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Research Article

# Effect of the Rootstock and Cultivar on Graft Success and Sapling Development and Graft Incompatibility in Pear

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**Abstract.** This study was carried out to determine the effects of different rootstocks on graft success, sapling development and graft compatibility/incompatibility of 'Deveci' and 'Williams' pear cultivars in Samsun ecological conditions between 2014 and 2016 years. Graft incompatibility was attempted to be associated with morphological measurements in the graft union. Rootstock, cultivar and rootstockxcultivar interaction had a significant effect on the all examined parameters. In the study, graft take ratios were between 91.5-100.0%, graft sprout ratios were between 89.2-99.0% and survival ratios were between 83.7-99.0%. The graft sprout ratio was the highest in the OHxF333 and lowest was in the BA29 rootstock. The graft sprout and survival ratios were lower in quince rootstock than in pear rootstocks. Rootstock diameters were higher in the OHxF333 and seedling rootstocks than in the Fox11 and BA29 rootstocks. Graft union diameter and shoot diameter were lower in the Fox11 than the other rootstocks. Shoot length was higher in the OHxF333 than the other rootstocks. Especially considering the graft success and the diameter measurements made in the graft union, it has been found that some scion/stock combinations may show graft incompatibility. The 'Williams'/BA29 combination may be incompatible due to the lower survival ratio and diameter values in the graft union than other combinations. Although graft success is sufficient, it should be noted that the 'Williams'/Fox11, whose rootstock diameter and graft union diameter are lower than the others, may show graft incompatibility. 'Deveci' cultivar shows good compatibility with all rootstocks due to the higher graft success and sapling performance.

# Anaç ve Çeşidin Armutta Aşı Başarısı, Fidan Gelişimi ve Aşı Uyuşmazlığı Üzerine Etkisi

**Anahtar kelimeler:**
Armut, anaç, aşı başarısı, aşı uyuşmazlığı, yaşama oranı

**Özet.** Bu çalışma 'Deveci' ve 'Williams' armut çeşitlerinin aşı başarısı, fidan gelişimi ve aşı uyuşma/uyuşmazlığı üzerine farklı anaçların etkilerini belirlemek amacıyla 2015-2016 yıllarında Samsun ekolojik koşularında yürütülmüştür. Aşı uyuşmazlığı aşı bölgesinde yapılan morfolojik ölçümlerle ilişkilendirilmeye çalışılmıştır. Araştırmada incelenen tüm özellikler üzerine anaç, çeşit ve anaçxçeşit interaksiyonunun etkisi önemli olmuştur. Aşı tutma oranı %91.5-100.0, aşı sürme oranı %89.2-99.0, fidan yaşama oranı %83.7-99.0 arasında değişmiştir. Aşı tutma oranı en yüksek OHxF333 en düşük ise BA29 anacında olmuştur. Aşı sürme ve fidan yaşama oranı ayva anacında armut anaçlarından daha düşük olmuştur. Anaç çapı OHxF333 ve çöğür anaçlarında Fox11 ve BA29 anaçlarından daha yüksek bulunmuştur. Aşı yeri çapı ve sürgün çapının Fox11 anacında diğer anaçlardan daha düşük olduğu belirlenmiştir. Aşı sürgün uzunluğu OHxF333 anacında diğer anaçlardan daha yüksek bulunmuştur. Özellikle aşı başarısı ve aşı bölgesinde yapılan çap ölçümleri de dikkate alındığında bazı kombinasyonların aşı uyuşmazlığı gösterebileceği tespit edilmiştir. Fidan yaşama oranı ve aşı bölgesindeki çap değerlerinin diğer kombinasyonlardan daha düşük olduğu 'Williams'/BA29 kombinasyonun uyuşmaz olabileceği ortaya konulmuştur. Aşı başarısı yeterli olmasına rağmen anaç ve aşı sürgünü çapı diğerlerine göre düşük olan 'Williams'/Fox11 kombinasyonunun aşı uyuşmazlığı gösterebileceğine dikkat edilmelidir. 'Deveci' çeşidinin aşı başarısı ve fidan gelişim performansının daha iyi olması dolayısıyla tüm anaçlarla iyi bir aşı uyuşması gösterdiği belirlenmiştir.

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## INTRODUCTION

Today, fruit growing has an important potential in the development of the horticultural crops (Nimbolkar *et al.*, 2016). Pear, which is the most produced temperate fruit after apples, is a fruit species its production increase day by day due to its good income and the benefits on human health (Jackson, 2003; Ozcagiran *et al.*, 2005). Pear cultivars used in the establishment of commercial pear orchards are generally grafted on seedling or clonal rootstocks (Jackson, 2003; Ozcagiran *et al.*, 2005; Francescatto *et al.*, 2010; Machado et el., 2016; Hepaksoy, 2019; Tatari *et al.*, 2020). Rootstocks have an important effect on fruit production by affecting the crown structure, growth characteristics, nutrient uptake, flowering, yield and fruit quality. In addition, rootstocks are resistant to biotic and abiotic stresses such as soil pathogens, thermal stress and salinity (Rom and Carlson, 1987; Mezey and Lesko, 2014). In modern pear cultivation, quince and pear clonal rootstocks are used instead of seedling rootstocks (Hancock and Lobos, 2008; Sharma *et al.*, 2010; Dondini and Sansavini, 2012). Pear clonal rootstocks show stronger development compared to quince rootstocks and so they are planted wider distances (Ozcagiran *et al.*, 2005; Sharma *et al.*, 2010). Quince rootstocks provide the control of the growth vigor (dwarfing) of the trees grafted to them, earliness in yield, increase in fruit yield and quality, high density planting, increase in fruit size, easy management practices such as pruning, spraying, weed control and harvesting. However, these rootstocks also have negative properties such as sensitivity to winter cold, calcareous soil, chlorosis and fire blight and poor graft compatibility (Ermel *et al.*, 1999; Pina and Errea, 2009; Francescatto *et al.*, 2010; Machado *et al.*, 2016; Dolkar *et al.*, 2018). Pears show graft incompatibility due to morphological, anatomical, physiological or biochemical reasons, especially when they are grafted on quince of the different genera (Özçağıran, 1982; Ermel *et al.*, 1999; Jackson, 2003; Francescatto *et al.*, 2010; Hudina *et al.*, 2014). In the pear, the graft incompatibility may occur with some symptoms in early and late stage of growing period on the quince rootstocks (Errea, 1998; Ermel *et al.*, 1999; Pina and Errea, 2005; Davarynejad *et al.*, 2008; Rahman *et al.*, 2017; Dolkar *et al.*, 2018). The swelling on the graft site, diameter differences between scion and stock, angle of shoot growth, leaflet becomes yellowish, low graft success and survival ratio, reduction of vegetative growth and differences in growth rate between rootstock and scion are some symptoms of the graft incompatibility (Pina and Errea, 2005; Davarynejad *et al.*, 2008; Hartman *et al.*, 2011; Machado *et al.*, 2016; Rahman *et al.*, 2017). This phenomena might be due to the absence of differentiation of callus tissues into new phloem tissues or necrosis of the cells in the site of scion (Pina and Errea, 2009; Hartmann *et al.*, 2011; Dolkar *et al.*, 2018). This can cause a miss-joining between rootstock and scion, leading to lack of lignification of cells in the graft union (Darikova *et al.*, 2011; Hartman *et al.*, 2011; Dogra *et al.*, 2018; Dolkar *et al.*, 2018). Normally, the diameter of the grafted cultivar trunk is slightly larger than that of the rootstock due to lignification in the graft union. When the graft diameter of the cultivar is slightly larger than the rootstock diameter in the graft union, this may be an indicator of anatomical graft incompatibility. This anatomical graft incompatibility may be due to the difference in the rate of cambium cell division of the rootstock and cultivar that causes discontinuity in the xylem vessels. The formation of new cambium tissue callus in the graft union region appears to be delayed in heterografts and/or interspecific grafts according to homografts and/or intraspecific grafts (Webster, 1995; Darikova *et al.*, 2011; Hartmann *et al.*, 2011; Dogra *et al.*, 2018).

In order to eliminate the negative effects of graft incompatibility in pear/quince grafting combinations, dwarf and semi-dwarf quince and pear clonal rootstocks such as BA29, Adams, Sydo, Pyrodwarf, OHxF, Farold, Fox, BP and CTS series in different rootstock breeding programs have been used in recent years (Jackson, 2003; Hancock and Lobous, 2008; Dondini and Sansavini, 2012; da Silva *et al.*, 2018). It is important for pear cultivation to investigate the effects of these new pear rootstocks on the growth and development vigor of the cultivars grafted on them, as well as their resistance to biotic and abiotic stress conditions. In addition to choosing a good cultivar for successful cultivation, selection of proper rootstocks for growing conditions is also very important (Hepaksoy, 2019). The effect of the cultivars grafted on rootstocks on growth characteristics determines the growing ability of the cultivar. In this respect, to reveal the graft compatibility/incompatibility with the cultivars grafted on rootstocks (Rahman *et al.*, 2017; da Silva *et al.*, 2018) is very important for the pear producer who will established the orchard with these saplings.

This research was carried out to determine the graft compatibility/incompatibility of pear cultivars grafted on quince and pear rootstocks in 2015 and 2016 years.

## MATERIAL AND METHOD

### *Experiment Location*

This study was carried out at the Agriculture Research Station of Ondokuz Mayıs University located in Samsun (Turkey) Province, Atakum County (North: 41 °21', East: 36° 11', Altitude: 173 m) during 2014 and 2016 years. The study was conducted on nursery parcel located in the open field. Grafting was also performed in the open field. The research area was flat and had a slope of about 1%. The nursery soil is clayed-loam, weakly acidic, lime-free, and unsalted, and it has high phosphorus, potassium and organic matter content. The plants were mulched against the weeds and drip irrigation was implemented.

The climate of Samsun proves its temperate climate character. For many years, the highest average temperature was 27.0 °C, the lowest temperature was 3.9°C, the annual average temperature was 14.4 °C, and the average annual rainfall was 733 mm. According to the obtained data, a large part of the precipitation falls in autumn and winter (TSMS 2020). The climatic data of experimental area were measured with a mechanical data logger (KIMO KH-100 Temp/RH data logger) and they presented Figure 1.

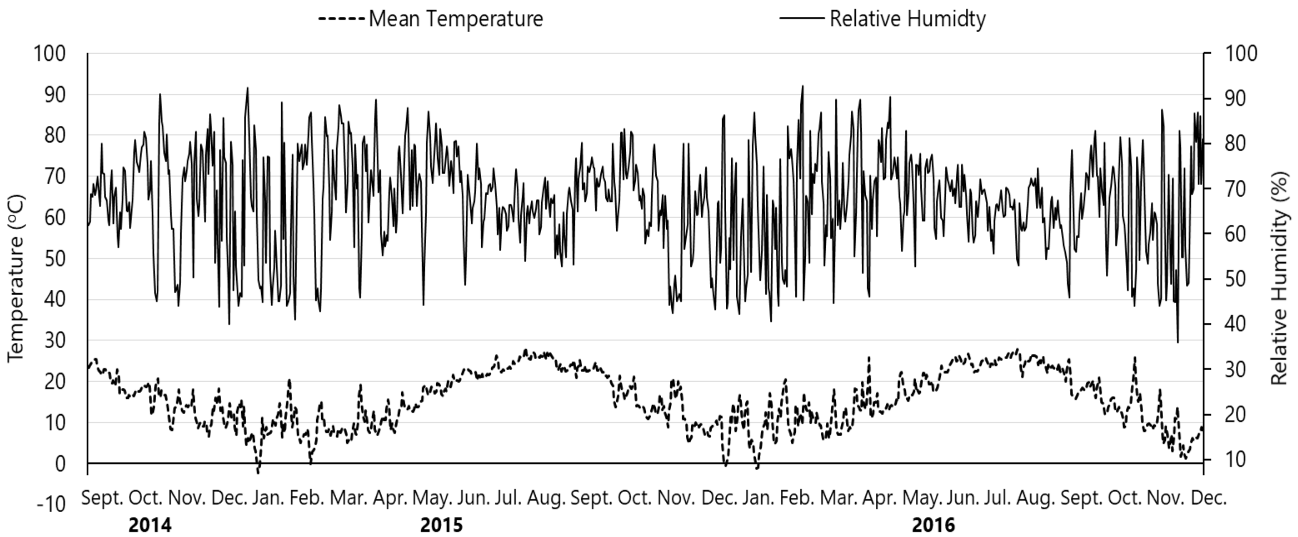


**Figure 1.** Mean temperature (°C) and relative humidity (%) data of experimental area between 2014-2016 years.
*Şekil 1. Deneme alanınada 2014-2016 yılları arasında gözlemlenen oratlama sıcaklık (°C) ve oransal nem (%) değerleri.*

### *Plant Materials*

In the study, one year old clonal rootstocks of quince (Quince BA 29), pear (OHxF 333 and Fox 11) and pear seedling were used. Rootstocks were planted at a distance of 120 cm and 30 cm rows and rows in February 2014 and cultivated in open field. 'Deveci' and 'Williams' pear cultivars were used as scions. 'Deveci' is known as compatible cultivar with quince rootstock (Ozcagiran *et al.*, 2005) and 'Williams' is known as compatible or moderate compatible cultivars with quince rootstocks (Gulen *et al.*, 2002; Dondini and Sansavini, 2012; Hudina *et al.*, 2014).

### *Grafting and Observations*

Similar sized (for thickness) rootstocks were selected for grafting. T-budding method, which has been using the most suitable graft method in the fall period (Westwood 1995; Hartmann *et al.* 2011) was used in the month of 1 September, 2014 and 2015. Grafting was performed 20 cm above the soil surface (Lewis and Alexander 2008; Hartmann *et al.* 2011). A total of 30 grafts was made in the study, 3 replicates in each rootstock and cultivar combination, and 10 grafting in each replicate. White colored, soft and silicone grafting tape was used to protect the graft area. Cultural applications such as irrigation, weed management and removal of suckers below the graft union were preformed regularly. As a ground cover, which is black colored, UV-added and polypropylene, was used between the rows for weed control. The rootstocks used in the study were irrigated during summer by drip irrigation systems. Fertilization was done fertigation, and NPK (20.10.20+ME, 3-4 kg decare-1) fertilizer was used, one month intervals. Chemical spraying was not performed in the orchard.

After 20 days of budding brown and black and shriveled buds were taken as dead, but green buds indicated bud take (Hartmann *et al.*, 2011). In the study, graft (bud) take ratio (%), graft (bud) sprout ratio (%), graft survival ratio (%), rootstock diameter (mm), graft union diameter (mm), shoot diameter (mm) and shoot length (cm) were determined according to previous relevant studies (Ozturk *et al*., 2009; Ozturk *et al*., 2011; Hudina *et al*., 2014; Ozturk and Ozturk, 2014; Rahmati *et al*., 2015; Rahman *et al*., 2017; Zenginbal *et al*., 2017; Zenginbal and Bostan 2019; Serttas and Ozturk, 2020). Graft take ratio (%) was determined by dividing the number of successful grafts with the total number of grafted plants. Graft sprout ratio (%) was determined by dividing the number of sprouting grafts with the total number of grafted plants after bud burst. Graft survival ratio (%) was determined by dividing the number of surviving grafts with the initially grafted total plants at the end of the vegetation period (December 1st). Rootstock diameter (mm) was measured by 0.01mm sensitive digital caliper at a point 5 cm below the graft union at the end of vegetation (December $1^{st}$) for each application. Graft union diameter (mm) was measured by 0.01mm sensitive digital caliper at graft union area at the end of vegetation (December $1^{st}$) for each application. Graft shoot diameter (mm) was measured by 0.01mm sensitive digital caliper at a point 5 cm above the graft union at the end of vegetation (December 1st) for each application. Graft shoot length (cm) was measured by meter from graft point to shoot tip at the end of vegetation (December $1^{st}$) for each application.

### *Data Analysis*

This study was arranged with randomized complete block design with three replications, each replication contained 10 plants, and totally each treatment had 30 plants. Data expressed as a percentage (bud take ratio, sprouting ratio and survival ratio) was transformed using the arc-sin√x transformation. Non-transformed values were given in the tables. Data analyses were performed using SPSS v 21.0 (IBM® SPSS® statistics) statistical package program via the license of Ondokuz Mayis University. The differences between the averages of rootstocks and cultivars and their interaction were determined by 'Duncan's Multiple Range Tests' at the 0.05% level. The results are given as two-year average in the tables.

## RESULTS AND DISCUSSION

### *Graft Take Ratio*

There was statistically significant effect of the rootstocks, cultivars and rootstock x cultivar interaction on the grafting take ratio. The highest graft take ratio was in the OHxF333 rootstock (98.5%); the lowest was in the BA29 rootstock (95%). In terms of cultivar average, the highest graft take ratio was found in the 'Deveci' cultivar (99.6%), it was the lowest in the 'Williams' cultivar (93.8%). In terms of rootstock x cultivar interaction, the highest graft take ratio (100%) was obtained by 'Deveci'/Fox11 and 'Deveci'/seedling and 'Deveci'/OHxF333, the lowest was in the 'Williams'/BA29 and 'Williams'/seedling rootstocks (91.5% and 91.7%). When the 'Deveci' was grafted on the BA29, the graft take ratio was lower than the other rootstocks. When the 'Williams' cultivar was grafted on the Fox11 and OHxF333, the graft take ratio was higher than the grafted on the BA29 and seedling (Table 1).

In this study, the graft take ratio was found higher in pear rootstocks than quince rootstock. In the previous relevant studies were stated that rootstocks and cultivars had a very important effect on the graft take ratio in the pear (Akçay, 2007; Rahman *et al*., 2017; Serttas and Ozturk, 2019; Zenginbal and Bostan, 2019). The graft take ratio in the pear; Elivar and Dumanoglu (1999) 74.5-96.1%; Kadan and Yarılgac (2005) 98-99%; Irrisarri *et al*. (2016) 53.33-91.67%; Rahman *et al*. (2017) 65.27-88.94%; Zenginbal and Bostan (2019) 60%; Serttas and Ozturk (2020) 86.7-100.0%. Irisarri *et al*. (2016) determined that the lowest graft take ratio when the 'Williams' was grafted on the BA29 (53.33%). In previous studies, it was found that the graft take ratio was higher for the pear rootstocks than the quince rootstock. It can be said that the reason for this is related to botanical relationship amongst the grafting in fruit species. As a matter of fact, it has been emphasized that the graft take ratio is lower than the intraspecific and interspecific grafting of pear (*Pyrus*) and quince (*Cydonia*) of different genera (Jackson, 2003; Hartmann *et al*., 2011). The 'Williams' pear cultivar had lower graft take ratio in the quince rootstock than the pear rootstocks compared the 'Deveci' cultivar in this study. While the results of the graft take ratio obtained from this study were a bit similar to the study by Elivar and Dumanoglu (1999); it is very similar to the study done by Kadan and Yarılgac (2005), Irisarri *et al*. (2016), Rahman *et al*. (2017), Zenginbal and Bostan (2019) and Serttas and Ozturk (2020).

### *Graft Sprout Ratio*

In this study, the graft sprout ratio was higher in the pear rootstocks than the quince rootstock. The graft sprout ratio was higher in the 'Deveci' (97.8%) than the 'Williams' (91.2%). In terms of rootstock x cultivar interaction, the highest graft sprout ratio was found in the 'Deveci' grafted on the Fox11, OHxF333 and seedling rootstocks (99.0%, 98.7% and 98.7%, respectively), and the lowest in the 'Williams' cultivar grafted on the BA 29 quince clone rootstock (89.2%). The highest graft sprout ratio was determined when the 'Williams' grafted on the OHxF333, while it was the lowest when grafted on the BA29 (Table 1).

**Table 1.** The effect of the rootstocks on graft success of pear cultivars.
*Çizelge 1. Armut çeşitlerinin aşı başarısı üzerine anaçların etkisi.*

| Cultivars | Rootstock | Graft take ratio (%) | Graft sprout ratio (%) | Graft survival ratio (%) |
|---|---|---|---|---|
| Deveci | BA29 | 98.5 b* b** | 95.1 b b | 93.4 bc b |
| | Fox11 | 100.0 a a | 99.0 a a | 99.0 a a |
| | OH*x*F 333 | 100.0 a a | 98.7 a a | 96.7 b ab |
| | Seedling | 100.0 a a | 98.7 a a | 98.7 a a |
| Williams | BA29 | 91.5 d b | 89.2 c b | 83.7 e b |
| | Fox11 | 95.0 c a | 91.4 ab ab | 91.3 cd a |
| | OH*x*F 333 | 97.0 c a | 93.0 ab a | 91.7 cd a |
| | Seedling | 91.7 d b | 91.3 ab ab | 87.3 de b |
| Factors' means | | | | |
| Rootstocks | BA29 | 95.0 c | 92.1 b | 88.5 b |
| | Fox11 | 97.5 ab | 95.2 a | 95.2 a |
| | OH*x*F 333 | 98.5 a | 95.8 a | 94.2 a |
| | Seedling | 95.8 b | 95.0 a | 93.0 a |
| Cultivars | Deveci | 99.6 a | 97.8 a | 96.9 a |
| | Williams | 93.8 b | 91.2 b | 88.5 b |

*: The difference between the means indicated by the same letter in the same column is not statistically significant in the p <0.05.
**: The difference between the means of the same cultivar indicated by the same letter in the same column is not statistically significant in the p <0.05.

In the study, rootstock and cultivar and rootstock x cultivar interaction had a statistically significant effect on the graft sprout ratio (Table 1). Temperatures immediately after grafting directly affect graft success. And also, in order to form the callus tissue on the graft formation, the environmental conditions such as temperature and humidity should be appropriate (Yılmaz 1994; Hartmann *et al.*, 2011). The temperature between 12.8°C and 32°C during or after grafting speeds up callus formation and allows the growth to continue rapidly. After grafting, callus formation and the cambium junction between the rootstock and scion occur after 7-14 days (Hartmann *et al.*, 2011) and therefore the first 15 days air temperatures after grafting directly affect the success of the graft. Hence, the measured temperatures during the grafting period in the research area in the specified temperature range (Figure 1), increased the graft take and sprout ratio. This study results about the graft sprout ratio are consistent with the previous studies in the pear was in 56.67-100% (Elivar and Dumanoglu, 1999; Kadan and Yarılgac, 2005; Zenginbal and Bostan, 2019 Serttas and Ozturk, 2020). As a result of this research, it was determined that the 'Deveci' pear cultivar had better graft sprout ratios compared to the 'Williams'. The good compatibility of the 'Williams' cultivar with the OHxF333 rootstock (Akçay, 2007) also affected the graft sprout ratios positively. In combinations of grafted on quince rootstock, the graft sprout ratio was lower than those grafted on pear rootstock. The difference between rootstocks and cultivars in the graft sprout ratio obtained in the study is due to the genetic difference of rootstocks and cultivars. As a matter of fact, it is reported that genetic differences affect graft success (Pektas *et al.*, 2009; Hartmann *et al.*, 2011; Zenginbal *et al.*, 2017; Serttas and Ozturk, 2020).

***Survival Ratio***

In the study, the survival ratio of pear rootstocks (95.2%, 94.2% and 93.0%, respectively) was higher than the quince rootstock (88.5%). In terms of cultivar average, the survival ratio was higher in the 'Deveci' (96.9%) than the 'Williams' (88.5%). In the study, the highest survival ratio was determined in the 'Deveci'/Fox11 (99.0%) and the 'Deveci'/seedling (98.7%) and the lowest in the 'Williams'/BA29 (83.7%) in terms of rootstock x cultivar interaction. The lowest survival ratio of 'Deveci' was grafted on the BA29, and in the 'Williams' was the lowest grafted on the BA29 (Table 1).

In the study, rootstock, cultivar and rootstock x cultivar interaction had a significant effect on the survival ratio. In today's modern fruit growing, rootstocks have became widespread due to their some advantages such as the tree shape and size, early fruiting, the quality of the fruits, adaptation to different ecological conditions, and their resistance to diseases and pests (Sharma *et al.*, 2010; da Silva *et al.*, 2018; Hepaksoy, 2019). First of all, knowing the graft compatibility between stock and scion used in the grafting will prevent possible problems in the future. Generally; the closer relatives of the plants to be grafted botanically, the higher the chances of success of grafting (Hartmann *et al*., 2011; Dogra *et al*., 2018; Dolkar *et al*., 2018). There are many factors that affect graft success, including ecological, physiological, morphological and genetic. Factors such as temperature, humidity, the condition of the rootstock, the technique of grafting, the skill of the expertise and relationship between the plants to be grafted directly affect the graft success (Hartmann *et al*., 2011). Failure of the grafting appropriate for the technique and time or a low rate of graft take can be associated with graft incompatibility. This can occur, especially when different species/genera are grafted on top of each other. Due to the graft incompatibility in the pear/quince graft combination of different genera, the symptoms of incompatibility do not appear immediately, but also appear as a delayed dispute after a few years (Ermel *et al*., 1995; 1997; Francescatto *et al*., 2010; Darikova *et al*., 2011; Hartmann *et al*., 2011). Rahman *et al*. (2017) reported that the survival ratio varies significantly between rootstocks and cultivars and that in terms of cultivars, the highest survival ratio was in the 'Williams', the lowest was in the 'Santa Maria', and in terms of rootstocks, a local variety of seedlings was in. In this study, differences in graft take and sprout ratios were found in the grafting between different genera. The difference between the genera in the survival ratio was slightly higher observed. This can result from pear/quince graft incompatibility. Especially in this study, 'Williams' cultivar, which has a lower survival ratio, has been reported to show graft incompatibility with some quince rootstocks (Gulen *et al*., 2002; Dondini and Sansavini, 2012) and pear clonal rootstocks such as Fox11 (Hudina *et al*., 2014). Serttas and Ozturk (2020) noted that the survival ratio was 93.3% (Williams) - 100.0 (Santa Maria) among the varieties and 93.3-98.9% among the rootstocks. In a similar study, Hudina *et al*. (2014), examined the graft compatibility/incompatibility of some standard pear cultivars grafted on different pear rootstocks, reported that rootstocks and cultivars affected the survival ratio, and the survival ratio varied between 25% and 100%. They reported that the lowest survival ratio was in ''Williams', 'Conference' and 'Abate Fetel' cultivars and they emphasized that this was due to biochemical reasons. It has been emphasized that graft incompatibility is a complex event resulting from physiological, anatomical and biochemical reasons, and the survival ratio is lower in combinations where graft incompatibility is high (Errea, 1998; Musacchi *et al*., 2002; Pina and Errea, 2009; Ciobotari *et al*., 2010). Hudina *et al*. (2014) reported that the survival ratio was lower in cultivars grafted on the BA29 and Fox11 compared to other rootstocks. The results obtained in the study are in accordance with the previous studies.

### *Rootstock Diameter*

In the research, pear cultivars examined had no effect on the rootstock diameter and rootstocks and rootstock x cultivar interaction had a statistically significant effect on the rootstock diameter. The rootstock diameter ranged between 22.52 mm and 32.25 mm in terms of rootstock averages, and 26.43 mm and 29.13 mm in terms of cultivar averages. The rootstock diameter was found to be the lowest in the Fox11 (22.25 mm) and the BA29 (24.69 mm) rootstocks, and it was the highest in the OHxF333 (31.67 mm) and seedling rootstock (32.25 mm). In terms of rootstock x cultivar interaction, the highest rootstock diameter was found in the 'Deveci'/seedling (35.83 mm) and 'Williams'/OHxF333 (33.46 mm) and the lowest was in the 'Williams'/BA29 (20.21 mm) scion/stock combination. When the 'Deveci' was grafted on the seedling rootstock, the rootstock diameter was the highest and it was the lowest when it was grafted on the Fox11. When the 'Williams' was grafted on the OHxF333, the rootstock diameter was the highest and the lowest was on the BA29 and Fox11 rootstocks (Table 2).

In the study, rootstocks and rootstock x cultivar interaction have a significant effect on the rootstock diameter, but there is no effect on cultivars. Cetinbas *et al*. (2018) found that the rootstock diameter was higher in the 'Deveci' cultivar than the 'Santa Maria' and amongst the rootstock, it was higher in the OHxF333, BA29, OHxF69 and Quince C rootstocks than the other examined rootstocks, and lowest in the Fox9 rootstock. Davarynejad and Davarynejad (2007) reported that the rootstock diameters differ statistically between cultivars, and they stated that some pear cultivars grafted on Quince A rootstock were 23.6 mm-69.2 mm 5 years after grafting. In a similar study, the different rootstocks affected the rootstock diameters under the nursery conditions (Rahman *et al*., 2017). In the research, the results about the rootstock diameter are partially consistent with other studies.

### *Graft Union Diameter*

The graft union diameter ranged between 25.38 - 37.78 mm in terms of rootstock averages and 32.21-35.61 mm in terms of cultivar averages. In terms of rootstock averages, the graft union diameter was found to be lower in the Fox11 (25.38 mm) than the other rootstocks. The graft union diameter of the 'Deveci' cultivar was higher than the 'Williams'. In terms of rootstock x cultivar interaction, the highest graft union diameter was detected in the 'Deveci'/BA29 (45.18 mm) and the lowest was when both cultivars were grafted on the Fox11 rootstock (24.51 mm and 26.25 mm) (Table 2).

**Table 2.** The effect of the rootstocks on nursery plant growth performance of pear cultivars.
*Çizelge 2. Armut çeşitlerinin fidan gelişim performansı üzerine anaçların etkisi*

| Cultivars | Rootstock | Rootstock diameter (mm) | Graft union diameter (mm) | Shoot diameter (mm) | Shoot length (cm) |
|---|---|---|---|---|---|
| Deveci | BA29 | 29.16 ab* b** | 45.18 a a | 33.53 a a | 163.06 ab a |
| | Fox11 | 21.66 cd c | 24.51 d d | 19.35 d c | 171.83 a a |
| | OH*x*F 333 | 29.87 ab b | 33.81 bc c | 25.74 bc b | 182.40 a a |
| | Seedling | 35.83 a a | 38.95 ab b | 28.09 b b | 164.87 ab a |
| Williams | BA29 | 20.21 d b | 30.39 cd ab | 17.89 d b | 98.11 c b |
| | Fox11 | 23.38 bcd b | 26.25 d b | 22.02 cd ab | 108.00 c b |
| | OH*x*F 333 | 33.46 a a | 38.23 ab a | 25.02 bc a | 186.07 a a |
| | Seedling | 28.67 abc ab | 34.39 bc ab | 21.52 cd ab | 128.67 bc b |
| Factors' means | | | | | |
| Rootstocks | BA29 | 24.69 b | 37.78 a | 25.71 a* | 130.58 b* |
| | Fox11 | 22.52 b | 25.38 b | 20.68 b | 139.92 b |
| | OH*x*F 333 | 31.67 a | 36.02 a | 25.38 a | 184.23 a |
| | Seedling | 32.25 a | 36.67 a | 24.81 a | 146.77 b |
| Cultivars | Deveci | 29.13 a | 35.61 a | 26.68 a | 170.54 a |
| | Williams | 26.43 a | 32.31 b | 21.61 b | 130.21 b |

*: The difference between the means indicated by the same letter in the same column is not statistically significant in the p <0.05.
**: The difference between the means of the same cultivar indicated by the same letter in the same column is not statistically significant in the p <0.05.

Rootstocks and cultivars and rootstock x cultivar interaction have statistically significant effects on the graft union diameter of standard pear cultivars grafted on some quince and pear rootstocks. For a successful grafting, the cambium tissues of the rootstock and scion must overlap, and the larger this overlap surface, the higher the rate of graft formation (Yılmaz, 1994; Hartmann *et al*., 2011). Özçağıran (1982) determined that a period of time should pass after grafting in order for the rootstock and scion to conjunction with each other and during this period new callus cells were formed in the rootstock and scion and the graft combined. Considering that the grafting process is a stress factor, there is a difference in diameter in the graft region due to wound combining and wound healing. Preventing transportation from this wound area during the transport of the assimilating materials between the scion/rootstock in the graft area may cause a difference in diameter (Hartmann *et al*., 2011). Davarynejad and Davarynejad (2007) reported that the diameter of the graft union was statistically different between cultivars and they stated that the graft union diameter of some pear cultivars grafted on quince A rootstock were 28.4 mm-78.6 mm 5 years after grafting. These researchers found that the diameter difference was higher in cultivars with incompatible with the Quince A. Serttas and Ozturk (2020) emphasized that the effect of rootstocks and cultivars on the graft union diameter was significant. It has been reported that the diameter difference between the rootstock and cultivar in the grafted plants may be related to the graft incompatibility (Özçağıran, 1982; Rodrigues *et al*., 2004; Darikova *et al*., 2011; Machado *et al*., 2016). Machado *et al*. (2016), who examined the graft incompatibility of EMC quince rootstock and some pear cultivars, reported that there was a difference in diameter between rootstocks and cultivars in the graft union region, and they found that the Williams/EMC combination was incompatible, the Rocha/EMC and Abate Fetel/EMC combinations were partially incompatible. Rodrigues *et al*. (2004) and Pio *et al*. (2008) and Francescatto *et al*. (2010) reported that large diameter differences between rootstocks and cultivars were indicative of morphological graft incompatibility symptom. This morphological incompatibility symptom causes the root system to weaken due to the decrease in the transport of nutrients from the graft region (Zarrouk *et al*., 2010; Milosevic and Milosevic, 2011). This situation is related to the interruption in the xylem and phloem veins that prevent the flow of carbohydrates produced in the crown part for the root part and increase the accumulation of carbohydrates in the crown parts of the plant (Zarrouk *et al*., 2010). The limitations in the transport of the assimilating substances from the graft site to the root area cause to poorly develop of sapling. This weak development resulted in graft incompatibility in the following years and the saplings death (Machado *et al.*, 2016). In this study, there was a diameter difference between the cultivars in the graft region because the 'Deveci' cultivar has a stronger development compared to the 'Williams' cultivar and the graft compatibility is better than the 'Williams' cultivar. This difference in the graft union diameter may result in rootstock-scion incompatibility, especially in the 'Williams' cultivar in the following years after the grafting. Indeed, the 'Williams' cultivar developed very slowly on Quince A (Özçağıran, 1982), Quince A (incompatible) and BA29 (moderately compatible) (Gulen *et al.*, 2002), BA29 (Irisarri *et al.* 2016) and graft union diameter of 'Williams' is lower than the other combinations and therefore it can be considered as incompatible with quince rootstocks. The results of this study are consistent with the previous similar studies.

***Shoot Diameter***

The shoot diameter was determined between 20.68 and 25.71 mm in terms of rootstock averages and 21.61 and 26.68 mm in terms of cultivar averages. The shoot diameter was lower (20.68 mm) in the Fox11 rootstock than other rootstocks. The shoot diameter of the 'Deveci' pear cultivar (26.68 mm) is higher than the 'Williams' (21.61 mm). In terms of rootstock x cultivar interaction, the highest shoot diameter was determined in the 'Deveci'/BA29 (33.53 mm), the lowest was in the 'Deveci'/Fox11 (19.35 mm) and 'Williams'/BA29 (17.89 mm) scion/stock combination in this study (Table 2).

In this study, rootstocks, cultivars and rootstock x variety interaction had significant effects on shoot diameter. Zenginbal and Bostan (2019) noted that the shoot diameter was changed to rootstocks and cultivars and growing condition. The shoot diameter in pear in previous studies, Soylu and Basyigit (1991) 'Santa Maria' 14.23-15.03 mm; Elivar and Dumanoglu (1999) 24.6 mm; Kadan and Yarılgac (2005) 10.68-12.95 mm; Davarynejad and Davarynejad (2007) 19.9-52.4 mm; Rahman *et al.* (2017) 9.83-14.81 mm; Zenginbal and Bostan (2019) 5.48-6.37 mm; Serttas and Ozturk (2020) 17.95-19.74 mm. were determined. In this study, the shoot diameter of the 'Deveci' cultivar was higher on the BA29 rootstock than other rootstocks. This is probably due to the fact that the 'Deveci' cultivar shows good graft compatibility with the BA29 quince clone rootstock (Demirel, 2017) and this rootstock grows better on the cultivar due to the strong development of pear rootstock in the first years. As a matter of fact, Öztürk and Öztürk (2014) reported that the 'Deveci', which grafted on the MC, BA29 and seedling rootstocks, had a higher shoot diameter on the BA29. Similarly, Cetinbas *et al.* (2018) reported that the shoot diameter of 'Deveci' cultivar was higher than that of the 'Santa Maria' cultivar. Zenginbal *et al.* (2017) reported that the effect of rootstocks and cultivars on shoot diameter of 14 different sweet cherry cultivars grafted on three different rootstocks was significant. In our study and other researches, the differences between rootstock and cultivar in terms of the shoots diameter have been based on the genetic differences of cultivars and rootstocks, and cultivation and maintenance practices (Hartmann *et al.*, 2011; Rahman *et al.*, 2017; Zenginbal *et al.*, 2017; Zenginbal and Bostan, 2019; Serttas and Ozturk, 2020).

***Shoot Length***

There were statistically significant effect on the shoot length in terms of rootstock and cultivar and rootstock x cultivar interaction in the study. The shoot length was found to be 130.58-184.53 cm in terms of rootstock averages and 130.21– 170.54 cm in terms of cultivar averages. The shoot length was higher in the OHxF333 rootstock (184.23 cm) than other rootstocks. The shoot length of 'Deveci' cultivar (170.54 cm) was higher than the 'Williams' (130.21 cm). In terms of rootstock x cultivar interaction, the highest shoot length was obtained in the 'Deveci' cultivar grafted on the OHxF333 and Fox11 (182.40 cm and 171.83 cm, respectively) and 'Williams' cultivar grafted on the 'OHxF333' (186.07 cm). The lowest shoot length was obtained by grafting 'Williams' on the Fox11 and BA29 rootstocks (108.00 cm and 98.11 cm, respectively) (Table 2).

In the study, it was determined that both rootstocks, varieties and rootstock x variety interaction had an important effect on the shoot length Rootstocks affect the growth of cultivars grafted on them, as well as cultivars affect the growth of rootstocks on which they are grafted (Rom and Carlson, 1987; Jackson 2003). The results of this study were similar to the relevant previous study report that rootstocks and cultivars had an important effect on shoot length in the pears. (Irisarri *et al.*, 2016; Rahman *et al.*, 2017; Cetinbas *et al.*, 2018; Zenginbal and Bostan, 2019; Serttas and Ozturk, 2020). The shoot length in the pear was 185.7-194.0 cm (Soylu and Basyigit, 1991); 43.7 cm (Elivar and Dumanoglu, 1999); 109.31-129.45 cm (Kadan and Yarılgac, 2005); 31.82-91.62 cm (Rahman *et al.*, 2017); 19.89-20.51 cm (Cetinbas *et al.*, 2018); 34.6-39.6 cm (Zenginbal and Bostan, 2019). While the results of the shoot length in the study are compatible with some previous studies and differ from some others. The differences were resulted from genetic (Hartman *et al.*, 2011; Rahman *et al.*, 2017), grafting time and ecological condition (Kuden and Gulen, 1997; Elivar and Dumanoglu, 1999; Kadan and Yarılgac 2005; Pektas *et al.*, 2009) and cultivation conditions (Cetinbas *et al.*, 2018; Zenginbal and Bostan, 2019).

## CONCLUSION

In the present study, it was tried to determine the relationship between graft success, sapling growth performance, and the graft relationship between rootstocks and cultivars of 'Deveci' and 'Williams' grafted on quince and pear rootstocks. Rootstocks and cultivars had significant effects on graft success and sapling development of cultivars. Pear rootstocks had higher graft success than quince rootstocks. 'Deveci' cultivar had higher graft success and sapling development performance than the 'Williams'. In this study, quality pear saplings were obtained in all cultivars/rootstocks combinations. It has been observed that all rootstocks and cultivars have reached sufficiently shoot height and diameter values that the quality seedlings must have and that sufficient sapling development performance is provided. Especially considering the graft success and the diameter measurements made in the graft union, it has been determined that some combinations may show graft incompatibility. It has been determined that the survival rate of the saplings is lower than the other combinations in the 'Williams'/BA29 combination and this combination may be incompatible. It should be noted that although the graft success is sufficient, the Fox11 rootstock, whose rootstock and graft shoot diameter is lower than other rootstocks, may also show graft incompatibility. 'Deveci' cultivar showed good graft compatibility with all rootstocks due to both graft success and sapling growth performance. When selecting suitable rootstocks and cultivars to be used in the pear orchard establishment, it will be important to consider these compatibility and/or incompatibility situations in advance for preventing future problems.

## CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this article.

## DECLARATION OF AUTHOR CONTRIBUTION

Nermin Coban conduced this MSc study under supervision of Ahmet Ozturk. Statistical analysis of the data, method, subject design and writing of the article were planed by supervisor.

## REFERENCES

Akçay, M.E. (2007). Armut yetiştiriciliğinde klon anaç kullanımı. *Hasad Bitkisel Üretim Dergisi, 23*(269), 50-53.

Cetinbas, M., Butar, S., Sesli, Y., & Yaman, B.. (2018). Effects of different cultivar/rootstock combinations on the some seedling characteristics for pear nursery growing. *Journal of Agriculture Faculty of Gaziosmanpasa University. 35(special issue),* 8-12.

Ciobotari, G., Brinza, M., Morariu, A., & Gradinariu, G. (2010). Graft incompatibility influence on assimilating pigments and soluble sugars amount of some pear (*Pyrus sativa*) cultivars. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 38*,187-192.

da Silva G.J., Villa, F., Grimaldi F., da Silva P. S., & Welter J. F. (2018). Pear (Pyrus spp.) Breeding. In J. M. Al-Khayri, S. M. Jain, & D. M. Johnson (Eds.), Advances in Plant Breeding Strategies: Fruits (pp 131-163), Gewerbestrasse, Switzerland: Springer.

Darikova, J. A., Savvaa, Y. V., Vaganova, E. A., Gracheva, A. M., & Kuznetsova. G. V. (2011). Grafts of woody plants and the problem of incompatibility between scion and rootstock (a review). *Journal of Siberian Federal University Biology, 1*(4), 54-63.

Davarynejad, G. H., & Davarynejad, E. (2007). Field performance of incompatibility of pear cultivars Natanz, Sebri and Shekari budded on QA rootstock. *Acta Horticulturae, 732,* 221-226.

Davarynejad, G. H., Shahriari, F., & Hamid, H. (2008). Identification of graft incompatibility of pear cultivars on Quince rootstock by using isozymes banding pattern and starch. *Asian Journal of Plant Science, 7*(1), 109-112.

Demirel, G. 2017. *Bazı klonal anaçlar üzerine aşılı armut çeşitlerinde fenolik maddelerin değişimi*. Yüksek Lisans Tezi, Ondokuz Mayıs üniversitesi Fen Bilimleri Enstitüsü, Samsun.

Dogra, K., Kour, K., Kumar, R., Bakshi, P., & Kumar, V. (2018). Graft-incompatibility in horticultural crops. *International Journal of Current Microbiology and Applied Science, 7*(2), 1805-1820.

Dolkar, T., Mansoor, A., Agleema, B., Divya, S., Lobzang, S., & Stanzin, K. (2018). Mitigation of temperate fruit crop problems through use of rootstock. *International Journal of Chemical Studies, 6*(2), 880-887.

Dondini, L., & Sansavini, S. (2012). *European pear.* In M. L. Badanes, & D. H. Byrne, (Eds.), Fruit Breeding (pp 363-413). Series: Handbook of Plant Breeding, Vol. 8, Springer Science+Business Media, New York.

Elivar, D. E., & Dumanoglu, H. (1999). The comparison of fall and spring budding for one-year-old nursery tree production of apple, pear and quince in Ayaş (Ankara). *Journal of Agriculture Science, 5*(2), *58-64*.

Ermel, F. F., Catesson, A. M., & Poessel, J. L. (1995). Early histological diagnosis of apricot/peach x almond graft incompatibility: statistical analysis of data from 5-month-old grafts. *Acta Horticulturae, 384*, 497-503.

Ermel, F.F., Kervella, J., Catesson, A. M., & Poessel, J. C. (1999). Localized graft ıncompatibility in pear/quince (*Pyrus communis/Cydonia oblonga*) combination: multivariate analysis of histological data form 5-month-old grafts. *Tree Physiology, 19,* 645-654.

Ermel, F.F., Poessel, J. L., Faurobert, M., & Catesson, A. M. (1997). Early scion/stock junction in compatible and incompatible pear/pear and pear/quince grafts: a histo-cytological study. *Annual Bot-London, 79,* 505-515.

Errea, P. (1998). Implications of phenolic compounds in graft incompatibility in fruit tree species. *Scientia Horticulture, 74,* 195-205.

Francescatto, P., Pazzin, D., Neto, A. G., Fachinello, J. C., & Giacobbo, C. L. (2010). Evaluation of graft compatibility between quince rootstocks and pear scions. *Acta Horticulturae. 872*, 253-260.

Gulen, H., Arora, R., Kuden, A., Krebs, S. L., & Postman, J. (2002). Peroxidase isozyme profiles in compatible and incompatible pear-quince graft combinations, *Journal of the American Society for Horticultural Science, 127*(2), 152-157.

Hancock, J. F., & Lobos, G. A. (2008). *Pears.* In J. F. Hancock (Edt.), Temperate Fruit Crop Breeding: Germplasm to Genomics (pp 299-336). Springer Science+Business Media, New York.

Hartmann, H. T., Kester, D. E., Davies, Jr. F. T., & Geneve, R. L. (2011). Plant propagation: principles and practices. 8th Edition. Regents/Prentice Hall International Editions, Englewood Cliffs, New Jersey.

Hepaksoy, S. (2019). Meyvecilikte Anaç Kullanımı: Armut Anaçları. Türk Bilimsel Derlemeler Dergisi, *12*(2), 69-74.

Hudina, M., Orazem, P., Jakopic, J., & Stampar, F. (2014). The phenolic content and its involvement in the graft incompatibility process of various pear rootstocks (*Pyrus communis* L.). *Journal of Plant Physiology, 171,* 76-84.

Irisarri, P., Pina, A., & Errea, P. (2016). Evaluation of the vegetative characteristics and graft compatibility of pear varieties grafted on 'BA-29' and 'OHF-87' rootstocks. *ITEA , 112(3),* 243-254.

Jackson, J.E. (2003). Biology of apples and pears. Cambridge University Press, Cambridge, U.K.

Kadan, H., & Yarılgac, T. (2005). Studies on propagation by dormant t-budding of apples and pears under Van ecological conditions. *Yüzüncü Yil University Journal of Agricultural Sciences, 15*(2), 167-176.

Kuden, A., & Gulen, H. (1997). Propagation of apples, pears and plums by grafted cuttings. *Acta Horticulturae, 441,* 231-236.

Lewis, W. J., & Alexander McE. D. (2008). Grafting & Budding. A Practical Guide for Fruit and Nut Plants and Ornamentals. Landlinks Press, 102, Australia.

Machado, B.D., Magro, M., Rufato, L., Bogo, A., & Kreztschmar, A. A. (2016). Graft compatibility between european pear cultivars and east malling "C" rootstock. *Revista Brasileira de Fruticultura. 39*, e-063.

Mezey, J., & Lesko, I. (2014). Callus and root-system formation in cherry rootstock Gisela 5. *Acta Horticulturae, 17,* 5–7.

Milosevic, T., & Milosevic, N. (2011). Influence of cultivar and rootstock on early growth and syllepsis in nursery tress of pear (*Pyrus communis* L., Rosaceae). *Brazilian Archives of Biology and Technology, Curitiba, 54*, 451-456.

Musacchi, S., Masia, A., & Fachinello, J. (2002). Variation of some enzymatic activities in relationship to scion/stock compatibility in pear/quince combinations. *Acta Horticulturae, 596,* 389-392.

Nimbolkar, P.K., Awachare, C., Reddy, Y.T.N., Chander, S., & Hussain, F. (2016). Role of Rootstocks in Fruit Production–A *Review. Journal of Agricultural Engineering and Food Technology, 3*(3), 183-188.

Özçağıran, R. (1982). Bazı armut çeşitlerinin ayva A anacı ile uyuşma durumları üzerine bir araştırma. *Ege Üniversitesi Ziraat Fakültesi Dergisi, 19(2), 77-83*.

Ozcagiran, R., Unal, A., Ozeker, E., & Isfendiyaroglu, M. (2004). *Pear,* In: Temperate Fruit Trees, Pome Fruits (Vol. II). Ege University. Agriculture Faculty Publications, Number: 556, Izmir, Turkey.

Ozturk, A., & Ozturk, B. (2014). The rootstock influences growth and development of 'Deveci' Pear. *Turkish Journal of Agriculture and Natural Science, 1,* 1049-1053.

Ozturk, A., Serdar, U., & Balci, G. (2009). The influence of different nursery conditions on graft success and plant survival using the inverted radicle grafting method on the chestnut. *Acta Horticulturae, 815,* 193-197.

Ozturk, B., Ozcan, M., & Ozturk, A. (2011). Effects of different rootstock diameters and budding periods on graft success and plant growth in kiwifruit seedling production. *Journal of Agricultural Sciences, 17*(4), 261-268.

Pektas, M., Canli, F. A., & Ozongun, S. (2009). Winter grafts as alternative methods to T-budding in pear (*Pyrus communis* L.) propagation. *International Journal of Natural and Engineering Sciences, 3*(1), 91-94.

Pina, A., & Errea, P. (2005). A review of new advances in mechanism of graft compatibility–incompatibility. *Scientia Horticulturae, 106,* 1–11.

Pina, A., & Errea, P. (2009) Morphological and histochemical features of compatible and incompatible stem unions. *Acta Horticulturae, 814,* 453–456.

Pio, R., Chagas, E. A., & Tombolato, A. F. C. (2008). Interspecific and intergeneric pear, apple and quince grafting using *Pyrus calleryana* as rootstock. *Acta Horticulturae, 800,* 173-178.

Rahman, J., Aftab, M., Rauf, M. A., Rahman, K. U., Farooq, W. B., & Ayub, G. (2017). Comparative study on compatibility and growth response of pear varieties on different rootstocks at nursery. *Pure Applied Biology, 6*(1), *286-292*.

Rahmati, M., Arzani, K., Yadollahi, A., & Abdollahi, H. (2015). Influence of Rootstock on Vegetative Growth and Graft Incompatibiiıty in Some Pear (*Pyrus spp*.) Cultıvars. *Indo-American Journal of Agriculture & Veterinary Science, 3*(1), 25-32.

Rodrigues, A. C., Fachinello, J. C., Sılva, J. B., Fortes, G. R. L., & Strelow, E. 2004. Compatibilidade entre diferentes combinações de cvs. copas e portaenxertos de Prunus sp. *Revista Brasileira de Agrociência, Pelotas, 10*, 185-189.

Rom, R. C., & Carlson, R. F. (1987). *Rootstocks for fruit crops*. John Wiley and Sons- Interscience Publication, New York, 497, USA.

Serttas, S., & Ozturk, A. (2020). Determination of the Stion Development Performances Different Pear Cultivars on Some Pear Clonal Rootstock. *Kahramanmaraş Sütcü İmam University, Journal of Agriculture and Nature, 23*(4), 842-850.

Sharma, R. M., Pandey, S. N., & Pandey, V. (2010). *Breeding and Improvement. In: The pear: production, postharvest management and protection.* IBDC Publishers, India.

Soylu, A., & Basyigit, H. (1991). Growth and branching characteristics of some fruit saplings produced in Bursa Kestel region. The First Turkish Arboriculture Symposium, Ankara, Turkey.

Tatari, M., Rezaei, M., & Ghasemi, A. (2020): Quince Rootstocks Affect Some Vegetative and Generative Traits. *International Journal of Fruit Science,* 1-15.

TSMS, (2020). Turkish State Meteorological Service Official Web Sites. https://mgm.gov.tr. Access date: May15, 2020.

Webster, A. D. (1995). Rootstock and interstock effects on deciduous fruit tree vigour, precocity, and yield productivity. *New Zealand Journal of Crop and Horticultural Science, 23*(4), 373-382.

Westwood, M. N. (1995). Temperate-zone pomology, physiology and culture. 3rd ed., Timber Pres, Oregon.

Yılmaz, M. (1994). *Bahçe Bitkileri Yetiştirme Tekniği*. Çukurova Üniversitesi Basımevi, 151, Adana.

Zarrouk, O., Testıllano, P. S., Rısuenõ, M. C., Angeles, M. M., & Gogorcena, W. (2010). Changes in cell/tissue organization and peroxidase activity as markers for early detection of graft incompatibility in peach/plum combinations. *Journal of the American Society for Horticultural Science, Geneva, 135*, 9-17.

Zenginbal, E., & Bostan, S. Z. (2019). Pear sapling production in greenhouse and external environment. *Bahçe, 48*(2), 57-64.

Zenginbal, H., Demir, T., Demirsoy, H., & Beyhan, O. (2017). The grafting success of fourteen genotypes grafted on three different rootstocks on production of sweet cherry (*Prunus avium* L.) sapling. *Acta Scientiarum Polonorum, Hortorum Cultus, 16*(1), 133–143.