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Tree and fruit characterization of peach genotypes grown under Ardabil and East Azarbaijan environmental conditions in Iran

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ABSTRACT

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Peach genotypes showing notable fruit and tree traits were selected in Ardabil and East Azarbaijan Provinces of Iran. Genotypes were grafted on seed rootstocks and cultured with 4×4 m spacing. Traits such as tree growth habit, flowering, maturity, morphological and qualitative fruit characteristics were described in 15 peach genotypes using IBPGR peach descriptors during the 2005-2007 seasons. Variation was found within genotypes for traits such as tree growth habit, bloom and harvest date, yield, fruit weight, soluble solids content, and titratable acidity. Some genotypes had upright or spreading growth habit. Tree vigor was intermediate to strong with green leaf color. Flowering occurred early to late in three years with 10 to 13 days of flowering period. Harvest time varied from early to extremely late (mid-June to late October). Genotypes showed a range of 120±1 g to 275±1 g for fruit weight, 22 to 114 kg for yield per tree, 11.60 to 16.40 °Brix for SSC, 0.54±0.01 to 0.92±0.02% for TA and ripening index from 1.73 to 2.02. Results showed 6 clingstone and 9 freestone genotypes with white and white-greenish to yellow flesh color. Genotypes were grouped into four clusters based on quality traits. High correlation was found between fruit quality traits using principal component analysis. These relationships may help to select a set of genotypes with better fruit quality. Selected genotypes showed good adaptability in Ardabil and East Azarbaijan Provinces and may be released as superior varieties for use in breeding programs.

Keywords: characterization, genetic diversity, morphological descriptors, peach genotypes, *Prunus persica* (L.) Batsch

INTRODUCTION

Peach [*Prunus persica* (L.) Batsch] belongs to the Rosaceae family and is one of the important stone fruits. This species is well adapted to temperate and subtropical regions, between 30º and 45º north and south latitudes. Peach is a self-fertile and naturally self-pollinating fruit species with very low genetic variability (Westwood, 1978). Peaches originated from China and were cultivated in the Middle East long before being introduced into Europe. This species includes different types of varieties: downy skin with freestone or clingstone (peach), and smooth skin with freestone or clingstone (Chalak *et al*., 2006).

Agronomic and fruit quality traits were evaluated and compared for three consecutive years on seedlings of 15 peach and nectarine crosses grown in a Mediterranean climate. Significant differences were found among and within the different progenies. Relationships between qualitative pomological and agronomic traits and fruit quality parameters were also reported (Cantin *et al*., 2010).

Chalak *et al*. (2006) characterized 27 peach accessions that are cultivated and distributed in different geographical zones of Lebanon. Each accession was described using 10 traits related to flowering date, maturity date, and morphological characteristics of leaves and fruit. Principal component analysis revealed that flowering and maturity dates, fruit type, and flesh color contributed significantly to total variation. From 1985 to 2000, tree and fruit characteristics of 46 white-fleshed peach and nectarine cultivars were studied in New Jersey, USA, by Frecon *et al*. (2002), who selected varieties presenting good firmness and White Lady was the best cultivar in the State of New Jersey.

Wen and Sherman (2002) evaluated 300 peach and nectarine genotypes for subtropical Taiwan. They reported that Maruvilha, p-112, and Premier had high sugar content and the best aroma and were the most adapted for commercial orchards. Russel and Topp (2002) evaluated 19 peach and two nectarine Brazilian varieties in the temperate region of Australia and found that Lotus cultivar had total soluble solid content of 24%. Sicilian peaches ripen from July to late October. The most desired traits are white flesh, clingstone, and high soluble solid content (Monte *et al.*, 2006). New early peach cultivars for subtropical regions of India are available that ripen from the third week of April to late May, for example, Flordaprince, with a mean yield of 100 kg per tree (Kanwar *et al*., 2002).

Seed propagated fruit trees such as peach created big variation within Iran's traditional orchards and put the country's commercial fruit crop production at a disadvantage, but they also created a big advantage for fruit tree breeding programs (Arzani, 2003). According to recent statistics (FAOSTAT, 2010), peach is one of the most important fruit crops in Iran, with 500,000 tons produced annually. Although most peach orchards in East Azarbaijan and Ardabil Provinces are seed propagated, this leads to high variation between local planting areas. Therefore, precise identification and characterization of cultivars/genotypes is essential for commercial peach production as well as future breeding programs.

The objective of the present research was to explore and monitor tree and fruit characterization of peach genotypes grown under environmental conditions of Ardabil and East Azarbaijan and use the results in commercial production as well as future peach breeding programs.

MATERIALS AND METHODS

Surveying and collecting samples

Field expeditions were initiated in 2004 with the aim of surveying and collecting different accessions of cultivated peach in major growth areas of Ardabil and East Azarbaijan in northwestern Iran (Fig. 1). Five stands (Meshkinshahr, Shabestar, Shendabad, Sardrood, and Maragheh) were studied due to their extended areas of peach cultivation: altitude ranged from 1077 m (in Meshkinshahr) to 1480 m (in Maragheh), latitude from 36º 45' (in East Azarbaijan) to 39º 42' (in Ardabil), and longitude from 45º,50 (East Azarbaijan) to 48º,55 (Ardabil). Minimum winter temperatures ranged from -3.5ºC to -6.6ºC and mean annual rainfall was 260-320 mm. Fifteen peach genotypes with desirable traits were nominated by farmers and propagators (Table 1).

Morphological and phenotypic characterization

To characterize the morphological traits and evaluate the fruit of these genotypes, 10 trees of each identified genotype were selected from the original orchards. Trees were planted at a spacing of 4 m x 4 m and were trained to the standard open vase system. Trees were grown under standard conditions of irrigation, fertilization, pest and disease controls. Hand thinning was carried out to reduce the fruit load when required. All vegetative and quantitative fruit quality characteristics were measured or scored according to international descriptors (IBPGR) for each genotype separately over a three-year period (2005-2007) and means of the three years were calculated.

Fig. 1. Stands of collected accessions of peaches located in Ardabil and East Azarbaijan Provinces (northwest Iran).

Vegetative and fruit quality trait evaluation

During the 2005-2007 seasons, agronomic and fruit quality traits were evaluated for each genotype. The studied traits included tree habit, tree vigor, leaf color, flower size, flowering season, flowering period (days), flower type, self-fertility, flowering date, maturity date, fruit shape (round or flat), fruit size, fruit diameter, fruit color (skin, flesh, and background), fruit texture, flesh firmness, fruit cracking, endocarp staining (redness around stone), yield (productivity), stone adherence (freestone or clingstone), stone size, stone shape, stone splitting, and downy skin (Bretaudeau and Fauré, 1991). Representative samples consisting of 20 fruits per tree were evaluated for fruit quality parameters. Finally, superior genotypes were selected by independent culling of the most important agronomic traits (harvest date and yield) and fruit quality traits.

Fruit shape and fruit diameter were scored using rating scales appropriate for each. Skin blush and endocarp staining (redness around stone) were scored as the percentage of skin surface with red color and redness around the stone. Soluble solids content (SSC) of the juice was measured with a temperature compensated refractometer (MT 098 model REF- 108, China), and data were expressed as °Brix at 20°C. Titratable acidity (TA) was determined by titration with NaOH 0.1 N to pH 8.1 (Cantin *et al*., 2010).

Flesh firmness was determined on opposite sides

Table 1. Local and geographical information on the 15 studied genotypes.

Genotype code	Local name	Scientific name	Collection location	Province	Date of collection	Latitude (0/N)*	Longitude (0/E)*	Altitude (m)*	Acqui da
MHF-103	Fasl e aval	*P. persica*	Meshkinshahr	Ardabil	04, 2004	38, 29N	47, 42 E	1120	09, 2
MHF-100	Paeezeh	*P. persica*	Meshkinshahr	Ardabil	04,2004	38, 29N	47, 42 E	1120	09, 2
MHF-102	Dastgir	*P. persica*	Meshkinshahr	Ardabil	04, 2004	38, 28N	47, 39E	1077	09, 2
MHF-104	Shendabad kardi	*P. persica*	Meshkinshahr	Ardabil	04, 2004	38, 28 N	47, 40E	1098	09, 2
MHF-105	Shendabad joda	*P. persica*	Meshkinshahr	Ardabil	04,2004	38, 28N	47, 39E	1077	09, 2
MHF-101	Gajelganat	*P. persica*	Meshkinshahr	Ardabil	04, 2004	38, 28N	47, 39E	1077	09, 2
MHF-106	Mouzi	*P. persica*	Meshkinshahr	Ardabil	04, 2004	38, 28N	47, 39E	1077	09, 2
EA-107	Anjiri Maleki	*P. persica*	Shend abad	E. Azarbaijan	05,2004	38, 08N	45, 36E	1331	09, 2
EA -108	Anjiri Zafarani	*P. persica*	Shabestar	E. Azarbaijan	05,2004	38, 17N	45, 70E	1469	09, 2
EA -109	Haj Kazemi	*P. persica*	Shendabad	E. Azarbaijan	06, 2004	38, 09N	45, 37E	1336	09, 2
EA -110	Kosari Khooni	*P. persica*	Shendabad	E. Azarbaijan	06, 2004	38,07N	45, 36E	1285	09, 2
EA -111	Sefid Sardrood	*P. persica*	Sardrood	E. Azarbaijan	07, 2004	38, 30N	46, 80E	1349	09, 2
EA -112	Bolmeh	*P. persica*	Shabestar	E. Azarbaijan	06, 2004	38, 11N	45, 42 E	1469	09, 2
EA -113	Shablon	*P. persica*	Maragheh	E. Azarbaijan	06, 2004	37,23N	46, 15E	1481	09, 2
EA -114	Noras	*P. persica*	Shendabad	E. Azarbaijan	07, 2004	38,08N	45, 36 E	1325	09, 2

* Data listed by GPS.

of the equator of each fruit with a penetrometer fitted with an 8-mm diameter probe on five fruits from each tree and a total of 15 fruits per genotype. Two readings were averaged for each fruit, and data were given in kg cm^{-2}. Cluster analysis of genotypes into similarity groups was done using Ward method analysis by SPSS 16.0 for Windows (Chicago, IL). The number of observed genotypes, maximum and minimum values, mean of standard error, and standard deviation for each trait were calculated to obtain basic statistics for all the studied plant material. To reveal possible associations, correlations between traits were calculated with raw data based on single plant estimates over the three years, using Pearson's correlation coefficient at $P \leq 0.05$.

RESULTS AND DISCUSSION

Seven genotypes were found in the Meshkinshahr, two genotypes in Shabestar, four genotypes in Shendabad, and one genotype in Sardrood and Maragheh stands (Fathi *et al*., 2007). Season and flowering period are shown in Table 2. In Mediterranean areas, early flowering is a desirable trait to obtain the earliest yield (George and Nissen, 1992; Caruso and Sottile, 1999), but spring frosts may damage and reduce production in some years in temperate regions. Although differences between genotypes were observed when blooming began, greater differences were observed during full bloom and at the end of it, due to the differences in blooming period duration in different genotypes. Blooming date is considered a quantitative trait in peach and other *Prunus* species (Dirlewanger *et al*., 1999; Vargas and Romero, 2001).

Regarding harvest maturity (Table 3), great differences were found in ripening time among the genotypes, ranging from early ripening (early June) to extremely late ripening (mid-October). The earliest genotypes harvested (early June) belonged to the Meshkinshahr and Shendabad stands. The latest genotypes were from the Meshkinshahr, Shendabad, and Shabestar stands, which were harvested from mid-August to mid-October.

Harvest time showed a normal distribution within each genotype (data not shown), reflecting quantitative genetic control, a trait that has been established as characteristic of each cultivar and is quantitatively inherited (Dirlewanger *et al.,* 1999; Vargas and Romero, 2001). This variability allows selecting the most desirable harvest time among the genotypes in order to cover market demands (Byrne, 2003), although blooming and harvesting dates may change each year due to environmental conditions, especially temperature (Mounzer *et al*., 2008).

Days after full bloom (DAFB) remained more or less stable for each genotype over years. Peach fruit development period is highly dependent on the cultivar or genotype (Cheng, 2008; Mounzer *et al*., 2008); however, research has shown that spring temperatures influence the harvest date of peach cultivars (López and DeJong, 2007). Very early-maturing and very late-maturing peach cultivars are of considerable interest to the peach industry (Caruso and Sottile, 1999). In the present work, fruit development period of the studied genotypes ranged from 85 to 180 days. The shortest fruit development period was observed in MHF-103 and EA-114, and the longest (180 days) in MHF-102, the latest ripening genotype that was harvested (Table 3). This and other desirable traits were considered in selecting 15 genotypes.

Fruit weight is a major quantitative inherited factor determining yield, fruit quality, and consumer acceptability (Dirlewanger *et al*., 1999). There was more than a 2.5-fold range (120 to 275 g) in mean fruit weight among the genotypes, due to the influence of genotype, cultivar, and fruit type (flat or round). This agrees with previous studies that have found high variability in this parameter among peaches (Quilot *et al*., 2004a; Iglesias and Echeverría; 2009).The highest mean fruit weight was found in MHF-106 (Table 4), although MHF-104, MHF-105, EA-111, MHF-101, and EA-109 also produced large fruit.

Tendency to have higher fruit weight was found in the latest ripening genotypes, such as MHF-106, MHF-102, MHF-101, and EA-111, in which a positive correlation between harvesting date and fruit weight has been reported (Dirlewanger *et al*., 1999; López and DeJong, 2007). The medium fruit weight observed in flat peach genotypes EA-107 and EA-108 agrees with previous reports on the reduction of fresh weight in flat peaches that carry the *S* gene, a dominant gene that controls fruit shape (*S-,* flat or *ss,* round) (Scorza and Sherman, 1996). Skin fruit color has a significant effect on consumer acceptance and sales of peaches and nectarines (Scorza and Sherman, 1996; Liverani *et al*., 2002).

The percentage of skin blush varied from 20 to 45% between genotypes (Table 4). Genotypes MHF-104 and MHF-105 showed the highest percentage with 45% blush, whereas MHF-102, MHF-106, EA-111, and EA-113 showed the lowest blush percentage. Fruit color intensity is positively related to consumer acceptance of fresh market peaches (Iglesias and Echeverría, 2009). Significant differences were found among genotypes for soluble solids content, which ranged from 11.6 to 16 °Brix

Table 2. Studied phenological and morphological characteristics of the 15 local peach genotypes in Iran.

Genotype code	Local name	Tree habit	Tree vigor	Leaf color	Flower size	Flowering season	Flowering period (days)
MHF-103	Fasl e aval	Upright	Strong	Green	Intermediate	Early	11
MHF-100	Paeezeh	Spreading	Strong	Green	Large	Late	10
MHF-102	Dastgir	Spreading	Intermediate	Green	Large	Late	11
MHF-104	Shendabad kardi	Upright	Intermediate	Green	Intermediate	Intermediate	12
MHF-105	Shendabad joda	Spreading	Strong	Green	Intermediate	Intermediate	13
MHF-101	Gajelganat	Spreading	Strong	Green	Large	Late	13
MHF-106	Mouzi	Spreading	Strong	Green	Large	Late	13
EA-107	Anjiri Maleki	Spreading	Intermediate	Green	Large	Intermediate	12
EA -108	Anjiri Zafarani	Spreading	Intermediate	Green	Large	Intermediate	12
EA -109	Haj Kazemi	Upright	Strong	Green	Large	Intermediate	13
EA -110	Kosari Khooni	Upright	Intermediate	Green	Intermediate	Intermediate	10
EA -111	Sefid Sardrood	Upright	Strong	Green	Intermediate	Intermediate	13
EA -112	Bolmeh	Upright	Strong	Green	Intermediate	Early	11
EA -113	Shablon	Spreading	Strong	Green	Intermediate	Intermediate	12
EA -114	Noras	Upright	Intermediate	Green	Intermediate	Early	10

Table 3. Fruit phenotypic characteristics in 15 selected desirable peach genotypes in Ardabil and East Azarbaijan Provin

Genotype code	Local name	Fruit size	Fruit shape	Skin pubescence	Skin cracking susceptibility	Harvest maturity	Productivity	Texture of flesh	ground color	Flesh color	Stone size	Eati qual
MHF-103	Fasl e aval	Intermediate	Rounded	High	Low	Early	Very high	Coarse	Cream	White	Medium	Po
MHF-100	Paeezeh	Intermediate	Oblong	Intermediate	Extremely low	Late	Very high	Intermediate	Green	White-greenish	Large	Fa
MHF-102	Dastgir	Intermediate	Elongated	Intermediate	Extremely low	Extremely Late	Very high	Coarse	Green	White-cream	Medium	Fa
MHF-104	Shendabad kardi	Large	Rounded	Intermediate	Extremely low	Late	Very high	Intermediate	Greenish-cream	White-cream	Large	Go
MHF-105	Shendabad joda	Extremely large	Ovate	Intermediate	Extremely low	Late	Very high	Fine	Greenish-cream	white	Small	Go
MHF-101	Gajelganat	large	Rounded	Poor	Extremely low	Very Late	Very high	Intermediate	Yellow	Yellow	Medium	Go
MHF-106	Mouzi	Extremely large	Elongated	Intermediate	Extremely low	Late	Intermediate	Intermediate	Green	White	Medium	Go
EA-107	Anjiri Maleki	Intermediate	Very flat1	Intermediate	Extremely low	Late	Intermediate	Fine	Green	white	Small	Excel
EA -108	Anjiri Zafarani	Intermediate	Very flat	Intermediate	Extremely low	Late	Intermediate	Fine	Yellow	Yellow	Small	Excel
EA -109	Haj Kazemi	Extremely large	Oblong	Instermediate	Extremely low	Late	Low	Fine	Green	White-cream	Medium	Go
EA -110	Kosari Khooni	Intermediate	Rounded	Intermediate	Extremely low	Midseason	Intermediate	Fine	yellow	Yellow-red	Medium	Go
EA -111	Sefid Sardrood	large	Oblong	Intermediate	Extremely low	Late	Intermediate	Fine	Cream	white	Medium	Excel
EA -112	Bolmeh	Intermediate	Rounded	Intermediate	Extremely low	Midseason	Intermediate	Fine	Yellow	Yellow	Medium	Go
EA -113	Shablon	Intermediate	Rounded	Intermediate	Extremely low	Midseason	Intermediate	Intermediate	Cream	White-cream	Medium	Fa
EA -114	Noras	Small	Elongated	Intermediate	Low	early	Intermediate	Intermediate	yellow	Yellow	Small	fai

Table 4. Comparison of fruit quality characteristics of 15 selected desirable peach genotypes in Ardabil and East Azarbaij

Genotype code	Local name	Fruit weight (g)	Soluble solids content (ºBrix)	Yield (kg/tree)	Titratable acidity (g 100 g^{-1} FW)	Ripening index	Fruit (k
MHF-103	Fasl e aval	165.0 g	12.40 f	45.33 h	0.750 d	16.59 f	5
MHF-100	Paeezeh	151.0 h	15.67 a	62.33 g	0. 567 h	28.10 ab	5
MHF-102	Dastgir	152.3 h	15.00 abc	96 .00c	0.917a	16.47 f	8
MHF-104	Shendabad kardi	217.5 cd	14.20 cde	114.00 ab	0.54 h	26.53 b	6
MHF-105	Shendabad joda	247.3 b	14.50 bcde	89.67 d	0.660 f	21.63 d	6
MHF-101	Gajelganat	209.7 d	15.50 ab	118.00 a	0.727 e	21.58 d	8
MHF-106	Mouzi	272.0 a	14.10cde	111.70 b	0.750 cd	18.71 e	5
EA-107	Anjiri Maleki	184.3 f	14.80 abcd	84.33 de	0.540 h	27.14 ab	6
EA -108	Anjiri Zafarani	170.0 g	15.60 a	89.67 d	0.540 h	28.79 a	6
EA -109	Haj Kazemi	199.3 e	13.60 e	96.33 c	0.770 C	17.46 ef	7
EA -110	Kosari Khooni	189.7 f	14.60 bcde	82.00 e	0.640fg	22.67 cd	6
EA -111	Sefid Sardrood	219.7 c	15.10abc	85.00 de	0.630 g	24.03 c	5
EA -112	Bolmeh	173.3 g	13.80 de	74.33 f	0.820 b	16.74 f	5
EA -113	Shablon	169.7 g	12.60 f	63.33 g	0.920 a	13.62 g	4
EA -114	Noras	120.0 i	11.60 f	22.00 i	0.840 b	13.81 g	4

Means, in each column, followed by similar letters are not significantly different at the 5% probability level-using Duncan's Multiple Range Test.

(Table 4).

All genotypes had greater SSC levels than 11 ºBrix. The highest value (16 ºBrix) was recorded in MHF-100 selected from Meshkinshahr and EA-108 selected from Shabestar, while the lowest value (11.6 ºBrix) was recorded in genotype EA-114 from Shendabad. The minimum SSC established by the EU for market peaches and nectarines is 8 ºBrix (Commission Regulation [EC] No. 1861/2004 of 28 October 2004), although SSC below 11 ºBrix are generally unacceptable to consumers (Hilaire, 2003; Crisosto and Crisosto, 2005). However, the relationship between SSC and consumer acceptance is cultivar specific, and there is not a single reliable SSC that assures a given percentage of satisfied consumers (Hilaire, 2003; Crisosto and Crisosto, 2005).

A tendency to have the highest SSC values can be observed in genotypes with the latest harvesting time, such as EA-110, EA-111, EA-108 and MHF-105 (Tables 3 and 4). Although a significant correlation between harvesting time and SSC was not found in this study, a positive correlation between later harvesting time and SSC was previously reported in peach (Dirlewanger *et al*., 1999). High variability was also found for SSC among seedlings within the progenies (Cantín *et al*., 2006), which can be explained by the quantitative regulation of this quality trait (Dirlewanger *et al*., 1999; Quilot *et al*., 2004b). This variability allows selecting the most desirable genotypes in terms of sweetness.

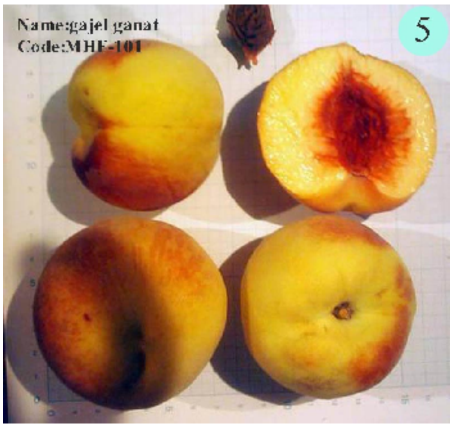
There were partial differences in TA among the studied genotypes (Table 4). Values for the studied genotypes ranged from 0.54 to 0.92 g 100 g^{-1} fresh weight. All the mean TA values, except those of MHF-102 and EA-113, were lower than 0.9%, which is considered the maximum limit for normal acidity in peaches (Hilaire, 2003). Titratable acidity plays an important role in consumer acceptance of grapes (Nelson *et al*., 1973), cherries (Crisosto *et al*., 2003; Fathi and Ramazani, 2007), and kiwifruit (Marsh *et al*., 2004). However, the perception of acidity in the mouth depends not only on the acid concentration (Pangborn, 1963) but also on the concentration and type of sugars (Bassi and Selli, 1990). High TA, low SSC and, consequently, a low ripening index was shown by genotypes EA-113 and EA-114.

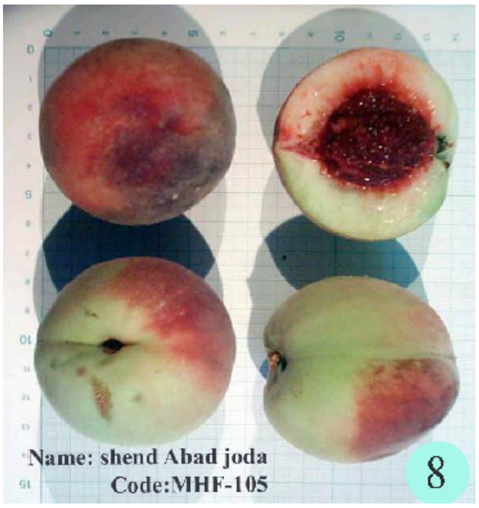
Fruit firmness measured on both cheeks of the fruit was highly variable between genotypes (from 4.6 to 8.65 kg cm^{-2}). The highest mean fruit firmness was found in genotypes MHF-102, MHF-101 and EA-109 (Table 4). It should be noted that the firmest fruits were found in Meshkinshahr genotypes, a finding corroborated by the significant differences in firmness between peach fruits. Such results have already been observed by other authors (Crisosto *et al*., 2001a; Valero *et al*., 2007). In contrast, lower mean fruit firmness was found in genotypes EA-113 and EA-114 at Shendabad and Maragheh. Firmness is an important fruit quality trait to consider in a breeding program, since it is directly related to susceptibility to mechanical damage during postharvest and transportation (Crisosto *et al*., 2001b).

Maximum fruit firmness for fresh-market peaches and nectarines was set by the EU at 63.7 N with an 8-mm diameter probe (Commission Regulation [EC] No. 1861/2004). Crisosto *et al*. (2001a) segregated peaches and nectarines into different classes by using firmness thresholds indicating critical changes during postharvest ripening and susceptibility to bruising damage. Classification of fresh peaches and nectarines into “ready to eat” and “others” was accomplished using an 18 N threshold. Fruit between 18 and 35 N was considered “ready to buy”, and the 35 N threshold was used to define “mature and immature” fruit (Crisosto *et al*., 2001a).

Differences were also found for fruit shape and size among the 15 genotypes (Table 3). Genotypes MHF-105, MHF-106, and EA-109 produced extremely large fruits with increased height (H), suture diameter (SD), and cheek diameter (CD) that also had the highest weight. Genotype EA-114 had the smallest fruits of all the test genotypes. According to reports, fruit shape is characterized by calculating H/SD and H/CD (Wert *et al*., 2007). Genotypes EA-107 and EA-108 had flat fruits, while fruits of MHF-102 and MHF-106 were more elongated (H/SD and H/CD) than those of the rest of genotypes.

Fruit shape is an important fruit quality attribute, since it influences consumer’s acceptance and postharvest handling. In peach and nectarine, round shapes without protruding tips are preferred by consumers (Cantin *et al*., 2010). In addition, protruding tips and sutures can be bruised during handling and shipping (Kader, 2002). Peaches of MHF-100 and EA-110 had a higher percentage of endocarp staining than other peaches. Whereas flat fruit showed medium endocarp staining between genotypes, lower endocarp staining was seen in MHF-102 and EA-114 (Table 4). These differences were probably due to the characteristics of the genotypes. White-fleshed fruits showed higher blush percentage than yellow-fleshed fruits, which agrees with the higher anthocyanin content observed in this type of fruit by Cantín *et al*. (2009). Photos of fruits of the studied genotype are shown in Figs. 3-13.





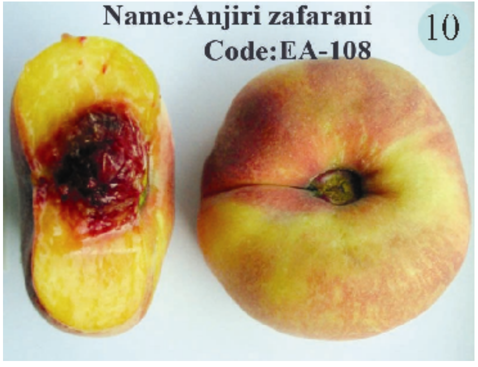


Fig. 3. 13 pictures of desirable peach genotypes in Ardabil and East Azaebaijan Provinces. 3. Dastgir; 4. Fasl e aval; 5. Gajelganat; 6. Haj Kazemi; 7. Mouzi; 8. Shendabad joda; 9. Anjiri Maleki; 10. Anjiri Zafarani; 11. Shendabad Kardi; 12. Sefid Sardrood; 13. Kosari Khooni.

Correlation between traits

Table 5 shows the correlations between fruit quality traits. Some of them appear significant, although no high coefficients were found when all genotypes were considered together. Harvest date was significantly correlated with fruit weight and fruit firmness, a suggested by the fact that early harvested genotypes generally had smaller fruits than late ones and that the fruit of late-harvested genotypes was harder than fruit of early-harvested genotypes, as was previously found in different peach cultivars (Dirlewanger *et al*., 1999; López and DeJong, 2007).

In this study, correlation coefficients varied depending on the genotypes, and were higher in specific genotypes such as MHF-102 and MHF-101. Harvest maturity also shows significant correlation with SSC, a tendency of late-harvested genotypes, which had higher SSC. Medium and late season cultivars are reported to have a greater capacity for accumulating sugar compared to early season cultivars due to non-interruption of the growing process (Engel *et al*., 1988; Byrne, 2002).

In contrast, titrable acidity showed a significant negative correlation with SSC and ripening index (SSC/TA). A positive significant correlation was observed between SSC and TA, suggesting dependent genetic control of both traits (Dirlewanger *et al*., 1999; Wu *et al*., 2003). In this research, the highest correlation coefficients ($P \leq 0.01$) were found between genotypes. In general, fruit weight was positively correlated with fruit size and soluble solids content, ripening index, and harvest maturity. Significant correlations ($P \leq 0.01$) were found between genotypes (r = 0.888 and r = 0.521). These correlations were to be expected, since these traits are due to the weight of the fruits (Tomás-Barberán *et al*., 2001). However, a significant positive correlation ($P \leq 0.01$) was observed in some genotypes that indicated a tendency of larger fruits to have higher sugar contents.

The significant positive correlation ($P \leq 0.01$) between annual yield and fruit weight in some genotypes such as MHF-106, MHF-101, MHF-105, EA-111, EA-109, and MHF-102 is worth pointing out, since it shows that these genotypes had greater potential for producing higher yield and larger fruits. This result was expected, given that the amount of translocated carbohydrates contributing to SSC determines fruit growth rate (Mounzer *et al*., 2008); at the same time, fruit size increases sink strength to attract sucrose and sorbitol from plant sources (Lo Bianco and Rieger, 2006).

No significant relationship was found between skin color and firmness in any of the studied genotypes, which is in agreement with previous work in peach (Génard *et al*., 1994).

Significant correlation was also found between firmness and other traits such as SSC and harvest maturity, which is in agreement with Byrne *et al*. (1991). A higher correlation between firmness and SSC (r = 0.593) and harvest maturity (r= 0.758) was found among genotypes. A positive relationship between firmness and SSC has also been reported in sweet cherry (Fathi and Ramazani, 2007; Jiménez *et al*., 2004).

This result suggests that, at the same level of ripening, firmer fruits showed a tendency to have higher SSC. This correlation is important since

Table 5. Correlation coefficients between fruit quality traits in 15 peach genotypes.

Fruit traits	Fruit weight (g)	Fruit firmness (kg cm^{-2})	Titrable acidity	Soluble solids content	Skin blush (%)	RI (SSC/TA)	Endocarp st
Fruit weight (g)	1						
Fruit firmness (kg cm^{-2})	0.099	1					
Titrable acidity	-0.259	-0.077	1				
Soluble solids content	0.521*	0.593*	-0.587*	1			
Skin blush (%)	-0.039	0.040	0.296	-0.144	1		
RI (SSC/TA)	0.276	0.153	-0.970**	0.683**	0.144	1	
Endocarp staining	-0.122	0.089	-0.462	0.352	0.358	0.407	1
Harvest maturity	0.562*	0.758**	-0.246	0.799**	-0.282	0.458	-0.144
Fruit size	0.888**	0.254	-0.133	0.236	0.003	0.137	-0.123

* and **:Significant at the 5% and 1% probability levels
RI: Ripening index.

selection of high SSC genotypes will aim first at higher firmness and, second, at lower susceptibility to mechanical damage during handling and packaging (Crisosto *et al.*, 2001b). The breeding response for one trait depends on genotypic variations of that trait within the breeding population and on genotypic correlations between traits. Thus, phenotypic correlations are important parameters to take into account in a breeding program.

Cluster analysis

A dendogram of 15 native Iranian peach genotypes cultivated in Ardabil and East Azarbaijan Provinces was constructed based on morphological and fruit qualitative traits and using the Ward method (Tables 3 and 4). Based on distance, 15 genotypes were divided into two main groups and as distance decreased, 15 to 5 genotypes were included in four main groups (Fig. 2).

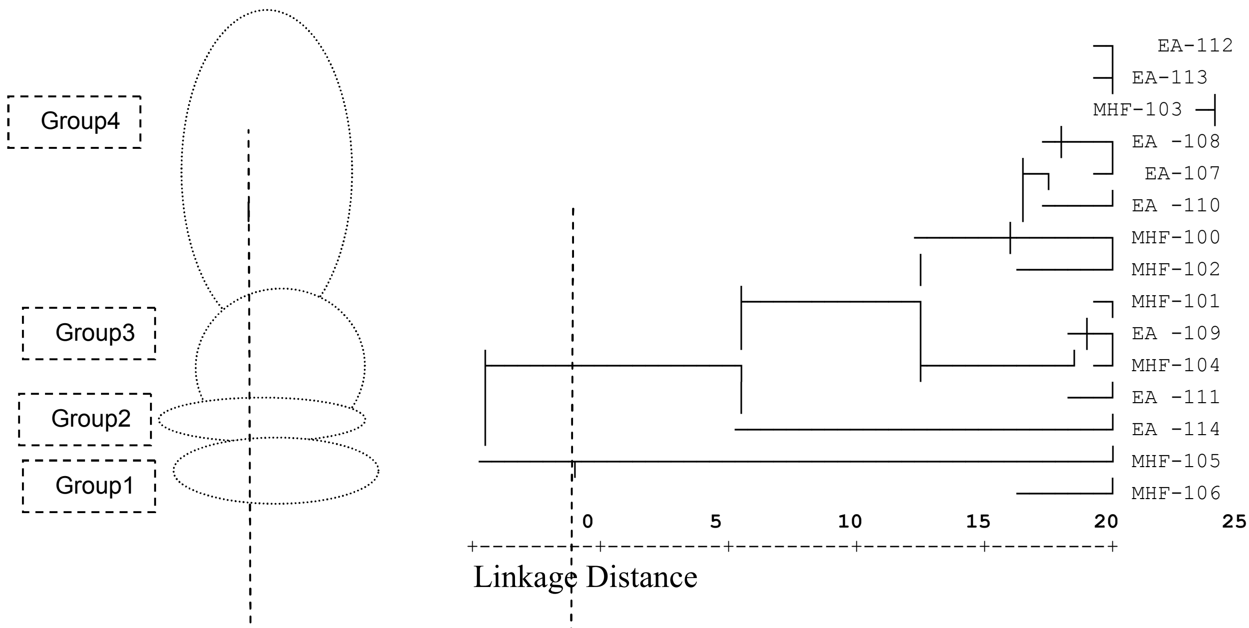


Figure 2. Dendrogram of 15 native peach genotypes cultivated in Ardabil and East Azarbaijan Provinces based on morphological data using the Ward method. (Obtained based on 16 fruit quality and phenotypic data using the SPSS program.)

The first group included two genotypes (MHF-105 and MHF-106), or 13.3% of all genotypes in this population, and had the highest fruit weight with flesh color, high SSC, and low TA. The second group was made up of one genotype (EA-114), or 6.66% of all genotypes, and had the lowest fruit weight and other fruit quality traits.

The third group included four genotypes (MHF-101,MHF-104, EA-109, and EA-111), or 26.66% of all genotypes, and had similar fruit weight, fruit size, fruit shape, firmness, texture of flesh, ground color, flesh color, fruit attractiveness, and SSC, but the lowest TA content. The fourth group comprised eight genotypes (EA-107, EA-108, EA-112, EA-113, MHF-103, EA-110, MHF-100, and MHF-102), or 53.33% of all genotypes. Their traits included fruit weight, fruit shape, stone adherence, flesh color, fruit attractiveness, skin cracking susceptibility, harvest maturity, productivity, and ground color. The smallest distance between accessions was found between the two ordinary peach accessions (downy skin and freestone).

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