Pomological attributes among Iranian sour pomegranates (*Punica granatum* L.)

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ABSTRACT

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Pomegranate is one of the most important horticultural crops in Iran. Fruit pomological characterization has usually been used for the assessment of pomegranate germplasm, and is a crucial step before the beginning of any molecular study. In spite of the commercial importance of Iranian pomegranate fruit worldwide, little information is available on the attributes of some of its genotypes. In this two-year study, 15 pomological attributes of 38 sour pomegranate genotypes growing in Markazi province were evaluated. A great variability was found among pomegranate genotypes in fruit weight and size, calyx size, 100 arils (g), total soluble solid contents, peel thickness, crack sensitivity, aril adhesion to the skin, aril colour, aril juiciness and seed hardiness. Some genotypes were notable for their various characteristics. For example,"6-3-S"genotypes with large fruit and good aril yield, red color, juicy aril, soft seeds, slight adhesion of the aril to the skin and low sensitivity to cracking is promising genotype for food processing and marketing. A greater part of variance was counted by traits such as calyx diameter, calyx length, fruit length, fruit weight and aril weight that showed wide variability among accessions and could be utilized for future breeding programs.

Keywords: Pomegranate, Pomology, Fruit, Iran

INTRODUCTION

Pomegranate (*Punica granatum* L., Lythraceae), an economically and pharmacologically valuable fruit, is a native plant from Iran to the Himalayas in northern India (Levin, 1994). Medicinal properties and nutritional benefits of the different parts of pomegranate, especially its fruit, have been proved by traditional and modern science. Recent scientific publications suggest that pomegranate has antioxidant, anti-carcinogenic, anti-diabetic, anti-inflammatory and antimicrobialactivities (Seeram *et al*., 2006; Lansky and Newman, 2007; Holland *et al*., 2009; Johanningsmeier and Harris, 2011; Smith *et al*., 2014). Despite abundant information on phytochemical composition and pharmacological properties, some pomegranate genotypes are still not fully characterized.

Iran is the biggest exporter of pomegranate (60,000 t) in the world (Jaime *et al*., 2013) and is vastly rich in genetic diversity of pomegranate with more than 700 genotypes grown in different regions throughout the country (Verma *et al*., 2010). In spite of the commercial importance of Iranian pomegranate fruit, little information is available on the attributes of some its genotypes.

Fruit pomological characterization has usually been used for the assessment of pomegranate germplasm, and is a crucial step before the beginning of any molecular study. Knowledge of pomology is important for the biodiversity evaluation, genetic resources preservation and proper genotype selection with desirable traits and future breeding planning (Zarei, 2017). Pomology of pomegranate has been studied in different regions. Sarkhosh, *et al*. (2009) studied the relationships among fruit quantitative and qualitative characteristics of some Iranian pomegranate genotypes and reported that fruit juice, aril, and seed characteristics are the main factors for separation of the pomegranate genotypes studied. Evaluation of physical and chemical properties of pomegranate fruit accessions from Croatia showed great differences in fruit physical characteristics and chemical composition among pomegranate accessions (Radunic *et al*., 2015). Correlation coefficients for different parameters of pomegranate fruit were reported by Okatan *et al*. (2015) in Turkey. They found considerable variation on fruit weight, aril weight, fruit length and fruit width, which are important for pomegranate breeding. Karimi and Mirdehghan (2013) evaluated correlation between the morphological characters of pomegranate traits in Iran. According to their study, leaf weight and chlorophyll index can be used for separation of sour from sweet cultivars in the juvenile phase. Characterization based on morphological parameters is commonly used to solve duplication problems within germplasm collections (Zaouay and Mars, 2012). Other studies on pomegranate have shown the large genetic variability of this crop by using molecular and morphological markers (Ferrara *et al*., 2014; Basaki *et al*., 2017).

The fruit morpho-pomological attributes of soure Iranian pomegranate genotypes have not been evaluated so far. Therefore, the present work aims to compare morpho-pomological attributes of 38 sour pomegranate genotypes to determine the overall polymorphism degree in the traits studied and correlations between pomological characteristics in the pomegranate germplasm of Iran.

MATERIALS AND METHODS

Thirty eight genotypes (Table 1) were selected from five-year-old pomegranate trees growing at the Pomegranate Research Center of Saveh, Markazi province, Iran (34°45΄N; 49°15΄E). The experiment was conducted in α-Latis design with two replications. For each genotype, 15 fruits (5 fruits per tree × 3 trees) were randomly harvested at the ripening stage in 2013 and 2014. The fruits were collected in plastic bags and rapidly transferred to the laboratory for subsequent analyses.

Fruit length (mm) and diameter (mm), calyx length (mm) and diameter (mm), were measured using a ruler and caliper. Fruit and 100 arils (g) were weighed using a digital balance. The quality traits, including peel thickness, crack sensitivity, aril adhesion to the skin, aril colour, aril juiciness and seed hardiness were investigated using pomegranate descriptor. Seed hardness was scored based on a scale of 1-3 (1: Soft, 2: Semi-hard and 3: Hard) (Sarkhosh *et al*., 2009). The aril color was evaluated using a scale ranging from 1-3 (1: White, 2: Pink and 3: Red) and aril juiciness was scored from 1-3 (1: juicy, 2: moderate and 3: shallow) (Bellini and Giordani, 1998). Peel thickness, crack sensitivity and aril adhesion to the skin were described based on the pomegranate descriptor developed by the Seed and Plant Improvement Institute, Iran**.** (Sadeghian Motahar, 2009). Juice pH was recorded with a digital pH meter at room temperature. Total soluble solids (TSS) of arils were determined with a digital hand-held refractometer at room temperature, and expressed as °Brix (Zhang *et al*., 2010).

Statistical analyses were performed by means of SPSS 16.0 software package for Windows (SPSS Science, Chicago, IL, USA). Analysis of variance (ANOVA) was done to determine the difference among genotypes. Significant differences between means were evaluated by Duncan's multiple range tests ($P < 0.01$). Correlation analyses using Pearson correlation and principal component analysis (PCA) were used to assessment the variation between fruit characteristics in the same software.

Results and Discussions

Morpho-pomological characteristics

In this study, all of the selected genotypes were registered as sour-taste genotypes. This is the first report on pomological characterization among sour pomegranate genotypes in Iran. We observed non-significant differences in the recorded data between two years (data not shown). Significant differences ($P < 0.01$) were recorded among the pomegranate genotypes for quantitative traits. As shown in Table 2, the fruit weight varied widely among genotypes, from a minimum of 27.40 g (6-153-S) to a maximum of 243.20 g (6-3-S). These amounts are generally lower than the amounts of different reports in Iran and other countries (Okatan *et al*., 2015; Zarei *et al*., 2010; Sarkosh *et al*., 2009; Tehranifar *et al*., 2010; Ferrara *et al*., 2014). Among analyzed cultivars by Zaouay and Mars (2011) and Zaouay *et al*., (2012), the smallest fruit was recorded for sour taste cultivar (GS1) with 87.1 and 101.3 g respectively. Dandachi *et al*. (2017) found that sour-taste Lebanese accession (Hamod B53) had lower fruit weight than sweet-taste LefaniSL67 accession (43.15 g as compared with 357.60 g respectively). Unlike our results, Ferrara *et al*. (2014) showed that two Italian sour pomegranate genotypes, Wond and SouOst, had the highest values for all the fruit size parameters. Greek sour pomegranate varieties were also the largest fruit among tested varieties (Drogoudi *et al*., 2005). Effects of cultivar and ecological condition on fruit weight were previously discussed by Shulman *et al*., (1984). Fruit length ranked from32.50 mm (6-153-S) and 71.50 mm (21-91-S). Fruit diameter ranged between a minimum of 32.50 mm (6-153-S) and a maximum of 79.50 mm (8-18-S). Our results were lower than other works

Table 1. Genotype code, genotype name, origin and some pomological traits of 15 pomological attributes of 38 sour pomegranate genotypes growing in Markazi Province, Iran.

Genotype Code	Genotype Name	City of Sampling	Skin Thickness	Cracking Sensitivity	Aril Adhesion to the Skin	Aril Color	Aril Juiciness	Seed Hardiness
2-5-S	Torsh-Poost Ghermez-Dareh Hourand	East-Azarbayejan	Moderate	Low	Slight	Pink	Moderate	Soft
2-152-S	Torsh-Dane Dorosht-Dareh Hourand	East-Azarbayejan	Thick	Low	Slight	White	Shallow	Hard
3-158-S	Torsh-Sabz-Charmak-Elam	Elam	Thin	Low	Slight	Pink	Juicy	Semi-hard
4-177-S	Berit-Mamoli-Kazeron	Fars	Moderate	Low	Slight	Red	Juicy	Semi-hard
6-3-S	Torsh-Jangali-Talesh-Rasht	Gilan	Moderate	Low	Slight	Red	Juicy	Soft
6-153-S	Torsh-Dareh Loushan	Gilan	Thin	Low	Strong	Pink	Shallow	Semi-hard
8-18-S	Bi name-Dastjerd	Isfahan	Thin	High	Strong	Pink	Moderate	Semi-hard
8-28-S	Torsh-Zaghi-Kouhpayeh	Isfahan	Thin	Low	Moderate	Pink	Shallow	Semi-hard
8-36-N	Torsh-Damagh baste-Kouhpayeh	Isfahan	Very thick	Low	Strong	Pink	Shallow	Hard
8-104-S	Anbari-Poost Koloft-Kashan	Isfahan	Thick	Low	Strong	White	Shallow	Soft
8-105-S	Torsh-Poost Sefid-Yaran	Isfahan	Thick	Low	Moderate	White	Shallow	Soft
8-121-S	Torsh-Khatooni-Natanz-Isfahan	Isfahan	Thick	Low	Strong	White	Shallow	Semi-hard
8-122-S	Shomare yek-Kashan	Isfahan	Thin	Low	Strong	Pink	Shallow	Hard
8-135-N	Aban mahi-Isfahan	Isfahan	Thick	High	Slight	Pink	Shallow	Hard
8-136-S	Torsh-Marmar	Isfahan	Thin	Low	Slight	White	Shallow	Semi-hard
8-163-S	Torsh-Isfahan	Isfahan	Thin	High	Slight	Pink	Shallow	Semi-hard
9-173-S	Torsh-Daneh Ghermez-Ravar	Kerman	Thin	Low	Slight	White	Juicy	Soft
10-112-S	Shahrbani-Torsh-Rijab-Bakhtaran	Kermanshah	Thin	Low	Moderate	Pink	Shallow	Semi-hard
10-144-S	Torsh-Poost Sefid-Rijab	Kermanshah	Thin	Low	Moderate	Pink	Moderate	Semi-hard
10-159-S	Torsh-Poost Koloft-Rijab-Bakhtaran	Kermanshah	Thick	Low	Strong	Pink	Shallow	Semi-hard
10-171-S	Razhnar-Ravansar-Paveh	Kermanshah	Thin	Low	Slight	Red	Juicy	Semi-hard
13-11-S	Torsh-Shooshtar	Khuzestan	Thick	Low	Strong	Pink	Shallow	Hard
14-7-S	Torsh nar-Daneh ghermez-A lot-Baneh	Kordestan	Thin	High	Slight	Red	Juicy	Semi-hard
14-63-N	Abbasi-Kordestan	Kordestan	Thick	Low	Slight	Pink	Juicy	Semi-hard
15-47-S	Soz-Lori-Shi-Nesha-Lorestan	Lorestan	Thick	Low	Strong	Pink	Juicy	Hard
15-80-S	Torsh-Poost Sefid-Khoramabad	Lorestan	Moderate	Low	Strong	White	Shallow	Soft
15-156-S	Torsh-Gav damagh-Kouhdasht	Lorestan	Moderate	Low	Slight	Pink	Juicy	Soft
19-74-S	Torsh-Zabol	Sistan Baluchestan	Thin	Low	Slight	Pink	Shallow	Soft
19-127-S	Torsh-Poost Sabz-Zahedan	Sistan Baluchestan	Thick	Low	Slight	Pink	Moderate	Semi-hard
20-113-N	Tokhm-Save dar-Kan	Tehran	Very thick	High	Strong	White	Shallow	Hard
21-17-S	Torsh-Tafti-Marvest-Yazd	Yazd	Moderate	High	Strong	Red	Moderate	Semi-hard
21-42-S	Karche-Tafti-Torsh	Yazd	Thick	Low	Slight	Pink	Juicy	Semi-hard
21-49-S	Se-anbeli-Taft-Yazd	Yazd	Thin	Low	Slight	Pink	Juicy	Semi-hard
21-67-N	Togh-Gardan-Torsh-Yazd	Yazd	Very thick	Low	Moderate	Pink	Shallow	Hard
21-89-S	Aban mahi-Torsh-Yazd	Yazd	Thin	Low	Strong	Red	Shallow	Hard
21-91-S	Zagh-Karche-Torsh-Yazd	Yazd	Moderate	Low	Slight	Pink	Moderate	Semi-hard
21-114-S	Torsh-Yazd	Yazd	Thick	Low	Moderate	White	Shallow	Hard
21-183-S	Koohi-Siri-Tabas-Torsh	Yazd	Thin	High	Moderate	White	Moderate	Semi-hard

(Okatan *et al*., 2015) but were close to the Turkish genotypes (Muradoglu *et al*., 2006) and Lebanese accessions (Dandachi *et al*. 2017). The calyx length varied between 14.90 mm (8-121-S) and 23.30 mm (21-89-S). Tehranifar *et al*., (2010) reported calyx length range from 13.45 mm in Agha Mandali Saveh to 24 mm in Shisheh Kab. The calyx diameter ranged between 10 mm (8-121-S) and 16.90 mm (8-18-S). These values were close to the values reported by Muradoglu *et al*. (2006).

Table 2. Mean values of fruit weight, length and diameter, calyx length and diameter, pH, aril weight and TSS of 38 sour pomegranate genotypes growing in Markazi Province, Iran (average for 2013 and 2014).

Genotype Number	Fruit weight (g)	Fruit length (mm)	Fruit diameter (mm)	Calyx length (mm)	Calyx diameter (mm)	pH	Aril weight (g 100 aril^{-1})	Total Soluble Solids (%)
2-5-S	44.10^{d}	55^{fghij}	54.5^{jkl}	18.3^{efghijk}	12.2^{cdefg}	2.75^{ef}	9^{ab}	11.00^{b}
2-152-S	134.15^{n}	58.5 ^{hijkl}	56.6^{lm}	19.2^{fghi}	12.9^{efghi}	3.04^{h}	23^{lm}	13.00^{f}
3-158-S	107.90^{l}	56 ^{ghijk}	56.5^{lm}	19.6^{efghij}	11.9^{cdefg}	2.93^{g}	20^{hij}	12.00^{d}
4-177-S	88.20j	51 ^{defghij}	50^{efgh}	18.5^{abcd}	12^{bcd}	3.62^{n}	30^{q}	15.00^{h}
6-3-S	243.20^{r}	65 ^{ijk}	65^{efghi}	16.5^{efghijk}	14.5^{bcdefg}	2.70^{c}	31^{q}	15.50^{i}
6-153-S	27.40^{b}	32.5 ^{ab}	32.5^{a}	15.4^{abc}	10.1^{abc}	2.80^{a}	9^{ab}	11.50^{c}
8-18-S	199.40^{q}	67.4 ^{klm}	79.5^{q}	23^{lmn}	16.9^{kl}	2.96^{g}	34^{r}	18.00^{k}
8-28-S	28.00^{b}	41.5 ^{abcde}	35.9^{a}	17.9^{cdefg}	11.7^{bcdefg}	2.83^{f}	11^{c}	13.00^{f}
8-36-N	47.40^{e}	47.5 ^{ijk}	45.5^{a}	21^{efghijk}	15^{cdefg}	3.07^{n}	51^{t}	14.00^{g}
8-104-S	101.50^{l}	56.5 ^{fghijk}	55^{efghij}	17^{n}	12.4^{defghi}	2.98^{g}	23^{lm}	10.00^{a}
8-105-S	64.10^{h}	47.5^{cdefghi}	45.8^{efghij}	19.3^{efghij}	11.4^{bcdef}	3.35^{k}	19^{gh}	10.00^{a}
8-121-S	48.20^{e}	40.5^{abcdef}	46.9^{fghijk}	14.9^{a}	10^{abc}	2.80^{ef}	8^{a}	14.00^{h}
8-122-S	59.05^{g}	47^{abcdefghi}	50.5^{hijkl}	20.6^{ghijklm}	11.8^{cdefg}	3.25^{j}	16de	12.00^{d}
8-135-N	45.15^{d}	46^{ijk}	44.5^{lm}	18.5^{abcde}	16.5^{a}	2.95^{g}	9.5^{b}	12.50^{de}
8-136-S	36.00^{c}	47.5^{abcd}	65.5^{cdefg}	17.5^{defg}	11.4^{ab}	2.84^{f}	11^{c}	13.50^{fg}
8-163-S	59.30^{g}	43^{abcdefg}	45^{efghi}	15.3^{abc}	11.6^{bcdefg}	2.57^{a}	10^{c}	10.00^{a}
9-173-S	155.50^{o}	67.5^{klm}	66.5^{no}	22.5^{klmn}	14.2^{hij}	2.60 ^{b}	12^{r}	11.00^{b}
10-112-S	107.85^{l}	57.5^{ghijkl}	53^{jkl}	21.7^{hijklmn}	13.4^{fghi}	3.11^{i}	33^{d}	13.00^{f}
10-144-S	162.45^{p}	66.6^{klm}	70.7^{op}	22.6^{klmn}	15.6^{jk}	3.63^{n}	21^{o}	13.00^{f}
10-159-S	47.15^{e}	45.5^{abcdefgh}	43.5^{defgh}	18.5^{defg}	11.8^{cdefg}	2.93^{g}	15de	12.00^{d}
10-171-S	32.00^{c}	47.5^{a}	45^{a}	17.5^{efghijk}	11.6^{hij}	2.83^{f}	26^{gh}	12.00d
13-11-S	73.25^{i}	46^{acdefghi}	48.1^{ghijk}	17.8^{cdefg}	11.2^{bcde}	3.06^{n}	16^{ef}	15.00^{i}
14-7-S	83.80^{j}	49^{abcdefghi}	52.2^{ijkl}	22.7^{klmn}	14.6^{ij}	2.84^{f}	18.7^{p}	13.20^{f}
14-63-N	50.70^{f}	53.5^{m}	53^{cdefg}	21^{defgh}	15^{defgh}	3.07^{n}	17^{c}	14.00^{h}
15-47-S	136.35^{n}	62^{jklm}	65.5^{no}	18.6^{defg}	16^{jk}	2.74 ^{dc}	28^{s}	16.00^{j}
15-80-S	85.55^{j}	55.3^{ijk}	54^{klm}	17.5^{abcdef}	14.1^{hij}	2.78 ^{de}	11^{ij}	18.00^{l}
15-156-S	94.90^{k}	57^{ghijk}	55.5^{lm}	20.3^{fghijkl}	12^{cdefg}	2.95^{g}	27^{mn}	13.00^{d}
19-74-S	126.75^{m}	60.5^{ijklm}	61^{mn}	22^{ijklmn}	12.8^{efghi}	2.94^{g}	20.5^{lm}	12.00^{d}
19-127-S	78.00^{i}	49^{defghij}	47^{cdefg}	17.5^{defg}	11.5^{cdefg}	3.06^{n}	24^{kl}	13.50^{g}
20-113-N	75.80^{i}	48.3^{bcdefghi}	43.5^{defgh}	20.2^{fghijk}	13.3^{efghi}	2.78 ^{de}	25^{fg}	12.00^{d}
21-17-S	69.00^{h}	46^{ghijkl}	44^{lm}	21^{n}	16.5^{l}	2.95^{g}	23^{q}	13.00^{f}
21-42-S	58.65^{g}	33.7^{abc}	39.2^{a}	15.1^{ab}	11.5^{bcdefg}	3.55^{m}	22^{n}	13.00^{f}
21-49-S	71.80^{i}	49^{defghij}	46^{efghij}	22.9^{lmn}	10.1^{abc}	2.95^{g}	18^{hi}	14.00^{h}
21-67-N	86.00^{j}	35^{fghij}	34.5^{cdefg}	21.2^{efghijk}	15.5^{cdefg}	3.07^{n}	30^{hij}	13.50^{g}
21-89-S	46.60^{d}	47^{abcdefgh}	39.8^{ab}	23.3^{mn}	10.3^{abc}	3.11^{i}	24.5^{jk}	12.50^{e}
21-91-S	160.05^{a}	71.5^{lm}	73.2^{pq}	23.1^{mnwelll}	13.6ghi	3.48^{l}	19.5^{hij}	14.00^{h}
21-114-S	79.00^{i}	52^{fij}	50^{hijkl}	17.5^{jklmn}	12^{ij}	3.12^{i}	20no	13.00^{f}
21-183-S	63.25^{h}	43.5^{abcdefgh}	47.5^{ghijk}	17.6^{bcdef}	12.8^{efghi}	2.95^{g}	21^{lm}	12.98^{e}
CV[a]	58.02	19.56	22	13.60	17.44	13.88	41.02	8.41

a Coefficient of Variation = (Standard deviation/Mean)×100

The lowest pH value was recorded for 8-163-S (2.57). 10-144-S and 4-177-S had the highest pH value of 3.63. The low value of pH in Iranian sour genotypes has been reported previously (Fadavi *et al*., 2005). These pH values are also very close to the results of Ferrara *et al*., (2014) for Italian and Israeli pomegranate genotypes and Muradoglu *et al*., (2006) for Turkish pomegranates.

The 100 arils weight ranged between 8g (8-121-S) and 34g (8-18-S). This range was lower than other Iranian genotypes (Tehranifar *et al*., 2010, Khadivi-Khub *et al*., 2015), Croatian accessions (Radunic *et al*., 2015) and Spanish cultivars (Martínez *et al*., 2006).

8-104-S, 8-105-S and 8-163-S showed the lowest TSS (10°Brix) while 8-18-S yielded the highest TSS content (18°Brix). These results were in agreement with values of Fadavi *et al*. (2005) that reported a range of (10–16.5°Brix) in other Iranian pomegranate genotypes. Muradoglu *et al*., (2006) were also showed a range of (12.2- 17.6) for Turkish pomegranate genotypes. Among the Italian genotypes, 18°Brix was also recorded for sour-taste genotype (SouMol). The higher levels of TSS for up to 19°Brix were recorded by Poyrazoglu *et al*. (2002) and Zarei *et al*. (2010) previously. Genotype, environmental conditions and harvesting time are the most important variables affecting technical composition (Mphahlele *et al*., 2014).

There was a wide variation in fruit skin thickness from thin to very thick among our genotypes (Table 1). Pomegranate fruits with thin peel are preferred by consumers because of fruit waste reduction and facility of peeling (Radunic *et al*., 2015).

Skin cracking in pomegranate causes crop and quality loss and reduction of shelf life (Saei *et al*., 2014). Among studied genotypes, seven genotypes showed high sensitivity to cracking whereas other genotypes did not sensitive (Table 1).

Aril color, Juiciness and adhesion to the skin are the most important pomegranate fruit characteristics that effect on pomegranate consumer acceptability and marketing. Our genotypes exhibited three-aril color including white, pink and red, and three kind of juiciness including shallow, moderate and juicy (Table 1). Three types of aril adhesion to the skin, strong, moderate and slight were detected for studied genotypes.

Soft-seeded is a desirable economic trait for pomegranate fruit (Sarkhosh *et al*., 2009). Seed hardiness of the studied genotypes was semi-hard to hard, but the soft seeds were observed for seven genotypes as shown in Table 1. In Turkish pomegranates, sour hard-seed genotypes were also observed as compared with sweet soft-seed ones (Caliskan and Bayazit, 2013). Alcaraz-Mármol *et al*. (2017) also showed that sour Spanish cultivars had the highest values in seed hardness as compared with sweet cultivars.

In general, sour genotypes in this study are not suitable for fresh consumption but among analyzed genotypes, 6-3-S (Torsh-Jangali-Talesh-Rasht) with large fruit and good aril yield, red color, juicy aril, soft seeds, slight adhesion of the aril to the skin and low sensitivity to cracking is promising genotype for food processing and marketing.

Correlations and principal component analyses

According to simple correlation analysis (Table 3), there was a high correlation between calyx length and diameter, fruit length, fruit weight, weight of 100 arils and TSS. The calyx diameter had the highest correlation with the calyx length (r = 0.900) and also with fruit weight (r = 0.795). Calyx length correlated highly with fruit length and fruit weight (r = 0.710 and r = 0.842 respectively). Others also reported similar results in pomegranate studies (Karimi *et al*., 2013; Khadivi-Khub *et al*., 2015; Radunic *et al*., 2015). There was no significant correlation between the pH and other studied traits. According to the report by Karimi *et al*. (2013), the juice pH showed no significant correlation with pomological traits.

Table 3. Correlation matrix of pomegranate morpho-pomological traits.

Traits	pH	TSS	Calyx Diameter	Calyx Length	Fruit Diameter	Fruit Length	Fruit Weight	Weight of 100 Arils
pH	1							
TSS	0.059	1						
Calyx Diameter	0.104	0.393*	1					
Calyx Length	0.068	0.435**	0.900**	1				
Fruit Diameter	0.149	-0.036	0.315*	0.305	1			
Fruit Length	-0.079	0.590**	0.639**	0.710**	0.331*	1		
Fruit Weight	-0.079	0.402**	0.795**	0.842**	0.252	0.679**	1	
Weight of 100 Arils	0.202	0.337*	0.509**	0.463**	0.278	0.621**	0.502**	1

*** Correlation is significant at the 0.05 level (2-tailed).**
**** Correlation is significant at the 0.01 level (2-tailed).**

The PCA analyses showed a large variation among studied genotypes (Table 4). The first three components explain about 56% of the total variance, with 30.29, 14.90 and 10.49% respectively. The important variables in the first component were calyx diameter, calyx length, fruit length, fruit weight, and aril weight. These results were in agreement with the results reported by Durgac *et al*. (2008). The second component was mainly correlated with skin thickness, aril adhesion to the skin and seed hardiness. The pH was the important variable for third component. As noted by Drogoudi *et al*., (2005), Sarkhosh *et al*., (2009) and Zaouay and Mars, (2011), the fruit and aril weight, fruit length, fruit diameter, fruit color, peel thickness, SSC and acidity were the most important variables among pomegranate traits. Calyx length and diameter also have the prominent role in

Table 4. Eigen values and cumulative variance of the first three principle component (PC) analysis for pomological characteristics in pomegranate genotypes.

Principal Components	PC1	PC2	PC3
Eigen Value	4.242	2.087	1.469
Variance (%)	30.299	14.907	10.496
Cumulative Variance (%)	30.299	45.206	55.702
Characters			
pH	0.047	0.064	-0.785
TSS	0.510	0.345	-0.194
Calyx Diameter	0.849	0.077	0.004
Calyx Length	0.889	0.043	0.139
Fruit Diameter	0.428	-0.168	0.027
Fruit Length	0.830	0.280	0.136
Fruit Weight	0.852	0.005	0.192
Aril Weight	0.687	0.218	-0.248
Skin Thickness	-0.112	0.637	-0.258
Cracking Sensitivity	0.157	0.131	0.473
Aril Adhesion to the Skin	-0.083	0.752	0.157
Aril Color	-0.255	0.341	0.428
Aril Juiciness	-0.510	0.574	0.282
Seed Hardiness	-0.172	0.606	-0.319

pomegranate groping (Sarkhosh *et al*., 2009). Khadivi-Khub *et al*., (2015) concluded that fruit size traits with the highest variation can be used for the study of pomegranate.

The results of this investigation showed a great diversity among sour pomegranate genotypes in Iran that can be used for studies of pomegranate germplasm and future breeding programs. Further studies are needed to determine different parameters regarding morpho-pomological and chemical characteristics and better evaluation of pomegranate diversity.

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