Research Article

Morphological and Pomological Diversity of Fig (*Ficus carica* L.) Cultivars in Northwest of Tunisia

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The fig (*Ficus carica* L.) is one of the oldest fruit trees cultivated in Tunisia. Djebba region is located in the northwest of Tunisia. It is very famous by fig culture. Many specific fig genotypes are very appreciated locally and nationally. Taking into account these considerations, Djebba fig cultivars are subject of label products, namely, “Djebba figs.” This study was focused on fig germplasm characterization of 17 cultivars in Djebba region based on morphological and pomological traits. Results revealed a large variability within the local fig germplasms. The comprehensive analyses of all the data permitted to distinguish some particular genotypes as distinct cultivars, and groups of cultivars as polyclone varieties. It was possible to discriminate six distinct cultivars and two groups of multiclone varieties (*Soltani* and *Thgagli*) with different degrees of polymorphism. Hypotheses of homonymy and synonymy were suggested for some cultivars. The diversity is currently threatened by genetic erosion. Measure of conservation is necessary to be undertaken.

1. Introduction

The common fig (*Ficus carica* L., $2n = 26$) belongs to the family *Moraceae*, with over 1400 species classified into about 40 genera. The genus *Ficus* contains about 700 species, mainly found in the tropics and currently classified into six subgenera [1]. Nowadays, the common fig grows wild in the Mediterranean Basin where it has been cultivated for its edible fruits for millennia in close association with olive and grapevine [2]. Three types of figs are grown commercially [3]: the common type that develops fruit parthenocarpically, the Smyrna type that requires pollination with pollen from caprifigs (caprification), and the San Pedro type that produces a first crop parthenocarpically and a second crop only after pollination. Total world fig production is over 1 million tons and 70% is produced in Turkey, Egypt, Greece, Iran, Morocco, Spain, and USA. Turkey produces nearly 25% of the total production [4].

In Tunisia, fig biodiversity is very high, and many niches are well suited for fig production. Despite its socioeconomic and historical importance, fig tree was considered as a secondary crop. Fig trees are grown all over the country,

with more than 2,500,000 trees occupying about 33800 ha. The total annual production is about 27.000 million tons [5]. Figs are mainly consumed as fresh fruits. A small portion is sun dried and little quantities are used for jam and alcoholic beverage production [6]. Tunisian fig cultivars are numerous and well adapted to local agroecological conditions [7]. Some are of the common type. Many others are of Smyrna type [8]. It should be stressed that several studies have reported the use of pomological traits in a number of Tunisian ecotypes collected from different zones [9]. Thus, 65 cultivars were described by Minangoin [10], 22 cultivars by Valdeyron and Crossa-Raynaud [11], and 28 by Lahbib [12]. It is noteworthy that a number of these cultivars have been destroyed as a consequence of the intensive urbanization in recent decades. Moreover, severe genetic erosion is also threatening the remaining germplasm. Thus, available information about the ancient landraces is very limited [6].

In order to preserve fig genetic resources, several prospecting and alternative strategies for genetic resources management were considered. Pomological and morphological traits as well as molecular markers were used to analyse genetic diversity and characterize local cultivars [8, 13–19]. Recently,

TABLE 1: Studied fig cultivars.

N°	Cultivar	Code	Type
1	Zidi	ZD1	Smyrna
2	Zidi Artab	ZD2	Smyrna
3	Soltani Abiadh	SAB	Smyrna
4	Soltani Ahmar	SAH	Smyrna
5	Thgagli Abiadh	TAB	Smyrna
6	Thgagli Akhdher	TAK	Smyrna
7	Nemri	NMR	Smyrna
8	Hemri	HMR	Smyrna
9	Bouhouli	BHL	San Pedro
10	Wahchi	WAH	San Pedro
11	Garaï	GRI	San Pedro
12	Khenziri	KNZ	San Pedro
13	Khartoumi	KRT	Smyrna
14	Boukhobza	BKB	Smyrna
15	Zergui	ZRG	Smyrna
16	Bouharrag	BHR	Smyrna
17	Fawari	FAW	Smyrna

San Pedro produces first and second crops and Smyrna produces only second crop.

various studies on fig genetic resources are continuing across the country. But no research results have been reported so far on northwest fig germplasm. This study is part of a project of the “Union Tunisienne de l’Agriculture et de la Pêche” aiming to establish a label to Djebba’s fig. The objectives are (i) identification of different fig cultivars grown in Djebba area and (ii) analysis of genetic diversity within the germplasm.

2. Materials and Methods

2.1. Plant Material and Study Area. This study concerned the region of Djebba (altitude, 700 m; latitude, 36° 40’N; longitude 9°0’E) located at the northwest of Tunisia. The climate is subhumid with mild winter and hot summer. Annual average temperature is around 20°C. Thermal amplitude is about 16.5°C in summer and 8°C in winter. Average annual rainfall is about 600 mm. The morphological and pomological variability was studied on adult fig trees of 17 local cultivars (one tree per cultivar) grown in this region (Table 1).

2.2. Morphological and Pomological Traits. Morphological and pomological parameters were chosen according to the fig descriptors [20]. On branches, 13 parameters related to the dimensions of shoots and internodes were measured (Table 2). For each cultivar, measurements were made after fall of leaves on six shoots per tree. For leaves, 16 parameters related to the lamina and petiole were measured on 20 mature leaves per tree and cultivar (Table 2).

On fruits (second crop), 16 parameters related to the size, external and internal appearance, and juice quality were taken into account (Table 2). During the harvesting period,

TABLE 2: Morphological and pomological traits used for fig cultivar characterization.

Traits	Code
Branch	
Terminal bud length (mm)	TBL
Terminal bud diameter (mm)	TBD
TBL/TBD ratio	TBL/TBD
1-year-old shoot length (mm)	S1Y
Length of the 1st internode on S1Y (mm)	L1N1Y
Diameter of the 1st internode on S1Y (mm)	D1N1Y
Length of the 2nd internode on S1Y (mm)	L2N1Y
Diameter of the 2nd internode on S1Y (mm)	D2N1Y
2-year-old shoot length (mm)	S2Y
Length of the 1st internode on S2Y (mm)	L1N2Y
Diameter of the 1st internode on S2Y (mm)	D1N2Y
Length of the 2nd internode on S2Y (mm)	L2N2Y
Diameter of the 2nd internode on S2Y (mm)	D2N2Y
Leaf	
Leaf shape (1: calcarate; 14: cordate)	LS
Shape of lobes (1: lyrate; 4: spatulate)	SL
Leaf color (1: light green; 12: dark green)	LC
Leaf margin dentation (1: undulate; 5: crenate)	LMD
Apex shape (1: truncate; 3: acute)	AS
Density of hairs (1: none; 7: pubescent/dense)	DH
Petiole color (1: light green; 6: pinkish)	PC
Leaf length (cm)	LL
Leaf width (cm)	LW
Petiole length (mm)	PL
Petiole diameter (mm)	PD
Depth of basal sinus (mm)	DBS
Depth of lateral sinus 1 (mm)	DLS1
Depth of lateral sinus 2 (mm)	DLS2
Depth of lateral sinus 3 (mm)	DLS3
Depth of lateral sinus 4 (mm)	DLS4
Fruit	
Fruit weight (g)	FW
Fruit length (mm)	FL
Fruit diameter (mm)	FD
Neck length (mm)	NL
Neck diameter (mm)	ND
Ostiole diameter (mm)	OD
Fruit shape (1: spheroid; 10: pyriform)	FS
External color (1: violet black; 13: yellowish green)	EC
Skin cracks (1: cracked skin; 4: not cracked skin)	SC
Internal color (1: greenish white; 11: red)	IC
Fruit cavity (3: very small; 9: large)	FC
Skin thickness (mm)	ST
Flesh thickness (mm)	FT
pH	pH
Total soluble solids (°Brix)	TSS
Titrate acidity (%)	TA

pomological measurements and chemical analysis carried out on samples of 20 mature fruits per tree and cultivar were randomly collected. Total soluble solids (°Brix) were determined with a digital refractometer, PR-101 ATAGO, and

Norfolk, and titratable acidity (citric acid %) was determined by titrating fig juice with 0.1 M NaOH.

2.3. Statistical Analysis. For all parameters, analysis of variance (one-way ANOVA) was used to determine differences between cultivars. Comparison of the mean values was made using the Duncan's multiple range test ($P < 0.05$). Multivariate relationships among cultivars were revealed through a principal component analysis (PCA) using a correlation matrix derived from the significant characters. The squared Euclidean distance was used to perform cluster analysis. Statistical analyses were computed using SPSS 13.0 statistical software.

3. Results

3.1. One-Way ANOVA. The average values of parameters measured on branches are shown in Table 3. Analysis of variance showed highly significant differences between cultivars for all parameters except terminal bud diameter (TBD). The study of morphological characteristics of fig tree shoots allowed the differentiation in biology of some cultivars such as *Zidi* (ZD1), *Zidi Artab* (ZD2), and *Nemri* (NMR). Moreover, the most discriminating variables were terminal bud length (TBL), 1-year-old shoot length (S1Y), and 2-year-old shoot length (S2Y).

The averages of characters related to leaf are shown in Table 4. Analysis of variance showed highly significant differences between cultivars for all parameters. The variability of leaf characteristics was very important and allowed the distinction between some cultivars for several parameters such as leaf shape, leaf margin dentation, and leaf dimensions (LS, LMD, LL, and LW), petiole color (PC), and the depth of basal and lateral sinus (DBS and DLS1, DLS2, DLS3, DLS4).

The averages of characters related to fruit are given in Table 5. Analysis of variance showed highly significant differences between cultivars for all parameters. The most discriminating variables were fruit weight (FW) and fruit dimensions (FL, FD).

3.2. Principal Component Analysis. Principal component analysis (PCA) was performed taking into account shoots, leaves, and fruits. The eigenvalues obtained by PCA indicate that the first three components provide a good summary of the data. They explained 51.91% of the total variability. The first component, PC1, had large positive loading for shoot length of the two years (S1Y and S2Y), lengths of the 1st, and 2nd internode on S1Y (L1N1Y and L2N1Y), diameters of the 1st, and 2nd internode on SY2 (D1N2Y and D2N2Y), depths of basal and lateral sinus (DBS, DLS1 and DLS2), leaf dimensions (LL and LW), fruit weight and diameter (FW and FD), and ostiole diameter (OD) and negative loadings for petiole color (PC), fruit external color (EC), and total soluble solids (TSS). It represented 26.46% of the total variation (Table 6). This component separated the cultivars *Zidi* (ZD1) and *Nemri* (NMR) from *Soltani Abiadh* (SAB), *Thaggli Akhder* (TAK), and *Khenziri* (KNZ) based on shoot length, fruit size, depth of sinus, and ostiole diameter. It allowed

the distinction of cultivars *Bouharrag* (BHR) and *Wahchi* (WAH) from ZD1 based on petiole color, fruit size, and total soluble solids (Figure 1). The second component, PC2, explained 13.67% of the variability observed. It is positively correlated with fruit length and shape (FL and FS), fruit neck dimensions (NL and ND) and negatively correlated with terminal bud length (TBL), 1-year-old shoot length (S1Y), and fruit cavity (FC). This component allowed the distinction of cultivars *Zergui* (ZRG), *Bouhouli* (BHL), *Garai* (GRI), KNZ, and TAK from SAB, *Soltani Ahmar* (SAH), and *Hemri* (HMR) on the basis of fruit shape, fruit neck, and cavity (Figure 1). The third component, PC3, accounted for 11.78% of the total variability estimated from shoots, leaf, and fruit traits. It is positively correlated to the apex shape (AS), fruit length (FL), and titratable acidity (TA), and negatively correlated to the internode diameter of shoots of the two years (D1N1Y, D2N1Y and D1N2Y, D2N2Y), shape of lobes (SL), depth of basal sinus (DBS), and pH. This component allowed the differentiation of cultivars *Fawari* (FAW), SAB, and HMR with thin shoots and acid fruits from cultivars *Boukhobza* (BKB), BHR, ZRG, and SAH presenting thick shoots and low acid fruits (Figure 1). The projection of cultivars in the 1–3 plot exhibited the distinction of some cultivars with particular traits such as ZD1 and *Zidi Artab* (ZD2) and others which are grouped together and having similar characters such as (SAB, WAH, and KNZ) and (BKB, BHR, and ZRG) (Figure 1).

3.3. Cluster Analysis. Morphological and pomological analysis based on different characters showed high polymorphism with 17 fig cultivars. The dendrogram based on squared Euclidian distance clustered cultivars into five major groups (Figure 2). The first cluster was constituted with three cultivars: *Zidi*, *Zidi Artab* (ZD2), and *Nemri* (NMR). ZD2 was the most divergent from the other cultivars ($d = 20$). It is characterized by long internodes, spatulate, and large leaves, deep sinus, and acid fruit juice. The cultivars ZD1 and NMR meet at $d = 15.9$. They shared the long shoots, large fruits size, and leaves with serrate margin dentation. The cultivar *Soltani Abiadh* (SAB) formed the second cluster at $d = 16.9$. This cultivar had the shortest shoots, flattened buds, and cordate leaves with apex acute. The fruits were very long, cracked with high acid juice. The third group, detached at $d = 15.9$, was constituted with the unique cultivar *Fawari* (FAW). It is distinguishable, particularly, by short vegetative shoots and internodes, flattened buds, and dark green, large and crenate leaves, with deep sinus and yellow petiole. Fruit shape was oblate producing high acid juice. The cultivar *Soltani Ahmar* (SAH) formed the fourth cluster at $d = 12.85$ of the remaining genotypes. It has short and thin shoots with flattened buds. The fruits were relatively small, purple with very thin skin, and give low acid juice with high pH. The leaves were pubescent, serrate with widened lobes and rounded apex. The fifth group consisted of 11 cultivars with a maximum internal dissimilarity level of 10. This cluster was divided into three subgroups. The first subgroup, detached at $d = 10$, comprised the cultivar *Thaggli Akhder* (TAK). It is distinguished essentially from the remaining genotypes

TABLE 3: Mean values and significance degree of differences between fig cultivars for branch characteristics.

Cultivar	TBL (mm)	TBD (mm)	TBL/TBD	SIY (mm)	LIN1Y (mm)	D1N1Y (mm)	L2N1Y (mm)	S2Y (mm)	LIN2Y (mm)	D1N2Y (mm)	L2N2Y (mm)	D2N2Y (mm)
ZD1	9.70 ^{def}	5.27	1.82 ^{bcd}	240.30a	38.13a	11.17 ^{bc}	39.59a	10.33 ^{abc}	264.90a	36.05	14.38 ^{ab}	39.06 ^b
ZD2	7.73f	5.33	1.46e	166.65 ^{cd}	24.27 ^{cde}	13.61 ^{ab}	21.67 ^{defgh}	12.08a	164.42 ^{bcd}	30.28	15.62a	24.79 ^{bcd}
SAB	8.57 ^{ef}	4.69	1.82 ^{bcd}	125.29d	15.19e	7.69 ^d	16.33 ^{fgh}	6.51d	131.00 ^{bcd}	23.12	8.27h	18.52 ^d
SAH	8.30 ^{ef}	5.31	1.58 ^{de}	135.36 ^{cd}	18.18 ^{cde}	9.68 ^{cd}	15.32 ^{gh}	9.23 ^{bcd}	144.83 ^{bcd}	20.17	11.43 ^{cde}	20.58 ^{bcd}
TAB	11.29 ^{bcd}	4.86	2.32 ^a	157.08 ^{cd}	22.76 ^{cde}	8.32 ^{cd}	19.01 ^{efgh}	7.36 ^{de}	152.32 ^{bcd}	22.00	10.11 ^{efgh}	17.05d
TAK	10.77 ^{cdef}	5.15	2.12 ^{abc}	169.80 ^{cd}	18.64 ^{cde}	9.03 ^{cd}	19.94 ^{defgh}	9.04 ^{bcd}	122.24 ^{cd}	18.61	10.50 ^{efg}	18.55 ^d
NMR	11.82 ^{bcd}	5.92	1.98 ^{abcd}	234.74 ^{ab}	35.19 ^{ab}	14.63a	35.99 ^{ab}	10.76 ^{ab}	192.88 ^b	27.08	13.45 ^{bc}	30.70 ^{abc}
HMR	13.07 ^{abc}	5.95	2.29 ^{ab}	164.16 ^{cd}	23.68 ^{cde}	9.13 ^{cd}	23.65 ^{defgh}	9.13 ^{bcd}	172.96 ^{bc}	24.20	10.96 ^{def}	27.44 ^{bcd}
BHL	15.15a	6.48	2.33a	181.04 ^{cd}	20.44 ^{cde}	10.44 ^{cd}	25.70 ^{cdef}	9.86 ^{bc}	162.56 ^{bcd}	28.07	12.11 ^{cde}	31.11 ^{abc}
WAH	9.19 ^{def}	5.09	1.80 ^{cde}	155.29 ^{cd}	25.03 ^{cde}	8.75 ^{cd}	26.73 ^{bcd}	8.45 ^{cd}	138.06 ^{bcd}	30.07	8.99 ^{fgh}	32.02 ^{ab}
GRI	11.15 ^{cde}	5.18	2.14 ^{abc}	169.08 ^{cd}	24.32 ^{cde}	9.82 ^{cd}	24.28 ^{cdefg}	9.90 ^{bc}	145.97 ^{bcd}	20.15	10.14 ^{efgh}	23.69 ^{bcd}
KNZ	9.40 ^{def}	5.25	1.80 ^{cde}	187.30 ^{bc}	26.62 ^{bcd}	8.63 ^{cd}	29.87 ^{bcd}	9.12 ^{bcd}	157.47 ^{bcd}	26.47	8.38 ^h	41.50a
KRT	9.72 ^{def}	5.94	1.67 ^{cde}	133.84 ^{cd}	22.42 ^{cde}	11.52 ^{bc}	28.63 ^{bcd}	10.41 ^{abc}	127.76 ^{bcd}	27.67	12.65 ^{bcd}	27.40 ^{bcd}
BKB	10.03 ^{def}	5.89	1.89 ^{abcde}	147.82 ^{cd}	17.46 ^{de}	11.11 ^{bc}	13.81h	10.03 ^{bc}	122.07 ^{cd}	22.61	13.30 ^{bc}	19.82 ^{cd}
ZRG	14.08 ^{ab}	6.13	2.33a	154.10 ^{cd}	25.23 ^{cde}	11.11 ^{bc}	25.71 ^{cdef}	10.72 ^{ab}	147.05 ^{bcd}	23.23	13.07 ^{bcd}	23.64 ^{bcd}
BHR	8.30 ^{ef}	5.31	1.58 ^{de}	161.59 ^{cd}	18.18 ^{cde}	9.68 ^{cd}	15.32 ^{gh}	9.23 ^{bcd}	144.83 ^{bcd}	20.70	12.67 ^{bcd}	19.64 ^{cd}
FAW	9.51 ^{def}	4.54	2.10 ^{abc}	151.43 ^{cd}	27.78 ^{bc}	7.73d	33.77 ^{abc}	6.62 ^d	104.72d	22.59	8.52 ^{gh}	21.21 ^{bcd}
F-value	5.04 ^{**}	1.22 ^{NS}	3.93 ^{**}	3.12 ^{**}	4.03 ^{**}	3.82 ^{**}	6.15 ^{**}	5.76 ^{**}	3.42 ^{**}	1.72 ^{NS}	11.09 ^{**}	4.26 ^{**}

Means in each column followed by the same letters are not significantly different at $P < 0.05$ according to Duncan's multiple range test.

* Significant at $P < 0.05$; ** significant at $P < 0.01$; NS: nonsignificant; TBL: terminal bud length; TBD: terminal bud diameter; TBL/TBD: TBL/TBD ratio; SIY: 1-year-old shoot length; LIN1Y: length of the 1st internode on SIY; D1N1Y: diameter of the 1st internode on SIY; L2N1Y: length of the 2nd internode on SIY; D2N1Y: diameter of the 2nd internode on SIY; S2Y: 2-year-old shoot length; LIN2Y: length of the 1st internode on S2Y; D1N2Y: diameter of the 1st internode on S2Y; L2N2Y: length of the 2nd internode on S2Y; D2N2Y: diameter of the 2nd internode on S2Y.

TABLE 4: Mean values and significance degree of differences between fig cultivars for leaf characteristics.

Cultivar	LS	SL	LC	LMD	AS	DH	PC	LL (cm)	LW (cm)	PL (mm)	PD (mm)	DBS (mm)	DLS1 (mm)	DLS2 (mm)	DLS3 (mm)	DLS4 (mm)
ZD1	12.84a	2.53e	6.63de	5.00a	2.79abc	4.79cdef	3.00fg	29.45a	25.42a	99.05ab	7.67a	46.37a	88.25ab	89.43a	--	--
ZD2	12.76ab	3.86a	6.43def	4.05b	2.74abc	3.86ghi	3.48cdef	30.05a	26.10a	94.58abcd	7.20ab	53.18a	77.72bc	76.64b	--	--
SAB	11.85c	3.45abc	3.05h	2.20d	2.95a	2.60k	3.95bcd	22.57cd	19.60cd	75.12fg	6.15c	11.00gh	70.07cd	71.10bc	--	--
SAH	8.00d	3.00cde	3.30h	2.95cd	2.65abcd	4.70cdefg	5.05a	21.97cde	19.33cde	86.95bcdef	5.75cd	17.28fgh	86.23ab	88.36a	35.95bc	37.65bc
TAB	7.25ef	3.25bcd	9.05ab	2.95cd	2.60bcd	4.60defg	3.85bcd	21.06cdef	19.23cdef	102.78a	5.63cd	25.24cdef	78.02bc	73.44bc	34.16bc	31.92cd
TAK	12.25bc	3.85a	7.60bcd	2.70cd	2.65abcd	5.90ab	4.10bc	16.71h	16.10g	61.32h	5.08de	13.34gh	38.41e	39.97f	--	--
NMR	7.70de	3.20bcd	7.30cd	3.25bc	2.95a	3.60hij	2.25h	25.71b	22.34b	76.30fg	7.00b	22.78cdef	90.46a	93.01a	40.54ab	41.02ab
HMR	12.35abc	2.90cde	2.60h	2.45cd	2.85ab	5.30bcd	3.70bcde	20.08efg	18.07def	93.57abcde	5.64cd	11.10gh	69.87cd	67.80bcd	--	--
BHL	12.85a	2.95cde	2.95h	3.05cd	2.85ab	3.20ijk	3.50cdef	20.34defg	17.53efg	82.76def	5.57cd	18.88efg	59.02d	57.73de	--	--
WAH	7.55def	2.90cde	2.90h	2.85cd	2.90ab	5.50abc	4.10bc	21.21cde	19.52cde	85.44cdef	5.65cd	9.49h	70.30cd	71.89bc	28.58cd	28.58de
GRI	7.30ef	2.80de	3.55gh	2.35cd	2.85ab	3.00ijk	2.50gh	21.36cde	19.04cdef	84.70def	5.46cd	23.57cdef	67.44cd	68.47bcd	28.61cd	27.12de
KNZ	11.90c	3.10cde	4.85fg	2.85cd	2.95a	5.10bcde	3.95bcd	18.93fg	17.29fg	81.21ef	4.68e	--	48.17e	47.94ef	--	--
KRT	6.40g	2.70de	8.85bc	2.10d	2.40d	3.20ijk	2.60gh	21.58cde	19.82cd	102.05a	5.86c	21.06def	92.12a	88.76a	46.41a	45.92a
BKB	2.95h	2.95cde	5.65ef	2.25cd	2.80abc	6.30a	3.20ef	20.63def	18.86cdef	89.26bcde	6.12c	29.80bc	70.11cd	76.51b	38.81b	37.73bc
ZRG	7.55def	3.75ab	5.15ef	3.00cd	2.60bcd	4.20fgh	3.35def	23.23c	20.03cd	65.44gh	5.93c	26.31bcde	65.03d	63.47cd	23.81d	21.82e
BHR	7.10f	3.70ab	8.65bc	5.00a	2.50cd	4.30efgh	4.20b	18.20gh	17.26fg	80.92ef	5.81c	28.12bcd	71.07cd	70.33bc	31.13cd	31.04cd
FAW	7.35ef	3.05cde	10.45a	5.00a	2.70abc	2.90jk	5.20a	26.18b	20.89bc	97.32abc	7.43ab	33.57b	95.03a	91.55a	38.94b	40.49ab
F-value	267.18**	5.16**	23.52**	10.62**	3.12**	16.00**	16.24**	25.79**	18.64**	9.34**	14.60**	24.76**	16.58**	14.23**	7.43**	10.33**

Means in each column followed by the same letters are not significantly different at $P < 0.05$ according to Duncan's multiple range test.

* Significant at $P < 0.05$; ** significant at $P < 0.01$; NS: nonsignificant; ---: absence of basal sinus; --: absence of lateral sinus 3 and 4.

LS: leaf shape; SL: shape of lobes; LC: leaf color; LMD: leaf margin dentation; AS: apex shape; DH: density of hairs; PC: petiole color; LL: leaf length; LW: leaf width; PL: petiole length; PD: petiole diameter; DBS: depth of basal sinus; DLS1: depth of lateral sinus 1; DLS2: depth of lateral sinus 2; DLS3: depth of lateral sinus 3; DLS4: depth of lateral sinus 4.

TABLE 5: Means values and significance degree of differences between fig cultivars for fruit characteristics.

Cultivar	FW (g)	FL (mm)	FD (mm)	NL (mm)	ND (mm)	OD (mm)	FS	EC	SC	IC	FC	ST (mm)	FT (mm)	pH	TSS (° Brix)	TA (%)
ZD1	96.45a	60.27a	60.52a	5.31cd	14.70a	12.74a	3.79cdef	1.79hi	4.00a	8.84abc	4.37bcdef	1.18de	12.13g	4.65ef	13.23g	0.21fg
ZD2	51.83efg	47.03de	43.90gh	7.71bc	11.80bc	5.81defg	3.90cde	1.86h	1.76f	9.95a	3.10efgh	1.25cd	17.56abc	4.88cd	15.95ef	0.17h
SAB	59.10cde	61.50a	45.82fgh	14.43a	12.06bc	6.45cdef	4.50bc	11.95a	1.55f	9.00abc	1.90h	1.53ab	18.31ab	4.52gh	15.46f	0.25a
SAH	44.45ghi	51.09bc	39.93i	14.89a	13.54ab	5.50efg	5.65a	3.25f	3.45bcd	9.35ab	3.70defg	1.05e	16.01cde	5.10a	15.58f	0.18h
TAB	62.20cd	42.75ef	53.65c	—	—	8.22b	2.70g	12.00a	3.75abc	7.85c	6.40a	1.26cd	9.05h	4.89cd	15.56f	0.20fg
TAK	51.95efg	42.17f	50.26de	5.95cd	9.66cde	5.18fg	3.15efg	10.95c	2.90e	8.95abc	6.00ab	1.56ab	14.86de	4.45h	15.96ef	0.22bcdef
NMR	82.36b	46.57def	58.62ab	—	—	7.34bc	3.00fg	4.50d	3.75abc	8.25bc	4.60bcde	1.48b	19.07a	4.82d	16.48de	0.23abcde
HMR	57.83cde	58.12a	44.95fgh	10.90b	11.45bc	4.84g	5.00ab	3.70e	3.45bcd	8.80abc	2.20gh	1.43bc	18.90ab	4.59fg	17.56c	0.25a
BHL	64.53c	48.38cd	56.03bc	3.44d	10.58cd	5.08fg	3.15efg	2.65g	3.90ab	4.65e	5.70abc	1.05e	16.00cde	4.91bcd	15.36f	0.21cdef
WAH	41.67hij	43.50ef	44.27gh	5.92cd	10.97bcd	6.36cdef	3.40efg	11.40b	3.70abc	6.30d	2.80fgh	1.16de	17.85abc	4.95bc	19.02a	0.23abc
GRI	54.23def	45.86def	49.99de	3.91cd	7.55e	7.12bcd	2.70g	10.00c	3.60abc	3.05f	4.70abcde	1.05e	19.24a	4.29i	16.32de	0.21defg
KNZ	44.27ghi	44.31def	47.34efg	5.21cd	10.42cd	5.78defg	2.85g	11.30bc	3.35cd	8.50bc	5.00abcde	1.54ab	12.13g	4.97bc	18.32b	0.23abcde
KRT	52.77defg	46.36def	47.99ef	5.71cd	11.31bc	5.81defg	4.25bcd	10.35c	3.80abc	8.55bc	4.20cdef	1.19de	14.24ef	4.46h	17.20c	0.24ab
BKB	34.54j	35.20g	43.81h	4.26cd	8.34de	5.59efg	3.55defg	11.90a	3.70abc	9.00abc	3.10efgh	1.72a	11.34g	4.71e	15.48f	0.22bcdef
ZRG	37.38ij	43.06ef	45.49fgh	—	—	6.85cde	2.70g	1.85h	3.10de	6.65d	5.20abcde	1.63ab	15.45de	5.00ab	16.84cd	0.19gh
BHR	46.87fgh	42.76ef	43.98gh	—	—	6.44cdef	3.15efg	1.40i	3.80abc	2.00f	2.70fgh	1.55ab	12.40fg	4.91bcd	17.00cd	0.21efg
FAW	53.58defg	53.64b	52.99cd	6.34cd	11.78bc	6.41cdef	3.85cdef	2.15h	3.60abc	5.45de	4.10cdef	1.58ab	16.89bcd	4.55fgh	17.26c	0.25a
F-value	26.00**	26.30**	28.16**	21.32**	5.50**	23.00**	10.46**	977.45**	23.24**	29.54**	6.12**	13.13**	21.22**	46.17**	31.75**	10.00**

Means in each column followed by the same letters are not significantly different at $P < 0.05$ according to Duncan's multiple range test.

* Significant at $P < 0.05$; ** significant at $P < 0.01$; NS: nonsignificant; —: neck less fruit.

FW: fruit weight; FL: fruit length; FD: fruit diameter; NL: neck length; ND: neck diameter; OD: ostiole diameter; FS: fruit shape; EC: external color; IC: internal color; FC: fruit cavity; ST: skin thickness; FT: flesh thickness; TSS: total soluble solids; TA: titratable acidity.

TABLE 6: Definition the first three components of ACP made on the basis of morphological and pomological traits of fig cultivars.

Principal components	PC1	PC2	PC3
Cumulative, %	26.46	40.13	51.91
Proportion, %	26.46	13.67	11.78
Character*	Eigenvalue		
TBL	0.01	−0.56	0.23
SY1	0.71	−0.47	0.28
L1N1Y	0.82	−0.22	0.34
D1N1Y	0.61	−0.24	−0.46
L2N1Y	0.69	−0.19	0.53
D2N1Y	0.47	−0.38	−0.50
SY2	0.80	−0.16	0.20
D1N2Y	0.63	−0.16	−0.65
L2N2Y	0.45	−0.28	0.48
D2N2Y	0.61	−0.24	−0.66
SL	−0.29	−0.08	−0.58
AS	0.02	−0.05	0.57
PC	−0.41	0.50	0.00
LL	0.84	0.32	−0.11
LW	0.85	0.27	−0.19
PD	0.80	0.38	−0.12
DBS	0.74	0.06	−0.50
DLS1	0.60	0.55	−0.05
DLS2	0.60	0.54	−0.07
FW	0.75	−0.04	0.43
FL	0.35	0.62	0.52
FD	0.62	−0.40	0.48
NL	−0.18	0.74	−0.09
ND	0.41	0.67	0.18
OD	0.74	−0.09	0.20
FS	−0.01	0.85	0.00
EC	−0.57	−0.19	0.25
FC	0.10	−0.70	0.07
pH	0.04	−0.05	−0.35
TA	−0.28	0.17	0.71
TSS	−0.50	−0.02	0.16

* See Table 2.

by small leaves with spatulate lobes, shallow sinus, and short petioles. The second subgroup contained the cultivar *Bouharrag* (BHR) associated with a level $d = 7.85$ to the three cultivars *Thaggli Abiadh* (TAB), *Boukhobza* (BKB), and *Khartoumi* (KRT). They are characterized particularly by green leaves with widened lobes, fruits oblate, and sweetened juice. The third subgroup consisted of six cultivars with a maximum internal dissimilarity level of 7.61. Two subsets were identified in this third subgroup. Subset 1 composed of cultivars *Garai* (GRI) and *Bouhouli* (BHL) which associated between them at high level of similarity ($d = 2.37$) and rejoined the cultivar *Zergui* (ZRG) at $d = 7.61$. These cultivars presented conical buds, light green cordate leaves, and oblate fruits without neck. Subset 2 composed of cultivars *Khenziri*

(KNZ), *Wahchi* (WAH), and *Hemri* (HMR) having cordate leaves with widened lobes and serrate margin dentation, acute apex, and yellowish green petiole. The fruits give a sweetened juice. WAH and KNZ have the highest level of similarity observed ($d = 0.71$). The averages values of their main characteristics were similar.

4. Discussion and Conclusions

Morphological and pomological traits considered in this study showed a large variability for Djebba figs. Among the 45 variables analyzed, those of high discriminating level were leaf dimensions, shoot dimensions, petiole color and dimensions, depth of sinus, fruit shape and color, fruit weight and dimensions, ostiole diameter, and juice acidity. Results of the PCA based on shoots, leaf, and fruits traits showed that 51.91% of the total variability is accounted by the three PCs. Studies based on morphological and pomological traits conducted for pomegranate and peach founded, respectively, 49.29% [21] and 63% [22] of the total variability. Characters related to shoots, leaf, and fruits were powerful for studying the genetic diversity of domestic fig in Djebba. Results showed that, among these characters, some were good criteria for discriminating between cultivars. Similar results were reported by Salah et al. [9] in fig collection in the oasis of Nefzaoua and by Chatti et al. [13] in fig collection in Chott Mariem. In addition, morphological study based on the characteristics of fig trees has shown that the first three axes of the PCA amounted to 71.7% and 81.9% of the total variability, respectively, for leaves and fruit traits [15].

The cluster analysis showed high degree of diversity in the germplasm of Djebba fig. Among the cultivars with the same names, there is a similarity between *Soltani Abiadh* (SAB) and *Soltani Ahmar* (SAH) and between *Thaggli Abiadh* (TAB) and *Thaggli Akhder* (TAK). However, the levels of similarity observed were not always high enough to believe that they are synonymous. Both cultivars *Soltani* have almost the same characteristics of shoots and leaf and differed mainly by the fruit external color. Both cultivars *Thaggli* have a significant similarity in terms of shoots and fruit, while they have a divergence in leaf and petiole. Thus, for *Soltani* and *Thaggli*, it seems to be “polyclones cultivars” or “multiclones cultivars.” Both cultivars *Zidi* and *Zidi Artab* have many differences that were focused on shoots strength developed during the two years. Also, differences were noted for leaves and fruits. The hypothesis of homonymy between these two cultivars could be proposed.

Significant similarities were observed among the cultivars *Wahchi* (WAH), *Khenziri* (KNZ), and *Hemri* (HMR) and between *Garai* (GRI) and *Bouhouli* (BHL) for all morphological and pomological traits. Thus, it seems to be a case of synonymy between these cultivars.

The characters adopted in this study could be used to establish a catalog of local fig cultivars. The concordance between the results of PCA and cluster analysis showed that morphological and pomological analysis can provide reliable information on the variability in fig tree. The overall analysis of all traits brings out a wide diversity in plant material that

FIGURE 1: Plot of the first and third principal components resulting from a PCA of the fig cultivars using morphological and pomological characters.

FIGURE 2: UPGMA dendrogram (based on squared Euclidean distance) of fig cultivars performed using morphological and pomological characters.

may have important implications for genetic resources management. This diversity could be due to the antiquity of the culture in this mountainous region and particular cultural practices [7]. More interest has been focused on the diversity since it was known that the domestication of fig tree occurred independently in different areas especially around the edge of the Mediterranean. Thus, it is very interesting to conduct the proper management of these genetic resources. This can be addressed by different tools such as the establishment

of *ex situ* collections. The on-farm conservation can ensure the sustainability of these resources. It is also possible to explore the techniques of tissue culture as an alternative as future protocols for *in vitro* micropropagation and even cell-cultured fig are already developed [23–26]. Further studies are needed involving chemical, biochemical, and molecular markers [14, 16, 17, 19]. They would clarify the genetic variation at the molecular level in these cultivars.

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