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Original Article

Evaluation of Genetic Variation of Common Fig (*Ficus carica* L.) in West of Iran

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Abstract

This study describes morphological diversity and relationship of 14 cultivars and 133 wild fig accessions from central Zagros Mountains located in the west of Iran, based on 58 morphological characters. Among all characters, secondary drooping branches, number of bark tubers, shape of central lobe, length of central lobe/length of lamina, little lateral lobes, shape of leaf without lobed, fruit shape, fruit weight, fruit neck length, fruit skin over color and fruit pulp cavity showed higher coefficient of variation (CV) indicating a high level of variation. The existence of high CV in the evaluated characters indicates that there is a high diversity among the studied cultivars and accessions. One of the important wild figs that called 'Ghir-vahshi' was found in 'Baba-Heyran 2' location showing very diverse characters. Cluster analysis divided the 147 genotypes into five main clusters. The results of principal components analysis showed that the first three components explained 33.22% of total variation in data. According to the factor analysis, eighteen factors justified about 75.62% of the total variation found among genotypes. The factor analysis showed that the most of discriminator variables were depend on leaf, fruit size and growth form. The obtained results revealed that central Zagros Mountains in the west of Iran is a rich source of fig genetic diversity which could be used for fig breeding programs.

Keywords: Fig, Genetic diversity, Morphological traits, Zagros Mountains

Introduction

One of the oldest traditional crops and sacred fruit tree is fig (*Ficus carica* L., 2n=2x=26) that is extensively present in several countries around the Mediterranean basin [1]. The common fig belongs to the family Moraceae, consisting of over 1400 species and about 40 genera. The genus *Ficus* L. mainly found in the tropics with about 700 species, which currently classified into six subgenera [2]. *F. carica* L. sativa (common fig) and *F. carica* L. caprificus (caprifig or wild type) are two subspecies of fig [3,4]. According to the pollination (caprification) requirement fig cultivars are divided into four types: the Caprifig type is not edible and is used as a source of pollen. Three edible types of fig are grown commercially: the Common type that develops fruits parthenocarpically can produce one or two crops which both of them first (breba crop) and second (main crop) crops are partenocarpic; the Smyrna type, which requires pollination with pollen from caprifigs to develop the main crop; and the San Pedro type, which produces breba crop parthenocarpically and the main crop after caprification with pollen of caprifigs [5-7].

Probably fig *(Ficus carica* L.) originated in Western Asia and spread to the Mediterranean [8]. Wild or ‘nearly wild’ figs are reported in the most areas of the Middle East and Mediterranean region [9]. Botanical valid documents indicate that Southern Arabia, Iran and Syria have been the main source of edible figs [10,11]. A detailed knowledge

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of the amount of genetic variability among existing fig germplasm is looking to expand the base of fig breeding programs has been created [12-17].

Iran is a well-known country for rich sources of many plant species and the fourth largest producer of fig with more than 76.41 tons production in 2010 [18]. The first step for the conservation of genetic resources is to identify the native varieties and wild species in each region. One of the serious threats remaining for germplasm is severe genetic erosion. Thus, information about the ancient landraces is very limited [19]. Several prospections and alternative strategies for genetic resources management were considered in order to preserve fig genetic resources. Identification of genotypes and evaluation of genetic resources in fig are mainly based on morpho-pomological characterization [13]. To better distinguish wild plants from cultivated ones, based on statistical significance, morphological traits that include characteristics of leaves and fruits can be used [20-22]. The current research was carried out in order to evaluate the genetic diversity of fig accessions in central Zagros Mountains located in the west of Iran using morphological traits and to determinate their relationships to the cultivars.

Material and Methods

The studied collection contains 147 fig genotypes, which includes 133 accessions randomly sampled in natural habitats, valleys, mountains from central Zagros in the west of Iran and 14 tree samples, representing nine different cultivars (some cultivars had more than one tree sample like 'Majifi', 'Bar-anjir', 'Sham' and 'Estahban-e-Sabz') (Table 1). These cultivars are the most important of the area. The cultivar that called 'Bar-anjir' it was the caprifig type. The evaluated fig accessions in this study were consisted of 10, 33 and 90 accessions from Kurdistan, Ilam and Kermanshah provinces, respectively (Fig. 1).

The climate of the Kermanshah, Kurdistan and Ilam provinces is a moderate and mountainous climate, with annual rainfall 445-475, 400-800 and 318-595 mm/year, and average temperature 14.4, 13.6 and 16.9 °C, respectively [23].

The sampling began on April 16, 2015 and continued until September 8, 2015. Geographical coordinates and altitude were determined by GPS for each sample. The genotypes were evaluated for 6 qualitative, 36 quantitative and 16 pseudo-qualitative characters of leaf, branch, trunk and fruit based on national guidelines for the conduct of test for distinctness, uniformity and stability in fig [24] (Table 2).

To evaluate the fruits and leaves for each genotype, ten mature fruits (main crop) and leaves were randomly selected. It should be noted that since, the figs have 2-3 types of fruits [17], therefore, the evaluation was conducted on the main crop of fig.

To understand the patterns of variation among accessions/genotypes, cluster analysis was performed based on Ward’s method and squared Euclidean distance. Principal component analysis (PCA) was carried out using the correlation matrix. Factors with Eigen values more than 1.0 were considered for factor analysis. The data collected for each variable were analyzed using SPSS (Version 22) and Minitab (Version 16) statistical softwares.

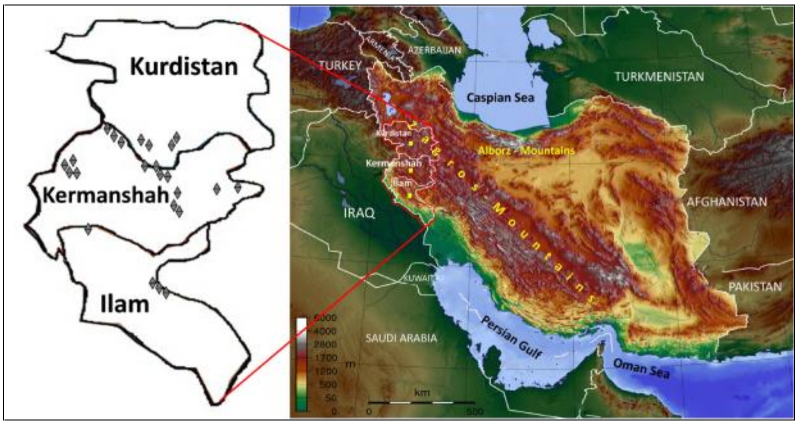

Fig. 1 Geographic zones of the 147 sampled fig genotypes.

Table 1 The characteristics of sampling locations and the accessions and cultivars studied in *Ficus carica* L.

Sample code			Province	Region	Location	No. of samples	Latitude (north)	Longitude (east)	Elevation (m)
I	Accession	-	-	-	-	-	-	-	-
10-19	-	-	Kermanshah	Dallaho	Zardeh	10	34° 31' 48"	45° 56' 24"	1028
23-31	-	-	-	Biseton	Nojubaran	9	34° 25' 48"	47° 23' 60"	1411
59-67	-	-	-	Ravansar	Baba-Heyran 1	9	34° 36' 36"	46° 44' 24"	1671
68-74	-	-	-	Ravansar	Baba-Heyran 2	7	34° 36' 36"	46° 44' 24"	1661
54	-	-	-	Kermanshah	Sarab-Ghanbar	1	34° 16' 48"	47° 2' 60"	1490
55-58	-	-	-	Kermanshah	Halashi	4	34° 14' 24"	47° 2' 60"	1633
75-87	-	-	-	Kermanshah	Doab	13	34° 25' 48"	47° 12' 0"	1562
88-94	-	-	-	Kermanshah	Ghazanchi	7	34° 25' 48"	47° 1' 48"	1583
119-122	-	-	-	Kermanshah	Yawan	4	34° 37' 48"	46° 55' 48"	1372
123	-	-	-	Kermanshah	Varmanjeh	1	34° 37' 12"	46° 56' 24"	1358
128	-	-	-	Kermanshah	Berenjan	1	34° 41' 24"	46° 53' 24"	1390
95-103	-	-	-	Paveh	Ghori-Ghale	9	34° 53' 24"	46° 30' 0"	1659
104	-	-	-	Paveh	Shamshir	1	34° 59' 24"	46° 24' 36"	1757
105-108	-	-	-	Paveh	Paveh	4	34° 59' 24"	46° 23' 60"	1706
109-118	-	-	-	Sahneh	Sarab	10	34° 29' 24"	47° 41' 24"	1531
32-53	-	-	Ilam	Aivan	Garmeh	22	33° 57' 36"	46° 12' 0"	1503
131-135	-	-	-	Badreh	Darband	5	33° 15' 36"	47° 4' 48"	1147
136-141	-	-	-	Kolm	Kolm	6	33° 20' 24"	46° 56' 24"	1076
124-126	-	-	Kurdistan	Kamyaran	Kacheleh	3	34° 55' 48"	46° 57' 0"	1582
127	-	-	-	Kamyaran	Faghih-Soleiman	1	35° 1' 12"	46° 57' 0"	1418
142-144	-	-	-	Kamyaran	Pashabad	3	34° 57' 36"	46° 44' 24"	1730
145-147	-	-	-	Kamyaran	Kashtar	3	35° 0' 0"	46° 39' 36"	1440
II	Cultivars	Cultivar type							
1	Lashei	Local cultivar	Kermanshah	Dallaho	Rijab	1	34° 28' 12"	45° 58' 48"	1098
2-4	Majifi	Iranian improved cultivar	-	Dallaho	Abodajaneh	3	34° 28' 48"	45° 57' 36"	963
5-6	Bar-anjir	Local cultivar	-	Dallaho	Abodajaneh	2	34° 28' 48"	45° 57' 36"	963
7-8	Sham	Local cultivar	-	Dallaho	Abodajaneh	2	34° 28' 48"	45° 57' 36"	977
9	Bavameli	Local cultivar	-	Dallaho	Abodajaneh	1	34° 28' 48"	45° 57' 36"	977
20	Shamamleh	Local cultivar	-	Dallaho	Shalan	1	34° 28' 48"	46° 0' 0"	1027
21	Zardleh	Local cultivar	-	Dallaho	Shalan	1	34° 28' 48"	46° 0' 0"	1027
22	Siavleh	Local cultivar	-	Dallaho	Shalan	1	34° 28' 48"	46° 0' 0"	1027
129-130	Estahban-e-Sabz	Iranian improved cultivar	Ilam	Badreh	Badreh	2	33° 17' 60"	47° 1' 48"	1063

Baba-Heyran 2: This location includes Ghir-vahshi accessions.

Table 2 The values of mean, maximum, minimum, variance, standard deviation and the coefficient of variation for the evaluated characters among the 147 fig genotypes

No.	Character		abbreviation	Min	Max	Mean	SD [a]	Variance	CV %[b]
1	Tree	Growth habit $^{(PQ)}$	TGH	1	3	1.91	0.89	0.79	46.59
2	Tree	Secondary drooping branches $^{(QL)}$	TSBD	1	9	3.77	3.82	14.59	101.20
3	Tree	Tree vigour $^{(QN)}$	TTV	3	7	4.00	1.39	1.93	34.74
4	Tree	Number of suckers $^{(QN)}$	TNS	1	7	3.99	2.37	5.66	59.60
5	Tree	Branch density $^{(QN)}$	TBD	3	7	5.31	1.61	2.61	30.42
6	Tree	Number of bark tubers $^{(QN)}$	TNBT	1	7	1.29	1.10	1.22	85.17
7	1 year branch	Colour $^{(QL)}$	OBC	1	4	2.63	0.93	0.87	35.58
8	1 year branch	Internode length (mm) $^{(QN)}$	OBIL	3	7	4.4	1.40	1.98	31.90
9	1 year branch	Number of internodes $^{(QN)}$	OBNI	3	7	5.69	1.01	1.02	17.75
10	Terminal bud	Length/width ratio $^{(QN)}$	TBLWR	3	7	4.61	1.47	2.18	32.04
11	Terminal bud	Size $^{(QN)}$	TBS	3	7	4.91	1.63	2.67	33.27
12	Terminal bud	Colour $^{(PQ)}$	TBC	1	3	1.19	0.41	0.16	34.52
13	Branch	Tubers formed on dormant buds $^{(QN)}$	BTDB	1	7	3.76	2.07	4.29	55.07
14	2 year branches	Tendency $^{(PQ)}$	TBT	1	3	1.55	0.56	0.31	36.33
15	Leaf	Shape $^{(PQ)}$	LS	1	3	1.44	0.74	0.55	51.20
16	Branch	Number of leaves per branch $^{(QN)}$	BNLB	3	9	4.71	0.96	0.93	20.47
17	Leaf	Shape of central lobe $^{(PQ)}$	LSCL	0	6	1.21	2.04	4.18	168.86
18	Leaf	Length of central lobe/length of lamina $^{(QN)}$	LLCLL	0	7	1.63	2.62	6.87	160.63
19	Leaf	Shape of leaf base $^{(PQ)}$	LSLB	2	5	3.87	0.82	0.67	21.22
20	Leaf lamina	Length (mm) $^{(QN)}$	LLL	3	7	4.65	1.48	2.21	31.91
21	Leaf lamina	Width (mm) $^{(QN)}$	LLW	3	7	5.05	1.44	2.07	28.52
22	Leaf	Petiole length (mm) $^{(QN)}$	LPL	3	7	4.90	1.33	1.77	27.13
23	Leaf	Length of petiole/length of lamina $^{(QN)}$	LLPLL	3	7	4.53	1.51	2.30	33.46
24	Leaf	Petiole thickness (mm) $^{(QN)}$	LPT	3	7	4.93	1.41	1.99	28.64
25	Leaf	Petiole colour $^{(QN)}$	LPC	1	3	1.50	0.55	0.30	36.82
26	Multi-lobed leaves	Little lateral lobes $^{(QL)}$	MLLLL	0	9	0.35	0.85	0.72	240.42
27	Multi-lobed leaves	Little lateral lobe size $^{(QN)}$	MLLLS	1	3	1.01	0.16	0.027	16.27
28	Leaf not lobed	Shape $^{(PQ)}$	LNLS	0	3	1.40	0.92	0.85	66.11
29	Fruit [c]	Shape $^{(PQ)}$	FSh	1	6	2.09	1.44	2.08	68.94
30	Fruit	Size $^{(QN)}$	FS	3	7	4.21	1.33	1.78	31.71
31	Fruit	Length (mm) $^{(QN)}$	FL	3	9	5.66	2.22	4.94	39.26
32	Fruit	Width (mm) $^{(QN)}$	FW	3	9	5.82	2.25	5.08	38.68
33	Fruit	Weight (g) $^{(QN)}$	FWe	1	7	2.40	1.97	3.91	82.37
34	Fruit	Neck length (mm) $^{(QN)}$	FNL	1	7	2.65	1.96	3.85	73.82
35	Fruit	Ostiole size $^{(QN)}$	FOS	3	7	4.41	1.46	2.14	33.20
36	Fruit	Stalk length (mm) $^{(PQ)}$	FSL	1	3	1.80	0.77	0.60	43.06
37	Fruit	Skin ground colour $^{(PQ)}$	FSGC	1	9	5.50	2.72	7.44	49.57
38	Fruit	Skin over colour $^{(PQ)}$	FSOC	1	11	4.44	4.00	16.00	89.91
39	Fruit	Lenticel number $^{(QN)}$	FLN	3	7	4.63	1.67	2.79	36.09
40	Fruit	Lenticel colour $^{(QL)}$	FLC	1	3	1.29	0.47	0.22	36.49
41	Fruit	Lenticel size $^{(QN)}$	FLS	3	7	4.19	1.51	2.28	35.99
42	Fruit	Pulp colour $^{(PQ)}$	FPC	1	5	3.61	0.99	0.99	27.50
43	Fruit	Pulp cavity $^{(QN)}$	FPCa	1	7	2.14	1.34	1.80	62.75
44	Fruit	Amount of juice $^{(QN)}$	FAJ	3	7	4.71	1.58	2.52	33.67
45	Fruit	Firmness of the fruit skin $^{(QN)}$	FFFS	1	9	5.87	2.06	4.27	35.22
46	Fruit	Achene amount $^{(QN)}$	FAA	3	7	5.14	1.42	2.03	27.68
47	Fruit	Achene size $^{(QN)}$	FAS	3	7	5.42	1.30	1.71	24.12
48	Fruit	Prominent veins $^{(PQ)}$	FPV	3	7	3.32	0.81	0.65	24.41
49	Fruit	Skin cracks $^{(PQ)}$	FSC	1	2	1.97	0.14	0.02	7.16
50	Fruit	Ostiole opening $^{(PQ)}$	FOO	1	3	1.42	0.53	0.28	37.65
51	Fruit	Number of fruits per branch $^{(QN)}$	FNFB	3	7	4.25	1.52	2.31	35.76
52	Fruit	Abscission $^{(QL)}$	FA	1	2	1.39	0.49	0.24	35.16
53	Fruit	Ease of peeling $^{(PQ)}$	FEP	1	3	2.25	0.84	0.71	37.42
54	Fruit	Type of fruit production $^{(QL)}$	FTFP	3	5	3.83	0.40	0.16	10.58
55	Fruit	Beginning of ripening $^{(QN)}$	FBR	3	7	5.21	1.28	1.65	24.62
56	Fruit	Abnormal fruit formation $^{(QN)}$	FAFF	3	7	4.23	1.54	2.37	36.35
57	Leaf	Foliation time $^{(QN)}$	LFT	3	7	4.78	1.12	1.26	23.54
58	Leaf	Abscission time $^{(QN)}$	LAT	3	7	5.12	1.46	2.14	28.62

[a] Standard deviation.

[b] CV, coefficient of variation = (standard deviation/mean) × 100.

[c] Fruit for the items 29-56 was main crop.

[QL] Qualitative.

[QN] Quantitative.

[PQ] Pseudo-qualitative.

Results

Variation of genotypes for measured characters

The values of mean, maximum, minimum, variance, standard deviation, and the coefficient of variation for each character of the genotypes were presented in Table 2. A large variation was observed among the studied genotypes of fig for most of the characters. Among all characters secondary drooping branches, number of bark tubers, shape of central lobe, length of central lobe/length of lamina, little lateral lobes, shape of leaf without lobed, fruit shape, fruit weight, fruit neck length, fruit skin over color and fruit pulp cavity showed higher coefficient of variation (CV) than other characters indicating a high level of variation. An accession called 'Ghir-vahshi' in location of 'Baba-Heyran 2' had the shortest height (Fig. 2) that it can be considered as the widest or shortest tree and the largest tree was observed in 'Kacheleh' location. Both of these locations were under nearly similar climate conditions/similar geographical characteristics but in two different provinces (Table 1), and both of these grown on the rock. Therefore the height can be indicative of genetic diversity among them. All collected fig fruits showed distinctive variation (Fig. 3). Most of the genotypes in this study were belong to Smyrna type. The genotypes called 'Ghir-vahshi' were non-edible among the studied wild accessions and 'Bar-anjir' was caprifig type and non-edible among the cultivars. Other studied genotypes were edible.

Fig. 2 An accession called 'Ghir-vahshi' in the location of 'Baba-Heyran 2'.

Similarities among evaluated fig genotypes

The classification of the genotypes into similar groups based on a large number of traits could be a reliable method to determine similarities among the evaluated genotypes. In order to determine the relationships between the 147 fig genotypes, cluster analysis was performed using Ward's method and squared Euclidean distance.

Fig. 3 The variation in fruit characteristics of the fig accessions.

The results of cluster analysis based on the characteristics listed in Table 2 are shown as a dendrogram (Fig. 4). The dendrogram divided the 147 fig genotypes into five major groups (group A to E).

The group A includes 48 accessions from locations of 'Halashi', 'Ghazanchi', 'Sarab', 'Kolm', 'Garmeh', 'Varmanjeh', 'Nojubaran', 'Baba-Heyran 2', 'Yawan', 'Ghori-Ghale' and most parts of 'Doab'. These samples were similar in secondary drooping branches, number of bark tubers, leaf shape and shape of leaf without lobe. All these accessions don’t have secondary drooping branches and bark tubers. The leaves were cordate-shaped and without lobe. The second group (group B) consisted of 28 accessions from 'Ghazanchi', 'Baba-Heyran 1', 'Baba-Heyran 2', 'Sarab', 'Garmeh', 'Nojubaran', 'Yawan', 'Ghori-Ghale', 'Kolm', 'Darband' and 'Berenjan' locations. These samples were similar in the number of bark tubers, leaf shape, fruit prominent veins and fruit skin cracks. All these accessions don’t have bark tubers and fruit prominent veins. The accessions in this group had leaves without lobe and fruits with scarce longitudinal cracks. The third cluster (group C) consisted of 14 accessions from 'Garmeh', 'Sarab-Ghanbar', 'Nojubaran', 'Doab', 'Yawan', 'Ghori-Ghale', 'Faghih-Soleiman', 'Kolm' and 'Darband' locations. These samples were similar in the number of bark tubers, secondary drooping branches, fruit skin cracks, fruit skin over color, fruit lenticel color and type of fruit production. All these accessions don’t have bark tubers. The secondary branches have drooping. The fruits were without regular bands or irregular blots over the skin. The lenticel color in these accessions is white. The fruits have scarce longitudinal cracks and the type of fruit production according to the caprification is Smyrna. The members of group D were one sample from cultivar 'Estahban-e-Sabz' (the genotype of number 129) and 21 accessions from 'Kolm', 'Baba-Heyran 1', 'Baba-Heyran 2', 'Nojubaran', 'Kacheleh', 'Ghori-Ghale', 'Shamshir', 'Garmeh', 'Darband' and 'Pashabad' locations. All these samples were similar in fruit skin cracks and their fruits had scarce longitudinal cracks. Finally, 22 accessions from the locations 'Ghori-Ghale', 'Paveh', 'Kacheleh', 'Pashabad', 'Kashtar', 'Baba-Heyran 1' and 'Zardeh' 13 samples from cultivars 'Lashei', 'Majifi', 'Bar-anjir', 'Sham', 'Bavameli', 'Shamamleh', 'Zardleh', 'Siavleh' and 'Estahban-e-Sabz' were belonged to the fifth cluster (group E).

Description of variability of evaluated fig characters

The purpose of principal component analysis is data reduction and show transparency relation between two or more of the characters. Principal component analysis indicated that the first three components justified 33.22% of the total variation. PC1, PC2 and PC3 accounted for 20.68%, 7.26% and 5.26% of the total variation, respectively. Finally, 75.62% of the total variation was justified by the eighteen components. Two-dimensional diagram of the first two components for the 147 fig genotypes was shown in Figure 5. All genotypes were divided into five groups. Accession No. 18 from 'Zardeh' location was located in a separated group in PCA by itself. This accession showed more differences in terms of leaf shape with other samples (Fig. 6).

Factor analysis was conducted to investigate variable relationships and to contract variables in the form of factors that each factor includes number of variables. Factor analysis divided the 58 variables into 18 factors (Table 3). Loading factors greater than 0.6, regardless of the respective sign were considered as significant coefficients. Eighteen factors justified about 75.62% of the total variation found among the studied genotypes.

The first factor justified 19.37% of the total variation and included leaf shape, shape of central lobe, length of central lobe/length of lamina, leaf lamina length, leaf lamina width, leaf petiole length, leaf petiole thickness, fruit size, fruit length, fruit width, fruit weight, fruit abscission and leaf abscission time with a positive coefficient and shape of leaf without lobe with a negative coefficient. Therefore, the first factor could be named as leaf and fruit size factor. The second factor, named the growth form factor accounted for 4.92% of the total variation. This factor had positive relationships with tree growth habit, tree secondary drooping branches, tree branch density and two year branches tendency. The third factor explained 4.32% of the total variation and included characters of little lateral lobes and little lateral lobe size. The third factor was named the factor affecting little lateral lobes. The remained factors (4^{th} to 18^{th} factor) together explained 47.01% of the total variation.

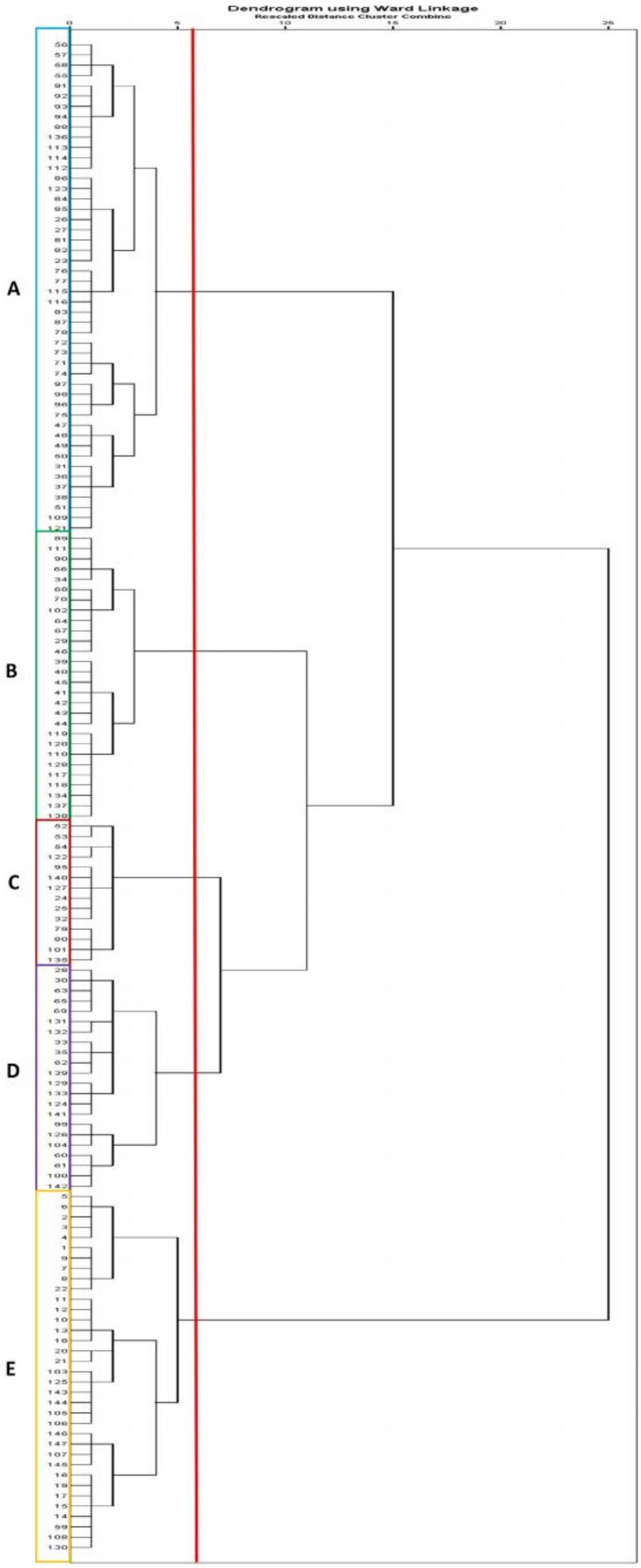

Fig. 4 Ward's dendrogram of the 147 accessions and cultivars based on 58 morphological characters.

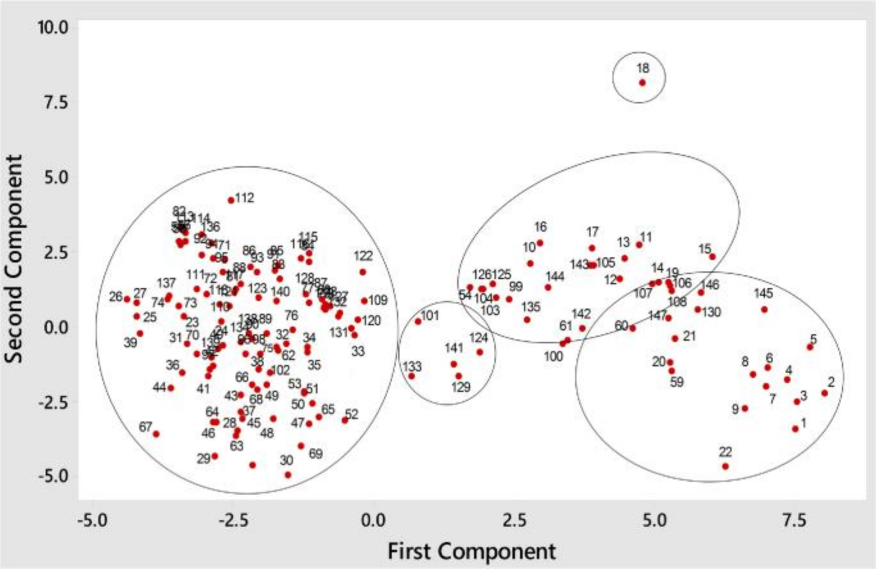

Fig. 5 Distribution of the 147 fig genotypes for the first two components by principal components analysis based on the 58 morphological characters

Fig. 6 The accession of number 18 from 'Zardeh' location with different leaf shapes.

Table 3 Loading factor, percentage of variance and cumulative variance of main factors with Quartimax rotation in the 147 fig genotypes

Characteristics	1	2	3	4	5	6	7	8	9	10
TGH	0.304	0.813	-0.012	0.145	0.020	0.002	-0.014	0.016	-0.035	0.045
TSBD	0.287	0.777	-0.101	-0.003	-0.085	0.073	0.093	-0.077	0.063	-0.048
TGP	0.340	0.537	-0.094	0.009	-0.012	0.105	0.417	-0.119	0.098	0.064
TNS	-0.099	-0.061	-0.169	-0.031	0.293	0.144	0.096	-0.023	0.410	0.047
TBD	0.159	0.657	0.131	0.024	-0.223	-0.041	0.066	0.270	-0.048	-0.079
TNBT	0.491	0.074	-0.058	0.074	0.033	-0.211	0.467	-0.053	0.015	0.190
OBC	0.132	-0.045	-0.177	-0.148	-0.131	0.038	0.035	-0.045	-0.762	-0.035
OBIL	0.061	-0.052	-0.091	-0.145	-0.055	0.187	0.072	0.704	0.054	-0.118
OBNOI	-0.032	0.157	-0.075	0.218	-0.230	-0.095	0.129	-0.231	0.275	-0.187
TBLWR	0.165	-0.003	0.040	-0.072	-0.033	0.879	-0.068	0.116	-0.081	0.004
TBS	0.277	0.196	-0.078	0.072	-0.022	0.777	0.113	0.049	0.019	-0.018
TBC	-0.137	-0.100	0.515	-0.133	-0.091	-0.035	0.078	-0.063	0.080	-0.020
BTDB	0.141	0.169	-0.219	-0.068	0.217	-0.055	0.063	0.060	0.403	0.127

TBT	0.149	0.658	0.082	-0.084	0.110	0.132	-0.133	-0.247	0.064	-0.032
LDT	0.880	-0.002	0.172	-0.076	-0.023	0.097	-0.035	0.057	0.055	-0.091
BNLB	0.335	0.082	0.504	0.125	0.047	0.014	-0.092	0-.065	-0.279	-0.079
LCLS	0.840	0.029	0.079	-0.080	-0.024	-0.009	-0.124	-0.009	0.004	-0.054
LLCLL	0.869	0.006	0.150	-0.064	-0.144	0.122	-0.153	0.087	0.028	-0.133
LSLB	0.419	0.154	0.122	-0.037	0.005	0.091	-0.080	0.243	-0.258	0.126
LLL	0.774	0.088	-0.143	0.148	0.055	0.027	0.102	0.039	0.097	0.027
LLW	0.817	0.028	-0.065	0.088	0.018	-0.062	-0.024	0.074	0.039	-0.044
LPL	0.732	0.043	-0.057	0.077	-0.025	-0.079	0.103	-0.069	0.242	0.045
LLPLL	0.534	-0.044	-0.004	-0.067	0.054	-0.173	-0.033	-0.068	0.207	0.122
LPT	0.624	0.030	-0.028	-0.083	0.079	0.032	0.122	-0.089	-0.123	-0.059
LPC	-0.174	0.121	0.058	-0.164	-0.107	0.069	0.005	-0.094	-0.066	-0.033
MLLLL	0.543	0.005	0.780	-0.082	-0.039	0.020	-0.066	0.022	0.067	-0.010
MLLLS	0.054	0.010	0.932	-0.056	-0.005	-0.035	-0.034	-0.003	0.085	0.055
LNLS	-0.929	-0.010	-0.094	0.063	0.071	-0.089	0.073	-0.053	-0.009	0.091
FS	0.031	0.027	-0.030	-0.105	0.056	0.008	0.072	0.120	-0.021	0.812
Fs	0.651	0.150	-0.042	0.026	-0.024	-0.013	0.217	0.180	-0.095	0.298
FL	0.766	0.192	-0.023	-0.109	0.028	0.036	-0.029	0.044	-0.133	0.238
FW	0.755	0.194	-0.177	0.049	-0.050	0.093	-0.090	0.030	-0.059	0.179
FWe	0.824	0.151	-0.017	-0.021	0.046	-0.001	0.154	0.027	-0.013	0.061
FNL	0.090	-0.161	0.111	0.122	-0.138	-0.111	0.171	-0.125	0.122	0.658
FOS	0.425	-0.087	0.004	0.053	0.400	-0.099	-0.035	0.061	0.110	0.193
FSL	-0.075	-0.096	0.093	0.062	-0.137	0.098	0.047	-0.045	0.049	-0.204
FSGC	0.106	0.001	0.066	-0.781	-0.136	0.052	0.103	-0.045	-0.166	0.022
FSOC	-0.141	0.084	0.001	0.782	0.110	0.055	-0.066	-0.162	-0.055	-0.051
FLN	-0.210	-0.047	-0.032	0.140	-0.077	0.002	0.069	0.015	0.028	-0.041
FLC	-0.160	-0.063	-0.031	0.401	0.073	-0.101	-0.341	0.296	0.178	-0.067
FLS	0.099	0.056	-0.042	0.080	-0.034	0.078	-0.052	-0.015	0.086	0.034
FPC	-0.203	-0.063	-0.028	0.031	0.715	-0.013	-0.085	0.078	0.006	0.000
FPCa	0.194	-0.065	0.091	0.070	0.075	0.075	0.142	0.692	-0.029	0.174
FAJ	0.283	0.048	-0.107	0.502	0.009	0.154	0.374	0.029	0.054	0.043
FFFS	0.153	-0.032	-0.009	-0.233	-0.427	0.229	0.027	-0.133	0.019	-0.042
FAA	0.018	-0.051	-0.011	0.136	0.735	0.016	0.081	-0.123	0.152	-0.016
FAS	-0.079	0.037	0.039	0.199	0.422	0.170	-0.121	0.091	0.060	-0.328
FPV	0.273	0.039	-0.151	-0.130	-0.290	0.036	-0.269	0.388	0.201	0.150
FSC	0.116	-0.026	0.028	0.141	-0.137	-0.038	-0.007	-0.036	-0.138	-0.016
FEO	0.377	-0.038	-0.043	0.097	0.133	0.041	0.050	-0.031	0.005	-0.020
FNFB	0.248	-0.028	0.022	-0.033	-0.119	0.084	-0.036	0.152	-0.149	0.135
FAT	0.601	-0.032	0.163	0.005	-0.101	0.239	-0.058	-0.053	-0.215	-0.187
FEP	-0.073	-0.147	0.110	-0.223	-0.407	0.217	-0.245	-0.246	-0.112	0.023
FPT	-0.199	-0.044	0.045	-0.170	-0.132	-0.497	0.167	-0.081	-0.430	0.181
FBR	0.165	-0.047	0.092	0.109	-0.011	0.010	-0.817	-0.160	-0.014	-0.153
FAFF	-0.269	0.094	-0.049	0.251	0.101	0-.094	0.033	0.276	0.073	0.157
LFT	-0.518	0.026	-0.188	0.251	0.020	0.003	-0.507	-0.193	0.239	0.058
LAT	0.687	0.153	0.132	-0.046	-0.055	0.157	-0.074	-0.364	-0.177	-0.042
Eigen values	12.000	4.215	3.056	2.769	2.472	2.172	1.955	1.829	1.671	1.654
% of variance	19.37	4.92	4.32	4.09	4.05	3.77	3.67	3.58	3.27	3.23
Cumulative variance	19.37	24.29	28.60	32.69	36.75	40.52	44.19	47.77	51.04	54.28

Table 3 Continued

Characteristics	11	12	13	14	15	16	17	18
TGH	0.035	0.010	-0.012	-0.025	-0.033	0.067	0.020	0.018
TDSB	0.080	-0.029	-0.134	-0.064	0.077	0.017	-0.044	-0.051
TGP	0.085	-0.148	0.127	0.105	0.164	0.199	-0.052	0.011
TNS	-0.190	0.379	0.118	0.112	0.021	-0.324	0.239	0.121
TBD	-0.086	0.180	0.067	-0.077	0.023	0.112	0.170	0.084

TNBT	0.128	0.126	0.143	0.174	0.021	0.132	-0.117	-0.012
OBC	-0.018	0.027	0.077	0.021	0.096	0.010	0.002	0.119
OBIL	-0.217	0.042	0.078	-0.038	-0.065	-0.032	0.095	-0.195
OBNOI	0.465	-0.005	-0.052	0.206	-0.058	0.102	-0.193	0.139
TBLWR	0.045	0.037	0.011	-0.097	-0.040	-0.026	0.050	-0.035
TBS	-0.095	0.084	0.037	0.105	-0.020	-0.068	-0.005	0.020
TBC	-0.113	-0.018	-0.196	0.418	-0.019	0.027	0.307	-0.238
BTDB	0.166	-0.203	-0.073	0.210	0.469	-0.046	0.158	0.093
TBT	0.028	0.072	-0.031	0.069	-0.125	-0.151	-0.089	-0.168
LDT	-0.030	0.111	-0.132	-0.014	-0.042	0.028	-0.079	0.045
BNLB	-0.162	0.032	0.109	0.080	-0.326	0.180	0.168	0.065
LCLS	-0.029	0.160	-0.216	-0.060	-0.039	-0.023	-0.098	0.054
LLCLL	0.032	0.103	-0.153	0.014	-0.037	0.022	-0.093	0.103
LSLB	-0.034	0.296	-0.468	0.217	-0.024	-0.005	-0.030	0.019
LLL	0.012	-0.091	-0.005	-0.008	0.027	-0.005	0.306	-0.068
LLW	0.023	-0.124	-0.015	-0.005	0.108	0.049	0.307	-0.024
LPL	0.046	0.093	0.191	-0.164	-0.012	0.024	0.385	-0.060
LLPLL	-0.056	0.289	0.360	-0.231	0.020	0.149	0.049	-0.081
LPT	0.178	-0.190	0.077	-0.022	0.095	-0.061	0.328	-0.272
LPC	0.183	0.767	0.034	-0.041	0.089	0.060	-0.027	-0.016
MLLLL	0.044	0.066	-0.040	-0.055	0.013	-0.058	-0.095	0.083
MLLLS	0.058	0.005	0.038	-0.064	0.041	-0.103	-0.052	0.053
LNLS	0.010	-0.123	0.111	0.037	0.037	-0.017	0.096	-0.075
FS	-0.022	0.008	0.073	0.041	-0.097	0.081	-0.100	-0.047
Fs	0.100	-0.144	0.053	0.114	0.022	-0.178	-0.280	-0.063
FL	0.008	-0.172	0.166	0.026	0.043	-0.187	-0.073	-0.055
FW	-0.003	-0.247	0.157	0.074	0.028	-0.154	-0.125	-0.004
FWe	-0.022	-0.163	0.090	0.107	0.034	0.016	-0.131	0.000
FNL	0.043	-0.054	-0.011	-0.125	0.237	0.223	0.197	0.050
FOS	-0.092	-0.063	0.102	0.153	0.199	0.229	-0.365	-0.028
FSL	-0.039	-0.076	0.089	-0.035	0.026	-0.752	0.001	0.076
FSGC	0.073	0.033	-0.001	0.048	-0.083	0.002	0.111	0.098
FSOC	-0.020	-0.135	-0.067	0.148	0.073	-0.119	0.110	-0.055
FLN	-0.827	-0.139	0.028	0.021	0.108	-0.004	-0.055	0.007
FLC	0.190	0.131	0.053	0.362	-0.086	-0.144	0.231	-0.141
FLS	-0.048	0.011	-0.014	0.022	0.008	0.067	0.027	-0.787
FPC	-0.065	-0.097	-0.096	0.145	-0.099	0.076	0.195	0.054
FPCa	0.111	-0.171	-0.045	0.005	0.020	0.076	-0.108	0.153
FAJ	-0.030	-0.056	0.009	-0.105	-0.026	0.324	-0.034	0.136
FFFS	-0.271	-0.233	-0.058	0.199	-0.053	0.347	-0.002	0.325
FAA	0.048	0.002	-0.037	-0.035	-0.037	0.046	-0.152	0.007
FAS	0.319	-0.052	0.109	0.164	0.407	0.216	0.063	0.073
FPV	0.141	0.023	0.170	0.231	0.162	0.098	-0.128	0.091
FSC	-0.207	0.148	0.011	-0.013	0.764	-0.033	-0.038	-0.065
FEO	0.024	-0.041	0.141	0.742	0.050	0.050	-0.073	0.030
FNFB	-0.018	0.053	0.740	0.149	0.022	-0.143	-0.035	0.063
FAST	0.054	-0.022	0.090	0.170	0.109	0.197	-0.047	-0.053
FEP	-0.278	0.060	0.125	0.125	-0.118	0.087	0.294	0.415
FPT	-0.025	0.133	-0.010	-0.108	-0.078	0.001	0.171	0.231
FBR	0.050	-0.057	0.071	-0.023	0.000	0.153	-0.073	-0.015
FAFF	0.229	-0.301	-0.448	-0.161	0.322	-0.024	-0.154	0.081
LFT	0.079	0.168	-0.022	0.035	0.096	-0.082	0.001	-0.039
Eigen values	1.502	1.413	1.355	1.291	1.215	1.172	1.075	1.042
% of variance	2.84	2.84	2.78	2.67	2.66	2.63	2.48	2.42
Cumulative variance	57.12	59.96	62.74	65.41	68.087	70.71	73.19	75.62

Bold values are those with loading factors greater than 0.600.

Discussion

The results have shown a great diversity among the fig accessions studied in the west of Iran. The existence of high CV in the evaluated characters indicates that there is a high diversity among the cultivars and accessions. One of the important collected samples among the accessions was 'Ghir-vahshi' in 'Baba-Heyran 2' location that it showed very diverse characters. Our findings support the view that some morphological characters are reliable to evaluate genetic diversity among fig genotypes and could efficiently be used for discrimination of these genotypes. The results of evaluation of 71 cultivated and wild Tunisian fig trees by using 8 morphological traits showed that the morphological characters are suitable to characterize figs and should be recommended in conservation management strategy [25]. Similarly, many studies [13,14,26-30] revealed that morphological traits are very useful for identification and evaluation of fig genotypes. Caliskan *et al*. (2017) used 44 morphological characteristics to evaluate the morphological diversity of six cultivars and 90 caprifig accessions grown in eastern Mediterranean region of Turkey. The results demonstrated great morphological variability among the caprifig accessions [31]. Qualitative and quantitative morphological features in the accessions of *Opuntia ficus indica* (L.) Mill. were significant when the morphological diversity of 20 accessions of *Opuntia ficus indica* (L.) Mill. collected from different bioclimatic localities in Algeria was evaluated [32]. Moreover, research about variation and genetic structure of fig populations using molecular markers is suggested. Most of the figs studied from 'Paveh', 'Pashabad' and 'Kashtar', in terms of fruit and leaf shape were similar to the cultivars, which had large fruits and multi-lobe leaves. The cluster analysis also confirmed this result and these samples were belonged to the fifth cluster. It could be concluded that the most of the studied accessions had leaves without lobe, small fruits, low number of bark tubers and low number of suckers as a result of environmental conditions. On the opposite, the cultivars had multi-lobed leaves, large fruits, much number of bark tubers and much number of suckers.

In this study, according to the two-dimensional diagram PCA, genotypes divided in to five groups. Results showed that accession No. 18 from 'Zardeh' location was located in a separated group in PCA by itself, but in the cluster analysis, it was classified with accessions of 'Ghori-Ghale', 'Paveh', 'Kacheleh', 'Pashabad', 'Kashtar', 'Baba-Heyran 1' locations and local cultivars 'Badreh' and 'Dallaho'. This accession showed more differences in terms of leaf shape with other samples (Fig. 6), of course, we are confident that the leaf shape is not due to a viral infection. The evaluated cultivars in this study were placed in a group, fairly matching with the results obtained from the cluster analysis. Those accessions that were very similar to the cultivars are located in this group. Of course, one sample of 'Estahban-e-Sabz' cultivar with samples of 'Darband', 'Ghori-Ghale', 'Kacheleh' and 'Kolm' were located in a separated group. Other accessions were located in two large groups. These groups were very close together also in the cluster analysis. The results of cluster analysis showed that genetic variation among the accessions was not correlated with geographical origin.

Factor analysis can identify the major discriminator factors which play an important role in determining variation among the studied genotypes. In current research, the most distinctive variables were dependent on leaf, fruit size and growth form.

The considerable genetic diversity observed in the studied characters indicates rich and valuable plant genetic resources for fig cultivar development programs. Further studies in collaborative approach may harness genetic diversity in central Zagros Mountains in the west of Iran. There is still need of effective management of local genetic resources for conservation and improvement from all regions of Zagros Mountains. Study and description of the wild fig genetic resources in the west of Iran can create a valuable collaboration for establishing a targeted management and evaluation program. The results obtained from the study of relationships between cultivars and wild accessions could be used in breeding programs to introduce new fig cultivars. For example, accessions that are very similar to cultivars and have fruits with desirable size and taste could be introduced as novel fig cultivars.

Conclusion

The similarities and differences among the studied genotypes and cultivars of fig in the west of Iran indicated that this region is a rich source with high genetic diversity for fig germplasm to release new cultivars. As a result of this present study, morphological characters are reliable to evaluate genetic diversity of fig. We suggested that in future studies of fig genetic diversity, characters related to the fruit and leaf size and growth form should be considered and evaluated.

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