

Full Length Research Paper

Plant natural resources and fruit characteristics of fig (*Ficus carica* L.) change from coastal to continental areas of Tunisia

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The fig (*Ficus carica* L.) is widely distributed and represents a natural wealth and diversity in all Tunisia. Investigations in the field showed that 'smyrna' type, bearing one generation of figs, were predominant in the coast while 'san pedro' type, bearing two generations of fruits, is more encountered in the continent. A large array of caprifig trees were counted in coastal 'Bekalta', while caprifigs are rare in 'Djebba' and are mostly found in wild form. Biodiversity of fig species was corroborated by analysis of the fruit. A wide range of size, shape (round, oblate and oblong) and colour (yellow green, purple green and purple black) was observed in the two areas. Fruits originated from continental zone were larger (59 mm) and heavier (82 g), while fruits from coastal zone were sweeter (18.4%) and tasteful. Comparison of cultivar 'Zidi' growing in the two contrasting areas revealed a gain of precocity in fruit ripeness in the coast. However, 'Zidi' figs picked from continental 'Djebba' were larger, heavier and sweeter than those picked from 'Bekalta'. Crossing the coastal semi-arid climate to the continental sub-humid, fig natural resources, growth tendency and development of the tree and characteristics of the fruit are not the same.

Keywords: *Ficus carica*, 'smyrna', environment, agro-ecosystem, fruit quality, biodiversity.

INTRODUCTION

Fig *Ficus carica* (2n = 26 chromosomes) belongs to the order of Urticales and the family of Moraceae, with over 1400 species classified into about 40 genera (Watson and Dallwitz, 2004). *Ficus carica* is a typical fruit tree of the Mediterranean area. In Tunisia, fig tree is recognized as one of most adapted specie since long time ago. The large diversity of cultivars allowed its presence in various bio-climatic zones of the country occupying about 33800 hectare (MARH, 2010). National production was estimated about 25000 tonnes (FAOSTAT, 2011) and is

entirely locally marketed. Figs are mainly consumed as fresh. A small portion is sun dried and little quantities are used for jam and alcoholic beverage production (Mars et al., 2008).

Prospection undertaken in different regions contributed to identify and to describe numerous cultivars (Ben Salah and Lejri, 1995; Mars et al., 1998; Chatti et al., 2004; Mars et al., 2009). Some, like 'Bither' and 'Bither besbessi', are of the common type (parthenocarpic) that produce figs without caprification (pollination). Many others, like 'Bidhi', 'Zidi', 'Kahli' and 'Soltani', are of smyrna type that need caprification. Smyrna type are predominant in the south while, in the north, cultivars of common type are equally represented (Mars, 2003). The utilization of fig germplasm consists of many ecotypes selected either for their fruit traits ('Bidhi' and 'Zidi') or their high adaptative potentialities ('Bouhouli' and 'Wahchi'). The cultivar Zidi (smyrna type) has a large geographical distribution in the country and is known for

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Abbreviations: BHL: Bouhouli; ZD: Zidi; THG: Thgagli; BD: Bidhi; KHD: Khedri; SPSS: Statistical Package for the Social Sciences; TSS: Total soluble solids; TA: Titratable acidity; IM: Index of maturity.

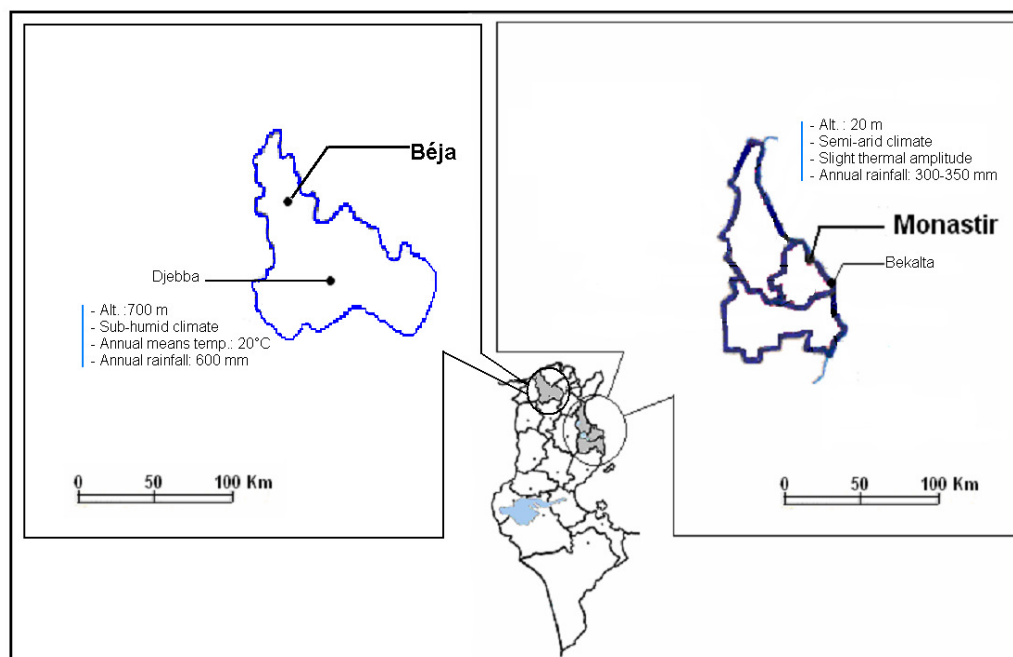


Figure 1. Location and climate conditions of the two sites (Alt.: altitude, temp.: temperature).

its high commercial value and best fruit taste for fresh consumption (Mars et al., 2008).

From coastal to continental zones of the country, a large discrepancy was observed concerning existing ecotypes, growth and development of the plant and quality-bearing fruit of the tree. The present work is a comparative study in fig cultivars diversity and fruit characteristics between two important zones of fig production: 'Djebba' a continental region and 'Monastir' a coastal zone of Tunisia. It aims to demonstrate changes in fig tree cultivars diversity and quality of the fruit when moving from the coast to continental regions.

MATERIALS AND METHODS

Location and environmental conditions

'Djebba' village belongs to governorate of 'Béja' situated in North-West part of the country (Figure 1). It is positioned at 700 m of altitude with a slope of 10% for 80% of its area. Soils are clay-silt in plain and marn-clay-chalky in sloping field. 'Djebba' belongs to sub-humid bio-climate with mild winter and hot summer. Annual means temperature is set around 20°C. Thermal amplitude is about 16°C in summer and 8°C in winter. This zone receives annual rain of about 600 mm and there are five main natural sources used for irrigation since long time ago (CRDA Béja, 2007). 'Bekalta' is a coastal region localized in the Central-East part of the country and is influenced by Mediterranean sea effects (Figure 1). Topography of the region is very heterogeneous with presence of hills and slopes in most of the region. Soils are silt-sandy with a good porosity. Winter is generally mild, frost is not to be frightening and thermal

amplitude is slight. Rainfall is irregular and stormy. Average annual rainfall is between 300 and 350 mm (CRDA Monastir, 2007). Prospection took place in two zones. Several farmers and local inhabitants in 'Djebba' and 'Bekalta' were visited. Farmers were questioned about diversity of fig cultivars, cultivation systems and main characteristics of the fruit.

Plant material

Figs from five cultivars (Bouhouli 'BHL' and Zidi 'ZD': dark coloured figs; Thgagli 'THG', Bidhi 'BD' and Khedri 'KHD': white coloured figs) were harvested from the two respective areas during cropping seasons 2009 and 2010. Cultivars were selected for their large distribution and their commercial value in the two regions. Fig cuttings from cultivars 'BHL', 'ZD' and 'THG' were planted in 1992 in 'Djebba', whereas 'BD', 'ZD' and 'KHD' were planted in 1997 in 'Bekalta'. In the two sites, the orchards were conducted with an open vase training system. However, fig trees, irrigated in the continent, are conducted on pluvial in the coast. Caprification (artificial pollination) is practiced at the receptivity time of female syconia.

Samples of thirty homogenous fruits (three replicates of 10 fruits each) were picked for each variety. Fruits were selected ripe and free from diseases and physical disorders during the last week of august in 'Djebba' and the last of July in 'Bekalta'. Fresh harvested figs were immediately carried for storage until use.

Morphological and physico-chemical analysis

Main descriptors for fig fruit were assessed for each variety (IPGRI and CIHEAM, 2003). Parameters measured were: fruit

Table 1. Natural resources of fig *Ficus carica* in the two contrasting sites.

Continental 'Djebba'				
Ecotype	Botanical type	Date of maturity	Frequency	Fruit colour
'Bouhouli'	San pedro	June + august	Abundant	Purple green
'Zidi'	Smyrna	August	common	Purple black
'Wahchi'	San pedro	June + august	common	Yellow green
'Thgagli'	Smyrna	August	Little	Yellow green
'Khartoumi'	Smyrna	August	Little	Yellow green
'Soltani'	Smyrna	August	Little	Yellow green
'Khenziri'	San pedro	June + august	Rare	Green
'Temri'	Smyrna	August	Rare	-
'Bouharrag'	Smyrna	August	Rare	-
'Boukhobza'	Smyrna	August	Rare	-
'Faouari'	Smyrna	August	Rare	-
'Zergui'	Smyrna	August	Rare	-
Coastal 'Bekalta'				
Ecotype	Botanical type	Date of maturity	Frequency	Fruit colour
'Bidhi'	Smyrna	July	Abundant	Yellow green
'Bither abiadh'	San pedro	June + august	Abundant	Green
'Kahli'	Smyrna	July	Abundant	Reddish black
'Zidi'	Smyrna	July	common	Purple black
'Soltani'	Smyrna	August	common	Yellow green
'Hemri'	Smyrna	July	common	Greenish red
'Ghabri'	Smyrna	August	common	Reddish green
'Goutti'	Smyrna	July	common	Purple yellow green
'Khedri'	Smyrna	July	Little	Yellow green
'Bithri'	Caprifig	-	Little	-
'Assafri'	Caprifig	-	Abundant	-
'Hemri'	Caprifig	-	Little	-
'Jrani'	Caprifig	-	Abundant	-
'Guerguenia'	Caprifig	-	Rare	-

size, shape, length, neck length, width and ostiole width. Firmness was measured using durometer (Duro10, SETOP GIRAUD Technology, Cavaillon, France) and external fruit colour was established according to IPGRI scale (IPGRI and CIHEAM, 2003). Total Soluble Solids (TSS) were determined with a digital refractometer (PR-101 ATAGO, Norfolk, VA) and expressed in percent (%) at 20°C. Titrable acidity (TA), expressed as mEq/kg FW, was determined by titrating fig juice with 0.1M NaOH.

Statistical analysis

Comparison between the two regions was made possible by statistical analysis of collected data. Physico-chemical analysis was carried out in triplicate from samples harvested over 2 years. Data were subject to one-way analysis of variance (ANOVA) and the results are given as means \pm standard deviations (SD). Statistics were performed using Statistical

Package for the Social Sciences (SPSS version 13.0; SPSS Inc.).

RESULTS AND DISCUSSION

Fig natural resources

Fig cultivars in 'Djebba' were numerous. We counted 12 distinct cultivars of smyrna botanical type in major part (Table 1). However, 'Bouhouli' (san pedro type) is the most frequent and represents about 85.5% of total. This cultivar is highly appreciated by farmers because of its good adaptation to the environment and its good commercial value. 'Zidi' cultivar ranked second and represents 9.8%. This cultivar is much known and encountered in various Tunisian agro-ecosystems. Some

Table 2. Fruit characteristics of fig cultivars harvested from the two regions.

	<i>In the continent</i>		<i>In the coast</i>			
	'Bouhouli'	'Thgagli'	'Zidi'	'Bidhi'	'Khedri'	'Zidi'
Fruit size (g)	54 ±4	76 ±11	82 ±17	56 ±9	54 ±6	56 ±11
Length (mm)	42 ±1	50 ±4	65 ±5	46 ±4	47 ±5	51 ±6
Neck length (mm)	0	0	10.2 ±0.9	0	0	10.8 ±0.7
Width (mm)	50 ±4	59 ±4	51 ±5	49 ±3	47 ±2	42 ±5
Ostiole width	7.5 ±2.6	13.7 ±3	9.9 ±0.6	6.2 ±0.6	5.5 ±1.1	8.5 ±0.5
Firmness (durofel)	17 ±1	16 ±1	16 ±1	17 ±1	17 ±1	17 ±1
TSS (°Brix)	17.6 ±1.0	16.1 ±1.1	16.2 ±1	18.4 ±0.9	17.9 ±1.1	14.3 ±1
TA (mEq/kg FW)	2.7 ±0.1	2.0 ±0.0	2.7 ±0.0	2.3 ±0.0	4.7 ±0.1	2.2 ±0.04
IM (TSS:TA)	65	80	60	80	38	65
Fruit shape ¹	Oblate	Oblate	Oblong	Round	Round	Oblong
Fruit colour ¹	P.Green	Y.Green	P.Black	Y.Green	Y.Green	P.Black

¹ descriptors for fig (IPGRI-CIHEAM, 2003)

P.Green: purple green. Y.Green: yellow green. P.Black: purple black.

cultivars like 'Wahchi', 'Thgagli', 'Khartoumi' and 'Soltani' are also cultivated but with few number despite the high quality of their fruit. Other cultivars like 'Zergui', 'Bouharrag', 'Faouari', 'Boukhobza' and 'Temri' were rarely found in some orchards (Table 1). Few caprifig trees were encountered. Some could be interesting considering their pollen richness and blastophage abundance. Low winter temperatures characterizing the continental region impede the fig pollinator (*Blastophaga psenes* L.) to fulfill its life cycle therefore to guarantee a good pollination of female syconia.

In 'Bekalta', a large array of cultivars was inventoried shared between smyrna, san pedro and caprifig type (Table 1). The main types were 'Bidhi' (25.3%), 'Bither Abiadh' (24.6%) and 'Kahli' (20%). With less frequency were described: 'Zidi' (6.9%), 'Soltani' (4.2 %), 'Hemri' (3.9%), 'Ghabri' (3.8 %), 'Goutti' (2.5%) and 'Khedri' (1.7%). Cultivars rarely encountered were 'Bidh Hsan' (0.6%), 'Asli' (0.34%), 'Soltani Abiadh' (0.29%), 'Khoffi' (0.13%), 'Kahli' (0.11%), 'Safri' (0.08%), 'Njali' (0.05%), 'Tchich Aâssal' (0.03%) and 'Soltani 2' (0.03%) (Table 1). Several caprifigs were also described. Some are well known and cultivated as 'Jrani' (precocious), 'Assafri' (mid-season) and 'Guerguenia' (late).

Differences between coastal and continental region are noteworthy concerning cultivars type and growth and development of the tree. In 'Djebba', san pedro type, that produces two generations of fig crops (breba and main crops), occupies the major part of fig orchards (88%). 'Bouhouli' remains the most cultivated and may produce until 60 kg/tree. 'Zidi', the second main cultivar, may produce until 65 kg/tree. When moving to coastal region of 'Bekalta', the smyrna type, that produces one generation of figs (main crop), becomes predominant (70% of total areas). 'Bidhi' and 'Kahli' were the most

important cultivars inventoried in this site. Production per tree can reach 95 kg particularly for cultivar 'Goutti'. 'Zidi' can produce until 80 kg/tree which means high-yield compared to the cultivar production in continental zone. Fig trees growing in the coast bear fruits that ripen earlier (July) than those originated from 'Djebba' (August). Pedo-climatic conditions seem to play a crucial role in productivity and precocity of fig trees grown in coastal area.

Fruit characteristics

Analysis of the fruit exhibited additional marks of the diversity characterizing fig specie in the two areas. A large array of size, shape and fruit colour could be observed between the various cultivars. The fruit can be oblate and oblong in continental region and round and oblong in coastal zone. Fruit colour varied from yellow green to purple black in both regions (Table 2). Fruit weight can reach high values in 'Djebba'. Fruit size is very important for fig fresh consumption and marketing (Aksoy et al., 1992). 'Zidi' and 'Thgagli' grown in 'Djebba' developed the heaviest fruit (82 g and 76 g respectively) and this could be due to nutrient supply characterizing the soils of 'Djebba'. Fruits from 'Zidi' cultivar harvested from the two areas showed a large discrepancy in size (82 g in 'Djebba' versus 56 g in 'Bekalta'), length (65 mm in 'Djebba' versus 52 mm in 'Bekalta') and width (51 mm in 'Djebba' versus 42 mm in 'Bekalta') and differences were significant ($\alpha \leq 0.05$). All figs, harvested at full ripeness, were relatively soft as shown by their low firmness values (16 - 17 durofel units; 0.34 - 0.36 kg/cm²). Total soluble solids (TSS) varied from 16.1 to 17.6% in the continent and from 14.3 to 18.4% in the

coast. 'Zidi' fruits harvested from 'Djebba' were sweeter than those originated from 'Bekalta' (16.2% in 'Djebba' versus 14.3% in 'Bekalta'). Titratable acidity (TA) ranged between 2.0 and 2.7 mEq/kg FW in continental areas and between 2.2 and 4.7 mEq/kg FW in coastal zone. Titratable acidity was slightly higher in 'Zidi' figs harvested from 'Djebba' compared to fruits picked from 'Bekalta' (2.7 mEq/kg FW in 'Djebba' versus 2.2 mEq/kg FW in 'Bekalta'). TSS values recorded in 'ZD' figs harvested from the two regions were significantly different ($\alpha \leq 0.05$). Other studies concerning fig tree grown in California showed that cultivars 'Mission', 'Brown Turkey', 'Calimyrna' and 'Kadota' reached respectively 19.1%, 18.0%, 18.9% and 19.3% of TSS and 0.38%, 0.29%, 0.42% and 0.22% of TA (Crisosto et al., 2010). Such values are quite similar to those recorded in Tunisian figs in general. The sugar/acid ratio (IM) is one of the most important factors in fruit taste (Karaçali, 2002). In our study, 'THG' and 'BD' fruits showed higher TSS:TA ratios than the other fruit cultivars. However, TSS/TA was higher in 'ZD' fruits originated from 'Bekalta' and this explains somewhat precocity of 'Zidi' fig tree grown in coastal region.

Ficus carica wealth and diversity is noteworthy in the two sites. Moving from coastal to continental area, fig tree behaviour and cultivar diversity change. Size and development of the tree are not the same. Shoot growth and leaf area become more important in 'Djebba' and confer much vigour to the tree. Smyrna type figs, abundant in the coast, become rare in the continent and san pedro type takes place bearing two generations of fig crops. Coloured figs are well appreciated by people living continental zones and are mainly used for fresh consumption. Thus, 'Bouhouli' is widespread and much more encountered, followed by 'Zidi'. In the coast, people prefer white coloured figs. 'Bidhi' and 'Bither Abiadh' are the most cultivated and appreciated a lot as well as fresh or dried.

Conclusion

Fig *Ficus carica* growing in coastal environment are precocious and ripen earlier than in the continent even for the same cultivar as 'Zidi'. This can be explained by climatic conditions particularly the variability between day and night temperatures. Environmental conditions play also an important role in the discordance between emerging wasps' period and female fig receptivity. The fluctuant weather conditions in the continent are responsible in a large part of the lack of fig wasps during the receptivity of female syconium which impede the pollination step and afterward development of the fruit. Quality of 'Zidi' figs change when moving from the coast to the continent. It becomes obvious that natural water sources in addition to soil and climate conditions

characterizing the mountain of 'Djebba' further contribute to improve final quality of figs.

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