Yuzuncu Yil University
Journal of Agricultural Sciences
(Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi)
https://dergipark.org.tr/en/pub/yyutbd
ISSN: 1308-7576
e-ISSN: 1308-7584

Research Article

Effects of Quince Rootstocks and Pear Cultivars on Fruit and Yield Characteristics

Tahsin KURT[1], Ahmet ÖZTÜRK*[2], Zaki Ahmad FAIZI[3], Yakup POLAT[4]

[1,2,3]Horticulture Department, Faculty of Agriculture, University of Ondokuz Mayıs, 55200 Samsun, Türkiye
[4]Horticulture Department, Faculty of Agriculture, University of Van Yuzuncu Yil University, Van, Türkiye

[1]https://orcid.org/ 0000-0002-1574-4083, [2]https://orcid.org/0000-0002-8800-1248, [3]https://orcid.org/0000-0002-1429-6493
[4]https://orcid.org/0000-0002-5831-8199

*Corresponding author e-mail: ozturka@omu.edu.tr

Article Info

Received: 10.03.2023
Accepted: 08.05.2023
Online published: 15.06.2023
DOI: 10.29133/yyutbd.1263145

Keywords

Black spot,
Fruit breeding,
Marketable rate,
Pyrus communis,
Yield efficiency

Abstract: The research carried out to evaluate the effects of quince rootstocks [Quince Province BA29 (BA29), Quince A (QA), Quince C (MC)], pear cultivars, and research years on fruit quality and yield efficiency in the years 2020-2021. The highest fruit weight was obtained from BA29 (196.02 g), and the lowest was from MC (158.09 g). In the cultivars, the highest fruit weight was obtained from 'Abate Fetel' (210.85 g), the lowest from Santa Maria (156.73 g). The highest number of fruits (17.06 pieces tree^{-1}), yield per tree (3.13 kg tree^{-1}), yield per hectare (5982.8 kg ha^{-1}), and yield per trunk cross sectional area (0.30 kg cm^{-2}) obtained from BA29 followed by QA. In the cultivars, the highest number of fruits (19.60 pieces tree^{-1}), yield per tree (2.98 kg tree^{-1}), and yield per hectare (5685.00 kg ha^{-1}) were obtained from 'Santa Maria'. In the research years, the pre-harvest fruit drop rate (PHFDR 11.04%) and black spotted fruit rate (BSFR 13.79%) were observed to be higher in 2021, while the marketable fruit rate (MFR 77.03%) was observed to be higher in 2020. In the rootstocks, the highest PHFDR (11.24%) was observed on BA29 rootstocks, while the highest MFR (73.72%) was recorded on QA. In terms of cultivars, the highest PHFDR (10.73%) was observed in 'Williams', while the highest BSFR (16.41%) was in 'Deveci', and the highest MFR (76.31%) in 'Santa Maria'. As a conclusion, the highest yield and marketable fruit rate were obtained from the 'Santa Maria' cultivar and yield from BA29 rootstock. It could be suggested that semi-dwarf cultivars and rootstocks for suitably perform under high density pear orchards.

To Cite: Kurt, T, Öztürk, A, Faizi, Z A, Polat, Y, 2023. Effects of Quince Rootstocks and Pear Cultivars on Fruit and Yield Characteristics. *Yuzuncu Yil University Journal of Agricultural Sciences*, 33(2): 288-297. DOI: https://doi.org/10.29133/yyutbd.1263145

1. Introduction

Pear is an important temperate fruit due to a great degree of adaptation to various climatic situations (Bhat et al., 2017). In 2021 world pear production recorded 25.7 million tons, 18 million tons of the production carried out by China followed by America, Argentina, and Türkiye in the 4th position (FAOSTAT, 2023). Türkiye's pear production in 2022 reported 551 086 tons (TSI, 2023). In modern orchards, pear cultivars are grafted on quince rootstocks to obtain more dwarf trees than those grafted on pear rootstocks (Ozturk and Faizi, 2022). Also, quince is recommended as rootstock for pear to come up with precocity, increasing fruit quality, and facilitating cultural processes (Francescatto et al., 2010). Pear orchards with around 2000 - 5000 trees h^{-1} can be established with the use of quince rootstocks

(Pasa et al., 2012; Jovanovic et al., 2022), and cause high yield per area as they own higher photosynthetic efficiency (Ladaniya et al., 2020), due to the enhanced utilization of solar energy, nutrients, and water (Ladaniya et al., 2021). Arbitrary conditions like temperature, humidity, and less sunshine in dense pear orchards could rally undesirable pest incidence in the orchards (Poornima et al., 2018). The long viability of trees is an unsolved problem of pear orchards grafted on quince rootstocks (Musacchi et al., 2021). It is possible to increase quality with quince rootstocks usage in pear cultivation, as cultivars on quince rootstocks produce less fruit per canopy volume and yield per area could be increased as possible to use about 8000 trees ha^{-1}. But economic life of the orchards with quince rootstocks was reported low (Zhang et al., 2016; Musacchi et al., 2021). The research aimed to consider the quince rootstocks, pear cultivars, and research years' main factors impact on fruit and yield characteristics during two consecutive research years 2020-2021.

2. Materials and Methods

2.1. Materials

In the research, 'Abate Fetel', 'Deveci', 'Santa Maria', and 'Williams' were used as cultivars, and BA29, MC, and QA as rootstocks. The research was done in 2020-2021. The experimental pear orchard was planted in 2018 in the fruit research station of Ondokuz Mayis University (altitude 20 m, 35° 52' 21'' E; 41° 33' 50'' N). The research area has a cool climate in winters, a hot & humid climate in summers, and precipitation mostly occurs in late autumn as well as early winter. The experimental area has an average temperature ranging between 3.3 to 26.2 °C (TSMS, 2022). The properties of 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^{-1} salt (no salt), 0.3-0.5 organic matter (low), 3-6% lime ($CaCO_3$) (less), 0.03-0.06% N (less), 5-10 ppm P (medium) level and the soil depth was more than 1 meter. The plants were irrigated with drip irrigation between 15 May to 15 September. 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.

2.2. Methods

At 3.5 m x 1.5 m distances (1910 tree ha^{-1}) trees were planted and pruned according to the modified leader system. Young planted trees were supported by a supporting system of metal poles against the wind as well as tie up and bending of branches to prevent breaking at the yielding age. For this purpose, 3 rows of wire were tied to the poles at 0.5, 1.0, and 1.5 m from the ground. The trees' irrigation was done regularly with pressure compensating drippers at 1.20 m intervals, with 2 pipes per row on both sides of the trees. Also, weed control and pruning were done regularly in the experimental orchard.

2.3. Observations

Observations were done according to (Ozturk and Ozturk, 2014; Ozturk et al., 2022). The weight of fruit (g) was measured, taking 30 fruits into consideration in each replication with the help of 0.01 g sensitive digital balance (CAMRY L-500). Fruit width and length (mm) along with the fruit stalk length and thickness (mm) determined with a 0.01 mm digital caliper (Mitutoyo CD-20CPX). Fruit skin color properties (L*, a*, b*, chroma, and hue angle) were determined by colorimeter (Minolta, CR-300; Japan) as explained by Erdem and Ozturk (2012). Fruit firmness (kg cm^{-2}) was evaluated with a hand penetrometer (EXTECH FHT 200- with 5/16 head). The total soluble solids content (%) was determined with a digital refractometer (ATAGO, PAL-1), and acidity (%) observed by using the colorimetric method (Ozturk and Faizi, 2022). The number of fruits (pieces tree^{-1}), yield per tree (kg), yield per hectare (kg), yield per trunk cross sectional area (kg cm^{-2}), and yield per canopy volume (kg m^{-3}) were recorded. Pre-harvest fruit drop rate (%) was calculated by counting the total number of fruits that existed on the tree around one month before the harvest, then once a week the number of dropped fruits was counted and divided by the number of fruits that were recorded at the beginning. The rate of black spotted fruits (%) was determined by counting the number of fruits with infection in each replication and was expressed as percentage. Marketable fruit rate (%) was calculated by separating the unsound fruits (over black spotted, fruits with *monilia*, fruit with worms and malformed) from healthy fruits in each replication and expressed as a percentage.

2.4. Data analysis

The research employed the Randomized Block Design (RBD) methodology with three replications and ten trees in each replication. The number of fruits used in each replication was 30 for pomological and biochemical investigation. IBM SPSS 21.0 was used to evaluate the data when they were collected (SPSS Inc. Chicago, ABD). In the case of ANOVA, the significance mean comparison with Duncan Multiple Comparison Test (DMRT) was calculated at a 5% level of significance ($p \leq 0.05$).

3. Results and Discussion

3.1. Pomological characteristics

Variance analysis of rootstocks, cultivars, and research years' effects on pomological characteristics of some standard pear cultivars on different quince clonal rootstocks were given in Table 1. Fruit width, fruit stalk length, fruit stalk thickness in the rootstocks, and fruit stalk thickness in the research years were found to be not significant. In the rootstocks, the highest values were observed on BA29 rootstocks, while the lowest were on MC. But in some properties, QA and MC showed the same values. In the cultivars, the highest fruit weight (F wt.), fruit length (FL) and fruit stalk thickness (FST) were observed on 'Abate Fetel' cultivar. While the highest fruit width (F wdt.) was observed on 'Deveci' cultivar.

Table 1. Effects of quince rootstocks, pear cultivars and research years on pomological characteristics

Main Effects		Weight of Fruit (g)	Width of Fruit (mm)	Length of Fruit (mm)	Length of Fruit Stalk (cm)	Thickness of Fruit Stalk (mm)
Rootstocks	QA	187.83 a*	63.99 a	89.14 b	14.64 a	4.15 a
	BA29	196.02 a	65.00 a	89.54 a	16.90 a	4.44 a
	MC	158.09 b	62.52 a	83.03 c	15.85 a	4.20 a
Cultivars	Deveci	188.16 b	68.68 a	67.74 d	15.13 b	3.77 b
	Williams	166.86 c	67.52 a	75.48 c	15.89 b	4.49 a
	Santa Maria	156.73 c	59.31 b	86.53 b	20.31 a	4.32 ab
	Abate Fetel	210.85 a	59.84 b	119.20 a	11.87 c	4.49 a
Years	2020	201.64 a	65.84 a	93.57 a	13.68 b	4.29 a
	2021	159.65 b	61.84 b	80.90 b	17.92 a	4.24 a
Significance						
Rootstocks		0.001	0.185	0.005	0.162	0.450
Cultivars		0.001	0.001	0.001	0.001	0.038
Years		0.001	0.001	0.001	0.001	0.854

* Means shown with different letters in the same column are statistically significant.

Fruit size in pears is a considerable factor in marketing (Ozturk and Faizi, 2022). Ideal rootstock selection for pear is a necessity in increasing the average fruit size for each cultivar (Pasa et al., 2017; Askari et al., 2019). Kucuker et al. (2015) recorded that the weight of fruit varied according to cultivars and research years. And they reported that fruit weight in 'Santa Maria' grafted on BA29 ranged from 147.5 to 169.4 g. Erdem and Ozturk (2012) reported 140.00-156.20 g. Lepaja et al. (2014) reported a fruit width of 61.18 to 81.86 mm and a fruit weight of 183.00 to 290.00 g. 'Santa Maria' fruit weight on different rootstocks in semi-arid conditions was reported 265.49 to 290.37 g (Ikinci et al., 2014). In calcareous soil and semi-arid conditions, Ikinci et al. (2016) reported a fruit weight of 304.1 g. Jovanovic et al. (2022) reported weight of the fruit was 188.4 g, the fruit length 8.8 cm, and the fruit width 6.5 cm in 'Santa Maria' pear cultivar. Fruit stalk length and thickness observed respectively, 31.54 to 32.56 mm; 3.94 to 4.75 mm in 'Deveci' grafted on BA29 by Uysal et al. (2016) and 11.1 to 14.2 mm; 4.6 to 5 mm in 'Abate Fetel' grafted on QA by Ozturk et al. (2016). Pomological results of our study are generally in agreement with previous studies.

3.2. Fruit skin color characteristics

Variance analysis of rootstocks, cultivars, and research years on fruit skin color were given in Table 2. All the color characteristics including L*, a*, b*, Chroma, and hue angle (h°) in the case of rootstocks and h° in the research year found not significant, out of those characteristics mentioned above all the observed data found significant statistically.

Table 2. Effects of quince rootstocks, pear cultivars and research years on fruit skin color characteristics

Main Effects		L*	a*	b*	Chroma	h°
Rootstocks	QA	65.71 a*	-13.34 a	31.66 a	33.01 a	107.73 a
	BA29	64.72 a	-16.75 a	30.67 a	34.20 a	112.05 a
	MC	65.24 a	-12.68 a	32.16 a	34.48 a	109.31 a
Cultivars	Deveci	76.41 a	-18.62 b	38.98 a	39.97 a	104.13 b
	Williams	56.05 b	-8.38 a	27.75 c	29.28 b	105.21 b
	Santa Maria	73.95 a	-19.89 b	34.88 b	38.39 a	120.83 a
	Abate Fetel	54.50 b	-10.15 a	24.36 d	27.95 b	108.62 b
Years	2020	53.57 b	-11.27 b	24.89 b	28.61 b	110.81 a
	2021	76.88 a	-17.24 a	38.10 a	39.18 a	108.58 a
Significance						
Rootstocks		0.679	0.269	0.344	0.748	0.443
Cultivars		0.001	0.001	0.001	0.001	0.001
Years		0.001	0.005	0.001	0.001	0.425

* Means shown with different letters in the same column are statistically significant.

Color is an important quality characteristic and variations in the color are mentioned to be related to the crown structure and leaf area of the trees as a result of vegetative growth and development. So, the trees with lower canopy achieved more sunlight which caused the formation of the red blush of pear bark color. L* and b* are among the best identifiers showing the degree of maturity in fruits of pear trees. As, increasing in the b* value which expresses the yellow color, indicated higher sugar content (Ozturk and Faizi, 2022). Many studies were shown that rootstocks have important effects on fruit color and other quality aspects of pear fruits (Erdem and Ozturk, 2012; Kucuker et al., 2015; Askari et al., 2019).

3.3. Fruit firmness and chemical properties

Analyzed data of rootstocks, cultivars, and research years' effects on fruit firmness and chemical characteristics were illustrated in Table 3. All results were obtained to be statistically significant, except for TSS in the case of research years which obtained not significant. Fruit firmness was the highest in the MC rootstocks (9.15 kg cm^{-2}) and lowest in the BA29 (8.64 kg cm^{-2}) in terms of rootstocks, and lower in 'Abate Fetel' than the other cultivars in terms of cultivars. In terms of rootstocks, the highest TSS content was determined in the BA29 (12.21%), the lowest in the MC (10.92%), and the lowest TSS content was determined in the 'Santa Maria' (9.94%) in terms of cultivars. The highest titratable acidity was determined in the BA29 (0.46%) in terms of rootstocks, the lowest in QA (0.40%); the highest in the 'Santa Maria' (0.54%), and the lowest in the 'Abate Fetel' (0.35%) in terms of cultivars (Table 3).

To determine pear fruit maturity, firmness is an important consideration (Ozturk and Faizi, 2022), and reported to differ based on rootstocks, growing years, and cultural practices in the pear orchards (Ikinci, 2017). Lepaja et al. (2014) reported the fruit firmness at 4.96 kg cm^{-2} in the 'Santa Maria'. Ikinci et al. (2014) notified that the rootstocks significantly affected the fruit firmness of the 'Santa Maria' pear cultivar, as the flesh firmness was highest on BA29 and MA rootstocks and the lowest on pear seedling rootstocks. Ikinci et al. (2016) stated that fruit firmness was 22.3 lb. Pasa et al. (2017) mentioned that fruit firmness was 62.11 - 66.46 N in 'Santa Maria'. Total soluble solids are a crucial consideration in pear fruits ripening and have a positive correlation with maturity, while acidity decreased with the increase in maturity (Ozturk and Faizi, 2022). 'Santa Maria' TSS was reported highest in pear seedlings, and lowest in BA29 rootstock, while titratable acid was reported highest in BA29 and lowest in the pear seedling rootstocks (Ikinci et al., 2014). Rootstocks and research years reported to have an important effect on the TSS and acidity of the 'Shamiveh' pear cultivar on different quince and pear rootstocks (Askari et al., 2019). Titratable acidity was reported at 0.46% in QA, 0.62% in BA29, and 0.56% in the MC rootstock while ‘Santa Maria’ grafted on them (Ozturk and Faizi, 2022). The average pH of ‘Santa Maria’ was reported 3.98 to 4 on BA29 rootstocks by Erdem ve Ozturk (2012); 3.75 to 3.85 on pear seedling rootstocks by Kellecioglu (2014); 3.98 to 4.06 on BA29 rootstocks by Kucuker et al. (2015); 3.40 on BA29 rootstocks by Ekinci and Akcay (2016).

Table 3. Effects of quince rootstocks, pear cultivars and research years on fruit firmness and chemical traits

Main Effects		Fruit Firmness (kg cm^{-2})	TSS (%)	Titratable Acidity (%)	pH
Rootstocks	QA	8.96 ab*	11.56 b	0.40 b	3.62 ab
	BA29	8.64 b	12.21 a	0.46 a	3.68 a
	MC	9.15 a	10.92 c	0.43 ab	3.56 b
Cultivars	Deveci	9.26 a	12.21 a	0.44 b	3.82 a
	Williams	9.08 a	11.91 a	0.39 bc	3.49 b
	Santa Maria	9.04 a	9.94 b	0.54 a	3.59 b
	Abate Fetel	8.28 b	12.18 a	0.35 c	3.59 b
Years	2020	8.51 b	11.63 a	0.49 a	3.68 a
	2021	9.32 a	11.49 a	0.37 b	3.56 b
Significance					
Rootstocks		0.025	0.001	0.041	0.044
Cultivars		0.001	0.001	0.001	0.001
Years		0.001	0.517	0.001	0.006

* Means shown with different letters in the same column are statistically significant.

3.4. Yield and yield efficiency

Analyzed results of rootstocks, cultivars, and research years’ effects on the number of fruits (NF), yield per tree (YT), yield per hectare (YH), yield per trunk cross sectional area (YTCSA) and yield per canopy volume (YCV) gave in Table 4.

Table 4. Effects of quince rootstocks, pear cultivars and research years on yield and yield efficiency

Main Effects		Number of Fruits (pieces tree^{-1})	Yield per Tree (kg tree^{-1})	Yield per Hectare (kg ha^{-1})	Yield Efficiency (kg cm^{-2})	Yield per Canopy Volume (kg m^{-3})
Rootstocks	QA	11.75 b*	2.13 b	4070.9 b	0.26 ab	15.64 a
	BA29	17.06 a	3.13 a	5982.8 a	0.30 a	15.24 a
	MC	11.80 b	1.62 c	3098.7 c	0.24 b	15.09 a
Cultivars	Deveci	16.63 a	2.93 a	5591.6 a	0.23 b	12.29 b
	Williams	9.89 b	1.64 b	3133.0 b	0.33 a	21.08 a
	Santa Maria	19.60 a	2.98 a	5685.0 a	0.31 a	12.53 b
	Abate Fetel	8.01 b	1.64 b	3127.0 b	0.19 b	15.40 ab
Years	2020	7.76 b	1.51 b	2877.6 b	0.25 a	17.94 a
	2021	19.30 a	3.08 a	5890.7 a	0.28 a	12.71 b
Significance						
Rootstocks		0.001	0.001	0.001	0.037	0.980
Cultivars		0.001	0.001	0.001	0.001	0.031
Years		0.001	0.001	0.001	0.103	0.026

* Means shown with different letters in the same column are statistically significant.

YTCSA in the research years and YCV in the rootstocks were found to be not significant. Except for those mentioned above, all others were found to be significant. The highest NF was determined in the BA29 rootstock (17.06 pieces tree^{-1}) in terms of rootstocks; ‘Deveci’ and ‘Santa Maria’ cultivars (19.60 and 16.63 pieces tree^{-1}, respectively) in terms of cultivars. In terms of rootstocks, the highest YT, YH, and YTCSA were observed from the BA29 rootstocks (3.13 kg tree^{-1}, 5982.8 kg ha^{-1}, and 0.30 kg cm^{-2}, respectively) and the lowest in the MC rootstock (1.62 kg tree^{-1}, 3098.7 kg ha^{-1} and 0.24 kg cm^{-2}, respectively). In terms of cultivars, the highest YT and YH were determined in the 'Santa Maria' and 'Deveci' cultivars. YCV was higher in the 'Williams' cultivar than the other cultivars (Table 4).

Rootstocks along with the cultivars' effects on the yield per tree, number of fruits per tree, and trunk cross-sectional area reported to be significant in the pear orchards in which the cultivars grafted on quince rootstocks (Ozturk and Faizi, 2022). The highest cumulative yield efficiency was reported in 'Santa Maria'/MC, and the highest cumulative yield was reported in 'Santa Maria'/BA29 and 'Santa Maria'/MC combinations (Ikinci et al., 2014; Ikinci et al., 2016). Cabrera et al. (2015) observed the rootstocks' significant effect on the 'Williams'/Farold40 yield (190 ton ha^{-1}). Pasa et al. (2015) reported that the number of trees per area had a significant effect on the number of fruits per plant, yield, and yield efficiency in the 'Santa Maria'. The highest yield efficiency in the 'Carrick' cultivar on different quince rootstocks was found in Portugal and MC rootstocks (Pasa et al., 2017). Pasa et al. (2020) observed the highest yield per tree (kg tree^{-1}), the number of fruits per tree, and yield efficiency (kg cm^{-2}) in 'Williams' grafted on Champion rootstock. Kucuker and Aglar (2021) reported a yield per plant of 3.80 to 7.60 kg tree^{-1}, a yield efficiency of 2.22 to 2.97 kg cm^{-2} in 'Santa Maria' grafted on QA rootstock. Number and quality of flowers, pollination efficacy, fruit set efficacy, the severity of natural or artificial fruitlet abscission, degree and rate of cellular proliferation and expansion in the persisting fruits, also genetical (scion cultivar and rootstock), environmental (climate and soil) and cultural practices (training, pruning, plant growth regulators, manuring) effect yield of pear trees (Pasa et al., 2012; Ikinci et al., 2016; Bhat et al., 2017; Pasa et al., 2020; Kucuker and Aglar, 2021; Jovanovic et al., 2022). Yield efficiency observed 0.07 to 0.49 kg m^{-3} in 'Santa Maria' combined with two research years, also reported 0.25 kg m^{-3} in QA, 0.22 kg m^{-3} in BA29, and 0.40 kg m^{-3} in the MC rootstock (Ozturk and Faizi, 2022). It can be said that the results obtained from this study are in accordance with previous researchers' findings.

3.5. Pre-harvest fruit drop rate, black spotted fruit rate and marketable fruit rate

Rootstocks, cultivars, and research years' effects on pre-harvest fruit drop rate (PHFDR), black spotted fruit rate (BSFR), and marketable fruit rate (MFR) are illustrated in Figure 1 and Figure 2. Except for BSFR in the rootstocks which were found not significant, all others were found to be statistically significant. The highest MFR was obtained from the QA rootstock and the lowest in the BA29 rootstock in the case of rootstocks. In terms of cultivars, MFR was lower in the 'Deveci' than the others (Figure 1). In terms of rootstocks, BA29 had higher PHFDR than the others. The highest PHFDR was determined in the 'Deveci' and 'Williams', and the lowest in the 'Abate Fetel' cultivars in the case of cultivars. In terms of cultivars, the highest BSFR was found in the 'Deveci' cultivar, and the lowest in the 'Williams' cultivar (Figure 2).

Many factors can cause the pre-harvest fruit drop rate, for example, short periods of high temperatures and water stress before harvest, different species and cultivars of fruit, cultural practices like irrigation, nutrition status of the trees, control of weeds, training system, and pruning affect the level of fruit drop. Ozturk et al. (2015) reported that NAA and AVG applications significantly reduced pre-harvest fruit drop (2.67-35.21%) in 'Breaburn' apple on M26 rootstock. Pre-harvest fruit drop of 'Deveci' on BA29 with the application of 1-Methylcyclopropene reported 1.75 to 26.50 pieces (Sakaldaş and Gündoğdu, 2016). Also, cumulative fruit drop was observed at 1.03 to 59.64% in the 'Scarlet Spur' on M26 rootstock (Unsal et al., 2017). 7.33 to 33.33% in the 'Starkrimson Delicious' on seedlings reported by (Sincan et al., 2020). Black spot is a fungal disease that occurs in moist conditions. Physical control, such as removing the infected fruits and leaves from the garden as well as chemical control can be done to decrease or prevent the disease. Our research garden is located in a flat area and humidity is high due to being close to the Kızılırmak River, which may have also caused to increase the rate of the disease. The severity of disease changes according to the climatic conditions and resistance level of cultivars and rootstocks, but can reach up to 100% in the absence of chemical spraying (Urbanovich and Kazlovskaya, 2008). 'Granny Smith Challenger' on M9 rootstock showed 2.7 to 12.3% of black spotted fruit in Samsun climate conditions (Ozturk et al., 2021). In the study, to determine the number of marketable products in pear fruit in Türkiye, was the first research done. Rootstock, cultivar, and research years were found effective on the amount of marketable yield of pear fruit. Total marketable fruit in three grade quality (extra, class I and II) obtained between 46.07 to 88.03%, while different apple cultivars grafted on M9, MM106, and MM111 rootstocks (Ozdemir et al., 2009). 'Granny Smith Challenger' on M9 rootstock showed 46.73 to 82.23% of extra quality fruit, 6.20 to 35.30% of first quality fruit, and 3.00 to 13.00% of second quality fruit (Ozturk et al., 2021).

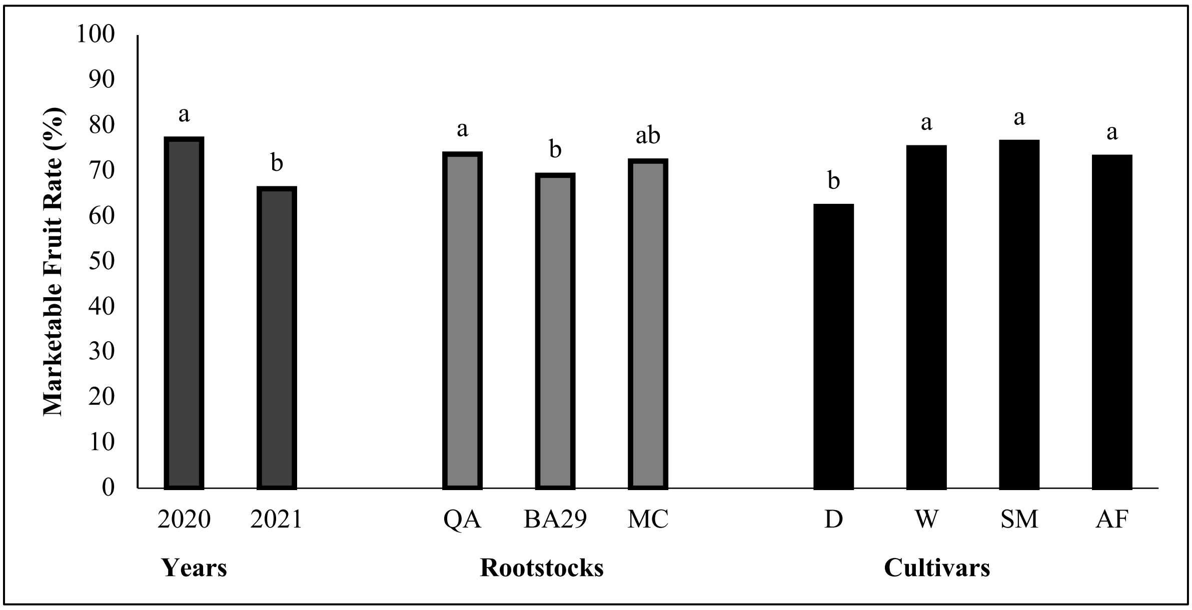

Figure 1. Marketable fruit rate (%) in the research years, rootstocks and cultivars. D= 'Deveci'. W= 'Williams'. SM= 'Santa Maria'. AF= 'Abate Fetel'.

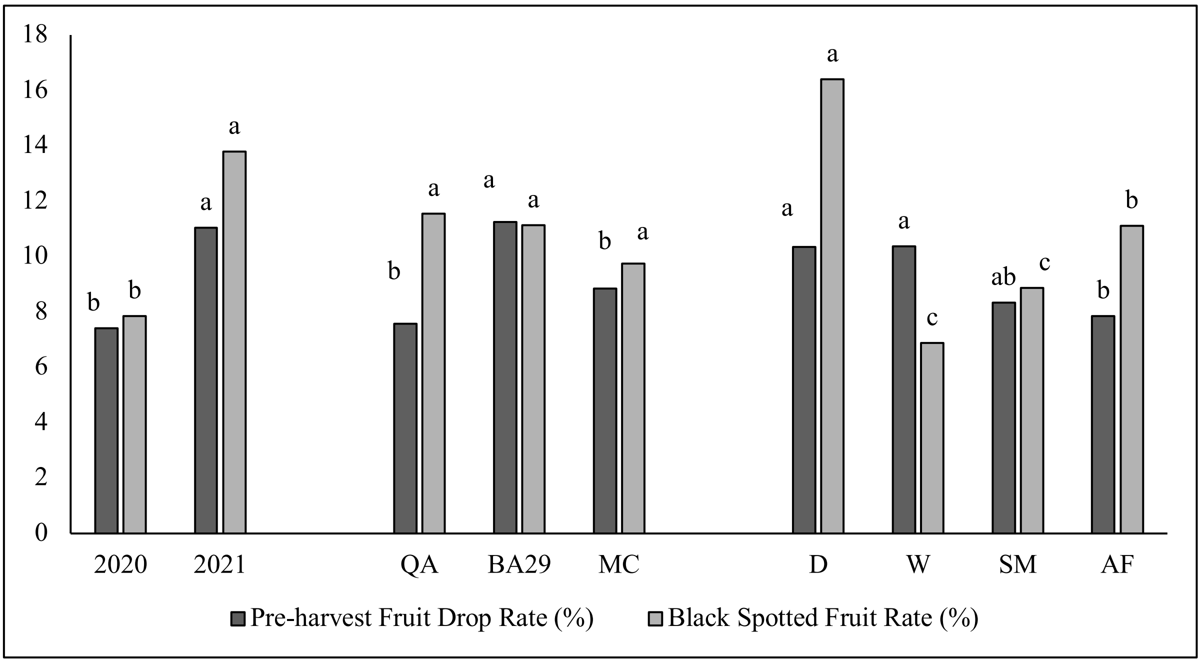

Figure 2. Pre-harvest fruit drop and black spotted fruit rate (%) in two research years, three rootstocks and four cultivars. D= 'Deveci'. W= 'Williams'. SM= 'Santa Maria'. AF= 'Abate Fetel'.

Conclusion

The highest yield and marketable fruit rate were obtained from the 'Santa Maria' cultivar and yield from BA29 rootstock. It could be said that early ripening cultivars are more suitable in regions with high relative humidity for better quality performances especially free of diseased fruit. And such cultivars are less prone to the adverse abiotic stress factors like water shortage in the summer season. Briefly, It could be suggested that semi-dwarf cultivars and rootstocks for suitably perform under high density pear orchards. For precise results, it is recommended that the research could be continued for a longer period of time as the used trees were young.

Acknowledgements

We would like to thank the support unit of Ondokuz Mayıs University Scientific Research Projects (OMU-BAP) for supporting this project (PYO.ZRT.1904.20.007).

Interest Conflict

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

Contributions of the Authors

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

References

Askari, K. 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

Bhat, R., Hussain, S., Sharma, M. K., & Singh, A. (2017). Effect of Growth Regulators on Growth, Yield and Quality of Pear cv. Carmen under high density planting. Division of Fruit Science, Sher-e-Kashmir University, Kashmir, India.

Cabrera, D., Rodriguez, P., & Zoppolo, R. (2015). Evaluation of Quince and Selected 'Farold®' Pear Rootstocks for Commercial 'Williams B.C.' Production in Uruguay. *Acta Hort., 1094,* 159-162. doi:10.17660/ActaHortic.2015.1094.19

Erdem, H., & Ozturk, B. (2012). Yapraktan uygulanan çinko'nun BA29 anacı üzerine aşılı armut çeşitlerinin verimi, mineral element içeriği ve biyokimyasal özellikleri üzerine etkisi. *Süleyman Demirel Üniversitesi Ziraat Fakültesi Dergisi,* 7 (1), 93-106.

FAO. (2023). *World pear production list*. https://www.fao.org/faostat/en/#data/QCL. Access date: 15 May 2023.

Francescatto, P., Pazzin, D., Gazolla, N. A., Fachinello, J., & Giacobbo, C. (2010). Evaluation of graft compatibility between quince rootstocks and pear scions. *Acta Horti*, *872,* 253-260. doi:10.17660/ActaHortic.2010.872.34

Ikinci, A., Bolat, I., Ercisli, S., & Kodad, O. (2014). Influence of rootstocks on growth, yield, fruit quality and leaf mineral element contents of pear cv. Santa Maria in semi-arid conditions. *Biological Research*, *47 (1),* 1-8. doi:10.1186/0717-6287-47-71

Ikinci, A., Bolat, İ., Ercisli, S., & Esitken, A. (2016). Response of Yield, Growth and Iron Deficiency Chlorosis of 'Santa Maria' Pear Trees on Four Rootstocks. *Not Bot Horti. Agrobo*, *44 (2),* 563-567. doi:10.15835/nbha44210501

Ikinci, A. (2017). The Effect of Different Pear Rootstocks on the Performance of Pear Cultivars Grown in Semi-Arid Climate and High Calcareous Soil Conditions. *Asian Journal of Soil Science and Plant Nutrition*, *2 (1),* 1-8.

Jovanovic, M., Milosevic, T., Milošević, N., Ercişli, S., Glišić, I., Paunović, G., & Ilić, R. (2022). Tree Growth, Productivity, and Fruit Quality Attributes of Pear Grown Under a High-Density Planting System on Heavy Soil. A Case Study. *Erwerbs-Obstbau*, 1-10. doi:10.1007/s10341-022-00671-0

Kucuker, E., Ozturk, B., Ozkan, Y., & Yıldız, K. (2015). Yapraktan Üre Uygulamasının Farklı Armut (*Pyrus communıs* L.) Çeşitlerinde Verim, Meyve Kalitesi ve Bioaktif Bileşikler Üzerine Etkisi. *Niğde Üniversitesi Mühendislik Bilimleri Dergisi*, *4 (2),* 78-86.

Kucuker, E., & Aglar, E. (2021). The Effect of the Different Training Systems on Yield and Vegetative Growth of 'Santa Maria' and 'Deveci' Pear Cultivars. *Yuzuncu Yil University Journal of Agricultural Sciences, 31, (4),* 870-875. doi:10.29133/yyutbd.940463

Kellecioglu, K. (2014). *Bursa koşullarında yetiştirilen Santa Maria armut çeşidinin hasat olgunluk zamanın saptanması*. (Yüksek Lisans Tezi) Çanakkale Onsekiz Mart Üniversitesi, Fen Bilimler Enstitüsü. Çanakkale, Türkiye.

Ladaniya, M. S., Marathe, R. A., Das, A. K., Rao, C. N., Huchche, A. D., Shirgure, P. S., & Murkute, A. A. (2020). High density planting studies in acid lime (*Citrus aurantifolia* Swingle). *Scientia Hortic., 261,* 108935. doi:10.1016/j.scienta.2019.108935

Ladaniya, M. S., Marathe, R. A., Murkute, A. A., Huchche, A. D., Das, A. K., George, A., Kolwadkar, J. (2021). Response of Nagpur mandarin (*Citrus reticulata* Blanco) to high density planting systems. *Scientific Reports, 11 (1),* 1-11. doi:10.1038/s41598-021-89221-4.

Lepaja, L., Kullaj, E., Lepaja, K., Shehaj, M., Zajmi, A. (2014). Fruit Quality Parameters of Five Pear Cultivars in Western Kosovo. *Agriculture & Food*, *2,* 245-250.

Musacchi, S., Iglesias, I., & Neri, D. (2021). Training systems and sustainable orchard management for European pear (*Pyrus communis* L.) in the Mediterranean area: A review. *Agronomy, 11 (9),* 1765.

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, B., Özkan, Y., Kılıç, K., Uçar, M., Karakaya, O., Karakaya, M. (2015). Braeburn Elmasının (*Malus domestica* Borkh.) Hasat Önü Dökümü ve Meyve Kalitesi Üzerine Hasat Öncesi Bitki Gelişim Düzenleyici Uygulamalarının Etkisi. *Journal of Agricultural Faculty of Gaziosmanpaşa University (JAFAG) , 32 (1) ,* 68-76 . doi:10.13002/jafag808

Ozturk, A., Demirsoy, L., & Demirel, G. (2016). Seçilmiş Bazı Armut Genotiplerinin Samsun Ekolojisindeki Fenolojik Özelliklerinin Belirlenmesi. Bahçe, 45 (1), 1084-1089.

Ozturk, A., Aydın, E., Öztürk, B.. & Ağlar, E. (2021). The effect of protective netting on fruit diameter, quality classification black spotted and discoloring fruit ratios of 'Granny Smith Challenger'. *Journal of Postharvest Technology, 9 (4),* 59-66.

Ozturk, A., Faizi, Z. A., & Kurt, T. (2022). Performance of Some Standard Quince Varieties under Ecological Conditions of Bafra, Samsun. *Yuzuncu Yıl University Journal of Agricultural Sciences*, *32 (2),* 320-330. doi:10.29133/yyutbd.1058908

Ozturk, A., & Faizi, Z.A. (2022). Comparative Evaluation of Pear Performances Under High- and Low-Density Planting Systems cv. 'Santa Maria'. Erwerbs-Obstbau. 1-10. Doi:10.1007/s10341-022-00741-3

Ozdemir, A. E., Dilbaz, R., & Kaplan, A. (2009). Niğde İlinde Modern Elma Yetiştiriciliğinin Bir Örneği. *International Journal of Agricultural and Natural Sciences*, *2 (1),* 169-175.

Pasa, M. D. S., Fachinello, J. C., Schmitz, J. D., Souza, A. L. K. D., Franceschi, É. D. (2012). Desenvolvimento, produtividade e qualidade de peras sobre porta-enxertos de marmeleiro e *Pyrus calleryana*. *Revista Brasileira de Fruticultura*, *34 (3),* 873-880. doi:10.1590/S0100-29452012000300029

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. doi:10.1590/S0100-204X2015000200004

Pasa, M. S., Silva, C. P., Carra, B., Brighenti, A. F., Souza, A. L. K., Schmitz, J. D., Katsurayama, J. M., & Ciotta, M. N. (2017). Fruit set and yield of 'Santa Maria' and 'Abate Fetel' pears are increased by early spring application of aminoethoxyvinilglycine (AVG). *Revista de Ciências Agroveterinárias, Lages*, *16 (4),* 487-491.

Pasa, M. D. S., Schmitz, J. D., Rosa, J. D., Souza, A. L. K. D., Malgarim, M. B., & Mello-Farias, P. C. D. (2020). Performance of 'Williams' pear grafted onto three rootstocks. *Revista Ceres, 67,* 133-136. doi:10.1590/0034-737X202067020006

Poornima, M. H., Gopali, J. B., Athani, S. I., Venkateshalu, P. S., & Suvarna, P. (2018). Impact of ultra-high density, high density and conventional planting systems on major insect pests of mango. J. *Entomol. Zool. Stud*, *6,* 292-297.

Sakaldaş, M. (2016). *'Deveci' Armut Çeşidinde Hasat Öncesi 1- Methylcyclopropene (Harvista) Uygulamalarının Meyve Dökümü Ve Olgunlaşmaya Etkileri*. Meyve Bilimi, *1,* 105-111.

Sincan, T., Yıldırım, A. N., Çelik, C., & Bayar, B. (2020). 'Starkrimson Delicious' Elma Çeşidinde Metil Jasmonat (Meja) ve Aminoethoksivinilglisin (AVG) Uygulamalarının Hasat Önü Dökümü ve Meyve Kalitesi Üzerine Etkileri. *Isparta Uygulamalı Bilimler Üniversitesi Ziraat Fakültesi Dergisi, 15 (1),* 41-55.

TSI. (2023). Turkish Statistical Institute. https://biruni.tuik.gov.tr/medas/?locale=tr. Accessed: 15 May 2023.

TSMS. (2022). Turkish state meteorological service. https://www.mgm.gov.tr/tahmin /il-ve-ilceler.aspx?m=SAMSUN#/. Accessed: 25 May 2022.

Uysal, E., Sağlam, M. T., & Büyükyılmaz, M. (2016). Deveci armut çeşidinde farklı azot uygulamalarının verim ve bazı kalite özellikleri üzerine etkisi. *Bache, 44 (1),* 1-13.

Unsal, Y. E., & Yıldırım, A. N. (2017). 'Scarlet Spur' Elma Çeşidinde Aminoethoksivinilglisin (AVG) Uygulamalarının Hasat Önü Dökümü ve Meyve Kalitesi Üzerine Etkileri. *Isparta Uygulamalı Bilimler Üniversitesi Ziraat Fakültesi Dergisi, 12 (2),* 55-65.

Urbanovich, O., & Kazlovskaya, Z. (2008). Identification of Scab Resistance Genes in Apple Trees by Molecular Markers. *Scientific Works of the Lithuanian Institute of Horticulture and Lithuanian University of Agriculture. Sodininkyste Ir Daržininkyste. 27 (2),* 347-357.

Zhang, J., Serra, S., Leisso, R. S., & Musacchi, S. (2016). Effect of light microclimate on the quality of 'd'Anjou' pears in mature open center tree architecture. *Biosystems engineering*, *141,* 1-11. doi:10.1016/j.biosystemseng.2015.11.002