morfolojik özelliklerini değerlendirmek amacıyla yürütülmüştür. En erken çiçeklenme BA29 ve MC anacı üzerine aşılanmış 'İstanbul' çeşidinde, en geç çiçeklenme MC anacı üzerine aşılanmış 'Akçakoca77' çeşidinde, en geç hasat ise BA29 anacı üzerine aşılanmış 'İstanbul' çeşidinde gözlemlenmiştir. BA29 ve QA anaçlarının anaç çapı, gövde çapı ve ağaç yüksekliği MC anacından daha yüksek bulunmuştur. 'İstanbul' muşmula çeşidinin taç hacmi 'Akçakoca77' çeşidinden daha yüksek bulunmuştur. Gövde kesit alanı anaç ortalamaları açısından MC anacı üzerinde (11.05 cm^2), BA29 ve QA anaçlarına göre daha düşük, çeşit ortalamaları açısından ise 'İstanbul' çeşidinde (28.58 cm^2), 'Akçakoca77' çeşidine (20.43 cm^2) göre daha yüksek bulunmuştur. Yaprak alanı üzerine anaç ve çeşitler önemli etki göstermiştir. 'Akçakoca77'/QA kombinasyonunun yaprak alanı diğer kombinasyonlardan daha yüksek bulunmuştur. Yıllık sürgün uzunluğu anaç açısından QA anacında (38,63 cm) MC anacına (25.89 cm) göre, çeşitler açısından ise 'Istanbul' (44.27 cm) 'Akçakoca77' çeşidine (21.40 cm) göre daha yüksek bulunmuştur. Araştırma sonucunda daha kesin sonuçlar elde etmek ve en uygun çeşit/anaç kombinasyonunu önermek için araştırmanın daha uzun süre devam ettirilmesi gerektiği sonucuna varılmıştır.

Anahtar Kelimeler: *Mespilus germanica*, çeşit, çiçeklenme, ayva anaci, ağaç ve yaprak özellikleri

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INTRODUCTION

Medlar (*Mespilus germanica*) belongs to the Rosaceae family (Milovan et al., 2013). The culture of medlar has spread little in Türkiye. However, there are studies on its medicinal properties (Bibalani and Mosazadeh-Sayadmahaleh, 2012). Medlar is native to Western Asia, Southern Europe, and North America (Baytop, 1999). It is a temperate climate plant and resistant to frost (Güngör et al., 2007). Medlar is botanically a pome fruit species. Medlar is consumed less frequently than apples and pears and has a wide range of uses by humans (Phipps et al., 2003), but it is also used as an ornamental plant and medicinal plant. Medlar has a high antioxidant capacity and some fatty acids (palmitic acid, citric acid, oleic acid, and linoleic acid) (Canbay et al., 2015). Medlar is found naturally in open forests, undergrowth under forests, rocks, and maquis in our country, and it is also cultivated as an indoor garden (Dönmez and Aydınözü, 2012). In Türkiye, medlar was produced with 5.217 tons in 2023, and Bursa ranked first with 1.175 tons (22.5%), followed by Çanakkale with 603 tons (11.6%), Sinop with 479 tons (9.2%) and Samsun with 440 tons (8.4%) (TSI, 2024). In Türkiye, the use of modern fruit growing systems in areas where the land structure is unfavorable for agriculture or in narrow areas will contribute to the development of fruit growing. The selection of species and varieties suitable for such regions should also be done correctly (Öztürk and Serttaş, 2018). The growth and development of plants and their phenological stages have a large annual variability. Individual factors (genes, age) and environmental factors (temperature and soil conditions, irrigation, disease and pests, etc.) significantly affect the growth and development of plants (Jackson, 2003). The correct characterization of phenological stages is the key to obtaining high quality and optimum weight of fruits, since there is a series of maintenance operations (pruning, fertilizers, diagnosis of physiological disorders, application of bioregulators, weed control, harvesting, pest control, etc.) that depend on the knowledge of specific phenological stages (Salazar et al., 2006; Salinero et al., 2009).

In modern fruit growing, clonal (vegetative) rootstocks are preferred instead of seedling rootstocks in orchard establishment. Seedling rootstocks are preferred less in fruit growing because they form larger tree canopy than clonal rootstocks, start yielding later, maintenance requires more labor, etc. Clonal rootstocks are preferred because they increase the yield per unit area as a result of dense planting, provide precocity, cultural procedures such as pruning, thinning, spraying, and harvesting can be applied more efficiently, and as a result, fruit quality is higher (Corso and Bonghi, 2014). In medlar cultivation, quince, hawthorn, pear, and buckthorn (*Crataegus oxyacantha*) rootstocks can be used to provide dwarfing and suitability for different soil types (Lombard and Westwood, 1987; Webster et al., 2008). Nowadays, instead of seedling rootstocks, quince clone rootstocks such as BA29, QA, MC, Adams, and Sydo are predominantly used in the establishment of modern orchards due to their dwarfing traits and increase precocity and fruit quality and ability to adapt to different soil types (Lewko et al. 2007). Generally, the variety/varieties grafted onto only one quince clone rootstock are used as saplings in newly established medlar orchards. In high-density (HDP) orchards, Adams and MC rootstocks, which are more dwarf than others, are used more (Jackson, 2003). To obtain optimum vegetative and generative growth from fruit trees, appropriate planting density, rootstock selection, and the orchard's ecological conditions should be considered (Hepaksoy, 2019). Determining the most suitable rootstock for growing conditions is crucial for successful fruit trees' phenological development and morphological growth. No study investigates the effects of both rootstocks and cultivars on medlar cultivation by grafting onto different rootstocks in same orchard. This study aims to determine the phenological and morphological characteristics of 'Istanbul' and 'Akçakoca77' medlar cultivars grafted onto different quince clone rootstocks, which are used more frequently than seedling rootstocks in medlar cultivation.

MATERIAL AND METHOD

Material

The research was carried out in the orchard established with 1-year old saplings within the scope of the project PYO.ZRT.1906.15.007 at Bafra Agricultural Research and Application Center with the support of Ondokuz Mayıs University Project Management Office in 2018. The research material consisted of 'Istanbul' and 'Akçakoca77' medlar cultivars grafted on BA29 (BA29), Quince A (QA), and Quince C (MC) quince clone rootstocks. Since MC rootstock is the most used dwarf rootstock (Jackson, 2003), planting was

done in high density with this rootstock compared to BA29 and QA rootstocks. The cultivars grafted on MC were planted at a distance of 1.5 x 3.5 m (191 plants ha^{-1}), while the cultivars grafted on BA29 and QA were planted at a distance of 3.0 x 3.5 m (95 plants ha^{-1}). Medlars were irrigated with a drip irrigation system from the second week of May until the end of September. Fertilization was done with 15 - 30 - 15 + ME fertigation method in May and with 20 - 20 - 20 compound fertilizer in the second week of August. Weed control was done using mulch on the rows and tilling the soil with a rotovator between the rows.

Climate and Soil Characteristics of The Experimental Area

The experiment area has low clay (%2.73-10), medium silt (%13.21-20), medium sand (%6.5-20), slightly alkaline (pH 7.5), salt-free (0.2-0.3 dS m^{-3}), low organic matter (%0.3-0.5), low lime content (%3-6 $CaCO_3$), low nitrogen content (%0.03-0.06), medium phosphorus (5-10 ppm) and soil depth more than 1 m. Black Sea climate prevails in the Bafra district. Summers are cool, and winters are slightly cold in Bafra, which receives 750-1000 mm of yearly rainfall. Average humidity in April and May is 77% - 79%, while absolute humidity in summer is at most 28%. Rainfall is highest in November and lowest in May. Annual rainfall is 700 m on average, with 100 rainy days per year (TSMS, 2024). The maximum, minimum, and average temperature (°C), humidity (%), and precipitation (monthly, mm) values detected in the study area are given in Figure 1 and Figure 2.

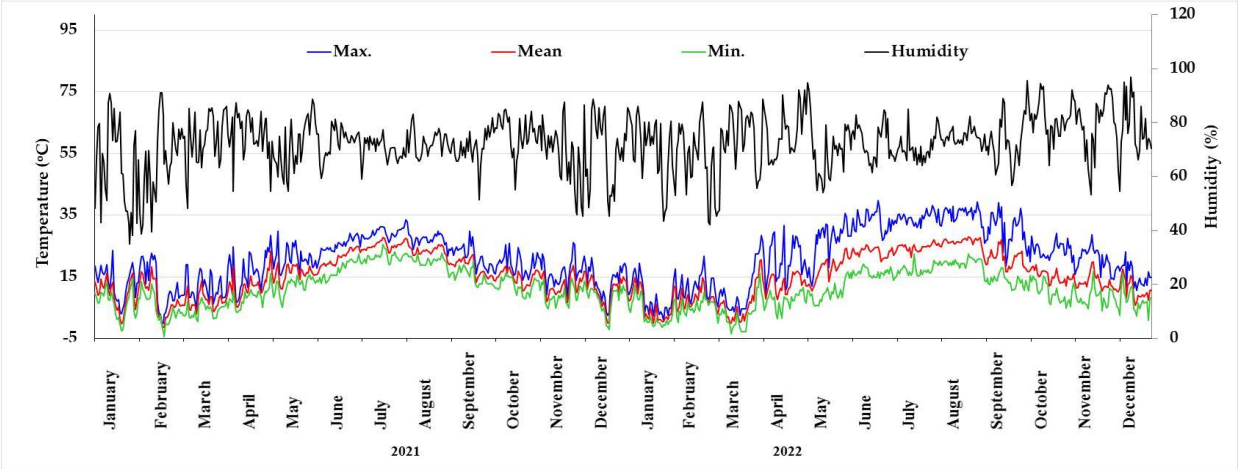

Figure 1. Air temperature (°C) and relative humidity (%) values observed in the experiment area.
Şekil 1. Deneme alanında gözlemlenen sıcaklık (°C) ve nem değerleri (%).

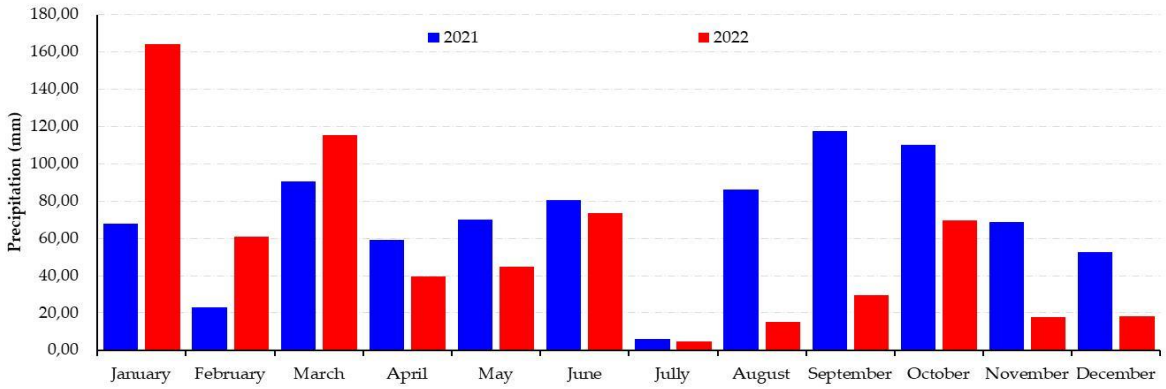

Figure 2. Monthly rainfall (mm) observed in the experiment area.
Şekil 2. Deneme alanında gözlemlenen aylık yağış miktarı (mm).

Method

Phenological stages of medlar cultivars grafted on different quince rootstocks such as beginning of bud break (BB, code 07), first leafing (FiL, code 11), first flowering (FiF, code 60), full flowering (FuF, code 65), end of flowering (EF, code 69), fruit set (FS, code 72), fruit maturity (FM, code 87), days from full flowering to harvest (DFFTH) and leaf falling (LF, code 97) were determined according to the BBCH scale (BBCH = Biologische Bundesanstalt Bundessortenamt and CHemical industry) reported by Meier et al. (2009) for fruit trees and Atay (2013) for medlar. Morphological traits such as tree height (m), trunk diameter (mm), rootstock diameter (mm), crown height (m), trunk cross-sectional area (TCSA) (cm^2), crown volume (m^3), leaf width and length (cm), petiole length and thickness, and annual shoot length (cm) were determined by the previous studies (Öztürk and Öztürk, 2014; Akçay et al., 2016; Cristofori et al., 2019). Leaf area was calculated according to the equation of Mendoza- de-Gyves et al. (2008).

Statistical Analysis

According to the Factorial Experiment Design in Randomized Blocks, the research was conducted with 3 different quince rootstocks and 2 medlar cultivars, with 3 replications and 5 plants in each replicate. The results acquired from the research were analyzed in the statistical package program (IBM SPSS 21.0). Differences between means were compared in the 'Duncan Multiple Comparison Test' at a 5% probability level, and differences were expressed with different letters.

RESULTS AND DISCUSSION

Phenological Characteristics

Beginning of bud break (BB, first green leaf tips just visible), first leafing (FiL), first flowering (FiF), full flowering (FuF), end of flowering (EF), fruit set (FS), fruit maturity (harvest, FM=HD), days from full flowering to harvest (DFFTH) and leaf falling (LF) dates are given in Table 1. In 2021, BB occurred between 8-22 April. The latest BB occurred in the 'Akçakoca77' (22 April) on the BA29 rootstock, and the earliest in the 'Istanbul' (8 April) on the QA rootstock. The latest FiL occurred in the 'Akçakoca77' (22 April) on the BA29, and the earliest in the 'Istanbul' (17 April) on the QA and the MC. The FiF was observed between 20 and 29 May. The earliest FiF was determined in the 'Istanbul' (20 May) on BA29 and MC, and the latest in 'Akçakoca77' (29 May) on BA29 rootstock. Full flowering was observed between 22-31 May, the earliest in 'Istanbul' (22 May) on MC rootstock and the latest in 'Akçakoca77' (31 May) on BA29. The end of flowering occurred between 29 May - 11 June. The latest EF was observed in the 'Akçakoca77' (11 June) on the BA29, and the earliest in the 'Istanbul' (29 May) on the MC rootstock. The latest FS was observed in the 'Akçakoca77' (17 June) on the BA29, and the earliest in the 'Istanbul' (9 June) on the MC rootstock. The HD occurred between 4 and 22 November. The latest HD was determined for the 'Istanbul' (22 November) on the BA29 rootstock and the earliest for the 'Akçakoca77' (4 November) on the MC, and the days from full flowering to harvest varied between 157 and 178 days. The longest DFFTH was observed in 'Istanbul' (178 days) on BA29 rootstock, and the smallest DFFTH was observed in 'Akçakoca77' (157 days) on MC. Leaf falling occurred between 17-26 December, and the LF was observed in 'Akçakoca77' (26 December) on BA29 rootstock and the earliest in 'Istanbul' (17 December) on MC (Table 1).

In 2022, a bud break was observed from 28 March to 9 April. The latest BB occurred in the 'Akçakoca77' (9 April) on the BA29 rootstock, and the earliest in the 'Istanbul' (28 March) grafted on the MC rootstock. The first leafing was observed between 5-10 April. The latest first leafing was observed in the 'Akçakoca77' (10 April) on the BA29 and MC rootstocks and the earliest in the 'Istanbul' (5 April) on the MC. The first flowering was determined between 8 and 15 May. The latest first flowering occurred in the 'Akçakoca77' (15 May) grafted on the BA29, and the earliest in the 'Istanbul' (8 May) grafted on the MC rootstock. Full flowering was observed between 13 and 18 May. The latest full flowering was observed in the 'Akçakoca77' (18 May) grafted on the BA29 and the QA, and the earliest in the 'Istanbul' (13 May) grafted on the MC rootstock. The end of flowering was determined between 20 and 30 May. The latest end of flowering occurred in the 'Akçakoca77' (30 May) grafted on the QA rootstock, and the earliest in the 'Istanbul' (20 May) grafted on the MC rootstock. The fruit set was determined between 27 May and 4 June. The latest fruit set was observed in 'Akçakoca77' (4 June) grafted on the BA29 rootstock, and the earliest in the 'Istanbul' (27 May) grafted on the QA rootstock. The fruit maturity was determined between 2 and 23

November. The latest harvest maturity occurred in the 'Istanbul' (23 November) grafted on the BA29 and the earliest in the 'Akçakoca77' grafted on the MC rootstock (2 November). The days from full flowering to harvest varied between 167 and 188. The highest days from full flowering to maturity occurred in 'Istanbul' (188 days) on BA29 rootstock, and the lowest occurred in 'Akçakoca77' (167 days) on QA. Leaf falling was observed between 25 and 30 December. The latest leaf falling was observed in the 'Akçakoca77' (30 December) on the BA29 and the QA rootstocks, and the earliest in the 'Istanbul' (25 December) grafted on the MC (Table 1).

Table 1. Phenological characteristics of medlar cultivars grafted on different quince clone rootstocks in 2021 and 2022.
Çizelge 1. Farklı ayva klon anaçları üzerine aşılı muşmula çeşitlerinin 2021 ve 2022 yılı fenolojik özellikleri.

Cultivar	Rootstock	BB	FiL	FiF	FuF	EF	FS	HD	DFFTH	LF
2021										
Istanbul	BA29	13-Apr	20-Apr	20-May	25-May	08-Jun	10-Jun	22-Nov	178	24-Dec
	QA	08-Apr	17-Apr	21-May	27-May	06-Jun	10-Jun	20-Nov	174	20-Dec
	MC	10-Apr	17-Apr	20-May	22-May	29-May	09-Jun	17-Nov	175	17-Dec
Akçakoca77	BA29	22-Apr	22-Apr	29-May	31-May	11-Jun	17-Jun	12-Nov	162	26-Dec
	QA	17-Apr	19-Apr	25-May	29-May	09-Jun	12-Jun	09-Nov	161	22-Dec
	MC	16-Apr	18-Apr	22-May	28-May	08-Jun	12-Jun	04-Nov	157	19-Dec
2022										
Istanbul	BA29	31-Mar	07-Apr	11-May	16-May	28-May	30-May	23-Nov	188	27-Dec
	QA	31-Mar	08-Apr	11-May	16-May	26-May	27-May	18-Nov	183	27-Dec
	MC	28-Mar	05-Apr	08-May	13-May	20-May	29-May	13-Nov	181	25-Dec
Akçakoca77	BA29	09-Apr	10-Apr	15-May	18-May	29-May	04-Jun	08-Nov	171	30-Dec
	QA	06-Apr	08-Apr	14-May	18-May	30-May	31-May	05-Nov	167	30-Dec
	MC	07-Apr	10-Apr	11-May	15-May	27-May	31-May	02-Nov	168	28-Dec

BB: Beginning of Bud Break, FiL: First Leafing, FiF: First Flowering, FuF: Full Flowering, EF: End of Flowering, FS: Fruit Set, HD: Harvest Date, DFFTH: Days From Full Flowering to Harvest, LF: Leaf Falling.

As a result of the study, it was determined that there were differences in phenological observations not only between years but also between rootstocks and cultivars. The differences observed between the years are directly related to the temperature and relative humidity. The temperature and the relative humidity of March - April - May, when medlar starts to grow, was slightly higher in 2022 than in 2021 (Figure 1), resulting in an earlier onset of phenology. In addition, the precipitation in March - April - May was higher in 2021 than in 2022 (Figure 2), and the temperatures in these months were lower in 2021 than in 2022, resulting in a delay in the phenological stages of medlar. However, the difference was not clearly evident and appeared in the form of a few days. Although the phenological characteristics of the cultivars are mainly affected by temperature, the relative humidity also has some effect (Özbek, 1977). The discrepancies observed in phenological traits between rootstocks and cultivars can be attributed to the differences in growth forces and genetic traits. Indeed, BA29 and QA rootstocks have higher vigor than MC rootstocks. In addition, among the quince clone rootstocks, MC rootstock, which has weak growth vigor, was found to grow earlier than other rootstocks, and its phenological characteristics were determined to be earlier than other rootstocks (Öztürk, 2021). Kurt et al. (2022) cited that phenological stages occurred earlier in cultivars grafted onto MC rootstock than in BA29 and QA quince rootstocks. The differences between varieties regarding phenological characteristics are due to genetic structure. As a matter of fact, it has been stated in the studies conducted on the subject that genetic differences also affect the phenological characteristics of the varieties (Atay, 2013; Akçay et al., 2016; Yılmaz et al., 2016; Cosmulescu et al., 2020). Cristofori et al. (2019) stated that there were differences in terms of bud break, full flowering, fruit set, and harvest time between medlar cultivars 'Precoce', 'Comune', 'Gigante', and 'Goccia' grafted on BA29 quince clone rootstock, emphasized that flowering in medlar cultivars was in mid and late May and harvest was in late October and early November. In medlar, Duman (2019) reported that the first flowering in Aybastı district of Ordu province was between 21 and 30 May, full flowering was between 25 May and 7 June, and

the end of flowering was between 30 May and 13 June; Yılmaz et al. (2016) cited that flowering started between 26 April and 6 May and lasted for 10 to 12 days in Tokat province of Türkiye. Similarly, it was reported that the phenological characteristics of 'Istanbul' and 'Akçakoca77' medlar cultivars grafted on BA29 quince clone rootstock in the Akçakoca district of Düzce province were earlier in the 'Istanbul' medlar cultivar than the 'Akçakoca77' cultivar (Akçay et al., 2016). It can be said that the observed difference is due to ecological conditions.

Morphological Characteristics

The morphological characteristics of the medlar given in Table 2 were statistically significant ($p< 0.05$). Rootstock diameter ranged between 40.90 - 67.25 mm regarding rootstock averages and 52.45 - 62.65 mm in cultivar averages. Rootstock diameter was the highest in BA29 (64.50 mm) and QA (67.25 mm) rootstocks and the lowest in MC (40.90 mm). The rootstock diameter of the 'Istanbul' (62.65 mm) was higher than that of the 'Akçakoca77' (52.45 mm). In terms of rootstock diameter, 2022 (61.75 mm) year was higher than 2021 (53.35 mm). According to rootstock x cultivar interaction, the highest rootstock diameter was determined in 'Istanbul' (73.18 mm, 79.36 mm) on BA29 and QA rootstocks, and the lowest was in 'Istanbul'/ MC (35.43 mm) (Table 2). Kurt et al. (2022) reported that the influence of quince clone rootstocks (BA29, QA, and MC) was significant on rootstock diameter regarding the year, cultivar, and rootstocks. They cited that differences between the years in the study can be attributed to the growth, development, and increasing age of the trees. The differences in diameter among the rootstocks can be attributed to the different growth strengths of the rootstocks. As a matter of fact, it has been emphasized that the diameter of rootstocks with weak growth, such as MC rootstock, is lower than those with strong growth (Jackson, 2003). Since the cultivars affected the rootstocks on which they were grafted in terms of growth and development, the rootstock diameter of the vigorously growing cultivar 'Istanbul' was found to be higher than that of the weakly growing cultivar 'Akçakoca77'. This situation is related to the genetic characteristics of the cultivars. It can be said that since vigorously growing cultivars perform more photosynthesis than weakly growing cultivars, they increase the strength of the rootstocks on which they are grafted and thicken the diameter of the rootstock.

Trunk diameter ranged between 36.26 - 62.03 mm for rootstocks and 49.80 - 56.66 mm for cultivars. The BA29 (62.03 mm) and QA (61.40 mm) rootstocks had higher trunk diameter than the MC rootstock (36.26 mm). The trunk diameter of the 'Istanbul' (56.66 mm) was higher than that of the 'Akçakoca77' (49.80 mm). With regard to rootstock x cultivar interactions, the highest trunk diameter was determined in the 'Istanbul' (71.32 mm and 70.30 mm) on the BA29 and the QA rootstocks, and the lowest was in the MC/ 'Istanbul' (28.38 mm) combination (Table 2). It was found that the influences of research years, cultivars, and rootstocks on trunk diameter were statistically significant. The rootstocks significantly influence trunk diameter (Kurt et al., 2022; Öztürk and Faizi, 2022). It is cited that cultivars and rootstocks with vigorous growth have higher trunk diameters than those with weak growth (Sugar and Basile, 2011).

Tree height was found to vary from 164.50 cm to 228.10 cm regarding rootstock averages. The highest tree height was determined on the QA (228.10 cm) and the BA29 (225.82 cm) rootstocks and the lowest on the MC (164.50 cm) rootstock. Tree height was higher in the 'Istanbul' (223.17 cm) than in the 'Akçakoca77' (189.12 cm) cultivar. Tree height varied between 138.67 - 270.87 cm regarding rootstock x cultivar and also the highest tree height was determined in the 'Istanbul' cultivar on the QA and the BA29 rootstocks (270.87 cm and 259.97 cm), and the lowest was detected in the 'Istanbul' cultivar on the MC (138.67 cm) (Table 2). Tree height is affected by rootstocks and cultivars (Dondini and Sansavini, 2012). Akçay et al. (2016) reported that the growth vigor of the 'Istanbul' and the 'Akçakoca77', two of the medlar cultivars they examined, was different and that the 'Akçakoca77' medlar cultivar grafted on semi-dwarf and dwarf rootstocks, grew semi-upright and spreading, while the 'Istanbul' medlar cultivar grew more upright. Medlar cultivars on quince clone rootstocks were reported to be shorter than those on the seedlings and other rootstocks (Sebek et al., 2017). It can be said that the findings related to tree height detected in the study are in accordance with previous studies, and the differences that emerged are due to ecological conditions, tree age, and genetic differences.

Table 2. Change in morphological characteristics of medlar cultivars according to quince rootstocks.
Çizelge 2. Ayva anaçlarına göre muşmula çeşitlerinin morfolojik özelliklerinin değişimi.

Rootstocks	Cultivars	Rootstock diameter (mm)	Trunk diameter (mm)	Tree height (cm)	Trunk cross-sectional area (cm^2)	Crown volume (m^3)
BA29	Istanbul	73.18 a	71.32 a	259.97 a	40.16 a	1.10 a*
	Akçakoca77	55.83 b	52.74 b	191.68 b	23.40 b	0.82 b
QA	Istanbul	79.36 a	70.30 a	270.87 a	39.16 a	1.15 a
	Akçakoca77	55.13 b	52.51 b	185.34 b	22.22 b	0.76 b
MC	Istanbul	35.43 d	28.38 c	138.67 c	6.44 c	0.59 c
	Akçakoca77	46.38 c	44.15 b	190.33 b	15.66 b	0.83 b
Main Factor Effects						
Year	2020	53.35 b**	46.87 b	187.42 b	19.07 b	0.79 b
	2021	61.75 a	59.60 a	224.86 a	29.94 a	0.88 a
Rootstock	BA29	64.50 a	62.03 a	225.82 a	31.78 a	0.96 a
	QA	67.25 a	61.40 a	228.10 a	30.69 a	0.95 a
	MC	40.90 b	36.26 b	164.50 b	11.05 b	0.71 b
Cultivar	Istanbul	62.65 a	56.66 a	223.17 a	28.58 a	0.95 a
	Akçakoca77	52.45 b	49.80 b	189.12 b	20.43 b	0.80 b
Significance						
Year		0.008	0.001	0.015	0.012	0.016
Rootstock		0.016	0.001	0.013	0.005	0.006
Cultivar		0.023	0.002	0.010	0.011	0.010
Year x Rootstock		0.045	0.002	0.144	0.025	0.013
Year x Cultivar		0.207	0.207	0.305	0.329	0.298
Rootstock x Cultivar		0.008	0.001	0.005	0.033	0.009
YearxRootstockx Cultivar		0.958	0.034	0.001	0.178	0.039

*: Differences between means shown with different letters in the same column are significant.
**: Differences between means shown with different letters in the same row are significant.

The highest TCSA was found in the BA29 (31.78 cm^2) and QA (30.69 cm^2) rootstocks; the lowest was in the MC rootstock (11.05 cm^2). The TCSA was higher in the 'Istanbul' (28.58 cm^2) than in the 'Akçakoca77' cultivar (20.43 cm^2). In terms of cultivar x rootstock interactions, the highest TCSA was determined in the 'Istanbul' (40.16 cm^2, 39.16 cm^2) on the BA29 and the QA rootstocks, and the lowest was in the 'Istanbul' (6.44 cm^2) on the MC. Regarding year averages, a higher TCSA was determined in 2022 than in 2021 (Table 2). The difference detected between the years in the research is due to the increase in plant growth and development. As a matter of fact, it is stated that the difference between years in some fruit species is due to the difference in growth and development (Yılmaz et al., 2016; Öztürk et al., 2022). The difference between cultivars and rootstocks is due to the mutual effects of rootstocks and cultivars on each other. Jackson (2003) reported that rootstocks affect the development of the cultivars grafted on them, and cultivars affect the rootstocks. Our study determined that the trunk cross-sectional area of MC rootstock, which developed more dwarf, was less than the other rootstock. Rom and Carlson (1987) reported that the growth of cultivars grafted on weak rootstocks was feeble, while the growth of cultivars grafted on vigor rootstocks was strong. Cristofori et al. (2019) noted that the influence of cultivars and research year on TCSA was significant in 4 medlar cultivars grafted on the BA29 quince clone rootstock. They stated that there was an increase in the TCSA as the years progressed and emphasized that the highest TCSA regarding cultivars was 'Precoce' (215.67 cm^2), and the lowest was 'Gigante' (164.20 cm^2). In previous studies, it was possible to compare cultivars since they were usually grafted on only one rootstock, while rootstock

comparisons could not be made. However, the results obtained from this study are consistent with those of previous studies.

Crown volume was determined between 0.71 - 0.96 m^3 for rootstock averages and 0.80 - 0.95 m^3 for cultivar averages. Among the rootstocks, the BA29 (0.96 m^3) and the QA (0.95 m^3) rootstocks had the highest crown volume than the MC (0.71 m^3) rootstock. The crown volume of the 'Istanbul' cultivar (0.95 m^3) was higher than the 'Akçakoca77' (0.80 m^3). Crown volume was higher in 2022 (0.88 m^3) than in 2021 (0.79 m^3). Regarding rootstock x cultivar averages, the highest crown volume was determined in the 'Istanbul' (1.15 m^3, 1.10 m^3) on the QA and the BA29 rootstocks, and the lowest was in the 'Istanbul' (0.59 m^3) on the MC (Table 2). Rootstocks have significant effects on the crown volume of the cultivars on which they are grafted in fruit species emphasized that the crown volume of cultivars grafted on dwarf rootstocks is smaller than the cultivars grafted on vigorous rootstocks (Loreti et al., 2002; Lepsis and Drudze, 2011; Öztürk, 2021). The growth and development pattern and strength of the cultivars significantly affect crown volume. The cultivars with strong growth characteristics grafted on strong-growing rootstocks have a larger crown structure and volume than cultivars with weak growth characteristics grafted on weak-growing rootstocks (Rom and Carlson, 1987; Dondini and Sansavini, 2012).

Petiole lengths ranged from 0.69 to 0.77 cm regarding rootstock averages. The highest petiole length was found on the QA rootstock (0.77 cm) and the lowest on the MC rootstock (0.69 cm). The 'Akçakoca77' cultivar (0.78 cm) had a higher petiole length than the 'Istanbul' cultivar (0.68 cm) using cultivar averages. Regarding rootstock x cultivar interaction, petiole length ranged from 0.53 cm to 0.85 cm. Petiole length was highest in the 'Akçakoca77' (0.85 cm) on the MC rootstock and the lowest in the 'Istanbul' (0.53 cm) on the MC rootstock (Table 3). The petiole length in medlar was found to be 19.8-23.2 mm by Sebek et al. (2019); 6.4-12.0 mm by Uzun and Bostan (2019); 4.9-6.3 mm by Aydın et al. (2020).

Petiole thickness varied from 1.69 mm to 1.88 mm in terms of rootstocks. The highest petiole thickness was found on the BA29 and the MC rootstocks (1.88 mm, 1.85 mm), and the lowest on the QA rootstock (1.69 mm). Regarding cultivar x rootstock effect, petiole thickness ranged from 1.59 mm to 1.93 mm, and the highest petiole thickness was found in the 'Istanbul' on the MC and the BA29 rootstocks (1.93 mm, 1.89 mm) and the 'Akçakoca77' on the BA29 rootstock (1.87 mm); the lowest in the 'Istanbul' on the QA rootstock (1.59 mm) (Table 3). In previous studies on medlar, petiole thickness varied between 2.00-2.80 mm in 27 medlar genotypes in Tonya district of Trabzon province (Közen and Bostan, 2016); 1.30-1.80 mm in 18 medlar genotypes in Sürmene district of Trabzon province (Uzun and Bostan, 2019); 0.60-0.80 mm in medlar genotypes growing naturally in Beykoz district of 'Istanbul' province (Aydın et al. 2020). In the studies mentioned above, it was determined that there were differences between genotypes in terms of leaf petiole thickness. However, the research found no difference between the examined cultivars regarding petiole thickness. This is due to genetic variations and differences in maintenance conditions. While the genotypes examined in the previous studies were located in different areas with different maintenance and growing conditions, the varieties in this study were on different rootstocks under the same maintenance and nutrition conditions.

Leaf length varied from 10.88 cm to 11.93 cm for rootstocks. The leaf length was higher in the QA rootstock (11.93 cm) than in the MC rootstock (10.88 cm). The leaf length was higher in the 'Akçakoca77' cultivar (12.24 cm) than in the 'Istanbul' cultivar (10.45 cm). In terms of rootstock x cultivar interaction, leaf length varied between 9.34-12.64 cm, and the highest leaf length was found in the 'Akçakoca77' (12.64 cm) grafted on the QA rootstock and the lowest in the 'Istanbul' (9.34 cm) grafted on the MC rootstock (Table 3). The effects of year, rootstock, and variety on leaf length were determined to be significant. The growth characteristics of rootstocks and cultivars affected leaf length. In previous studies in medlar, leaf length was reported to vary between 81.0-123.5 mm by Közen and Bostan (2016); 6.5-10 cm by Sülüşoğlu-Durul and Ünver (2016); 34.53-74.27 mm by Khadivi et al. (2019); 76-106 mm by Uzun and Bostan (2019); 0.60-0.80 mm by Aydın et al. (2020). In the studies mentioned above, it was determined that there were differences between genotypes in terms of petiole thickness, while in our study, there was no difference between the examined cultivars in terms of petiole thickness. This is due to genetic variations and differences in

maintenance conditions. While the examined genotypes in the previous studies were located in different areas with different maintenance and growing conditions, the cultivars in this study were on different rootstocks under the same maintenance and nutrition conditions.

Table 3. Change in leaf characteristics of medlar cultivars according to quince rootstocks.
Çizelge 3. Ayva anaçlarına muşmula çeşitlerinin yaprak özelliklerindeki değişim.

Rootstocks	Cultivars	Petiole Length (cm)	Petiole Thickness (mm)	Leaf Length (cm)	Leaf Width (cm)	Laef Area (cm^2)	Annual Shoot Length (cm)
BA29	Istanbul	0.76 ab	1.89 a	10.77 d	4.38 b	33.74 c	48.15 b*
	Akçakoca77	0.71 b	1.87 a	11.88 bc	5.73 a	48.80 b	19.83 d
QA	Istanbul	0.75 ab	1.59 b	11.22 cd	4.62 b	37.10 c	53.52 a
	Akçakoca77	0.79 ab	1.79 ab	12.64 a	6.00 a	54.25 a	19.83 d
MC	Istanbul	0.53 c	1.93 a	9.34 e	3.98 c	26.58 d	23.73 d
	Akçakoca77	0.85 a	1.78 ab	12.41 ab	5.93 a	52.72 ab	20.66 d
Main Factor Effect							
Year	2021	0.73 a**	1.88 a	11.51 a	5.08 a	42.64 a	32.20 a
	2022	0.73 a	1.73 b	11.17 b	5.14 a	41.76 a	33.47 a
Rootstock	BA29	0.73 ab	1.88 a	11.32 b	5.06 b	41.27 b	33.99 b
	QA	0.77 a	1.69 b	11.93 a	5.31 a	45.67 a	38.63 a
	MC	0.69 b	1.85 a	10.88 c	4.95 b	39.65 b	25.89 c
Cultivar	Istanbul	0.68 b	1.80 a	10.06 b	4.33 b	32.47 b	44.27 a
	Akçakoca77	0.78 a	1.81 a	12.24 a	5.89 a	51.92 a	21.40 b
Significance							
Year		0.814	0.009	0.002	0.114	0.341	0.401
Rootstock		0.032	0.019	0.007	0.001	0.004	0.001
Cultivar		0.001	0.803	0.035	0.004	0.005	0.001
Year x Rootstock		0.074	0.116	0.095	0.104	0.085	0.990
Year x Cultivar		0.001	0.212	0.007	0.103	0.070	0.792
Rootstock x Cultivar		0.001	0.049	0.023	0.003	0.008	0.001
Year x rootstock x Cultivar		0.044	0.031	0.015	0.124	0.003	0.949

*: Differences between means shown with different letters in the same column are significant.
**: Differences between means shown with different letters in the same row are significant.

Leaf width ranged between 4.95-5.31 cm for rootstock averages and 4.33-5.89 cm for cultivar means. The leaf width was the highest in the QA rootstock (5.31 cm) and the lowest in the BA29 and the MC rootstocks (5.06 cm, 4.95 cm). The leaf width of the 'Akçakoca77' cultivar (5.89 cm) was higher than the 'Istanbul' cultivar (4.33 cm). Regarding the rootstock x cultivar, the leaf width was highest in the 'Akçakoca77' on the QA, the MC and the BA29 rootstocks (6.00 cm, 5.93 cm, and 5.73 cm, respectively) and the lowest in the 'Istanbul' (3.98 cm) on the MC rootstock (Table 3). Sülüşoğlu-Durul and Ünver (2016) reported that the leaf width of medlar genotypes varied between 3.50-5.60 cm.

The leaf area varied between 39.65-45.67 cm^2 in terms of rootstocks. The leaf area was the highest in the QA (45.67 cm^2) and the lowest in the BA29 and the MC rootstocks (41.27 cm^2, 39.65 cm^2). Leaf area was higher in the 'Akçakoca77' cultivar (51.92 cm^2) than in the 'Istanbul' cultivar (32.47 cm^2) (Table 3). Mendoza-de Gyves et al. (2008) reported that leaf area varied between 10-55 cm2 in medlar genotypes. Cosmulescu et al. (2020) reported that leaf size plays an essential role in plant growth and productivity and selection of new genotypes, that leaf shape and size may vary among genotypes of the same species and that leaf area varied between 22.95-48.8 cm^2 in medlar genotypes. Our research showed a significant difference between rootstocks and cultivars regarding leaf area. It can be said that the difference in leaf area among varieties is due to genetic structure. Mendoza-de-Gyves et al. (2008), who stated that 8 medlar genotypes examined

in Italy, differed in leaf size and area, reported that leaf area varied between 10.00-55.00 cm^2 in genotypes. Similarly, Cosmulescu et al. (2020) found that medlar leaf area varied between 22.95-48.8 cm^2. Rootstocks have a significant effect on the leaf area of varieties (Öztürk and Öztürk, 2014; Kurt et al. 2022). The differences in vegetative growth observed in fruit species and varieties are due to genetic and ecological factors (Rom and Carlson, 1987; Jackson, 2003). The difference in leaf areas of varieties grown on rootstocks with different growth vigours in the same ecological conditions is due to genetic structure. It is also reported that leaf area, which is an essential criterion for production considering the photosynthetic activity in fruit trees, is significantly affected by biotic (species, cultivars, genotypes, age of the tree, and pests) and abiotic (weather, soil properties, irrigation, planting spacing, etc.) factors (Cosmulescu et al., 2020).

Regarding rootstock average, annual shoot length (ASL) varied from 25.89 cm to 38.63 cm. The highest ASL was found on the QA (38.63 cm) and the lowest on the MC (25.89 cm) rootstock. The ASL was higher in the 'Istanbul' (44.27 cm) than in the 'Akçakoca77' cultivar (21.40 cm) (Table 3). In this study, the annual shoot length of strong-growing rootstocks was higher than that of weak-growing rootstocks. In addition to the growth strength of rootstocks, the growth characteristics of cultivars also affected shoot growth. Compared to the 'Akçakoca77' cultivar, the annual shoot length of the 'Istanbul' cultivar, which showed more vigorous growth, was higher. Cristofori et al. (2019) reported a difference between annual shoot length varieties of 15.00-26.70 cm in 4 different medlar varieties grafted on the BA29 quince clone rootstock in Italy. The growth vigor of rootstocks affects the growth and development vigor of the plants grafted on them. It has been reported that the annual shoot length, which indicates adequate growth and development of fruit trees, is higher in strong-growing trees than in weak-growing trees (Jackson, 2003). As a matter of fact, Kurt et al. (2022) cited that the influence of rootstocks on ASL was significant and that the ASL of the MC rootstock, which showed weak growth, was shorter than other rootstocks.

CONCLUSION

This study determined that different quince clone rootstocks affected the phenological and morphological characteristics of 'Istanbul' and 'Akçakoca77' medlar cultivars. The research used quince clone rootstocks, which have been used more intensively in recent years compared to medlar seedling rootstocks. The study attempted to reveal which cultivar/rootstock combination could be recommended to growers. Among the cultivar/rootstock combinations, the MC rootstock showed weaker plant growth than the other cultivar/rootstock combinations in both cultivars used in the study. The 'Istanbul' cultivar grafted on the BA29 and the QA rootstock showed better plant growth performance than other rootstock/cultivar combinations. Mainly, the sandy-loamy soil, which is very suitable for the growth of quince clone rootstocks, contributed to the better growth of the trees. Both cultivars in the study were found to be suitable for medlar cultivation in the ecological conditions in which the research was conducted. As a result of the research, it was determined that both cultivars ('Istanbul' and 'Akçakoca77') had sufficient fruit sets and were economically profitable varieties.

Regarding rootstocks, the MC rootstock can be preferred for early harvesting as it reaches harvest maturity earlier than the others. In addition, MC rootstock can be used for high-density planting due to its dwarf growth compared to other rootstocks. Recently, medlar cultivation on quince clone rootstocks has been recommended for consumer demand and as a production area where producers can earn sufficient economic income. In addition, the research results are essential for growers engaged in medlar cultivation or aiming to do so as suitable cultivar /rootstock combinations are revealed. According to the current research results, the 'Istanbul' cultivar with the BA29 rootstock can be recommended to growers because of its better performance than other cultivars/rootstocks. However, since the trees used in the experiment were 5 years old young trees that have yet to reach full yield, the research needs to be continued for a long time, and more studies are needed to reach certain results for the medlar plant.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest with respect to the research, authorship, and/or publication of this article.

DECLARATION OF AUTHOR CONTRIBUTION

Yakup Mert Kul: Investigations, Visualization, Writing of original draft. **Ahmet Öztürk**: Supervision, Data analysing, Visualization, Review and editing.

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