

Genetic variation of selected Siah Mashhad sweet cherry genotypes grown under Mashhad environmental conditions in Iran

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ABSTRACT

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This study was conducted with the main purpose of investigating genetic variation among 13 selected sweet cherry (*Prunus avium* cv. Siah Mashhad) genotypes, *i.e.*, the most important Iranian sweet cherry cultivars based on their pomological, morphological, and phonological characteristics. The experiment was laid out in a randomized complete block design with three replications at Khorasan-e-Razavi Agriculture and Natural Resource Research Center, Mashhad-Iran, during 2007-2009. Wide variation in pomological (fruit weight, stone weight, soluble solids content, pH, total acid content), morphological (crown volume, trunk diameter, current season growth), and phonological (first bloom, full bloom) characteristics ($P \leq 0.01$) was observed. Genotype SH7 had the highest fruit weight (9.27 g), while SH1 had the lowest fruit and stone weights (4.51 g, 0.38 g, respectively). Crown volume ranged between 16.53 m³ (SH23) and 32.67 m³ (SH13) in Siah Mashhad sweet cherry genotypes. Current season vegetative growth ranged between 45.66 and 58.00 cm. Results also showed that genotypes SH21 and SH20 had the lowest and highest trunk diameter (93.65 mm and 161.99 mm, respectively). Our results indicate there is wide variation in flowering, growth, and fruit characteristics of Siah Mashhad sweet cherry genotypes.

Keywords: clonal selection, fruit quality, genetic diversity, sweet cherry (*Prunus avium*)

INTRODUCTION

Sweet cherry is one of the world's important and attractive fruits. Many stone fruits like sweet cherry (*Prunus avium* L.) have been cultivated since ancient times (Naderiboldaji *et al.*, 2008). Due to its suitable weather, Iran is the third biggest sweet cherry producer in the world, producing 224, 900 tons per year (FAOSTAT, 2009). In Iran, sweet cherry is valuable due to its good taste, short ripening period, and the fact that it blooms in the spring, the first season of the year (Ganji Moghaddam and Bouzari, 2009).

Genetic variation has been studied in sour cherry (*P. cerasus* L.), sweet cherry (*P. avium* L.) and mahaleb (*P. mahaleb* L.) in different countries (Rakonjac *et al.*, 1996). Recognizing and measuring such diversity, as well as its nature and magnitude, are beneficial or even crucial to a breeding program.

Fruit weight is considered an important trait in the fresh-market group; fruit shape is very important for packaging and transportation; fruit size is very important for the canning industry; and sugar content and total soluble solids content are very important for the food industry. Cultivars affect all these traits (Caliskan and Polat, 2008; Gozlekci,

2010).

Many studies have been conducted on the physical, chemical, pomological, and nutritional properties of sweet cherry (e.g., Naderiboldaji *et al.*, 2008, Radicevic *et al.*, 2008). Hodun and Hodun (2002) stated that the earliest and the latest flowering cultivars covered the span of three to nine days. Although the onset of flowering in sweet cherries depends on weather conditions, the sequence of flowering onset in cultivars grown under identical agro-environmental conditions depends on hereditary characteristics of cultivars, whereby this influence particularly dominates in years with earlier flowering onset. Ganji Moghaddam *et al.* (2009) reported that the flowering period of 25 sweet cherry cultivars lasted approximately 11-18 days; however, flowering time may change depending on weather conditions. In most studied sweet cherry cultivars in Serbia, full flowering began, on average, three days after flowering onset and the flowering period took between 9 (cultivars Bing and Lambert) and 13 days (cultivars Lyons Early, Souvenir, Burlat, and Sunburst) (Radicevic *et al.*, 2011).

Pırlak and Bolat (2001) determined the

phenological and pomological properties of five sweet cherry cultivars (Kırdar, Ak_ehir Napolyonu, Salihli, Sapıkısa, Yerli) in Uzundere vicinity of Erzurum, Turkey, during 1996-1997. In these cultivars, total soluble solids content ranged between 12.10% and 16.90%. There are considerable genotypic differences in fruit firmness in sweet cherry (Esti *et al.*, 2002). Blazkova *et al.* (2002) determined that fruit firmness of sweet cherry cultivar Karesova decreased from approximately 2.5 N at the beginning of the period to approximately 1.5 N at its end. Usenik *et al.* (2008) found that cultivar Lapins had the highest average fruit weight and Ferprime had the lowest. Fruit weight depends not only on genotype (Goncalves *et al.*, 2006), but also on crop load. Kalyoncu *et al.* (2009) studied several physico-chemical properties and mineral content of the earliest (May 19) sweet cherry grown in the Konya region. Jānes *et al.* (2010) evaluated 12 Estonian sweet cherry cultivars for yield, ripening time, fruit weight, and biochemical characteristics during 2007-2009 at the Polli Horticultural Research Centre. Results showed that the earliest ripening of all studied genotypes was Elo (16.06), while the latest one was Polli 2-1 (29.07). Cultivar Iputj produced the largest fruit (6.5 g), while Elo produced the smallest (3.2 g).

This study aimed at observing and identifying the genetic variation in cultivar Siah Mashhad and, in particular, to investigate the genetic variation among 13 selected genotypes of Siah Mashhad grown under Mashhad environmental conditions.

MATERIALS AND METHODS

This study was carried out on 13 Siah Mashhad sweet cherry genotypes (Table 1) selected from commercial orchards of Khorasan-e-Razavi Province. Selected genotypes were vegetatively reproduced on Mahaleb (*Prunus mahaleb* L.) rootstock, planted at the Golmakan Agricultural Research Station. The planting distance was 4 × 3 m. Samples were collected from three out of five trees per genotype during 2007-2009. This research was laid out in a randomized complete block with three replications. The following pomological, morphological and phenological characteristics were studied: blooming, ripening time, fruit weight, stone weight, fruit weight to stone weight ratio, total soluble solids, pH, total titratable acid, fruit shape, skin color, juice color, flesh firmness, crown volume, stem diameter, and current season vegetative growth.

Phenological observations

Flowering phenological stages including date of first bloom and full bloom were recorded when

approximately 10% and 75% of the flowers were open, respectively (Tzoner and Yamaguchi, 1999).

Table 1. Different stages of flowering and ripening in 13 Siah Mashhad sweet cherry genotypes.

No.	Genotypes	First bloom	Full bloom	Ripe
1	SH1	28 March	1 April	24 May
2	SH2	28 March	2 April	25 May
3	SH3	25 March	29 March	24 May
4	SH4	23 March	26 March	18 May
5	SH7	3 April	5 April	6 June
6	SH8	28 March	1 April	27 May
7	SH9	29 March	4 April	28 May
8	SH13	30 March	3 April	29 May
9	SH15	28 March	1 April	24 May
10	SH19	30 March	3 April	25 May
11	SH20	29 March	2 April	2 June
12	SH21	4 April	8 April	7 June
13	SH23	28 March	1 April	26 May

Pomological characteristics

Time of ripening: This parameter was defined as the time when one quarter of all fruit was ready for picking. When determining this date, similar difficulties arose as when date of full bloom was determined, that is, temperatures were relatively low during the ripening period, making it difficult to fix the date of picking accurately. Consequently, knowledge of flowering characteristics could play an important role to ensure successive pollination and synchronous activity of reproductive organs.

The fruits were selected for laboratory analysis according to uniformity of shape and color, juice color, flesh color, and fruit shape based on the International Plant Genetic Resources Institute (IPGRI) (Schmidt *et al.*, 1985) and Distinctness Uniformity Stability (UPOV, 2006) cherry (*P. avium* L.) descriptors and by direct observation in laboratory. Fruit weight, stone weight, and fruit weight to stone weight ratio were measured by using a digital balance on 30 fruit.

Skin color was evaluated on an eight-step scale from yellow to blackish red. Total soluble solids content was determined on samples of fruit pulp with a hand refractometer at room temperature (ranging from 18 to 23°C) (Cemeroglu and Acar, 1986). Total acidity was assessed by titration NaOH (0.1 N). The pH measurements were performed by using a digital pH meter (D-82362/Wueckgeun, Germany) (Murphey, 1988).

Mean values of all traits were calculated during two years of investigation. During this study, trees were planted under uniform environmental conditions using the same orchard management. Statistical analysis of variance was performed using SAS and EXCEL for Windows statistical software. Data were subjected to analysis of variance, and Duncan's multiple range tests were used to compare treatment means.

Morphological characteristics

Stem diameter and crown volume were determined according to Westwood (1993). The average current season vegetative growth was determined on four branches.

RESULTS AND DISCUSSION

Our results showed that there are significant differences in the phenological, pomological, and morphological characteristics of 13 sweet cherry genotypes studied.

Phenological characteristics

It is well known that flower initiation and differentiation may vary according to cultivar and climate type. This study indicates that blooming occurs at the beginning of March. As can be seen in Table 1, genotypes such as SH4 showed the earliest blooming (on March 23th) and SH21 showed the latest (on April 4th). The first blooming stages for the other genotypes occurred between March 23th and April 4th. Within 2-4 days after this stage, full bloom began (Table 1), and great differences among the full blooms of fruit trees were observed.

De Vries (1967) reported a difference of 7-14 days in the full bloom of early and late blooming sour cherry cultivars. Westwood (1978) reported that this phase is affected by annual environmental conditions, especially temperature. Nyeki (1989) reported a blooming period of 10 to 14 days in sweet cherry, and at least 4 to 6 days of blooming coverage is necessary. He understood that in stone fruit, 3 days of overlap in full bloom is adequate. Bilgener *et al.* (1998) investigated the pomology and phenology of four local sweet cherry varieties in

Amasya, Turkey, and found that the flowering period for all studied varieties was between March 23th and April 16th.

Detailed information about the timing of floral development is useful for tree crop research and management, as put forward by the studies on sweet cherry conducted by Whiting *et al.* (2006). The differences in phenological characteristics might be important in orchard planning regarding pollination. Our results show that the 13 studied Siah Mashhad genotypes differ in phenologic characteristics, and three groups of similar genotypes were separated based on these characteristics: the first group included SH4, SH3, the second included SH1, SH2, SH8, SH9, SH13, SH15, SH19, SH20, and SH23, and the third included SH7 and SH21.

Pomological characteristics

The fruits of all Siah Mashhad genotypes were different at harvest time. Ripening parameters are summarized in Table 1. Ripening stage lasted from May 18th to June 7th, and genotypes SH4 and SH21 showed early and later ripening, respectively. Sparks *et al.* (2000) explained that there is a direct connection between blooming and ripening time (Table 1). Our results also indicated that the direct connection between blooming and ripening date depends on genotype. This association, however, may explain only a small part of the above-mentioned variability in this characteristic.

Pomologic parameters such as fruit weight, stone weight, and fruit weight to stone weight ratio of genotypes differed significantly (Table 2); SH7 had the highest fruit weight (9.27 g), while SH1 had the lowest (4.51 g). Naderiboldaji *et al.* (2008)

Table 2. Mean comparison for pomological traits of 13 Siah Mashhad sweet cherry genotypes.

Number	Genotypes	Fruit weight (gr)	Stone weight (gr)	Fruit weight/ Stone weight
1	SH1	4.51 f	0.39 d	11.64 f
2	SH2	9.02 a	0.43 cd	21.15 ab
3	SH3	7.83 bcd	0.51 abc	15.25 cdef
4	SH4	7.90 bcd	0.57 a	13.88 ef
5	SH7	9.27 a	0.50 abc	18.84 abc
6	SH8	6.49 e	0.45 bcd	14.39 def
7	SH9	8.21 abc	0.45 bcd	18.32 abcd
8	SH13	8.95 ab	0.53 ab	16.92 bcde
9	SH15	8.57 abc	0.40 d	21.68 a
10	SH19	7.01 de	0.43 cd	16.25 cde
11	SH20	8.93 ab	0.47 bc	19.20 abc
12	SH21	7.72 dc	0.46 bcd	16.68 cde
13	SH23	7.49 cde	0.44 cd	17.08 cdef

Means, in each column, followed similar letters are not significantly different at the 1% probability level- using Duncan's Multiple Range Test.

determined the length (24.72), width (22.87), and thickness (17.04 mm) values for sweet cherry cultivar Siah Mashhad. Fruit weight in sweet cherries is strongly affected by the cultivar but also depends on the crop load (Goncalves *et al.*, 2006). Radicevic *et al.* (2008) studied nine sweet cherry

cultivars originating from Canada: Lapins, early Van compact, Summit, compact Lambert, compact Stella, Sunburst, New Star, Vega, and Vista. Sunburst produced the largest fruit (11.2 g), while the highest and lowest soluble solids contents were recorded in Vega (18.2%) and New Star (13.5%), respectively.

Table 3. Pomological information of 13 Siah Mashhad sweet cherry genotypes.

No.	Genotypes	Skin color	Flesh color	Juice color	Fruit shape	Firmness of flesh	Total acid titratable
1	SH1	Blackish Red	Dark Red	Blackish Red	Kidney-shaped	Firm	1.15
2	SH2	Dark Red	Pink	Red	Kidney-shaped	Firm	0.70
3	SH3	Dark Red	Red	Dark Red	Kidney-shaped	Firm	0.77
4	SH4	Blackish Red	Dark Red	Blackish Red	Kidney-shaped	Firm	0.96
5	SH7	Dark Red	Light Red	Dark Red	Kidney-shaped	Firm	0.57
6	SH8	Dark Red	Light Red	Dark Red	Kidney-shaped	Firm	0.70
7	SH9	Dark Red	Pink	Red	Kidney-shaped	Firm	0.77
8	SH13	Dark Red	Light Red	Blackish Red	Kidney-shaped	Firm	0.83
9	SH15	Dark Red	Red	Dark Red	Kidney-shaped	Medium	0.58
10	SH19	Dark Red	Red	Blackish Red	Kidney-shaped	Firm	0.93
11	SH20	Dark Red	Light Pink	Blackish Red	Kidney-shaped	Firm	0.93
12	SH21	Dark Red	Dark Red	Dark Red	Kidney-shaped	Firm	0.96
13	SH23	Dark Red	Dark Pink	Red	Kidney-shaped	Firm	0.70

Means, in each column, followed similar letters in each row are not significantly different at the 1% probability using Duncan's M

Genotypes SH4 (0.57 g) and SH1 (0.39 g) showed the greatest and lowest stone fruit, respectively. Fruit weight to stone weight ratio was determined to be between 11.64 and 21.68 in SH1 and SH15, respectively (Table 2). Fruit weight and soluble solids content can be used to determine the best time to harvest cherries (Sansavini and Lugli, 2005; Whiting and Ophardt, 2005). Our results show statistically significant differences in the fruit weight, stone weight, fruit weight to stone weight ratio among the studied genotypes.

Sweet cherries are highly appreciated by the consumer and their acceptance is mainly based on skin color, total soluble solids (TSS), acidity, absence of stem browning, freshness, and overall appearance (Crisosto *et al.*, 2003). In Iran, sweet cherries with high TSS content are highly accepted by consumers. In our analyses, measured TSS was found to range from 21.83% in SH4 (highest) to 15.0% in SH2 (lowest) (Table 3). TSS in sweet cherry fruit ranges between 11 and 25%, mainly due to glucose and fructose and less to the presence of sucrose and sorbitol, indicating that it is a cultivar-dependent parameter (Martinez-Romero *et al.*, 2006), while low variation in TSS during ripening has also been found in other sweet cherry cultivars (Bernalte *et al.*, 2003). Our results showed that the soluble solids content in sweet cherries is mostly dependent on conditions during the year.

Also included in our study were other fruit characteristics such as flesh color, skin color, juice color, fruit firmness, pH, and total titratable acid. All genotypes were kidney-shaped and fruit color ranged from dark red (SH2, SH3, SH7, SH8, SH9, SH13, SH15, SH19, 152.SH20, SH21, SH23) to blackish (SH1, SH4). Skin color was considered to be the most important index of cherry quality and maturity. Texture was firm except for SH15 (medium). In our study, pH values ranged between 3.33 (SH15) and 3.91 (SH8) (Table 3), which is

similar to the findings of Hepaksoy and Akcay (1995), who analyzed four sweet cherry cultivars originating from Turkey, Europe, and USA, and of Vursavu *et al.* (2006), who studied three sweet cherry cultivars from Turkey, USA, and France.

The reported pH values were 4.20 for sweet cherry cultivar Nour De Guben, 4.10 for 0 - 900 Ziraat, and 3.82 for Van. Total titratable acid was lowest in genotype SH7 (0.57%) and highest in SH1 (1.15%). Burak *et al.* (1995) found that acidity was between 0.70 and 1.0% for two sweet cherry cultivars grown in Turkey. Ercisli *et al.* (2006) also analyzed two sweet cherry cultivars and obtained similar data (0.55-0.98%). Our results are in accordance with those of Kuden and Kaska (1995), who found acidity between 0.81 and 1.02 when analyzing a total of 21 cultivated sweet cherries mostly from Turkey, Europe, and the USA. Firmness is one of the most important attributes of sweet cherries and is often used to assess fruit quality (Esti *et al.*, 2002). Late cultivars were found to be firm, while early cultivars were generally much softer (Christensen, 1995).

Morphological characteristics

Crown volume ranged between 16.53 and 32.67 m³ in Siah Mashhad sweet cherry genotypes, with SH23 having the largest crown volume and SH13 the smallest (Fig. 1). Current season vegetative growth was found to be from 45.66 to 58.00 cm (Fig. 2). Upon comparing the means of trunk diameter, we found that SH21 had the lowest (93.65 mm²) and SH20 has the highest (161.99 mm²) trunk diameter (Fig. 3). Anderson *et al.* (1996) measured the trunk diameter of Montmorency sour cherry and found significant differences in rootstock. Growth stage and plant physiological conditions of tree can be very effective on its growth vigor (Hjalmarsson and Ortiz, 2000). Our results show there were significant differences in the morphologic characteristics of all studied genotypes.

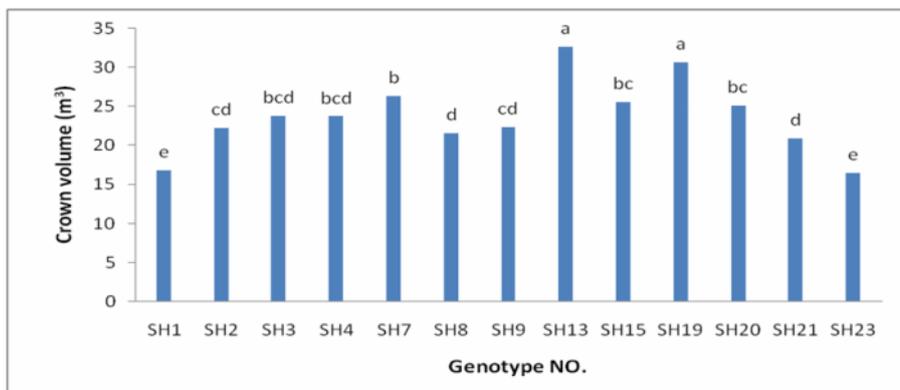


Fig. 1. Comparison of crown volume means of selected Siah Mashhad sweet cherry genotypes.

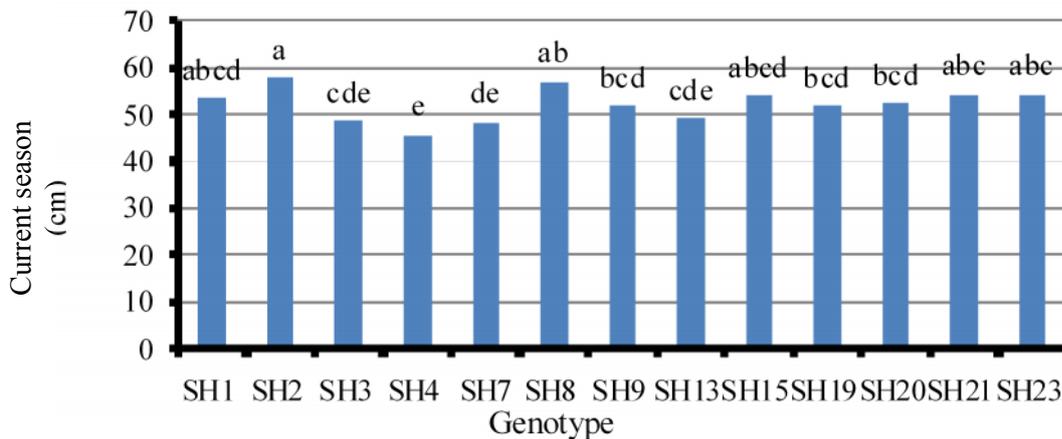


Fig. 2. Comparison of means of current season vegetative growth in selected Siah Mashhad sweet cherry genotypes.

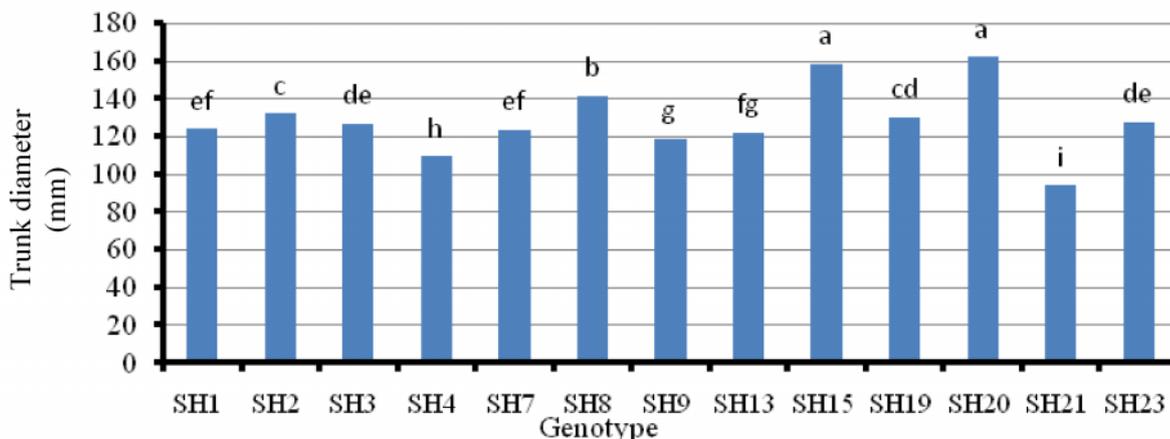


Fig. 3. Comparison of trunk diameter means in selected Siah Mashhad sweet cherry genotypes.

CONCLUSIONS

Results of this study will be useful for conserving and managing Siah Mashhad genetic resources. Our results show large variations in the morphologic and pomological properties of 13 Siah Mashhad sweet cherry genotypes. Statistically significant differences were observed in blooming phenology, ripening time, fruit weight, stone weight, soluble solid content, pH, total acid content, fruit shape, skin color, juice color, firmness of flesh, crown volume, trunk diameter, and current season vegetative growth.

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