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Effect of olive trees density on the quality and composition of olive oil from cv. Arbequina

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ABSTRACT

The number of plants per hectare is a key factor for olive tree productivity. Nevertheless, information about the effect of tree density on olive oil quality and composition is scarce. Thus, the effect of planting densities of cv. Arbequina trees on olive oil quality and composition was studied along the first four years of production. Two types of planting tree arrangements were evaluated, namely olive trees planted at different distances within a row (2.0 m; 1.5 m; 1.25 m; and 1.0 m, fixing the space between rows equal to 4.0 m) or at different distances between rows (4.0 m; 3.5 m; and 3.0 m, fixing the space within the same row at 1.5 m), which led to planting densities from 1250 to 2500 trees ha^{-1}. The results indicated that the quality parameters, composition, antioxidant activity and oxidative stability were significantly affected by the densities of plants and the crop year (P-value $<$ 0.0001, for one-way ANOVA). An increase of plants in the row and between rows showed a tendency for a slight increase of free acidity, and a reduction of the peroxide value and of the extinction specific coefficients. Fatty acid composition was also affected, with a tendency for the decrease of C16:0, C18:0, SFA and PUFA, and an increase of C18:1, C18:2 and MUFA. The antioxidant activity and the oxidative stability also showed a reduction trend. For all parameters evaluated, the crop year had a marked influence. The year of production had significant statistical effects on the evaluated parameters, which could be related to agro-climatic factors.

1. Introduction

World consumption of olive oil has been increasing, especially in the last decades, leading to the search of new geographical areas for olive trees plantations as well as of new production practices aiming to increase the olive oil productivity per plant or per area (Rufat et al., 2014). Traditional extensive olive groves, with few plants per hectare, are not irrigated, require high labor and maintenance, and have low yields, which results in high production costs per kilogram of olives, reducing market competitiveness of the produced olive oil (Duarte et al., 2008; Proietti et al., 2012). In contrast, high-density plantations, with high number of plants per hectare, are irrigated and intensively managed, reaching higher productivity and, although having high production costs, present lower olive oil production prices (Connor et al., 2014).

Thus, the number of high-density olive groves, with 1500–2200 trees per hectare (Rius and Lacarte, 2010), has increased significantly in non-traditional producing regions, especially in some regions of Spain (Tous et al., 2007), Italy (Godini et al., 2006), Morocco, Tunisia and in the United States of America (Berenguer et al., 2006). Nevertheless, in some regions, due to plants density and positional distribution the effective solar exposition could be a limiting factor for fruit yield. As the radiation penetrates the olive tree canopy, it is absorbed and reflected, mainly by leaves, altering light quality (Mariscal et al., 2000; Connor et al., 2014). Also, light spectral distribution is dependent on leaves density and location in the tree, influencing productivity (Bastías and Corelli-Grappadelli, 2012). Therefore, the conduction system of trees in high-density hedges and rows orientation should guaranty a good adjustment of light to achieve better productions and maximize crop management. Despite all these factors are known to influence olive

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grove productivity, their effect on olive oil quality and composition is still not completely understood.

The selection of olive cultivar is also a key factor in high-density olive groves. Most traditional cultivars (e.g. Cornicabra, Galega, Hojiblanca and Picual) are not well adapted to this type of high-density orchards due to their low growth rate, late fructification age and high vigor. Spanish cv. Arbequina was the first cultivar successfully adapted to high-density groves (Proietti et al., 2012; Abenoza et al., 2014). Other cultivars also showed easy adaptation, namely Arbosana and Chiquitita from Spain; Koroneiki from Greece; which, together with Arbequina, are the most widely used worldwide (Torres et al., 2009; Allalout et al., 2011; Rondanini et al., 2011; Tous et al., 2011; Bakhouche et al., 2013; Yousfi et al., 2012; Abenoza et al., 2014).

Some works have reported the study of the effect of tree density on olive tree productivity (Vossen, 2007), the physiological responses of olive trees to environmental stress (Abdallah et al., 2017), as well as the effect of irrigation deficit on photosynthesis, growth and productivity in high-density olive orchards (i.e., more than 1500 trees/ha) (Hernandez-Santana et al., 2017). However, the way how plant density affects olive oil quality is poorly documented. In this context, the possible effect of tree density on olive oil composition was studied, using a cv. Arbequina high-density olive grove, installed in a non-traditional olive production region in Valladolid Province (Spain). The study was conducted during four consecutive growing seasons, with four plant densities that had the same distance between rows (4.0 m) but different spaces between tree in each row (from 1.0 m to 2.0 m), and three plant densities that differ in the distance between rows fixing the space of tree within the rows (Fig. 1). All olive oils were assessed taking into account the quality parameters (free acidity, peroxide value, coefficient of specific extinction, and sensory analyses), chemical composition (fatty acid composition, tocopherol profile and total phenols content), oxidative stability and antioxidant activity (DPPH, and $ABTS^+$).

2. Material and methods

2.1. Sampling

An experimental olive grove with olive trees from Arbequina cultivar was installed in Medina de Rioseco (41°52′48.3″N 5°00′17.9″W, 850 m of altitude), Valladolid Province (Spain), in May 2008. The trees were planted in rows, with different spaces within the rows (fixing the distance between rows to 4.0 m), namely 4.0 m × 2.0 m (planting density: 1250 trees ha^{-1}, d1250), 4.0 m × 1.5 m (1667 trees ha^{-1}, d1667), 4.0 m × 1.25 m (2000 trees ha^{-1}, d2000), and 4.0 m × 1.0 m (2500 trees ha^{-1}, d2500), and with different spaces between rows (fixing the distance between plants in the row to 1.5 m), with 4.0 m × 1.5 m (1667 trees ha^{-1}, d1667), 3.5 m × 1.5 m (1905 trees ha^{-1}, d1905) and 3.0 m × 1.5 m (2222 trees ha^{-1}, d2222) (Fig. 1). The experimental design was a completely randomized block design with three replicates. At the 2012 crop season, and during four consecutive years, for each density and at the same time (end of October or beginning of November), three independent samples of 3 kg each, were handpicked and immediately transported to the laboratory of the Instituto Tecnológico Agrario de Castilla y León (ITACyL), Valladolid (Spain). The fruits were extracted in a pilot extraction plant with an Abencor system (Comercial Abengoa S.A., Sevilla, Spain) with three main units: a mill, a thermobeater where malaxation takes place at controlled temperature, and a centrifuge. The yields varied from 12 to 13% (kg of olive oil/100 kg of fruits). The obtained olive oils were filtered and stored in 100 mL dark bottles and were analyzed within 3 months after extraction. All assays were carried out in triplicate.

2.2. Quality parameters determination

All samples were analyzed following the European Union standard methods (Annexes II and IX in Commission Regulation EEC/2568/91 from 11th July and amendments), being assessed the following parameters: free acidity (FA, in % of oleic acid), peroxide values (PV, in mEq O_2/kg), as well as the specific coefficients of extinction at 232 nm

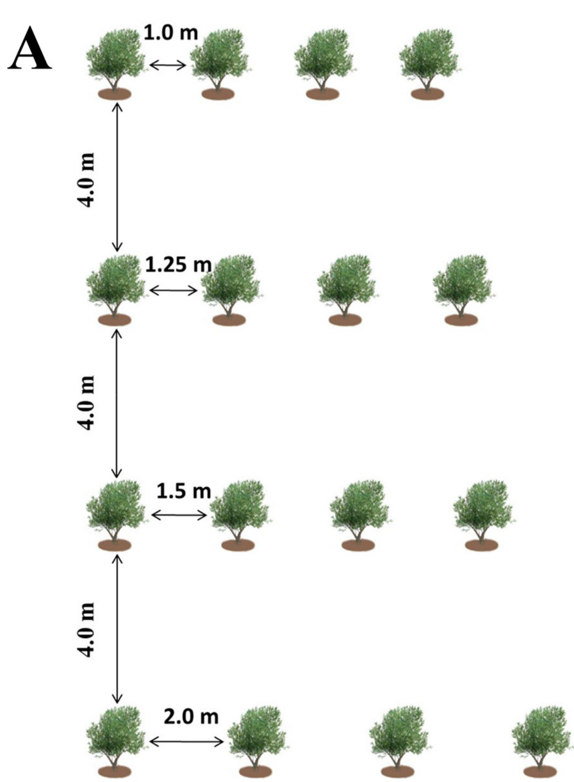

Fig. 1. Experimental design.