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Variations in tree and fruit characteristics revealed potential dwarfing genotypes within Iran's pomegranate germplasm

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Abstract: This study aimed to explore diversity in dwarfing tendencies, determine the correlation of measured traits with dwarfing, and identify and select promising dwarf candidates as potential scions or rootstock cultivars. Growth habit, vegetative attributes, fruit physicochemical characteristics,and leaf stomatal densityof 19 Iranian pomegranate cultivars, which have been collected across the country and established in the Yazd pomegranate germplasm, were assessed. Results showed that the cultivars differed in almost all measuredtraits. The tree height and canopy width, current year's shoot, and internode length were within the range of 1.97-4.6 m, 1.53-4 m, 15-41.5 cm 1.96-3.39 cm, respectively. Moreover, a positive correlation was observed between tree height and internode length (r= 0.55), whereas a negative correlation was obtained between stomatal density and tree height (r= -0.44). Based on characteristics measured for the vegetative growth, 'Malas No. 1 Saravan' and 'Torosh Nar Riz Zirab' proved dwarfing habit. 'Rabab Poost Ghermez Neyriz',a commercial cultivar, showed semi-dwarfing growth and 'Khajei Ghasrodasht Fars', 'Shahsavar Seydan Marvdasht', 'Bihaste Ravar', 'Bihaste Sangan Khash', 'Torosh Goli Naz Behshahr' and 'Anar Siah' resulted in vigorous trees. This preliminary study found promising dwarf and semi-dwarf genotypes at Iran's pomegranate germplasm.

1. Introduction

According to historical documents, pomegranates originated in central Asia, especially in parts of Iran, and believed to have spread to nearby areas due to traveling and incursion (Harlan, 1975; Levin, 1994; Verma *et al.*, 2010). The main Iranian collection of pomegranate in Yazd contains 762 accessions, including wild, semi-wild, and commercial types (Behzadi Shahrbabaki, 1998; Zamani *et al.*, 2007). These diverse and valuable

genetic resources would benefit from a further genetic improvement to develop dwarfing scion and rootstock genotypes to establish modern high-density pomegranate orchards. Ingels *et al.* (2002) suggested that the term 'dwarf tree' applies to a tree that appears smaller than usual owing to selection of dwarf genotypes, specific training or pruning methods, or grafting on dwarfing rootstocks. Besides, in classifying trees according to size, dwarf trees are approximately 2.5 m or less when they mature (Castle, 1992). Dwarf trees have many benefits compared to larger vigorous ones, such as being able to be spaced closer together without suffering from excessive crowding or the need for frequent, severe pruning. Moreover, dwarf trees allow for ease of pruning, pest control, fruit thinning, spraying, harvesting, and increased production of high-grade fruit, higher fruit quality and decreased production costs (Tukey, 1964). The advantages of dwarf and semi-dwarf genotype trees have been demonstrated in the fruit industry resulting in the widespread use of dwarfing rootstocks in tree crops such as apple (Looney and Lane, 1983), cashew (Moura, 2001), and peach (DeJong *et al.*, 2005). Lately, breeding efforts have resulted in the selection of dwarfing rootstock or scion cultivars in almost all temperate and tropical fruit tree crops (Busov *et al.*, 2003). The primary identification of dwarf genotypes should be based on field evaluations of fruit tree cultivars and genotypes. Genetic dwarfism often manifests itself in distinctive morphological characteristics, easily identified, and often appears to a casual observer (Castle, 1992). Analysis of morphological diversity as tree height, canopy shape, internode, and branching pattern is a useful method for detecting dwarfing phenotypes in a population of many genotypes. Although some pomegranate cultivars, such as Nana, are considered dwarfing (Terakami *et al.*, 2007), these are ornamentals, and there are no published reports on new dwarfing pomegranates. The objectives of this study were: 1) evaluate tree growth habits, vegetative and fruit characteristics of 19 Iranian pomegranate cultivars, 2) to examine diversity in dwarfing potential, 3) determine inter-correlations among measured traits with dwarfism, and 4) identify promising candidates with dwarfing potential as pomegranate scions and rootstocks.

2. Materials and Methods

Plant materials

The experiment was conducted in 2015, at the Agriculture and Natural Resources Research Centre

Table 1 - Name, origin, fruit and tree characteristics of pomegranate cultivars used in this study

Cultivars	Provinces	Cities	Skin color	Aril color	Taste	Uses
Anar Siah	Esfahan	Esfahan	Black	Dark red	Sweet	Medicinal
Bihaste Ravar	Kerman	Ravar	Yellow-pink	White	Sweet	Local
Bihaste Sangan Khash	Sistan Baluchistan	Khash	White	White	Sweet	Local
Jangali Poost Ghermez Roodbar	Gilan	Roodbar	Red	Red	Sweet-sour	Local
Khajei Ghasrodasht Fars	Fars	Shiraz	Pink	White	Sweet	Local
Malas Pishva Varamin	Tehran	Varamin	yellow	White	Sweet	Local
MalasYazdi	Yazd	Yazd	Red	Red	Sweet-sour	Commercial
Makhmal Malas Shahreza	Esfahan	Shahreza	Red	Red	Sweet-sour	Local
Malas No. 1 Saravan	Sistan Baluchistan	Saravan	Yellow	White	Sweet-sour	Local
Poost Nazok Torosh Abarkuh	Yazd	Abarkuh	Red	Red	Sweet-sour	Local
Poost Sefid Dezfoul	Khuzestan	Dezfoul	Yellow-white	White	Sweet-sour	Local
Rabab Poost Ghermez Neyriz	Fars	Neyriz	Red	Red	Sweet-sour	Commercial
Rabab Poost Ghermez Kazeroon	Fars	Kazeroon	Red	Pink	Sweet-sour	Local
Sefid Biardal Borujen	Chahar Mahal-e Bakhtiar	Borujen	Yellwo	Pink	Sour	Local
Shirin Jangal Sisangan	Mazandaran	Sisangan	Red-yellow	Pink	Sweet-sour	Local
Shirin Semnan	Semnan	Semnan	Green-yellow	White	Sweet	Local
Shahsavar Seydan Marvdasht	Fars	Marvdasht	White-yellow	White	Sweet-	Local
Torosh Goli Naz Behshahr	Mazandaran	Behshahr	White-yellow	White	Sour	Local
Torosh Nar Riz Zirab	Fars	Darab	Green-yellow	White	Very sour	Wild

(ANRRC), Yazd Province, Iran. Nineteen pomegranate cultivars were used in the study (Table 1). Two of the cultivars, 'Rabab Poost Ghermez Neyriz' and 'Malas Yazdi', are commercial cultivars widely cultivated in the country. The rest are of local importance in different provinces, except 'Torosh Nar Riz Zirab', a non-commercial (semi-wild type) from the Darab region. The pomegranate cultivars have been planted in a randomized complete block design (RCBD) with three replications per cultivar. Trees were 26-year-old at the time of the experiment and managed following the region's recommended orchard practices.

Measurement of vegetative characteristics

A total of 6 trees per cultivar (3 trees × 3 replicates) was used for vegetative traits measurements. Since the pomegranate trees are trained to the multiple trunk (3-4 trunks) system (the common practice in Iran's commercial orchards), individual trunks diameters were measured at 30 cm above the soil surface and then averaged to get the value for the single trunk diameter. Bark thickness was measured in a small-detached section of bark at 30 cm above the soil surface. Tree height (from the ground level up to the tree peak) and canopy width (in the widest point). Numbers of suckers were simply counted on trees and for shoot angle (°), the insertion of shoots that came directly from the scaffold were measured. In addition, the current year's shoot length (cm) was evaluated after shoot growth stopped (in November) on three scaffolds of trees. Moreover, internode length (cm) was calculated by dividing the current year's shoot length by its corresponded node number.

Measurement of fruit quality attributes

Physical properties. At harvest (which was varied for each cultivar), measurements of fruit physical properties were done on 90 randomly selected fruits per cultivar (10 fruits per tree × 3 trees per replicate × 3 replicate = 90 fruits for each cultivar). Fruits were weighed using a digital balance. Peel and arils were carefully separated manually from the fruit to measure the edible portion. The extracted arils were collected in a tray and mixed thoroughly to assure uni formity.The edible portion of the fruit was determined using the following formula (Ghasemi Soloklui *et al.,* 2019):

Edible portion of fruit (%)=

$$\frac{\text{fresh weight - peel weight - capillary membranes}}{\text{fruit weight}} \times 100$$

Chemicals properties. At harvest, total soluble solids content (TSS) and total acidity (TA) were measured in juice extracted from 90 fruits per cultivar (10 fruits per tree × 3 trees per replicate × 3 replicates = 90 fruits for each cultivar). TSS (in °Brix) was determined using a digital refractometer (model PR-1, Atago, Japan) and TA by titration to pH end-point 8.2 with 0.1 N NaOH and expressed as citric acid equivalent (g CAE100 mL^{-1}) (Horwitz, 1980).

Measurement of stomatal density

In late summer, fully expanded leaves (15 leaves per replication) were collected randomly from the midpoint of the current season's shoots. Stomata numbers were determined using the replica method (Soleimani *et al.*, 2002). The stellate hairs were removed from the lower surface of each leaf using an adhesive tape. A thin film of cellulose acetate was painted directly onto the lower epidermis of the leaf. The cellulose acetate was allowed to dry at room temperature before being peeled from the leaf. Sections were taken from the middle of each leaf. The slides were coded, and a binocular microscope was used for stomatal counts at x 40 magnification. Stomatal density was counted in a field area of one mm^2.

Statistical analysis

Analysis of variances (ANOVA) was performed using SAS version 9.1 (SAS, 2003.). The means were carried out at $P<0.05$ using Duncan's multiple range tests. Correlation between pairs of traits was determined using Pearson's correlation coefficient.

3. Results

Vegetative characteristics

Measured vegetative traits are presented in Table 2 and figure 1. Tree height varied between 1.97 to 4.6 m (Fig. 1). The highest tree height value was observed in 'Khajei Ghasrodasht Fars' (4.6 m), followed by 'Bihaste Ravar' (4.3 m), 'Bihaste Sangan Khash' (4.26 m), and 'Shahsavar Seydan Marvdasht' (4.26 m). 'Malas No. 1 Saravan' showed the smallest tree height (1.97 m) (Fig. 2), some cultivars such as 'Rabab Poost Ghermez Neyriz' and 'Shirin Semnan' categorized as medium height (Fig. 1).

Among the 19 cultivars, the greatest canopy width (4 m) was observed in 'Shahsavar Seydan Marvdasht', while 'Makhmal Malas Shahreza'showed the smallest canopy width (1.50 m) (Fig. 1). 'Khajei

Table 2 - Vegetative tree characteristics of the pomegranate cultivars used in the experiment

Cultivars	Trunk diameter (mm)	Current year shoot length (cm)	Internode length (cm)	Shoot angle (°)	Number of suckers	Bark thickness (mm)
Anar Siah	114 ab	21 bcdefg	3.11 ab	57 defg	18 gh	2.03 b
Bihaste Ravar	98 ab	24.16 b	3.17 ab	60.16 defg	55 bc	2.60 b
Bihaste Sangan Khash	99 ab	17 defg	2.83 abc	53.33 fg	90 cd	2.22 b
Jangali Poost Ghermez Roodbar	78 ab	15.66 fg	2.57 abc	63.33 defg	191 bcd	2.83 b
Khajei Ghasrodasht Fars	121.33 a	22 bcde	3.39 a	65 def	8.33 h	2.56 b
Malas Pishva Varamin	97.67 ab	16.33 efg	3.17 ab	65 def	161 abc	1.82 b
Malas Yazdi	74.67 ab	23 bcd	2.14 c	46.66 g	70 efg	2.46 b
Makhmal Malas Shahreza	77 ab	26.50 b	2.05 c	86.66 ab	180 abc	1.77 b
Malas No. 1 Saravan	61.0 b	17.6 cdefg	1.96 c	60 defg	22 gh	1.70 b
Poost Nazok Torosh Abarkuh	93.83 ab	41.50 a	3.39 a	63.33 defg	70 efg	3.24 a
Poost Sefid Dezfoul	89 ab	15 g	2.39 bc	73.33 abcde	93 def	1.64 g
Rabab Poost Ghermez Neyriz	110 ab	21 bcdefg	2.52 abc	56.66 efg	143 bcd	2.23 bcdefg
Rabab Poost Ghermez Kazeroon	107.17 ab	16.33 efg	2.33 bc	83.33 abc	1 h	1.62 g
Sefid Biardal Borujen	111.33 ab	23.50 bc	2.61 abc	86.66 ab	215 a	1.55 g
Shirin Jangal Sisangan	73.76 ab	17.6 cdefg	2.01 c	68.33 cdef	89 def	2.10 cdefg
Shirin Semnan	99 ab	16.83 defg	2.80 abc	75 abcd	126 def	2.92 ab
Shahsavar Seydan Marvdasht	114 ab	21.3 bcdef	3.17 ab	70 bcdef	35 fgh	2.64 abcd
Torosh Goli Naz Behshahr	67.75 ab	17.6 cdefg	2.33 bc	90 a	35 fgh	2.40 bcdef
Torosh Nar Riz Zirab	62.17 b	21.3 bcdef	2.52 abc	66.66 cdef	69 efg	2.42 bcdef

Similar letters in each column indicate non-significant differences among cultivars at P≤0.05.

Ghasrodasht Fars' had the greatest single trunk diameter (121.33 mm), whereas 'Malas No.1 Saravan', had the lowest single trunk diameter (61 mm) (Table 2).

The longest current year's shoot length (41.50 cm) was recorded in 'Poost Nazok Torosh Abarkuh', while the shortest (15 cm) obtained in 'Poost Sefid Dezfoul' (Table 2). Internode length varied from 1.96 cm ('Malas No. 1 Saravan') to 3.39 cm ('Khajei Ghasrodasht Fars') (Table 2). The correlation between internode length and tree height was also statistically significant (r=0.55; p=0.0001) (Fig. 3). Shoot angle was within the range of 46.6 to 90 (Table 2). Significant differences were observed in the number of suckers among the pomegranate cultivars. The highest number of suckers per tree was recorded in 'Sefid Biardal Borujen' (215), while the lowest number was counted in 'Rabab Poost Ghermez Kazeroon'. In addition, the highest (3.24 mm) and lowest (1.55 mm) bark thickness were recorded in 'Poost Nazok Torosh Abarkuh' and 'Sefid Biardal Borujen', respectively (Table 2).

Considering all vegetative characteristics, in particular, tree height, trunk diameter and internode length; cultivars could be classified into four groups,

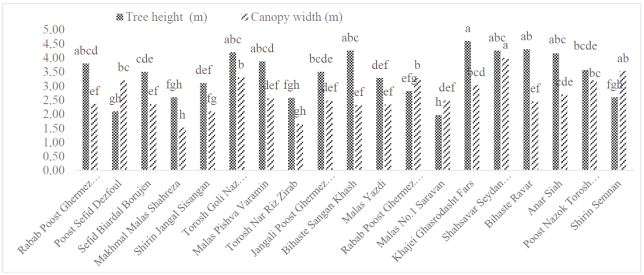

Fig. 1 - Tree height and canopy width in 19 Iranian pomegranate cultivars. Similar letters indicate non-significant differences among cultivars (P≤0.05).

Fig. 2 - Comparison of tree height between a vigorous pomegranate cultivar (A) and 'Malas No. 1 Saravan' (B), the most dwarf cultivar in the pomegranate genotypes studied.

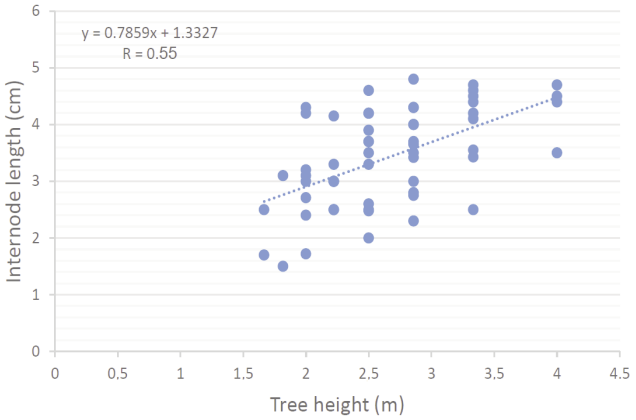

Fig. 3 - Pearson's correlation coefficients between internode length and tree height in 19 Iranian pomegranate cultivars.

1) vigorous cultivars: 'Khajei Ghasrodasht Fars', 'Shahsavar Seydan Marvdasht', 'Bihaste Ravar', 'Bihaste Sangan Khash', 'Torosh Goli Naz Behshahr' and 'Anar Siah', 2) Semi-vigorous cultivars: 'Malas Pishva Varamin', 'Rabab Poost Ghermez Kazeroon', 'Poost Nazok Torosh Abarkuh', 'Jangali Poost Ghermez Roodbar', 'Sefid Biardal Borujen', 'Malas Yazdi' and 'Shirin Jangal Sisangan', 3) Semi-dwarf cultivars: 'Rabab Poost Ghermez Neyriz', 'Shirin Semnan', 'Makhmal Malas Shahreza' and 'Poost Sefid Dezfoul', and 4) Dwarf cultivars: 'Torosh Nar Riz Zirab' and 'Malas No. 1 Saravan'.

Stomata density

As shown in figure 4, a large variation in stomatal density (from 46.91 to 108.91 stomata per mm^2) was observed among studied cultivars. 'Shirin Semnan', showed the highest stomatal density, while 'Shahsavar Seydan Marvdasht' had the lowest stomatal density. Results of Pearson correlation analysis provide significant negative correlations between stomatal density and tree height (r = -0.44; *P* =0.0005) (Fig. 5).

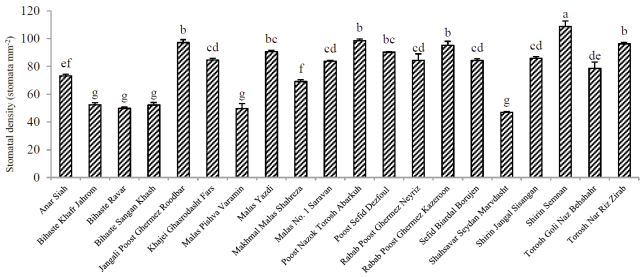

Fig. 4 - Frequency distribution of stomatal density in 19 Iranian pomegranate cultivars. Bars indicate SE (n=45).

Fruit quality traits

The highest fruit weight was perceived in 'Shahsavar Seydan Marvdasht' (378.17 g), followed by 'Malas Yazdi' (230.83 g) and 'Jangali Poost Ghermez Roodbar' (214.67 g), while the smallest fruit (62.17 g) was observed in 'Torosh Nar Riz Zirab' (a semi-wild cultivar) (Table 3). The percentage of the edible portion of the fruit ranged from 49.80 (in 'Torosh Nar Riz Zirab') to 71.98% (in 'Biardal Borujen') (Table 3). The highest (18.7°Brix) and lowest (13.0°Brix) TSS was measured in 'Sefid Biardal Borujen' and 'Shahsavar Seydan Marvdasht', respectively (Table 3). Fruit juice pH varied from 3.13 to 4.43 among the studied pomegranate cultivars, with the minimum and maximum pH measured respectively in 'Torosh Nar RizZirab', and 'Anar Siah'. Moreover, the highest and lowest TA were observed in 'Torosh Nar Riz Zirab' (8.47 g CAE 100 mL^{-1}) and 'Bihaste Sangan Khash' (0.50 g CAE 100 mL^{-1}), respectively.

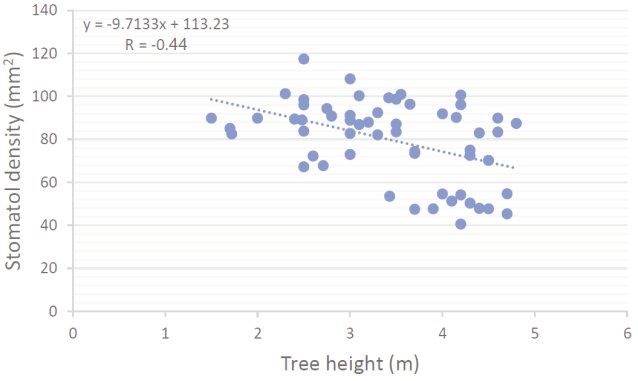

Fig. 5 - Pearson's correlation coefficients between stomatal density and tree height in 19 Iranian pomegranate cultivars.

4. Discussion and Conclusions

The results of this research present a wide range of vigor and dwarfing potential in Iranian pomegranates. In high-density orchards, controlling tree vigor and canopy size is important for enhancing the orchard efficiency and productivity (Umar and Sharma, 2008). Vegetative growth can be defined by several parameters such as; total shoot length, internode length, number of terminals and lateral shoot, and trunk cross-sectional area (Weibel *et al.*, 2003). In classifying trees according to size, dwarf trees are approximately 2.5 m or less in height when mature (Castle, 1992). Considering the above men-

Table 3 - Fruit characteristics of the pomegranate cultivars used in the experiment

Cultivars	Fruit weight (g)	Edible portion (%)	TSS (°Brix)	pH	TA (%)
Anar Siah	124.0 ef	53.31 cd	13.8 hi	4.43 a	0.70 hi
Bihaste Ravar	140.32 e	54.30 cd	14.0 fghi	4.06 cd	0.55 i
Bihaste Sangan Khash	156.0 de	60.39 abcd	13.83 ghi	4.38 ab	0.50 i
Jangali Poost Ghermez Roodbar	214.67 b	61.88 abcd	18.33 ab	3.49 hij	2.17 efg
Khajei Ghasrodasht Fars	207.50 bc	59.53 abcd	14.66 efghi	3.65 gh	2.51 def
Malas Pishva Varamin	131.0 ef	67.81 ab	15.5 defgh	3.89 def	1.41 ghi
MalasYazdi	230.83 b	49.80 d	16.0 cdef	3.70 fgh	1.85 fg
Makhmal Malas Shahreza	133.50 ef	60.32 ab	17.66 abc	4.2 bc	0.6 i
Malas No. 1 Saravan	125.83 ef	61.52 abcd	15.33 defgh	3.34 ijk	3.30 cd
Poost Nazok Torosh Abarkuh	129.50 ef	62.66 abcd	16.0 cdef	3.49 hij	2.8 de
Poost Sefid Dezfoul	88.0 fg	57.94 bcd	16.66 bcde	4.16 bc	0.88 hi
Rabab Poost Ghermez Neyriz	190.0 bcd	56.61 bcd	14.83 efghi	3.53 hi	2.57 def
Rabab Poost Ghermez Kazeroon	161.67 cde	54.16 cd	15.8 cdefg	3.84 efg	1.55 k
Sefid Biardal Borujen	159.33 de	71.98 a	18.66 a	3.28 jk	3.97 c
Shirin Jangal Sisangan	192.67 bcd	55.10 bcd	15.5 defgh	4.04 cde	1.35 ghi
Shirin Semnan	158.0 de	62.01 abcd	14.0 fghi	4.16 bc	0.70 hi
Shahsavar Seydan Marvdasht	378.17 a	56.52 bcd	13 i	4.16 sm	0.61 i
Torosh Goli Naz Behshahr	126.83 ef	64.67 abc	17.16 abcd	3.14 k	5.47 b
Torosh Nar Riz Zirab	62.17 g	60.77 abcd	16.66 bcde	3.13 k	8.47 a

Similar letters in each column indicate non-significant differences among cultivars at P≤0.05.

tioned vegetative attributes and keeping in mind the Castle (1992) scale, 'Malas No. 1 Saravan' and 'Torosh Nar Riz Zirab' were the most dwarf size, about half that of vigorous cultivars. Thus, this cultivar has potential to be used directly as dwarfing pomegranate rootstocks, although a more detailed study on propagation, graft compatibility, and tolerance to biotic and abiotic stress will shed more light on the suitability of these cultivars as rootstock. As a dwarfing source, these cultivars could be utilized as parents in breeding programs to develop superior dwarf scion and rootstock cultivars.

This study demonstrated that internode length was associated with tree size. In general, some cultivars such as 'Makhmal Malas Shahreza', 'Poost Sefid Dezfoul' and 'Malas No. 1 Saravan' have the smallest tree sizes and shorter internodes lengths than other cultivars. The average internode length depended on the number of nodes per extension unit (Costes and Garcia-Villanueva, 2007). Dwarf trees usually produce very short internodes length, resulting in branches more compact than vigorous trees (Ingels *et al.*, 2002). Obtained results for internode length are in agreement with those of Murase *et al.* (1990), on peach trees grafted on dwarfing rootstocks that had shorter internodes than trees grafted on vigorous rootstock. The results of the current study also showed a wide variation in sucker production among cultivars. In this regard, cultivars such as 'Rabab Poost Ghermez Kazeroon' and 'Khajei Ghasrodasht Fars' with the lowest number of suckers have the advantage of easy management and also may be suitable for preferred single trunk training system in modern fruit orchards.

Stomata are directly responsible for the trade-off between water loss and carbon acquisition (Raven, 2002). Stomatal density as a quantitative attribute is genetically determined (Gailing *et al.*, 2008). Some plant species have been reported as possessing generally high heritability (i.e., less dependence on environmental conditions) in their stomatal traits (Sharma and Dunn, 1969; Orlovic *et al.*, 1998). Drogoudi *et al.* (2012) reported stomatal density among four pomegranate cultivars ranging from 68 to 149.9 stomata mm^{-2}. Also, Meena *et al.* (2011) reported astomatal density of 130.67 stomata mm^{-2} for pomegranate. These results are following the findings of the current study, and minor differences in the results could be due to cultivar or climate differences. Interestingly, some of the vigorous cultivars such as 'Bihaste Ravar', 'Shahsavar Seydan Marvdasht' and 'Bihaste Sangan Khash' had low

stomatal density (between 46 to 52 stomata mm^{-2}), whereas dwarf and semi-dwarf cultivars, including 'Shirin Semnan', 'Torosh Nar Riz Zirab' and 'Poost Sefid Dezfoul' possess very high stomatal density (108, 96 and 90 stomata mm^{-2}, respectively). These results are in line with the findings of Barrientos-Pérez and Sanchez-Colín (1982), who reported that stomatal density could be a good method to classify the growth habit in avocado trees (Barrientos-Pérez and Sánchez-Colín, 1982).

Thus, the data on fruit attributes would provide useful information for selecting the best dwarf cultivars to be used directly as scion cultivars on their root or as parent materials in scion cultivars breeding programs. The evaluation of pomegranate fruit quality (physical and chemical) in the local material has previously been carried out in Iran (Akbarpour *et al.*, 2009), Turkey (Özkan, 2001), Italy (Barone *et al.*, 2001), and Greece (Drogoudi *et al.*, 2005). Tehranifar *et al.* (2010) described important fruit traits of 20 pomegranate cultivars from different regions in Iran. They found that the fruit weight, peel percentage, aril percentage, and juice percentage were within the range of 196.89-315.28 g, 32.28-59.82%, 37.59-65% and 26.95-46.55%, respectively, which are in line with the results of the current study. Moreover, Yıldız *et al.* (2003) reported that promising pomegranate genotypes, selected from Hizan (Bitlis) in Turkey, had 192.3-388.3 g fruit weight, 28-55% juice percentage, 0.33-4.03% juice acidity and 10.0-17.0% juice soluble solids content. On the other hand, Mars and Marrakchi (1999) defined fruit characteristics of 30 pomegranate genotypes from Tunisia. They reported fruit weights ranging from 196.1 to 673.6 g, pH from 2.9 to 4.6, soluble solid contents from 13.3 to 16.9°Brix, and acidity from 0.2 to 3.1 g CAE 100 mL^{-1}. Consequently, the pomegranate studied herein had many similarities to those described in other studies concerning fruit traits such as fruit weight, soluble solids content, pH and acidity. Minor differences in these traits across the studies could arise from different plant materials and varied climatic conditions. In this study edible portion was between 49.80 to 71.98%; whereas, Al-Maiman and Ahmad (2002) reported an edible portion of about 55-60% of the total fruit weight. This study showed that most cultivars except 'Torosh Nar Riz Zirab' and 'Poost Sefid Dezfoul' have big and medium sized fruits.

In general, considering vegetative characteristics and fruit quality attributes, 'Rabab Poost Ghermez Neyriz' a commercial cultivar with semi-dwarfing growth habit and good fruit quality (have big fruits, with high TSS contents and low acidity) is a promising candidate for establishing high-density orchards on its roots. Moreover, some cultivars such as 'Shirin Semnan', 'Makhmal Malas Shahreza' and 'Malas No. 1 Saravan', which categorized as dwarfing or semi-dwarfing cultivars and possessed quite good fruit quality, have the potential to be used as a parent in breeding programs to develop dwarf pomegranate cultivars or dwarfing rootstocks. 'Torosh Nar Riz Zirab' is a semi-wild cultivar with small tree size (dwarf cultivar) but represents poor fruit quality attributes. Thus, this cultivar can be considered as a dwarfing rootstock in pomegranate production. However, a more detailed study on propagation, graft compatibility, and tolerance to biotic and abiotic stress will shed more light on these cultivars' potentials as rootstock.

References

AKBARPOUR V., HEMMATI K., SHARIFANI M., 2009 - *Physical and chemical properties of pomegranate (*Punica granatum *L.) fruit in maturation stage*. - Am. Eurasian. J. Agric. Environ. Sci., 6(4): 411-416.

AL-MAIMAN S.A., AHMAD D., 2002 - *Changes in physical and chemical properties during pomegranate (*Punica granatum *L.) fruit maturation*. - Food. Chem., 76(4): 437-441.

BARONE E., CARUSO T., MARRA F., SOTTILE F., 2001 - *Preliminary observations on some sicilian pomegranate (*Punica granatum *L.) varieties.* - J. Am. Pomol. Soc., 55(1): 4-7.

BARRIENTOS-PÉREZ F., SÁNCHEZ-COLÍN S., 1982 - *Height variability obtained from a new dwarf avocado tree population*. - Fruit. Breeding., XXI IHC, 140: 163-168.

BEHZADI SHAHRBABAKI H., 1998 - *Genetic diversity of pomegranate genotypes in iran*: Nashr Amoozesh Keshavarzi.

BUSOV V.B., MEILAN R., PEARCE D.W., MA C., ROOD S.B., STRAUSS S.H., 2003 - *Activation tagging of a dominant gibberellin catabolism gene (ga 2-oxidase) from poplar that regulates tree stature*. - Plant. Physiol., 132(3): 1283-1291.

CASTLE W S., 1992 - *Tree size control and dwarfing rootstocks*. - Fact Sheet HS-146.

COSTES E., GARCIA-VILLANUEVA E., 2007 - *Clarifying the effects of dwarfing rootstock on vegetative and reproductive growth during tree development: A study on apple trees*. - Ann. Bot., 100(2): 347-357.

DEJONG T., JOHNSON R., DOYLE J., RAMMING D., 2005 - *Labor costs may be reduced research yields size-con-*

trolling rootstocks for peach production. - Calif. Agric., 59(2): 80-83.

DROGOUDI P., PANTELIDIS G., MANGANARIS A., 2012 - *Morphological and physiological characteristics in pomegranate cultivars with different yields*. - Cah. Options. Mediterr., 103: 67-69.

DROGOUDI P.D., TSIPOURIDIS C., MICHAILIDIS Z., 2005 - *Physical and chemical characteristics of pomegranates*. - HortSci., 40(5): 1200-1203.

GAILING O., LANGENFELD-HEYSER R., POLLE A., FINKELDEY R., 2008 - *Quantitative trait loci affecting stomatal density and growth in a quercus robur progeny: Implications for the adaptation to changing environments*. - Global. Change. Biol., 14(8): 1934-1946.

GHASEMI SOLOKLUI A.A., GHARAGHANI A., ORAGUZIE N., RAMEZANIAN A., 2019 - *Shelf life and changes in biochemical composition of ready-to-eat arils of nineteen Iranian pomegranate (*Punica granatum *L.) cultivars during storage*. - Food Sci. Technol., 56(3): 1416-1426.

HARLAN J.R., 1975 - *Crops and man*. - American Society of Agronomy, Madison, WI, USA, pp. 284.

HORWITZ W., 1980 - *Official methods of analysis* - AOAC, Arlington, VA, Washington DC, Vol. 534, pp. 1038.

INGELS C., GEISEL P.M., UNRUH C.L., 2002 - *Fruit trees: Training and pruning deciduous trees* - University of California, ANR Publications, 8057, pp. 8.

LEVIN G.M., 1994 - *Pomegranate* (Punica granatum) *plant genetic resources in Turkmenistan*. - Plant Genetic Resources Newsletter, IPGRI, 106: 47-49.

LOONEY N., LANE W., 1983 - *Spur-type growth mutants of Mcintosh apple: A review of their genetics, physiology and field performance.* - Acta Horticulturae, 146: 31-46.

MARS M., MARRAKCHI M., 1999 - *Diversity of pomegranate (*Punica granatum *L.) germplasm in Tunisia*. -Genet. Resour. - Crop. Evol., 46(5): 461-467.

MEENA K., SINGH R., PAREEK S., KASHYAP P., SHEIKH M., MOKASHI A., ROKHADE A., 2011 - *Evaluation of pomegranate (*Punica granatum *L.) genotypes for morphological and flowering characteristics under semi-arid climate*. - Acta Horticulturae, 890: 233-237.

MOURA C.F.H., ALVES R.E., INNECCO R., FILGUEIRAS H.A.C., MOSCA J.L., PINTO S.A.A., 2001 - *Physical characteritics of cashew apples for fresh fruit market*. - Revista Brasileira de Fruticultura, 23: 537-540.

MURASE S., YAMAZAKI T., INOMATA Y., SUZUKI K., 1990 - *Dwarfing rootstock for peach*. - Jpn. Agric. Res. Q., 23: 294-300.

ORLOVIC S., GUZINA V., KRSTIC B., MERKULOV L., 1998 - *Genetic variability in anatomical, physiological and growth characteristics of hybrid poplar (*Populus *x* euramericana *dode (guinier)) and eastern cottonwood (*Populus deltoides *bartr.) clones*. - Silvae. Gene., 47(4): 183-189.

ÖZKAN Y., 2001 - *Determination of pomological characteristics of Niksar district pomegranates (*Punica granatum L.) *of the Tokat province*. - International Symposium on Sustainable Use of Plant Biodiversity to Promote New Opportunities for Horticultural Production, 598

RAVEN J.A., 2002 - *Selection pressures on stomatal evolution*. - New Phytol., 153(3): 371-386.

SAS, 2003 - *SAS. Statistical analysis system. Sas release 9.1*. - SAS Institute, Cary, NC, USA.

SHARMA G.K., DUNN D.B., 1969 - *Environmental modifications of leaf surface traits in datura stramonium*. - Can. J. Bot., 47(8): 1211-1216.

SOLEIMANI A., LESSANI H., TALAIE A., 2002 - *Relationship between stomatal density and ionic leakage as indicators of cold hardiness in olive (*Olea europaea *L.).*- Acta Horticulturae, 618: 521-525.

TEHRANIFAR A., ZAREI M., NEMATI Z., ESFANDIYARI B., VAZIFESHENAS M.R., 2010 - *Investigation of physicochemical properties and antioxidant activity of twenty iranian pomegranate (*Punica granatum *L.) cultivars*. - Sci. Hortic., 126(2): 180-185.

TERAKAMI S., MATSUTA N., YAMAMOTO T., SUGAYA S., GEMMA H., SOEJIMA J., 2007 - *Agrobacterium-mediated transformation of the dwarf pomegranate (*Punica granatum *L. var. Nana)*. - Plant. Cell. Rep., 26(8): 1243-1251.

TUKEY H.B., 1964 - *Tree structure, physiology and dwarfing: Dwarf fruit trees*. - Cornell University Press, UK, pp. 562.

UMAR I., SHARMA A., 2008 - *Control of height through growth retardants in fruit trees*. - Asia. J. Hort., 3: 473-478.

VERMA N., MOHANTY A., LAL A., 2010 - *Pomegranate genetic resources and germplasm conservation: A review*. - Fruit.Veg. Cereal. Sci. Biotech., 4: 120-125.

WEIBEL A., JOHNSON R.S., DEJONG T.M., 2003 - *Comparative vegetative growth responses of two peach cultivars grown on size-controlling versus standard rootstocks*. - J. Am. Soc. Hortic. Sci., 128: 463-471.

YILDIZ K.F., MURADOĞLU H.İ., OGUZ H. YILMAZ, 2003 - *Pomological characteristics of pomegranate varieties rown in Hizan town of Bitlis*. - Congress, Antalya, Turkey, pp. 238-240.

ZAMANI Z., SARKHOSH A., FATAHI R., EBADI A., 2007 - *Genetic relationships among pomegranate genotypes studied by fruit characteristics and rapd markers*. - J. Hort. Sci. Biotech., 82:11-18.