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Growth characteristics, yield, and fruit quality of the Asian pear genotypes (*Pyrus serotina* Rehd.) in climatic conditions of Isfahan- Iran

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ABSTRACT

Purpose: Selection and evaluation of imported cultivars is one of the main programs for the breeding of fruit trees, including pears. Comparison of quantitative and qualitative traits of imported cultivars and genotypes with available cultivars of each region is necessary to obtain superior cultivars and introduce them to producers. **Research method:** In this study, the growth and yield of 10 introduced Asian pear genotypes named Ks6, Ks7, Ks8, Ks9, Ks10, Ks12, Ks13 and Ks14 along with two European pear cultivars named 'Shahmiveh' and 'Spadona' as controls grafting on 'Dargazi' seedling rootstock were studied during five years (2015-2019) in the climatic conditions of Isfahan (Iran). **Findings:** The highest rootstock, grafting, and scion diameter as well as the highest tree height were observed in 'Shahmiveh' and 'Espadona' cultivars. Ks8 and Ks9 had the lowest rootstock and grafting diameter and Ks10 showed the lowest scion diameter and tree height. Two European pear cultivars, 'Shahmiveh' and 'Espadona', had lower yield and yield efficiency than Asian genotypes. The highest yield and yield efficiency belonged to Ks13 and Ks8, respectively. 'Shahmiveh' and Ks9 had the highest and lowest fruit dimensions, respectively. European cultivars had higher TSS than Asian genotypes. The highest and the lowest fruit firmness were observed in Ks13 and 'Shahmiveh', respectively. **Research limitations:** No limitations were found. **Originality/Value:** In general, Ks13 and Ks8 are recommended for cultivation and expansion in the climatic conditions of Isfahan due to their good yield and taste index.

INTRODUCTION

The wide range of temperatures and specific climatic conditions in Iran creates potential features for the fruit industry in terms of culture and producing the high quality of different fruit crops. In addition, there is good potential for the establishment of orchards with newly introduced fruit species in suitable areas (Arzani, 2021). The pear is one of the most important fruit trees that has been cultivated in Europe and Asia for at least two to three thousand years. This tree is grown commercially in more than 50 countries in temperate regions (Wolko et al., 2010). Pears belong to the genus *Pyrus*, subfamily Maloidae and family Rosaceae (Katayama et al., 2016). In the genus pear (*Pyrus spp*.), there are at least 22 species, six inter-specific hybrids, and three artificial hybrids. All pear species are native to Europe, temperate regions of Asia, and the mountainous regions of North Africa (Abdollahi, 2015). In addition, Iran has been reported as a important region along the silk road for gene flow and is rich in pear germplasm (Kadkhodaei et al., 2021). Species of European pear (*Pyrus communis* L.), Japanese (*Pyrus pyrifolia* Nakai) and Chinese (*Pyrus ussuriensis* Maxim.) as well as *Pyrus bretschneideri* Rehd. are edible and are used for fruit production (Yamamoto et al., 2014).

The asian pear (*Pyrus serotina* Rehd.) is a large group of pears that originated in East Asia. Most of them have a round shape and others, such as European pears (*Pyrus communis* L.), are pyriform. Although the most common skin color of the fruit is golden brown, they are also observed in green, yellow, and orange colors. These fruits are also known as Chinese and Japanese pears (Shang & Chen, 2003).

Some Asian pear genotypes have been introduced to Iran from Belgium by the Department of Horticultural Sciences of Tarbiat Modares University (Arzani, 2002). The names of the imported scions were not known. Therefore, nine imported Asian pear genotypes were named Ks7, Ks8, Ks9, Ks10, Ks11, Ks12, Ks13, and Ks14. After the quarantine period, research on these seedlings was conducted in various fields, including regional adaptations. One of the important characteristics of imported Asian pear genotypes is the differences in shape, size, color, crispness, aroma, taste, and flavor of the fruit. Based on the results of observations, the ripening time of imported genotypes in three genotypes is late July to August, four genotypes in September, and two genotypes in December (Arzani, 2007). Asian pear genotypes differ in self-pollination (Koushesh-Saba et al., 2007), fruit development (Kashefi et al., 2008), and storage capacity. Some genotypes such as Ks8 have a long shelf life and some of them, such as Ks9 and Ks13, need harvesting at a specific time and special care after harvest (Arzani, 2007).

Factors such as total soluble solids (TSS), titratable acid (TA), and fruit firmness determine the quality of Asian pear fruit (Childers et al., 1995). The fruit firmness of Asian pear cultivars was 8-11 pounds per kilogram and TSS was between 11 to 14%, depending on the cultivar (Childers et al., 1995).

In a study conducted by Arzani et al. (2008) on two Asian pear genotypes and one European pear cultivar, the physic-chemical properties of the fruit such as sugars, organic compounds, TSS, TA, firmness, the fresh and dry weight as well as the color of the fruit were discussed. Elshihy et al. (2004) examined the characteristics of six Syrian pear genotypes, such as fruit ripening time, fruit shape and size, fruit skin color, and seed size and weight. In a study in Lithuania, the weight, and quality traits of 18 pear cultivars were evaluated for 6 years. Cultivars showed great diversity in the studied traits. The highest fruit weight, with 292 g, was obtained from the Tavricheskaya cultivar (Lace & Lacis, 2015).

Due to the existence of imported pear genotypes and the increasing demand for cultivating new cultivars with high yields, it is necessary to carry out research to compare the quantitative and qualitative traits of these genotypes with the dominant cultivars of the region to select suitable cultivars and introduce them to producers. This study aimed to investigate the effect of genotype on grafting success, growth, and size of seedlings, amount and quality of yield, and also to investigate the climate compatibility of Asian pear genotypes with the central region of Iran.

MATERIALS AND METHODS

Plant materials

In this study, nine Asian pear genotypes named Ks6, Ks7, Ks8, Ks9, Ks10, Ks12, Ks13, and Ks14 (Arzani, 2002a; Arzani, 2002b; Arzani, 2005; Arzani, 2021) along with 'Shahmiveh' and 'Spadona' cultivars as controls were evaluated in the Isfahan Agricultural Research Station, Iran. These pear genotypes, after grafting on 'Dargazi' seedling rootstock in March 2011, were transferred to the orchard.

Measurement of traits

Before the trees begin to bear fruit and after leaf abscission, vegetative traits include rootstock diameter at a distance of 5 cm below the grafting site, grafting site diameter, and scion diameter at a distance of 10 cm above the grafting site, tree height and annual growth of branches were evaluated. Longitudinal and diameter growth of trees were measured with meters and calipers, respectively. At the reproductive stage in 2017, quantitative and qualitative characteristics of fruit, including the yield of each tree, yield efficiency, fruit weight, and dimensions, TSS, TA, taste index, fruit length/fruit width, and fruit firmness were studied. Harvest time, uniformity, skin color, and taste of fruit were also recorded in different genotypes.

The weight of the fruit was measured using a balance (electronic balance usually to 2 decimal places). The total fruit weight of each tree was considered as the yield. The yield efficiency is expressed in kg/cm^2 of the trunk cross sectional area (TCSA).

Fruit firmness was measured by a penetrometer (model EFFEGI, Italy, plunger diameter 11.1 mm, depth 7.9 mm), at opposite peeled sides, and expressed as Kg/cm^2. Total soluble solids (TSS) were determined using a digital refractometer (ATAGO N-1α, Japan) at 22°C. Titrable acids (TA) were determined in 10 g of pulp samples by titration of extracted juice with sodium hydroxide (0.1 N) up to pH 8.1 and expressed as a percent of malic acid. The taste index was calculated from the TSS to TA ratio.

Experimental design

The experiment was conducted as a combined analysis in a randomized complete block design with three replications from 2015 to 2019 for 5 years. Each block consisted of 10 experimental plots and 6 trees were planted in each plot. Data was analyzed using SAS software (version 9.1) and the means were compared with the LSD test at a probability level of 5%.

RESULTS

Vegetative traits

Analysis of variance of vegetative traits in different Asian pear genotypes from 2015 to 2019 is shown in Table 1. According to the results, all measured vegetative traits have increased since 2015 and reached the highest value in 2019. There was no significant difference in tree height and annual growth of branch traits between 2018 and 2019 (Table 2).
The highest rootstock diameter belongs to 'Spadona' (7.47 cm), followed by 'Shahmiveh' (6.85 cm) and the lowest values of this trait were observed in Ks9 (5.79 cm) and Ks10 (5.97 cm)

genotypes. 'Spadona' and then 'Shahmiveh' showed the highest grafting site diameter with averages of 8.43 and 7.47 cm, respectively. Ks9 (6.28 cm) and Ks10 (6.44 cm) genotypes had the lowest grafting site diameter. Similarly, 'Spadona' had the highest scion diameter with an average of 7.68 cm, followed by 'Shahmiveh' (7.16 cm). The lowest scion diameter belonged to the Ks8 genotype (5.01 cm) (Table 3).

'Spadona' had the highest tree height (322.6 cm) and Ks8 (182.33 cm) and Ks7 (190.4 cm) had the lowest tree height. The highest annual growth of the branch belonged to the Ks12 genotype (50.98 cm) and the lowest of this trait was related to the Ks9 genotype (33.59 cm) (Table 3).

According to the results of Table 4, the Ks12 genotype had the highest annual growth of branch (65.33 cm) in 2019. The lowest rate of this trait was related to 'Shahmiveh' (17.33 cm) in 2015.

Table 1. Analysis of variance for the effect of year and genotype on vegetative characteristics of pear trees

S.O.V.	df	Mean square				
		Rootstock diameter	Grafting site diameter	Scion diameter	Tree height	Annual growth
Year	4	80.34**	102.24**	113.69**	14870.42**	3886.27**
Rep (year)	10	1.85	0.33	0.66	379.79	28.73
Genotype	9	3.23**	5.76**	9.27**	23982.78**	312.09**
Year×genotype	36	0.12ns	0.31ns	0.33ns	755.61ns	82.33**
Erorr	90	0.41	0.32	0.35	535.88	36.83
Corrected total	149	-	-	-	-	-
C.V.	-	9.84	8.13	9.41	10.87	14.85

**,* and ns: Significant at the 1% and 5% probability level and non-significant difference respectively

Table 2. Mean comparison for the effect of year on vegetative traits of different Asian pear genotypes in 2015-2019

Year	Rootstock diameter (cm)	Grafting site diameter (cm)	Scion diameter (cm)	Height of the tree (cm)	Annual growth of branch (cm)
2015	4.6d	4.84e	4.08e	182d	24.83d
2016	5.35d	5.59d	4.77d	197.66c	32.96c
2017	6.46c	7.17c	6.45c	224b	46.66b
2018	7.54b	8.2b	7.61b	225.2ab	49.21ab
2019	8.67a	9.35a	8.78a	235.7a	50.64a

Similar letters in each column indicate no significant difference at the 5% level of LSD

Table 3. Mean comparison for the effect of genotype on vegetative traits of Asian pears in 2015-2019

Genotype and cultivar	Rootstock diameter (cm)	Grafting site diameter (cm)	Scion diameter (cm)	Height of the tree (cm)	Annual growth of branch (cm)
Ks6	6.43d	6.88cd	6.16c	215.6b	37.83bc
Ks7	6.38d	6.48de	6.32c	190.4cd	37.32bc
Ks8	6.77bc	7.24bc	5.01e	182.3d	40.02bc
Ks9	5.79e	6.28e	5.64d	193.2bcd	33.59c
Ks10	5.97e	6.44e	5.96cd	194.4bcd	40.47bc
Ks12	6.57cd	7.14bc	7.12b	206.8bc	50.98a
Ks13	6.46d	6.94c	6.15c	209.3bc	41.96b
Ks14	6.53cd	7.01c	6.19c	212.9bc	42.32b
Spadona	7.47a	8.43a	7.68a	322.6a	43.33b
Shahmiveh	6.85b	7.47b	7.16b	201.4bcd	40.76bc

Similar letters in each column indicate no significant difference at the 5% level of LSD

Table 4. Mean comparison for the effect of genotype and year on the annual growth of branch in Asian pears in 2015-2019

Year	Genotype and cultivar	Annual growth of branch (cm)	Year	Genotype and cultivar	Annual growth of branch (cm)	Year	Genotype and cultivar	Annual growth of branch (cm)
2015	Spadona	18w	2016	Ks8	35.66m-s	2018	Ks14	54.8b-e
2015	Ks10	25t-w	2016	Ks9	27.33s-v	2018	Ks6	40.4i-o
2015	Ks12	31.66p-t	2016	Shahmiveh	29.66r-u	2018	Ks7	41.73h-n
2015	Ks13	31.33q-t	2017	Spadona	51.66c-g	2018	Ks8	47.46e-j
2015	Ks14	21.66vvm	2017	Ks10	48.63d-i	2018	Ks9	41.2h-n
2015	Ks6	31q-t	2017	Ks12	56.16a-d	2018	Shahmiveh	52.7c-f
2015	Ks7	27.66s-v	2017	Ks13	44.16g-l	2019	Spadona	63ab
2015	Ks8	24.66t-w	2017	Ks14	47.5e-j	2019	Ks10	45f-l
2015	Ks9	20vw	2017	Ks6	40.03j-p	2019	Ks12	65.33a
2015	Shahmiveh	17.33w	2017	Ks7	42.86h-m	2019	Ks13	52c-g
2016	Spadona	27.66s-v	2017	Ks8	45f-l	2019	Ks14	58abc
2016	Ks10	34.33n-s	2017	Ks9	41.1h-n	2019	Ks6	40.73i-o
2016	Ks12	40.33i-o	2017	Shahmiveh	49.46d-h	2019	Ks7	42h-n
2016	Ks13	35.66m-s	2018	Spadona	56.33a-d	2019	Ks8	47.33e-j
2016	Ks14	29.66r-u	2018	Ks10	49.4d-h	2019	Ks9	38.33k-q
2016	Ks6	37l-r	2018	Ks12	61.4ab	2019	Shahmiveh	54.66b-e
2016	Ks7	32.33o-t	2018	Ks13	46.66e-k			

Similar letters in each column indicate no significant difference at the 5% level of LSD

Table 5. Analysis of variance for effect of year and genotype on reproductive characteristics

S.O.V.	df	Mean square									
		Tree yield	Yield efficiency	Fruit weight	Fruit length	Fruit width	Fruit length/Fruit width	TSS	TA	TSS/TA	Firmness
Year	2	2061.90**	0.39**	30.00**	0.30**	0.27**	0.00006ns	0.70ns	0.007**	106.71**	1.20**
Rep (year)	6	1.35	0.005	250.13	2.50	2.25	0.0005	0.40	0.002	1.26	10.00
Genotype	9	71.01**	0.12**	10721.56**	17.33**	2.31**	0.42**	5.02**	0.007**	114.78**	10.51**
genotype×Year	18	7.41ns	0.006ns	0.0008**	0.0003ns	0.0005**	0.00008**	0.0001ns	0.00004**	0.17ns	0.00006ns
Erorr	54	5.70	0.003	0.13	0.0008	0.008	0.0007	0.40	0.0001	4.30	0.0005
Corrected total	89	-	-	-	-	-	-	-	-	-	-
C.V.	-	16.68	20.37	0.31	0.58	1.8	2.79	3.74	3.02	5.11	4.25

Table 6. Average comparison for the effect of year on the tree yield and yield efficiency in Asian pears in 2017-2019

Year	Tree yield (kg)	Yield efficiency (kg/cm^2)
2017	5.36c	0.17b
2018	15.85b	0.37a
2019	21.72a	0.37a

Similar letters in each column indicate no significant difference at the 5% level of LSD

Reproductive traits

Analysis of variance of reproductive traits in different Asian pear genotypes from 2017 to 2019 is shown in Table 5.

The trend of tree yield and yield efficiency increased over time. The highest tree yield was achieved in 2019 with an average of 21.72 kg. There was no significant difference between these two traits between 2018 and 2019 (Table 6).

The Ks13 genotype had the highest yield with an average of 17.85 kg and did not show a significant difference between Ks7, Ks8, Ks9, and Ks10 genotypes. 'Shahmiveh' and

'Spadana' cultivars with averages of 9.53 and 10.29 kg, respectively had the lowest yield compared to Asian pear genotypes (Fig. 1).

The Ks8 genotype with an average of 0.55 kg/cm^2 had the highest yield efficiency. The lowest value of this trait belonged to 'Shahmiveh' and 'Spadona' cultivars, with a similar average of 0.16 kg/cm^2 (Fig. 2).

The highest fruit weight (196 g) and fruit length (8.3 cm) belonged to the 'Shahmiveh' cultivar. The lowest values of these two traits were related to the Ks9 genotype, with averages of 77 g and 3.7 cm, respectively. 'Shahmiveh' and 'Spadana' had higher fruit weight and fruit length than the Asian pear genotypes. Ks14 genotype had the highest fruit width (5.8 cm), while Ks9 genotype (4.3 cm) had the lowest value for this trait. 'Shahmiveh' cultivar and Ks12 genotype had the highest and the lowest fruit length/fruit width, respectively (Table 7).

'Shahmiveh' and 'Spadana' had similarly the highest fruit TSS (18.03%). Asian pear genotypes had lower TSS than these two European pear cultivars. The highest and lowest TA were observed in Ks12 (0.48%) and Ks8 (0.37%) genotypes, respectively. The highest taste index belonged to 'Shahmiveh', Ks6, and Ks14 genotypes. The Ks8 genotype had the lowest taste index.

The Ks13 and Ks14 genotypes similarly showed the highest fruit firmness, with an average of 6.5 kg/cm^2. European cultivars, especially 'Shahmiveh' (3.2 kg/cm^2) had the lowest fruit firmness.

Based on observations, none of the incompatibility symptoms were observed in the studied genotypes and cultivars.

In table 8, some fruit qualitative traits of Asian pear genotypes were shown during 2017-2019. In this table, the approximate ripening time of these genotypes is mentioned. The ripening time in the studied genotypes showed differences so that the ripening time varied from mid-August in Ks10 to mid-September in Ks13, Ks14, and 'Spadona'. All genotypes and cultivars produce uniform and almost uniform fruits. The fruit skin color was different in genotypes and it was observed in yellow, orange, and green. According to the panel test, first 'Shahmiveh' and then Ks8, Ks9, Ks10, Ks12, Ks13, and 'Spadona' had better taste and flavor.

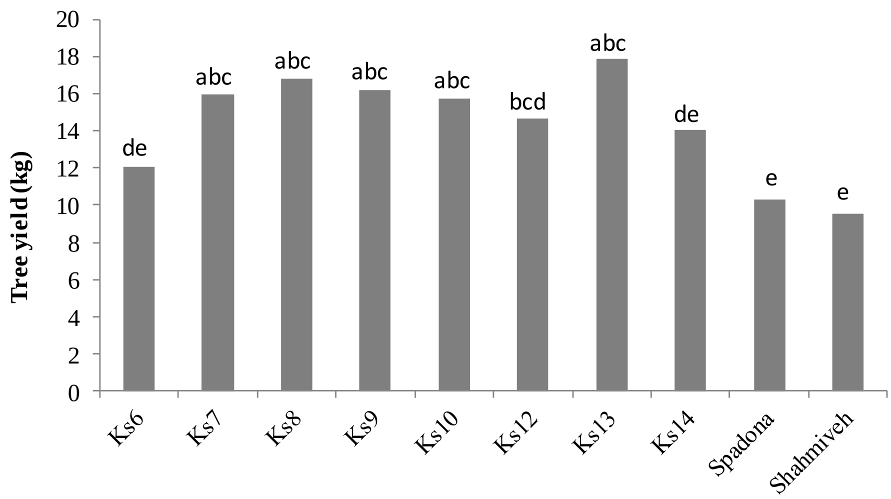

Fig. 1. Mean comparison of the effect of pear genotypes and cultivars on tree yield in 2017-2019.

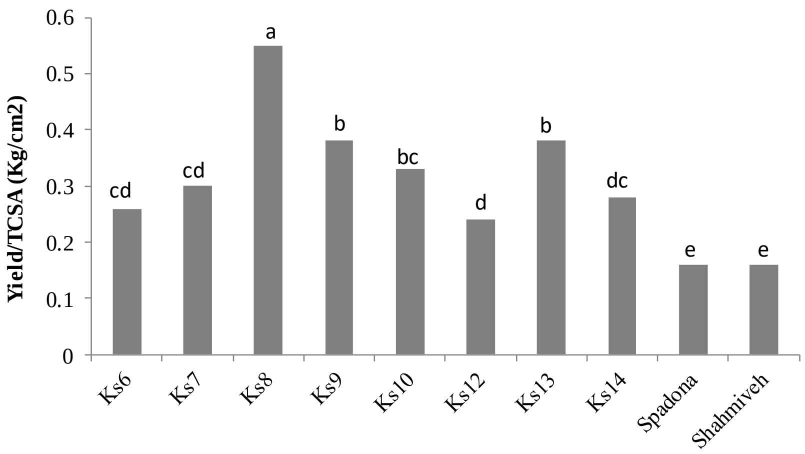

Fig. 2. Mean comparison of the effect of pear genotypes and cultivars on yield efficiency in 2017-2019.

Table 7. Mean comparison for the effect of genotype on fruit traits of Asian pear in 2017-2019

Genotype and cultivar	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Fruit length/Fruit width	TSS (%)	TA (%)	TSS/TA	Firmness (Kg/cm^2)
KS6	116d	3.8i	4.67g	1.29b	16.53c	0.41d	44.38a	5.3d
KS7	103f	4.5g	5.18d	0.95c	16.03d	0.40e	39.95b	6.5a
KS8	89i	4.6f	5.03f	0.96c	17.03b	0.37f	32.95c	5.5c
KS9	77j	3.7j	4.3i	0.84de	16.03d	0.40e	39.03b	5.5c
KS10	101g	4.4h	4.6h	0.86de	17.03b	0.42c	40.91b	6b
KS12	109e	5.1c	5.3c	0.81e	16.03d	0.48a	39.86b	6b
KS13	120c	4.8e	5.7b	0.86de	17.03b	0.43b	39.45b	6.5a
KS14	100.33h	5d	5.8a	0.91cd	17.03b	0.41d	45.27a	6.5a
Spadona	153b	6.6b	5.1e	0.85de	18.03a	0.40e	39.61b	4.2e
Shahmiveh	196a	8.3a	5.7b	1.45a	18.03a	0.40e	44.38a	3.2f

Similar letters in each column indicate no significant difference at the 5% level of LSD

Table 8. Study of fruit qualitative characteristics of pear genotypes and cultivars in 2017-2019

Genotype and cultivar	Harvesting time	Fruit uniformity	Fruit skin color	Fruit taste
KS6	Early September	Uniform	Yellow	Sweet - little aroma
KS7	Late August	Almost uniform	Light yellow	Sweet - little aroma
KS8	Late August	Uniform	Orange	Sweet
KS9	Late August	Uniform	Yellow	Sweet
KS10	Mid-August	Uniform	Light yellow	Sweet
KS12	Late August	Uniform	Light green	Sweet
KS13	Mid-September	Almost uniform	Dark yellow to orange	Sweet
KS14	Mid-September	Uniform	Orange	Sweet - little aroma
Spadona	Mid-September	Almost uniform	Light green	Sweet
Shahmiveh	Early September	Uniform	Yellow	Sweet and fragrant

DISCUSSION

All measured vegetative traits increased over time and reached maximum amounts in 2019. Naturally, after the establishment of the tree in the soil and with the increasing age of trees, the roots develop and the rate of vegetative growth increases with the active absorption of nutrients. There was no significant difference between tree height and annual growth of branch traits in 2018 and 2019 (Table 2). It seems that the lack of significant differences was due to competition between vegetative and reproductive growth, which was also due to the fruiting of trees in those years (Faust, 1989).

The highest rootstock, grafting site, and scion diameter belonged to 'Spadona' and then 'Shahmiveh'. The Ks9 and Ks10 genotypes had the lowest rootstock and grafting site diameter. The least scion diameter was related to the Ks8 genotype (Table 3). In a study, the highest and the lowest trunk diameter were observed in 'Red Bartlett' and 'Nart' with an average of 2.8 and 4 cm, respectively. 'Shahmiveh' with a trunk diameter of 3.95 cm had a higher trunk diameter than most studied cultivars (Henareh & Hasani, 2019), which is similar to the results of this study.

'Spadona' had the highest tree height and the Ks8 and Ks7 genotypes had the lowest tree height. Similarly, Rasouli and Arzani (2012) introduced the Ks7 genotype as a genotype with the lowest height among different Asian pear genotypes in the Tehran climate. Tree height is affected by soil, climate, cultivar, and rootstock (Wertheim, 2000). In the study on European pears, the lowest and highest heights of eight-year-old trees were related to 'Red Bartlett' and 'Williams' with the average height of 1.9 and 2.4 m, respectively (Henareh & Hasani, 2019), which were lower compared to European pears studied in the present study.

The highest and the lowest annual growth of branches belonged to Ks12 and Ks9 genotypes with averages of 50.98 and 33.59 cm, respectively (Table 3). Grafting results of some Asian cultivars on European pears showed that Xue Hau-Li and Gout cultivars had the highest and lowest growth lengths, respectively (Stanica, 2002). Elshihy et al. (2004) showed that the length of the annual branch of pear varied among different genotypes. In their experiments, the highest and the lowest amounts of this trait were 40 and 18 cm, which had a smaller range than the current research. Khoshghalb (2001) also observed the differences in the branch length of different Asian pear genotypes. Henareh and Hasani (2019) studied some European pear cultivars. They observed the lowest annual growth of the branch in 'Red bartlett' (45.8 cm) and the highest of it in 'Packham's triumph', 'Nart' and ' Williams' (62 cm), which was more than the annual growth range of the branch in the present study.

The Ks12 genotype had the highest annual growth of the branch in 2019. The lowest annual growth of the branch was related to 'Shahmiveh' in 2015 (Table 4). In the study conducted by Arzani and Khoshghalb (2009), the highest vegetative growth of the scion belonged to Ks12 and the lowest of them was related to 'Shahmiveh' and Ks14. According to their results, 'Shahmiveh' had better growth in the first year, but Asian genotypes grew better than 'Shahmiveh' in the following years. In the present study, 'Shahmiveh' also had lower annual growth than other cultivars and genotypes in 2015. It has been reported that in addition to the genetic structure of the scion, other different factors are involved in the vegetative growth of different pear cultivars, including rootstock, soil, and climatic conditions (Wertheim, 2000).

Tree yield and yield efficiency increased over time, but no significant difference was observed in the values of these two traits in 2018 and 2019 (Table 6). In a study by Henareh and Hasani (2019), yields increased with the increasing age of trees, although this increase was not significant from the second year of the reproductive phase to the third year. An increasing trend in yield efficiency was also observed by Dehghani et al. (2013).

Ks13 genotype showed the highest yield and 'Shahmiveh', as well as 'Spadana' showed the lowest of this trait (Fig. 1). Similarly, Dehghani et al. (2013) reported that the Ks13 genotype produced the highest yield per tree. They introduced this genotype as a mid-bearing with a low percentage of fruit abscission. The fruit volume of this genotype was higher than other genotypes, which was effective in its higher yield. Ks7 had the highest number of fruit in Tehran conditions (Arzani, 2005). In the study of Henareh and Hasani (2019), a significant difference was observed in the yield of cultivars, so that 'Shahmiveh' with 2.72 and 'Melina' with 7.66 kg per tree had the lowest and highest yields, respectively.

The Ks8 genotype had the highest yield efficiency. The lowest value of this trait also belonged to 'Shahmiveh', and 'Spadana' (Fig. 2). In a study, yield efficiency in the Ks11 and Ks14 genotypes was the highest and the lowest, respectively (Arzani & Khoshghalb, 2009). In a study of some European pear cultivars, the lowest value of this index was 0.06 kg/cm^2 for 'Shahmiveh' and the highest value of 0.644 kg/cm^2 was recorded for 'Melina' (Henareh & Hasani, 2019). The range of this trait in the present study (0.16-0.55 kg/cm^2) was less than the reported range in their research. Differences in yield efficiency of pear cultivars in the studies of Loreti et al. (2000) and Khoshghalb (2001) have also been mentioned.

The highest fruit weight and length belonged to 'Shahmiveh'. The lowest value of these two traits was related to the Ks9 genotype. It has been reported that fruit weight has the greatest effect on yield (Najafzade & Arzani, 2016), but in the present study, 'Shahmiveh', despite having the highest fruit weight, did not have the highest yield due to fewer fruits per tree. Ks9 genotype, which had the lowest fruit weight, but had a high yield. Differences in fruit weight can be related to genotype, cultivar, rootstock, environmental conditions, and nutritional status (Najafzade & Arzani, 2016).

Elshihy et al. (2004) showed that fruit dimensions vary between different cultivars. The difference in fruit dimensions between different genotypes has been shown by Krause et al. (2007) on Himalayan pears and by Katayama and Uematsu (2006) on Asian pears.

TSS depends on the cultivar, planting site, and climatic conditions, which usually increase at harvest time and can be a good indicator for cultivar harvest time (Ozturk et al., 2009). In the present study, the TSS range varied between 16.03-18.03%. Asian pear genotypes had less TSS than European cultivars of 'Shahmiveh' and 'Spadana'. TSS was reported from 12 to 14% by Ozturk et al. (2009). TSS varied among different pear cultivars, so that in research, it was 8-12.5% (Chen et al., 2007) and in another study, TSS was 11.1 to 16% (Henareh & Hasani, 2019). TSS values in the current study were higher than those values.

The highest and lowest TA were observed in Ks12 (0.48%) and Ks8 (0.37%) genotypes, respectively. In European pears, the range of fruit TA was reported as 0.38-0.41% by Najafzade and Arzani (2016) and it was reported 0.22-0.31% by Henareh and Hasani (2019). In the study of 18 pear cultivars in Lithuania, the percentage of TA ranged from 0.07 to 0.19 (Lace & Lacis, 2015). Differences in TA values of pear cultivars have also been reported by Ozturk et al. (2009) and Chen et al. (2007).

The highest taste index belonged to 'Shahmiveh', Ks6, and Ks14. The taste index was in the range of 32.95-45.27, which was much less than the range of the taste index reported by Najafzade et al. (2012) on European pears. This difference was due to the lower range of TA in their research compared to the present study.

The Ks13 and Ks14 genotypes had the highest fruit firmness and European cultivars, especially 'Shahmiveh', had the lowest fruit firmness, so that the range of firmness was between 3.5-6.5 kg/cm^2. The fruit firmness has a great effect on the storage of the fruit. With fruit ripening, fruit firmness decreases (Radwan et al., 2015). In a study, the range of fruit firmness of European pear cultivars was reported between 1-2.37 kg/cm^2 (Najafzade & Arzani, 2016). In the study of four pear cultivars including 'Comice', 'Koshia', 'Anjou' and 'Meskawi' in Syria, the fruit firmness varied between 3.4 to 6.6 kg/cm^2 (Radwan et al., 2015), which is close to the values of this trait in the present study.

Incompatibility of rootstock and grafted cultivar is evident with apparent symptoms such as significant differences in rootstock or scion growth rate, graft non-connection, graft site fracture, or early abscission of the grafted cultivar (Abdollahi et al., 2012). Based on the observations, none of these symptoms were observed in the studied cultivars and genotypes.

CONCLUSION

Asian pear genotypes, especially Ks13 genotype due to favorable yield, yield efficiency, fruit weight, taste index, and fruit firmness, and Ks8 genotype due to favorable yield, yield efficiency, and TSS are suitable for cultivation in climatic conditions of Isfahan (Iran).

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Conflict of interest

The authors have no conflict of interest to report.

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