South Western Journal of *Vol.13, No.2, 2022*
Horticulture, Biology and Environment *pp.109-125*
P-Issn: 2067- 9874, E-Issn: 2068-7958 Art.no. e22108

CHARACTERIZATION AND IDENTIFICATION OF SUPERIOR GENOTYPES OF CORNELIAN CHERRY (*Cornus mas* L.) FROM SEEDLING ORCHARDS

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Abstract. *Cornelian cherry (Cornus mas L.) is a popular and valuable small fruit. There are seedling-based orchards of cornelian cherry in Iran which are rich sources of genetic diversity for identifying superior genotypes for cultivation or improving cornelian cherry cultivars. However, little research has been conducted to evaluate the populations and identify superior cornelian cherry genotypes in Iran. In this study, characteristics of 36 superior cornelian cherry genotypes from seedling orchards in the Alamut region in Qazvin province were investigated. Fruit traits including fruit mass, fruit length, fruit diameter, fruit juice pH, soluble solids content, kernel mass, kernel length, kernel diameter and pulp/fruit ratio were measured. A large diversity was found in fruit size, shape and quality parameters of the genotypes. Fruit mass, fruit length, and fruit diameter ranged from 1.646-4.303g, 1.36-3.35cm, and 0.733-2.30cm, respectively. Fruit shape was obligated to semi-round in the genotypes. Kernel mass and pulp portion of the fruits ranged from 1.07-0.253g and 39.77-88.64%, respectively. Fruit juice pH and soluble solids content varied between 2.80-3.16 and 13.2-22.5°Brix, respectively. Based on the results, SOM2, KKP2, SOT1, KK7 and KKP3 genotypes with elongated (SOM2) to oval (KKP3) shaped fruits and weighing more than 3.50g, were introduced as superior genotypes for fresh consumption. The genotypes KKP2, KK7, SOT1, KK6 and KKP3 with the highest pulp mass and high pulp-to-fruit ratio represented suitable traits for processing and juice extraction. In sum, KKP2 and SOT1 genotypes with fruit mass over 4.0 g were the superior high-yielding genotypes.*

Keywords*: diversity, fruit size, fruit quality, superior genotype, genetic diversity.*

INTRODUCTION

Cornelian cherry (*Cornus mas* L.) is a semi-domesticated plant and native to central and southern Europe and parts of western Asia (Mamedov & Craker 2004). This species grows at an altitude of up to 1400 m (Hassanpour et al. 2012, Klimenko 2004, Otakar et al. 2010). Cornelian cherry fruits are a source of vitamin C, phenolic acids, flavonoids, and anthocyanins (Cosmulescu et al. 2019). The fruits are consumed as fresh, dried, or processed such as syrup, juice, jam, and other traditional products (Brindza et al. 2007, Bijelic et al. 2011, Yilmaz et al. 2009, Pawlowska et al. 2010). In some Asian countries, corneal cherries are used in traditional medicine for the treatment of diabetes (Jayaprakasam et al. 2005, Bijelic et al. 2011). In Iran, cornelian cherries are mainly cultivated in the Northern and Western regions of the country and the economy of many families depends on the fruit of this plant. In addition, a part of cornelian cherry fruits come from wild trees in the forests in northern Iran. There are 1015 hectares of mature cornelian cherry orchards in Iran, with a production of approximately 4627 tons (Anonymous 2017). Alamut in the north of Qazvin province is another main site of cornelian cherry production in Iran. Great diversity in cornelian cherry genotypes is found in this region. In the Alamut region, most of the cornelian cherry crop is harvested from seedlings (Hassanpour et al. 2012). Such an extensive diversity in the cornelian cherry orchards creates problems in fruit harvesting. Because the ripening time of the fruit is very diverse in different genotypes, and this makes it difficult to harvest the fruit. On the other hand, this condition provides a unique opportunity to identify and select superior genotypes from cultivated plants. There is a high genetic diversity in terms of productivity and fruit characteristics, such as taste, size, shape, color, and nutritional value. Evaluation of these genotypes for identifying superior genotypes is a basic step in the breeding of fruit trees (Peng et al. 2014, Kiani et al. 2010). High variations in morphological and phenotypic characteristics are useful for finding superior genotypes with desirable features such as an attractive color, high vitamin C, high sugar, and low tannin contents (Brindza et al. 2007, Karadeniz 2002, Hassanpour et al. 2012, Ercisli et al. 2008, Volkan 2016, Cosmulescu & Cornescu 2020). Selected promising genotypes in such populations are valuable in the establishment of new orchards to achieve the goal of more productivity with higher fruit quality. Several studies have been conducted to evaluate the populations of cornelian cherries in Europe and Turkey (Brindza et al. 2007, Yilmaz et al. 2009, Bijelic et al. 2011, Hassanpour et al. 2012, Cornescu & Cosmulescu 2017). Brindza et al. (2007) evaluated 250 cornelian cherry ecotypes in Slovakia. In addition to variations in the size and quality indices of the fruits, they observed great variations in the chemical composition of the seeds. Based on their evaluation, several genotypes were introduced for potential release. Yilmaz et al. (2009) evaluated 16 promising cornelian cherry genotypes in Turkey and observed variations in mass, quality indices, and bioactive compounds in the fruits. Their results indicated the potential of certain cornelian cherry genotypes, for improvement of the nutritional value of cornelian cherry cultivars. Bijelic et al. (2011) reported high variability in fruit mass, quality, and chemical composition in 18 cornelian cherry genotypes in Serbia. They suggest that genotypic variations of cornelian cherry can be investigated based on their chemical composition. In the evaluation conducted by Hassanpour et al. (2012) on 20 Iranian cornelian cherries, variations in fruit size, ascorbic acid content, titratable acidity, and total soluble solids were reported. Cornescu & Cosmulescu (2017) reported high variability in the quality of 6 Romanian cornelian cherry genotypes. Their results revealed high diversity in terms of fruit size, total soluble solids, and biochemical characteristics in cornelian cherry populations within different ecological areas. In addition to visual differences, Cosmulescu et al. (2019) observed large variations in bioactive compounds and antioxidative capacity in fruits of selected cornelian cherry wild genotypes. Such investigations and results are useful for selecting superior genotypes of cornelian cherry for cultivation. A limited number of studies have explored the Iranian cornelian cherry populations to identify superior cornelian cherry genotypes. The Alamut region is one of the major cornelian cherry growing regions in Iran, therefore, this research was conducted to select and introduce superior genotypes of cornelian cherry from the high-yield and quality seedlings from orchards of this region. The results are significant for improving the productivity and quality of this species.

MATERIAL AND METHODS

<u>Plant material collection</u>

To find superior cornelian cherry an area of about 700 hectares of cornelian cherry orchards in the Alamut region of Qazvin province, Iran was surveyed during 2016-

2017. Based on information obtained from the growers and considering a healthy appearance and superior characteristics in terms of fruit size, mass, and yield, 36 cornelian cherry trees were identified and marked. The geographical coordinates and altitude for the trees are shown in Table 1. The trees were 25 years old seedlings.

Table 1. The geographical coordinates and altitude of the superior cornelian cherry trees of the Alamut region, Qazvin province, Iran.

No.		Latitude (N)	Longitude (E)	Altitude
1	KK1	50° 14′ 31.4″	36° 34′ 06.2″	1189
2	KK2	50° 14′ 31.3″	36° 34′ 05.6″	1200
3	KK3	50° 14′ 32.1″	36° 34′ 04.9″	1200
4	KK5	50° 14′ 33.0″	36° 34′ 05.7″	1207
5	KK6	50° 14′ 29.8″	36° 34′ 59.5″	1187
6	KK7	50° 14′ 29.2″	36° 34′ 00.3″	1184
7	KKP1	50° 14′ 28.2″	36° 34′ 02.9″	1163
8	KKP2	50° 14′ 27.9″	36° 34′ 02.8″	1160
9	KKP3	50° 14′ 28.5″	36° 34′ 02.7″	1217
10	KKP4	50° 14′ 28.9″	36° 34′ 02.5″	1215
11	SOA1	50° 14′ 31.7″	36° 34′ 35.8″	1183
12	SOA2	50° 14′ 35.3″	36° 34′ 35.5″	1200
13	SOA3	50° 14′ 35.3″	36° 34′ 35.5″	1200
14	SOA4	50° 14′ 35.3″	36° 34′ 35.4″	1212
15	SOA5	50° 14′ 35.3″	36° 34′ 35.4″	1212
16	SOH1	50° 14′ 23.4″	36° 34′ 23.0″	1196
17	SOH2	50° 14′ 23.4″	36° 34′ 23.0″	1196
18	SOH3	50° 14′ 23.4″	36° 34′ 23.0″	1196
19	SOK1	50° 14′ 32.1″	36° 34′ 35.3″	1183
20	SOK2	50° 14′ 32.3″	36° 34′ 35.6″	1180
21	SOK3	50° 14′ 31.8″	36° 34′ 31.3″	1190
22	SOK4	50° 14′ 32.1″	36° 34′ 35.4″	1174
23	SOM1	50° 14′ 30.1″	36° 34′ 30.9″	1201
24	SOM2	50° 14′ 30.0″	36° 34′ 30.9″	1201
25	SOM3	50° 14′ 30.0″	36° 34′ 30.8″	1201
26	SOM4	50° 14′ 30.1″	36° 34′ 30.8″	1201
27	SOS1	50° 14′ 35.4″	36° 34′ 33.3″	1222
28	SOS2	50° 14′ 35.4″	36° 34′ 33.3″	1221
29	SOT1	50° 14′ 31.7″	36° 34′ 31.2″	1220
30	SOV1	50° 14′ 30.3″	36° 34′ 32.3″	1201
31	SOV2	50° 14′ 30.3″	36° 34′ 32.3″	1202
32	SOV3	50° 14′ 30.3″	36° 34′ 32.3″	1202
33	SOY1	50° 14′ 22.3″	36° 34′ 22.7″	1207
34	SOY2	50° 14′ 22.3″	36° 34′ 22.7″	1207
35	SOY3	50° 14′ 32.3″	36° 34′ 04.8″	1191
36	SOY4	50° 14′ 23.1″	36° 34′ 22.5″	1192

<u>Measurements</u>

Fruits were harvested at the commercial maturity stage when 90% of the fruit skin became red (Yarilgaç et al. 2018). In each tree, three main branches were selected as three replications and 500 g of fruits per branch was sampled. Yield and quality characteristics such as fruit mass, fruit length, fruit diameter, fruit juice pH and total soluble solids (TSS) content, kernel mass, kernel length, kernel diameter, and pulp/fruit ratio were measured. Fruit mass and kernel mass were measured by using a digital balance with an accuracy of 1 mg (Sartorius, Germany). Fruit length and diameter, kernel length, and kernel diameter were measured by a digital caliper (Shoka Gulf, Spain). Fruit shape (roundness) was determined by dividing fruit length by width. Fruit juice pH was measured by a pH meter (Hanna, USA). Total soluble solids (TSS) in fruit juice were measured by a refractometer (Atago, Japan).

<u>Data analyses</u>

Data were subjected to multivariate analysis of variance and mean comparisons of the measured traits were performed by Duncan's multiple range test (DMRT) at $P \leq 0.05$. To clarify the genetic distances among the studied genotypes, a dendrogram was constructed based on the studied parameters using the Ward method. Moreover, the correlation between major parameters was investigated using the Pearson method. The statistical analyses were performed using SPSS v.21 software.

RESULTS

The results of analyses of variance of the investigated parameters are presented in Table 2. Significant differences were found among all genotypes for the measured parameters at $P \leq 0.01$ level. Fruit size, shape and mass data are represented in Table 3. Fruit length was varied from 1.36 to 3.35cm among the genotypes. The highest and the lowest values of fruit length belonged to KKP2 and SOY4, respectively. Fruit diameter varied from 0.73 to 2.30cm among the genotypes. The highest and the lowest fruit diameter belonged to KKP2 and SOY4, respectively. Fruit length:width ratio (shape) varied between 1.20 and 1.86. SOY4 had the most obligated fruits (1.86), and the most round fruits were found in KKP3 and SOY1 genotypes. The fruit mass of the genotypes varied from 1.64 to 4.30 g. The highest and the lowest fruit mass belonged to KKP2 and SOY4 genotypes, respectively. Kernel mass varied between 0.25 and 1.07 g. The highest and the lowest kernel mass belonged to SOT1 and KKP1 genotypes, respectively (Table

4). Kernel length of fruit was varied between 0.983 and 2.44 cm. KKP2 and SOY4 genotypes had the highest and the lowest kernel length, respectively (Table 4). Kernel diameter was varied between 0.54 and 1.07 cm. The highest and the lowest kernel diameter belonged to KKP2 and SOH2 genotypes, respectively (Table 4).

Table 2. Results of analyses of variance and the variation limits of the investigated parameters in cornelian cherry genotypes (**significant at $P \leq 0.01$)

Parameters	*df*	Mean square	Error mean squere	Minimum	Maximum
Fruit length (cm)	35	0.266**	0.028	1.36	3.35
Fruit diameter (cm)	35	0.153**	0.015	0.73	2.30
Fruit shape	35	0.298**	0.052	1.20	1.86
Fruit mass (g)	35	1.323**	0.052	1.64	4.30
Kernel mass (g)	35	0.185**	0.003	0.25	1.07
Kernel length (cm)	35	0.148**	0.020	0.98	2.44
Kernel diameter (cm)	35	0.027**	0.007	0.54	1.07
Pulp ratio (%)	35	274.228**	2.908	39.77	88.64
Pulp mass (g)	35	12.516**	3.485	0.65	3.43
Fruit juice pH	35	0.018**	0.0004	2.80	3.16
Fruit juice TSS (°Brix)	35	14.822**	3.711	13.2	22.5
Error	72				

In terms of the pulp portion of fruit, SOA4 genotype had the highest pulp/fruit ratio with an average of 88.64%. The lowest percentage of pulp to fruit (39.77%) was detected in SOY4 genotype (Table 4). The pulp mass of the fruits ranged between 0.65 and 3.43 g. SOY4 had the lowest pulp mass among the studied genotypes. The highest pulp mass was found in KKP2 and KK7 (Figure 1). Fruit juice pH of the genotypes was varied between 2.80 and 3.16. The highest and the lowest fruit juice pH belonged to SOK3 and KKP2 genotypes, respectively. In terms of soluble solid content (TSS), the variation range was 13.2 to 22.5 °Brix.

The genotypes of SOK4 and SOM2 showed the highest and the lowest soluble solid content, respectively (Figure 2). Based on the investigated parameters , the genotypes were classified (Figure 3). By cutting the

Table 3. Visual characteristics of fruits in different cornelian cherry genotypes (Different letters in each column show significant differences according to Duncan's multiple range test at $P \leq 0.05$)

Genotype		Fruit length (cm)	Fruit diameter (cm)	Fruit shape	Fruit mass (g)
1	KK1	$2.10^{b\text{-}f}$	$1.50^{b\text{-}i}$	1.40^{def}	$3.14^{d\text{-}g}$
2	KK2	$2.02^{c\text{-}g}$	1.53^{bf}	1.32^{f}	$3.07^{e\text{-}h}$
3	KK3	$1.95^{c\text{-}h}$	$1.34^{e\text{-}k}$	1.46^{cd}	$2.29^{l\text{-}p}$
4	KK5	2.16^{bcd}	$1.28^{g\text{-}k}$	1.69^{ab}	$2.64^{h\text{-}m}$
5	KK6	$2.11^{b\text{-}e}$	1.59^{bd}	1.33^{ef}	3.39^{cde}
6	KK7	2.20^{bc}	1.64^{bc}	1.34^{ef}	3.92^{ab}
7	KKP1	1.67^{hi}	$1.25^{i\text{-}k}$	1.34^{ef}	$1.79^{r\text{-}s}$
8	KKP2	3.35^{a}	2.30^{a}	1.46^{cd}	4.30^{a}
9	KKP3	$2.04^{c\text{-}g}$	1.68^{b}	1.20^{g}	3.52^{cd}
10	KKP4	$1.80^{e\text{-}i}$	1.24^{jk}	1.45^{cde}	$1.84^{q\text{-}s}$
11	SOA1	$2.03^{c\text{-}g}$	$1.26^{h\text{-}k}$	1.61^{b}	$2.22^{m\text{-}q}$
12	SOA2	$2.02^{c\text{-}g}$	$1.38^{d\text{-}k}$	1.46^{b}	$2.63^{h\text{-}m}$
13	SOA3	$1.76^{f\text{-}i}$	$1.30^{e\text{-}k}$	1.35^{ef}	$2.17^{n\text{-}s}$
14	SOA4	$1.96^{c\text{-}h}$	$1.41^{c\text{-}k}$	1.39^{cde}	$2.67^{h\text{-}l}$
15	SOA5	$2.00^{c\text{-}h}$	$1.49^{b\text{-}i}$	1.34^{def}	$3.01^{e\text{-}j}$
16	SOH1	$1.99^{c\text{-}h}$	$1.40^{d\text{-}k}$	$1.42^{c\text{-}f}$	$2.96^{f\text{-}j}$
17	SOH2	$1.81^{e\text{-}i}$	1.20^{jk}	1.51^{cd}	$1.92^{p\text{-}s}$
18	SOH3	$2.04^{c\text{-}g}$	$1.42^{c\text{-}j}$	1.44^{bc}	$2.49^{k\text{-}o}$
19	SOK1	$1.91^{c\text{-}i}$	$1.44^{c\text{-}j}$	1.30^{f}	$2.75^{g\text{-}k}$
20	SOK2	$1.89^{c\text{-}i}$	$1.31^{e\text{-}k}$	1.44^{cde}	$2.06^{o\text{-}s}$
21	SOK3	1.74^{ghi}	1.24^{jk}	1.40^{def}	$1.76^{r\text{-}s}$
22	SOK4	1.60^{ij}	1.17^{k}	1.36^{def}	$1.97^{p\text{-}s}$
23	SOM1	$2.02^{c\text{-}g}$	$1.43^{c\text{-}j}$	1.41^{def}	$2.72^{g\text{-}l}$
24	SOM2	2.38^{b}	$1.54^{b\text{-}e}$	1.55^{bc}	3.69^{bc}
25	SOM3	$2.08^{b\text{-}f}$	$1.36^{d\text{-}k}$	1.53^{bc}	$2.96^{f\text{-}j}$
26	SOM4	$1.84^{d\text{-}i}$	$1.29^{f\text{-}k}$	1.43^{cde}	$2.23^{m\text{-}q}$
27	SOS1	$1.88^{c\text{-}i}$	$1.32^{e\text{-}k}$	$1.42^{c\text{-}f}$	$2.35^{k\text{-}q}$
28	SOS2	$1.85^{d\text{-}i}$	$1.42^{c\text{-}j}$	1.30^{f}	$2.95^{f\text{-}j}$
29	SOT1	$2.04^{c\text{-}g}$	$1.52^{b\text{-}g}$	1.34^{ef}	4.04^{ab}
30	SOV1	$1.95^{c\text{-}h}$	$1.34^{e\text{-}k}$	1.46^{cd}	$2.55^{j\text{-}n}$
31	SOV2	$1.98^{c\text{-}h}$	$1.35^{e\text{-}k}$	1.47^{cd}	$2.58^{i\text{-}n}$
32	SOV3	$1.83^{d\text{-}i}$	$1.27^{h\text{-}k}$	1.44^{cde}	$2.69^{h\text{-}l}$
33	SOY1	$1.80^{d\text{-}i}$	$1.50^{b\text{-}h}$	1.20^{g}	$2.95^{f\text{-}j}$
34	SOY2	$1.80^{e\text{-}i}$	$1.36^{d\text{-}k}$	1.32^{f}	$2.41^{k\text{-}o}$
35	SOY3	$2.00^{c\text{-}h}$	$1.44^{c\text{-}j}$	1.39^{def}	$3.36^{c\text{-}f}$
36	SOY4	1.36^{j}	0.73^{l}	1.86^{a}	1.64^{s}

dendrogram from a distance of about 5 euclidean, the cornelian cherry genotypes were divided into 3 groups. 20 genotypes were grouped in the first cluster. There were 15 genotypes in the second group and only one genotype (SOY4) was in the third group. The SOY4 genotype in the third group showed the greatest difference with the SOA2 genotype in the first group. In the case of the investigated traits, the major differences among the genotypes were due to the kernel mass and pulp to kernel ratio, respectively. Pearson correlation analysis uncovered some correlations between the investigated traits at $P \leq 0.05$ and $P \leq 0.01$ levels. Fruit mass was positively correlated with fruit length, fruit diameter, kernel length, kernel diameter and kernel mass at the level of 1% probability. Also, there was a negative correlation between fruit mass with fruit juice pH and TSS parameters at the level of $P \leq 0.05$ and $P \leq 0.01$, respectively. The ratio of pulp to fruit only showed a negative and significant correlation with Kernel mass ($P \leq 0.01$). Other correlations are represented in Table 5.

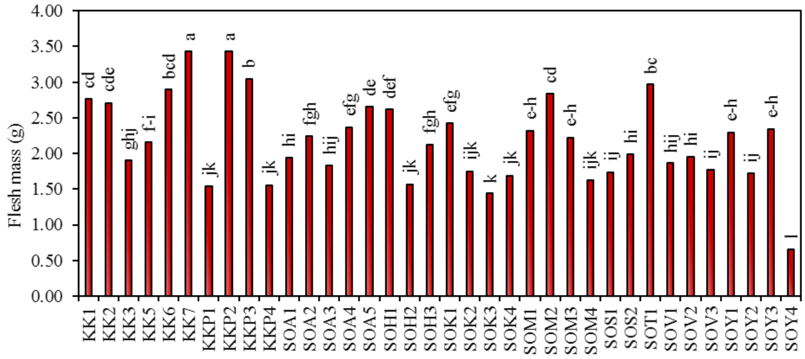

Figure 1. Pulp mass in fruits of cornelian cherry genotypes (different letters in each column show significant differences according to Duncan's multiple range test at $P \leq 0.05$)

DISCUSSION

Finding superior high-yield genotypes with premium crop is a major step in improving fruit tree cultivars and establishment of productive orchards. Seedling-based orchards are unique and valuable collections of fruit tree germplasms for breeders. Our survey in seedling orchards indicated that significant variations exist in fruit size, shape and quality among cultivated cornelian cherry seedlings. The large size of fruits is the major criterion in selecting superior cornelian cherry genotypes (Bijelic et al. 2007, Karadeniz 2000). Fruit mass is expected to be higher in trees with larger fruits. Higher fruit size and mass directly increase the yield of the tree. In the present study, fruit mass was positively correlated with fruit length and diameter. Similar results were reported by Hassanpour et al. (2012) and Cosmulescu & Cornescu (2020). The minimum length and width of the fruits were comparable to those reported by previous studies; however, the maximum length of the fruits was larger than those reported by Demir & Kalyoncu (2003): 1.09-1.64cm, Tural & Koca (2008): 0.96-1.32cm, Brindza et al. (2009): 0.74-1.52cm, Hassanpour et al. (2012): 1.02-1.63cm, Imani & Rad (2015): 1.08-1.60cm and by Cornescu & Cosmulescu (2017): 0.88-1.46cm.

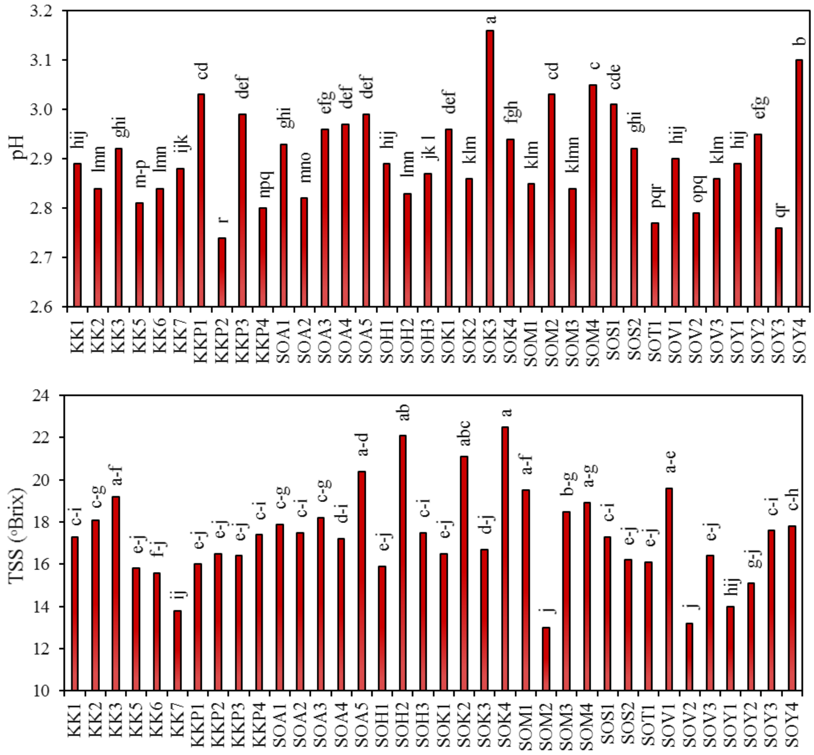

Figure 2. Juice pH and TSS content in cornelian cherry genotypes (different letters in each column show significant differences according to Duncan's multiple range test at $P \leq 0.05$)

Table 4. Kernel characteristics and flesh ratio of fruits in different cornelian cherry genotypes (Different letters in each column show significant differences according to Duncan's multiple range test at $P \leq 0.05$)

Genotype		Kernel mass (g)	Kernel length (cm)	Kernel diameter (cm)	Pulp / fruit ratio (%)
1	KK1	0.38 ^{jkl}	1.50 ^{cde}	0.65 ^{cd}	87.84 ^{abc}
2	KK2	0.36 $^{j-m}$	1.37 $^{c-f}$	0.63 ^{cd}	88.00 ^{ab}
3	KK3	0.39 $^{h-k}$	1.40 $^{c-f}$	0.62 ^{cd}	82.87 ^{def}
4	KK5	0.48 $^{g-h}$	1.54 ^{cd}	0.57 ^{d}	81.68 ^{efg}
5	KK6	0.49 ^{g}	1.43 $^{c-f}$	0.64 ^{cd}	85.31 $^{b-d}$
6	KK7	0.49 ^{g}	1.48 $^{c-f}$	0.66 ^{cd}	87.45 ^{abc}
7	KKP1	0.25 ^{n}	1.21 ^{f}	0.58 ^{cd}	85.41 $^{a-d}$
8	KKP2	0.86 ^{d}	2.44 ^{a}	1.07 ^{a}	79.65 ^{gh}
9	KKP3	0.47 ^{ghi}	1.38 $^{c-f}$	0.74 ^{bc}	86.45 ^{abc}
10	KKP4	0.28 ^{lmn}	1.27 $^{d-f}$	0.56 ^{d}	84.60 $^{c-e}$
11	SOA1	0.28 ^{mn}	1.42 $^{c-f}$	0.55 ^{d}	87.41 ^{abc}
12	SOA2	0.39 ^{ijk}	1.49 $^{c-f}$	0.64 ^{cd}	85.12 $^{b-d}$
13	SOA3	0.33 $^{j-n}$	1.23 ^{ef}	0.60 ^{cd}	84.63 $^{c-e}$
14	SOA4	0.30 $^{k-n}$	1.37 $^{c-f}$	0.55 ^{d}	88.64 ^{a}
15	SOA5	0.36 $^{j-m}$	1.38 $^{c-f}$	0.83 ^{b}	87.87 ^{abc}
16	SOH1	0.35 $^{j-m}$	1.33 ^{def}	0.58 ^{cd}	87.81 ^{abc}
17	SOH2	0.35 $^{j-m}$	1.35 ^{def}	0.54 ^{d}	81.43 ^{fg}
18	SOH3	0.37 $^{j-m}$	1.43 $^{c-f}$	0.61 ^{d}	85.14 $^{b-d}$
19	SOK1	0.32 $^{j-n}$	1.31 ^{df}	0.57 ^{cd}	88.04 ^{ab}
20	SOK2	0.31 $^{j-n}$	1.41 $^{c-f}$	0.60 ^{cd}	84.70 $^{b-e}$
21	SOK3	0.31 $^{j-n}$	1.30 ^{df}	0.60 ^{cd}	81.83 ^{efg}
22	SOK4	0.28 ^{lmn}	1.26 ^{df}	0.55 ^{d}	85.62 $^{a-d}$
23	SOM1	0.40 $^{g-j}$	1.47 $^{c-f}$	0.63 ^{cd}	85.08 $^{b-d}$
24	SOM2	0.86 ^{d}	1.80 ^{b}	0.70 ^{bcd}	76.72 ^{ij}
25	SOM3	0.74 ^{e}	1.63 ^{bc}	0.63 ^{cd}	74.97 ^{ijk}
26	SOM4	0.61 ^{f}	1.35 ^{def}	0.57 ^{d}	72.63 ^{kl}
27	SOS1	0.61 ^{f}	1.32 ^{def}	0.58 ^{cd}	73.95 ^{jkl}
28	SOS2	0.96 ^{bc}	1.25 ^{ef}	0.60 ^{cd}	67.42 ^{no}
29	SOT1	1.07 ^{a}	1.51 ^{cde}	0.64 ^{cd}	73.45 ^{kl}
30	SOV1	0.69 ^{ef}	1.47 $^{c-f}$	0.63 ^{cd}	72.88 ^{kl}
31	SOV2	0.63 ^{f}	1.32 ^{def}	0.60 ^{cd}	75.64 ^{ijk}
32	SOV3	0.92 ^{cd}	1.34 ^{def}	0.54 ^{d}	65.58 ^{o}
33	SOY1	0.66 ^{ef}	1.34 ^{def}	0.62 ^{cd}	77.37 ^{hi}
34	SOY2	0.68 ^{ef}	1.38 $^{c-f}$	0.63 ^{cd}	71.50 ^{lm}
35	SOY3	1.02 ^{ab}	1.46 $^{c-f}$	0.59 ^{cd}	69.61 ^{mn}
36	SOY4	0.99 ^{abc}	0.98 ^{g}	0.60 ^{cd}	39.77 ^{p}

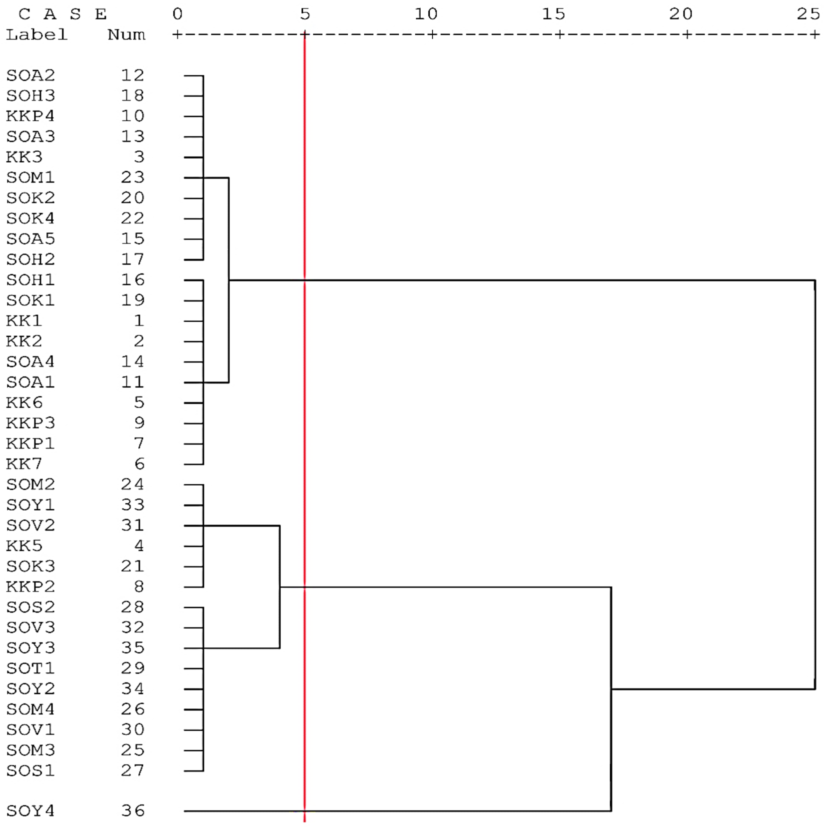

Figure 3. Cluster analysis of cornelian cherry genotypes based on fruit-related traits

The fruit length in our genotypes was almost similar to that reported by Yilmaz et al. (2009) in Turkish genotypes (1.48–3.11cm). The maximum value of fruit width was also larger than those reported in Demir & Kalyoncu (2003): 1.09–1.64 cm, Tural & Koca (2008): 0.96–1.32 cm, Brindza et al. (2009): 0.74–1.52cm, Hassanpour et al. (2012): 1.02–1.63cm, Imani and Rad (2015): 1.08–1.60cm and by Cornescu & Cosmulescu (2017): 0.88-1.46cm. Among the investigated genotypes, KKP2 had the largest fruits. Different studies have indicated that the fruit mass of cornelian cherry genotypes ranged from 0.39-9.2g. In this study, the fruit mass of the investigated genotypes was between 1.64 to 4.30g. The mass of the fruits reported by Tural & Koca (2008) in Turkey (0.39–1.03g), Brindza et al. (2007) in Slovakia (0.5 to 3.4g) and Drkenda et al. (2014) in Bosnia

Table 5. Correlations between the fruit traits in cornelian cherry genotypes (ns, non-significant; ** and *, significant at $P \leq 0.01$ and $P \leq 0.05$)

	Fruit mass	Fruit length	Fruit diameter	pH	TSS	Kernel length	Kernel diameter	Kernel mass
Fruit length	0.745**							
Fruit diameter	0.826**	0.887**						
pH	-0.421*	-0.473**	-0.399*					
TSS	-0.449**	-0.262ns	-0.307ns	0.002ns				
Kernel length	0.670**	0.958**	0.811**	-0.446**	-0.160ns			
Kernel diameter	0.620**	0.782**	0.779**	-0.178ns	-0.118ns	0.757**		
Kernel mass	0.446**	0.189ns	0.128ns	-0.192ns	-0.338*	0.254ns	0.233ns	
Pulp ratio	0.132ns	0.276ns	0.407*	-0.135ns	0.109ns	0.189ns	0.076ns	-0.789**

Herzegovina (1.8–2.60g) was lower than the genotypes investigated in the current study. Bijelic et al. (2011) reported that the average fruit mass in the Serbian cornelian cherry populations was 3.65 g. Bijelic et al. (2011) in Slovakia, Ercisli (2004) and Yilmaz et al. (2009) in Turkey found genotypes with fruit mass 6.5, 6.71 and 9.2g, respectively. The differences in the size and weight of the fruits, which are observed in different research, are primarily due to the difference in the genetics of the plants (Kim et al., 2003). In addition, the difference in climatic conditions can also be involved to some extent in creating such differences. In this regard, Cosmulescu & Cornescu (2020) showed that the growth of cornelian cherry fruit in different places and even in different years had significant differences. This issue can reduce the reproducibility of the results, especially when the genotypes are collected from wild populations. Collecting superior genotypes from among the cultivars available in orchards can be effective in reducing environmental effects on growth indicators and fruit quality to a great extent. Because in gardens, the environmental conditions for plant growth and performance are optimized to a great extent, and this allows for a more accurate assessment of the plant's genetic potential in production. In most studies, the mass of cornelian cherry fruits is reported1.2-3.5 g (Ercisli et al. 2006, Brindza et al. 2009, Hassanpour et al. 2012, Imani & Rad 2015). Therefore, the results of this research suggested that it is possible to find genotypes with heavy fruits among the trees grown in seedling-based orchards. In this regard, SOM2, KKP2, SOT1, KK7 and KKP3 with oval to elongated shapes had the largest fruits with an average mass of over 3.5g and were introduced as superior genotypes (Figure 4). Jacimovic & Bozovic (2014) suggested that genotypes with fruit mass over 4.0 g are suitable for fresh consumption. Therefore, the genotypes KKP2 and SOT1 with an average fruit mass over 4.0 g were the most suitable genotypes for fresh consumption. Although having bigger fruits can indicate the higher yield capacity of the tree and the marketability of the crop, the quality of the fruit also depends on the size of the kernel and the ratio of pulp to fruit. A large diversity in the kernel size (mass and dimensions) was observed. Previous researchers have also reported diversity in kernel mass. Our results were close to those reported by Hassanpour et al. (2012): 0.26-0.64 g and Cosmulescu & Cornescu (2020): 0.22-0.58 g. However, the kernel mass reported in Imani & Rad (2015): 1.26-3.01 g is beyond the other studies. Positive relationships between kernel size (dimension and mass) and fruit size and mass were observed. The formation and presence of seeds are necessary for fruit set and growth. The seed induces fruit growth by producing growth-stimulating phytohormones (Balaguera-López et al. 2020). However, since the kernel is a redundant part of the fruit, the presence of large seeds can reduce the quality value of the fruits. Fruits with high pulp-to-fruit ratios are valuable (Cosmulescu & Cornescu 2020). The pulp ratio in the investigated genotypes covered a wide range. With the exception of SOY4 with non-fleshy fruits (pulp ratio 39.77%), the pulp ratio in the other genotypes ranged from 65.58-88.64%. Our results were similar to those reported by Cosmulescu & Cornescu (2020): 66.71-90.02%. Cornescu & Cosmulescu (2017) pulp ratio in six Romanian cornelian cherry genotypes, ranged from 61.53-78.58%, which was lower than that in the current study. Ercisli et al. (2006) and Bijelic et al. (2011) reported a more limited range of pulp-to-fruit ratios (79.0-88.0% and 78.52-88.74%, respectively). Pulp to fruit ratio represented a negative relationship with kernel mass and a positive relationship with fruit diameter. Therefore, it seems that breeding of cornelian cherry with the aim of increasing the diameter of the fruits and developing oval shaped fruits will increase the quality of the crop. Low pulp ratio is not acceptable for fresh consumption of fruits. Moreover, the processing of such fruits is difficult and non-efficient. Jacimovic & Bozovic (2014) stated that genotypes with a pulp-to-fruit ratio of over 89% are suitable for processing. However, our results indicated that a high pulp ratio does not necessarily indicate the quality and application of cornelian cherry fruits. Genotypes such as KKP1 had a high pulp ratio of over 85%, but the pulp mass in its fruits was as low as 1.50 g. Therefore, in addition to the pulp ratio, the pulp mass of the fruits should be considered in the determination of fruit application in cornelian cherry genotypes. It was suggested that genotypes whose fruits have a pulp ratio of about 80% and pulp mass about 3.0 g can be used for processing and juice extraction. In this regard, the genotypes KK6, KK7, KKP2, KKP3, and SOT1 represented suitable traits.

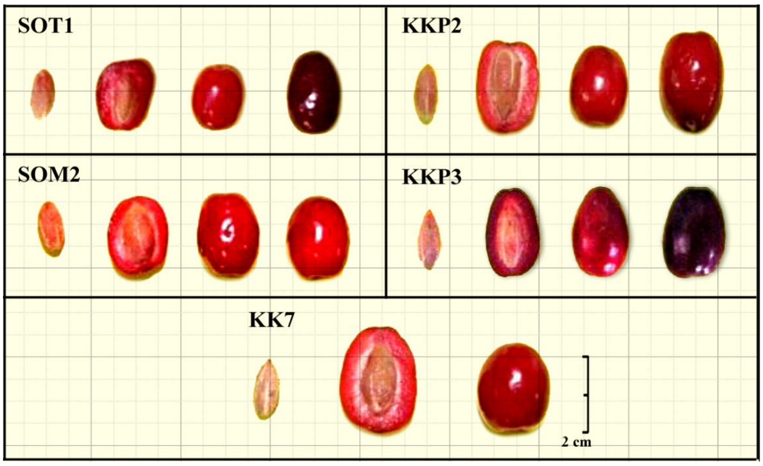

Figure 4. Superior cornelian cherry genotypes found in the seedling orchards of the Alamout region

Cornelian cherry fruit has a higher TSS content compared to other small fruits such as strawberry (8.00°Brix), raspberry (10.70°Brix) and blackberry (12.81Brix) (Martinović & Cavoski 2020). In our study the maximum soluble solid content, 22.5°Brix (in SOK4), was close to that reported by Yilmaz et al. (2009): 21.17°Brix. However, we found genotypes with higher TSS than previous reports; i.e. 17.53°Brix in Copur et al. (2003) and 12.2°Brix in Hassanpour et al. (2012). The fruit juice pH of the genotypes varied between 2.80 (in KKP2) to 3.16 (in SOK3). Low pH is a characteristic of cornelian cherries fruits and indicates a high concentration of organic acids in the fruit (Martinović & Cavoski 2020, Tural & Koca 2008, Drkenda et al., 2014). Our results were close to that reported by Brindza et al. (2007): 2.78-3.17. However, other researchers have reported higher values of juice pH in cornelian cherries. In a study carried out in Slovenia, the average amount of pH in cornelian cherry genotypes was 3.38 (Oblak 1980). In a study conducted by Volkan (2016) in Turkey, pH varied between 2.60 and 4.02. Investigating the correlations between the fruit parameters indicated that larger fruits had lower fruit juice pH and TSS (Table 4). This result suggested that large fruits are sourer than small fruits.

Grouping of cornelian cherry genotypes based on the morphological and biochemical data was performed and the genotypes were divided into three groups. The kernel size and pulp-to-fruit ratio data were useful in the classification of the genotypes. The first cluster consisted of genotypes with a lower kernel mass and high pulp ratio. The second cluster consisted of the genotypes with high kernel mass and low pulp ratio. The SOY4 genotype was the only member of the third cluster. This genotype is characterized by large seeds and the lowest pulp ratio. Our results were inconsistence with Hassanpour et al. (2012) who demonstrated that kernel properties were important traits in the classification of cornelian cherry genotypes.

CONCLUSION

A large diversity was found in seedling-based cornelian cherry orchards in the Alamut region. Based on the results, SOM2, KKP2, SOT1, KK7 and KKP3 genotypes with elongated (SOM2) to oval (KKP3) shaped fruits and weighing more than 3.50 g, were introduced as superior genotypes for fresh consumption. The genotypes KKP2, KK7, SOT1, KK6 and KKP3 with the highest pulp mass and high pulp-to-fruit ratio represented suitable traits for processing and juice extraction. The introduced genotypes can be used for the establishment of new orchards or may be involved in cornelian cherry breeding programs.

Acknowledgment

We would like to express our gratitude to the Qazvin Agricultural and Natural Resources Research and Education Center for supporting this study.

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