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Superior Growth Characteristics, Yield, and Fruit Quality in Promising European Pear (*Pyrus communis* L.) Chance Seedlings in Iran

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ABSTRACT

Selection of superior chance seedling genotypes is an important task in pear breeding programs. This research was carried out in order to explore and evaluate some of European pear (*Pyrus communis* L.) chance seedling genotypes that are primarily used as rootstock for the Asian pear (*Pyrus serotina* Rehd.) in Tarbiat Modares University (TMU) Asian Pear Collection Orchard. After four years visual observations of the genotypes, the evaluation process started on the pre-selected genotypes in order to identify the superior promising individuals during 2009 and 2010 growing seasons. Selected chance seedling genotypes were A_{95}, A_{101}, A_{189}, A_{195}, and A_{374}. A local commercial cultivar `Shahmiveh' was used as a reference and labeled as A_{238} in the evaluation program database. Results showed significant differences among the studied genotypes in most of the evaluated characters. Among the studied genotypes, genotype A_{95} showed indications of appropriate fruit physicochemical properties and higher fruit quality compared with the reference cultivar. Good fruit aroma as well as a reddish background skin color, highest acidity and lowest pH among the examined genotypes were other superior characters of A_{95}. Based on the measured characters compared with `Shahmiveh' as a good reference commercial Iranian pear cultivar, we conclude that A_{95} showed superiority and higher rank in flavor, fruit color, and attractiveness. Also, this promising genotype showed a good productivity potential in terms of producing higher yield with a suitable supporting vigor. Further research on the standard rootstocks within the TMU pear breeding program will continue in the framework of final new cultivar release program.

Keywords: Fruit physicochemical characteristics, Morphological characteristics, Pear breeding program, Promising pear genotype.

INTRODUCTION

European pear (*Pyrus communis* L.) is commercially grown throughout the temperate zones of the world and Iran. Recently, Asian pear (*Pyrus serotina* Rehd.) was introduced to Iran in order to start its commercial production after appropriate study in the country (Arzani, 2005). Genetic diversity in European pear is more than other pome fruit species (Lane, 1979) and the diversity in this species is very high because of the existence of gametophytic self incompatibility system in its flowering and fruiting (Bell and Hough, 1986) as well as seed based propagation in the past (Arzani, 2003). Morphological classifications provide useful tool to species relationships and develop deeper insight for plant breeders and gene bank managers for further breeding programs with specific breeding objectives for developing new commercial cultivars with better fruit quality or dwarfing as well as resistant rootstocks (Arzani, 2003; Hrotko *et al.*, 2008; Magyar and Hrotko, 2008). The first comprehensive

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work in pear was conducted by Challice and Westwood (1973) in which pear species were categorized based on their growing sites after using morphological and chemical traits.

Pear breeders are usually interested in bigger fruit size with better quality and market acceptability. High genetic diversity and accessible gene resources have made it possible for breeders to breed and achieve such breeding objectives (Bell, 1990). Several works have been carried out in different countries to study genetic variability in pear by morphological traits. Having more than 10 species of pear, Iran is one of the important genetic sources of this fruit in the world (Khatamsaz, 1992). *Pyrus* species are scattered over a large area in Iran from north to northwest, west, and south central regions. Since most fruit trees in Iranian traditional orchards were propagated by seed in the past, an abundant genetic diversity can be seen in this huge mass population. It is obvious that the great diversity in landraces of fruit trees in Iran has provided a great opportunity for breeders such as already available seed propagated commercial orchards. The chance of the existence of single tree individuals with higher vegetative and fruit quality traits in the country's traditional orchards is high, thus, pear breeders need to look for naturally available superiority traits in the existing valuable population. Therefore, study on chance seedling genotypes and identification of their desirable and inheritable traits might lead to introduction of new cultivars, after passing the required tests under different set of environmental conditions (Arzani, 2003). Preliminary investigation on morphological and fruit physicochemical characteristics of some pre-selected European pear chance seedling genotypes were investigated and reported (Arzani, 2014). The objective of the present research was to describe the variability in such pre-selected chance seedling genotypes to identify the most useful variables for discrimination among the studied individuals in order to identify superior genotypes for further evaluations within Tarbiat Modares University (TMU) pear breeding programs.

MATERIALS AND METHODS

Plant Materials

The plant materials studied were the pre-selected European pear (*Pyrus cummunis*) chance seedlings, primarily used as rootstock for Asian pears in North-South rows at spacing of 2×1 m at TMU Asian pear collection orchard, located in 20 km west of Tehran, Iran (Arzani, 2005; Arzani, 2008; Arzani, 2014). Note that these chance seedling genotypes were primarily propagated from seeds that had been collected from open pollinated European pear cv. \`Dargazy' grown in environmental conditions of Mashhad, Iran. Some of Asian pear (*Pyrus serotina*) scions on the European pear seedling rootstocks failed to grow; the other rootstocks were allowed to grow and fruit on their own roots in the TMU Asian pear collection orchard. After four years visual observation of the genotypes, some of these chance seedling genotypes seemed to have a better quality in terms of fruit characteristics (Arzani, National Asian pear project, unpublished results) (Figure 1). Then, evaluation process started on the selected genotypes in order to select the superior promising genotypes during 2009 and 2010 growing seasons. Selected European pear chance seedling genotypes were A_{95}, A_{101}, A_{189}, A_{195} and A_{374}. In addition, a local European pear commercial cultivar \`Shahmiveh' was used as a reference (the control) and coded in this experiment as $A_{238}$, which, in the results and the other parts of this study, may be referred to as cultivar \`Shahmiveh' or A_{238}. Evaluations were performed in terms of morphological and fruit physicochemical characteristics based on International Plant Genetic Resources Institute (IPGRI) descriptor. Leaf and fruit samples from these genotypes were randomly selected and morphological and fruit physicochemical characteristics were determined.

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Figure 1. Trees and fruit of the studied promising genotypes, chance seedling 1 (A_{95}) and fruit of `Shahmiveh' cultivar.

Vigor and Vegetative Growth

Vigor was determined by using trunk cross sectional area. Trees circumference determined in the beginning and at the end of the studied growing season and the trunk cross sectional area (TCSA) was calculated (Arzani and Roosta, 2004). Also, tree height (TH) and current season shoot length (CSHL) were measured at the end of the season. Growth habit was determined as erect, spreading, and erect to spreading.

Flowering, Fruiting, Crop Density, and Yield

Flowering characteristics (start, full, and the end of bloom) were determined according to Arzani (1994). Fruit ripening season was expressed as early September to mid September, late September, mid and late August. Crop density (CD) was determined by number of fruits in 50 cm of shoot and expressed as percentage (Arzani *et al.,* 2009) and Yield (Y) was determined per tree and expressed as kg tree^{-1}.

Leaf Characteristics and Mineral Nutrients

Leaf length (LL), width (LW), shape index (LL/LW ratio), density, fresh weight, and dry weight were measured. Leaf area was determined with area measuring device (model DELTA-T MK2, Germany) using Area Measurement System (AMS). Leaf N, P, K, and Ca contents were analyzed by, respectively, Kjeldahl Auto Analyzer, Spectrophotometer, Flame Photometer, and Atomic Absorption Method (Emami, 1996).

Fruit Physicochemical Characteristics and Color

Fruit length (FL), width (FW), shape index (FL/FW ratio), stalk length, volume, fresh weight and dry weight (in 30 g of fresh weight) were measured. Fruit color was measured by the *'L, a,* *b'* parameter with Hunter Lab (Hunter Associates Laboratory, VA, USA). Firmness was measured at two locations per fruit with a penetrometer (CNS FARNELL) equipped with a 12 mm plunger (Arzani *et al*., 2008). Total soluble solids were measured by a hand-held refractometer (model 9703, Japan) and expressed in °Brix (Arzani *et al*., 2008), and pH was determined by a pH-meter (model Metrohm, 744, Sois). Titratable Acidity was determined by neutralization to pH 8.3 using 0.1N NaOH. Data are given as % malic acid (Chen and Mellenthin, 1981). Ripening index was calculated as *TSS/TA* ratio (Ferrer *et al.,* 2005).

Fruit Qualitative Characteristics or Panel Test

To measure the qualitative characteristics (appearance and attractiveness, taste and flavor) of the fruit, samples were evaluated by a group of graduate students, who were randomly asked to express their opinion based on the following scale: 1- Bad, 2- Moderate, 3- Good, 4- Very good, and 5- Excellent.

Statistical Analysis

The experiment was arranged based on Completely Randomized Design (CRD). The results were statistically evaluated by analysis of variance (ANOVA) and means were compared using Duncan's multiple range test (DMRT); differences were considered statistically significant at $P\leq 0.05$. Correlations among the traits were determined using the Pearson correlation coefficient. Relationships among the genotypes were monitored using principal component analysis (PCA). Mean values were used to create a correlation matrix from which standardized principal component (PC) scores were extracted. Scatter plot and the cluster analysis were created to evaluate similarity among genotypes. In addition, cluster analysis was carried out by calculating the standardized matrix and using the Ward method with the distance coefficient by SPSS 16.0.

RESULTS

Characteristics of Genotypes

Results showed significant differences among the studied genotypes in most of the studied characters. The analysis of variance showed that all parameters were significant ($P\leq 0.01$). Mean comparisons of quantitative parameters for each genotype are shown in Table 1 and 2.

Vigor and Vegetative Growth

The *TCSA* values ranged from 11.46-35.78 and 13.45-43.99 cm^2 at the beginning and end of the growing season, respectively. The highest values belonged to A_{195} (35.78) and A_{189} (35.10) genotypes at the beginning and the highest values recorded for A_{95} (43.99) and A_{195} (43.97) genotypes at the end of the growing season. The highest values for difference between TCSA at the beginning and the end of growing season were those of A_{95} (11.19) and A_{195} (8.19) (Figure 2).

Tree height varied from 173 to 373 cm. The highest and lowest values belonged to A_{95} and A_{238}, respectively. Current season shoot length values ranged from 18.67 to 47.07 cm. The highest value was that of A_{95} and the lowest value belonged to A_{189} (Figure 3).

Flowering, Fruiting, Crop Density, and Yield

Results indicated difference among the studied genotypes in terms of flowering (beginning, full bloom and end of bloom) and fruit ripening season. For the first year fruiting, crop density ranged from 1.33% in A_{195} to 10% in A_{95}. Also, yield ranged from 0.56 kg tree^{-1} in A_{374} to 5.50 kg tree^{-1} in A_{95}, which had also the highest crop density and yield (Figure 4). The evaluation of the other characters is summarized in Table 3.

Table 1. Mean values of leaf characters of the studied pear genotypes.[a]

Genotype	Length (cm)	Width (cm)	Shape index (LL/LW)	Density (%)	Leaf area (cm^2)	Fresh weight (g)	Dry weight (g)	Leaf N content (%)	Leaf P content (%)	Leaf K content %	Leaf Ca content %
A_{95}	8.02 ^{a}	4.64 ^{b}	1.72 ^{a}	27.08 ^{a}	30.00 ^{c}	0.89 ^{a}	0.74 ^{a}	1.43 ^{d}	0.05 ^{c}	0.98 ^{e}	1.21 ^{c}
A_{101}	5.03 ^{c}	3.46 ^{c}	1.45 ^{b}	26.72 ^{a}	13.00 ^{f}	0.54 ^{bc}	0.42 ^{b}	1.90 ^{a}	0.04 ^{d}	2.11 ^{a}	0.70 ^{e}
A_{189}	6.49 ^{b}	4.69 ^{b}	1.37 ^{bc}	28.57 ^{a}	24.67 ^{d}	0.65 ^{b}	0.49 ^{b}	1.54 ^{b}	0.08 ^{b}	1.14 ^{c}	1.18 ^{d}
A_{195}	8.05 ^{a}	5.88 ^{a}	1.36 ^{c}	23.57 ^{a}	37.00 ^{a}	0.41 ^{c}	0.26 ^{c}	1.33 ^{e}	0.09 ^{a}	1.11 ^{c}	1.41 ^{b}
A_{374}	6.08 ^{b}	4.35 ^{b}	1.39 ^{bc}	27.96 ^{a}	20.33 ^{e}	0.36 ^{c}	0.20 ^{c}	1.49 ^{c}	0.04 ^{d}	1.04 ^{d}	1.77 ^{a}
A_{238}	7.42 ^{a}	6.03 ^{a}	1.23 ^{d}	27.87 ^{a}	33.33 ^{b}	0.88 ^{a}	0.66 ^{a}	1.23 ^{f}	0.04 ^{d}	1.21 ^{b}	1.77 ^{a}

[a] Means in a same column with different letters are significantly different ($P \leq 0.05$).

Table 2. Mean values of fruit physicochemical characteristics of the studied pear genotypes.[a]

Genotype	Length (cm)	Width (cm)	Shape index (FL/FW)	Stalk length (cm)	Fresh weight (g)	Dry weight (g)	Volume (cm^3)	Firmness (Kg cm^{-2})	TSS (°Brix)	Ripening index (TSS/TA)
A_{95}	9.82 ^{a}	6.79 ^{a}	1.44 ^{bc}	3.41 ^{a}	218.10 ^{b}	5.12 ^{ab}	212.33 ^{b}	2.37 ^{a}	16.43 ^{bc}	40.49 ^{d}
A_{101}	6.99 ^{b}	4.69 ^{c}	1.50 ^{ab}	2.20 ^{b}	80.50 ^{d}	4.84 ^{bc}	86.33 ^{d}	1.00 ^{b}	17.63 ^{a}	46.09 ^{d}
A_{189}	7.13 ^{b}	5.67 ^{b}	1.23 ^{e}	3.73 ^{a}	152.21 ^{c}	4.52 ^{c}	154 ^{c}	2.03 ^{a}	14.90 ^{d}	78.94 ^{b}
A_{195}	7.41 ^{b}	5.85 ^{b}	1.27 ^{de}	3.10 ^{a}	168.32 ^{bc}	4.90 ^{bc}	153 ^{c}	1.33 ^{b}	17.10 ^{ab}	92.66 ^{a}
A_{374}	9.47 ^{a}	5.91 ^{b}	1.59 ^{a}	2.91 ^{ab}	188.90 ^{bc}	4.77 ^{bc}	181 ^{bc}	1.93 ^{a}	17.57 ^{a}	76.53 ^{bc}
A_{238}	9.79 ^{a}	7.17 ^{a}	1.37 ^{cd}	3.20 ^{a}	308.91 ^{a}	5.36 ^{a}	270.70 ^{a}	1.27 ^{b}	16.03 ^{c}	65.19 ^{c}

[a] Means in a same column with different letters are significantly different ($P \leq 0.05$).

Table 3. Overall traits appearance of the studied pear genotypes.

Genotype	Growth habit	SB [a]	FB [b]	EB [c]	Fruit ripening season	Fruit shape	Fruit skin color	Panel test
A_{95}	Erect to spreading	March 19	March 21	March 26	ES [d]	Pyriform elongate	Green to red	Excellent
A_{101}	Erect to spreading	March 22	March 25	March 31	MS [e]	Oblate	Yellowish green	Good
A_{189}	Spreading	March 18	March 20	March 31	MA [f]	Pyriform	Very light green	Very good
A_{195}	Spreading	March 19	March 21	March 28	LA [g]	Pyriform	Very light green	Very good
A_{374}	Erect	March 22	March 24	March 29	LS [h]	Pyriform globose	Yellowish green	Good
A_{238}	Spreading	March 19	March 21	March 29	LA	Oblate	Yellowish green	Excellent

[a] Starting; [b] Full, and [c] End of Bloom, [d] Early September; [e] Mid September; [f] Mid August; [g] Late August, [h] Late September.

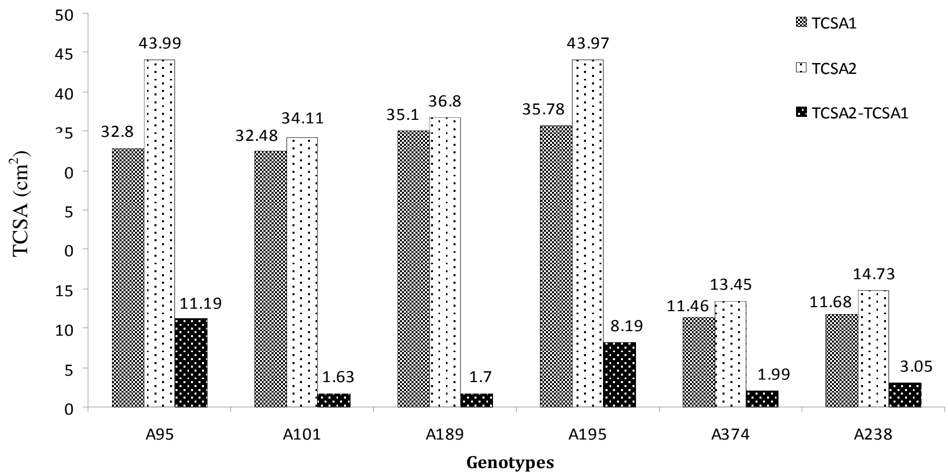

Figure 2. Trunk cross sectional area (TCSA) of the studied pear genotypes at the beginning and end of the growing season.

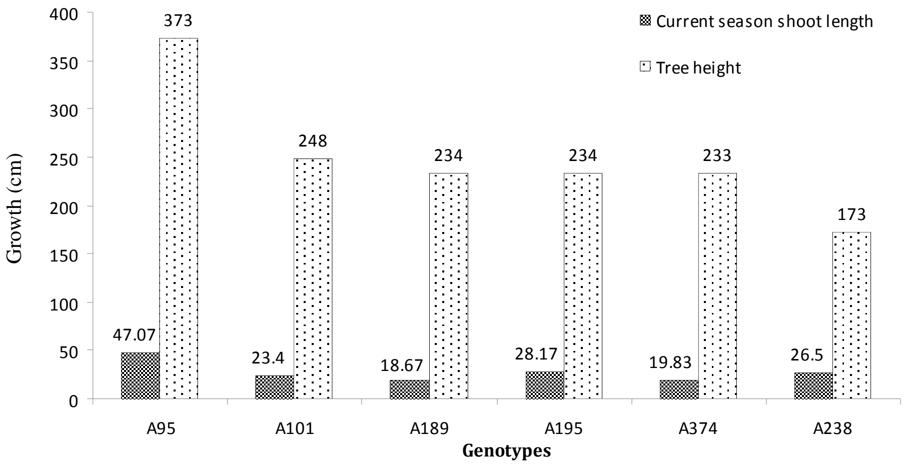

Figure 3. Tree height and current season shoot length of the studied pear genotypes.

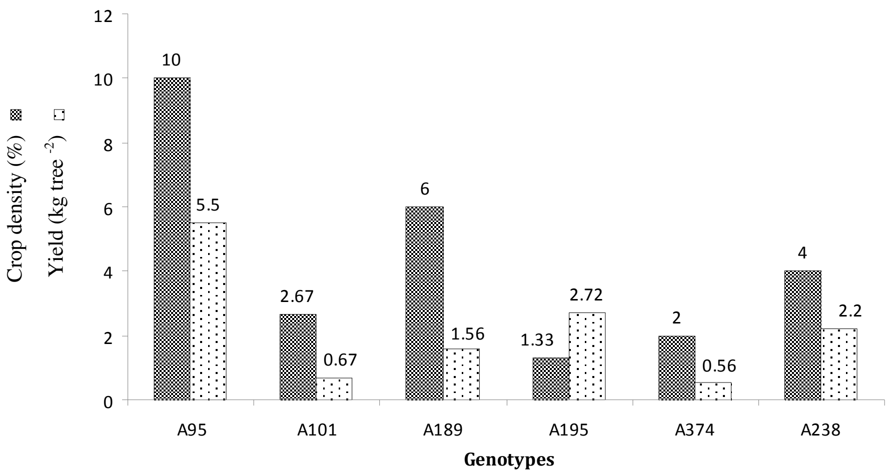

Figure 4. Crop density and yield of the studied pear genotypes.

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Leaf Characteristics and Mineral Nutrients

Results showed that leaf length varied from 5.03 to 8.05 cm (Table 1). The highest values belonged to A_{195} and A_{95}. Also, the highest values of leaf width belonged to A_{238} (6.03 cm) and A_{195} (5.88 cm). The leaf shape index varied from 1.23 to 1.72, with maximum in A_{95} and minimum in A_{238}. Leaf density ranged from 23.57 to 28.57% in 20 cm of the shoot, and leaf area ranged from 13.00 to 37 cm^2. Leaf fresh weight ranged from 0.36 g in A_{374} to 0.89 g in A_{95}, while leaf dry weight ranged from 0.20 g in A_{374} to 0.74 g in A_{95}. Also, results indicated difference among the studied genotypes in terms of leaf N (ranged from 1.23 to 1.90%), P (0.04 to 0.09%), K (0.98 to 2.11%), and Ca content (0.7 to 1.77%). The evaluation of these characters is summarized in Table 1.

Fruit Physicochemical Characteristics and Color

Data analyses indicated difference among the studied genotypes in terms of fruit length (ranged from 6.99 to 9.82 cm), width (4.69 to 7.17 cm), shape index (1.23 to 1.59), and fruit stalk length (2.2 to 3.73 cm) (Table 2). The highest fruit length and width belonged to A_{95} and A_{238}, respectively. Fruit shape index was also different among the genotypes and the highest value was recorded fro A_{374}. Fruit fresh weight ranged from 80.5 to 308.9 g, dry weight ranged from 4.52 to 5.36 g, and fruit volume ranged from 86.33 to 270.7 cm^3. A_{238} and A_{101} showed the highest (308.91 g) and lowest fresh weight (80.50 g), respectively. Also, A_{238} had the highest dry weight (5.36 g) and A_{189} had the lowest dry weight (4.52 g). Fruit firmness at the time of harvest varied from 1 to 2.37 kg cm^{-2} and the highest value belonged to A_{95} (2.37 kg cm^{-2}) (Table 2).

Significant differences were found among the genotypes in terms of color. Fruit colors were very light green to yellowish green and green to red with *L** value 60.47 to 74.08, *a** value 2.44 to 8.19, *b** value 46.09 to 53.21, *H** value 80.06 to 86.95 and *C** value 46.16 to 53.43 (Figure 5).

Results indicated differences among the studied genotypes in terms of TSS, ranging from 14.9 to 17.63 °Brix (Table 2). TA ranged from 0.18 to 0.41% malic acid, TSS to TA ratio or ripening index ranged from 40.49 to 92.66, and pH ranged from 3.95 to 5.33 (Figure 6). The highest TA (0.41%) and the lowest pH (3.95) were obtained in A_{95}.

Fruit Qualitative Characteristics or Panel Test

Genotypes A_{95} and A_{238} had the best fruit panel test results. A_{95} showed a red halo color in fruit skin with attractive fruit background appearance (Figure 1). The evaluation of the panel tests is summarized in Table 3.

Correlations among the Traits

The bivariate correlations among the parameters are shown in Tables 4 and 5. There was a positive correlation between leaf length and leaf area (r= 0.95), leaf width and leaf area (r= 0.93), leaf fresh weight and leaf dry weight (r= 0.99), leaf dry weight and crop density (r= 0.83), and leaf N and K contents (r= 0.81). On the other hand, leaf N content negatively correlated with parameters such as leaf length (r= -0.85), leaf width (r=-0.92), leaf area (r= -0.91), and leaf Ca content (r= -0.82). According to the results, fruit length positively correlated with parameters such as fruit width (r= 0.83), fresh weight (r= 0.81) and volume (r= 0.84). In addition, fruit width was positively correlated with fruit fresh weight (r= 0.96) and volume (r= 0.98). Also there was a positive correlation between fruit fresh weight and fruit volume (r=0.99), *b** color and *C** color (r= -0.99), pH and TSS/TA ratio (r= 0.87). In contrast, negative correlation was observed between TA and pH (r=-0.84), TA and TSS/TA ratio (r= -0.96), *a** color and *H** color
(r= -0.99).

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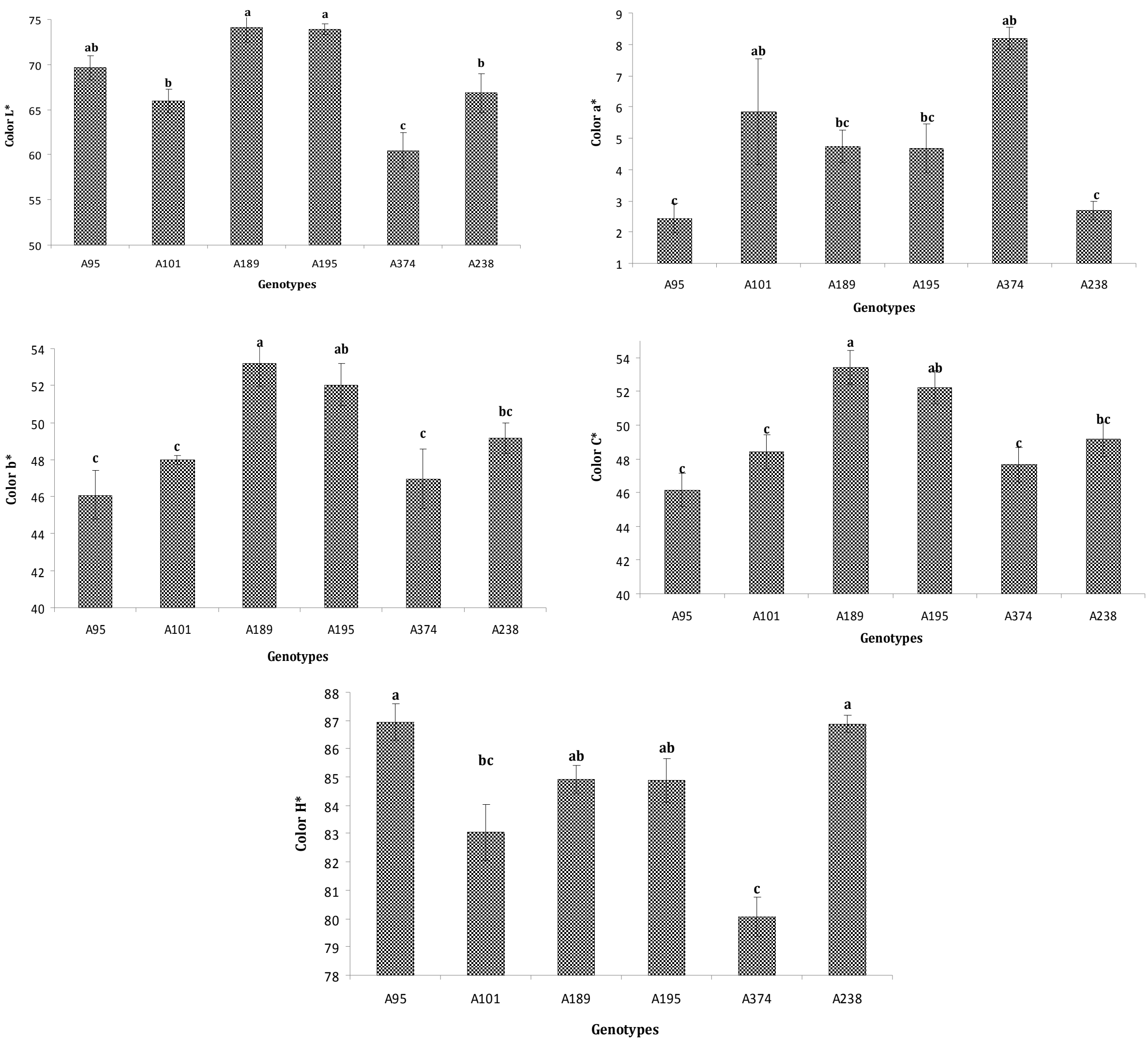

Figure 5. Fruit color characters of the studied pear genotypes. Means with different letters are significantly different (P≤ 0.05).

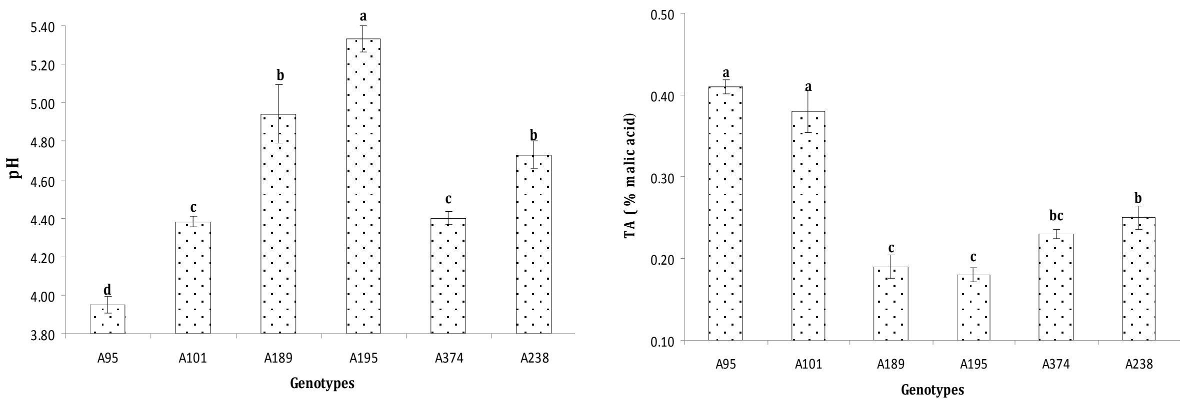

Figure 6. Fruit pH and Titratable Acidity (TA) of the studied pear genotypes. Means with different letters are significantly different

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Table 4. Simple matching coefficients among the studied vegetative variables using Pearson correlation coefficient.

Traits	CSHL [a]	LL [b]	LW [c]	LSI [d]	LA [e]	LFW [f]	LDW [g]	LN [h]	LP [i]	LK [j]	LCa [k]	LD [m]	CD [n]
CSHL	1												
LL	0.63	1											
LW	0.12	0.79	1										
LSI	0.77	0.17	-0.45	1									
LA	0.40	0.95**	0.94**	-0.12	1								
LFW	0.59	0.40	0.23	0.26	0.31	1							
LDW	0.63	0.36	0.14	0.35	0.24	0.99**	1						
LN	-0.26	-0.85*	-0.92**	0.25	-0.91*	-0.31	-0.21	1					
LP	-0.08	0.42	0.40	-0.09	0.49	-0.27	-0.26	-0.23	1				
LK	-0.29	-0.74	-0.59	-0.08	-0.69	-0.16	-0.09	0.81*	-0.33	1			
LCa	-0.10	0.43	0.66	-0.44	0.52	0.00	-0.11	-0.82*	-0.09	-0.71	1		
LD	-0.23	-0.40	-0.33	-0.05	-0.44	0.39	0.37	0.14	-0.51	-0.04	0.12	1	
CD	0.71	0.36	-0.09	0.70	0.13	0.78	0.83*	-0.09	-0.07	-0.32	-0.19	0.39	1

[a] Current Season Shoot Length; [b] Leaf Length; [c] Leaf Width; [d] Leaf Shape Index; [e] Leaf Area; [f] Leaf Fresh Weight; [g] Leaf Dry Weight; [h] Leaf N, [i] Leaf P, [j] Leaf K, [k] Leaf Ca; [m] Leaf density, and [n] Crop Density (CD). * and ** Correlation coefficient significant at $P= 0.05$ and $P= 0.01$, respectively.

Table 5. Simple matching coefficients among the studied fruit variables using Pearson correlation coefficient.

Traits	FL [a]	FW [b]	FSI [c]	FSL [d]	L*	a*	b*	H	C*	FFW [e]	FDW [f]	FV [g]	FF [h]	TSS [i]	TA [j]	RI [k]	pH
FL	1																
FW	0.83*	1															
FSI	0.44	-0.12	1														
FSL	0.23	0.59	-0.62	1													
L*	-0.50	0.01	-0.94**	0.55	1												
a*	-0.26	-0.64	0.52	-0.46	-0.54	1											
b*	-0.66	-0.19	-0.88*	0.41	0.74	-0.06	1										
H	0.17	0.59	-0.61	0.50	0.62	-0.99**	0.18	1									
C*	0.68	-0.25	-0.83*	0.38	0.70	0.02	0.99**	0.09	1								
FFW	0.81*	0.96*	-0.08	0.48	-0.10	-0.53	-0.15	0.49	-0.20	1							
FDW	0.68	0.72	0.13	-0.06	-0.19	-0.63	-0.45	0.56	-0.51	0.74	1						
FV	0.86*	0.98**	-0.06	0.53	-0.10	-0.54	-0.19	0.50	-0.24	0.99**	0.71	1					
FF	0.41	0.37	0.02	0.69	0.09	-0.10	-0.19	0.08	-0.19	0.19	-0.20	0.29	1				
TSS	0.03	-0.38	0.72	-0.84*	-0.60	0.54	-0.55	-0.59	-0.51	-0.33	0.10	-0.37	-0.39	1			
TA	0.23	-0.03	0.49	-0.40	-0.25	-0.28	-0.75	0.20	-0.77	-0.15	0.35	-0.10	-0.08	0.31	1		
RI	-0.29	-0.04	-0.46	0.30	0.29	0.23	-0.72	-0.25	0.75	0.04	-0.38	-0.01	-0.10	-0.13	-0.96**	1	
pH	-0.53	-0.12	-0.72	0.21	0.56	0.04	0.89*	0.06	0.90*	-0.03	-0.24	-0.11	-0.41	-0.23	-0.84*	0.87*	1

[a] Fruit Length; [b] Fruit Width; [c] Fruit Shape Index; [d] Fruit Stalk Length; [e] Fruit Fresh Weight; [f] Fruit Dry Weight; [g] Fruit Volume; [h] Fruit Firmness; [i] Total Soluble Solids; [j] Titratable Acidity, and [k] Ripening Index. * and ** Correlation coefficient significant at $P= 0.05$ and $P= 0.01$, respectively.

Principal Component Analysis (PCA)

Principal component analysis was used to identify the most significant variables in the data set. Results from the PCA (Table 6) indicated that the first four components explained about 94% of the total variability observed. Variables with higher scores on PC1 were related to vegetative (TCSA1, TCSA2, TH, CD, Y, LL, LW, LA, LN, LK) and fruit characteristics (FW, FSL, FFW, FV, a^*, H). The highest contribution on PC2 corresponded to variables LP, FL, FSI, b^*, C^*, TA, RI and pH. The highest scores on PC3 were due to LCa and L^* and for PC4 the higher scores were related to FF.

Cluster Analysis

Cluster analysis of morphological and fruit physicochemical characteristics indicated that the studied chance seedling genotypes were divided into three clusters (Figure 7). The first cluster included A_{95} and A_{238} genotypes that had high fruit qualitative and quantitative characteristics such as fruit length, width, fresh and dry weight, volume, firmness and panel test. Also, these

Table 6. Eigen values, proportion variance for four major factors obtained from factor analysis and parameters within each factor for the studied pear genotypes.

Variable	PC1	PC2	PC3	PC4
TCSA1	0.671**	0.330	-0.152	-0.212
TCSA2	0.693**	0.460	-0.122	-0.155
TCSA2-TCSA1	0.613	0.525	-0.012	0.076
TH	0.661**	0.531	-0.142	-0.515
CSHL	0.432	0.645	0.366	-0.216
CD	0.681**	0.480	-0.322	-0.255
Y	0.674**	0.560	-0.626	-0.358
LL	0.891**	-0.004	0.091	-0.102
LW	0.856**	-0.324	-0.142	0.328
LSI	-0.080	0.584	0.388	-0.618
LA	0.900**	-0.214	0.022	0.100
LFW	0.586	0.556	0.466	0.131
LDW	0.509	0.582	0.549	0.089
LN	-0.930**	.093	0.320	-0.082
LP	0.265	-0.808**	0.335	-0.277
LK	-0.786**	0.098	0.333	0.509
LCa	0.615	-0.056	-0.780**	0.059
FL	0.545	0.681**	-0.482	-0.051
FW	0.912**	0.354	-0.188	0.056
FSI	-0.503	0.663**	-0.550	-0.050
FSL	0.781**	-0.241	0.144	-0.479
L*	0.396	-0.543	0.710**	-0.129
a*	-0.712**	-0.271	-0.609	-0.219
b*	0.188	-0.927**	0.286	0.068
H	0.715**	0.160	0.644	0.218
C*	0.125	-0.953**	0.235	0.044
FFW	0.854**	0.284	-0.324	0.240
FDW	0.535	0.591	-0.057	0.567
FV	0.858**	0.331	-0.303	0.144
FF	0.359	0.233	-0.018	-0.889**
TSS	-0.577	0.274	-0.426	0.183
TA	-0.277	0.857**	0.406	-0.014
RI	0.216	-0.881**	-0.406	-0.034
pH	0.210	-0.926**	-0.009	0.282
Eigen value	10.957	8.544	5.024	2.743
% Var.	37.784	29.463	17.323	9.457
% Cum.	37.784	67.247	84.570	94.027

** Significant factor loadings (considered values above 0.65).

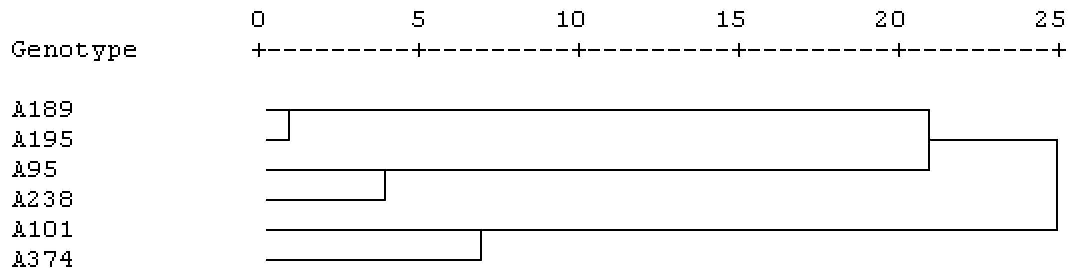

Figure 7. Dendrogram obtained with the Ward method by using morphological and fruit physicochemical characteristics in the studied genotypes.

genotypes had the best aroma. Also, these genotypes showed higher leaf length and width, leaf fresh and dry weight, and crop density compared to the other genotypes. Second cluster included A_{189} and A_{195} genotypes that were characterized by high fruit stalk length, *L**, *b**, *C** colors, pH, and low current season shoot length. The next cluster included A_{101} and A_{374} genotypes that had high a* color, TSS and low crop density, yield, TCSA, and current season shoot length. Bio-Plot results indicated that distribution of genotypes based on the PC1 and PC2, which explained about 67% of the total observed variability, showed the morphological variation among the studied genotypes (Figure 8).

DISCUSSION

The earlier four years visual observations on the studied genotypes (Arzani, 2008; Arzani, 2014) as well as the overall results obtained in the current research suggested A_{95} superiority in the vegetative and fruiting characteristics (Figure 1). The amount of shoot growth and suitable vigor in this genotype support its fruiting potential and yield obtained and recorded in vegetative and reproductive data. Arzani (1994) demonstrated that the suitable shoot growth and vigor was necessary for optimum photosynthesis to supply enough carbohydrates for strong fruit sink and higher yield. Since tree size is affected by soil, climatic conditions, and genotype (Loreti *et al.,* 2000; Wertheim, 2000), in the current research all studied genotypes were grown in identical and similar soil and environmental conditions. Although the current season shoot growth might be influenced by various applied treatments (Arzani, 1994; Arzani and Roosta, 2004; Arzani *et al*., 2009), it is inherently

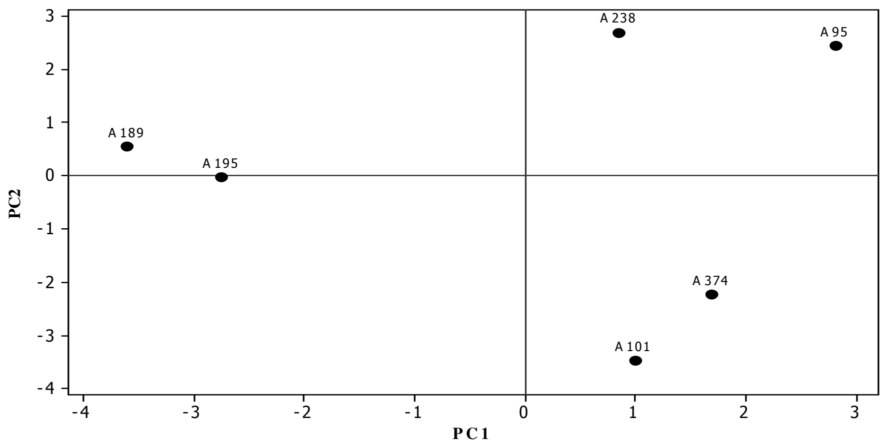

Figure 8. Distribution of genotypes based on the PC1 and PC2 (Bio-Plot).

influenced by species and genotypes (Elshihy *et al*., 2004). Compared with the other studied genotypes in the current research, the potential of excessive vegetative growth by A_{95} genotype might raise this question that too much vegetative growth could limit high density planting and reduce resource utilization efficiency. Notably, all the studied genotypes, except `Shahmiveh' cultivar ($A_{238}$ genotype), were grown on their own rooting system. However, the genetic makeup of `Sahmiveh' rooting system was quiet similar to the other studied genotypes, therefore, all of the studied trees were seed propagated from 'Dargazy' cultivar, which is one of the local commercial pears in Iran (Arzani, 2014). It is important at this stage to make sure about producing enough carbohydrates by vegetative source in order to meet the demand of fruit sinks and other reserves. Arzani (1994) demonstrated in detail the possibility of various applied treatments in order to reduce negative effects of excessive vegetative growth even in the absence of limited dwarfing rootstock. In addition, there is a possibility for using potential dwarfing rootstocks for pear. In the current research, A_{95} had also the highest crop density and yield among the examined genotypes. Although various factors such as adequate and suitable pollination, hormonal level, enough vegetative growth, and orchard management affect final yield, but genotype has great influence on plant performance (Iezzoni *et al.,* 1991; Arzani, 1994).

Results indicated that A_{95} had the highest leaf dimensions and fresh and dry weight among the examined genotypes, which provided the tree with a better situation in terms of photosynthetic products. Elshihy *et al.* (2004) showed that length, width, and length to width ratio of pear leaf varied in different genotypes. They reported that the leaf length was 5.5-7 cm, leaf width was 2-5 cm and length to width ratio was 1.40-2.75. In some of Iranian pear species studied, variation in leaf characters such as leaf length, width, shape, and leaf area (Sharifani *et al.,* 2006) has been reported. Also, the variation in leaf size among different wild pear genotypes has been noticed by Paganova (2009). The present research will continue with more focus in order to evaluate A_{95} under different set of environmental conditions using similar or different rootstock. The study on the photosynthetic potential of this promising genotype using appropriate training system is another future pear breeding objectives at TMU breeding program (Arzani, 2014). It is obvious that leaf area and leaf characteristic is a genetic characteristic that is influenced by various cultural practice, rootstock as well as environmental factors (Arzani, 1994).

The presented results showed that A_{95} genotype had a high fruit length, width, fresh weight, dry weight and volume among the studied genotypes and in comparison with the reference cultivar. These fruit traits data together with the other mentioned characters lead to the conclusion that A_{95} has the potential to be nominated as a promising chance seedling genotype for better fruit size and appearance. It is obvious that in most markets fruit size is an important character for final yield, with better marketability and also better return (Arzani, 2014). Also, fruit length varied among different cultivars and other fruit characteristics were strongly influenced by genotypes (Elshihy *et al.*, 2004) as well as cultural and orchard management system (Arzani, 1994). In addition, in a study on different pear genotypes, variation in pear fruit length (3.5 to 12 cm) has been reported by Krause *et al*. (2007) and Katayama and Uematsu (2006). Fruit fresh and dry weight and size are other important issues that our data showed higher values for A_{95} among the studied genotypes, but it was lower than the reference cultivar. In addition, A_{95} showed higher firmness at the time of fruit harvest at TMU collection orchard than the reference cultivar. Note that, in the present research, fruits were harvested at the time of commercial maturity and mainly based on fruit color and appearance. Thus, seemingly, there was a negative correlation between more advanced color from greenness to yellowness of fruit skin and firmness. As noticed in 2013 growing season, firmness at the green to green with red shadow color on the skin of A_{95} ranged from 5.1 to 5.7 and declined to 2.7 when the color turned yellow. Therefore, more research is suggested in order to determine the

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correct time of fruit harvest for this promising genotype (Arzani, 2014 unpublished results). Firmness of fruit texture is influenced by environment, type of cultivar, and cultivation (Chen *et al.,* 2007) and is one of the important indicators of pears quality, maturity, and fruit crispness (Ozturk *et al.,* 2009). Further research will warrant the potential appearance of this promising chance seedling genotype (A_{95}) with more attention to the correct time of fruit harvest (Arzani, 2014): its correct harvest time may be later than that of` Shahmiveh' cultivar. Fruit weight has the most direct effect on tree yield. Variation in fruit weight can be related to type of genotype and cultivar, the rootstock, environmental conditions, and nutrition status. Karadenis and Sen (1990) reported that the weight of pears varied from 50 to 368 g that is in agreement with the present research, although Arzani (2008) has been reported fruit fresh weight of 780 g for late maturing `KS_8' Asian pear cultivar grown on 'Dargazi' European pear seeding rootstock under semi intensive planting system at TMU research orchard.

Also results showed that A_{95} had a good appearance with a red fruit skin halo that increases the fruit attractiveness of this genotype. In the Iranian and most of exporting target markets, European pear such as `Shahmiveh' is mostly marketed for fresh consumption, so it must have attractive appearance (Arzani, 2014). Although, there is an extensive diversity in fruit skin color in some fruit crops and can be an important indicator for quality and maturity of some pear cultivars. Reports show that there is a strong correlation between maturity and scales of L^*, a^* and b^* in different pear cultivars. Scales of L^*, a^* and b^* increase simultaneously with fruit maturity (Kawamura, 2000).

According to the obtained results, A_{95} genotype showed 16.43 °Brix in fruit TSS in compare with 16.03 of the reference cultivar. It has been reported that TSS is another quality factors and used as one of the important harvest index (Arzani *et al*., 2008), varied in different cultivars and influence with environmental factors (Karadeniz and Sen, 1990; Ozturk *et al*., 2009). Chen *et al*. (2007) reported that fruit TSS varied in different cultivars. They reported that pear TSS was 8-12.5 °Brix under China environmental conditions. The higher amount of 14.7 (Arzani, 2004) and 15.1 °Brix TSS (Arzani *et al*., 2008) were reported on `KS_{13}' Asian pear fruit grown under TMU Asian pear collection orchard.

In the present research, A_{95} genotype had the best fruit panel test results with a red halo in fruit skin and attractive fruit color that is very important in marketability of fruit. In addition, this promising genotype showed the highest acidity, lowest pH and the best aroma among the examined genotypes. It has been reported that Titratable Acidity (TA) varied in different cultivars and was affected by environmental conditions and growing season. The aroma is a combination of sugars, organic acids, and aromatic substances (Chen *et al*., 2007; Ozturk *et al*., 2009).

In the present research, computed correlations among the various traits showed that leaf length, width, fresh weight, dry weight, leaf area, leaf N and Ca contents were the most important characters. It has been reported that leaf length and width are function of the increase in leaf area, which provides the tree with a better situation in terms of photosynthetic products (Arzani, 1994). Higher photosynthetic activity led to increase in fruit size (Bell *et al.,* 1996). In addition, it affects the amount of organic acids and, consequently, has influence on flavor and fruit quality (Chen *et al.,* 2007). Our data from PCA analysis indicated the importance of fruit length, width, weight, volume and TA on fruit quality attributes, which explained about 94% of the total variability observed. Variables with higher scores on four PC are related to LL, LW, LA, LN, LP, LCa, LK, FL, FSI, L^*, b^*, C^*, TA, RI FW, FSL, FFW, FV, FF, a^*, H, and pH.

CONCLUSIONS

Based on the earlier four year visual observations on the chance seedlings (Arzani, 2008; Arzani, 2014) as well as the results obtained in the present research and compared with the reference `Shahmiveh' cultivar, we suggested that A_{95} pear has superiority in the vegetative and fruiting characteristics. In

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addition, A_{95} fruit appearance and physicochemical attributes compared to the reference cultivar led to the conclusion that this chance seedling genotype has potential to be nominated as a promising new pear cultivar for release from TMU pear breeding program. This conclusion also was supported by cluster analysis, which indicated that the studied chance seedling genotypes were divided into three clusters, with A_{95} genotype and A_{238}, as the reference cultivar, positioned in the same cluster group. Since `Shahmiveh' cultivar (A_{238}) is now recognized as an important and commercial pear cultivar with good fruit qualitative properties in Iran, we conclude that A_{95} genotype has potential to be one of the attractive new pear cultivars in the country and possibly in the world pear industry. A_{95} fruit showed good aroma with attractive and a reddish background skin color. The higher acidity and lower pH among the examined genotypes added to its superiority characters. Based on the measured characters and compared with `Shahmiveh' cultivar as a reference, we conclude that A_{95} showed superiority and higher rank in flavor, fruit color, and attractiveness. Also, this promising genotype showed a good productivity in terms of producing higher yield and vigor. Its higher firmness at the time of fruit harvest compared with the studied genotypes as well as `Shahmiveh' is another advantage for possibly better shelf life and storage ability than the reference cultivar. This genotype is considered as a promising genotype; accordingly, its true-to-type multiplication on local rootstock has been started. Additional and supplemental research and evaluation using true-to-type trees on standard rootstock within the TMU pear breeding program will continue in the framework of final new cultivar release program. Further research results based on the aforementioned specific objectives will warrant and support such breeding objectives and goals (Arzani, 2014).

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برتری ویژگی‌های رشدی، عملکرد و کیفیت میوه در ژنوتیپ امیدبخش حاصل از دانهال اتفاقی گلابی اروپایی(*Pyrus communis* L.) در ایران

ر. نجف زاده ، و ک. ارزانی

چکیده

انتخاب ژنوتیپ‌های برتر حاصل از دانهال‌های اتفاقی در برنامه‌های اصلاحی درختان میوه بخصوص در برنامه‌های اصلاحی گلابی از اهمیت زیادی برخوردار است. این پژوهش به منظور بررسی و ارزیابی تعدادی از ژنوتیپ های حاصل از دانهال های اتفاقی گلابی اروپایی(*Pyrus communis* L.) که در ابتدا به منظور پایه برای گلابی آسیایی (*Pyrus serotina* Rehd.) در کلکسیون گلابی آسیایی دانشگاه تربیت مدرس کشت شده بودند انجام شد. پس از چهار سال ارزیابی های اوالیه و بصری این ژنوتیپ ها، پروسه ارزیابی بر روی ژنوتیپ های از پیش سلکسیون شده به منظور تعیین برترین ژنوتیپ امید بخش در طی سال های باغی ۱۳۸۸ و ۱۳۸۹ صورت گرفت. دانهال های تصادفی انتخاب شده شامل A_{95}, A_{101}, A_{189}وA_{374} بودند. رقم "شاه میوه" بعنوان یک رقم تجاری محلی گلابی و بعنوان رقم شاهد مورد استفاده قرار گرفت و در برنامه ارزیابی داده برداری با کد A_{238}مشخص شد. نتایج اختلاف معنی داری را در بین اکثر پارامترهای مورد ارزیابی و در بین ژنوتیپ های مورد بررسی نشان داد. ژنوتیپ A_{95} ویژگی های مناسب فیزیکوشیمیایی و برتری در کیفیت میوه را در بین ژنوتیپ های مورد ارزیابی و همچنین نسبت به رقم شاهد نشان داد. عطر و طعم خوب، همراه با رنگ زمینه قرمز، اسیدیته بالا و پایین بودن پ هاش این ژنوتیپ در بین ژنوتیپ‌های مورد مطالعه از دیگر خصوصیات برتر ژنوتیپ A_{95} بوده است. بر اساس خصوصیات اندازه‌گیری شده در مقایسه با رقم شاه میوه بعنوان رقم شاهد که یکی از مهمترین ارقام تجاری گلابی در ایران می‌باشد ما چنین نتیجه گیری می کنیم که ژنوتیپ A_{95} خصوصیات برتر و امتیاز بالاتری را در زمینه طعم، رنگ میوه و جذابیت میوه را به خود اختصاص داده است. همچنین این ژنوتیپ امید بخش از یک پتانسیل بارآوری و میوه دهی بالایی از نظر تولید محصول بیشتر و به همراه رشد رویشی مناسب برای تامین نیازهای محصول بیشتر برخوردار است. هم اکنون تکثیر غیرجنسی این ژنوتیپ با پیوند جوانه بر روی پایه استاندارد محلی و در قالب برنامه‌های اصلاحی گلابی در دانشگاه تربیت مدرس شروع شده است. پژوهش‌های تکمیلی بر روی این ژنوتیپ امیدبخش و با استفاده از پایه استاندارد و در قالب پروژه اصلاح گلابی در دانشگاه تربیت مدرس و در راستای معرفی بعنوان رقم جدیدی از گلابی در کشور ادامه خواهد یافت.

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