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Original article

Characterization of local fig clones (*Ficus carica* L.) collected in Northern Morocco

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Summary

Introduction – **A survey of family yards and traditional orchards was conducted to collect and evaluate phenotypic variation of fig (*Ficus carica* L.) accessions grown in Northern Morocco.** *Materials and methods* – **20 local farmers were surveyed to identify different fig accessions grown in three northern regions of Morocco (Taounate, Ouazzane, and Meknes). The survey targeted the varietal profile of cultivated fig trees, propagation methods and selection and denomination criteria. Fruit samples were collected, and their pomological and colorimetric traits were characterized. In total, 33 descriptors established by IPGRI were used, 22 of which were qualitative and 11 of which were quantitative.** *Results and discussion* – **Pomologic and colorimetric analysis revealed a wide range of variation and highly significant level of variability ($p < 0.05$) among all sampled genotypes. The principal component analysis revealed two mean groups with a total inertia of 78.7% based on the quantitative traits. While three distinctive groups with a total inertia of 90.92% were found based on pomological traits. Pomology analysis exhibited a dominance of both globose and rounded shapes. Most of the genotypes have skin ribs and did not present the drop at the ostiole. Hierarchical ascendant classification (HAC) performed on all 38 variables (color and pomological descriptors) resulted in two main clusters. With the exception of 'Ghoudan' and 'Ghani', all genotypes with the same denominations were clustered into the same group.** *Conclusion* – **This work revealed a mislabeling within the local fig germplasm according to morphological, pomological and colorimetric traits of collected figs. This problem was found to be correlated to denomination criteria used by local farmers. Indeed, the combination of pomological and colorimetric parameters exhibited an important level of discrimination.**

Keywords
germplasm characterization, fig diversity, fig denominations, skin color, survey

Significance of this study

What is already known on this subject?

- In Morocco, the cultivation of fig trees is of particular importance. However, the varietal diversity remains confusing and undocumented.

What are the new findings?

- Moroccan figs have a polyclonal origin with large varietal confusion due to mislabeling problems that hinder the fig germplasm development.

What is the expected impact on horticulture?

- The findings are of importance for planning fig genetic resources inventory, preserving the existing genetic variability and establishing national collections.

Introduction

Fig (*Ficus carica* L., $2n = 26$) is a deciduous tree. It belongs to the *Moraceae* family. The genus *Ficus* has more than 700 species. For millennia, figs have been cultivated for their edible fruits, both fresh and dry, in close association with olive and grapevine (Gaaliche *et al.*, 2012). Fig trees are probably the first domesticated trees of the Neolithic Revolution, about a thousand years before the cereals. It was previously reported that the fig has been domesticated five thousand years earlier than millet and wheat (Hirst *et al.*, 1996). Since that, scientists have been attended to detect and study the genetic variability of fig (Khadivi *et al.*, 2018). They are one of the earliest cultivated fruit trees in the world. It is a widespread species commonly grown, especially in Mediterranean basin. Nowadays, fig is a common fruit worldwide due to its increasing international trade, as consumers seek continuously for fresh quality products from less familiar fruits (Solomon *et al.*, 2006; Slantar *et al.*, 2011; Wojdyło *et al.*, 2016). World fig production is mainly concentrated in the Mediterranean countries with Turkey as a leader in the world amounting to about 267,471.65 tonnes (average 1994–2016), followed by Egypt (202,074.52 t) and Morocco (82,878.74 t) (FAO, 2016). In Morocco, it has been cultivated as a secondary crop. However, it recently gained popularity and interest due to its high economic and nutritional values (Badgujar *et al.*, 2014), and its resilience in a context of climate change (Rival and McKey, 2008).

Fig tree is easily propagated via the rooting of stem-cuttings, and its varietal distributions are named and selected by local farmers (Fachinello *et al.*, 2005). Local clones are defined managed by farmers in a given geographical area

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(Niebla, 2004). Farmers distinguish these clones based on either qualitative criteria or the proper given names associated with a set of pruning, pollination and protection practices that make them similar regardless of being genetically far from each other (Hmimsa *et al*., 2017). Traditionally, the genetic diversity has been evaluated based on conventional morphological and pomological markers. Although their expression is strongly influenced by environmental conditions and agronomic practices, they are highly recommended as a first step before moving to more in-depth biochemical or molecular analysis (Hoogendijk and Williams, 2001). The inventory of plant material based on morphological and pomological traits is important for managing genetic resources, maintaining the existing genetic variability, and establishing a germplasm collection (Podgornik *et al*., 2010). Authors stress the relevance of morphoagronomic variability in the identification and breeding programs of cultivars, and claim such analysis should be performed before molecular studies are carried out (Podgornik *et al*., 2010; Khadivi-Khub *et al*., 2012; Djordjević *et al*., 2014; Khadivi *et al*., 2018). This characterization usually involves a wide range of data which include both qualitative and quantitative traits (Khadivi-Khub *et al*., 2012). In agricultural sciences, the application of multivariate statistics is fundamental, and the most used techniques are the principal component analysis and cluster analysis.

In Northern Morocco, fig planting is ancestral. Identified in historical sources as a main fig cultivation and production region (l'Africain, 1980; Oukabli, 2002). Numerous studies have shown that most of the cultivated varieties in traditional orchards have polyclonal origin with large varietal confusion due to mislabeling problems (synonymy and homonymy) (Khadari *et al*., 2004, 2005; Ater *et al*., 2008; Achtak *et al*., 2009; Khadari, 2012; Hmimsa *et al*., 2012). This varietal confusion has been highlighted using agro-morphological descriptors and genetic markers. However, to the best of our knowledge, neither biochemical markers nor CIE color coordinates were used as a tool to solve this problematic. Thus, this study is aiming to: 1) make an inventory of local fig varieties most cultivated in different orchards and home gardens in the northern regions of Morocco; 2) describe and evaluate the collected plant materials according to morphological, pomological, and colorimetric (CIE coordinates) characteristics; and 3) determine the amount of diversity among genotypes.

Materials and methods

Survey and plant material collecting

A random sample of 20 local farmers from randomly selected sites (Taounate, Ouzzane, and Meknes regions) (Figure 1) was surveyed using a standardized survey questionnaire. The surveyed area is known for its calcimagnetic soil. The precipitation averages 655 mm, with an average temperature of 26.5 °C.

The interviewed are the household head or the persons who own and manage a traditional orchard. Questions focused on fig varieties planted, their origin, as well selection methods adopted by each farmer. In parallel, samples of 23 genotypes that are mainly cultivated in the area were collected during their maturity period (June–October) (Table 1). Figs were considered fully ripened when the receptacle had three-fourths reddish-purple coloration and when they were easily separated from the twig. They were picked randomly

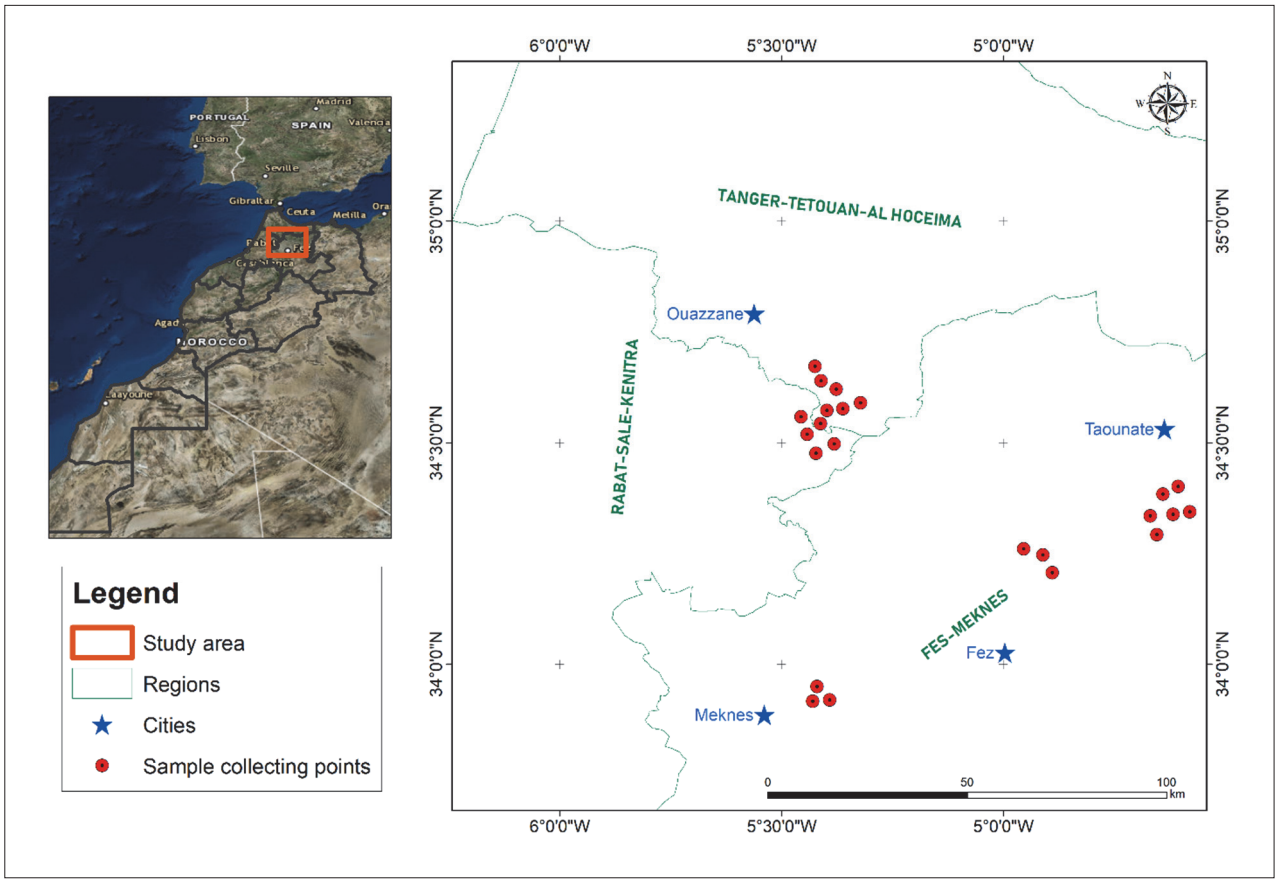

Figure 1. Map representing the area of survey and points of samples collection.

from a single tree at different positions around the canopy and at a height of 160 cm. Each sample was labeled according to its local given name and its location.

Morphoagronomic characterization

Fig plant samples were characterized using 33 descriptors established by International Plant Genetic Resources Institute (IPGRI), 22 of which were qualitative and 11 of which were quantitative (IPGRI, 1997). Fifteen replications per sample were considered. Quantitative measurements (*i.e.*, fruit dimensions, skin thickness, ostiole white, *etc.*) were measured using a digital caliper (Digital Caliper 68,202, ML Tools and Equipment, Burlingame, CA).

Skin color measurements were obtained from two spots located on opposite sides of the equatorial region of the fruit using a NH310 colorimeter (Shenzhen 3NH Technology, China). The Chroma meter was calibrated to a white calibration plate. The mean of the two measurements was considered as one replicate. Chromatic analysis was carried out following the CIE (Commission International de l'Eclairage) system of 1976. Total soluble solids (TSS) were determined using a digital refractometer (Atago Inc., Japan). Fifteen replications per sample were considered for both skin color and TSS.

Statistical analysis

Data analysis was performed using SPSS statistical software (version 22.0). Analysis of variance (ANOVA) was performed to test significant differences among the samples collected. Duncan test was done to compare sample means at $p < 0.05$. Correlation coefficients and their levels of significance were calculated using Pearson correlation. Principal component analysis was carried out using correlation matrix and Varimax rotation method with Kaizer normalization. Hierarchical ascendant classification was performed using the Euclidean distance, as being the most common in similar studies and of which the results are greatly influenced by variables that have the largest value (Hill and Lewicki, 2007). We concluded that the large variation of morphologic and biochemical attributes was related to cultivars while small variation was attributed to the environment.

Results and discussion

Survey analysis

The survey questions targeted mainly the 1) varietal profile of cultivated fig trees; 2) propagation methods; and 3) selection and denomination criteria. The survey results showed that the most dominant varieties in the study area were: 'Nabout', 'Ghoudan', 'El Quouti lbied', 'Zerqui,' 'Ghani', 'Sbeti', 'Tabli', 'Lamtal', 'Mssari', 'Ounq Hmam', 'Arguil', 'Chaari', and 'Jaadi'. It is worth mentioning that two different local dialects in the area are increasing nominations diversity.

According to our survey results, these varieties were all propagated using hardwood stem cuttings. This method is

Table 1. List of qualitative and quantitative IPGRI *Ficus carica* L. descriptors and colorimetric coordinates included into morphological analysis of fig collected samples.

IPGRI descriptor	Fruit shape (7.4.1)
	Fruit shape according to the location of maximum width (7.4.2)
	Fruit apex shape (7.4.3)
	Fruit volume (measured by displacement of water) (7.4.5)
	Fruit width (7.4.5) & length (7.4.7)
	Fruit neck length (7.4.8) & width (7.4.8a)
	Uniformity of fruit size (7.4.9) & fruit symmetry (7.4.10)
	Ostiole width (7.4.11)
	Color of liquid drop at the ostiole (7.4.13)
	Ostiole color (7.4.14)
	Fruit stalk length (7.4.16) & width (7.4.16)
	Abscission of the stalk from the twig (7.4.18)
	Ease of peeling (7.4.19) & fruit ribs (7.4.20)
	Fruit skin cracks (7.4.21) & fruit skin thickness (7.4.23)
	Fruit skin ground color (7.4.26) & over color (regular bands) (7.4.27)
	Fruit skin over color (irregular patches) (7.4.27)
	Fruit lenticels quantity (7.4.28), color (7.4.29) & size (7.4.30)
	Color formation in the flesh (7.4.31)
	Pulp internal color (7.4.32), texture (7.4.34) and juiciness (7.4.35)
	Fruit cavity (7.4.36)
Other descriptors	Abundance of seeds & size
	Total soluble solids TSS (°Brix determined with a digital refractometer expressed in % of sugar)
CIE* coordinates	L* = lightness
	a* = redness to greenness
	b* = yellowness to blueness
	c* = color intensity calculated as $C = (a^2 + b^2)1/2$
	h° = Hue°, calculated using the formula $hue° = \tan^{-1}(b/a)$

Numbers between brackets refer to No. of descriptor given by IPGRI.

* International Commission on Illumination (Commission Internationale de l'Eclairage [CIE]).

generally basic and does not require high technicality. Understanding the denomination criteria adopted by local farmers implies taking into account the technical and social practices related to the selection, usage and maintenance of diversity. In fact, different criteria are involved in fig varieties denomination. Local farmers refer particularly to fruit skin color, shape (width and neck length), taste and flavor to describe and denominate their plant material. For example, the variety 'Ghoudan' indicates the darkness of skin color and 'Zerqui' refers to the blueness of fruit skin. 'Ounq Hmam' refers to the length of the neck (long fruit neck) and means in the local dialect "pigeon neck." Denomination of 'Jaadi' describes genotypes having ribs over the skin. 'Nabout' is a generic term which means "tree that grows spontaneously" (Hmimsa *et al*., 2012).

Previous research by Hmimsa *et al*., (2012), counted about 133 denominations in the Rif Mountains. They reported 191 lexemes corresponding to 133 morphotypes or varieties reproduced by vegetative propagation in the Rif area. Furthermore, they concluded that names may vary from one locality to another for the same morphotype, which explains the problem of mislabeling that characterized the cultivated varieties in the Rif Mountains.

Morphological and biochemical analysis

Descriptive data are summarized in Tables 2 and 3. Among the two fruit shapes observed, the "globose" shape was the most dominant (74%) with an index (width/length) varying from 0.91 to 1.1. Only six genotypes were oblong with index values between 0.73 and 0.89. The majority (64%) of studied genotypes had a symmetric shape of fruit and did not have a drop at the eye (78%). The fig shape and its index are of great importance when it comes to trade. The globose shape is preferred for its suitability for packaging and transportation (Benettayeb *et al*., 2017) (Tables 2 and 3).

Most samples were relatively easy to peel (69%). The skin cracks were mostly absent. However, the ribs on the fig skin were abundant. More than 95% of samples had a color varying from yellow to green and purple. Cavity was absent for most genotypes (80%). Pulp texture was coarse with a percentage of 70%, while the predominant internal color (pulp color) was dark-red (52%) and purple (22%). The majority of analyzed genotypes had a white ostiole (56%), and were less juicy (65%). Most genotypes had a medium seed size (Tables 2 and 3).

Analysis of variance showed significant differences ($p < 0.05$) among evaluated genotypes for quantitative variables. Thus, a very important range of variation was observed in the figs' pomological traits, especially the weight which varied from 5 to 71.23 g, with an average of 30.8 g. The genotype 'Tabli_PS19' recorded the highest average weight (51.5 g) (Tables 2 and 3). According to previous works, this character ranged between 24 and 58 g (Aljane *et al*., 2008), 30 and 85 g (Podgornik *et al*., 2010), and 12.3 and 99.4 g (Çalişkan and Polat, 2012). The fruit size is an important trait that reflects how the fig trees were maintained (Tamboli *et al*., 2015). However, this character is usually negatively impacted by the fruit load on the tree. Besides the genetic effect, fruit weight depends also on the growing location, as well as the interaction between the genotype and the maturity stage which is properly explained by in the index of maturity (total soluble sugar/titratable acidity) (Benettayeb *et al*., 2017).

The length and width of the fig neck varied, respectively, from 2 to 11.8 mm and from 2 to 20 mm. Low correlation coefficients (between $r^2 = 0.22$ and $r^2 = 0.86$), but significant ($p < 0.05$), were generally observed between weight, fruit dimensions, neck and stalk dimensions. Regarding other fruit dimensions, length varied from 20.2 to 47.6 mm, while width ranged from 21 to 57 mm. Index of refraction varied significantly from 15 to 48 of sugar (°Brix), with an average of 23% (Tables 2 and 3). The genotype 'Ounq Hmam_PS14' recorded the highest value of total soluble solids (TSS), for which average concentration was 40% (Table 3). Gozlekci (2003), reported TSS between 13 and 29%, whereas Ateyyeh and Sadder (2006), found that the TSS varied between 21.61 and 26.75%. This parameter negatively and significantly correlated to the weight, width and the volume ($r^2 = -.341^{**}$; $r^2 = -.329^{**}$ and $r^2 = -.316^{**}$ respectively), which means that culti-

Table 2. Descriptive analysis and analysis of variance of quantitative characteristics of evaluated samples (*N*=23).

	Minimum	Maximum	Average	Standard deviation	Mean square	Homogeneous groups number
Weight (g)	5.19	71.23	30.82	10.98	24.800***	9
Fruit length (mm)	20.26	47.64	33.32	4.55	14.275***	11
Fruit width (mm)	21.81	56.31	37	5.66	24.258***	8
Fruit stalk length (mm)	0	38.39	6.79	3.973	6.629***	8
Fruit stalk width (mm)	0	8.13	4.52	1.05	6.287***	10
Fruit neck length (mm)	2.48	11.77	6.49	1.99	12.897***	8
Fruit neck width (mm)	2.22	19.75	7.47	2.83	31.766***	10
Ostiole width (mm)	0.00	8.20	3.95	1.72	13.744***	8
Fruit skin thickness (mm)	0.98	5.29	3.01	0.97	16.746***	10
Total soluble solids (TSS) (%)	15.30	48.00	23.14	5.78	4.997***	6
Fruit volume (cm^3)	10.00	50.00	28.20	8.92	2.727**	5
L*	20.28	84.48	51.34	18.81	120.75***	12
a*	-7.18	19.93	2.58	6.32	54.56***	14
b*	-1.55	51.78	23.12	16.70	152.17***	11
c*	2.15	52.12	25.60	14.32	140.42***	11
h°	1.28	360	97.3	87.87	21.32***	5

*** Significant differences at level of $P < 0.001$.

Table 3. Description of some morphological and pomological characteristics and fruit skin color in prospected genotypes. Average values ± standard error of mean are presented.

Genotypes	Fruit shape	Fruit symmetry	Easy of peeling	Weight (g)	Length (mm)	Stalk length (mm)	Neck length (mm)	Ostiole width (mm)	Skin thickness (mm)	TTS (%)	L*	c*	h°
Arguil_PS8	Globose	Ovoid	Easy	22.13± 4.5	26.54± 2.6	5.74± 1.5	-	3.58± 1.2	2.99± 0.2	23.53± 1.8	30.8± 6.1	10.77± 4.4	22.67± 6.8
Chaari_PS15	Globose	Ovoid	Hard	37± 9	34.16± 2.5	6.65± 1.1	-	4.15± 1	1.81± 0.3	20.77± 1.8	32.89± 1	10.66± 1.7	7.89± 0.4
ElQuoti Lbied_PS11	Globose	Ovoid	Medium	34.1± 4.7	35.4± 2.2	7.87± 0.8	-	4.6± 0.8	4.98± 0.3	20.2± 1.7	57.26± 5.5	34.05± 7.8	98.26± 1.6
ELQuoti Lbied_PS20	Globose	Ovoid	Easy	36.13± 7.8	33.6± 3.2	3.63± 0.3	6.64± 2	4.9± 0.6	3.05± 0.6	26.93± 4.8	48.8± 1.7	37.29± 1.1	95.72± 2.8
ElQuoti Lbied_PS3	Globose	Ovoid	Easy	41.67± 6.1	34.2± 2.3	3.65± 0.8	8.34± 1.3	4.88± 1	3.79± 0.4	18.33± 2.1	70.33± 6.7	34.23± 1.0	97.36± 1.7
ElQuoti Lbied_PS6	Globose	Ovoid	Hard	28.67± 4.9	33.23± 2.7	6.06± 1.5	5.67± 0.7	4.06± 0.9	3.74± 0.5	22.8± 2.7	73.15± 2.6	36.29± 2.4	102.1± 0.9
Ghani	Globose	Pyriform	Easy	34.79± 7.7	35.22± 4	14.64± 7.6	9.01± 1.9	6.06± 0.7	2.73± 0.4	17.57± 2	48.69± 4.4	22.09± 3.8	88.92± 3.2
Ghani_PS2	Globose	Ovoid	Hard	25.01± 5.9	32.73± 4	10.25± 4.2	-	4.91± 1.2	2.56± 0.4	23.17± 1.7	62.84± 9.7	38.85± 1.9	97.58± 1.2
Ghoudan 2227	Globose	Ovoid	Medium	37.25± 6.2	36.14± 3.3	9.25± 2.1	-	5.63± 1.9	3.24± 0.3	20.23± 1.8	34.91± 6.3	15.83± 2.9	19.24± 4.7
Ghoudan_PS1	Oblong	Pyriform	Hard	15.1± 3.8	33.56± 3.3	8.97± 4.7	-	1.66± 1.4	2.09± 0.3	29.63± 1.3	21.75± 0.7	3.5± 0.91	361.71± 3.4
Ghoudan_PS17	Oblong	Pyriform	Medium	25.46± 4.3	38.56± 3.2	6.87± 2.4	-	5.94± 1.1	4.61± 0.6	21.6± 3.5	28.19± 4.1	4.56± 1.8	209.16± 44.1
Ghoudan_PS4	Oblong	Pyriform	Hard	25.69± 3.6	39.11± 2.2	3.33± 0.6	-	3.06± 0.7	2.96± 0.3	21.47± 1.1	27.97± 4.4	3.62± 1.4	187.64± 61.3
Jaadi_PS16	Globose	Ovoid	Easy	28.24± 6.3	29.05± 3.1	5.7± 0.8	2.8± 0.1	4.49± 0.7	2± 0.2	18.03± 0.8	51.47± 7.8	25.37± 6.1	74.78± 6.5
Lamtal_PS9	Globose	Ovoid	Easy	29.52± 4.7	32.03± 1.7	4.25± 1.2	3.82± 0.7	4± 0.7	2.91± 0.3	21.1± 4.2	78.45± 3.7	33.01± 1.8	101.51± 1.2
Mssari_PS13	Globose	Ovoid	Hard	28.14± 7.3	32.82± 2.5	5.48± 3.3	6.5± 1.3	2.82± 2.1	3.69± 0.7	28.37± 3	63.89± 7.4	42.2± 2.5	92.89± 0.9
Nabout 2893	Globose	Ovoid	Medium	25.67± 8.1	29.76± 3.2	8.21± 2.6	-	4.18± 1	2.09± 0.3	22.4± 1.9	40.8± 10.7	16.31± 3.6	26.92± 4.2
Nabout_PS12	Globose	Ovoid	Medium	37.98± 5.5	35.37± 2.9	5.11± 1.6	6.2± 2.2	4.8± 0.7	3.01± 0.2	23.17± 1.1	76.43± 2.2	34.51± 1.1	96.4± 1.3
Nabout_PS6	Globose	Ovoid	Easy	34.81± 4.9	31.49± 2.7	3.52± 0.9	5.63± 0.9	3.92± 0.5	3.09± 0.4	24.83± 1.9	70.6± 2.3	48.27± 2.4	101.56± 1
Ounq Hmam_PS14	Oblong	Pyriform	Easy	13.11± 4.4	25.46± 3.5	4.65± 3	6.82± 1.6	1.26± 1.5	1.87± 0.2	40.07± 13	27.17± 6.4	12.12± 3.2	29.36± 9.3
Sebti_PS10	Globose	Ovoid	Easy	21.31± 4	28.29± 2.3	7.32± 2.2	4.3± 0.5	3.17± 0.6	1.34± 0.3	18.87± 2.4	71.45± 5.1	32.27± 5.9	94.53± 1.3
Tabli_PS18	Oblong	Pyriform	Hard	42.14± 11	39.12± 4.6	4.92± 1.2	-	2.94± 2.2	3.95± 0.9	25.83± 6.6	61.56± 1.9	31.11± 2.5	92.31± 0.8
Tabli_PS19	Globose	Ovoid	Easy	51.52± 15.7	36.12± 4.2	3.46± 1	6.33± 0.9	4.49± 0.9	3.8± 0.7	18.87± 3.3	65.12± 1.9	47.48± 1.4	87.74± 0.9
Zerqui_PS5	Oblong	Pyriform	Easy	14.75± 4.8	30.35± 3.7	9.27± 5.5	-	1.39± 1.4	2.94± 0.7	24.6± 1.2	36.29± 1.2	14.58± 8.9	51.63± 5.8

vars with high content of total soluble solids would have the tendency to present reduction in the fruit weight, width and volume. Similar results were demonstrated in figs (Gozlekci, 2011) as well as other fruits such as yellow passion (Viana *et al*., 2003).

Skin color is an appreciated quality parameter in fig fruit. Color indexes derived from CIE L*a*b* measurements. The present study focused particularly on L*, c* and h° indices, since a* and b* are merely coordinates that indirectly reflect hue and Chroma, and were reported not independent variables (Hunter, 1942; Little, 1975; Francis, 1980). In addition, discrimination of skin color differences is mainly based on these three coordinates.

Skin colors of sampled fruits varied from the blue-purple (negative L* value) to the green-yellow (positive L* value), passing through the intermediate colors (Table 2). In fact, the color coordinates showed significant level of variation among genotypes ($p < 0.05$). Lightening (L*) values ranged from 20 (dark skin color) to 84.5 (bright skin color). The genotypes 'Lamtal_PS9' and 'El Quoti Lbied_PS6' had the brightest and clearest skin color. Darkening (expressed as a decrease in L* value) and development of red coloration (expressed as an increase in a*) were observed in only six genotypes where the darkness was especially a characteristic of 'Ghoudan' types (Tables 2 and 3). The lightness coordinate was found positively to the fruits seize but negatively correlated to the amounts of TSS. This means that dark fruits with a high caliber contain high levels of total sugars. The lightness of fruit skin colors is influenced by the pigment and the presence of hygroscopic substances. Thus, once fruits are thermally treated, they increase volume and light reflection, and therefore lightness (Koskitalo and Ormrod, 1972; Viurda-Martos *et al*., 2015). There were 12 homogeneous groups detected based on the fruit skin color according to Duncan test. Chroma is an indication of the saturation or vividness of color. When an increase in chromaticity is observed, the color becomes more intense; when it decreases, the color becomes more dull (Minguez-Mosquera *et al*., 1991). This variable varied significantly among genotypes, within an interval from 2 to 52. The Duncan test revealed 11 homogeneous groups for this coordinate. The highest values were recorded by genotypes with a bright skin color (Tables 2 and 3).

Hue angle varied between 1° (near bluish-red color) and 360° (blue). Genotypes with a clear skin had a hue angle between 90° (yellow) and 180° (green). This coordinate generated 5 homogenous groups based on Duncan test ($p < 0.05$) (Tables 2 and 3). According to the literature, this color coordinate is correlated to the anthocyanin concentration in vegetables (Crisosto *et al*., 2010). Colorimetric analysis using CIE coordinates is of great importance in characterization and assessment of fruit quality. Several authors have highlighted the strong correlation between color coordinates and antioxidant compounds, essentially phenols (anthocyanins, tannins, catechins, *etc*.) and carotenoids (lycopene, beta-carotene, *etc*.) (Pissarra *et al*., 2003; Itle *et al.,* 2009; Stinco *et al*., 2013; Kuś *et al*., 2014).

Principal component analysis

Only three principal components were retained. Component matrix retentive for quantitative parameters indicates that the first three PCs explained 28.37%, 24.8% and 25.56% of the total (78.7%) variation (Table 4). The important variables composing PC1 are: stalk width ($r^2 = 0.4$), stalk length ($r^2 = 0.28$) and ostiole width ($r^2 = 0.29$). Weight ($r^2 = 0.228$), length ($r^2 = 0.29$), width ($r^2 = 0.195$), skin thickness ($r^2 = 0.36$), and total soluble solids ($r^2 = 0.07$) are positively correlated to PC2 and explain its inertia. PC3 is composed by the following variables: neck dimensions (length $r^2 = 0.4$ and width $r^2 = 0.39$) and fruit volume ($r^2 = 0.18$) (Table 4).

The PCA of the qualitative traits classified the sampled genotypes into two main groups (Figure 2). The first group (G1) contains fifteen genotypes and is positively correlated to the first component (28.37%). This group encloses the genotypes with higher sizes of fruit stalk and a large fruit ostiole. The second (G2) group is positively correlated with the second component, which characterizes genotypes with high fruit dimensions, weight and high skin thickness. However, the genotypes 'Ounq Hmam_PS14' (high values of neck dimensions) and 'Ghani' (highest value of total soluble solids) were largely distinguished from the other individuals. These two genotypes have a contrasted performance according to PC1. This means they have contrasted stalk dimensions and percentage of total soluble solids (Figure 2).

Principal component analysis revealed two principal components with more than 90% of total inertia (Table 5). The first component explains about 67% of total inertia and is composed by L*, b* and c* ($r^2 = 0.283$, $r^2 = 0.293$ and $r^2 = 0.288$ respectively). The PC2 is composed by the following color coordinates: a* ($r^2 = -0.40$) and h° ($r^2 = 0.81$) (Table 5).

The colorimetric principal component analysis showed three distinctive and homogeneous groups (Figure 3). The first group (G1) contains the brightest and clearest fruit skin color (very high values of L* and c* coordinates). The genotypes 'Jaadi_PS16' and 'Ghani' had the lowest values of

Table 4. Matrix for principal components loadings for quantitative traits.

	Components		
	PC1 (28.37%)	PC2 (24.8%)	PC3 (25.56%)
Weight (g)	0.010	0.228	0.079
Length (mm)	0.033	0.293	-0.172
Width (mm)	0.027	0.195	0.094
Stalk width (mm)	0.401	-0.387	-0.094
Stalk length (mm)	0.279	-0.032	-0.029
Neck length (mm)	-0.088	-0.094	0.409
Neck width (mm)	0.013	-0.140	0.388
Ostiole width (mm)	0.296	-0.057	0.001
Skin thickness (mm)	-0.099	0.360	-0.120
Total soluble solids (%)	-0.295	0.074	0.050
Volume (cm^3)	0.074	0.063	0.179

Chroma within the group, which attest the strength of their surface color. The second group encloses less bright skin colors tending to blue or red-purple, which explains their lower hue values. The last group (G3) contains only three genotypes that have the same denomination 'Ghoudan' except the genotype 'Ghoudan 2227' which has a relatively clear purple skin color. Genotypes of this group are characterized by figs with a dark skin color (low values of L* and negative ones for a* and/or b* coordinates). Obviously, referring to the first PC, G1 is contrasted to the two other groups (G2 and G3) based on brightness and color intensity. However, 'Jaadi_PS16' and 'Ghani' had an intermediate skin color between G1 and G2. Similarly, the groups G1 and G2 are contrasted to the third group according to the second principal component (PC2). This divergence is explained particularly by the difference in the hue angle (Figure 3).

Table 5. Matrix for principal components loadings for skin color coordinates.

	Components	
	PC 1 (66.93%)	PC 2 (23.99%)
L*	0.283	-0.066
a*	-0.218	-0.404
b*	0.293	-0.044
c*	0.288	-0.125
h°	-0.048	0.806

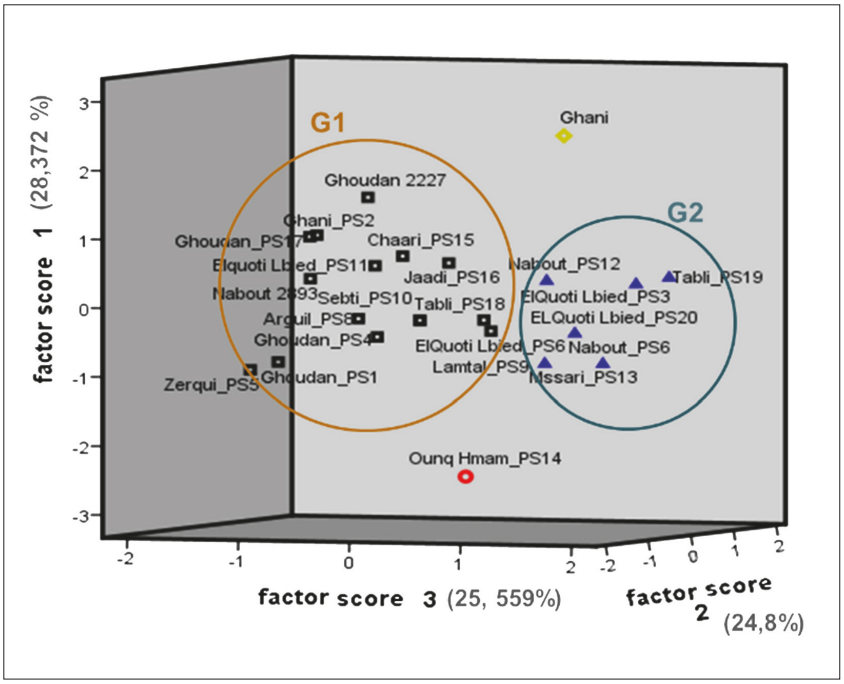

Figure 2. 3D Principal component analysis (PCA) based on quantitative traits with total inertia of 78.73%. G1 and G2 denote the two main groups revealed. Similar genotypes are presented by the same color and geometric form.

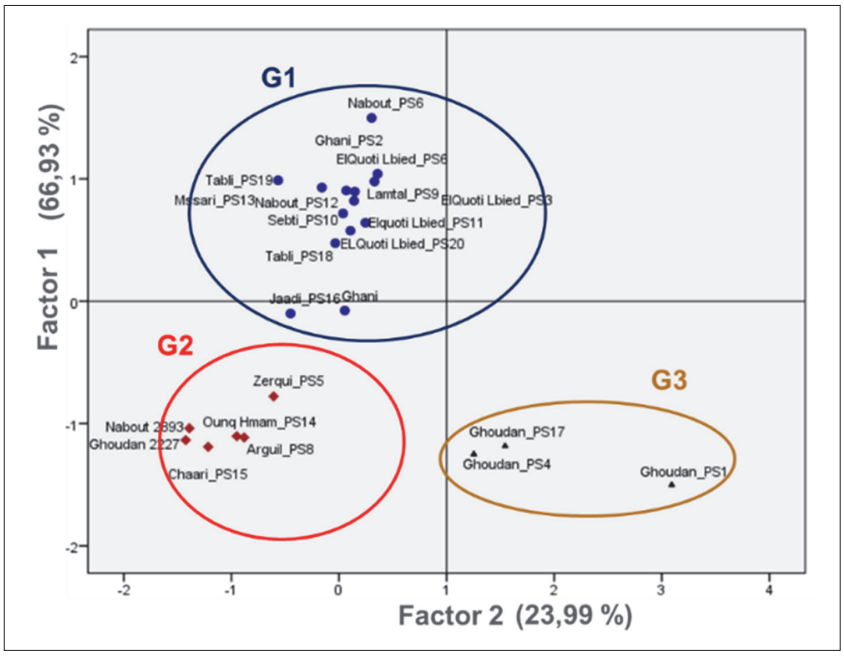

Figure 3. Principal component analysis (PCA) based on colorimetric characteristics with total inertia of 90.92%. G1, G2 and G3 denote the main groups revealed. Similar genotypes are presented by the same color and geometric form.

Cluster analysis

Using Euclidean distance based on all 38 variables used in this characterization (color, morphological and pomological descriptors), two main clusters have been identified (Figure 4). Each one is subdivided distinctively into two homogeneous subgroups with a mean distance of 10. In fact, all genotypes with the same denominations were clustered into the same subgroup, except 'Ghoudan' and 'Ghani'. Every subgroup is discriminated according to a specific group of characters (Figure 4).

The first cluster contains six genotypes which are 'Ghoudan' clones (PS17, PS4 and Ghoudan_PS1), 'Nabout2893', 'Zerqui_PS5' and 'Ounq Hmam_PS14'. This group is distinguished by a lower fruit weight (average of 20 g), purple to dark skin color (low values of L* and C*), an oblong and pyriform fruit shape, and without drop at ostiole. This cluster is subdivided into two distinctive and homogeneous subgroups (C1-1 and C1-2). The subgroup C1-1 consists of genotypes with a dark skin color (low values of L* with an average of 26) and a highest hue angle (h°) values that varied between 187 and 360°. These genotypes also have an important concentration of total soluble solids. The second subgroup (C1-2) includes genotypes with skin color varying between red and purple colors (average value of brightness is 34.7). This group includes the following genotypes 'Nabout2893', 'Zerqui_PS5', and 'Ounq Hmam_PS14', since the genotype 'Nabout 2892' was clustered in this subgroup, while its figs have a bright fruit skin color, this confirms that this genotype has been mislabeled (Figure 4). The same problem has also been reported in some species including pomegranate, peach and apple genotypes (Ahmad *et al.*, 2004; Baric *et al.*, 2009; Sarkhosh *et al.*, 2011).

The second cluster (C2) included the remaining 17 genotypes, distinguished by a high value of fruit weight, globose shape of fruit, bright skin color, and absence of drop at ostiole. This cluster is subdivided into two homogeneous subgroups (C2-1 and C2-2). The genotypes 'ElQuoti Lbied_PS3', 'Nabout_PS12', 'ElQuoti Lbied_PS20', 'Nabout_PS6', 'Tabli_PS19', 'ElQuoti Lbied_PS6', 'Ghani_PS2', 'Mssari_PS13', 'ElQuoti Lbied_PS11', 'Tabli_PS18', 'Lamtal_PS9', and 'Sebti_PS10' are classified in the subgroup C2-1 and characterized by very high values of both brightness (L*; average of 66.3) and hue angle, with a variation from 96 to 102. Only four genotypes are in the subgroup C2-2, and are characterized by positive values of a* coordinate and an important width of ostiole (Figure 4). Cluster data showed an important similarity between genotypes which nominations meanings, seem probably to be synonyms in the local dialect. Knowing these denominations were given essentially based on fruit color (*i.e.*, 'ElQuoti Lbied', which indicates a bright skin color) or shape (*i.e.*, 'Tabli', which indicates oblate shape of fruit) may prove them genetically linked. Being enabled, based on these results, to verify any potential correlation can be proven between the origin (collecting area) of the genotypes studied and the clusters resulted. Analysis at molecular and biochemical level is certainly needed to confirm the hypothesis of a common genetic basis.

Conclusions

Local fig clones are often named by local farmers based on fruit shape, color, taste and flavor. Consequently, a problem of mislabeling surfaces when it comes to plant selection and identification. Pomological and colorimetric parameters exhibited an important level of variability among those genotypes. Based on cluster, a relatively close relationship was also detected between several genotypes that have the same denominations, especially 'Ghoudan' and 'Nabout' types, which have two contrasted profiles. In addition, some genotypes having similar characteristics, mainly fruit shape, total soluble solids and fruit skin color were clustered in the same group. The results were expected since the evaluated genotypes were named by local farmers in different local dialects based on their characteristics, especially fruit shape and color.

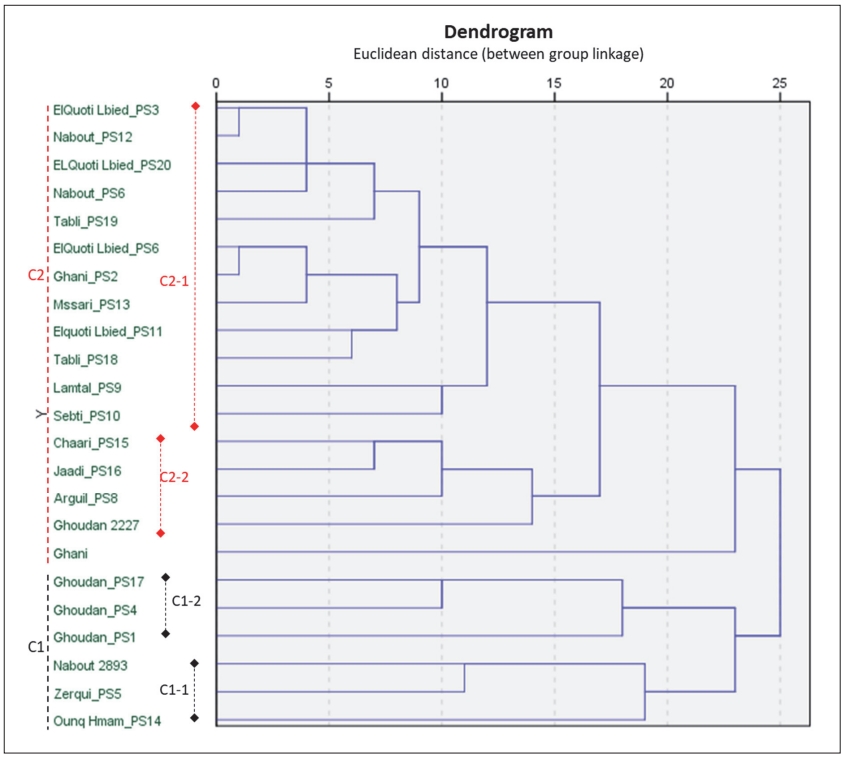

Figure 4. Dendrogram obtained using the Euclidean distance between the studied genotypes based on 38 variables (color, morphological and pomological descriptors). C1 and C2 denote the main clusters revealed. C1-1, C1-2, C2-1 and C2-2 refer to homogenous subgroups.

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