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Changes in the profiles of mineral elements, phenols, tocopherols and soluble carbohydrates of olive fruit following foliar nutrient fertilization

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ABSTRACT

The present research was accomplished on olive fruits cv. Picholine. It aimed to study the effects of nutrient fertilization on mineral elements, phenolics, tocopherols and soluble carbohydrates. The foliar applications were carried out during two successive years and included four treatments: TC (control, without foliar nutrition), T1 (rich in nitrogen, applied at the start of vegetation, 10 days later and 20 days later), T2 (rich in boron, magnesium, sulfur and manganese, applied at the beginning of flowering and 10 days later) and T3 (T1 + T2). At the end of the experiment (after two experimental years), olive fruits were analyzed. This study showed that fertilization caused a significant decrease of total phenols and tocopherols contents and induced qualitative changes in the profiles of minerals, phenols, tocopherols and carbohydrates. The results elucidated an evident association between environmental concentrations of nutrients and chemical composition of olive fruits.

1. Introduction

Table olives are well-known sources of compounds with beneficial relevance. These benefits are associated with their fatty acids content, mainly monounsaturated fatty acids, and to minor constituents such as tocopherols, phenolic compounds and phytosterols (Bianchi, 2003). Among hydrosoluble components, polyphenols play an important role in olive fruits since they have a wide range of biochemical and pharmaceutical effects, including anticarcinogenic, antiatherogenic, antimicrobial and antioxidant activities (Visioli & Galli, 1998). Phenolic compounds may contribute to fruit quality in a number of ways; for example, by contributing to sensory attributes, such as color and flavor, and through the contribution of some specific phenolics, in particular those derived from the hydrolysis of oleuropein, to the intense bitterness of the olive fruit (Amiot, Fleuriet, & Macheix, 1986), especially hydroxytyrosol, tyrosol, caffeic acid, coumaric acids, and p-hydroxybenzoic acid (Kiritsakis, 1998). Phenolics can also contribute to fruit quality via their role in browning reactions. Thus, oxidation products of oleuropein, in conjunction with those of other native phenolics are known to be responsible for the characteristic black colour of mature olive fruits (Kiritsakis & Markakis, 1987). In addition, the phenolics in olives have attracted attention as antioxidants (Le Tutour & Guedon, 1992). Comparing to phenolics, fewer studies are dedicated to table olive tocopherols, the main lipophilic antioxidant (Sakouhi et al., 2008). Many studies describe α-tocopherol as having a protective action on human health against different pathologies, contributing to minimize the adverse effects of inflammatory diseases by defending the body against free radicals (Bogani, Galli, Villa, & Visioli, 2007). Carbohydrates serve as a source for the acetyl needed for fatty acid biosynthesis (Simcox, Garland, Deluca, Canvin, & Dennis, 1979). Therefore, both total and individual sugars have been measured in olive fruits only at the beginning and end of the fruit development period (Nergiz & Engez, 2000).

Chemical composition of table olives has been studied by several works as influenced by some aspects such as processing and preparation methods (Marsilio, Campestre, Lanza, & De Angelis,

Abbreviations: PAL, Phenylalanine Ammonia-Lyase; PPO, polyphenol oxidase; OeMaT1, *Olea europaea* Mannitol Transporter 1.

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2001; Montaño, Sánchez, Casado, de Castro, & Rejano, 2003) ripening time (Marsilio et al., 2001; Sakouhi et al., 2008), cultivar (Montaño et al., 2003), and agronomical aspects (Marsilio et al. 2006). To our knowledge, there are few studies which consider the effect of nutrients on fruit quality and chemical composition. For instance, some studies on fruit trees reported that nutritional status affects crop yield (Casero, Benavides, Puy, & Recasens, 2004; Nestby et al., 2004) and showed correlations among mineral element contents and fruit quality such as orange (Storey & Treeby, 2000), apple (Casero et al., 2004), peach (Tagliavini et al., 2000), mango (Nguyen et al., 2004) and olive (Jordaó, Duarte, Calouro, & Silva, 1990). For the particular case of olive tree, current research is focused on the understanding of possible relationships between olive tree nutritional status and olive quality parameters such as the concentration of phenols, tocopherols and sugars that are responsible for the nutritional value and taste of fruits (Hudina & Stampar, 2000; Kiritsakis, 1998). Fertilization is the most important and controllable factor affecting the nutritional value of fruits. The type and value of fertilizer and the level of application directly influence the level of nutrients available in plants and indirectly influence plant physiology and the biosynthesis of primary and secondary compounds in plants. In olive trees, despite the general practice of fertilization in intensive orchards, little is known about the effect on fruit quality. Most of the studies on olive fruit described the response of the total chemical compound fractions (particularly phenols, sugars and tocopherols) to fertilization (Saadati, Moallemi, Mortazavi, & Seyyednejad, 2013). There are little or no works which focused on studying the effects of fertilization on the individual composition of each fraction. In this context, the present work aimed to study the response of some fruit quality parameters, such as phenolics, tocopherols and soluble carbohydrates to the application of two foliar fertilizers and to elucidate an evident association between fruit mineral levels and fruit quality parameters. To our knowledge, for the particular case of olive trees, this is the first work which described the changes of mineral composition of olive fruits under foliar fertilization in relation to the individual phenolic compounds, soluble sugars and tocopherol isomers.

2. Material and methods

2.1. Field site and experimental materiel

The present study was carried out on fruits of mature "Picholine" olive trees grown in an orchard located at Enfidha, Tunisia, North latitude 36° 08′, East longitude 10° 22′. The climate of this region is typical Mediterranean with a mean annual rainfall of 400 mm, concentrated mainly from autumn to spring and an average evapotranspiration (ETc) of 1200 mm. In this olive orchard, water was delivered three times per week (from March to September) using a localized irrigation system with four drip nozzles of 8 l/h each per tree (two per side), placed in a line along the rows at a distance of 0.5 and 1 m from the trunk. Olive trees were irrigated with 75% of crop evapotranspiration (ETc) calculated using the Penman–Monteith-FAO method (Allen, Pereira, Raes, & Smith, 1998, p. 56) with a single estimated crop coefficient (Kc = 0.6) and a coverage coefficient (Kr = 0.7) (D'Andria et al., 2004). The experimental soil has a sandy texture. A composite sample Soil (0–20 cm depth) taken from the soil of the experimental farm was analyzed. Physico-Chemical properties of the soil are shown in Table 1. The trees are planted at 7 × 7 m apart and received the same horticultural management except fertilization with foliar treatments. The trees were arranged in a randomized block design with three blocks (392 m^2 each) and four treatments that consisted of the annual application of TC, T1, T2 and T3:

Table 1
Some physico-chemical characteristics of the experimental soil of olive orchard.

Sand (g kg^{-1})	690
Clay (g kg^{-1})	140
Silt (g kg^{-1})	170
Texture grade	Sandy
Organic C (g kg^{-1})	8.7
pH (1:5 extract)	8
E.C (1:5 extract) (mΩ^{-1} cm^{-1})	0.82
N (g kg^{-1})	7.3
P_{Olsen} (mg kg^{-1})	5

- TC: Control treatments (untreated trees, foliar application of water)
- T1: is a formulation of urea formaldehyde used as a source of nitrogen (N). It combines nitrogen with a specific mineral balance to remove any aggression of foliar applications and improve the efficiency of nitrogen in the olive tree (Table 2). Foliar application consisted of three sprays per season: at the start of vegetation, 10 days later and 20 days later. T1 is applied at 5 l/ha.
- T2: is a liquid formulation which combines effects of Boron (B), Manganese (Mn), Magnesium (Mg) and Sulfur (S) (Table 2). Foliar application consisted of two sprays per season: beginning of flowering and 10 days later. T2 is applied at 3 l/ha.
- T3: Foliar application of T1 and T2: T1 foliar application consisted of three sprays per season (at the start of vegetation, 10 days later and 20 days later), while T2 application consisted of two sprays per season (beginning of flowering and 10 days later).

Foliar fertilizers used in this study were purchased from Agronutrition (France, Carbonne). TC, T1, T2 and T3 were applied during two successive years. All sampling events included the collection of olive fruits samples, at the end of the experiment (at harvest, after two years), from three random locations in each plot. A random sample of fruits was handpicked from each experimental tree and transported to the laboratory on the same day. Fruit samples were collected with a maturity index ranged from 1 to 1.2 on a scale of 0–7.

2.2. Preparation of olive samples

Only healthy fruits, without any kind of infection or physical damage, were used for analysis. Olives from each replicate were destoned and immediately freeze-dried.

2.3. Determination of olive pulp nutrient concentrations

Total N was determined in accordance with the Kjeldahl method, with a 25 ml aliquot of pure extract, followed by distillation and titration, as described by Bremmer and Mulvaney (1982). For other element determinations, about 100 mg of dry samples were ashed in a muffle furnace at 700 °C for 24 h, and mineralized with HNO_3 (standard iso 11885). Phosphorus concentrations were determined by spectrophotometry (Murphy & Riley, 1965). Ca, K, Mg, Zn, Mn, Fe, and B were quantified by atomic absorption spectroscopy (Cottenie, 1980).

Table 2
Mineral compositions (w/v: g/L) of the two foliar fertilizers used in this study.

Foliar fertilizers	N	MgO	SO_3	B	Cu	Fe	Mn	Mo	Zn
T1	355			0.215	0.085	0.500	0.530	0.020	0.410
T2		50	111	27			10		