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Genetic diversity of some accessions of Tunisian fig tree (*Ficus carica* L.) based in morphological and chemical traits

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ABSTRACT

In the present study a set of 17 fig (Ficus carica L., Moraceae) accessions originated from southeast of Tunisia were evaluated in terms of morphological and chemical traits. The results revealed that fig accessions have a high diversity. This diversity was investigated in terms of fruit shape index, skin colour, internal colour, fruit stalk shape, fruit skin cracks, fruit skin bands and fruit cavity. In fact, all genotypes showed a range of 23 to 59 g in fruit weight, 33 to 52 mm in fruit width and 2 to 11 mm in stalk length, 0 to 18 mm in neck length and 0.7 to 13 mm in ostiole opening. The chemical properties, reveal that total soluble solid varied from 17 to 29 ° Brix, titrable acidity changed from 0.1 to 1.9 g/ l and fruit polyphenols contents ranged from 1.4 to 3.2 mg/ 100 g equivalent acid Gallic. Using, morphological traits, some synonymies and homonymous were detected between accessions. Thus, many accessions were selected as promising for future breeding programs.

Keywords: Fig tree, *Ficus carica L.*, Genetic diversity, Accessions, Fruits, Morphological and chemical traits, Tunisia

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INTRODUCTION

Fig tree (*Ficus carica* L., *Moraceae*) is a gynodiocious fruit crop and it has been traditionally cultivated since ancient time under diverse agro-climatic [1]. Fig trees adapted very well to Mediterranean climate conditions. As well, it growns in Ethiopia, Syria, Iran, Iraq, Saudi Arabia, Canaries islands, Afghanistan and California [2]. Total world fig production is upper than 1 million tons/ year. Turkey's production of 285 000 t is 27 % of total world production [3]. Tunisian's production is about 29 000 t, it represents 3 % of total word production [4]. Production and consumption of fresh and dried fig fruits is increasing. The fact that fig fruit has different industrial usage fields such as syrup, juice, jam, spirit beverage, fig is also used like a traditional medicine [5, 6, 7].

The Mediterranean region has rich genetic resources of fig. For this reason, several selection studies have been carried out and many promising fig genotypes have been determined [2, 3, 9-17] . Maturity period, fruit weight, fruit sizes, skin colour, stalk abscission from the twig, firmness of the fruit skin, peeling of skin, ostiole width, fruit skin cracks, fruit shape, total soluble solids, titrable acidity are considered among the important fruit and plant characteristics for fresh fig selection programs [2, 3]. In addition, dried fig traits were: fruit weight, number of fruits per Kg, seed number per fruit, total dried matter [6, 18, 19, 20].

In Tunisia, local varieties are numerous and well adapted to agro climatic conditions [13, 23].. Interchange of varieties was very frequent between zones. Some studies have showed many synonymies and homonymous [12, 21]. Few varieties are being commercially propagated and used in new orchards [22]. During the last two decades, many new plantations were installed in the west middle region of Tunisia [23].

In South-East of Tunisia, it exists wide genetic diversity of fig in some microclimatic areas like *Matmata* mountain chain which represents a high genetic potential zone with extraordinary orchards of pluvial olive and fig trees. This region produces 34 % of the Tunisian figs production [4, 23].

For this reason, The objectives of the present work were to characterize 17 fig accessions from south-East of Tunisia using morphological and chemical traits, in order to identify the most promising ones and to contribute in selection and breeding future programs.

MATERIALS AND METHODS

Plant materials

This research was carried out on 17 fig accessions (Table 1) belonging to the experimental field in the '*Centre de Formation Professionnelle Agricole' ('CFPA') 'El Gordhab'* located in delegation of '*Ghomrassen'*- department of '*Tataouine'* in South-East of Tunisia during three consecutive years 2006, 2007 and 2008 and containing the majority of Tunisian accessions. It is worth to notice that South-eastern Tunisia is under arid climate, the annual precipitation varied from 100 to 200 mm, which is concentrated during autumn and winter. Seventeen accessions were studied ex situ (Table 1). They are most widely grown in South-east of Tunisia and were described morphologically in situ in a previous work [4, 15]. The plant material was propagated by hardwood cuttings. The experimental orchard was established in 5 replicates of 5 X 5 m in 2003. It was installed on sandy soils, irrigated with localized irrigation drip and received the same fertilization and standard cultural practices.

Table 1. Name, label, race and origin of fig accessions studied ex situ

N°	Accession	Label	Race	Pace of origin
1	Bayoudhi	BYD	Common type	Beni Kheddache
2	Bither Breba crop	BTH BC	Agricultural Professional San Pedro type	Bir Amir
3	Bither Main crop	BTH MC	San Pedro type	Bir Amir
4	Chetoui	CHT	Common type	Beni Kheddache
5	Croussi	CRS	Agricultural Professional Smyrna type	Beni Kheddache
6	Jemaâoui	JMA	Smyrna type	Zammour
7	Magouli	MAG	Smyrna type	Bir Amir
8	Makhbech	MKH	Common type	Bir Amir
9	Minouri	MNR	Agricultural Professional Smyrna type	Bir Amir
10	Ragoubi	RGB	Smyrna type	Zammmour
11	Romani	ROM	Smyrna type	Bir Amir
12	Safouri	SAF	Common type	Zammour
13	Tayouri Akhdhar	TAD	Agricultural Professional Smyrna type	Bir Amir
14	Tayouri Asfar	TAS	Smyrna type	Bir Amir
15	Tayouri Ahmar	TAH	Smyrna type	Bir Amir
16	Wedlani	WDL	Smyrna type	Zammour
17	Zidi	ZID	Smyrna type	Bir Amir

Morphological and chemical traits analysis

Twenty fruit from 17 accessions were collected along the sampling seasons 2006, 2007 and 2008. Morphological characters were done by adapting the International Plant Genetic Resources Institute (IPGRI) descriptors for fig *Ficus carica* [24]. A set of 24 (11quantitative and 13 qualitative) morphological traits were measured on 20 fruits/ accessions/ season: Fruit weight (FW) was measured with a scale sensitive to 0.01g. Fruit length (FL), Fruit diameter (FD), Stalk length (SL), Stalk diameter (SD), Neck length (NL), Neck diameter (ND), Ostiole diameter (OD), Opening Ostiole (OO), Skin thickness (ST) and Flesh thickness (FT) were measured by a digital compass (Borletti, 0 - 150 mm). By the same time 13 qualitative morphological characters and are measured on 20 fruits/ accessions/ season: Fruit shape (FS), External colour (EC), Fruit skin cracks (SC), Internal colour (IC), Drop at the

eye (DE), Fruit lenticels size (LS), Lenticels adherence (LA), Abscission of the stalk from the twig (AS), Shape of the fruit stalk (SS), Ease of peeling (EP), Firmness of the fruit skin (DD), Fruit skin bands (BC) and Fruit internal cavity (FC).

Concerning the chemical analysis, 10 fruits/ accessions/ season were analysed using the following 12 traits: pH (PH) was determined using a digital pH-meter (Thermo Orion A+, Hong Kong). Titrable acidity (TA): was measured by neutralization of fruit juice to pH 7.0 with 0.1 N NaOH and total acidity given as the quantity of citric acid (g/ l) in fruit juice [25]. Total Soluble solids (SS), expressed as ° Brix, were determined using a refractometer (OPTECH. MOD. RPU. 0- 30 Germany). The total content of dry matter (DM) was determined by its burning at the temperature of 105 °C and weighting by means of the analytical scales 'Technica of the values expressed in percentages [18] .The polyphenols (PP) was extracted and analysed in spectrophotometer. Its content was determined with Folin-Ciocalteu reagent using Gallic acid as a standard as described by Häkkinen et al. [26] and Solomon et al. [27] with some modifications. The total polyphenols were expressed in mg/ 100 g of fresh weight EAG (equivalence acid gallic).

Data analysis

One-way variance (ANOVA) was conducted for all the quantitative morphological and chemical characters. Differences between accession were tested using the Duncan's multiple range test at $p < 0.05$ [28] using SPSS for Windows (Version 12.0, SPSS Inc., Chicago, IL, USA). In order to find the main variation trends within fruit characters and to evaluate their correlation, means values were processed to perform multivariate analysis.

The principal component analysis (PCA) was performed on quantitative morphological and chemical characters; to reveal common principles in the data, to pool all sampling seasons (2006, 2007 and 2008), to study correlations among characters and establish relationship among accessions. The PCA solution was accepted when eigenvalues where superior than 1. Only factor loadings equal or greater than 0.4 were considered strong correlation between principal component and quantitative traits. The data for the qualitative characters was analysed statistically in a factorial correspondence analysis (FCA). FCA was performed to plot accessions distribution and to establish the correlations within characters. Hierarchical canonical analysis (HCA) was utilized to investigate the similarities and dissimilarities among the accessions with respect to morphological quantitative and chemical fruit characters. For classification, the squared Euclidean distance was used as the dissimilarity measure for Ward's method. These statistical analyses are commonly used for the characterization of fig genetic resources [4, 9, 12, 13, 17]. The software used for the previous analysis is Stat Box 6.0.

RESULTS AND DISCUSSION

Qualitative Morphological analysis

Values obtained for qualitative morphological traits were presented in table2. The fruit shape (FS) differed between the 17 accessions studies. 'Bayoudhi' and 'Minouri' were globose, 'Bither', 'Croussi', 'Makhbech', 'Romani', 'Tayouri Asfar' and 'Wedlani' were oblong and the rest were piriform. It is worth to notice that the distinction between colours remains subjective as objective measures are very complex. The skin colour (EC) ranged from yellow to purple black. In fact, 2 accessions had yellow skin colours, 5 were yellow-green. Five accessions were reddish-yellow, while 2 green, 2 greenish-red and 1 accession was purple black. Fruit skin cracks (SC) ranged from scarce longitudinal cracks for 12 accessions, 3 with minute cracks and 2 accessions had a skin cracks. Internal colour (IC) of fruits displays a large variation going from Light yellow for 'Jemâaoui' and 'Tayouri Asfar' to dark red for 'Ragoubi', 'Romani', 'Safouri', 'Tayouri Akhdhar', 'Wedlani' and 'Zidi' and the remaining accessions were reddish-white. The drop at the eye observed at maturation showed that only 4 accessions ('Croussi', 'Ragoubi', 'Tayouri Akhdhar' and 'Wedlani') had drop in the fruits. The fruit lenticels size ranged from small to large with adherence varied from detached to adherent. The abscission of the stalk from the twig was easy for 7 accessions and hard for the others. Fruit stalk shape was short and thick for 11 accessions and long and slender for 6 accessions. Ease of peeling is an interesting trait for fresh fig consummation. Generally, all the fruit accessions showed an ease of peeling. The fruit firmness varied among accessions and most of them present a skin firm or rubbery only 3 accessions ('Chetoui', 'Makhbech' and 'Tayouri Akhdhar') were soft. The fruit skin bands were absent for all the yellow and green accessions, while the skin bands for the rest were varied (red, yellow, green and purple). Finally fruit internal cavities were either absent, very small, small, medium and large (Table 2).

Quantitative Morphological traits

The average values for quantitative morphological characters of all sampling seasons in 2006, 2007 and 2008 were statistically different at a 5% level (Table 3), which reveals the wide genetic diversity within accessions. It can be seen from results of Duncan's multiple range tests that fruit weight (FW), fruit diameters (FD), skin thickness (ST) and flesh thickness (FT) characters had the highest values in 'Bither' breba crop and 'Zidi' accessions and the

Table 2. Qualitative morphological traits as recorded to describe 17 studied fig accessions

Accessions	FS	EC	SC	IC	DE	LS	AL	AS	SS	EP	FS	BC	FC
Bayoudhi	Globose with out neck	Yellowish green	Scarce longitudinal cracks	Reddish white	Absent	Medium	Detached	Easy	Long and slender	Easy	Rubbery	Absent	Medium
Bither BC	Oblate with neck	Yellowish green	Scarce longitudinal cracks	Reddish white	Absent	Medium	Semi- adherent	Easy	Short and thick	Difficult	Medium	Absent	None
Bither MC	Oblate with neck	Yellowish green	Scarce longitudinal cracks	Reddish white	Absent	Large	Semi- adherent	Hard	Short and thick	Easy	Firm	Absent	Small
Chetoui	Pyriform with massif neck	Yellow	Scarce longitudinal cracks	Yellowish red	Absent	Small	Detached	Easy	Short and thick	Easy	Soft	Green	Medium
Croussi	Oblate with neck	Greenish red	Skin cracks	Reddish white	Present	Medium	Semi- adherent	Hard	Short and thick	Easy	Firm	Red	None
Jemaâoui	Pyriform with massif neck	Reddish yellow	Minute cracks	Light yellow	Absent	Medium	Semi- adherent	Hard	Long and slender	Easy	Firm	Red	Small
Magouli	Sphéroïdale sans cou	Yellowish green	Minute cracks	Reddish white	Absent	Large	Semi- adherent	Easy	Short and thick	Difficult	Rubbery	Yellow	Small
Makhbech	Oblong with neck	Green	Scarce longitudinal cracks	Reddish white	Absent	Small	Detached	Hard	Long and slender	Easy	Soft	Yellow	Medium
Minouri	Globose with neck	Reddish yellow	Scarce longitudinal cracks	Reddish white	Absent	Large	Detached	Hard	Short and thick	Easy	Rubbery	Red	None
Ragoubi	Piriforme with long and curved neck	Reddish yellow	Scarce longitudinal cracks	Dark red	Present	Small	Semi- adherent	Hard	Long and slender	Easy	Firm	Red	None
Romani	Oblate with neck	Reddish yellow	Skin cracks	Dark red	Absent	Large	Detached	Hard	Short and thick	Medium	Rubbery	Green	Small
Safouri	Piriforme with long and curved neck	Yellow	Scarce longitudinal cracks	Dark red	Absent	Small	Semi- adherent	Easy	Long and slender	Easy	Firm	Absent	Small
Tayouri Akhdhar	Pyriform with massif neck	Green	Minute cracks	Dark red	Present	Large	Adherent	Easy	Short and thick	Medium	Soft	Absent	None
Tayouri Asfar	Oblong with out neck	Yellowish green	Scarce longitudinal cracks	Reddish white	Absent	Small	Semi- adherent	Hard	Long and slender	Easy	Rubbery	Absent	Very small
Tayouri Ahmar	Pyriform with massif neck	Reddish yellow	Scarce longitudinal cracks	Light yellow	Absent	Medium	Adherent	Hard	Short and thick	Difficult	Firm	Red	Large
Wedlani	Oblate with neck	Greenish red	Scarce longitudinal cracks	Dark red	Present	Large	Adherent	Hard	Short and thick	Easy	Medium	Purple	Very small
Zidi	Pyriform with massif neck	Purple black	Scarce longitudinal cracks	Dark red	Absent	Large	Detached	Easy	Short and thick	Easy	Rubbery	Green	Very small

FS: Fruit shape, EC: External colour, SC: Fruit skin cracks, IC: Internal colour, DE: Drop at the eye, LS: Fruit lenticels size, LA: Lenticels adherence, AS: Abscission of the stalk from the twig , SS: Shape of the fruit stalk, EP: Ease of peeling, DD: Firmness of the fruit skin, BC: Fruit skin bands, FC: Fruit internal cavity: Breba crop, MC: Main crop,

Table 3. Means, ''F'' values from one-way ANOVA and results of Duncan range test at the 5 % level of Morphological and chemical fruit traits of 17 studied fig accessions (average of seasons 2006, 2007 and 2008)

Accessions	FW g	FL mm	FD mm	SL mm	SD mm	NL mm	ND mm	OD mm	OO mm	ST mm	FT mm	DM %	SS °Brix	TA g/ l	pH	PP mg/ 100 g EAG
Bayoudhi	37.85	45.72	43.91	8.70	4.75	0.00	0.00	6.12	2.42	0.95	14.80	28.33	21.10	0.28	4.87	2.392
Bither BC	58.50	54.24	52.43	4.55	5.60	6.05	9.83	8.77	2.54	1.27	20.80	29.85	18.70	1.399	5.17	1.966
Bither MC	47.72	47.49	46.85	4.04	5.49	0.00	0.00	6.10	1.99	0.88	16.61	25.25	20.63	0.373	5.31	2.534
Chetoui	42.22	38.47	32.14	6.37	4.16	6.40	7.83	3.84	0.74	0.66	11.76	32.01	20.10	0.322	4.88	2.425
Croussi	36.32	41.95	44.50	6.50	5.98	3.20	5.49	5.99	2.61	1.03	14.66	29.54	19.80	0.294	4.97	1.936
Jemaâoui	23.37	57.37	34.14	9.35	4.93	14.42	8.95	4.53	1.76	0.79	13.10	29.2	17.43	0.187	5.19	3.256
Magouli	40.51	43.12	44.75	6.79	6.11	0.00	0.00	7.57	3.55	0.87	18.03	32.14	24.63	0.371	4.67	1.697
Makhbech	38.17	44.98	41.88	11.41	4.41	0.00	0.00	5.69	2.34	1.14	13.52	23.85	21.30	0.411	5.01	1.985
Minouri	26.61	38.35	38.89	2.60	4.59	6.12	8.08	6.04	2.59	0.82	13.86	24.33	18.55	0.325	5.15	2.156
Ragoubi	30.33	64.75	35.75	9.17	5.50	18.51	8.96	4.02	1.08	0.80	14.35	26.08	21.83	0.347	4.93	1.915
Romani	36.17	30.91	43.86	2.33	5.94	0.00	0.00	18.42	13.08	0.85	18.18	29.34	20.73	0.413	5.08	2.241
Safouri	23.90	49.08	36.52	5.21	3.96	9.84	6.98	3.82	1.10	0.81	14.02	23.94	21.90	0.394	4.84	1.478
Tayouri Akhdhar	48.67	49.08	41.14	3.06	4.03	5.96	6.37	6.19	2.30	1.15	18.02	30.91	26.36	0.270	4.83	1.762
Tayouri Asfar	25.59	47.02	33.35	6.85	2.92	2.08	0.89	4.37	1.87	0.60	14.33	30.84	29.66	0.294	5.25	1.658
Tayouri Ahmar	37.05	47.13	42.48	5.66	5.99	8.57	9.63	7.46	2.59	1.03	14.00	27.67	18.76	1.944	5.38	1.419
Wedlani	49.29	47.34	48.26	6.30	5.87	8.94	11.42	7.83	3.77	1.08	19.83	29.23	19.66	0.234	4.88	2.392
Zidi	59.21	61.36	48.63	7.35	7.81	11.19	11.09	9.44	4.25	0.70	21.02	31.32	21.56	1.057	5.08	3.966
F calculate	*35.113*	*13.876*	*30.763*	*7.942*	*18.606*	*63.232*	*46.837*	*10.932*	*11.701*	*3.640*	*11.521*	28.330	*12.579*	*4.750*	*10.147*	*9.547*
Significance	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*

FW: Fruit weight, FL: Fruit length, FD: Fruit diameter, SL: Stalk length, SD: Stalk diameter, NL: Neck length, ND: Neck diameter, OD: Ostiole diameter, OO: Opening Ostiole, ST: Skin thickness, FT: Flesh thickness, TA: Titrable acidity, SS: Total Soluble solids, DM: dry matter, PP: polyphenols
0.000: Statistically significant differences within accessions at. P<0.0

lowest means in 'Jemaâoui' 'Minouri', 'Safouri' and 'Tayouri Asfar'. Stalk characters like length (SL) exhibit the highest values in accessions 'Jemaâoui', 'Makhbech' and 'Ragoubli' and the lowest in 'Romani' and 'Tayouri Akhdhar'. As well, this character shows that abscission of the stalk from the twig during fruit picking. Ostiole opening (OO) varied from 0.74 ('Chetoui') to 13.08 mm ('Romani') (Table 3).

Chemical analysis

The chemical properties of fig accessions (Table 3) revealed that, dry matter content of fig ranged from 23.85 % ('Makhbech') to 32.14 % ('Magouli'). Dry matter content is one of the most important parameters that shows the commercial value if figs. In general, fig accessions with high dry matter amount content are suitable for drying ('Bayoudhi', 'Bither' main crop, 'Makhbech' and 'Safouri'). It's important to mention that fig with low dry matter content are very sensitive to transportation and handling ('Bither' breba crop, 'Jemâaoui', 'Magouli' and 'Zidi'). These one are preferably consumed as fresh fruits. Concerning the others chemical characters, pH of all fruits juices were ranged between 4.67 and 5.38. The titrable acidity values varied among the accessions. The lowest content was recorded in the fruits of the accessions 'Bither breba crop', 'Jemâaoui' and 'Tayouri Ahmar', and the highest one was mentioned in those of 'Makhbech', 'Tayouri Akhdhar' and 'Tayouri Asfar'. Soluble solid content of the fig accessions varied from 24.63 ('Magouli') to 29.66 ('Tayouri Asfar') ° Brix. It is important to notice that, sweet fig fruits are better suitable for producing dried figs. Total polyphenols in ripe fruits belong to the widespread class of gallic acid. Results showed that dark accessions were richer in polyphenols (Table 3), ranging from 3.256 to 3.933 mg/100g EAG of fresh matter for 'Jemâaoui' and Zidi, respectively. Polyphenols content of the Purple accessions varied from 1.915 ('Ragoubi') to 2.392 ('Wedlani') mg/100g EAG of fresh matter and the lighter ones present a lowest content of polyphenols (Table 3).

Principal component analysis

Table 4 illustrates a results relating to a definition of axes by principal components analysis. More than 61.90 % of the variability observed was explained by the first three components (PC1-PC3). The first component (PC1), accounting for 28.91 % of the total variance, is dominated by fruit characters, namely Fruit diameter (FD) and flesh thickness (FT). In the second component (PC2), fruit length (FL), Neck length (NL) and Neck diameter (ND) characterized by a high positive loading were the main contributors and explained 21.40 % of the variance. Finally, the third principal components (PC3), accounts 11.59 % of the total variance, is dominated by the chemical fruit properties like; dry matter content (DM) Total soluble solids (SS) and pH.

The PCA was discriminated the sampled accessions in four groups and one individual accession using the first two components (PC1 and PC2) and accounted for about 50 % of the total variability among the fig accessions, base on fruit qualitative morphological and chemical characters, respectively. Groups I and II are placed on the left-higher quadrant. But, cluster III is plotted on the central position. Finally, the fourth group is clustered on the right-higher quadrant (Fig. 1).

Correlation within traits

The correlation between quantitative morphological and chemical characters of 17 fig accessions were presented in Table 5. Significant Pearson correlation was found. These correlations are important for the agro industrial profitability. The highest correlation (0.80-0.97) was between NL-ND and OD-OO. This correlation can be explained by the great relationship of these characters. All accessions showed a positive correlation between fruit weight (FW) and FD, SD, FT, DM. These could be as fruits with larger in size would also have larger diameter, stalk, flesh and high dry matter content. The correlation within fruit length (FL) and neck length (NL) was determined to be $r = 0.73$. There was positive correlation between polyphenols content (PP) and fruit weight (FW). Polyphenols content are positive correlated with flesh thickness (FT). The ostiole diameter (OD) was correlated positively with Flesh thickness (FT) and Ostiole opening (OO). The highest correlation coefficients (0.82 and 0.97) were shown between NL-ND and OD-OO and can be explained by the great relationship of these characters (Table 5).

Table 4. Factor loadings for each trait on the component analysis of PCA analysis

	PC1	PC2	PC3
Eigen values	4.63	3.43	1.85
% of variance	28.91	21.41	11.59
Cumulative %	28.91	50.31	61.90
Fruit weight	0.34	0.04	0.30
Fruit length	0.02	**0.44**	0.24
Fruit diameter	**0.41**	-0.04	0.03
Stalk length	-0.16	0.22	0.19
Stalk diameter	0.36	0.11	0.08
Neck length	-0.04	**0.45**	0.02
Neck diameter	0.11	**0.43**	-0.04
Ostiole diameter	0.33	-0.27	-0.14
Ostiole opening	0.25	-0.33	-0.13
Skin thickness	0.21	0.02	-0.18
Flesh thickness	**0.40**	-0.03	0.26
Dry matter	0.06	-0.16	**0.50**
Soluble solids	-0.16	-0.22	**0.41**
Titrabe acidity	0.25	0.19	-0.26
pH	0.07	0.10	**-0.41**
Polyphenol	0.28	0.22	0.12

Factor loadings >0.4 are in bold.

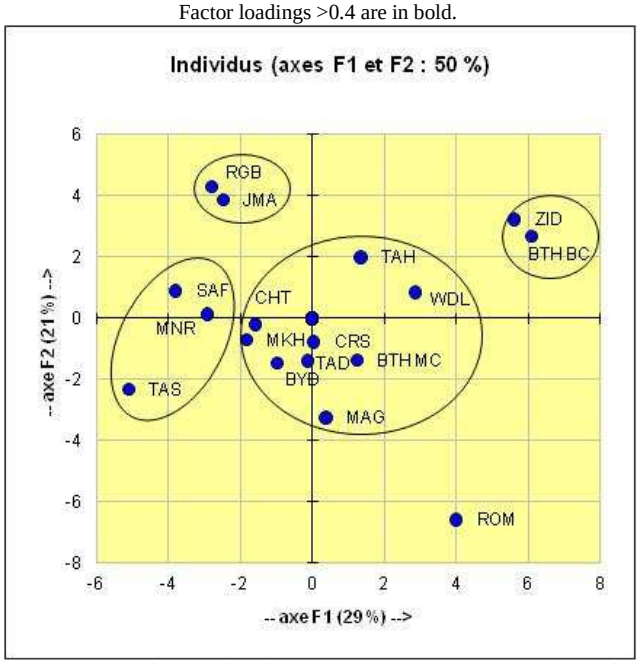

Fig 1. Projection of score of 17 fig accessions onto the plane (PCA) defined by the principal coordinates (1-2) of morphological and chemical traits

Table 5 Correlation coefficients between morphological and chemical traits of fruit for each accession

FW	1															
FL	0,10	1														
FD	**0,66**	0,03	1													
SL	-0,16	**0,46**	-0,22	1												
SD	**0,48**	0,23	**0,68**	-0,01	1											
NL	-0,13	**0,73**	-0,30	0,21	0,16	1										
ND	0,22	**0,50**	0,03	-0,06	0,29	**0,82**	1									
OD	0,27	**-0,39**	**0,52**	**-0,44**	**0,51**	-0,32	-0,17	1								
OO	0,08	**-0,47**	**0,34**	**-0,40**	**0,39**	-0,33	-0,27	**0,97**	1							
ST	**0,36**	-0,01	**0,62**	-0,07	0,14	-0,19	0,08	0,16	0,02	1						
FT	**0,66**	0,19	**0,82**	**-0,33**	**0,60**	-0,07	0,16	**0,58**	**0,43**	**0,36**	1					
PH	-0,10	0,09	0,04	-0,15	0,05	0,04	0,09	0,11	0,05	-0,06	-0,09	1				
TA	**0,35**	0,22	**0,41**	-0,12	**0,43**	0,14	**0,38**	0,23	0,03	0,30	0,27	**0,50**	1			
SS	-0,09	0,01	-0,24	-0,01	**-0,43**	-0,28	**-0,44**	-0,13	-0,06	-0,25	0,08	-0,25	-0,28	1		
DM	**0,36**	-0,10	0,00	-0,09	0,20	-0,18	-0,14	0,14	0,16	**-0,35**	0,23	-0,15	-0,16	**0,37**	1	
PP	**0,55**	**0,40**	**0,44**	0,06	**0,46**	0,21	**0,37**	0,22	0,08	0,06	**0,50**	0,24	0,23	**-0,42**	0,08	1
	FW	FL	FD	SL	SD	NL	ND	OD	OO	ST	FT	PH	TA	SS	DM	PP

FW: Fruit weight, FL: Fruit length, FD: Fruit diameter, SL: Stalk length, SD: Stalk diameter, NL: Neck length, ND: Neck diameter, OD: Ostiole diameter, OO: Opening Ostiole, ST: Skin thickness, FT: Flesh thickness, TA: Titrable acidity, SS: Total Soluble solids, DM: dry matter, PP: polyphenols
Highlighted values: Significant level at alpha 5%

Hierarchical canonical analysis

By applying hierarchical canonical analysis (HCA) to characters those retained by PCA in fig. 2, four groups (I, II, III and IV) were detected and composed by 2, 3, 9 and 2 accessions, respectively and one individual accession which was isolated at a dissimilarity level of 502.82. Among the studied accessions in this research, 'Jemâaoui' and 'Ragoubi' had high fruit length (FL), stalk length (SL) and neck length (NL). The second group included 3 accessions; they have very small fruits and the lowest ostiole opening. Cluster III contained 9 accessions; which are characterized by a medium fruit weight (FW) and fruit sizes (FL, FD). The fourth one constituted by 'Bither' breba crop and 'Zidi'. These accessions have a high fruit weight (FW), high fruit sizes (FL, FD), producing fig fruits with high neck diameter (ND) and low ostiole diameter (OD).An individual accession ('Romani') was differentiated, it was characterized by low fruit length (FL) and stalk length (SL), fruits are without neck (NL, ND) and had a large ostiole (OD, OO) (Fig. 2).

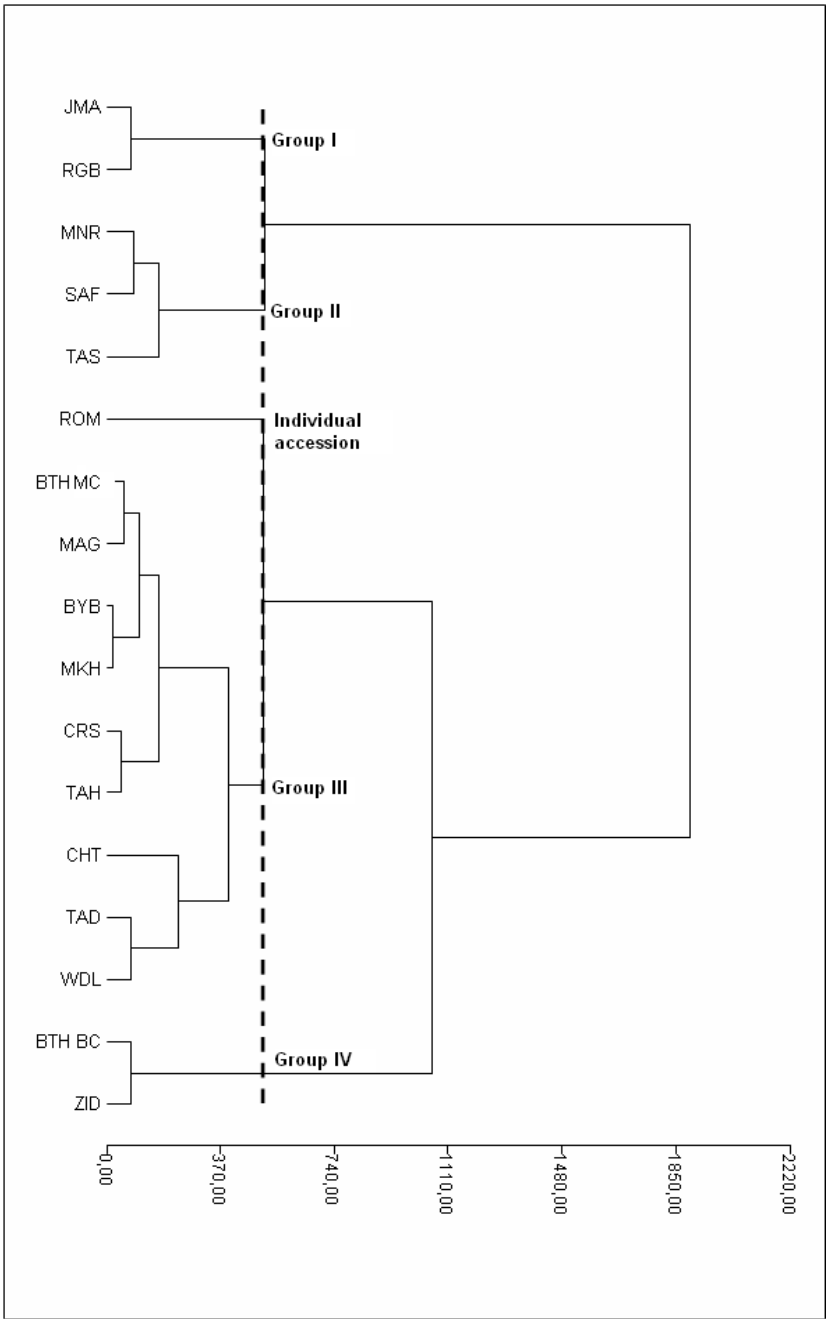

Fig 2. Hierarchical canonical analysis (HCA) of 17 accessions of *Ficus carica* according to the morphological and chemical traits

Fig accessions can be characterised using a combination of qualitative and quantitative morphological fruit characters, as well chemical fruits properties. Those traits are important and have been traditionally used for the

identification and classification of fig genotypes. Moreover, most of these traits are of economic interest and consequently usually serve as target characters for selection by growers and breeders [2, 16, 29].

In the present study, yield values of morphological and chemical characters were compared with those from other countries of the Mediterranean basin namely, Greece [29], Morocco [30], Turkey [3, 16], Tunisia [12], Israel [27], Italy [31] and Lebanon [17].

The fruit characteristics of fig accessions we studied in situ and were reported in a previous experiment [4, 15]. The current work carried out on accessions maintained in ex situ collection. Thus, the morphological and chemical values do not include an environmental component. The study was done on fig trees from the age of 4 years to till 7. Knowing that fig trees reached optimum production at 7 years old according to [3].

These accessions had a great diversity of fruit shape, skin colour, skin cracks, flesh colour, stalk shape, ease of peeling, fruit cavity, *etc*. Fruit shape is very important for packaging and transportation [11]. The most suitable fruit shape is globose [16, 32]. The fig fruit skin colour ranged from yellow to black. Ease of peeling is critical for local global customer preferences [16, 33].

Fruit weight is very important for fresh consumption [16]. In similar studies of fig cultivars, the fruit weights ranged from 30 to 90 g [10] and 28 to 107 g [2]. However, in this study, the fruit weight is between 23 and 59 g. These values are lower than those cited before, can be explained due to the fact that plants were very young.

To quantify fruit sizes (diameter, length, stalk length, neck length), our results were comparable with those of many authors [3, 2, 10, 16, 33].

A large ostiole is an undesirable property as pests and pathogens enter the fruit [34]. Ostiole width was similar with studies reported as 1.5 -4.0 mm [35] and 1.0-9.4 mm [2].

Chemical properties (pH, acidity titrable, total soluble solids, dry matter and polyphenols) were in agreement with other reports [9, 16, 18, 31, and 35]. The sugar/acid ratios are one of the most important factors in fruit taste [36]. Preferred ratio will vary with the use of fig fruits, but ratios will provide guidance in selecting accessions for specific uses. In fact, accessions with high soluble solids/acid ratios produce high dried for quality. Result show that figs with dark skin colour had higher polyphenols than light one [27]. Again, polyphenols are localized in the peel and pulp [31].

CONCLUSION

The present findings on the morphological and chemical characterization of Tunisian fig accessions that exhibited diverse patterns of fruit characteristics could be the basis of a programme preferentially assisted by a molecular genetic marker approach, aiming at the genetic improvement of this species, and at the optimization of its fresh and dried exploitation.

Moreover, the development of varieties more adapted to industrial uses must take in consideration a strategy that prevents genetic erosion. The commercial plantations that took place in south- eastern Tunisia has been based on a limited number of accessions ‘Bither’, ‘Zidi’, ‘Makhbech’, ‘Bayoudhi’, thus the reduction of the diversity if this species in this region is a real risk. Furthermore, the evaluation of the diversity in fig trees dispersed all over the country is a fundamental step for the implementation of a conservation strategy. A varietal collection contained 130 fig and 20 caprifig accessions was established in South-East of Tunisia, which represents Tunisian local germplasm.

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