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Inter- and intra-tree variability in quality of figs. Influence of altitude, leaf area and fruit position in the canopy

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ABSTRACT

Shading effect on quality of fig (*Ficus carica* L.) is noteworthy within the tree. Leaf area and canopy density enhanced shade conditions and altered microclimate inside 'Bouhouli' fig tree. With leaf area index (LAI) of about 3.3 there was a tendency to have smaller, firmer and lighter skin coloured fruit inside the canopy. Altitude level had a little influence on quality of 'Bouhouli' figs. Though, fruits from mountainous zone of 'Djebba' ripened earlier and were heavier and less acid than fruits from nearby plain of 'Thibar'. Position of the fruit in the canopy significantly affected fruit firmness, titratable acidity (TA) and TSS:TA ratio ($p < 0.01$). There were greater fruit loads with soften receptacle and lower acidity in the outside canopy positions than in the inside positions. No differences exist in dry matter (18.7%) and soluble solids content (18.3%) between light exposed and shaded fruits. Yet, TSS:TA ratio was higher in figs harvested from the periphery. Sugar and organic acid concentrations were little influenced by fruit position in altitude or in the tree. Glucose, fructose and sucrose showed the same proportions 0.47, 0.38 and 0.15, respectively, inside and outside the canopy. Citric acid, the predominant organic acid in figs, had comparable concentrations in fruit from inner and outer part of the tree. Citric acid levels were though different ($p < 0.05$) between fruits from the two locations (1.95 mequiv./100 g FW in the plain versus 2.80 mequiv./100 g FW in the mountain). Temperature was positively correlated with fresh weight ($r = 0.74^{*}$) but negatively correlated with firmness and titratable acidity ($r = -0.91^{**}$). High temperature degrees during maturity enhance fruit enlargement and softening and reduce acidity of fig juice. Growing figs in mountainous and uneven zones with high altitude remains profitable to farmers living these areas. To improve light penetration into the foliage, summer pruning, leaf removal and shoot vigour control, little practiced in fig species, are recommended close to maturity and lead to homogeneous quality of fig crops.

1. Introduction

In woody plants, bearing fruit may result on heterogeneity in final quality sometimes more perceptible between fruits within the same tree than that from different trees. This problem observed in many fruit species (apple, apricot, citrus, etc.) may be an obstacle for crop marketing (Mars and Marrakchi, 2000). Inter- and intra-tree variability was attributed to many factors such as the rootstock used (Lipe and Perry, 1988), growing techniques: pruning, fruit thinning (Fellahi and Simons, 1993) or the microclimate generated by the amount of light intercepted by the canopy, temperature or humidity (Erez and Flore, 1986; Audergon et al., 1991; Mars et al., 1994).

Crop composition and quality is determined by sunlight distribution within the canopy, with shade reducing fruit quality. This is a general issue among perennial fruit crops and has been reported for apple, citrus, peach, cherry, kiwifruit and red raspberry (Palmer, 1989). In figs, *Ficus carica*, the phenomenon is even more accentuated since the species develops a highly dense canopy marked by a large leaf area which could represent in some cases a natural sunshade for the fruit. Several parameters are considered to be influenced by solar radiation, including fruit size, flesh firmness, soluble solids, anthocyanin and starch content, acidity, pH and dry matter (Erez and Flore, 1986; Kliewer and Smart, 1989). High sugar levels, an appropriate sugar/acid ratio and adequate flesh firmness are among most important characteristics of high-quality figs (Çaliskan and Polat, 2008; Trad et al., 2012). Berries, known to be rich in organic acids (Koyuncu, 2004), are influenced by environmental conditions. Mulberry, belonging to the Moraceae family, had not the same chemical composition in fruits from

Abbreviations: LA, leaf area; LAI, leaf area index; RH, relative humidity; TSS, total soluble solids; TA, titratable acidity; FW, fresh weight; DM, dry matter; SD, standard deviations; ANOVA, analysis of variance; SPSS, statistical package for social sciences; cv, cultivar.

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different growing areas (Ercisli and Orhan, 2007). In black mulberry (*Morus nigra* L.), the amount of total organic acids was dependant on the geographical origin. Especially differences in the climate are likely to explain these distinctions (Koyuncu, 2004).

Distribution of fruits within the fig tree underlines heterogeneity in visual aspects of quality between figs underneath the foliage and those from the periphery. This could disrupt harvest campaign and impede product marketing. In our observations, there was a variation on fruit quality and maturity between figs (cv. 'Bouhouli') harvested from the plain of 'Thibar' and fruits gathered from mountainous region of 'Djebba'. Altitude seems to affect quality of figs. In Tunisia, the mountainous location of 'Djebba' represents a particular agro-ecological site for fig crop cultivation with a substantial genetic diversity. Little attention was paid to the climate prevailing during maturity of figs in relation with situation of the fruit as well as in distant orchards or in the same tree. Fruit quality is highly influenced by environmental conditions, climate and orchard management and may change from year to year (Inglese et al., 2002; Ochoa et al., 2006).

The aim of this study was to analyze the effect of altitude, proximate environment and fruit position in the canopy on morphological and chemical aspects of quality in figs (cv. 'Bouhouli'). The results given below could enable fig growers to set up and manage their orchard and to manipulate the fig tree to produce a higher yield of top quality fruit at harvest time since tree training and pruning skills in general remain not much controlled.

2. Materials and methods

2.1. Plant material

Figs from cultivar 'Bouhouli' (dark skinned fruit) were selected for this study. Fruits were gathered from an extended area of fig production: 'Thibar' in the Northwest of Tunisia (altitude, 327 m; latitude, 36°31′ N; longitude, 9°5′ E) distinguished by a sub-humid climate, annual mean temperature of 20 °C and annual rainfall of 600 mm. Fig trees produced by cutting were planted in 1991 with 7 m × 7 m spacing and shaped under goblet.

The influence of altitude on fruit quality was evaluated in figs from mountainous zone of 'Djebba' (altitude, 800 m; latitude, 36°40′ N; longitude, 9°0′ E) with comparison to fruits harvested from the plain of 'Thibar'. 'Djebba', situated in a sloping field, is characterized by a sub-humid climate. Annual means temperature is set around 20 °C. Thermal amplitude is about 16.5 °C in summer and 8 °C in winter. This zone receives annual rain of about 600 mm. Three trees from each location were selected for fruit sampling. From each tree, 20 fruits were picked at full maturity. The same cultivation techniques, especially irrigation and caprification, were applied in two.

2.2. Leaf area and fruit environment assessment

Leaf area (LA) determination was conducted on three trees from cultivar 'Bouhouli' in the region of 'Thibar'. Total canopies for each tree as well as total leaf number from one canopy already selected were counted. From the same canopy, 25 leaves were picked. Leaves selected were those reaching their final size and bearing fruits underneath (Hunt, 1990; Can, 2008). Leaf area was measured in the laboratory using a planimeter (Type AM 200, ADC Bioscientific Ltd., Hoddesdon, Herts, England). Determination of leaf area index (LAI) required the measurement of the total leaf area of the canopy and the total ground area upon which it stands (Hunt, 1990). The same trees were selected to monitor the internal and external microclimate surrounding fig fruit in the tree. Thermo-hygrometers (Type 46618 Badget Packolabel Systems, Delhi, India) were simultaneously installed inside and outside the canopy (50 cm from the tip of the canopy) (Mars et al., 1994). Three measurements of temperature and relative humidity (RH) were taken daily starting from the last week before harvest (beginning of fruit veraison) in the time period between 11.00 h and 13.00 h (most enlightened phase of the day).

2.3. Fruit sampling

Twenty fruits per tree (10 from the periphery and 10 from the inside of the tree) were picked to constitute a final sample of 60 figs for each altitude. Fruits were harvested in late august during two cropping seasons, 2009 and 2010. The fruits were randomly picked, fully ripe, from the all sides and immediately stored until analysis. Samples kept first at −20 °C, were then ground in liquid nitrogen using a basic analytical mill (IKA®A11. Germany) and the powder obtained was stored at −80 °C for chemical analysis.

2.4. Fruit analysis

2.4.1. Morphological and physico-chemical description

Main descriptors for fig fruit (IPGRI and CIHEAM, 2003) were assessed for the cultivar 'Bouhouli'. Parameters measured were: fruit size, shape, length, neck length, width and ostiole width. Firmness was measured using the durofel (durometer Duro10, SETOP GIRAUD Technology, Cavaillon, France) and external fruit colour was determined according to IPGRI scale (IPGRI and CIHEAM, 2003). Total soluble solids (TSS) was determined using a hand-held digital refractometer (PR-101 ATAGO, Norfolk, VA) and expressed in percent (%) at 20 °C. titratable acidity (TA), expressed as mequiv./100 g FW, was determined by titrating fig juice with 0.1 M NaOH. Four grams of fresh powder of the fruit were dried (70 °C for 96 h) and removed to be weighed again for dry matter (DM) determination.

2.4.2. Sugars and organic acids determination

From each sample, 5 g of frozen fig powder were mixed with 20 ml ultra pure water. Samples were ground with an ultraturrax T25 equipment (Ika Labortechnik, Staufen, Germany) to obtain slurry. The mixture was homogenized and then centrifuged for 5 min at 4 °C (9000 rpm). Samples were then filtered and the supernatant recovered. The extracts were kept at −20 °C until analysis. Glucose, fructose and sucrose, malic and citric acids were quantified using enzymatic methods with kits for food analysis (Boehringer Mannheim Co., Mannhein, Germany) and expressed in g/100 g of fresh weight for sugars and mequiv./100 g FW for acids. Spectrophotometric measurements were performed using an automatic analyser (BM-704, Hitachi, Tokyo, Japan).

2.5. Statistics

Results presented are as means ($N = 3$) ± standard deviations (SD). Environment effects on quality of figs were carried out in triplicate from samples harvested over 2 years. Data were subject to one-way analysis of variance (ANOVA). Significant differences were assessed with *Duncan*'s multiple range test ($p < 0.05$). Pearson's correlation coefficients were estimated between climatic factors and quality parameters of the fruit and correlation plot was displayed in the circle of correlations. Statistics were performed using PC software package SPSS (version 13.0; SPSS Inc.).

3. Results and discussion

3.1. Effect of altitude on quality of figs

Data related to quality of figs under the influence of altitude were displayed in Table 1. Figs harvested from mountainous