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Determination of Phenological and Morphological Characteristics of Some Standard Pear Cultivars on Different Quince Clonal Rootstocks

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Abstract

This study was conducted to determine the effects of Quince BA29 (BA29), Quince A (QA), and Quince C (MC) rootstocks on phenological and morphological characteristics of 'Deveci', 'Santa Maria', 'Abate Fetel', and 'Williams' pear cultivars in Bafra (Samsun) ecological conditions between 2020-2021 years. It has been determined that the effect of rootstocks and cultivars on phenological characteristics was significant. In the study, the earliest flowering and harvest were in 'Abate Fetel', the latest flowering was in 'Williams', and the latest harvest was in the 'Deveci' cultivar. The highest rootstock diameter, trunk diameter and tree height were in BA29 and the lowest in MC rootstock. The highest canopy volume was determined in the 'Santa Maria' cultivar and the lowest in the 'Williams' cultivar. The effect of rootstocks and cultivars on leaf area was significant and the highest leaf area was determined in 'Santa Maria'/QA combination. Annual shoot length of the MC rootstock was lower than the other rootstocks. It is thought that it would be more appropriate to continue the research for a long time to determine the most suitable cultivar/rootstock combination as a result of the data obtained due to the young trees of the plants where the research was carried out.
Keywords: Rootstock, Pear, Cultivar, Phenology, Morphology.

Farkı Ayva Klon Anaçları Üzerine Aşılı Standart Bazı Armut Çeşitlerinin Fenolojik ve Morfolojik Özelliklerinin Belirlenmesi

Öz

Bu çalışma, Bafra (Samsun) ekolojik koşullarında Quince BA29 (BA29), Quince A (QA) ve Quince C (MC) ayva klon anaçlarının 'Deveci', 'Santa Maria', 'Abate Fetel' ve 'Williams' armut çeşitlerinin fenolojik ve morfolojik özellikleri üzerine etkisini belirlemek amacıyla 2020-2021 yılları arasında yürütülmüştür. Çalışmada en erken çiçeklenme ve hasat 'Abate Fetel', en geç çiçeklenme 'Williams', en geç hasat ise 'Deveci' çeşidinde olmuştur. En yüksek anaç çapı, gövde çapı ve ağaç boyunun BA29 en düşük ise MC anacında olduğu belirlenmiştir. En yüksek taç hacmi 'Santa Maria' en düşük ise 'Williams' çeşitlerinde belirlenmiştir. Yaprak alanı üzerine anaçların ve çeşitlerin etkisi önemli olup en yüksek yaprak alanı 'Santa Maria'/QA kombinasyonunda belirlenmiştir. MC anacının yıllık sürgün uzunluğunun diğer anaçlardan daha düşük olduğu belirlenmiştir. Araştırmadan elde edilen verilerin sonucunda en uygun çeşit/anaç kombinasyonunun belirlenmesi için araştırmanın uzun süre devam ettirilmesi gerektiği düşünülmektedir.
Anahtar Kelimeler: Anaç, Armut, Çeşit, Fenoloji, Morfoloji.

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1. Introduction

Pear is one of the most grown and consumed pome fruits worldwide after apple. *Pyrus communis* L. is one of the most important pear species in terms of fruit growing techniques (Orman 2005). Pear is more resistant to heat and drought than apples but less resistant to cold than apple trees. Spring late frosts limit pear cultivation. Pear can withstand up to -30 °C, but shoot tips are damaged in long-term cold situations. Pear flowers are damaged at -2.2 °C, while small fruits are damaged at 1.1 °C (Özçağıran et al., 2005). In order to be able to establish modern fruit orchards, it has been one of the important conditions to use rootstocks that provide stunting. Therefore, especially since the second half of the 20th century, the desired characteristics of rootstocks and cultivars in orchards have changed (Öztürk et al., 2013; Bolat and İkinci, 2019; Kurt et al., 2022). Among the most important reasons for the widespread use of rootstock in fruit trees are their adaptation to adverse climatic and soil conditions, increased fruit quality and yield, and high tolerance to diseases and pests (Carso and Bonghi, 2014). Sydo, QA, and BA29 quince clonal rootstocks, are widely used by European pear growers to establish standard pear orchards. While in densely planted high-density gardens, the Adams and MC are mostly preferred (Simard et al., 2004; Dondini and Sansavini, 2012). In order to obtain optimum vegetative and generative development from fruit trees, appropriate planting density, correct rootstock selection, and appropriate ecology are important strategies (Pasa et al., 2015; Hepaksoy, 2019). BA29 was selected from Province quinces at the fruit breeding station in France in 1963. It forms a canopy about 50% higher than standard quince rootstocks and shows slightly stronger growth than QA and OHF333 rootstocks. The propagation rate of BA29 is slow, but the yield efficiency is high. Although it is resistant to pear powdery mildew and root cancer, but has poor tolerance to leaf spot and fire blight diseases. BA29 is resistant to pear dent and cotton louse, and dwarf trees can be obtained by dense planting. BA29 rootstocks are well compatible with ‘Williams’ but not with ‘Beurre Bosc’ and ‘Dr Jules Guyot’ cultivars (Jackson, 2003; Özçağıran et al., 2005). QA is one of the oldest quince rootstocks and was selected in the International East Malling Horticulture Research Station. This rootstock can be easily propagated by layering. Due to winter cold in Spain, France, and Italy, Sydo rootstocks instead of QA have recently become more prominent, but the use of QA rootstock is common yet (Dondini and Sansavini, 2012). MC rootstock is one of the oldest quince rootstocks which selected in the International East Malling Horticulture Research Station. Its growth is lower as compared to QA, and easier to propagate. It must be cultivated carefully in the soil as the root system is exposed and superficial and fragile, so it needs a supporting system (Dondini and Sansavini, 2012). This study was carried out to determine the effect of quince clonal rootstocks on the phenological and

morphological properties of ‘Deveci’, ‘Williams’, ‘Santa Maria’ and ‘Abate Fetel’ pear cultivars, which have an important place in pear cultivation of Türkiye.

2. Materials and Methods

2.1. Materials

In the experiment BA29, QA, and MC as clonal rootstocks were used. While, Deveci, Williams, Santa Maria, and Abate Fetel as cultivars that have an important share in pear cultivation on Türkiye.

2.2. Characteristics of Experiment Area

Soil of the research area included 2.73 - 10% clay (low), 13.21 - 20% silt (medium), 6.5 - 20% sand (moderate), pH 7.5 (slightly alkaline), 0.2 - 0.3 dS/m salt (no salt), 0.3 - 0.5 organic matter (low), 3 - 6% lime ($CaCO_3$) (low), 0.03 - 0.06 N (low), 5 - 10 ppm P (moderate) level, and soil depth is more than 1 m. The typical Black Sea climate is seen in the district of Bafra, with cool summers and slightly cold and rainy winters (about 750 - 1000 mm per year). Hot and dry winds blowing from the south and southwest directions in the district reduce the humidity, and the average relative humidity of Bafra is about 73%. Especially in April and May, relative humidity reaches 77 - 79% on average. Since absolute humidity is directly proportional to temperature, it reaches the highest value of 28% in summer. The highest precipitation in the district falls in November, and the least precipitation falls in May. The average annual precipitation is around 700 mm, and the average number of rainy days per year is 100 days (TSMS, 2022). The study area temperature (max, min and average in ^{o}C), relative humidity (%), and monthly total precipitation (mm) values are presented in Figure 1, Figure 2, and Figure 3.

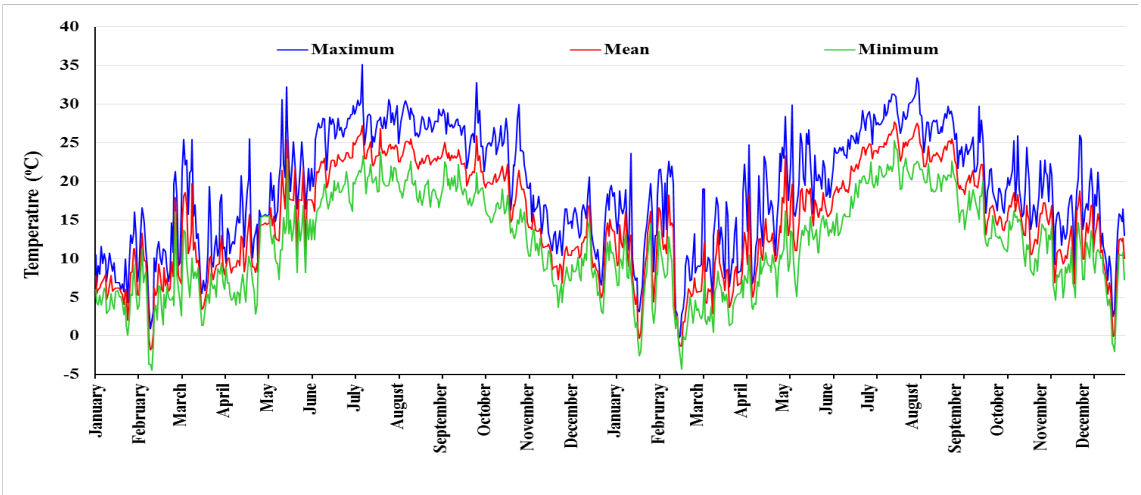

Figure 1. Daily temperature (°C) values recorded in the trial area during the research period.

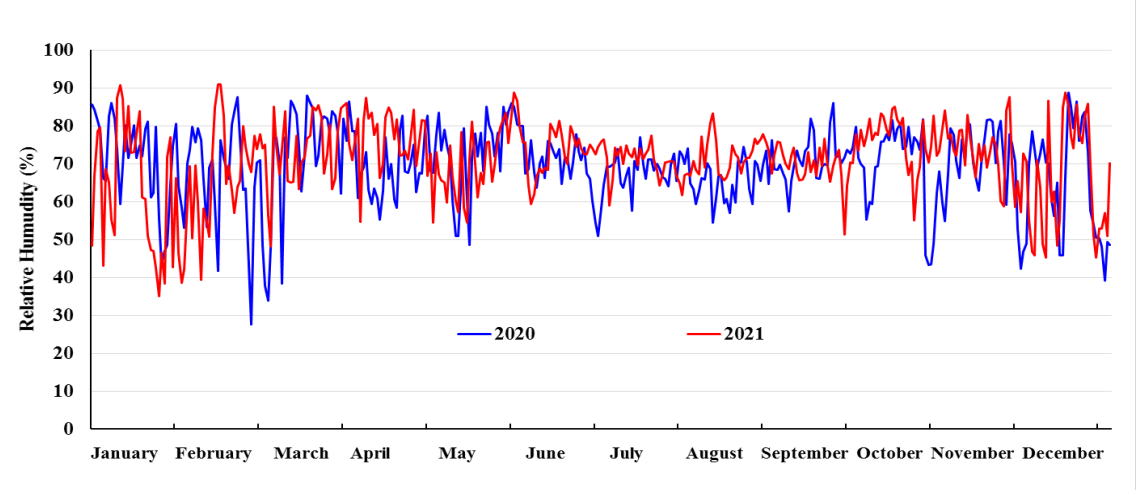

Figure 2. Daily relative humidity (%) values recorded in the trial field during the research period.

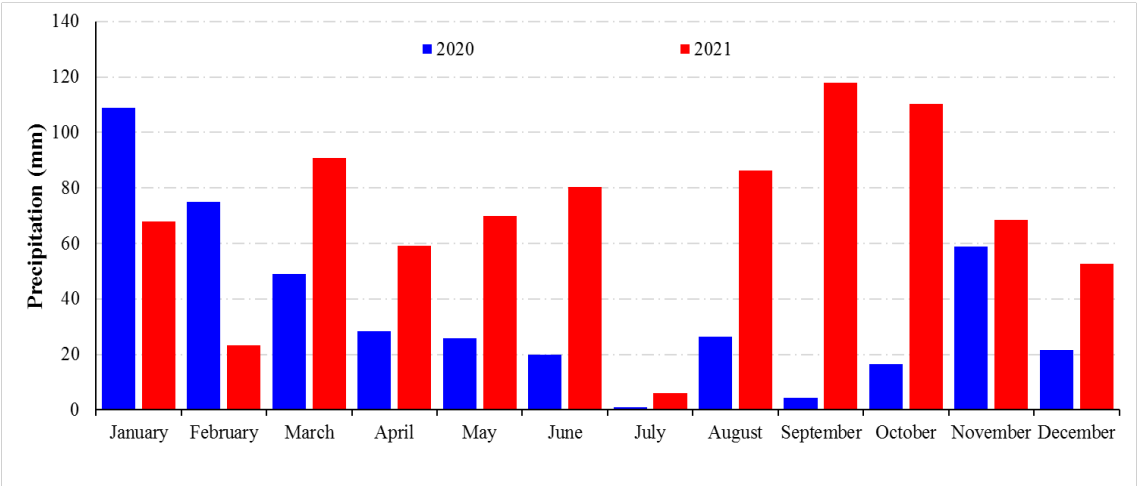

Figure 3. Monthly total precipitation (mm) values recorded in the trial area during the research period.

2.3 Methods

The research was carried out at the Bafra agricultural research center of Ondokuz Mayıs University, Faculty of Agriculture, in the pear orchard established with 1-year-old saplings in March 2018, and saplings were planted at 1.5 m x 3.5 m spacing. The plants were supported with metal poles at the height of 3.5 m, with 4 rows of galvanized wires on the horizontal arms 50 cm from the ground. Modified central leader applied as training system and regularly every year trees were pruned. In the study, the plants were irrigated with drip irrigation between 15 May and 15 September. Fertilization was done by drip irrigation with 15 - 30 - 15 + ME fertilizer at the beginning of summer and 20 - 20 - 20 NPK fertilizer in autumn. Weed control was carried out by mulching ground on the row and regularly breaking the weeds with a rotovator between the rows.

2.4. Phenological Observations

Bud burst, first flowering, full flowering, end of flowering, fruit set, the number of days between full bloom and harvest, harvest date, and leaf fall were determined according to previous studies as phenological observations (Büyükyılmaz et al., 1994; Orman, 2005).

2.5. Morphological Observations

Rootstock diameter (mm), trunk diameter (mm), tree height (cm), canopy width (cm), canopy length (cm), canopy height (cm), canopy volume (m^3), trunk cross sectional area (cm^2), leaf width (cm), leaf length (cm), petiole length (cm), petiole thickness (mm), leaf area (cm^2), annual shoot length (cm) were determined according to previous studies as morphological observations (Westwood, 1995; Öztürk and Öztürk, 2014).

2.6. Statistical Analysis

The research was carried out according to the randomized blocks design, with 4 cultivars, 3 rootstocks, 3 replications, and 10 plants in each replication. The obtained data were analyzed in the IBM SPSS 21.0 statistical package program licensed by Ondokuz Mayıs University. The differences between the obtained averages were determined according to Duncan Multiple Comparison Test at the 5% level ($p > 0.05$).

3. Results and Discussion

3.1. Phenological characteristics

The results of the observations regarding the bursting of vegetative bud, bursting of flower bud, first flowering, full flowering, end of flowering, fruit set, harvest date, number of days from full flowering to harvest and the leaf fall date were given in Table 1 and Table 2. In the research, the bursting of flower buds in 2020 occurred between 6-20 March. Flower bud bursting occurred earliest on 'Abate Fetel' (6 March) on MC rootstock and latest on 'Williams' (20 March) on BA29 and MC rootstocks. The vegetative buds bursting took place between 10 - 30 March. The earliest vegetative bud bursting occurred in 'Abate Fetel' cultivar grafted on MC rootstock on March 10, and the latest on March 30 in BA29 and MC rootstocks in the same cultivar. The first flowering took place between 30 March to 10 April. The first flowering occurred on 'Abate Fetel' on QA at the earliest (30 March), and the latest on 'Williams' cultivar on QA in 10 April. Full flowering occurred on 10-20 April, earliest (April 10) observed on 'Abate Fetel' on BA29 and MC rootstock, and latest (April 20) on 'Williams' on BA29, QA and MC. The end of flowering in cultivars occurred between 15-26 April. The earliest flowering (15 April) of 'Abate Fetel' was observed on BA29 and MC, while the latest flowering occurred in 'Williams' on QA rootstock on 26 April. The fruit set was occurred between 22 April - 3 May. The earliest fruit set occurred on April 23 in Abate Fetel grafted on BA29 and MC rootstocks, and the latest recorded in 'Williams' grafted on QA rootstock on 3 May. The number of days from full flowering to harvest varied between 117-184 days. In the study, the number of days from full bloom to harvest was determined to be the lowest (117 days) in 'Santa Maria' grafted on BA29 rootstock, while the highest (184 days) in 'Deveci' grafted on QA. Fruit harvesting of the examined cultivars was carried out between 10 August to 13 October. The earliest harvest was made in the 'Santa Maria' cultivar on 10 August, while the latest in 'Deveci' cultivar on 13 October on all rootstocks. The leaf shedding date occurred between 23 and 27 November. It was determined that the earliest defoliation occurred on 23 November in 'Williams' and 'Santa Maria' on all rootstocks examined and the latest on November 27 in Abate Fetel and Deveci cultivars on all rootstocks (Table 1).

Table 1. Phenological observation dates of some pear cultivars grafted on quince clonal rootstocks in 2020.

Rootstocks	Cultivars	FBBD	VBBD	FiFD	FuFD	LFD	FSD	HD	DFFBTH	LFD
BA29	Deveci	08 Mar.	12 Mar.	07 Apr.	15 Apr.	20 Apr.	28 Apr.	13 Oct.	182	27 Nov.
	Williams	20 Mar.	30 Mar.	08 Apr.	20 Apr.	24 Apr.	02 May.	08 Sep.	142	23 Nov.
	Santa Maria	09 Mar.	14 Mar.	04 Apr.	16 Apr.	20 Apr.	28 Apr.	10 Aug.	117	23 Nov.
	Abate Fetel	07 Mar.	12 Mar.	01 Apr.	10 Apr.	15 Apr.	22 Apr.	08 Sep.	152	27 Nov.
QA	Deveci	08 Mar.	12 Mar.	07 Apr.	13 Apr.	20 Apr.	28 Apr.	13 Oct.	184	27 Nov.
	Williams	20 Mar.	27 Mar.	10 Apr.	20 Apr.	26 Apr.	03 May.	08 Sep.	142	23 Nov.
	Santa Maria	08 Mar.	12 Mar.	09 Apr.	14 Apr.	20 Apr.	27 Apr.	10 Aug.	119	23 Nov.
	Abate Fetel	07 Mar.	12 Mar.	30 Mar.	11 Apr.	16 Apr.	23 Apr.	08 Sep.	151	27 Nov.
MC	Deveci	08 Mar.	12 Mar.	07 Apr.	18 Apr.	20 Apr.	28 Apr.	13 Oct.	179	27 Nov.
	Williams	19 Mar.	30 Mar.	08 Apr.	20 Apr.	25 Apr.	02 May.	08 Sep.	142	23 Nov.
	Santa Maria	08 Mar.	12 Mar.	07 Apr.	15 Apr.	20 Apr.	28 Apr.	10 Aug.	118	23 Nov.
	Abate Fetel	06 Mar.	10 Mar.	04 Apr.	10 Apr.	15 Apr.	22 Apr.	08 Sep.	152	27 Nov.

*: **FBBD**: flower bud burst date, **WBBD**: wood bud burst date, **FiFD**: first flower date, **FuFD**: full flower date, **LFD**: last flower date, **FSD**: fruit set date, **HD**: harvest date, **DFFBTH**: days from full bloom to harvest, **LFD**: leaf fall date.

Flower buds burst dates in 2021 recorded from 22 March to 21 April. Flower buds burst observed earliest on 'Abate Fetel' on MC and BA29 rootstocks (22 March), and latest (21 April) in 'Williams' on BA29, MC and QA rootstocks. The wood bud burst date ranged between 7 and 26 April. The earliest (7 April) wood bud bursting was in the 'Abate Fetel', grafted on MC and BA29 rootstocks, and the latest (26 April) in 'Williams' on all rootstocks. The first flowering dates occurred between 15 - 29 April. The first flowering occurred earliest (15 April) in 'Abate Fetel' on QA and MC rootstocks, and the latest on 29 April in 'Williams on all rootstocks. Full flowering took place between 21 April and 3 May. The end of flowering in cultivars occurred from 29 April to 7 May. The earliest flowering end on 29 April served in 'Abate Fetel' grafted on BA29 and MC, the latest on 7 May in 'Deveci' cultivar grafted on MC. The days from full bloom to harvest were recorded between 105 and 171 days. The lowest number of days from full bloom to harvest was determined in 'Santa Maria' grafted on BA29 and QA rootstocks (105 days), and the highest (175 days) in 'Deveci' grafted on QA (Table 2).

Table 2. Phenological observation dates of some pear cultivars grafted on quince clonal rootstocks in 2021.

Rootstocks	Cultivars	FBBD	WBBD	FiFD	FuFD	LFD	FSD	HD	DFBTH	LFD
BA29	Deveci	13 Apr.	19 Apr.	26 Apr.	3 May.	5 May.	7 May.	21 Oct.	171	16 Nov.
	Williams	21 Apr.	26 Apr.	29 Apr.	3 May.	7 May.	10 May.	13 Sep.	133	13 Nov.
	Santa Maria	21 Apr.	26 Apr.	29 Apr.	3 May.	7 May.	10 May.	16 Aug.	105	5 Nov.
	Abate Fetel	22 Mar.	7 Apr.	15 Apr.	21 Apr.	29 Apr.	5 May.	13 Sep.	145	1 Nov.
QA	Deveci	15 Apr.	21 Apr.	26 Apr.	29 Apr.	7 May.	9 May.	21 Oct.	175	16 Nov.
	Williams	21 Apr.	26 Apr.	29 Apr.	3 May.	7 May.	10 May.	13 Sep.	133	13 Nov.
	Santa Maria	13 Apr.	21 Apr.	26 Apr.	3 May.	7 May.	9 May.	16 Aug.	105	5 Nov.
	Abate Fetel	21 Apr.	26 Apr.	29 Apr.	3 May.	5 May.	9 May.	15 Sep.	135	1 Nov.
MC	Deveci	13 Apr.	21 Apr.	26 Apr.	3 May.	7 May.	10 May.	21 Oct.	171	16 Nov.
	Williams	21 Apr.	26 Apr.	29 Apr.	3 May.	5 May.	10 May.	15 Sep.	135	13 Nov.
	Santa Maria	15 Apr.	21 Apr.	26 Apr.	29 Apr.	3 May.	5 May.	16 Aug.	112	5 Nov.
	Abate Fetel	22 Mar.	7 Apr.	15 Apr.	26 Apr.	29 Apr.	5 May.	13 Sep.	140	1 Nov.

*: **FBBD**: flower bud burst date, **WBBD**: wood bud burst date, **FiFD**: first flower date, **FuFD**: full flower date, **LFD**: last flower date, **FSD**: fruit set date, **HD**: harvest date, **DFBTH**: days from full bloom to harvest, **LFD**: leaf fall date.

It has been determined that the phenological observations made in the research showed significant differences according to the years, and some differences according to the rootstocks and cultivars. We can say that the difference between the years was due to the climatic differences in the research years. The research determined that the temperature values in February and March, when the plants came out of rest and growth began, were slightly lower in 2021 compared to 2020 (Figure 1). The rootstocks observed that the cultivars grafted on MC caused earlier dormancy compared to others. It was observed that the 'Abate Fetel' cultivar started to develop vegetatively earlier than other cultivars. Mixed buds are produced in the pome fruit species; the buds that open the flowers burst earlier than the wood buds. As a matter of fact, in our study, it was determined that flower buds burst earlier than wood buds. No apparent differences between rootstocks regarding harvest date were observed, while the differences between cultivars were noticeable. It was observed that the cultivar with the earliest fruit harvest was 'Santa Maria', and the latest was 'Deveci'. It can be said that this situation is caused by the difference in genetic structures of the trees. Indeed, in previously performed studies on similar subjects, it was stated that the phenological differences between cultivars were mainly due to genetic differences, as well as the environmental conditions that trees are grown (Özbek 1977; Büyükyılmaz et al., 1994; Jackson, 2003; Akçay et al., 2009; Ertürk et al., 2009; Kaplan 2011; Dondini and Sansavini, 2012; Osmanoğlu et al., 2013; Bağcı 2015; Öztürk et al., 2016; Çoban 2019; Mete 2019; Öztürk et al., 2022). In hot and dry weather, all

the flowers on the tree open in a short time, and in cool and rainy weather, flowering continues on the same tree for 2-10 days (Özbek, 1977; Özçağıran et al., 2005). Our research observed that the temperature (Figure 1) and humidity (Figure 2) values in April and May, when flowering occurs, were higher in 2021 than in 2020. The high temperature in 2021 caused a shortening of the flowering period. It has been observed that the phenological characteristics we obtained regarding the cultivars are compatible with the results obtained from other studies.

3.2. Morphological Characteristics

In the research, the effects of year, rootstock, cultivar, and rootstock x cultivar interactions on rootstock diameter, trunk diameter, tree height, trunk cross-sectional area, and canopy volume of grafted pear cultivars on different quince rootstocks, were found to be significant. However, it was observed that the rootstock effect was not significant in the study on canopy volume (Table 3). From rootstock diameter, it was determined that the rootstock averages varied between 30.20 - 38.98 mm. The highest rootstock diameter was determined in BA29 (38.98 mm) and the lowest in MC (30.20 mm) rootstock. The study determined that the rootstock diameter ranged between 25.18 - 41.75 mm in terms of cultivar averages. It was determined that ‘Deveci’ had the highest (41.75 mm) rootstock diameter and ‘Williams’ cultivar had the lowest (25.18 mm). It has been determined that rootstock diameter in 2021 was higher (38.92 mm) than in 2020 (30.79 mm) in terms of years' average. In terms of rootstock x cultivar interactions, it was determined that the highest rootstock diameter was in ‘Deveci’/BA29 (46.67 mm) and the lowest in ‘Williams’/MC (16.27 mm) combinations (Table 3). Francescatto et al. (2010) reported that rootstock diameter was the lowest in EMC rootstock in ‘Packham's pear variety grafted on 7 different rootstocks. Likewise, Öztürk and Öztürk (2014) reported that the highest rootstock diameter was in BA29 and the lowest in MC rootstocks. Different researchers also reported that the effect of rootstocks on rootstock diameter was significant (Giacobbo et al., 2010; Machado et al., 2016; Rahman et al., 2017). Çetinbaş et al. (2018) stated that the effect of rootstocks and cultivars on rootstock diameter was significant; rootstock diameter was observed higher in ‘Deveci’ than in ‘Santa Maria’ in terms of cultivars. They found that it was higher in OHF 333, BA29, OHF 69, and MC rootstocks than in the other rootstocks examined. Rootstock diameter of the Deveci pear cultivar grafted on BA29, MC, and seedling rootstocks changed in terms of research years and rootstocks and reported lowest in the MC clonal rootstock than others (Öztürk, 2021).

The stem diameter in rootstock averages varied between 25.98 - 33.30 mm. The highest stem diameter was determined in BA29 (33.30 mm) and the lowest in MC (25.98 mm) rootstock. In terms of cultivar averages, it varied between 21.58 - 33.39 mm. The highest stem diameter was

found in ‘Deveci’ (33.39 mm), ‘Santa Maria’ (32.06 mm), and ‘Abate Fetel’ (31.40 mm), while the lowest (21.58 mm) in ‘Williams’ cultivars. In terms of rootstock x cultivar interaction, it was determined that the stem diameter ranged between 14.19-37.88 mm. The highest (37.88 mm) stem diameter was observed in ‘Deveci’/BA29 and the lowest (14.19 mm) in ‘Williams’/MC combination (Table 3). The results of the stem diameter we obtained are compatible with similar studies previously performed (Castro and Rodriguez, 2002; Loreti et al., 2002; Sotiropoulos, 2006; Maas, 2008; Ertürk et al., 2009; Francescatto et al., 2014; Öztürk and Öztürk 2014; Machado et al., 2016; Mete, 2019; Öztürk, 2021). It was emphasized in similar studies that the effects of rootstocks on the stem diameter of cultivars were significant. The stem diameter of the cultivars grafted on vigorous rootstocks was observed to be higher than on the weak rootstocks (du Plooy and van Huyssteen, 2000; Urbina et al., 2003; Jackson, 2003; Özçağıran et al., 2005; Hancock and Labous, 2008; Sugar and Basile, 2011; Dondini and Sansavini, 2012; Askari-Khorosgani et al., 2019).

Tree height in terms of rootstock averages varied between 153.93 - 184.18 cm. It was found that the highest tree height was on BA29 (184.18 cm), and the lowest was recorded on MC rootstock (153.93 cm). The study determined that the tree height varied between 142.73 - 191.34 cm in terms of cultivars. The highest tree height was determined in ‘Santa Maria’ (191.34 cm) and ‘Deveci’ (180.54 cm), and the lowest (142.73 cm) in the ‘Williams’ cultivar. In terms of rootstock x cultivar interactions, it was determined that the tree height varied between 111.83 - 198.43 cm. The highest tree height was determined in ‘Deveci’/BA29 (198.43 cm) and the lowest (111.83 cm) in the ‘Williams’/MC combinations (Table 3). Tree height reported that affected by the rootstocks and cultivars (Jackson, 2003; Giacobbo et al., 2010; Lepsis and Duredze, 2011; Dondini and Sansavini, 2012). The tree height of ‘Abate Fetel’ and ‘Conference’ cultivars grafted on BA29, MA, and pear seedling rootstocks. Castro and Rodriguez (2002) cited tree height being higher in pear seedlings than in the other rootstocks. According to research conducted in the Lithuania, it was reported that tree height was not statistically significant among QA, MC, Sydo, BA29, and *Pyrus communis* seedlings rootstocks (Kviklys and Kvikliene, 2004). It was reported that the tree height was 159 cm in the ‘Williams’ pear cultivar and 225 cm in the ‘Deveci’ cultivar grafted on QA rootstock (Akçay et al., 2009). Considering the performance of 'Seleta' pear cultivar on Adams, EMC and Portugal quince rootstocks and *Pyrus calleryana* pear seedling, Giacobbo et al. (2018) determined that all quince rootstocks reduced the cultivar tree height by 60% compared to *Pyrus calleryana* rootstock. It was determined that the highest plant height of the ‘Deveci’ cultivar was in BA29 rootstock and the lowest in MC rootstock (Öztürk, 2021). There were differences in tree height between the research years. It can be said that difference was due to the age of the trees (Gerçekçioğlu et al., 2014).

Trunk cross-sectional area in terms of rootstock averages varied between 6.88 - 10.71 cm². The highest trunk cross-sectional area was determined in BA29 (10.71 cm²), and the lowest in MC rootstock (6.88 cm²). In terms of cultivar averages, it has been determined that the values varied between 4.79 - 11.56 cm². The highest trunk cross-sectional area was found in 'Deveci' (11.56 cm²) and the lowest in 'Williams' (4.79 cm²) cultivar. In terms of rootstock x cultivar interactions, it was found that the trunk cross-sectional area varied between 1.86 -14.64 cm². The highest trunk cross-sectional area was observed in 'Deveci'/BA29 (14.64 cm²) and the lowest (1.86 cm²) in 'Williams'/MC combinations (Table 3). Other researchers have also reported that the trunk cross-sectional area differs in terms of production years, cultivars, and rootstocks (Loreti et al., 2002; Kosina, 2003; Iglesias and Asin, 2011; Sugar and Basile, 2011; Kaplan, 2011; Leipsis and Drudze, 2011; Öztürk and Öztürk, 2014; Mete, 2019; Öztürk, 2021; Küçüker and Ağlar, 2021; Jovanovic et al., 2022).

Canopy volume in terms of rootstock averages varied between 0.20 - 0.29 m³. Regarding cultivar averages, it varied between 0.12 - 0.36 m³. Regarding cultivar averages, the highest canopy volume was in 'Santa Maria' (0.36 m³), and the lowest in 'Williams' (0.12 m³) cultivar. In terms of years, it was determined that the crown volume in 2021 was higher (0.34 m³) than in 2020 (0.14 m³). The canopy volume observed between 0.03 - 0.56 m³ in terms of rootstock x cultivar interactions. It was determined that the highest (0.56 m³) canopy volume was in 'Santa Maria'/MC and the lowest (0.03 m³) in 'Williams'/MC combinations (Table 3). Giocabbo (2010) said that the rootstocks significantly affect the canopy volume of cultivars. Canopy volume of 'Deveci' cultivar grafted on QA was found to be 0.20 - 0.76 m³, and 'Santa Maria' found to be 0.26 - 1.02 m³ (Engin and Özkan 2011). Kaplan (2011) stated that there was a statistical difference in terms of canopy volume between pear cultivars grafted on QA rootstock. He emphasized that it was highest in 'B. Hardy' and 'B.P. Morettini', while lowest in 'Williams'. It was determined that the lowest crown volume was found in QA and MC rootstocks in the 'Suvenirs' pear cultivar grafted on different rootstocks (Lepsis and Drudze, 2011). Öztürk and Öztürk (2014) determined that the canopy volume of the 'Deveci' pear cultivar was higher on BA29 quince rootstock than on MC rootstock. In the evaluation of 'Deveci' pear performance on different rootstocks, Öztürk (2021) emphasized that the highest (2.32 m³) canopy volume was found in BA29, and the lowest (0.74 m³) in the MC rootstock. In the Tokat ecological conditions, the canopy volume of 'Santa Maria' grafted on QA rootstock ranged between 0.71 - 2.00 m³; and the 'Deveci' between 0.67 - 1.86 m³ (Küçüker and Ağlar, 2021). It can be said that the results obtained from the research are compatible with previous studies that reported canopy volume was affected by the research years, rootstocks and cultivars (Büyükyılmaz and Bulagay, 1984; Büyükyılmaz et al., 1994; Urbina et al., 2003; Stern and Doron, 2009; Hudina et al., 2014).

Table 3. The effect of quince rootstocks on the morphological characteristics of some standard pear cultivars.

Rootstocks	Cultivars	Rootstock Diameter (mm)	Trunk Diameter (mm)	Tree Height (cm)	Trunk Cross Sectional Area (cm^2)	Canopy Volume (m^3)
QA	Deveci	38.85 ab*	30.58 abc	167.38 ab	9.97 b	0.20 bc
	Williams	24.99 d	21.43 d	138.88 bc	4.29 de	0.08 bc
	Santa Maria	37.74 ab	31.39 abc	194.89 a	9.66 bc	0.23 bc
	Abate Fetel	39.94 ab	34.77 ab	193.72 a	11.16 ab	0.27 bc
BA29	Deveci	46.60 a	37.88 a	198.43 a	14.64 a	0.36 ab
	Williams	34.27 bc	29.12 bc	177.48 a	8.22 bcd	0.26 bc
	Santa Maria	37.65 ab	32.04 abc	192.47 a	9.66 bc	0.28 bc
	Abate Fetel	37.41 b	34.16 ab	168.36 ab	10.35 ab	0.25 bc
MC	Deveci	39.81 ab	31.70 abc	175.81 a	10.08 b	0.31 abc
	Williams	16.27 e	14.19 e	111.83 c	1.86 e	0.03 c
	Santa Maria	38.21 ab	32.75 abc	186.67 a	10.13 b	0.56 a
	Abate Fetel	26.50 cd	25.27 cd	141.42 bc	5.43 cde	0.07 bc
Main factors effects						
Year	2020	30.79 b	25.16 b	153.70 b	6.44 b	0.14 b
	2021	38.92 a	34.05 a	187.51 a	11.14 a	0.39 a
Rootstocks	QA	35.38 b	29.54 b	173.72 b	8.77 b	0.20 a
	BA29	38.98 a	33.30 a	184.18 a	10.71 a	0.29 a
	MC	30.20 c	25.98 c	153.93 c	6.88 c	0.24 a
Cultivars	Deveci	41.75 a	33.39 a	180.54 a	11.56 a	0.29 ab
	Williams	25.18 c	21.58 b	142.73 c	4.79 c	0.12 c
	Santa Maria	37.87 b	32.06 a	191.34 a	9.82 b	0.36 a
	Abate Fetel	34.62 b	31.40 a	167.83 b	8.98 b	0.19 bc
Significance						
Years		0.001	0.001	0.001	0.001	0.001
Rootstocks		0.001	0.001	0.001	0.001	0.208
Cultivars		0.001	0.001	0.001	0.001	0.001
Years x Rootstocks		0.042	0.023	0.032	0.017	0.046
Years x Cultivars		0.048	0.030	0.041	0.042	0.016
Rootstocks x Cultivars		0.001	0.001	0.001	0.001	0.004
Yrs. x Rts. x Cultivars		0.641	0.129	0.032	0.049	0.041

*: Averages shown with different letters in the same column. The difference between them is statistically significant.

The effect of rootstock, cultivar and rootstock x cultivar interactions on petiole length, petiole thickness, leaf length, leaf width, leaf area, and annual shoot length of pear cultivars grafted on different quince rootstocks were found to be statistically significant. However, it was stated that the effect of the study year on petiole length, petiole thickness, and leaf width was insignificant (Table

4). Regarding rootstock averages, petiole length varied between 19.26 - 30.74 mm. The highest petiole length (30.74 mm) was determined in QA, and the lowest (19.26 mm) in MC rootstock. Regarding cultivar averages, petiole length was observed between 22.34 - 28.50 mm; the highest was determined in 'Deveci' (28.50 mm) and the lowest (22.34 mm) in 'Williams'. Regarding rootstock x cultivar interactions, the petiole length varied between 16.30 - 38.29 mm. The highest (38.29 mm) petiole length was in 'Deveci'/QA, and the lowest (16.30 mm) was in 'Santa Maria'/MC combinations (Table 4).

On the petiole length; Öztürk and Öztürk (2014) determined that rootstocks had a significant effect on the 'Deveci' pear. They reported that the petiole length of 'Deveci' ranged from 33.5 mm to 44.3 mm. Furthermore, the highest petiole length on BA29 (44.3 mm) and the lowest on pear seedlings (33.5 mm) were mentioned. Çoban and Öztürk (2020) determined that rootstocks, cultivars, and rootstock x cultivar interactions significantly affected the average petiole length and reported that the petiole length was 22.5 - 37.6 mm in rootstocks and 29.3 - 35.7 mm in cultivars. The findings of our study differ partially from the results obtained by previous researchers. We can say that the resulting difference is due to the growing conditions, the rootstocks and cultivars.

In terms of rootstock averages, petiole thickness varied between 0.71 - 0.80 mm. It was determined that the petiole thickness was highest in BA29 and QA (0.80 mm and 0.76 mm, respectively) and the lowest in MC rootstock (0.71 mm). In terms of cultivars, they varied between 0.74 - 0.79 mm. The highest petiole thickness was in 'Abate Fetel' (0.79 mm) and 'Santa Maria' (0.79 mm), while the lowest was in 'Deveci' (0.74 mm). Regarding rootstock x cultivar interactions, petiole thickness was found to vary between 0.63 and 0.88 mm. The highest (0.88 mm) petiole thickness was in 'Abate Fetel'/BA29 and the lowest (0.63 mm) in 'Santa Maria'/MC combinations (Table 4). The study petiole thickness was significantly affected by rootstock, cultivar, and rootstock x cultivar interactions. Öztürk and Öztürk (2014) emphasized that rootstocks had an important effect on petiole thickness in 'Deveci' pear, and they reported that petiole thickness ranged from 0.58 to 0.76 mm. In the same study, it was determined that the highest average petiole thickness was in BA29 quince clonal rootstock (0.76 mm) and seedling (0.70 mm), while the lowest (0.58 mm) in plants grafted on EMC rootstock. Çoban (2019) determined that the effect of pear rootstocks, cultivars, and rootstock x cultivar combinations on the average petiole thickness was significant, and reported that the average petiole thickness was 0.97 - 1.27 mm in rootstocks and 1.06 - 1.16 mm in the cultivars. The researchers emphasized that the highest average petiole thickness was in Fox11 (1.27 mm), while the lowest was in seedling (0.97 mm) and OHF 333 (1.04 mm) rootstocks.

Table 4. The effect of quince rootstocks on leaf and annual shoot length of some standard pear cultivars.

Rootstocks	Cultivars	Leaf Petiole Length (mm)	Leaf Petiole Thickness (mm)	Leaf Length (mm)	Leaf Width (mm)	Leaf Area (cm^2)	Annual Shoot Length (cm)
QA	Deveci	38.29 a*	0.76 cd	44.78 d	31.21 b	10.01 c	38.03 bc*
	Williams	24.59 fg	0.74 cde	36.40 e	27.52 c	7.19 de	41.22 abc
	Santa Maria	33.47 bc	0.76 cd	55.64 a	35.68 a	14.20 a	49.15 ab
	Abate Fetel	26.61 ef	0.81 abc	48.30 c	23.25 d	8.07 d	37.91 bc
BA29	Deveci	28.65 de	0.69 def	46.50 cd	21.81 d	7.29 d	46.17 ab
	Williams	23.32 g	0.77 cd	37.50 e	23.07 d	6.20 ef	37.58 bc
	Santa Maria	33.83 b	0.84 ab	56.26 a	32.30 b	13.03 b	43.20 abc
	Abate Fetel	31.10 cd	0.88 a	51.47 b	26.73 c	9.87 c	53.42 a
MC	Deveci	18.56 hı	0.76 cd	35.57 e	21.66 d	5.58 fg	22.47 de
	Williams	19.10 h	0.79 bc	32.77 f	22.18 d	5.31 fg	17.17 e
	Santa Maria	16.30 ı	0.63 f	35.70 e	18.45 e	4.69 g	30.84 cd
	Abate Fetel	23.07 g	0.68 ef	45.61 d	21.96 d	7.20 de	37.06 bc
Main factors effects							
Year	2020	26.09 a	0.77 a	44.13 a	25.89 a	8.37 a	44.29 a
	2021	26.72 a	0.75 a	43.62 b	25.08 a	8.07 b	31.41 b
Rootstocks	QA	30.74 a	0.76 a	46.28 b	29.41 a	9.87 a	41.58 a
	BA29	29.22 b	0.80 a	47.93 a	25.98 b	9.10 b	45.09 a
	MC	19.26 c	0.71 b	37.41 c	21.06 c	5.70 c	26.88 b
Cultivars	Deveci	28.50 a	0.74 b	42.28 c	24.89 b	7.63 c	35.56 b
	Williams	22.34 c	0.76 ab	35.56 d	24.25 b	6.24 d	31.99 b
	Santa Maria	27.86 ab	0.74 b	49.20 a	28.81 a	10.64 a	41.06 a
	Abate Fetel	26.93 b	0.79 a	48.46 b	23.98 b	8.38 b	42.79 a
Significance							
Years		0.230	0.079	0.050	0.086	0.047	0.001
Rootstocks		0.001	0.001	0.001	0.001	0.001	0.001
Cultivars		0.001	0.044	0.001	0.001	0.003	0.001
Years x Rootstocks		0.034	0.048	0.001	0.003	0.001	0.041
Years x Cultivars		0.046	0.390	0.001	0.047	0.005	0.035
Rootstocks x Cultivars		0.001	0.001	0.001	0.001	0.001	0.001
Yrs. x Rts. x Cultivars		0.404	0.243	0.001	0.007	0.023	0.041

*: Averages shown with different letters in the same column. The difference between them is statistically significant.

Leaf length in the case of rootstock averages varied between 37.41 - 47.93 mm. The highest leaf length was determined on QA (47.93 mm) and the lowest on MC (37.41 mm). In terms of cultivars' averages, it was determined that they varied between 35.56-49.20 mm. In terms of

cultivars, the highest leaf length was found in 'Santa Maria' (49.20 mm) and the lowest in 'Williams' (35.56 mm). In terms of rootstock x cultivar interactions, it was determined that the leaf length was recorded between 32.77 - 56.26 mm. The highest leaf length was in 'Santa Maria'/BA29 and 'Santa Maria'/QA (56.26 mm and 55.64 mm, respectively), while the lowest (32.77 mm) was in 'Williams'/MC combinations (Table 4). In our study, it was observed that the leaf length varied between 35.56 - 49.20 mm. Serttaş (2019) stated that the leaf length of pear varied in terms of rootstock and cultivars; she reported that the leaf length was between 59.0 - 65.2 mm between rootstocks. In addition, she determined that the highest leaf length was in 'Santa Maria' (65.5 mm) and the lowest in 'Williams' and 'Abate Fetel' (61.7 mm and 61.5 mm, respectively). The highest leaf length foun in the 'Deveci'/ BA29 (Öztürk ve Öztürk, 2014). Kılıç (2015) reported leaf lengths between 32.00 - 60.18 mm in the case of different pear genotypes. Çoban and Öztürk (2020) emphasized that rootstocks and cultivars had an important effect on leaf length in 'Deveci' and 'Williams' pear cultivars that were grafted on different quince and pear clonal rootstocks. They noted that the leaf height was 6.67 - 6.88 cm in rootstock averages and 6.42 - 7.23 in cultivar averages. When our findings compared with previous studies, it was determined that the leaf length was slightly lower. Indeed, the ecological conditions of the research region where the plants were grown at an optimum level for cultivation positively affected the photosynthesis in the plant, so caused an increase in vegetative growth and development (Uzun, 1997). The genetic structures of rootstocks and cultivars caused differences in growth characteristics, which can also affect leaf length (Çoban, 2019; Serttaş, 2019; Çoban and Öztürk, 2020; Serttaş and Öztürk, 2020).

Leaf width in terms of rootstock varied between 21.06 - 29.41 mm. The highest leaf width was determined in QA (29.41 mm) and the lowest (21.06 mm) in MC rootstock. The leaf width was between 23.98 - 28.81 mm, reported in terms of cultivar averages. The highest leaf width was determined in 'Santa Maria' (28.81 mm). Regarding rootstock x cultivar interactions, the leaf width varied between 18.45 - 35.68 mm. The highest (35.68 mm) leaf width was in 'Santa Maria'/QA, and the lowest (18.45 mm) was in 'Santa Maria'/MC combinations (Table 4). Öztürk and Öztürk (2014) cited that rootstocks had a significant effect on leaf sizes of 'Deveci' pear; they reported that leaf blade width was the highest in plants grafted on BA29 rootstocks. Kılıç (2015) reported that, leaf blade width differed between pear genotypes examined and varied between 28.99 - 48.34 mm. Çoban and Öztürk (2020) reported that the effects of cultivars, rootstocks, and rootstock x cultivar combinations on the leaf width of grafted pear cultivars were significant; they reported that leaf blade width was 36 - 37 mm in cultivars and 35 - 38 mm in the rootstocks. Serttaş and Öztürk (2020) reported that leaf blade width was the highest in 'Deveci' and 'Santa Maria' (3.75 cm and 3.44 cm), and the lowest (3.40 cm and 3.34 cm) in 'Abate Fetel' and 'Williams' cultivars. It was stated that the differences in the results were due to the genotypic variations in the cultivars.

Leaf area (LA) in the case of rootstocks ranged between 5.70 - 9.87 cm^2, the highest in QA (9.87 cm^2) and the lowest in MC (5.70 cm^2). The case of cultivars ranged between 6.24 - 10.80 cm^2, the highest in 'Santa Maria' (10.80 cm^2) and the lowest in 'Williams' (6.24 cm^2). In the case of rootstocks x cultivars combinations ranged between 4.69 - 14.20 cm^2, the highest in 'Santa Maria'/QA (14.20 cm^2) and the lowest in 'Santa Maria'/MC (4.69 cm^2) (Table 4). Leaf area is an important consideration of tree canopy volume efficiency and fruit quality (Zhang et al., 2016). Also, to understand evaporation, respiration, photosynthesis, light reception, water, and nutrient usage, flowering, fruit set, and efficiency of yield, leaf area is a withstand factor; they mentioned the leaf area of 'Santa Maria' was 23.82 cm^2 while grafted on BA29 (Ozturk et al., 2019). In other research stated that the effect of rootstocks on the leaf area of the 'Deveci' pear was significant; they reported that the leaf area of the plants grafted on BA29 was higher than the other rootstocks (Öztürk and Öztürk, 2014). Engin (2011) reported that leaf area was observed (15.72 to 23.78 cm^2) in 'Santa Maria'/QA, and (17.07 to 21.61 cm^2) in 'Santa Maria'/OHF 333 combinations.

Annual shoot length in terms of rootstock averages varied between 26.88 - 45.09 cm. The longest annual shoot length was determined in BA29 and QA (45.09 cm and 41.58 cm, respectively), and the shortest (26.88 cm) in the MC rootstock. In terms of cultivars reported between 31.99 - 42.79 cm. The longest annual shoots were observed in 'Abate Fetel' and 'Santa Maria' (42.79 cm and 41.06 cm, respectively), and the shortest in 'Williams' and 'Deveci' (31.99 cm and 35.56 cm, respectively). Regarding rootstock x cultivar interactions, the annual shoot length was 17.17 - 53.42 cm. The highest (53.42 cm) annual shoot length was determined in 'Abate Fetel'/BA29 and the lowest (17.17 cm) in 'Williams'/MC combinations (Table 4). In the 'Abate Fetel' cultivar grafted on different rootstocks, the longest annual shoot length was found in the seedling (82.0 cm), the lowest in BA29 (4.6 cm) and MA (5.2 cm) rootstocks. Also, they reported that the 'Conference' cultivar's longest annual shoots were observed on the seedling (83.3 cm), and the shortest (2.6 cm) was on the BA29 rootstock (Castro and Rodriguez, 2002). Kviklys and Kvikliene (2004) stated that there were significant differences between rootstocks in annual shoot length in 'Conference' pear cultivar grafted on different rootstocks, and they reported the highest annual shoot length was in MC, Sydo, and seedling rootstocks. Annual shoot length in QA was reported as 13.97 - 23.14 cm by (Ertürk et al., 2009). The longest shoot length was observed on 'Coscia' and 'Deveci' (23.14 cm, 21.65 cm), respectively, while the lowest (13.97 cm) was in the 'Williams' cultivar (Ertürk et al., 2009). Annual shoot length was reported to be 26.00 - 44.56 cm in 'Deveci'/QA, 35.56 - 49.00 cm in 'Santa Maria'/QA, 22.89 - 46.44 cm in 'Deveci'/OHF 333, and 16.67 - 37.90 cm in the 'Santa Maria'/OHF 333 (Engin and Özkan, 2011). Osmanoğlu et al. (2013) reported that the annual shoot length of 'Ankara', 'Akça', 'Williams', 'Santa Maria', and 'Deveci' pear cultivars grown in Bingöl ecological conditions varied between 22.0 and 86.0 cm. The highest

annual shoot length was in ‘Ankara’, and the lowest was in the ‘Santa Maria’ cultivar. In the ‘Shahmiveh’ pear cultivar grafted on different rootstocks, the longest annual shoot length was obtained from Konjoni and pear seedlings. In contrast, the shortest was obtained from hawthorn seedlings and MC rootstock (Akbari et al., 2014). Considering the effect of Champion, Melliforme, *and P. calleryana* pear rootstock on the annual shoot length of the ‘Williams’ cultivar, they found that the growth force of Champion rootstock was weaker than other rootstocks (Pasa et al., 2020).

4. Conclusion

It was determined that the ‘Williams’ cultivar did not perform well in plant growth compared to other cultivars grafted on QA. It was thought that this situation might result from incompatibility between the rootstock and the grafted cultivar on it. For this purpose, if the ‘Williams’ cultivar is to be grown on the QA rootstock, the appropriate intermediate stock should be used. In our study, we found that MC rootstock may be suitable for dense planting because it is more stunted in terms of plant growth. ‘Deveci’, ‘Williams’, and ‘Santa Maria’ pear cultivars suited Samsun ecological conditions. Due to the early flowering of the ‘Abate Fetel’ cultivar, the low temperatures in this period as well as the high amount of precipitation negatively affected pollination and caused poor fruit set, so care should be taken in the cultivation of this cultivar. Phenological observations showed significant differences over the research years. The rootstocks, cultivars and variations of the climatical conditions were among the reasons for the differences.

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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.

Author Contributions

All authors contributed to the research application, preparation of research article, reading and approving of the final manuscript.

Statement of Research and Publication Ethics

The author declares that this study complies with Research and Publication Ethics.

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