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Regional Evaluation of Seven Newly Introduced Sweet Cherry Cultivars in North-East of Iran (Shahrood)

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Abstract

We evaluated five new introduced cultivars of sweet cherry (‘Stella’, ‘Sunburst’, ‘Summit’, ‘Subima’, and ‘Germesdorfi Coln 3’) with two control cultivars (‘Siah Mashhad’ and ‘Sileg Belamarka’) in one of the main temperate fruit production regions in North-East of Iran (Shahrood) during 2014 to 2016. Tree growth, flowering phenology, pollination, fruit set characteristics, and fruit quality were assessed in ten-year-old trees. ‘Summit’ and ‘Sunburst’ had the maximum and minimum tree height and tree canopy extension, respectively. ‘Stella’ had the highest yield and received the highest score in the organoleptic test. The lowest yield was observed in ‘Sunburst’ with the highest fruit weight (7.40 g). ‘Sileg Belamarka’ had the highest percentage of fruit set when open-pollinated. Complete compatibility in a field self-pollination experiment was confirmed for ‘Sunburst’ and ‘Stella’ and relative compatibility was observed in ‘Germesdorfi Coln 3’. All the introduced cultivars especially ‘Stella’ appeared well adapted to the Shahrood climate conditions.

Introduction

Introducing and evaluating the adaptability of new cultivars in different production regions is one aspect of breeding. Successful production of new fruit tree cultivars in a region requires, not only a complete survey of the regional climate condition, but also information on pollination, fruit set, and consumer preferences (Badenes and Byrne, 2012). Shahrood is one of the most important regions for stone fruit production in Iran. Sweet cherry (*Prunus avium* L.) is one of the important stone fruits which have a unique economic value in Iran. In 1999, five new sweet cherry cultivars were imported to Iran (Arzani, 2005). These cultivars were evaluated in three main temperate fruit production regions in Iran including Mashhad, Karaj, and Meshkinshahr. Former studies confirmed adaptability of ‘Stella’, ‘Germesdorfi Coln 3’, and ‘Sunburst’ to Mashhad climate (Ganji Moghadam *et al.*, 2014); ‘Stella’, ‘Summit’ and ‘Sileg Belamarka’ to Meshkinshahr climate (Fathi *et al.*, 2013); and ‘Stella’, ‘Sunburst’, ‘Summit’, ‘Subima’ and ‘Germesdorfi Coln 3’ to Karaj climate (Akbari *et al.*, 2014). These researchers indicated a diverse adaptability of these new cultivars to the different environmental conditions. ‘Stella’ is the first self-compatible cultivar of sweet cherry that was introduced in 1968 (Lapins, 1971). Self-compatible cultivars which have been released to date include: ‘Symphony’, ‘Sweet heart’, ‘Lapins’, ‘Sunburst’, ‘Tehrani vee’, ‘White Gold’, and ‘Samba’ (Arzani, 2005). Self-incompatible cultivars usually have less fruit set (3-5%) than self-compatible cultivars (Choi *et al.*, 2002). Self-incompatibility in the most popular Iranian sweet cherry cultivar was reported for ‘Siah Mashhad’ (Arzani, 1988). ‘Summit’ with 11% fruit set in a self-pollinated test was reported as a self-compatible cultivar (Wlodzimierz et

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al., 2008). However, in a study on pollination requirement with 13 sweet cherry cultivars in Serbia, 'Summit' and 'Germesdorfi Coln 3' were introduced as self-incompatible cultivars (Radicevic *et al.*, 2015), showing that environmental conditions can influence self-incompatibility of some cultivars. Self-compatible sweet cherry cultivars with cross-pollination have greater final fruit set than self-pollinated trees (Blazková, 1996). Fruit set of 'Summit' increased from 20.7% to 38.2% in self-pollination to cross-pollination (Blazková, 1996). After open pollination, self-fertile sweet cherry seedlings produced 5–10% higher yield than the self-sterile trees (Blazková, 1996).

Genotype and environmental parameters influence the time of anthesis and the length of the flowering period. Effective pollination period in sweet cherry is about 4 to 5 days, indicating that knowledge of flowering phenology in fruit trees is an essential factor in effective pollination and fertilization (Stosser and Anvari, 1983). Hosseini (2009) evaluated the genetic diversity of 25 sweet cherry cultivars and based on the flowering phenology, the cultivars were divided into three groups: early, middle, and late flowering. Environmental conditions initiate double fruiting in sweet cherry cultivars (Engin and Unal, 2004); e.g., water stress and high temperature at the time of flower initiation accelerate the formation of doubling fruits (Beppu and Kataoka, 1999; Engin and Unal, 2004).

This study aimed to evaluate growth and yield parameters of five newly introduced sweet cherry cultivars in comparison with two standard cultivars in the Shahrood region. Also, the flowering phenology, pollination compatibility, and fruit set of these cultivars were studied, as well as an organoleptic test panel judged the fruit quality.

Materials and Methods

The research was conducted at the Shahrood Agricultural and Natural Resources Research and Education Centre (longitude: 54°57′ E, latitude 36°25′ N, 1367 m elevation). Shahrood has a cold and dry climate with an average annual temperature of 14.4 °C, relative humidity of 63%, and average rainfall is about 160 mm per year.

Five newly introduced sweet cherry cultivars from Hungary including; 'Stella', 'Sunburst', 'Germesdorfi Coln3', 'Summit', and 'Subima' (Arzani, 2005) along with a native compatible cultivar, 'Siah Mashhad', and a non-native compatible cultivar, 'Sileg Belamarka'were grafted on 'Mahaleb' rootstock (*Prunus mahaleb* L.), and transferred to the field in April 2006. Trees were planted at 5 × 4 meters in a completely randomized block design (CRBD) with three replications, and four trees of each cultivar in each plot. All horticulture practices such as drip irrigation, fertigation and foliar applications, pruning, pest's management, and harvesting were performed similarly on all of them and trees were trained in a spindle form. The cultivars were evaluated in two years, 2015 to 2016.

Growth characters such as annual growth, tree height, trunk cross-sectional area, and canopy volume of each tree were measured at the end of the growing season in Sept. 2015 and 2016. Trunk cross-sectional area calculated from trunk diameter at 20 cm above the graft union. Tree canopy volume was calculated as $V=1.33\pi a^2 b$ (if height was more than width) or $V=1.33\pi ab^2$ (if the width was more than height) formula (a =half of big diameter, and b = half of small diameter.

Flowering phenological stages of the whole tree such as flower bud break, balloon stage, full bloom, end of flowering, petal fall, and fruit maturity was recorded in each year for all cultivars. The full bloom stage was considered when 75% of the flowers were open, end of flowering was recorded when over 95% of the flowers opened, and when 5% of the flowers still had petals was considered as a petal fall stage (Tzoner and Yamaguchi, 1999), measured on four branches on different sides of each tree.

Self-incompatibility was evaluated by

the level of fruit set in self-pollination (SP) and open-pollination (OP) tests. Four shoots with 100 to 150 flowers approximately around the canopy for each tree were used for each pollination test. SP was measured by determining the rate of self-fertility in isolated emasculated and non-emasculated (intact) flowers. To prevent unwanted pollination in both tests, shoots were isolated by covering shoots with cotton bags before the balloon stage. For the SP test, flowers were emasculated by removing petals and anthers at the balloon stage, and then shoots were bagged. Flowers were pollinated with a pen using pollen collected from the same tree. This operation was repeated 24 hours later to ensure adequate pollination. For the SP test, flowering shoots with non-emasculated (intact flower) flowers were bagged before flowers opened. After bloom, to ensure pollination, a fine brush was used to transfer pollen from the stamens to the stigmas of the same flowers. Four non-treated shoots per tree were used to evaluate fruit set of open-pollinated shoots. The number of harvested fruit per shoot was used calculate the percentage of flowers that set fruit.

Ten trained panelists, five males, and five females, between 25 to 40 years, were asked to evaluated fruit quality. All the panelists assessed three fruits per cultivar labeled with a code with three replications. Panelists evaluated the size, color, appearance, texture, aroma, flavor, taste, and overall acceptability by scoring each index on a scale from 1 to 9 (1= lowest quality and 9= best quality). Coffee powder was used as blind for quality traits assessment.

Yield (kg per tree) and fruit weight (average of 20 fruit per tree) were recorded annually. Fruit length and diameter were measured with a digital caliper. Fruit firmness was measured with a Penetrometer (Wagner FT 30, Greenwich, CT, USA) and total soluble solids concentration (TSS) of fruit juice obtained from 100 g commercially ripened fruits was measured with a refractometer (ATAGO master 5EM, Japan). Total acidity (TA) of fruit juice was also assessed by titration NaOH (0.1 N).

Data for tree characteristics were analyzed as a randomized complete block design with SAS 9.4 software (SAS/STAT Software , 2014). The experimental unit was the four-tree plot for each cultivar randomized within each of the three blocks. Means for the four-tree plots were analyzed with SAS's Proc Glimmix, where block was specified as a random effect, and LSmeans were comparing with Tukey's test. Data from evaluations for fruit characteristics were analyzed as a split-plot, where year was the whole-plot and cultivar was the split-plot. When the year×cultivar interaction was significant, cultivar LSmeans were compared within each year with the Slicediff adjustment.

Results and Discussion

The results of data analysis (P-value) were presented in Table 1. The cultivars had significantly different canopy characteristics (Table 1). 'Subima' trees were the largest, with a volume of 17.07 m^3, but did not differ from 'Summit' and 'Stella' (Table 2).

Table 1. P-values from analysis of variances for various characteristics of trees and fruit for seven sweet cherry cultivars in two years.

Effect	Pr > F															
	DF	CV[z]	TCSA	TH	FSOP	FSIF	FSEF	FL	FW	FEW	FWR	FF	DF	TSS	TA	TSS/TA
Year	1	0.0081	0.6332	0.0232	0.0400	0.0030	0.0023	0.1995	0.0879	0.0935	<.0001	0.0002	0.2165	0.1414	<.0001	<.0001
Cultivar	6	0.0378	0.0003	0.0106	<.0001	<.0001	<.0001	0.2007	0.0154	0.0030	0.0080	0.0005	<.0001	0.0105	0.0607	0.0719
year*cultivar	6	0.8321	0.8613	0.6782	0.0002	<.0001	<.0001	0.0021	0.0002	<.0001	0.0017	0.0052	0.0019	0.5937	0.1464	0.1150

[z] Canopy volume (CV), trunk Cross-section area (TCSA), Tree height (TH), Final fruit set after open pollination (FSOP), fruit set after Self pollination of intact flower (FSIF), fruit set after Self pollination of emasculated flower (FSEF), Fruit length (FL), Fruit width (FW), Fruit weight (FEW), Fruit to stone weight ratio (FWR), Fruit firmnes (FF), Double fruiting (DF), Total soluble solids concentration (TSS), titratable acidity (TA) and TSS/TA ratio.

Table 2. Canopy volume, trunk cross sectional area (TCSA), and tree height of 11 year-old trees of seven sweet cherry cultivars in Shahrood, Iran.

Cultivar name	Canopy volume (m^3)	TCSA (cm^2)	Tree height (cm)
Germesdorfi Coln3	12.87 ab[z]	93.11 cd	275.9 b
Sileg Belamarka	12.49 b	86.65 d	287.4 b
Subima	17.07a	133.51 b	318.3 a
Siah Mashhad	11.15 b	94.07 cd	291.5 ab
Summit	16.5 a	109.80 c	340.4 a
Sunburst	9.38 b	105.06 c	267.3 b
Stella	16.05 a	159.82 a	313.5 ab

[Z] Means within columns followed by common letters do not differ at the 5% level of significance, by Tukey's test.

'Sunburst' trees were the smallest, with an average canopy volume of 9.38 m^3 and were similar to 'Siah Mashhad' (Table 2). The starting date of the fruit-bearing in 'Sunburst' was earlier than other cultivars (Data not shown) and this may be one of the reasons for low canopy volume of this cultivar. 'Stella' had the largest trunks, whereas cultivars with the smallest trunks included 'Sileg Belamarka', 'Germesdorfi Coln3' and 'Siah Mashhad' (Table 2). The tallest and shortest trees were 'Summit' and 'Sunburst', respectively (Table 2). 'Summit', 'Subima' and 'Stella' trees were the tallest (Table 2).

A cursory investigation of flower morphological characteristics showed that all cultivars had similar numbers of stamen, pistils, sepals, and petals. Flower phenological stages including swelling flower buds, tip green stage, balloon stage, full bloom, end of flowering, petal fall stages and leaf initiation in each cultivar were presented as a schematic (Fig. 1). For most cultivars, the bud break stage lasted 2 to 3 days, and balloon stage lasted 3 to 4 days, but cultivar differences were not significant in the two years of study. The time of anthesis varied with cultivar (Fig. 1). The difference between early- and late-blooming cultivars was about six days in 2015 and eight days in 2016. The earliest flowering cultivars in both years were 'Siah Mashhad' and 'Germesdorfi Coln3', and the latest flowering cultivars were 'Stella' and 'Summit' cultivars (Fig. 1). Petal abscission lasted 4 to 6 days for all cultivars. For most cultivars, trees started blooming earlier in 2016 than in 2015 bloom ranged from 3 days in 'Sileg Belamarka' to 9 days in 'Sunburst'. Seasonal environmental changes and weather conditions influence date of flowering (Tooke and Nicholas, 2010). Based on the number of days from anthesis to end of flowering the cultivars were divided into three groups that can be used as pollinizer for each other: 1) early included 'Germesdorfi Coln3' and 'Siah Mashhad', 2) middle included 'Subima', 'Sileg Belamarka', and 3) late included 'Summit' and 'Stella'. Brozik (1971) showed that the optimum blooming duration in cherry is 10–14 days, and for incompatible cultivars, at least 4–6 days overlapping was necessary for good pollination and fruit set. Also, early cultivars cannot be recommended as pollinators for late cultivars (Kiris, 1992), e.g. 'Stella' and 'Summit' cannot be used as pollinizers for the early flowering cultivars, 'Germesdorfi Coln3' and 'Siah Mashhad'. Fathi et al. (2013) studied the adaptation of these cultivars in the Meshkinshar region in Iran and recommended 'Stella' and 'Summit' as late-flowering cultivars, which agree with our results. However, they indicated that 'Sileg Belamarka' and 'Subima' bloomed early which conflicts with our results in Shahrood. 'Sileg Belamarka' and 'Summit' was reported as early and late flowering cultivars in Mashhad climate (Iran), respectively (Ganji Moghadam *et al.*, 2014).

In the Shahrood region, 'Germesdorfi

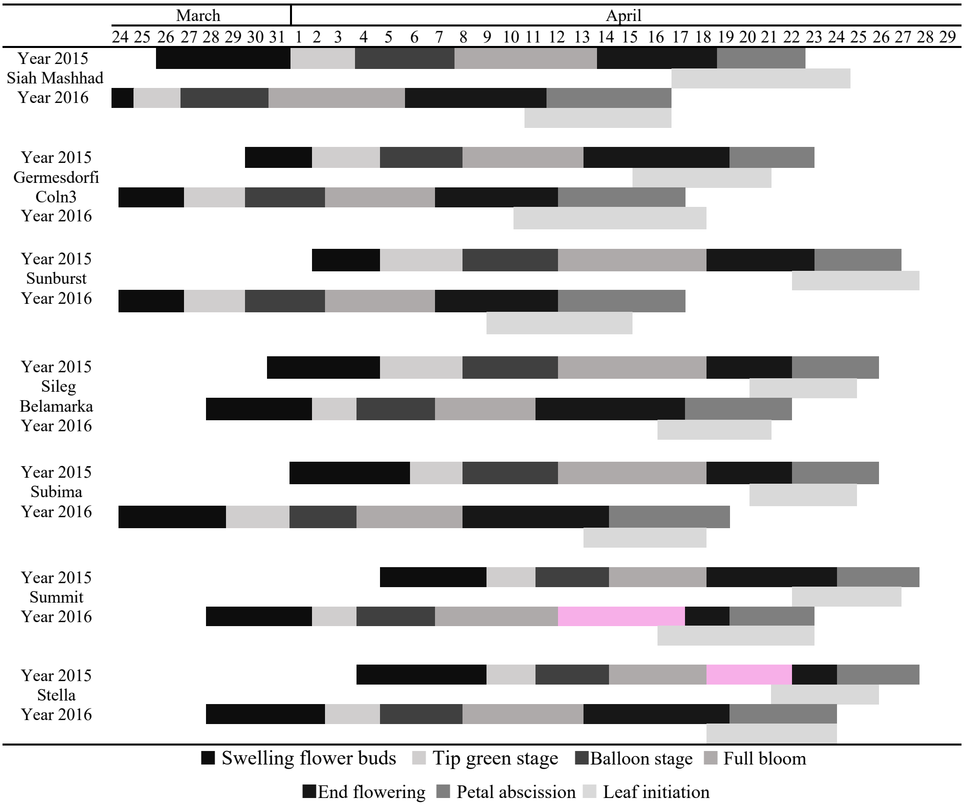

Figure 1. Flowering phenological stages (Webster and Looney, 1996) for seven sweet cherry cultivars in Shahrood, Iran.

Coln3' and 'Siah Mashhad' fruit ripened on 20 June 2015 and 9 June 2016, whereas other cultivars ripened on 6 June 2015 and 3 June 2016. However, in Mashhad 'Sileg Belamarka' required 43 days for fruit maturity and was introduced as an early cultivar and 'Siah Mashhad' required 73 days for fruit maturity was introduced as a late ripening cultivar (Ganji Moghadam *et al.*, 2014). Evaluation of phenological stages indicated obvious differences among studied cultivars, which confirmed other research on phenology in sweet cherry (Hossieni 2009; Ahmadi Moghdam *et al.*, 2012). Ahmadi Moghdam et al., (2012) studied phenological flowering stage of 13 sweet cherry genotypes obtained from 'Siah Mashhad' and there was no significant difference in the early stages of flower bud development, swelling bud and green tip stages. However, there was a significant difference between the beginning of flowering among genotypes from 23 March in SH4 genotype to 2 April in SH21 genotype and petal fall stage for all genotypes was six days.

Cultivars significantly influenced fruit set for SP (artificial and natural SP) and OP (Table 2). For all cultivars, OP limbs had significantly higher fruit set than SP limbs. For the OP treatment, 'Stela' had the lowest fruit set in 2015, but not in 2016 (Table 3). 'Sileg Belamarka', 'Siah Mashhad', and 'Summit' had the highest fruit set in both years. The same results were reported by

Table 3. Final fruit set (%) for open pollinated (OP) and self-pollinated (SP) flowers of seven sweet cherry cultivars in Shahrood in 2015 and 2016.

Year	Cultivars	Fruit set at Harvest (%)		
		OP	SP of emasculated flower	SP of intact flower
2015	Germesdorfi Coln3	50.44 b[z]	3.74 c	4.67 c
	Sileg Belamarka	60.93 a	0.00 d	0.00 d
	Subima	54.12 ab	0.17 d	0.00 d
	Siah Mashhad	45.28 b	0.63 d	0.95 d
	Summit	50.68 b	0.00 d	0.00 d
	Sunburst	55.37 ab	16.08 a	14.61 a
	Stella	17.14 b	12.12 b	11.72 b
2016	Germesdorfi Coln3	56.65 ab	8.67 c	8.89 c
	Sileg Belmarka	65.17 a	0.16 d	0.00 d
	Subima	56.99 ab	1.48 d	1.88 d
	Siah Mashhad	64.71 a	0.00 d	0.95 d
	Summit	61.56 ab	0.34 d	0.64 d
	Sunburst	55.46 b	32.06 a	23.57 b
	Stella	58.94 ab	17.62 b	29.90 a

[z] LSmeans within years and columns followed by common letters are not significant at the 5% level, by the SLICEDIFF adjustment.

(Akbari et al., 2012; Fathi *et al.*, 2013), where 'Summit' had the highest percentage of fruit set. For both years the SP treatments had less than 3% fruit set for 'Subima', 'Sileg Belamarka', 'Summit', and 'Siah Mashhad', which are self-incompatible. 'Sunburst' and 'Stella' had more than 5% self-pollinated fruit set and are complete self-compatible cultivars, and 'Germesdorfi Coln 3' is a relative self-compatible cultivar (Table 3). Similar results were reported by (Akbari *et al.*, 2012; Ganji Moghadam *et al.*, 2014). 'Sunburst' with 39.4% fruit set in an isolated SP test was considered as self-compatible in Turkey climate (Sutyemez, 2011) which coincides with our results. These results were also confirmed by (Fathi, 2000; Choi *et al.*, 2002), however in their study most sweet cherry cultivars were self-incompatible.

'Stella' had the highest yield, with 55 kg/tree, and the lowest yield of 15 kg/tree was recorded for 'Sunburst' (Table 4). Over two years in a study in Karaj, Iran the highest yield was recorded for 'Sileg Belamarka' with 21.8 kg/tree, and the lowest yield was 6.4 kg/tree for 'Siah Mashhad' (Akbari, 2012), which was not confirmed by our results. In addition to the genotype, yield is influenced by other factors such as management system, nutritional conditions, climate conditions, tree age and biotic and abiotic stress. (Iezzoni *et al.*, 1990). However, yield performance for tree fruit cultivars requires several years of data.

In the judgment of panelists, 'Stella' had the highest overall acceptance and 'Siah

Table 4. Yield of seven newly introduced sweet cherry cultivars years 2015.

Cultivar	Yield (kg/tree)
Germesdorfi Coln3	21.66 d[z]
Sileg Belamarka	38.33 bc
Subima	36.66 c
Siah Mashhad	25.00 d
Summit	46.66 b
Sunburst	15.00 e
Stella	55.00 a

[z] Means followed by common letters do not differ a the 5% level of signficance, by Tukey's test.

Table 5. Organoleptic ratings for seven sweet cherry cultivars based on test panels in 2015.

Cultivar	Juiciness[z]	Size[y]	Color[y]	Texture[x]	Aroma and Odor[x]	Flavor[v]	Overall Acceptance[u]
Germesdorfi Coln3	5.37 a[t]	5.04 b	6.70 a	5.06 b	4.66 ab	5.45 bc	6.08 b
Sileg Belamarka	5.72 a	6.18 ab	6.82 a	3.96 c	4.60 ab	5.70 b	5.88 bc
Subima	5.53 a	5.83 ab	6.93 a	4.48b c	4.76 ab	5.65 b	6.05 b
Siah Mashhad	4.45 b	3.15 c	5.15 b	4.50b c	3.25 b	3.85 c	4.20 c
Sunburst	5.36 a	5.13 b	5.76 b	5.03 b	4.40 ab	4.56 bc	5.20 b
Stella	5.93 a	7.23 a	7.10 a	6.33 a	5.36 a	6.30 a	7.13 a
Summit	5.85 a	5.65 ab	4.40 c	3.90 c	5.1 a	6.87 a	5.75 b

[t] Means within columns followed by common letters do not differ at the 5% level of significance, by Tukey's test.
[z] 1-5 low water - juicy [x] 1-9 very soft - crisp [v] 1-9 bad taste - delicious
[y] 1-9 weak - excellent [w] 1-9 weak - excellent [u] 1-9 inedible - excellent

Mashhad' had the lowest (Table 5). In a test panel with the same cultivars, 'Stella' and 'Sunburst' had the highest acceptance (Akbari, 2012). All of the introduced cultivars received higher scores for juiciness, size, aroma, and aroma and flavor than the control cultivar 'Siah Mashhad'. 'Summit' received the lowest score for fruit texture and colour (Table 5).

Fruit parameters such as fruit length, diameter, weight, the ratio of fruit pulp weight to fruit stone weight, and double fruiting was revealed significant differences among cultivars (Table 6). 'Sileg Belamarka' and 'Subima' had the most double fruit both years and 'Germezdorfi Coln3', 'Siah Mashhad' and 'Stella' the lowest percentage of double fruits (Table 6).' Low and high fruit doubling in sweet cherry cultivars was reported by other researchers (Bouzari and Arzani, 2006). Fruit doubling in 'Stella' was 2% in 1977 and 29% in 1980 in southern

Table 6. The length, width, weight, firmness and the ratio of fruit weight to stone weight of seven sweet cherry cultivars in 2015 and 2016.

Cultivar	Year	Fruit length (mm)	Fruith width (mm)	Fruit wt. (g)	Fruit wt. /Stone wt.	Firmness (kg/cm^2)	Double fruiting %
Germesdorfi Coln3	2015	18.75 bz	16.97 c	4.83 c	13.06 c	1.18 b	1.39 d
Sileg Belamarka		20.35 ab	18.29 bc	5.58 bc	20.40 a	1.24 ab	8.65 a
Subima		20.53 a	18.15 bc	5.63 bc	16.34 bc	1.16 b	7.35 b
Siah Mashhad		19.11 ab	17.03 c	4.25 c	14.41 c	1.12 b	1.18 d
Sunburst		19.01 ab	18.06 bc	4.68 c	14.60 c	1.32 ab	2.74 c
Stella		20.66 a	20.14 a	6.75 a	19.06 ab	1.38 a	0.99 d
Summit		20.64 a	18.78 b	5.94 b	17.56 b	1.24 ab	2.62 c
Germesdorfi Coln3	2016	21.26 ab	20.26 ab	6.53 b	12.06 ab	2.20 a	1.18 e
Sileg Belamarka		20.30 ab	19.21 b	5.33 c	11.61 b	1.55 d	5.33 b
Subima		21.83 ab	19.53 b	6.80 ab	14.04 a	1.88 bc	6.56 a
Siah Mashhad		20.46 ab	19.89 ab	5.60 c	9.80 b	1.79 c	1.37 e
Sunburst		22.08 a	21.26 a	7.40 a	14.12 a	2.00 b	4.48 d
Stella		19.65 b	19.51 b	5.69 c	11.68 b	2.11 ab	1.11 e
Summit		18.59 b	17.34 c	4.95 c	10.37 b	1.90 bc	1.27 e

[z] Means within years and columns followed by common letters do not differ at the 5% level of significance, by the SLICE adjustment.

San Joaquin valley of California (Mike *et al.*, 1983) Temperatures above 28 °C and drought stress during the time of flower bud initiation increased double fruiting in peach (Johnson *et al.*, 1992).

In 2015 'Germesdorfi', 'Sunburst', and 'Siah Mashhad' had the lowest fruit length and diameter, but results in 2016 were quite different. Akbari *et al.* (2014) studied the same cultivars in Karaj, Iran and reported the highest and lowest fruit length for 'Sunburst' and 'Sileg Belamarka', respectively, whereas 'Stella' had the highest fruit diameter and 'Subima' had the lowest in one year. Fruit weight was not consistent both years. Fruit weight was highest in 2015 for 'Stella' and for 'Sunburst' in 2016. The big fruit of 'Sunburst' was also reported by others researchers (Radicevic *et al.*, 2008; Dzhurinov, 2009). The ratio of fruit pulp to stone weight ranged between 14.18% for 'Siah Mashhad' to 24.67% for 'Sunburst' (Table 6). The maximum and minimum of fruit firmness were recorded for 'Germesdorfi Coln3' in 2016 and 'Siah Mashhad' in 2015, respectively (Table 6). TSS, TA and TSS/TA were affected significantly by cultivars (Table 1). 'Sublime' had highest TSS which was significantly higher than 'Siah Mashhad' and 'Summit' (Table 7). The TA of 'Summit' fruits was significantly lower than other cultivars. 'Subima' had higher fruit flavor index, TSS/TA ratio, than the other cultivars except 'Summit' (Table 7). TSS in sweet cherries is mostly dependent on environmental conditions (Akbari *et al.*, 2014). 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 and TSS is a cultivar-dependent parameter in sweet cherry (Martinez-Romero *et al.*, 2006). Acidity changes are low during fruit maturation, and ripening of sweet cherry (Akbari *et al.*, 2014) and the malic acid in sweet cherry is much less than other of temperate fruits (Crisosto *et al.*, 2002).

Table 7. Total soluble solids concentration (TSS), titratable acidity (TA) and TSS/TA ratio of fruits of seven sweet cherry cultivars grown in Shahrood, Iran.

Cultivar	TSS	TA	TSS/TA
Germesdorfi Coln3	19.48 ab[z]	0.59 a	34.13 b
Sileg Belamarka	20.08 ab	0.59 a	36.70 b
Subima	20.47 a	0.52 b	44.72 a
Siah Mashhad	18.88 b	0.58 a	35.73 b
Sunburst	19.12 ab	0.60 a	38.81 b
Stella	19.33 ab	0.56 ab	40.12 b
Summit	18.93 b	0.45 c	43.13 ab

[z] Means within columns followed by common letters do not differ at the 5% level of signficance, by Tukey's test.

Conclusions

The evaluation of seven sweet cherry cultivars in Shahrood, Iran indicated that 'Stella', 'Summit', and 'Subima' produce larger trees than the other cultivars. There were obvious differences in flowering phenological stage, and based on bloom dates, the cultivars were divided into three groups, which can be used to pollinate for each other within a group. Pollination tests indicated that 'Subima', 'Sileg Belamarka', 'Summit', and 'Siah Mashhad' were self-incompatible.'Sunburst' and 'Stella', with more than 5% self-pollinated fruit set, were complete self-compatible cultivars, and 'Germesdorfi Coln3' is a relative self-compatible cultivar. In two years of evaluation, high double fruiting was observed in 'Sileg Belamarka'; 'Subima' had more double fruit than other's cultivars and 'Germezdorfi Coln3', 'Siah Mashhad' and 'Stella' had low double fruiting. 'Stella' had the highest overall acceptance rating. 'Sunburst', 'Subima', and 'Stella' had the largest fruits with high fruit flavor rating. In general, all the introduced cultivars were well adapted to Shahrood climate. However, based on tree growth, pollination requirement, yield and fruit quality, 'Stella' is recommended for cultivation in Shahrood, Iran.

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