Growth and Yield Characteristics of Some Selected Quince (*Cydonia oblonga* Mill.) Cultivars and Promising Genotypes

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Summary

The variety of commercial cultivars in the quince species is less than other pome fruit trees, therefore it is necessary to compare quince cultivars and genotypes and select the most favorable ones for different regions, as well as evaluate promising quince genotypes in order to introduce new cultivars. In order to investigate some morphological and biochemical traits of Isfahan, Behta, and Viduja cultivars and KVD2, NB1, and NB4 the promising genotypes in the climatic conditions of Isfahan, Iran, this research was carried out in a randomized complete block design in 2020 and 2021. The highest tree height and canopy width belonged to Behta cultivar. Viduja cultivar had the lowest trunk cross-sectional area and tree height. The highest fruit weight was shown by NB4 genotype (average 218.4 g), followed by Behta and Isfahan. Despite having the lowest fruit weight, the Viduja cultivar had the highest yield and yield efficiency with averages of 29.8 kg tree^{-1} and 0.42 kg/cm^2, respectively. Behta cultivar and NB4 genotype had the highest yield after Viduja. NB1 genotype showed the lowest yield, yield efficiency and the highest content of pectin. There was a correlation between phenol content and antioxidant capacity, so that KVD2 genotype and Isfahan cultivar had the highest total phenol content and antioxidant capacity. The lowest phenol content and antioxidant capacity were recorded for NB1 genotype. The highest and the lowest fruit firmness belonged to Behta and Viduja cultivars, with the averages of 4.35 and 3.71 kg/cm^2, respectively. Viduja and Isfahan cultivars had the highest taste index, and KVD2 and NB1 genotypes had the lowest values of this trait. Among the three investigated genotypes, the NB4 genotype is considered as a promising genotype due to its large fruit and optimal yield and yield efficiency, and it is recommended for cultivation along with the three investigated cultivars.

Key words

promising genotype, antioxidant capacity, phenolic content, taste index, Behta, Viduja

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Introduction

Quince belongs to Rosaceae family, *Cydonia* genus and has only one species named *Cydonia oblonga*. This domesticated species belongs to southwestern Europe and Asia Minor (Rodrigues-Guisado et al., 2009). Iran is considered one of the most important countries in the world producing quince (FAO, 2021). This fruit is in great demand for the processing and production of marmalade, jam, jelly and cake (Silva et al., 2005). Quince has low fat content and is an important source of organic acids, sugars, fiber and elements such as potassium, phosphorus and calcium, as well as phenolic compounds with antioxidant activity (Rodrigues-Guisado et al., 2009).

Many cultivars of pome fruit trees such as apple and pear have been collected or produced, but not many research activities in this field have been carried out on the quince trees, and there are a limited number of cultivars (Tatari et al., 2018). It is common to establish orchards with single cultivars for products such as quince. However, from an economic point of view, the cultivation of fruit tree cultivars with single cultivars has caused many concerns about pollination, fruit set, quality and economic yield (Rasouli et al., 2010). In quince orchards with single cultivars where self-pollination is carried out, flower and fruit abscission leads to a severe yield reduction (Tatari et al., 2018). In this regard, the cultivation of several cultivars in the orchard can prevent the flower and fruit-let abscission and increase the yield per unit area. Most of the quince orchard cultivated areas in Iran belong to the Isfahan cultivar. This cultivar is of high quality and has a special aroma and taste. For this reason, it has received more attention than other figures (Tatari et al., 2018). The first program for the collection of quince cultivars and genotypes in Iran was carried out by Ghasemi (2002) in Isfahan province, and 14 genotypes were identified and collected in this province. KVD1, KVD2, KVD4, NB4, NB3, PH2, PK2, SVS2 and SVS1 genotypes have been identified and collected from Isfahan province and have been proposed as promising genotypes after conducting preliminary and advanced evaluations. Among them, KVD1 genotype was introduced in 2014 as Viduja cultivar and PH2 genotype as Behta cultivar in 2019, and some of these genotypes are also being introduced (Abdollahi, 2021).

Different genotypes of this tree in Spain (Rodriguez-Guisado et al., 2009), Greece (Thomidis et al., 2004), Turkey (Bayazit et al., 2011) and Turkmenistan (Frantskevich, 1978) were also identified and evaluated. The chemical, morphological and organoleptic characteristics of five quince genotypes in Spain were investigated. The result of the evaluation of these genotypes showed that the uniformity of leaf and fruit shape was high and MEMB3 genotype had the highest total soluble solids. Also, in all genotypes the fiber was high and total soluble solids varied between 11.5 and 14.7 (Rodriguez-Guisado et al., 2009). Sykes (1972) examined the botanical and morphological characteristics of different collected quince cultivars from western Turkey, and they were divided into five different groups based on fruit size, including cultivars with large, large to medium, medium, medium to small and small fruit. In this study, Tex, Seker, Ekmek, Limon and Midili cultivars were the indicators of each selection group. Quince fruits have antioxidant effects caused by the polyphenolic substances (Moradi et al., 2017). In examining the characteristics of 12 cultivars and genotypes in the Czech Republic, the pectin content of the fruits was high. The highest content of pectin was reported for Hruskovita cultivar with an average of 3.51 g 100 g^{-1} FW (Rop et al., 2011). Nuzzo et al. (1999) studied 22 different Italian quince cultivars and observed great variation in tree vigor, yield, flowering and fruit weight, and size as well as taste quality. A number of promising hybrids were produced in the cross-breeding program carried out among cultivars from Fruit Research Institute, Čačak, Serbia, and one of them was introduced and named Morava. This cultivar has medium to large fruit with an average weight of 250 g, good flavour, and appropriate storage potential (Stancevic and Nikolic, 1992).

Due to the expansion of cities, the excessive increase in the world's population and the limited resources of water and agricultural soil in countries like Iran, the possibility of increasing the cultivated area is very low. In order to optimize the use of these limited resources and achieve sustainable agriculture and food security, the cultivation of cultivars with high yield and compatibility with the climatic conditions of the region should be considered to increase the production per unit area. One of the main problems of quince breeders is the lack of access to new and high-yielding cultivars, so it is necessary to compare promising cultivars and genotypes and choose the most favourable cultivars for different regions.

Materials and Methods

Plant Materials

In this research, some vegetative and reproductive traits of six cultivars and promising genotypes of (*Cydonia oblonga* Mill.) including Behta, Viduja and Isfahan cultivars as well as KVD2, NB1 and NB4 genotypes were evaluated in the climatic conditions of Isfahan, Iran, in 2020 and 2021. The evaluated quince trees were 20 years old and were grafted on the hawthorn seedling rootstocks. All orchard management operations including irrigation, fertilizing and controlling pests, diseases and weeds were carried out. The trees were trained in a modified central leader form. The fruits of the studied cultivars and genotypes were harvested based on the most suitable harvest time from the full bloom (Tatari, 2023). In this way, Viduja cultivar was harvested 185 days, Behta and Isfahan cultivars as well as NB1 and NB4 genotypes 193 days and KVD2 genotype 200 days after the full bloom.

Morphological Evaluated Traits

The morphological traits included Trunk cross-sectional area, tree height, canopy width, internode length, annual branch diameter, leaf length and width, fruit weight, yield per tree and yield efficiency. The perimeter of the trunk was measured at a height of 10 cm from the soil surface. Using the perimeter and diameter of the trunk, the cross-sectional area of the trunk was calculated. Tree height and canopy width were measured using a meter and internode length, leaf length and width were measured using a ruler. The branch diameter was also measured from the middle part of the branch with a caliper and the fruit weight was measured using an accurate scale. From each repetition, four branches from four geographical directions of each tree were selected and leaves, branches and fruits were evaluated on these

branches. The total yield of each tree was weighed and recorded as the yield of the tree. Yield efficiency was obtained by dividing the yield in the tree by the trunk cross-sectional area.

Physiological Evaluated Traits

Physiological characteristics of fruit including fruit firmness, soluble solids (TSS), pectin, total phenol content, antioxidant activity, titratable acid (TA) and taste index were evaluated and recorded. 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 were determined by extracting and mixing two drops of juice from the two cut ends of each fruit into a digital refractometer (ATAGO N-1α, Japan) at 22 C.

Pectin content was measured according to Thakur et al. (1996). Briefly, 100 g of fruit tissue were grated and 400 mL of distilled water were added and boiled for an hour. After passing through the filter paper, 300 mL of distilled water and 10 mL NaOH were added, and the resulting solution was kept overnight at room temperature, then 50 mL acetic acid (1N) and 25 mL of calcium chloride were added to the solution. The resulting solution was kept for one hour at room temperature and then was boiled for an hour and then the boiled solution was passed through filter paper. The difference between initial and secondary weight of filter paper was reported as pectin weight based on grams per 100 g of fruit pulp.

Total phenols were measured in fruit juice using Folin-Ciocalteu (Singelton and Rossi, 1965). The absorbance of the samples was determined at 765 nm wavelength with spectrophotometer model T80 UV/Visible, then compared with the standard of gallic acid and expressed as mg gallic acid per 100 g of fresh weight.

In order to evaluate the antioxidant activity, 30 microliters of fruit juice were added to a 0.1 mM DPPH solution in methanol. The absorbance of the solution was read after 15 minutes in the dark at a wavelength of 515 nm using a spectrophotometer. The DPPH inhibitory activity of fruit juice, which is a measure of the antiradical activity of fruit juice, was calculated according to the following formula (Sun and Ho, 2005):

$$\%RSA = \frac{OD\ control - OD\ sample}{OD\ control} * 100$$

In this formula, *OD control* = control sample absorption (without DPPH), *OD sample* = sample absorption and *RSA* = free radical scavenging activity.

The total titratable acidity was determined by titration with sodium hydroxide (0.1 N) and expressed as percentage of malic acid. TSS to TA ratio was reported as taste index.

Qualitative traits including growth vigor and habit, flower size and flowering time, fruit size and fruit ripening time were scored and estimated based on Distinctness, Uniformity and Stability (DUS) Testing.

Experimental Design

This research was conducted as a randomized complete block design. Morphological traits were measured and recorded with five repetitions, and physiological data with three repetitions. The obtained data were analyzed using SAS software version 9.1 and the comparison of the means was checked with the least significant difference (LSD) test at the 5% probability level.

Results

Morphological Traits

The average comparison of the measured traits is shown in Table 1. Behta cultivar had the highest cross-sectional area of the tree trunk. Isfahan cultivar and NB1 genotype did not show any significant difference from Behta. Similarly, the highest tree height and canopy width belonged to Behta cultivar. NB4 genotype also had a canopy width similar to Behta. Behta and Isfahan cultivars had the highest annual branch diameter. The lowest trunk cross-sectional area and tree height belonged to Viduja cultivar. The two KVD2 and NB1 genotypes also showed the lowest canopy width and annual branch diameter.

There was no significant difference in internode length among cultivars and genotypes. The highest leaf length and width belonged to the Isfahan cultivar. NB4 genotype had no significant difference with Isfahan cultivar in leaf width trait. Viduja cultivar and NB1 genotype had the lowest leaf length and width (Table 1).

NB4 genotype showed the highest fruit weight with an average of 218.4 grams. After that, Behta and Isfahan had the highest fruit weight with averages of 206.9 and 191.2 g respectively. The lightest fruit belonged to Viduja cultivar with an average of 128.6 g (Fig. 1).

The highest yield was recorded for Viduja with an average of 29.8 kg $tree^{-1}$. Behta cultivar and NB4 genotype were similar in this trait. NB1 genotype showed the lowest yield (12.5 kg $tree^{-1}$) (Fig. 2). Viduja cultivar showed the highest yield efficiency with an average of 0.42 kg cm^{-2}. NB1 genotype had the lowest value of this trait (0.11).

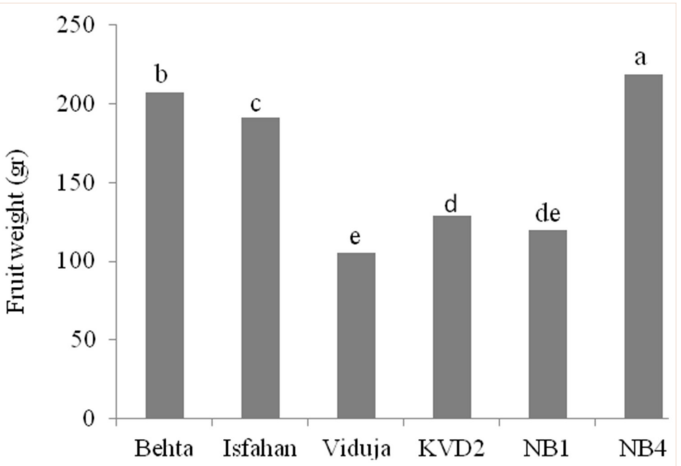

Figure 1. The effect of evaluated quince cultivars and genotypes on fruit weight

Note: Same letters in each column indicate no significant difference at the $P < 0.05$ level < according to LSD test

Table 1. Effect of quince cultivar/genotype on some morphological traits (mean ± SD)

Cultivar/ genotype	Trunk cross-sectional area (cm^2)	Tree height (m)	Canopy width (m)	Brunch diameter (mm)	Internode length	Leaf length (cm)	Leaf width (cm)
Behta	136.72±10.77^{a}	4.2±0.27^{a}	4.1±0.44^{a}	7.22±0.92^{a}	3.13±0.78^{a}	8.38±0.38^{b}	6.38±1.07^{ab}
Isfahan	119.11±12.53^{a}	2.9±1.88^{ab}	3.57±0.89^{ab}	7.4±0.52^{a}	2.53±0.44^{a}	9.62±0.6^{a}	7.36±0.58^{a}
Viduja	71.22±12.69^{b}	2.16±0.23^{c}	3.52±0.32^{ab}	6.34±1.27^{ab}	2.76±0.53^{a}	7.28±0.72^{c}	4.96±0.53^{c}
KVD2	96.08±9^{ab}	3.2±1.03^{b}	3.1±1.11^{b}	5.7±0.62^{b}	2.72±0.33^{a}	8.62±0.88^{ab}	5.58±0.63^{bc}
NB1	116.66±14.99^{a}	2.9±0.41^{b}	3.18±0.11^{b}	5.26±0.15^{b}	2.39±0.47^{a}	7.06±0.8c	5.02±0.51^{c}
NB4	96.08±11.2^{ab}	3.6±0.54^{ab}	4.1±0.44a^{a}	6.62±1.32^{ab}	2.71±0.6^{a}	8.92±1.19^{ab}	6.72±1.16^{a}

Note: Same letters in each column indicate no significant difference at the $P < 0.05$ level < according to LSD test

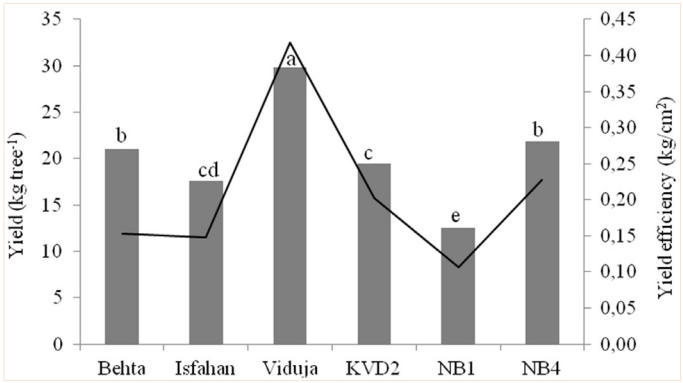

Figure 2. The effect of quince cultivars and genotypes on yield and yield efficiency

Note: Same letters in each column indicate no significant difference at the $P < 0.05$ level < according to LSD test

Physiological Traits

NB4 genotype had the highest amount of pectin, with an average of 0.65 g 100 g^{-1}. Other cultivars and genotypes did not have significant differences in fruit pectin content (Fig. 3).

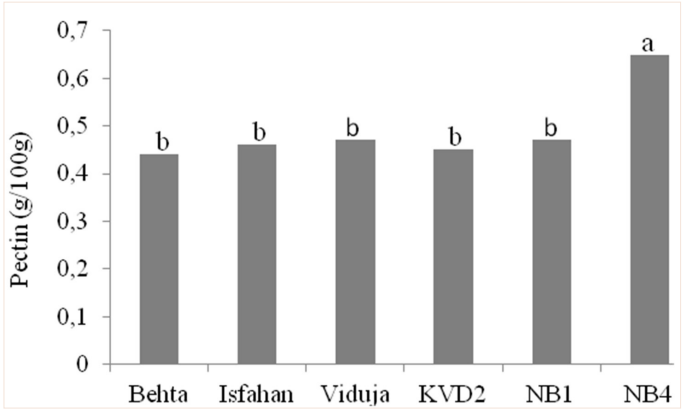

Figure 3. The effect of evaluated quince cultivars and genotypes on fruit pectin content

Note: Same letters in each column indicate no significant difference at the $P < 0.05$ level < according to LSD test

KVD2 genotype had the highest total phenol content with an average of 43.34 mg/100 g FW, and Isfahan cultivar (average of 40.37 mg 100 g^{-1} FW) did not show any significant difference from this genotype. The lowest total phenol content was recorded for NB1 genotype, with an average of 27.3 mg 100 g^{-1} FW. Similarly, KVD2 genotype and then Isfahan cultivar had the highest antioxidant capacity with averages of 62.01 and 57.6%, respectively. The lowest antioxidant capacity belonged to NB1 and NB4 genotypes (Fig. 4).

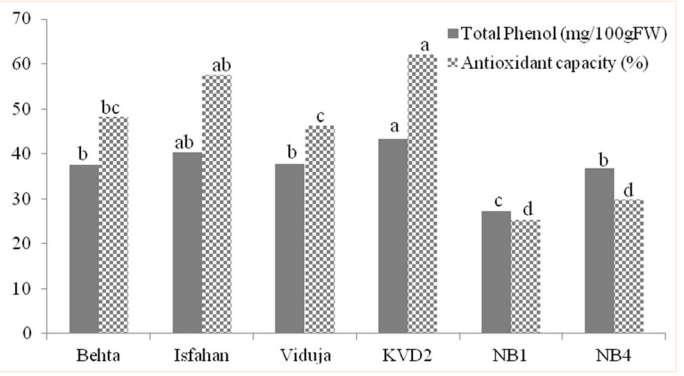

Figure 4. The effect of quince cultivars and genotypes on total phenol content and antioxidant capacity

Note: Same letters in each column indicate no significant difference at the $P < 0.05$ level < according to LSD test

The highest and lowest fruit firmness belonged to Behta and Viduja cultivars, respectively, with averages of 4.35 and 3.71 kg cm^{-2}. The rates of fruit firmness in Isfahan cultivar and other genotypes were between these two values (Table 2). The highest TA was recorded for KVD2 genotype and then NB1. Isfahan cultivar showed the lowest amount of TA, with an average of 0.51% (Table 2). Viduja followed by Behta cultivars had the highest TSS. NB1 genotype had the lowest value of this trait. Viduja and Isfahan cultivars had the highest taste index, with averages of 28.74 and 28.63, respectively. The lowest taste index belonged to KVD2 and NB1 genotypes, with averages of 20.03 and 20.58, respectively. The taste index in Behta and NB4 was not different from each other (Table 2).

Table 2. Effect of quince cultivar/genotype on some physiological (traits ± SD)

Cultivar/ genotype	Fruit firmness (kg/cm^2)	TA (%)	TSS (%)	TSS/TA
Behta	4.35 ± 0.5^{a}	0.64 ± 0.09^{b}	15.83 ± 2.3^{b}	24.65 ± 3.6^{b}
Isfahan	3.92 ± 0.3^{b}	0.51 ± 0.1^{d}	14.66 ± 2.6^{c}	28.63 ± 3.2^{a}
Viduja	3.71±0.2c	0.57 ± 0.07^{c}	16.33 ± 1.9^{a}	28.74 ± 4.1^{a}
KVD2	3.89 ± 0.6^{b}	0.71 ± 0.1^{a}	14.83 ± 2.01^{c}	20.03 ± 2.9^{c}
NB1	4.03 ± 0.4^{b}	0.68 ± 0.08^{ab}	13.99 ± 1.8^{d}	20.58 ± 3.1^{c}
NB4	3.89 ± 0.7^{b}	0.62 ± 0.09^{b}	14.33 ± 1.71^{c}	23.11 ± 3.5^{b}

Note: Same letters in each column indicate no significant difference at the $P < 0.05$ level < according to LSD test

According to Table 3, Behta and Viduja cultivars had vigorous and weak growth vigor, respectively, while Isfahan cultivar and the examined genotypes had medium growth vigor. Behta and Isfahan cultivars had an upright growth habit, Viduja was wide, and the other three genotypes had a semi-wide growth habit. The flower size in two KVD2 and NB1 genotypes was medium and in others was large. Isfahan and Behta cultivars as well as NB4 genotype were late-flowering and others were early-flowering. The evaluation of fruit size indicated small to large-sized fruits. Fruit size in Isfahan and Behta cultivars along with NB4 genotype was large. Ripening times in Viduja and KVD2 were early and late, respectively, and in the others they were medium (Fig 5).

Figure 5. Comparison of the tree growth vigor and habit (first upper row), color and form of leaf and annual shoots (second upper row), color and form of bloom (third row), general form of fruit (last row) in studied quince cultivars and promising genotypes in this research

Table 3. Qualitative characters in the tree, flower and fruit of quince cultivars and genotypes

Cultivar/ genotype	Tree		Flower		Fruit	
	Vigor	Growth habit	Size	Flowering time	Size	Ripening time
Behta	Vigorous	Upright	Large	Late	Large	Medium
Isfahan	Medium	Upright	Large	Late	Large	Medium
Viduja	Weak	Wide	Large	Early	Medium	Early
KVD2	Medium	Semi-upright	Medium	Early	Medium	Late
NB1	Medium	Semi-upright	Medium	Early	Small	Medium
NB4	Medium	Semi-upright	Large	Late	Large	Medium

Discussion

Morphological Traits

The vigor of cultivars is determined by the trunk cross-sectional area (Radovic et al., 2016). The average cross-sectional area of the trunk in this research was 105.98 cm^2 and was between 71.22 and 136.72 cm^2 for Viduja and Behta cultivars, respectively (Table 1). The average trunk cross-sectional area in 14-year-old trees of the Leskovacka cultivar was 81.1 cm^2 (Radovic et al., 2016) and was close to the Behta cultivar. Similarly, the highest and the lowest tree heights belonged to Behta and Viduja cultivars (Table 1). In the research conducted by Naeimi et al. (2020), the internode length was between 2.4 and 3.5 cm, and similarly to this research, no significant difference was observed between cultivars and genotypes. This trait is important due to its correlation with tolerance to fire blight disease in pome fruit trees such as apple (Abdollahi and Majidi Heravan, 2005).

The highest leaf length and width belonged to Isfahan cultivar (Table 1). In another study, Isfahan quince cultivar showed the highest leaf length with an average of 8.94 cm (Naeimi et al., 2020), which was less than the reported value in this study. The lowest ratio of leaf length to width belonged to the Isfahan cultivar. The combination of the leaf length and width can be considered a measure of the general form of the leaf in this species. Alipour et al. (2014) reported the range of leaf length and width of quince cultivars and genotypes 5.63-7.97 cm and 4.57-6.98 cm, respectively. The reported range in the present research was wider than in their research. In another research that was carried out on different quince genotypes in Ardabil province, Iran, the range of leaf length was 3.46-10.44 cm and the range of leaf width was 4.25-6.89 cm (Azaddel and Ghanbari, 2018). Differences in genotypes, climate conditions, and altitude are the causes of these differences. It has been reported that leaf length and width traits can be used as a distinct trait to identify quince cultivars and genotypes (Tatari and Abdollahi, 2021). A comparison of the wide variation in leaf traits of quince genotypes in Iran with the results of Rodriguez-Guisado et al. (2009) shows very little variation in Spanish genotypes.

In some research, the fruit weight in the studied quince genotypes was between 241 g in Ispolinskaya genotype and 360.7 g in Zolotistaya genotype (Chepinoga and Tikhonova, 2021). In the current research, the average fruit weight was between 218.4 g in NB4 genotype and 128.6 g in Behta cultivar (Fig. 1). Ropp et al. (2011) stated that the range of fruit weight in quince cultivars from the Czech Republic was between 89.7 g in Juranska apple-shaped cultivar and 472.1 g in Bereckeho cultivar. Also Rodriguez-Guisado (2009) reported that the fruit weight in the studied quince clones varied between 194.01 g in MEMB5 clone and 297.86 g in MEMB2 clone. The range of the highest and the lowest fruit weight in the present study was lower than the reported results by this researcher. In another research, the highest fruit weight was reported for Isfahan cultivar (Naeimi et al. (2020), while in this study, the NB4 genotype showed the highest fruit weight (Fig. 1).

The average yield per tree among cultivars and genotypes in the two studied years was 20.38 kg. Despite having the lowest fruit weight, the Viduja cultivar had a higher yield per tree than other cultivars and genotypes due to a higher number of fruits (Fig. 2). The growth habit of the spore type and the uniform distribution of the spores throughout the branch led to the achievement of a significant yield in Viduja cultivar compared to other cultivars and genotypes. In the research conducted by Radovic et al. (2016), the Leskovacka cultivar had a yield of 29.1 kg $tree^{-1}$, which was close to the yield of the Viduja cultivar with an average of 29.8 kg $tree^{-1}$. In their research, the Triumph cultivar had a yield of 67.4 kg per tree. This difference in yield is due to genetic differences among cultivars and genotypes, as well as differences in environmental conditions among the studied locations. Naeimi et al. (2020) reported the highest quince yield with an average of 28 kg $tree^{-1}$ in the Givi cultivar.

Although Isfahan cultivar had a higher trunk cross-sectional area than Behta cultivar, due to the higher yield in Behta cultivar, the yield efficiency was similar in these two cultivars. The highest yield efficiency was observed in Viduja with an average of 0.42 kg cm^{-2} (Fig. 2). This cultivar had the lowest vigor and trunk cross-sectional area and the highest yield, so it can be cultivated in small areas in order to obtain the highest yield in area. In some research, the yield efficiency in Vranjska cultivar was 0.49 kg cm^{-2} (Radovic et al., 2016), which was close to the value of this trait in Viduja. According to Fig. 2, NB1 genotype showed the lowest yield efficiency (0.11) due to having the lowest yield (12.5 kg $tree^{-1}$).

Physiological Traits

Quince is important in processing due to its high pectin content (Rop et al., 2011). Except for NB1 genotype, which showed the highest amount of pectin (average 0.65 g 100 g^{-1}), other cultivars and genotypes did not have significant differences in fruit pectin content (Fig. 3). Tatari (2023) also did not observe a significant difference among the pectin content of cultivars and genotypes. In another study conducted on 22 quince genotypes in the Czech Republic, pectin content was between 1.75 and 3.51 g 100 g^{-1} (Rop et al., 2011), which was higher than the reported values in this study. Differences in genotypes and growing conditions can be the causes of this difference.

Quince is a valuable source of natural phenolic antioxidants, and can be used as raw material to elaborate diverse food products, providing important functional properties (Bland et al., 2020). KVD2 genotype (43.34 mg 100 g^{-1} FW) and the Isfahan cultivar (40.37 mg 100 g^{-1} FW) had the highest and NB1 genotype (27.3 mg 100 g^{-1} FW) had the lowest total phenol content (Fig. 4). The lower amount of phenol in Behta cultivar and NB4 genotype compared to Isfahan cultivar has already been reported by Tatari (2023). Ghozati et al. (2016) studied 12 selected quince genotypes and reported that KVD4 genotype and Isfahan cultivar had the highest and lowest amount of total phenol in leaves, respectively, while in the present study, the total phenol content in the fruit of Isfahan cultivar was remarkable. It seems that phenol content in the fruits of this cultivar is higher than the phenol content in its leaves.

Similarly, KVD2 genotype and the Isfahan cultivar had the highest antioxidant capacity with averages of 62.01 and 57.6%, respectively. The lowest antioxidant capacity belonged to NB1 and NB4 genotypes (Fig. 4). The difference in antioxidant activity between 13 cultivars and 5 genotypes was also reported by Wojdylo et al. (2013). The difference in antioxidant capacity among cultivars and genotypes could be due to differences in their total phenol content (Wojdylo et al., 2013). A positive correlation was seen between total phenol content and antioxidant capacity. This relationship was reported by Babashpour-Asl and Piryaei (2021) in quince fruit and by Szklarz and Pacholak (2000) in apple fruit. Phenolic compounds are the main factors that can give hydrogen to free radicals and break the chain reaction of lipid oxidation in the first step (Babashpour-Asl and Piryaei, 2021).

Behta and Viduja cultivars had the highest (4.35 kg cm^{-2}) and the lowest (3.71 kg cm^{-2}) fruit firmness, respectively (Table 2). Tatari (2023) has also reported that the Behta cultivar has a firmer texture compared to the others. In other studies, differences in fruit firmness of apple cultivars have been reported. For example, the fruit tissue of 'Red Delicious' was much firmer than that of 'Golden Delicious'. The firmness of 'Gol Shahi' was higher than 'Red Delicious', 'Golden Delicious' and 'Abbasi' in the Khorasan region, Iran (Hoseini Farahi et al., 2008). Fruit firmness depends on the structure and composition of the cell wall (Valero and Serrno, 2010). This trait is one of the important qualitative traits in agricultural products that are directly related to mechanical damage and fruit storage (Radwan et al., 2015).

In this research, TSS in the studied cultivars was more than TSS in promising genotypes, but TA in the promising genotypes was more than TA in investigated cultivars. The range of TSS was between 13.99% and 16.33% (Table 2). In the research carried out by Rop et al. (2011), 22 quince genotypes were evaluated and the range of TSS was reported between 10.9% in Buchlovice genotype and 17.7% in Pinter genotype. The reported range by Rop et al. (2011) was wider than the reported range in the present research, which could be due to the higher number of genotypes in their research. In the study of 17 quince cultivars in Russia, the highest TSS was related to the Zvezdnaya cultivar with an average of 14.9% (Chepinoga and Tikhonova, 2021), which was lower than the TSS of Viduja and Behta cultivars. The range of taste index of cultivars and genotypes was 20.03 in KVD2 genotype and 28.74 in Viduja cultivar (Table 2). These values in the research conducted by Chepinoga and Tikhonova (2021) were between 6.9 and 11.2, which is much lower than the reported values in the present study. The taste index has a great impact on the acceptability of the fruit by the consumer.

The growth vigor of cultivars and genotypes was from vigorous in Behta cultivar to weak in Viduja cultivar. Other cultivars and genotypes had medium growth vigor (Table 3). Alipour et al. (2014) and Naeimi et al. (2020) also reported weak to vigorous growth vigor in the investigation of quince genotypes. The low growth vigor indicates the dwarfing trait in the populations originating in Isfahan, as was observed in Viduja cultivar. The tree growth habit was also observed as upright (Behta and Isfahan), wide (Viduja), and semi-upright. Most quince genotypes with low growth vigor have a wide growth habit (Naeimi et al., 2020). Viduja, in addition to its low growth vigor and wide growth habit, also produces a lot of spores, which provides dwarfing, high yield potential and the possibility of semi-density planting. It should be noted that the growth habit trait has significant stability and can be considered as a key trait in identification of cultivars (Khandan et al., 2011).

Naeimi et al. (2020), in the evaluation of 13 quince genotypes, reported that the flower size in Isfahan cultivar and LA2 genotype were medium and large, respectively. In this research, the flower in the studied cultivars and NB4 genotype was larger than others (Table 3). One of the main problems of quince tree is the low yield of cultivars such as Isfahan. Due to the reports of self-incompatibility in some quince cultivars (Tatari et al., 2018), it is recommended that compatible cultivars with similar flowering time be cultured next to each other. In this research, the studied cultivars and genotypes based on flowering time were divided into two groups, early flowering and late flowering, which should be taken into consideration in the planting of cultivars and genotypes. The evaluation of fruit size showed that there were fruits with small to large sizes. Isfahan and Behta cultivars along with NB4 genotype had large -sized fruits. The large fruit size in Isfahan cultivar by Naeimi et al. (2020) and the early-ripening of Viduja cultivar by Tatari (2023) have also been previously reported.

Conclusion

Among the investigated cultivars and genotypes, Isfahan and Behta cultivars and NB4 promising genotype have large fruits and superior quality. The Viduja cultivar also has an appropriate yield and taste index. Among the examined genotypes, the NB4 genotype with favourable quantitative and qualitative characteristics can be introduced as a new cultivar. Of course, doing this will require presenting all the obtained results in the fields of disease resistance, horticultural value and marketability compared to the available commercial cultivars.

CRediT authorship contribution statement

Maryam Tatari: Overall project management, Investigation and manuscript writing. **Azam Jafari:** Project management and editing of the manuscript. **Mostafa Shirmardi:** Data analysis, Manuscript editing. **Zahra Bagheri:** Performed some of experiments.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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