Anadolu Tarım Bilimleri Dergisi,
Anadolu Journal of Agricultural Sciences
e-ISSN: 1308-8769, ANAJAS June 2022, 37 (2): 405-420

Survival Rate of Young Pear Trees in Different Rootstock and Cultivar Combinations under Field Conditions: Preliminary Results

Genç Armut Ağaçlarının Arazi Koşullarındaki Farklı Anaç ve Çeşit Kombinasyonlarında Yaşama Oranı: İlk Sonuçlar

Tahsin KURT[1], Ahmet ÖZTÜRK[2], Zaki Ahmad FAİZİ[3]

[1]Ondokuz Mayıs Üniversitesi Ziraat Fakültesi Bahçe Bitkileri Bölümü, Samsun
• **tahsinkurt88@gmail.com** • ORCİD > 0000-0002-1574-4083

[2]Ondokuz Mayıs Üniversitesi Ziraat Fakültesi Bahçe Bitkileri Bölümü, Samsun
• **ozturka@omu.edu.tr** • ORCİD > 0000-0002-8800-1248

[3]Ondokuz Mayıs Üniversitesi Ziraat Fakültesi Bahçe Bitkileri Bölümü, Samsun
• **99330347176@stu.omu.edu.tr** • ORCİD > 0000-0002-1429-6493

Makale Bilgisi / Article Information

Makale Türü / Article Types: Araştırma Makalesi / Research Article
Geliş Tarihi / Received: 21 Mart / March 2022
Kabul Tarihi / Accepted: 12 Nisan / April 2022
Yıl / Year: 2022 | **Cilt – Volume:** 37 | **Sayı – Issue:** 2 |**Sayfa / Pages:** 405-420

Atıf/Cite as: Kurt, T., Öztürk, A. ve Faizi, Z. A. "Survival Rate of Young Pear Trees in Different Rootstock and Cultivar Combinations under Field Conditions: Preliminary Results". *Anadolu Journal of Agricultural Sciences*, 37(2), June 2022: 405-420.

Sorumlu Yazar / Corresponding Author: Ahmet Öztürk

https://doi.org/10.7161/omuanajas.1091137

SURVIVAL RATE OF YOUNG PEAR TREES IN DIFFERENT ROOTSTOCK AND CULTIVAR COMBINATIONS UNDER FIELD CONDITIONS: PRELIMINARY RESULTS

ABSTRACT:

This study was carried out to determine the effects of 7 different rootstocks on rootstock diameter (mm), stem diameter (mm), and plant survival ratio (%) of some pear cultivars between 2019-2021. Rootstocks, cultivars, research years, and their interactions significantly affected all examined parameters in the study, except for the interaction of year x rootstock x cultivar. The 'Deveci'/BA29 and 'Deveci'/OHxF333 had the largest rootstock and trunk diameters, while the 'Williams'/MC had the smallest. The Fox11 and OHxF333 rootstocks had the highest plant survival ratios, whereas the MC rootstocks had the lowest. In terms of cultivar, the maximum plant survival ratio was found in the 'Deveci'. At the end of the first 3 years after planting, there was a decrease in the survival ratio of the plants. 'Williams' had the lowest rootstock diameter, trunk diameter and survival ratio. The highest trunk diameter was in the OHxF333, BA29, Fox11 and Farold40 rootstocks, and the cultivar was in the 'Deveci'. Plant survival ratios in quince clonal rootstocks were slightly lower than in pear rootstocks. This is due to the graft incompatibility between quince rootstocks and some pear cultivars. Compatible inter-stock with rootstock and cultivar should be employed to overcome this incompatibility problem caused by localized graft incompatibility. According to the findings of this study on young plants, it is required to extend the research and conduct additional observations in order to give more precise recommendations.

Keywords: *Pear, Rootstock, Cultivar, Rootstock Diameter, Trunk Diameter, Survival ratio.*

❋❋❋

GENÇ ARMUT AĞAÇLARININ ARAZİ KOŞULLARINDAKI FARKLI ANAÇ VE ÇEŞİT KOMBİNASYONLARINDA YAŞAMA ORANI: İLK SONUÇLAR

ÖZ:

Bu araştırma bazı armut çeşitlerinin anaç çapı (mm) ve gövde çapı (mm) gelişimi ile bitki yaşama oranı (%) üzerine 7 farklı anacın etkilerini belirlemek amacıyla 2019-2021 yılları arasında yürütülmüştür. Araştırmada incelenen tüm parametreler üzerinde yıl x anaç x çeşit interaksiyonu hariç anaçların, çeşitlerin, araştırma yıllarının ve bunların interaksiyonlarının önemli etkisi olmuştur. En yüksek anaç çapı ve gövde çapı 'Deveci'/BA29 ve 'Deveci'/OHxF333 kombinasyonunda belirlenirken en düşük ise 'Williams'/MC kombinasyonunda belirlenmiştir. Bitki yaşama

oranı en yüksek anaçların Fox11 ve OHxF333, en düşük MC anacının olduğu belirlenirken, yaşama oranı en yüksek çeşidin ise Deveci olduğu belirlenmiştir. Dikimden itibaren ilk 3. yıl sonunda fidan yaşama oranında azalma olmuştur. Araştırmada anaç çapı, gövde çapı ve yaşama oranı en düşük çeşit Williams olmuştur. Gövde çapı en yüksek olan anaçların OHxF333, BA29, Fox11 ve Farold40, çeşidin ise Deveci olduğu belirlenmiştir. Bitki yaşama oranı ayva klon anaçlarında armut anaçlarından biraz daha düşük olmuştur. Bu durum ayva anaçları ile bazı armut çeşitleri arasında görülen aşı uyuşmazlığından kaynaklanmaktadır. Yerleşik aşı uyuşmazlığından kaynaklanan bu uyuşmazlık problemini çözmek için anaç ve çeşit ile uyuşur ara-anaçlı fidanlar kullanılmalıdır. Genç bitkiler üzerinde yürütülen bu çalışma sonuçlarına göre daha doğru tavsiyelerde bulunulabilmesi için araştırmanın daha uzun süre devam ettirilmesi ve gözlemlerin yapılması gerekmektedir.

Anahtar Kelimeler: *Armut, Anaç, Çeşit, Anaç Çapı, Gövde Çapı, Yaşama Oranı.*

1. INTRODUCTION

Pear fruit (*Pyrus communis* L.) is an important fruit species that can be grown in all temperate regions in the world (Jackson, 2003; Hancock and Lobos, 2008; Da Silva et al., 2018). Generally, pear trees are propagated via vegetative methods in which various kinds of grafting and budding are the most appropriate methods of propagation (Rahman et al., 2017). Rootstock use is an essential need in modern fruit production and breeding due to their ability to pursue their normal life under adverse biotic and abiotic factors (Hartmann et al., 2011; Dolkar et al., 2018). Quince rootstocks such as Quince A, Quince C, BA29, Adams, Sydo, have been used for quality fruit production of pear and facilitate cultural practices as they are dwarfed compared to the pear seedlings or pear clonal rootstocks (Sharma et al., 2009; Ozturk and Ozturk, 2014). Besides the quince rootstocks, Pyrus rootstocks such as Pyrodwarf, BP, OHxF, Farold, and Fox series have been widely used due to their many strong characteristics but produce larger trees than quince rootstocks (Jackson, 2003; Stern and Doron, 2009; Francescatto et al., 2010).

When grafting on different genera in pear growing, graft incompatibility may occur. The early or late occurrence of graft incompatibility after grafting causes significant economic losses to growers and decreases the survival ratio of trees in the short or long term (Ermel et al., 1999; Hartmann et al., 2011). The short or long-term survival rate of grafted fruit trees is the main factor determining the validity of grafting (Reig et al., 2018). Apart from the compatibility or incompatibility between rootstock and scion, the survival rate depends on the resistance to climatic conditions of the rootstock (Lepsis et al., 2013), pest and disease (Hudina et al., 2014; Shaltiel, 2018; Habibi et al., 2022), soil conditions and salinity (Okubo and Sakuratani, 2000). Grafted fruit trees with good graft compatibility and the ability to form a vascular system will survive for many years and continue their normal

lives without any restrictions (Mauro et al., 2022). Quince rootstocks had a lower survival ratio than pear rootstocks with lower graft incompatibility, and different rootstock and cultivar combinations had significantly different survival ratios (Ozturk, 2021a). Symptoms of graft incompatibility in fruit trees include low survival ratio, poor growth, early yellowing of leaves, cracking of bark tissues, and swelling at the grafting union in the pear orchard (Jackson, 2003; Chen et al., 2016). An important way to increase the survival ratio of pear trees is to use appropriate rootstocks as well as to grow on pear-based rootstocks and their own roots (Baviera et al., 1988; Goldschmidt 2014). The survival rate of pear trees varies according to rootstocks and cultivars, and the survival ratio decreases as the orchard age progresses (Arzani, 2004; Hudina et al., 2014; Rahman et al., 2017; Ozturk, 2021a). It is still debated that grafted pear trees, like most fruit trees, do not survive for many years due to delayed graft incompatibility (Rasool et al., 2020).

Appropriate planting density and proper rootstock selection are essential strategies for optimum vegetative and generative development and fruit quality from fruit trees (Pasa et al., 2015; Hepaksoy, 2019). It affects the cultivar grafted on the rootstocks used in pear production at different levels. The resulting differences mainly depend on the growth vigor of the tree, yield (Massai et al., 2008, Iglesias and Batlle, 2011) and orchard management (Webster, 2002), differences in tree habitus, and development under certain environmental conditions (Costes et al., 2006). The performance of the rootstock used in production may vary. However, little is known about the reasons why the performance of the rootstock to be used in production changes over time (Meszaros et al., 2019). Appropriate rootstock selection is significant in increasing the fruit yield and quality of the 'Deveci', 'Santa Maria, 'Williams' and 'Abate Fetel', which have an important place in pear production in Turkey, for both the producers to obtain maximum income and the consumers to consume quality products. In addition, when appropriate cultivation techniques and rootstock selection are not used for these cultivars, yield reductions, undesirable lower quality fruits, low SSC content, insufficient coloring and weak flavor may occur.

The aim of this study is to determine the effects of rootstocks on plant growth and the survival ratio of some standard pear varieties grafted on different quince and pear rootstocks during 2019-2021.

2. MATERIAL AND METHODS

2.1. Material

This study was carried out at the Bafra Agricultural Research Center of Ondokuz Mayis University (41°33'50" N, 35°52'23" E and 20 m altitude) in 2019-2021. Orchard was established with 1-year-old saplings at 1.5x3.5 m with dwarf rootsto-

cks and 3.0x3.5 m distances with semi-dwarf and seedling rootstocks. In the study, 'Deveci', 'Williams', 'Santa Maria' and 'Abate Fetel' pear cultivars grafted on BA29, Quince A and Quince MC quince clone rootstock, and OHxF333, Fox11, Farold40, and seedlings of pear rootstocks were used. The plants were irrigated with drip irrigation between May 15th and September 15th. Fertilization was done with 15-30-15+ME fertilizer at the beginning of summer and 20-20-20 NPK-containing fertilizer in autumn with drip irrigation. Weed control was carried out by mulching the black ground on the row and regularly breaking the weeds with a rotovator between the rows. The properties of the experimental area soil were recorded as 2.73-10% clay (low), 13.21-20% silt (moderate), 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 (CaCO3) (less), 0.03-0.06% N (less), 5-10 ppm P (medium) level and the soil depth was more than 1 meter.

2.2. Methods

Rootstock diameter (mm) by measuring 10 cm below the grafting union and trunk diameter by measuring the trunk from approximately 20 cm above the soil level (mm) with a digital caliper (Mitutoyo CD-20CPX) sensitive to 0.01 mm was determined at the end of the growing season of all trees in each replication in each cultivar/rootstock combination (Ozturk and Ozturk, 2014). The number of dead plants at the end of each year was divided by the number of plants planted in the orchard establishment to determine the plant survival ratio (Ozturk et al., 2009; Hudina et al., 2014)

2.3. Statistical analysis

The research was established in a randomized block design with 3 replications and 10 plants with dwarf rootstocks, and 5 plants with semi-dwarf and vigorous rootstocks in each replication. The obtained data were analyzed in the IBM SPSS 21.0 statistical package program, and the differences between the averages were determined using the 'Duncan Multiple Comparison Test' at $p<0.05$ level.

3. RESULTS AND DISCUSSION

Rootstocks, cultivars, and research years had a significant effect on rootstock diameters of 'Deveci', 'Williams', 'Santa Maria' and 'Abate Fetel' pear cultivars grafted on different pear and quince clone rootstocks and pear seedling rootstock. In the study, except for the year x rootstock x cultivar interaction, all interactions significantly affected rootstock diameter. It has been determined that the rootstock diameter varies between 30.54 mm - 44.50 mm in terms of rootstock average, 32.71 mm - 42.88 mm in terms of cultivar average, and 30.71 mm - 47.33 mm in terms of years average. The highest rootstock diameter was observed in the OHxF333

(44.50 mm), the lowest was in the MC quince rootstock (30.54 mm) in terms of rootstock average. In terms of cultivar average, the highest rootstock diameter was determined in the 'Deveci' (42.88 mm), while the lowest was found in the 'Williams' (32.71 mm) pear cultivars. Depending on the growth and development of the plants, the highest rootstock diameter was determined in the 2021 year (47.33 mm) in terms of years averages (Table 1).

Table 1. Effect of different rootstocks on rootstocks diameter (mm) of pear cultivars

Rootstocks	Cultivars	Years			Mean
		2019	2020	2021	
Quince BA29	Deveci	38.65	52.52	53.27	**48.15 a***
	Williams	31.77	34.71	36.60	**34.36 cde**
	Santa Maria	34.15	41.16	42.74	**39.35 abcd**
	Abate Fetel	33.21	44.39	47.02	**41.54 abc**
Quince A	Deveci	33.53	45.51	47.96	**42.33 abc**
	Williams	22.72	27.28	27.54	**25.85 e**
	Santa Maria	28.97	42.35	44.08	**38.46 abcd**
	Abate Fetel	32.56	42.60	45.05	**40.07 abc**
Quince MC	Deveci	38.16	41.46	42.21	**40.61 abc**
	Williams	16.35	14.50	16.19	**15.68 f**
	Santa Maria	32.26	35.95	44.17	**37.46 abcd**
	Abate Fetel	24.41	28.58	32.25	**28.42 de**
Fox11	Deveci	34.46	35.82	54.75	**41.68 abc**
	Williams	31.39	34.08	53.86	**39.78 abc**
	Santa Maria	31.88	33.69	48.13	**37.90 abcd**
	Abate Fetel	31.20	32.52	60.25	**41.32 abc**
OHxF333	Deveci	37.15	45.80	62.47	**48.47 a**
	Williams	36.41	43.29	47.17	**42.29 abc**
	Santa Maria	33.42	43.60	45.87	**40.96 abc**
	Abate Fetel	35.45	44.19	59.14	**46.26 ab**
Farold 40	Deveci	31.95	41.81	58.46	**44.07 abc**
	Williams	32.41	41.35	53.44	**42.40 abc**
	Santa Maria	30.39	43.48	46.28	**40.05 abc**
	Abate Fetel	28.26	37.61	55.97	**40.62 abc**
Seedling	Deveci	26.88	29.94	47.76	**34.86 bcde**
	Williams	19.96	24.05	41.93	**28.65 de**
	Santa Maria	28.03	29.77	49.83	**35.88 bcde**
	Abate Fetel	23.84	28.74	61.00	**37.86 abcd**
Main Effects of					
Rootstock	BA29	34.44 defg	43.20 c	44.90 bc	**40.85 b**
	QA	29.44 fgh	39.44 cde	41.16 cd	**36.68 c**
	MC	27.80 gh	30.12 fgh	33.70 efg	**30.54 d**
	Fox11	32.23 fg	34.03 efg	54.25 a	**40.17 b**
	OHxF333	35.61 def	44.22 bc	53.66 a	**44.50 a**
	Farold40	30.75 fgh	41.06 cd	53.54 a	**41.78 b**
	Seedling	24.68 h	28.13 gh	50.13 ab	**34.31 c**
Cultivar	Deveci	34.40 def	41.84 bc	52.41 a	**42.88 a**
	Williams	27.29 g	31.33 efg	39.53 cd	**32.71 c**
	Santa Maria	31.30 efg	38.57 cd	45.87 b	**38.58 b**
	Abate Fetel	29.85 fg	36.95 cde	51.53 a	**39.44 b**
Year		30.71 c**	37.17 b	47.33 a	

Year	0,001	Year x Cultivar	0,006
Rootstock	0,001	Rootstock x Cultivar	0,001
Cultivar	0,001	Year x Rootstock x Cultivar	0.887
Year x Rootstock	0,000		

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

In terms of cultivar average, the highest rootstock diameter was determined in the 'Deveci' (42.88 mm), while the lowest was found in the 'Williams' (32.71 mm) pear cultivars. Depending on the growth and development of the plants, the highest rootstock diameter was determined in the 2021 year (47.33 mm) in terms of years averages (Table 1). Rootstock diameter ranged from 15.68 mm to 48.47 mm in terms of rootstock x cultivar. In terms of rootstock x cultivar interaction, the highest rootstock diameter was in the 'Deveci'/BA29 (48.15 mm) and 'Deveci'/OHxF333 (48.47 mm), while the lowest in the 'Williams'/MC (15.68 mm) combination. Rootstock diameter ranged from 24.68 mm to 54.25 mm in the year x rootstock interaction. Rootstock diameter in 2021 was highest in the Fox11, the OHxF333 and the Farold40 rootstocks (54.25 mm, 53.66 mm and 53.54 mm, respectively), and lowest in the pear seedling rootstock (24.68 mm) in 2019. The rootstock diameter ranged from 27.29 mm to 52.41 mm in year x cultivar interactions. The highest rootstock diameter was detected in the 'Deveci' (52.41 mm) and 'Abate Fetel' (51.53 mm) in the 2021 year, and the lowest was in the 'Williams' (27.29 mm) in 2019 (Table 1).

In the research, it can be said that the difference between the years in terms of rootstock diameter is due to the increase in the growth and development of the plants from year to year. Gercekcioglu et al. (2014) reported that the difference in tree growth was due to the age of the trees and the increase in growth and development. Tatari et al. (2020), who stated that rootstock diameter differs according to research years, also reported that rootstock diameter increased in the following research years. The difference in the diameter of rootstocks and cultivars can be attributed to the variations in growth characteristics as well as the genetic differences of rootstocks and cultivars. Differences in growth vigor of rootstocks also show themselves in diameter development. While the diameter values of strongly growing rootstocks were high, the diameter values of weakly growing rootstocks were low (Jackson, 2003). Francescatto et al. (2010) noted that the effect of rootstocks on trunk diameter of the 'Carrick' pear cultivar grafted on 14 different rootstocks was significant. The researcher stated that the rootstock diameter of the 'Packham's pear cultivar grafted on 7 different rootstocks was the lowest in the EMC rootstock. In the 'Williams' pear cultivar grafted on 16 different rootstocks, the lowest rootstock diameter was in the EMC and the highest was in the Melliforme rootstock (Francescatto et al. 2010). Giacobbo et al. (2010) reported that the effect of rootstocks on trunk diameter was significant in 'Carrick' pear cultivars grafted on 13 different quince and 1 pear rootstocks. Ozturk and Ozturk (2014) stated that the effect of rootstocks on the trunk diameter of the 'Deveci' pear grafted on different rootstocks is important, and also, the highest rootstock diameter was in the BA29 and the lowest in the MC rootstocks. Machado et al. (2016) stated that the rootstock diameter varies according to the varieties and that the rootstock diameter was the lowest in the 'Williams' from 3 different pear cultivars grafted on

the EMC quince clonal rootstock. The researcher reported that rootstocks' effect on rootstock diameter is significant and the Quince C rootstock is the most dwarf growing rootstock among the quince rootstocks. Askari-Khorosgani et al. (2019) reported that rootstocks and research years had a significant effect on rootstock diameter in the 'Shahmiveh' pear cultivar, and they stated that quince rootstocks had a lower rootstock diameter than pear rootstocks. Ozturk (2021b) stated that the rootstock and research years significantly affected the rootstock diameter of the 'Deveci' pear. He reported that the rootstock diameter was the lowest in the MC rootstock. It can be stated that the rootstock diameter results obtained from this study are compatible with the other studies that partially included the rootstocks and cultivars used in this study.

The effects of rootstocks, cultivars, and research years were significant on the trunk diameter of 'Deveci', 'Williams', 'Santa Maria', and 'Abate Fetel' pear cultivars grafted on different pear and quince clonal rootstocks and pear seedling rootstocks. In the study, other interactions had a statistically significant effect on trunk diameter except for year x rootstock x cultivar interaction. In terms of rootstock average, the trunk diameter ranged from 27.59 mm to 37.72 mm, from 28.00 mm to 37.28 mm in cultivar averages, and in terms of year's average, it ranged from 25.07 mm to 43.52 mm. Among the examined rootstocks, the highest trunk diameter was detected in the OHxF333, BA29, Fox11 and Farold40 rootstocks (37.72 mm, 36.36 mm, 36.12 mm and 35.36 mm, respectively), while the lowest was in the MC quince clonal rootstock (27.98 mm) and the pear seedling rootstock (27.59 mm). While the trunk diameter was the highest (37.28 mm) in the 'Deveci', the lowest was in the 'Williams' cultivar (28.00 mm). The highest trunk diameter was found in the 2021 year (43.52 mm) depending on the growth and development of the plants between the research years (Table 2).

In terms of rootstock x cultivar interactions, the trunk diameter ranged from 14.12 mm to 43.34 mm. As regards to the rootstock x cultivar interactions, the highest stem diameter was determined in the 'Deveci'/OHxF333 (43.34 mm) and 'Deveci'/BA29 (43.11 mm), and the lowest in the 'Williams'/MC (14.12 mm). In terms of year x rootstock interactions, trunk diameter varied between 19.41 mm and 51.47 mm. The highest trunk diameter was determined on the Fox11 rootstock (51.47 mm) in 2021 and the lowest in the seedling rootstock (19.41 mm) in the 2019 year. The trunk diameter ranged from 22.11 mm to 49.47 mm concerning the year x cultivar interactions. The highest trunk diameter was detected in the 'Deveci' (49.47 mm) cultivar in 2021 (Table 2).

In studies determining the performance of cultivars' grafted on different rootstock in pear, the effect of rootstocks, cultivars, and research years on trunk diameter was found to be statistically significant. Furthermore, these studies noted that the growth vigor of quince rootstocks is generally lower than that of pear roo-

tstocks. Loreti et al. (2002) stated that the trunk diameter of the 'Conference' pear cultivar grafted on BA29 was higher than that of Quince MA and MC rootstocks. Stiropoulos (2006) stated that the trunk diameter of the 'Williams' pear cultivar grafted on different rootstocks was higher in the pear rootstock than the quince rootstocks, and also he reported that BA29 was the weakest growing rootstock among the quince rootstocks examined in terms of trunk diameter.

Table 2. Effect of different rootstocks on trunk diameter of pear cultivars

Rootstocks	Cultivars	Years			Mean
		2019	2020	2021	
Quince BA29	Deveci	30.19	47.10	52.04	**43.11 a***
	Williams	25.18	32.34	33.32	**30.28 bcd**
	Santa Maria	28.72	35.35	39.89	**34.66 ab**
	Abate Fetel	26.83	39.15	46.19	**37.39 ab**
Quince A	Deveci	23.19	37.41	49.82	**36.81 ab**
	Williams	17.06	24.30	26.02	**22.46 de**
	Santa Maria	24.01	35.20	42.33	**33.85 abc**
	Abate Fetel	27.57	39.12	44.73	**37.14 ab**
Quince MC	Deveci	29.06	34.33	40.83	**34.74 ab**
	Williams	12.68	14.00	15.70	**14.12 e**
	Santa Maria	27.88	37.62	40.69	**35.39 ab**
	Abate Fetel	20.56	29.98	32.50	**27.68 bcd**
Fox11	Deveci	30.27	30.27	51.46	**37.34 ab**
	Williams	26.49	27.68	48.69	**34.29 abc**
	Santa Maria	28.38	30.33	45.33	**34.68 ab**
	Abate Fetel	26.45	27.70	60.38	**38.17 ab**
OHxF333	Deveci	31.54	37.81	60.67	**43.34 a**
	Williams	29.91	33.62	45.64	**36.39 ab**
	Santa Maria	26.30	32.82	40.13	**33.08 abcd**
	Abate Fetel	29.35	36.63	48.19	**38.06 ab**
Farold 40	Deveci	27.74	34.13	52.26	**38.04 ab**
	Williams	26.35	31.58	47.64	**35.19 ab**
	Santa Maria	28.07	36.21	43.44	**35.91 ab**
	Abate Fetel	22.67	26.34	47.92	**32.31 abcd**
Seedling	Deveci	20.48	22.97	39.21	**27.55 bcd**
	Williams	17.14	19.00	33.60	**23.24 cde**
	Santa Maria	19.04	20.85	45.83	**28.57 bcd**
	Abate Fetel	18.80	20.99	44.00	**27.93 bcd**
Main Effects of					
Rootstock	BA29	27.73 def	38.49 cd	42.86 bc	**36.36 a**
	QA	22.96 ef	34.01 de	40.73 bc	**32.56 b**
	MC	22.54 ef	28.98 def	32.43 de	**27.98 c**
	Fox11	27.90 def	29.00 def	51.47 a	**36.12 a**
	OHxF333	29.28 def	35.22 de	48.66 ab	**37.72 a**
	Farold40	26.21 def	32.06 de	47.82 ab	**35.36 a**
	Seedling	19.41 f	26.71 def	36.64 cd	**27.59 c**
Cultivar	Deveci	27.50 de	34.86 c	49.47 a	**37.28 a**
	Williams	22.11 e	26.07 e	35.80 c	**28.00 c**
	Santa Maria	26.06 e	32.63 cd	42.52 b	**33.73 b**
	Abate Fetel	24.92 e	34.70 c	43.98 ab	**34.53 b**
Year		**25.07 c****	**31.24 b**	**43.52 a**	

Year	0.001	Year x Cultivar	0.001
Rootstock	0.001	Rootstock x Cultivar	0.001
Cultivar	0.001	Year x Rootstock x Cultivar	0.254
Year x Rootstock	0.001		

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

Evaluating rootstocks for 'Conference' and 'Doyenne du Comice' pear cultivars in high density planted pear orchards. Maas (2008) cited that the effect of rootstocks on the trunk diameter of cultivars was significant. Emphasizing that there are significant differences in trunk diameters of different pear cultivars grafted on Quince A. Ertürk et al. (2009) determined that the cultivar with the highest trunk diameter was 'Coscia' and the lowest was in the 'Williams'. The trunk diameter of the 'Williams' pear cultivar grafted on different rootstocks was the highest on the seedling rootstock and the lowest on the Quince C (EMC) quince clonal rootstock (Francescatto et al., 2010). The trunk diameter of the 'Comice' pear cultivar was higher in the BA29 than that of the MC rootstock (Sugar and Basile, 2011). Ozturk and Ozturk (2014) who stated that the effect of rootstocks on the trunk diameter of the 'Deveci' pear grafted on different rootstocks was significant, reported that the highest trunk diameter was in the BA29 and the lowest in the pear seedling rootstocks. Machado et al. (2016) reported that the trunk diameter of 3 different pear cultivars grafted on the EMC quince clonal rootstocks varied depending on the cultivar and research years, and the 'Williams'/EMC had the lowest turnk diameter. Askari-Khorosgani et al. (2019) reported that the trunk diameter of the 'Shahmiveh' pear cultivar grafted on different rootstocks was thicker on pear rootstocks than on quince rootstocks. Ozturk (2021b), who stated that the rootstock and research years had a significant effect on the trunk diameter of the 'Deveci' pear, reported that the trunk diameter was the highest in the BA29 rootstock. It has been emphasized in similar studies that the effects of rootstocks on the trunk diameters of the cultivars grafted on them were significant and that the trunk diameters of the cultivars grafted on vigorous rootstocks were higher than those grafted on weak rootstocks (Jackson, 2003; Urbina et al., 2003; Maas, 2008; Sugar and Basile, 2011; Askari-Khorosgani et al., 2019; Ozturk, 2021a, b).

Rootstocks, cultivars, and research years statistically affected the survival ratio of 'Deveci', 'Williams', 'Santa Maria' and 'Abate Fetel' pear cultivars were grafted on different rootstocks. In the study, other interactions had a statistically significant effect on plant survival ratio except for the year x rootstock x cultivar interaction. The survival ratio varied between 87.96% - 99.54% in terms of rootstock average, 88.57% - 98.94% in terms of cultivar averages, and 91.17% - 97.60% in terms of years average. Among the examined rootstocks, the highest survival rate was detected 99.54% in the Fox11 and 99.07% in the OHxF333 rootstock, and the lowest in the MC quince clone rootstock (87.96%). The highest survival ratio in terms of cultivars was determined in the 'Deveci' (98.94%) and the lowest in the 'Williams' (88.57%). The highest survival ratio was determined in 2019 and 2020 (97.60% and 96.33%, respectively) and the lowest (91.17%) in the 2021 year, in terms of years (Table 3).

In terms of rootstock x cultivar interactions, the survival ratio ranged from 66.67% to 100.00%. The lowest survival rate in terms of rootstock x cultivar in-

teraction was found in the 'Williams'/MC (66.67%) followed by 'Williams'/QA (75.56%) scion/rootstock combinations (Figure 1, Table 3). In terms of year x rootstock interactions, the plant survival ratio varied between 76.39% and 100.00%. The highest plant survival ratio in 2019 was recorded in the Fox11, OHxF333, Farold40 and seedlings (100.00%, 100.00%, 100.00% and 97.92%, respectively), in 2020 it was observed in the Fox11, OHxF333 and Farold40 (100.00%, 100.00% and 97.22%) and in 2021 were in the Fox11 and OHxF333 (98.61% and 97.22%, respectively), lowest survival ratio was determined in the MC (76.39%) rootstock in the 2021 year. The plant survival ratio ranged between 80.94% and 100.00% in terms of year x cultivar interactions. In terms of year x cultivar interactions, the highest survival ratio was found in the 'Deveci' (100.00%) in 2019 and 2020, and the lowest was in the 'Williams' (80.94%) in 2021 (Table 3).

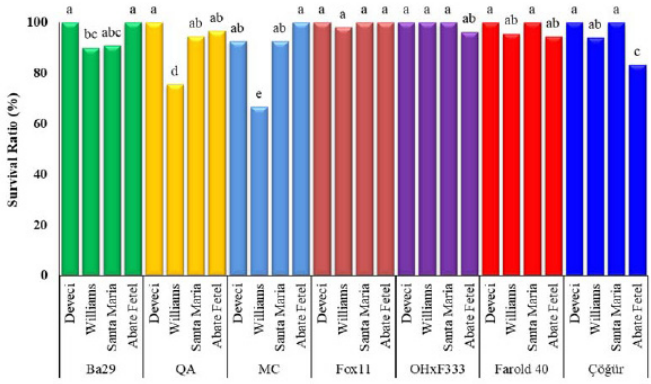

Figure 1. Pear trees survival ratio in various rootstocks x cultivars combinations

The plant survival ratio decreased as the research years progressed in this study. In addition, it was determined that the plant survival ratio among rootstocks was lower in quince rootstocks than in pear rootstocks. The cause for the decrease in the combinations with low plant survival ratio, which was found to reduce the growth and development of fruit trees from year to year, can be linked to the age of the trees. However, according to Mauro et al. (2022), weak connection and formation of vascular system after some years led to abnormal and restricted growth of fruit trees, and graft incompatibility may be the reason for the decrease in plant survival ratio when the pear is grafted on quince. When closely related species or cultivars are grafted onto each other, the survival rate increases, while the survival ratio in distant relatives decreases. Graft incompatibility is among the reasons for the low graft success ratio and survival ratio. In addition, when the pear is grafted on quince, the decrease in survival ratio does not occur immediately due to graft incompatibility. The reason for the decrease in survival rate, especially in

the following years, is called delayed graft incompatibility. It is stated that the incompatibility occurring in the pear/quince graft combination is the localized graft incompatibility.

Table 3. Effect of different rootstocks on plant survival ratio of pear cultivars

Rootstocks	Cultivars	Years			Mean
		2019	2020	2021	
Quince BA29	Deveci	100.00	100.00	100.00	**100.00 a***
	Williams	90.00	90.00	90.00	**90.00 bc**
	Santa Maria	96.67	87.78	87.78	**90.74 abc**
	Abate Fetel	100.00	100.00	100.00	**100.00 a**
Quince A	Deveci	100.00	100.00	100.00	**100.00 a**
	Williams	85.00	78.33	63.33	**75.56 d**
	Santa Maria	94.44	94.44	94.44	**94.44 ab**
	Abate Fetel	100.00	96.67	92.96	**96.54 ab**
Quince MC	Deveci	100.00	100.00	77.78	**92.59 ab**
	Williams	75.00	75.00	50.00	**66.67 e**
	Santa Maria	100.00	100.00	77.78	**92.59 ab**
	Abate Fetel	100.00	100.00	100.00	**100.00 a**
Fox11	Deveci	100.00	100.00	100.00	**100.00 a**
	Williams	100.00	100.00	94.44	**98.15 ab**
	Santa Maria	100.00	100.00	100.00	**100.00 a**
	Abate Fetel	100.00	100.00	100.00	**100.00 a**
OHxF333	Deveci	100.00	100.00	100.00	**100.00 a**
	Williams	100.00	100.00	100.00	**100.00 a**
	Santa Maria	100.00	100.00	100.00	**100.00 a**
	Abate Fetel	100.00	100.00	88.89	**96.30 ab**
Farold 40	Deveci	100.00	100.00	100.00	**100.00 a**
	Williams	100.00	100.00	86.67	**95.56 ab**
	Santa Maria	100.00	100.00	100.00	**100.00 a**
	Abate Fetel	100.00	91.67	91.67	**94.44 ab**
Seedling	Deveci	100.00	100.00	100.00	**100.00 a**
	Williams	100.00	100.00	82.14	**94.05 ab**
	Santa Maria	100.00	100.00	100.00	**100.00 a**
	Abate Fetel	91.67	83.33	75.00	**83.33 c**
Main Effects of					
Rootstock	BA29	96.67 ab	94.44 bc	94.44 bc	**95.19 b**
	QA	94.86 bc	92.36 cd	87.68 ef	**91.64 c**
	MC	93.75 cd	93.75 cd	76.39 f	**87.96 d**
	Fox11	100.00 a	100.00 a	98.61 a	**99.54 a**
	OHxF333	100.00 a	100.00 a	97.22 a	**99.07 a**
	Farold40	100.00 a	97.92 a	94.58 bc	**97.50 ab**
	Seedling	97.92 a	95.83 ab	89.29 de	**94.35 bc**
Cultivar	Deveci	100.00 a	100.00 a	96.83 ab	**98.94 a**
	Williams	92.86 b	91.90 b	80.94 c	**88.57 c**
	Santa Maria	98.73 ab	97.46 ab	94.29 ab	**96.82 ab**
	Abate Fetel	98.81 ab	95.95 ab	92.65 b	**95.80 b**
Year		**97.60 a****	**96.33 a**	**91.17 b**	

Year	0.001	Year x Cultivar	0.038
Rootstock	0.001	Rootstock x Cultivar	0.001
Cultivar	0.001	Year x Rootstock x Cultivar	0.346
Year x Rootstock	0.002		

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

**: Differences between means with different letters in the same line are significant.

This incompatibility can be eliminated by using rootstock and used for inter-stem compatibility with the scion (Jackson, 2003; Hartmann et al., 2011; Bodens and Breyne, 2012). The lowest plant survival ratio was detected among the cultivars in the 'Williams' and the highest in the 'Deveci' cultivar. The 'Williams' cultivar, which had a lower plant survival ratio, showed graft incompatibility with some quince rootstocks (Dondini and Sansavini, 2012) and pear clone rootstocks such as Fox11 (Hudina et al., 2014). Similar to our findings, a significant difference of rootstocks and cultivars combinations on the survival ratio of pear saplings has been reported by Ozturk (2021a) in pear and quince rootstocks. He cited that the survival ratio was higher in the pear rootstock than the quince rootstock in the nursery conditions and also reported that the survival ratio was lowest in BA29 quince rootstock, while the highest was in the Fox11 pear rootstock. The low survival ratio of some pear clone rootstocks like Farold40, which were grafted with some pear varieties, was also related to how resistant the rootstock is to the adverse conditions of area ether biotic or abiotic combination of both factors apart from compatibility. They are more compatible with the quince clonal rootstocks (Moore, 1984; Shaltiel, 2018). In addition, the low survival rate of MC in our research may be related to the cold-hardy features of rootstock as Pyrus communis seedling rootstocks showed a higher survival rate than quince rootstocks, especially MC in the Baltic region (Lepsis et al., 2013), or it can be due to partial incompatibility of 'Williams' with quince rootstocks according to Baviera et al. (1988) and Ciobotari et al. (2010). In a research, it was observed that the secondary metabolites like catechin, arbutin and prunasin on pear/quince combinations were increased after four years of grafting. Variations in the expression of genes encoding enzymes, polarity, the physical structure of the graft, ecological conditions, plant growth regulators, virus and fungal infections are also the factors that suppress survival of grafted pear trees especially in pear and quince combinations (Hudina et al., 2014; Habibi et al., 2022). In another study on the incompatibility of some pear and quince scion/rootstock combinations, Mosse and Herrero (1951) noticed that even growth and development of grafted trees are normal for a few years. However, due to the weakness of the union's mechanical structure, the trees will not survive as normal ones and their lives will be terminated after some years, the same idea mentioned by Rasool et al. (2020). A study carried out in Pakistan reported that the survival rate at the end of the growing season was 73.10 % in Williams and 44.55 % in Santa Maria as they were grafted on quince and local pear rootstocks (Rahman et al., 2017). The research was conducted to investigate the survival ratios of some Asian pear cultivars on European pear seedlings and some genotypes, and all Asian pear cultivars showed good performance and survival ratio on European pear seedling rootstocks (Arzani, 2004). The results regarding the plant survival ratio reported in this study are compatible with those obtained in other studies on similar subjects.

4. CONCLUSION

Rootstocks, cultivars, and research years had a significant impact on the parameters examined in this study, in which the effects of some standard pear varieties grafted on different rootstocks on rootstock diameter, stem diameter development, and plant survival rate were investigated. According to the examinations made between 2019-2021 in the established orchard in 2018, the highest rootstock diameter was observed from the OHxF333, and the cultivar was in the 'Deveci'. The highest stem diameter was in the OHxF333, BA29, Fox11, and Farold40, and the cultivar was in the 'Deveci'. The lowest rootstock diameter was determined in the QA and the pear seedling, and the lowest trunk diameter was in the MC and the pear seedling. The highest plant survival ratio was observed in the Fox11 and OHxF333 rootstocks, and the lowest was in the QA rootstocks. The highest survival ratio was determined in the 'Deveci' cultivar. The 'Williams' cultivar had the study's lowest rootstock diameter, stem diameter, and plant survival ratio. In addition, the plant survival ratio was slightly lower in quince clone rootstocks than in pear rootstocks. This is due to the graft incompatibility between some quince rootstocks and pear cultivars. In such cases, to solve graft incompatibility, a compatible inter-stock with both rootstock and cultivar should be used. As a result, it is necessary to do extensive study and make detailed observations to make precise decisions based on the results.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethics

This study does not require ethics committee approval.

Author Contribution Rates

Design of Study (Çalışmanın Tasarlanması): AO (%50), TK (%25), ZAF (%25)

Data Acquisition (Veri Toplanması): AO (%30), TK (%40), ZAF (%30)

Data Analysis (Veri Analizi): AO (%70), TK (%15), ZAF (%15)

Writing up (Makalenin Yazımı): AO (%75), TK (%10), ZAF (%15)

Submission and Revision (Makalenin Gönderimi ve Revizyonu): AO (%85), TK (%5), ZAF (%10)

REFERENCES

Arzani, K., 2004. Progress in the national Asian pear project: A study on the adaptation of some Asian pear (*Pyrus serotina* Rehd) cultivars to Iranian environmental conditions. In *IX International Pear Symposium 671*: 209-212.

Askari-Khorasgani, O., Jafarpour, M., Hadad, M. M., Pessarakli, M., 2019. Fruit yield and quality characteristics of "Shahmiveh" pear cultivar grafted on six rootstocks, *Journal of Plant Nutrition 42(4)*: 323-332. doi: 10.1080/01904167.2018.1555592.

Baviera, J. A., Garca, J. L., Ibarra, M., 1988. Commercial in vitro micro-propagation of pear cv. Conference. In *V International Symposium on Pear Growing 256*: 63-68.

Bodens M. L., Byrne D. H., 2012. Fruit breeding. In: Handbook of plant breeding. Wien, Springer, p. 875.

Chen, Z., Zhao, J., Qin, Y., Hu, G., 2016. Study on the graft compatibility between 'Jingganghongnuo' and other litchi cultivars. *Scientia Horticulturae*, 199: 56-62.

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*(1): 187-192.

Costes E., Lauri P. E., Regnard, J. L., 2006. Analyzing fruit tree architecture: implications for tree management and fruit production. Horticultural Reviews 32: 1-61.

Da Silva, G. J., Villa, F., Da Silva P. S., Welter, J. F., 2018. Pear (*Pyrus* spp.) breeding, Advances in plant breeding strategies: Fruits. Gewerbestrasse 11, 6330 Cham, Switzerland. 3: 131-164.

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, Handbook of Plant Breeding: Fruit Breeding. Springer, New York. 11: 369-413.

Ermel, F. F., Kervella, J., Catesson, A. M., Poessel, J. L., 1999. Localized graft incompatibility in pear/quince (*Pyrus communis/Cydonia oblonga*) combinations: multivariate analysis of histological data from 5-month-old grafts. Tree physiology, 19(10).

Ertürk, Y., Güleryüz, M., Erdoğan, U. G., 2009. Quince A üzerine aşılı bazı armut çeşitlerinin İspir (Yukarı Çoruh Havzası) koşullarındaki verim ve gelişme durumlarının belirlenmesi. *BAHÇE 38(1)*: 11-17.

Francescatto, P., Pazzin, D., Gazolla Neto, A., Fachinello, J. C., Giacobbo, C. L., 2010. Evaluation of graft compatibility between quince rootstocks and pear scions. Acta horticulturae, *872*: 253-260.

Gercekcioglu, R., Gencer, S., & Oz, O. (2014). Tokat ekolojisinde yetiştirilen "Eşme" ve "Limon" ayva (*Cydonia vulgaris* L.) çeşitlerinin bitkisel ve pomolojik özellikleri. Tarım Bilimleri Araştırma Dergisi 7 (1), 01-05.

Giacobbo, C. L., Neto, A. G., Pazzin, D., Francescatto, P., Fachinello, J. C., 2010. The assessment of different rootstocks to the pear tree cultivar 'Carrick'. Acta Horticulture, 872: 353-358

Goldschmidt, E. E., 2014. Plant grafting: new mechanisms, evolutionary implications. Frontiers in plant Science, 5: 727.

Habibi, F., Liu, T., Folta, K., Sarkhosh, A., 2022. Physiological, biochemical, and molecular aspects of grafting in fruit trees. Horticulture Research. Horticultural Sciences Department, University of Florida, Gainesville FL 32607 USA, 1-27.

Hancock, J. F., Lobos, G. A., 2008. Pears. In Temperate fruit crop breeding, Springer, Dordrecht, 299-336.

Hartmann, H. T., Kester D. E., Davies, F. T., Geneve, R. L., 2011. Plant propagation: Principles and practices. 8th ed. Regents/Prentice Hall International Edition. 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(5): 76-84.

Iglesias, I., Batlle, I., 2011. Agronomical Performance and Fruit Quality of 'Conference' on Some Cydonia and Pyrus Rootstocks. Acta Horticulture, 909: 195-200.

Jackson, J. E., 2003. Biology of apples and pears. Cambridge University Press, Cambridge, UK. doi:10.1017/CBO9780511542657.

Lepsis, J., Lepse, L., Kviklys, D., Univer, N., 2013. Evaluation of pear rootstocks for the cultivar 'Suvenirs' in the Baltic region. In Proceedings of the Latvian Academy of Sciences. Section B. Natural, Exact, and Applied Sciences,

67(2): 145-150.
Loreti, F., Massai, R., Fei, C., Cinelli, F., 2002. Performance of 'Conference' cultivar on several quince and pear rootstocks: preliminary results. Acta Horticulturae, 596: 311–18. doi: 10.17660/ActaHortic.2002.596.48.
Maas, F., 2008. Evaluation of Pyrus and quince rootstocks for high density pear orchards. *Acta Horticulturae*, 800: 599-609.
Machado, B. D., Magro, M., Rufato, L., Bogo, A., Kreztschmar, A.A., 2016. Graft Compatibility between European Pear Cultivars and East Malling "C" Rootstock. Rev. Bras. Frutic., 39(3): (e-063) DOI 10.1590/0100-29452017 063.
Massai, R., Loreti, F., Fei, C., 2008. Growth and yield of 'Conference' pears grafted on quince and pear rootstocks. Acta Horticulturae, 800: 617-624.
Mauro, R. P., Perez-Alfocea, F., Cookson, S. J., Ollat, N., Vitale, A., 2022. Physiological and Molecular Aspects of Plant Rootstock-Scion Interactions. Frontiers Media SA, 11: 71.
Meszaros, M., Lanar, L., Kosina, J., Namestek, J., 2019. Aspects influencing the rootstock-scion performance during long term evaluation in pear orchard. Horticultural Science (Prague) 46(1): 1-8. https://doi.org/10.17221/55/2017-HORTSCI
Moore, R., 1984. A model for graft compatibility-incompatibility in higher plants. American Journal of Botany, 71(5): 752-758.
Mosse, B., Herrero, J., 1951. Studies on incompatibility between some pear and quince grafts. Journal of *Horticultural Science*, 26(3): 238-245.
Okubo, M., Sakuratani, T., 2000. Effects of sodium chloride on survival and stem elongation of two Asian pear rootstock seedlings. *Scientia Horticulturae*, 85(1-2): 85-90.
Ozturk, A., 2021a. The Effects of Different Rootstocks on the Graft Success and Scion Development of Some Pear Cultivars. *International Journal of Fruit Science*, 21(1): 932-944.
Ozturk, A., 2021b. Farklı Anaçlar Üzerine Aşılı 'Deveci' Armudunun Büyüme ve Meyve Kalite Özellikleri. *Bağbahçe Bilim Dergisi*, 8(3): 179-187. 10.35163/bagbahce.999637
Ozturk, A., Ozturk, B., 2014. The rootstock influences growth and development of 'Deveci'pear. *Turkish Journal of Agricultural and Natural Sciences*, 1(1): 1049-1053.
Ozturk, A., Serdar, Ü., 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*: 193-198.
Pasa, M. S., Fachinello, J. C., Rosa Júnior, H. F., Franceschi, E., Schmitz, J. D. Souza, A. L. K., 2015. Performance of 'Rocha' and 'Santa Maria' pear as affected by planting density. *Pesquisa Agropecuária Brasileira* 50:126-131.
Rahman, J., Aftab, M., Rauf, M. A., Rahman, K. U., Wasim Bilal, F., Ayub, G., 2017. Comparative study on compatibility and growth response of pear varieties on different rootstocks at nursery. *Pure and Applied Biology*, 6(1): 286-292.
Rasool, A., Mansoor, S., Bhat, K. M., Hassan, G. I., Baba, T. R., Alyemeni, M. N., Ahmad, P., 2020. Mechanisms underlying graft union formation and rootstock scion interaction in horticultural plants. *Frontiers in Plant Science*, 1778.
Reig, G., Zarrouk, O., Forcada, C. F., Moreno, M. Á., 2018. Anatomical graft compatibility study between apricot cultivars and different plum based rootstocks. *Scientia Horticulturae*, 237: 67-73.
Shaltiel, H, L., Gerchman, Y., Ibdah, M., Kedoshim, R., Rachmany, D., Hatib, K., Holland, D., 2018. Grafting on resistant interstocks reduces scion susceptibility to pear psylla, *Cacopsylla bidens. Pest management Science*, 74(3): 617-626.
Sharma, S., Rehalia, A. S., Sharma, S. D., 2009. Vegetative growth restriction in pome and stone fruits-A review. *Agricultural Reviews*, 30(1): 13-23.
Stern, R. A. Doron, I., 2009. Performance of 'Coscia' pear (*Pyrus communis*) on nine rootstocks in the north of *Israel. Sci Hortic.*, 119: 252-256.
Stiropoulos, T. E., 2006. Performance of the pear (*Pyrus communis*) cultivar William's Bon Chretien grafted on seven rootstocks. *Australian Journal of Experimental Agriculture*, 46: 701-705
Sugar, D., Basile, S. R., 2011. Performance of 'Comice' Pear on Quince Rootstocks in Oregon, USA. *Acta Horticulturae*, 909: 215-218.
Tatari, M., Rezaei, M., Ghasemi, A., 2020. Quince Rootstocks Affect Some Vegetative and Generative Traits, International Journal of Fruit Science, 20(2): 668-682, doi: 10.1080/15538362.2020.1764462.
Urbina, V., Dalmases, J., Pascual, M., Dalmau, R., 2003. Performance of `Williams' pear on five rootstocks. *Journal of Horticultural Science & Biotechnology*, 78(2): 193-196.
Webster, T., 2002. Dwarfing rootstocks: past, present and future. *Compact Fruit Tree*, 35: 67-72.