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GENETIC DIVERSITY OF SOME APPLE CULTIVARS IN THE SOUTH OF SYRIA BASED ON MORPHOLOGICAL CHARACTERS

O. AL-Halabi[1]* and B. Muzher[2]
[1,2] General Commission for Scientific Agriculture Research (GCSAR), Sweida-Syria
*Corresponding author: Ola_halabi@msn.com

Abstract

This work was aimed to evaluate genetic diversity among five local and six introduced apple cultivars in the germplasm which located in the South of Syria based on 29 morphological characters of leaf and fruit. The analysis of variance showed significant differences at $P < 0.05$ for all measured parameters, however the mean values of Limb length and width, fruit weight, length, and width indicated to a wide range of diversity between local and introduced cultivars, that the introduced cultivars have mostly the highest mean value while the local cultivars have the lowest mean values, that clearly found in the local apple cultivar Ksairi (K) which revealed the lowest mean value of fruit weight (FW), fruit length (FL) and fruit diameter (FD) in the comparison with all studied cultivars. Likewise, principal component analysis (PCA) was used and the first 4 principal components accounted for 76.4% of the total variance, with eigen values 29.2%, 18.8%, 16.9% and 11.5% respectively. The main important characters in PC1 are correlated with the high mean value of width of stalk cavity (WP), fruit weight (FW), fruit diameter (FD), fruit length (FL), core length (CL), width of calyx cavity (WC), core width (CW), depth of stalk cavity (DP), stalk diameter (SD), seed width (SeW) and leaf margin (LM). PC2 discriminated among cultivars depending on Fruit shape (FS), leaf shape (LS), over color (OC), maturity time (MT), core shape (CS), limp length (LL) and leaf base (LB) which were able to differentiate between all studied cultivars . PC3 is correlated with the high mean value of Stalk length (SL), titratable acidity (TA), total sugar (TS), and total soluble solids (TSS). PC4 is correlated with the high mean value of depth of calyx cavity (DC), leaf apices (LA) and fruit cross section (FCS). Cluster analysis was also used that divided the studied cultivars into two clusters, the first cluster included all local apple cultivars, in addition to Leaz Golden (LG) cultivar, however AbouGhabra (AG) and Ksairi (K) cultivars revealed the highest similarity, which have the same fruit shape(FS), background color (BC), core shape (CS), fruit cross section (FCS), leaf shape (Ls) and leaf margin (LM). While the second cluster included all the other introduced cultivars.

Key words: Apple, genetic diversity and morphological character

Introduction

Apples are members of the genus *Malus* Miller, which is placed in the subfamily *Maloideae* of the family *Rosaceae* (Phipps *et al*., 1991). The common domesticated apple *Malus* x *domestica* Borkh is supposed as an interspecific hybrid species (Korban and Skirvin, 1984). *Malus* species belong to the region of Asia Minor, the Caucasus, central Asia, Himalayan India, Pakistan and western China (Juniper et al., 1998). Apple is cultivated worldwide at high elevations in moderate regions (Luby, 2003). The maintenance of apple genetic diversity are important for future breeding because genetic diversity gives species the ability to environmental changing adoption (Bull and Wichmann, 2001; Martinelli et al., 2008), and improved resistance to diseases and pests (Bignami et al., 2003; Kumar et al., 2010). However, the essential step in cultivar improvement is to collect and evaluate the local germplasm (Damyar et al., 2007; Forte et al., 2002 and Mratinic and FotricAksic, 2012). The improved cultivars will meet future market requirements, increase productivity and decrease production costs (Kumar et al., 2010), and can expand the apple market (Itoiz and Royo, 2003; Pereira-Lorenzo et al., 2007). Although, breeders worldwide create more new selections annually of named cultivars, at one time each country and area had their own native apple cultivars (Janick et al., 1996), and their project to conserve and evaluate the diversity within *Malus* gene pool, such as Estonian (Kask, 2002), Portugal (Bettencourt, 2002), Spain (Fuente, 2002) and Belgium (Lateur, 2002). For efficient management and effective utilization, germplasm collection must be characterized, using international descriptors (UPOV, 1974 and IBPGRI, 1982). Moreover, traditional methods of cultivar characterization, based on agronomic and morphological parameters are usually used to distinguish cultivars of the same species (Cantini et al., 1999; Barranco and Rallo, 2000 and Farrokhi et al., 2011). Likewise, the evaluation of native apples accessions in the germplasm in Serbia showed an important variance of agronomic traits among studied accessions (Mratinic and FotricAksic, 2012). Multivariate analysis and principal component analysis (PCA) have been used as an efficient tool to study the correlation among variables, to evaluate cultivars and interpret relationships among genotypes for germplasm characterization (Pereira-Lorenzo et al., 2003; Aljane and Ferchichi, 2009). In Syria, apple germplasm contains more than 100 commercial introduced cultivars and 15 local apple cultivars, the current investigation aimed to analyze and evaluate the variability of five local apple cultivars and six introduced cultivars using morphological characters.

Material and methods

This work was achieved at the General Commission for Scientific Agriculture Researches (GCSAR), Sweida/ Syria during 2009 – 2011.

Plant material

Eleven cultivars; five local apple cultivars and six introduced cultivars were planted in 1990 in the apple germplasm in South of Syria at 1500m altitude, the mean rainfall 525 m m (Table 1).

Table 1: List of studied apple cultivars (five local and six introduced cultivars)

Cultivar name	Origin	Label	Cultivar name	Origin	Label
Skarji	local	Sk	Early McIntosh	Introduced	EMc
Khlati	local	Kh	Stark Spur Ludi	Introduced	SSL
AboGhabra	local	AG	Leaz Golden	Introduced	LG
Feddi	local	F	FreyBurg	Introduced	FB
Ksairi	local	K	Oray	Introduced	O
			KandilSinap	Introduced	KS

Morphological characterization

Seven morphological characters of leaves (25 leaves from each cultivar) and 22 morphological characters of fruits (25 fruits from each cultivar) were measured to evaluate the studied cultivars, depending on the descriptors (UPOV, 1974) and (IBPGRI, 1982),

Leaf characters were as following:

1- Limp length (LL): Average limp length in m m.
2- Limp width (LW): Average limp width in m m.
3- Leaf shape (LS): (1) ovate, (1.1) oblanceolate, (1.2) obovate, (1.3) oval, (1.4) long oval, (1.5) wide oval, (1.6) orbicular, (1.7) cordate (Porter, 1959; Muzher and Al-Halabi, 2010).
4- Leaf apices (LA): (1) acuminate, (1.1) cuspidate, (1.2) mucronate (Porter, 1959).
5- Leaf base (LB): (1) acute, (1.1) rounded, (1.2) cordate (Porter, 1959).
6- Leaf margin (LM): (1) serrate, (1.1) doubly serrate, (1.2) dentate, (1.3) crenate (Porter, 1959).
7- Petiole length (PL): Average petiole length in m m.

Fruit characters were as following:

1- Maturity time: (1) early,(2) mediate, (3) late
2- Fruit weight (FW): Average fruit weight in g.
3- Fruit length (FL): Average fruit length in m m (UPOV, 1974)
4- Fruit width (FW): Average fruit width in m m (UPOV, 1974)
5- Depth of calyx cavity (DC): Average depth of calyx cavity in m m (UPOV, 1974)
6- Width of calyx cavity (Wc): Average width of calyx in m m (UPOV, 1974)
7- Depth of Stalk cavity (Dp): Average depth of stalk cavity in m m
8- Width of Stalk cavity (Wp): Average width of stalk cavity in m m (UPOV, 1974)
9- Fruit shape (FS): "(1.0) Globose, (1.1) Globose-conical, (1.2) Short-globose-conical, (2.0) Flat, (2.1) Flat-globose (oblate), (3.0) Conical, (3.2) Intermediate – conical, (4.0) Ellipsoid, (4.1) Ellipsoid-conical (ovate), (5.0) Oblong, (5.1)Oblong-conical, (5.2) oblong-waisted" (IBPGRI, 1982).
10- Background color (BC): "(1) Red, (2) Orange,(3) Cream-white, (4) Yellow, (5) Green-yellow,(6) Green" (IBPGRI, 1982).
11- Over color (OC): "(1) Orange, (2) Pink, (3) Red, (4) Dark red, (5) Purple, (6) Brown" (IBPGRI, 1982).
12- Stalk length (SL): Average stalk length in m m.
13- Stalk diameter (SD): Average stalk diameter in m m.
14- Core shape (CS):(1) turnip-shape, (2) onion-shape, (3) flat- globose, (4) globose, (5) spindle-shape, (6)ovate, (7) elliptical (Hamed and Abu Trabi, 2005).
15- Core length (CL): Average core length in m m.
16- Core width (CW): Average core width in m m.
17- Fruit cross section (FCS): (1) regular, (2): angular
18- Seed Length (SeL): Average seed length in m m.
19- Seed width (SeW): Average seed width in m m.
20- Total Soluble solids (TSS) was measured by the refractometer in ^{o}Brix.
21- Total sugar content (TS) was measured by calibration Fehling A, B and blue methylene and presented in %.
22- Titratable acidity (TA) was determined as % of malic acid.

Statistical analysis

The experiment was designed in completely randomized design (CRD), data were analyzed using analysis of variance (ANOVA) to compare cultivars means for measured parameters, mean comparison was achieved using LSD test ($p < 0.05$), means for each parameter were also used to perform a principal component analysis (PCA) using SPSS 17 software, and cluster analysis using un weighted pair group method with arithmetic mean (UPGMA) based on Euclidean distance using the Past software.

Results

Analysis of Variance (ANOVA)

Analysis of variance ANOVA among studied cultivars for leaf characters showed significant differences at $P < 0.05$, comparison of means revealed that Feddi (F) cultivar has significantly the highest mean values of Limb length which was 92 m m, while KandilSenap (KS) cultivar revealed the lowest mean value (70.1 m m). Concerning the Limp width (LW), Early McIntosh (EMc) showed the highest mean value (66.8 m m) which was in significant in relation to studied cultivars, followed by Stark Spur Ludy (SSL) and Skarji (Sk) cultivars (61.7 and 60.5 m m, respectively), while AboGhabra (AG) cultivar revealed the lowest mean value (36.5 m m). On the other hand, Early McIntosh (EMc) cultivar has significantly the highest mean value of Petiole length (29.3m m) as compared to all studied cultivars, while Khlati (Kh) cultivar has the lowest mean value of petiole length (17.5 m m) as shown in Table (2). Analysis of variance ANOVA of fruit characters among studied cultivars showed significant difference at $P < 0.05$, comparison of means revealed that the introduced cultivar KandilSenap (KS) significantly revealed the highest mean values of fruit weight (FW)"except Stark Spur Ludy (SSL) cultivar", fruit length (FL), depth of calyx cavity (DC) and depth of stalk cavity (DP) in the comparison with all studied cultivars which were 157.2 g, 73.7 m m, 9.1 m m and 14.1 m m, respectively. Likewise, Stark Spur Ludy (SSL) cultivar significantly showed the highest mean values of fruit diameter (FD), Stalk diameter (SD), Width of stalk cavity (Wp), Core length (CL), and Core width (CW), in comparison with all studied cultivars, which were 74.3 m m, 3.7 m m, 43 m m, 41 m m, and 46 m m, respectively. Concerning the other fruit traits, Oray (O) cultivar significantly showed high mean value of total sugar (TS) in the comparison with all studied cultivars. Moreover, Oray cultivar (O) has the highest mean value of seed width (SeW) which was in significant with AboGhabra (AG) and Ksairi (K) cultivars, width of calyx cavity (Wc) which was in significant with local apple cultivars except Skarji (SK) cultivar, and stock length (SL) which was in significant with all studied cultivars except Leaz Golden (LG) and AboGhabra (AG) cultivars. FreyBurg (FB) cultivar significantly revealed the highest mean value of total soluble solids (TSS). On the other hand, the local apple cultivar Ksairi (K) significantly revealed the highest mean value of tetratable acidity (TA), beside that, it showed the lowest mean value of fruit weight (FW), fruit length (FL) and fruit diameter (FD) in the comparison with all studied cultivars, and Skarji (SK) cultivar showed the lowest mean value of core length (CL) which was in significant with all studied cultivars except AboGhabra (AG) cultivar, and significantly showed the lowest mean value of core width (CW) with all introduced cultivars except KandilSenap (KS) cultivar. Khlati (Kh) cultivar showed the lowest mean value of stock length (SL) followed by Stark Spur Ludy (SSL) cultivar. In addition, Khlati (Kh) cultivar significantly showed the lowest mean value of depth of stalk cavity (DP) in the comparison with all studied cultivars, except Skarji (SK) and Ksairi (K)

cultivars; and the highest mean value of seed length (SeL) in the comparison with all studied cultivars, except Leaz Golden (LG) cultivar (Table 2).

Table 2. The mean values of fruit and leaf characters

	Fruit characters																Leaf characters		
	FW	FL	FD	SL	SD	DC	Wc	DP	WP	CL	CW	SeL	SeW	TSS	TS	TA	LL	LW	PL
Skarji	48.8	40	50.5	18.5	2.2	4.4	29	6.6	28.5	14	22	7.5	4.5	14.6	12.1	0.3	84.5	60.5	19
Khlati	68	62	50	14	2.6	5.1	23	6.2	23.5	26	27	9.2	4.3	15.6	13	0.25	74.5	43.5	17.5
AboGabra	41.5	41.5	47	22	1.6	6.6	22.5	8.6	21.5	16	23.5	7.95	4	15.5	13.1	0.2	78.6	36.5	25
Feddi	67.5	48.5	57.5	18.5	1.95	7.3	26	9.2	27	18.5	27	8	4.1	14	10.8	0.25	92	47.5	26
Ksairi	36	36	44.5	15.5	2.6	9.2	21	6.95	17.5	19.5	27.5	7	4	11.8	9.6	1.5	77.5	42.5	19
EMc	114.2	53.4	66.6	17.6	2.8	5.2	29	8.8	29.8	20	25	8.2	4.2	15.5	13.8	0.44	76.3	66.8	29.3
SSL	154.7	64	74.3	13.6	3.7	5.1	27.8	10.6	43	41	46	8.4	4.5	14.3	10.6	0.85	77	61.7	26.6
LG	89	51.9	58.3	23.1	2.3	5.7	26.6	8.2	29.7	21.3	28.2	9.1	4.4	16.4	12.6	0.23	85	53.2	28.1
FB	122	53.3	66.3	14.5	2.6	6.7	31.2	10.7	33.3	21.1	33.5	7.2	4.5	19.1	12.2	0.34	82.5	47.4	29.1
O	113.5	61	61	23.4	2.4	6.2	33.7	10.9	37.9	26.9	32.9	8.5	4.8	17.8	15.3	0.2	83.1	48.7	25.3
KS	157.2	73.7	63.1	13.5	2.5	9.8	28.1	14.1	30.8	26.8	25	8	4.2	16.9	11.5	0.53	70.1	44.4	23.1
LSD5%	25	7	6.3	4.1	0.5	2.5	6.7	1.95	7.9	4.4	5.8	0.7	0.8	1.58	1.55	0.23	8.1	5.3	4.5

Principal Component Analysis (PCA)

Using PCA over the correlation Matrix of the 29 morphological studied characters (22 fruit characters and 7 leaf characters), the first 4 principal components accounted for 76.4% of the variance with Eigen values 29.2%, 18.8%, 16.9% and 11.5% respectively (Table 3).

Table 3. Eigen-values, cumulated proportion of variation and eigenvectors with the first four principle component estimated from the correlation matrix of seven leaf characters and 22 fruit characters

	Component			
	1	2	3	4
% of variance	29.2	18.8	16.9	11.5
WP	.951	-.156	.125	.074
FW	.945	.134	-.137	-.212
FD	.943	-.181	-.035	-.055
FL	.767	.596	-.086	-.078
CL	.748	.210	-.425	.125
WC	.746	-.141	.474	-.073
CW	.696	-.217	-.305	.097
DP	.686	.157	-.073	-.654
SD	.681	-.075	-.569	.318
SeW	.661	-.027	.408	.251
LM	-.641	.145	.186	.029
PL	.534	-.417	.362	-.371
LW	.514	-.459	.047	.496
FS	.259	.852	-.105	.078
LS	.195	-.771	-.219	.305
OC	.069	.770	.110	.114
MT	.057	.755	.418	-.127
CS	-.411	.630	.022	.411
LL	-.187	-.570	.530	.048
LB	.299	-.564	.532	.146
SeL	.248	.517	.340	.344
GC	.479	.484	-.444	.304
TA	-.144	-.225	-.856	-.125
TS	.215	.353	.807	.094
SL	-.237	-.169	.796	-.165
TSS	.538	.265	.577	-.272
DC	-.205	.205	-.447	-.813
LA	-.265	.291	.060	.776
FCS	.158	-.186	-.131	.595

Extraction Method: Principal Component Analysis.

Variability within the highest Eigen vectors in each PC were as follows:

PC1: The main important characters are correlated with the high mean value of width of stalk cavity (WP), fruit weight (FW), fruit diameter (FD), fruit length (FL), core length (CL), width of calyx cavity (WC), core width (CW), depth of stalk cavity (DP), stalk diameter (SD), seed width (SeW) and leaf margin (LM). PC1 discriminated between local and introduced cultivars depending on fruit weight (FW), fruit diameter (FD) and fruit length (FL). The characters width of stalk cavity (WP) and core length (CL) differentiated the introduced cultivar Stark Spur Ludy (SSL). On the other hand, fruit weight (FW), fruit length

(FL) and fruit diameter (FD) discriminated the local cultivar Ksairi (K). Likewise, the leaf margin (LM) which was negatively correlated with PC1 differentiated the cultivar Oray (O) which has dentate leaf margin among studied cultivars which divided between doubly serrate and crenate ones (Table 4).

Table 4: **The qualitative characters of fruit and leaf , and the percentage of each character**

cultivar	Fruit characters						Leaf characters			
	MT	**FS**	**BC**	**OC**	**CS**	**FCS**	**LS**	**LA**	**LB**	**LM**
Sk	2	2.1	4	0	1	2	1.6	1.1	1.1	1.1
Kh	3	5.2	5	4	7	2	1.2	1.1	1	1.3
AG	2	2.1	4	2	3	1	1.4	1	1.1	1.3
F	2	2.1	4	0	3	2	1.4	1	1.1	1.3
K	1	2.1	4	0	3	1	1.4	1	1	1.3
EMc	1	2.1	5	4	3	1	1.5	1	1.2	1.3
SSL	1	3	5	0	1	2	1.6	1	1.1	1.1
LG	2	1.1	4	0	1	1	1.3	1	1.1	1.3
FB	2	1.1	4	0	1	2	1.4	1	1.1	1.1
O	3	5.1	4	2	3	1	1.3	1	1.1	1.2
KS	3	5.1	5	3	1	1	1.3	1	1	1.1
Percentage of each character	1:27.3 % 2:45.4 % 3:27.3 %	1.1:18..1 % 2.1:45.4% 3:9.2% 5.1:18.1% 5.2:9.2%	4:63.6 % 5:36.4 %	0:54.6 % 2:18.1 % 3:9.2% 4:18.1 %	1:45.4 % 3:45.4 % 7:9.2%	1:54.6 % 2:45.4 %	1.2:9.2% 1.3:27.2 % 1.4:36.3 % 1.5:9.2% 1.6:18.1 %	1:81.8% 1.1:18.2 %	1:27.2% 1.1:63.6 % 1.2:9.2%	1.1:36.3 % 1.2:9.1% 1.3:54.6 %

PC2: Fruit shape (FS), leaf shape (LS), over color (OC), maturity time (MT), core shape (CS), limp length (LL) and leaf base (LB). Fruit shape (FS) was positively and strongly associated (85.2%), the percentage of flat globose was 45.4% among studied cultivars, while conical and oblong-waisted shapes revealed the same percentage which was 9.2%; and globose conical and oblong conical shapes were 18.1% for each of them (Table 4). PC2 was negatively correlated with leaf shape (LS), limp length (LL) and leaf base (LB) as shown in Table (3), the percentage of long oval shape (leaf shape) was 36.3%, followed by oval shape, orbicular shape, obvate shape and wide oval shape, they were 27.2%, 18.1%, 9.2% and 9.2% (Table ,4), respectively. The absence of over color(OC) showed the highest percentage (54.6%) among studied cultivars, while red color showed only 9.2 %. The mediate maturity time showed the highest percentage 45.4%, followed by early and late maturity time which was 27.3% for each of them (Table 4). Concerning the core shape (CS), turnip shape and flat globose shape revealed the same percentage (45.4%) among studied cultivars, while elliptical

shape showed the lowest percentage 9.2% (Table 4). Finally, the percentage of rounded base was 63.6% among studied cultivars, while it was 9.2% for cordate base. So, PC2 differentiated cultivars depending on these characters that the conical fruit shape presented only in the introduced cultivar Stark Spur Ludy (SSL), while the oblong wasted fruit shape, the obvate leaf shape and elliptical core shape presented only in the local cultivar Khlati (Kh). The red over color discriminated the introduced cultivar KandilSenap (KS). The wide oval leaf shape and cordate leaf base distinguished the introduced cultivar Early McIntosh (EMc). These results illustrated that the most characters in PC2 were qualitative except limp length.

PC3: Stalk length (SL), titratable acidity (TA), total sugar (TS), and total soluble solids (TSS). The correlation was negative with titratable acidity (TA) while it was positive with others (Table 3). PC3 differentiated cultivars depending on chemical analysis of fruit that the highest mean value of titratable acidity (TA) distinguished the local cultivar Ksairi (K).

PC4: is correlated with the high mean value of depth of calyx cavity (DC), leaf apices (LA) and fruit cross section (FCS). The correlation was negative with depth of calyx cavity (DC), as shown in Table (3). The acuminate leaf apices was the highest percentage (81.9%) among studied cultivars, and the cuspidate leaf apices formed (18.1%). While fruit cross shape divided the cultivars into regular 54.6% and angular 45.4% (Table 4). PC4 differentiated cultivars depending on these characters, that the highest mean value of depth of calyx cavity (DC) presented in the introduced cultivar KandilSenap (KS). The cuspidate leaf apices distinguished the local cultivars Khlati (Kh) and Skarji (SK).

Cluster analysis

Cluster analysis was achieved depending on leaves and fruit characters, the obtained data was able to differentiate between local apple cultivars and introduced cultivars, the eleven apple cultivars clustered into two distinct clusters (Figure 1), the first cluster included all local apple cultivars in addition to the introduced cultivar Leaz Golden (LG), this cluster formed two groups, the first group contains three local apple cultivars which branched into two subgroups, the first one contains AbouGhabra (AG), Ksairi (K) cultivars which have the same fruit shape(FS), background color (BC), core shape (CS), fruit cross section (FCS), leaf shape (Ls) and leaf margin (LM).While the second subgroup composed only Skarji (Sk) cultivar which shares the other two cultivars with fruit shape (FS), background color (BC) and core shape (CS). The second group divided into two subgroups: the first one included the local apple cultivar Feddi (F) and the introduced cultivar Leaz Golden (LG).The two cultivars have the same maturity time (MT), background color (BC), leaf apices (LA) leaf base (LB), and leaf margin (LM). While the second subgroup contained only one cultivar Khlati (Kh) which has different fruit shape (FS), over color (OC) and core shape (CS) than all other local apple cultivars. Most local apple cultivars have less mean values of measured

characters like fruit weight and fruit dimension, than the introduced cultivars. The second cluster included all the other introduced cultivars which grouped into two subclusters, the first subcluster contained three cultivars Oray (O), Fery Berg (FB) and Early MacIntosh (EMc). The second subcluster contained two cultivars KandelSinap (KS) and Stark Spur Ludy (SSL), they have the same background color (BC), core shape (CS) and leaf apices (LA).

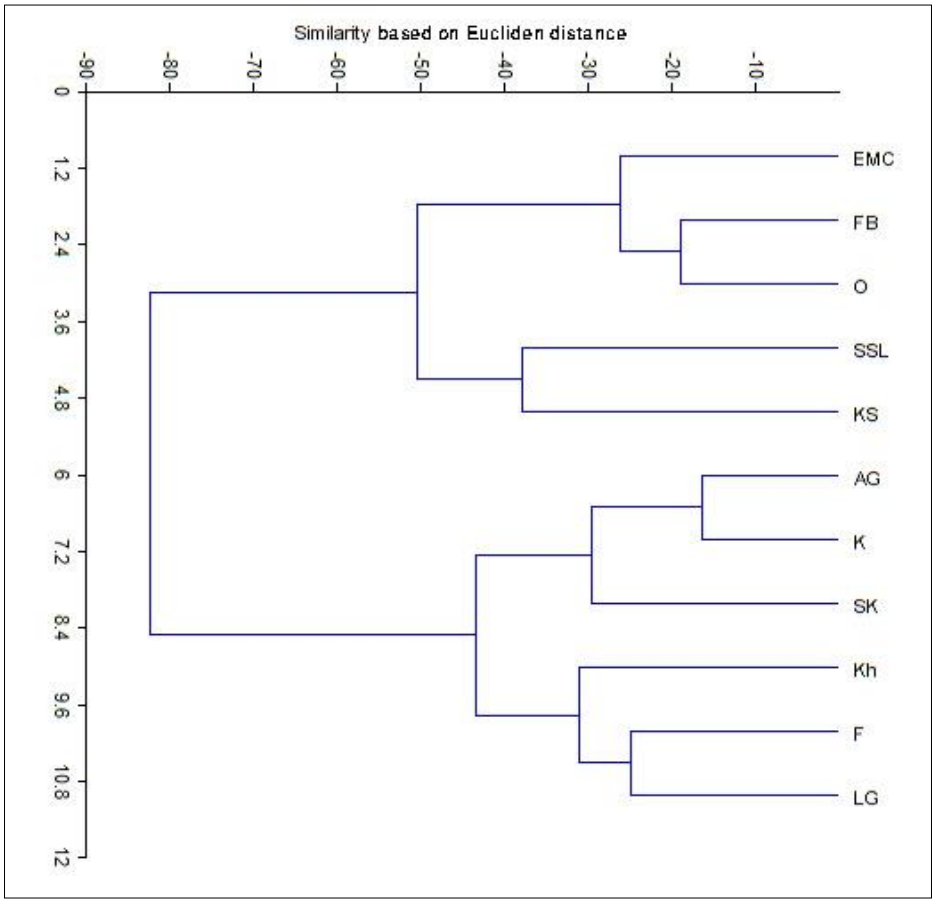

Figure 1. Cluster dendrogram of apple cultivars on leaf and fruit characters

Discussion

Analysis of Variance (ANOVA)

The variance among studied cultivars in leaf characters indicated the importance of leaf characters in discriminating among cultivars which were in agreement with Hajnajari et al. (2012) that the leaf characters such leaf length (LL), leaf width (LW) and Petiole length (PL)

are important characters in the evaluation of apple cultivars. These characters are usually used in evaluation of apple germplasms beside flower and fruit characters (Damyar et al., 2007; Kiraly et al., 2012). However, Reim et al. (2012) depended on the flower and leaf characters and less on the fruit characters for grouping putative *M. sylvestris* trees. The variance in fruit characters reflected the large range of variance among studied cultivars, which clearly distinguished between local and introduces cultivars, particularly the introduced cultivars have mostly the highest mean value while the local cultivars have the lowest mean value. This was in agreement with the results of Muzher and Al-Halabi (2012), In which, the most introduced cultivars have extremely high to high weight values. On the other hand, the local apple cultivars have moderate to low weight (El-Halabi et al., 2009). The evaluation of native cultivars of apples in Iran showed mean values of fruit weight, length and width around the mean values obtained in this study of local apple cultivars, having values of 84.8g, 52.6m m and 59.3 m m, respectively (Damyar et al., 2007). Mratinic and FotricAksic (2012) used the analysis of variance for 21 characters of 18 autochthonous apple cultivars in Serbia in which significant differences among studied accessions was reported. Hajnajary (2008), stated that fruit characters such flesh firmness, weight, shape, length, diameter and chemical components as TSS and TA play an important role in pomological analysis.

Principal Component Analysis (PCA)

The results obtained by PCA were useful in determining the most powerful characters, which can be used in germplasm evaluation based on morphological characters like fruit weight, fruit length, fruit diameter, width and depth of stalk cavity, width of calyx cavity, total soluble solids, fruit shape, stalk length and diameter, core shape and over color, in addition to limp length, leaf base, and leaf margin. Principal component analysis (PCA) has been used previously in many studies to evaluate germplasm of apple, and our results were in agreement with Pereira-Lorenzo et al. (2003) findings regarding characterization of 89 morphological characters of 408 apple accessions using, the PCA revealed six main sources of variability in the following order: size of fruit, color of skin, acidity and sweetness. Mratinic and FotricAksic (2011) found that the first three components accounted for 65% of the total variable traits among 18 apple cultivars using 12 morphological characters.

Cluster analysis

Cluster analysis was able to discriminate between local apple cultivars and introduced cultivars based on morphological characters, This result clearly indicated that morphological characterization was a useful tool for preliminary evaluation of apple germplasm, particularly to discriminate cultivars within a wide range of diversity. Pereira- Lorenzo et al. (2003) found that the cluster analysis using morphological characters was useful to classify and find

synonyms of local apple cultivars. Also, Damyar et al. (2007) stated that the classification of apple genotypes using cluster analysis depending on morphological data was helpful in differentiating among 59 apple genotypes that were classified into five groups.

Conclusion

The present investigation was able to discriminate between local and introduced apple cultivars, which reflected the genetic diversity between the two groups. Consequently, morphological characterization is an efficient tool in germplasm evaluation using principal component analysis and cluster analysis. However, local apple cultivars are considered as a valuable genetic resources which form an important platform for breeding program, so it is necessary to be evaluated and reserved.

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