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Contrasting patterns of fatty acid composition and oil accumulation during fruit growth in several olive varieties and locations in a non-Mediterranean region

Déborah P. Rondanini*, Diego N. Castro, Peter S. Searles, M. Cecilia Rousseaux

Centro Regional de Investigaciones Científicas y Transferencia Tecnológica de La Rioja (CRILAR-CONICET), Entre Ríos y Mendoza s/n, Anillaco 5301, La Rioja, Argentina[1]

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ABSTRACT

Olive growing has expanded considerably in the last few decades outside of the Mediterranean Basin to non-traditional regions in the Southern Hemisphere. When growing olive genotypes (i.e., varieties) outside of their area of origin, the importance of environmental factors such as temperature and genotype × environment interactions in determining olive oil production and oil quality has been suggested. In several Mediterranean varieties and one South American variety, we assessed the dynamics of fruit growth and oil accumulation along with the evolution of fatty acid composition at multiple locations over two growing seasons. Oleic acid content (%), the principal fatty acid present in olive oil, showed four contrasting patterns during fruit growth when modeled against thermal time from flowering using linear and bilinear regressions: (1) a sharp linear decrease for the varieties 'Arauco' and 'Arbequina'; (2) a plateau followed by a late linear decrease of moderate slope for 'Barnea' and 'Manzanilla Fina'; (3) a slow linear decrease for 'Frantoio'; and (4) no decrease in 'Coratina'. Linoleic acid (%) showed linear increases in 'Arauco' and 'Arbequina' that appear to be inversely related to the decreases in oleic acid, while bilinear patterns were found for many other varieties. Both the rates of fruit growth and of oil accumulation were more important in determining maximum fruit dry weight and oil concentration (%), respectively, than duration when expressed on a thermal time basis. Temperature during oil synthesis was negatively related to final oil concentration. Experiments under controlled conditions would greatly contribute to our understanding of how fruit growth as well as oil quantity and quality are influenced by environmental factors.

1. Introduction

Olive oil production in modern, intensively managed orchards is becoming increasingly important in the Southern Hemisphere (Grigg, 2001; Vossen, 2007). Non-traditional growing regions around the world use varieties from the Mediterranean Basin, but the olive oil quality obtained can be quite different from that of the Mediterranean (Mailer, 2005; Ceci and Carelli, 2010). Thus, a possible interaction between genotype and environment that modifies olive oil composition has been suggested for many of these regions (e.g., Mannina et al., 2001; Torres et al., 2009).

One of the aspects of olive oil quality that seems to be most affected by the environment is fatty acid composition. Low percentages of oleic acid (<55%) along with high palmitic acid (>16%) and linoleic acid (>21%) are common characteristics of the fatty acid profiles of some Mediterranean Basin varieties when grown in the northern regions of Argentina or Australia (Ravetti, 1999; Mailer et al., 2010; Rondanini et al., 2011). However, low values of oleic acid, the dominant unsaturated fatty acid in olive oil, do not allow for the potential human health benefits of olive oil to be fully achieved (Covas et al., 2006). The decrease in oleic acid along the south-to-north latitudinal gradient is somewhat surprising given that temperature is increasing along this gradient in the Southern Hemisphere, and given that annual oilseed crops such as sunflower show an increase in oleic acid with temperature (Lajara et al., 1990; Izquierdo et al., 2002; Sobrino et al., 2003; Rondanini et al., 2003). In addition, seasonal temperature during the oil accumulation period in olive can negatively correlate with oleic acid (%) at harvest (Rondanini et al., 2011).

Several studies from the Mediterranean Basin have observed that oleic acid remains fairly constant or shows a slight increase during fruit ripening, while saturated fatty acids such as palmitic may decrease (Poiana and Mincione, 2004; Anastasopoulos et al.,

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* Corresponding author at: Cátedra de Cerealicultura, Facultad de Agronomía, Universidad de Buenos Aires, Av. San Martín 4453, 1417 DSE, Buenos Aires, Argentina. Tel.: +54 11 4524 8053; fax: +54 11 4524 8053.

E-mail address: rondanin@agro.uba.ar (D.P. Rondanini).

[1] Tel.: +54 3827 494251; fax: +54 3827 494231.

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2011). Such a pattern occurs in many Spanish genotypes (Uceda and Hermoso, 2001) although alternative patterns including a “V shape” for oleic acid have been reported for traditional Spanish varieties (Gómez-González et al., 2011). In contrast, an early study from central-western Argentina observed a drop in oleic acid and a rise in linoleic acid during olive fruit maturation in the variety ‘Arbequina’ (Cattaneo and Karman de Sutton, 1959). A similar pattern has been found for the variety ‘Souri’ in Israel (Dag et al., 2011).

In addition to oil quality, an indicator of oil quantity should be considered for non-traditional growing regions. Final oil concentration in olive fruit (principally in the fleshy mesocarp) is a direct consequence of the rate of oil synthesis and the duration of the oil accumulation period (Trentacoste et al., 2012). Similarly to fatty acid composition, both rate and duration of oil synthesis are controlled by several factors including genotype, environment, and their interaction. Genotypic differences in fruit growth and oil synthesis capacity have been identified at different levels of organization from crop to fruit tissue (Lavee and Wodner, 2004; Trentacoste et al., 2010; Hammami et al., 2011). During fruit ripening, there are changes in skin and flesh colors that serve as visual indicators of changes in chemical composition as oil accumulates and water is lost in the fruit (Beltrán et al., 2004). Alternatively to ripening index, thermal time (i.e., calendar time weighted by temperature) is a useful developmental index in fruit trees, as in other crops, that allows locations and seasons differing in temperatures to be compared (DeJong and Goudriaan, 1989; Pérez-López et al., 2008; Trentacoste et al., 2012).

Combining an analysis of both oil concentration and fatty acid composition for several well-known olive varieties grown in multiple locations would help to better understand the dynamics of oil accumulation and composition in a perennial oil fruit crop that ostensibly differs from oilseed crops in some environmental responses. Thus, the specific objectives of this study were to: (1) evaluate the dynamics of fruit growth and oil concentration and (2) determine the evolution of fatty acid composition in six olive varieties growing at three locations over two consecutive growing seasons. Variety, location, and growing season were considered as main factors, and the developmental time needed to maximize oil concentration and maintain fatty acid composition within industry standards was also taken into account.

2. Materials and methods

2.1. Experimental sites

Six varieties (‘Arauco’, ‘Arbequina’, ‘Barnea’, ‘Coratina’, ‘Frantoio’, and ‘Manzanilla Fina’) were evaluated in the valleys of Aimogasta (800 m above sea level, masl) and La Rioja (420 masl) during the 2006–2007 and 2007–2008 growing seasons in north-western Argentina (Table 1). All of these varieties are frequently grown in the Mediterranean Basin with the exception of ‘Arauco’, which is considered to be unique to Argentina. The Aimogasta and La Rioja Valleys are separated by the Sierras de Velasco mountain range (4000 masl) and a distance of 100 km. In the second growing season, the valley of Chilecito (850 masl), lying 80 km to the west of the other two valleys at the base of the Sierra de Famatina (6000 masl) was incorporated into the study. Two to three commercial farms in each valley were employed (eight in total) with many varieties being sampled in multiple farms per valley. Within a farm, three orchards (i.e., experimental plots, $n = 3$) of a given variety were selected, and 6 trees were sampled per plot. The plots were monovarietal except for a farm in Chilecito that had rows of three different varieties within the same plot. The trees were 8–11 years-old with planting densities of 300–500 trees per hectare. Annual rainfall is scarce in the three locations (Table 1) so drip irrigation (1000–1200 mm per year) was applied to supplement rainfall. Potential evapotranspiration for this region has been estimated to be 1600 mm per year with a crop coefficient of about 0.7 (Correa-Tedesco et al., 2010). Adequate fertilization via the irrigation system or as solid-organic compost was applied. Chemical control of pests and diseases was also common.

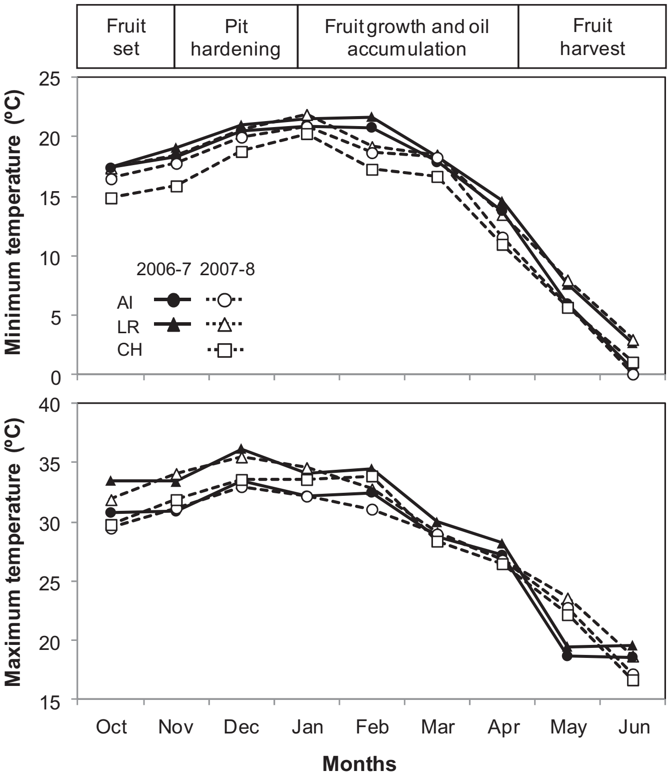

Fig. 1. Dynamics of minimum and maximum monthly temperatures during olive fruit growth in the valleys of Aimogasta (AI), La Rioja (LR), and Chilecito (CH) for two growing seasons (2006–2007 and 2007–2008). The phenological stages shown are representative for most of the olive oil varieties in the region.

2.2. Temperature conditions

Minimum and maximum monthly temperatures showed a slight increase from October to December during fruit set and pit hardening, and an acute decrease (3.5 °C per month) from February to June during the principal fruit growth and oil accumulation phase and fruit harvest (Fig. 1). In the 2006–2007 and 2007–2008 growing seasons, overall minimum values were similar with the exception of February and April when the 2007–2008 temperatures were somewhat lower than 2006–2007. The minimum temperature values varied among locations with the highest elevation location (Chilecito, 850 masl) exhibiting the lowest values (average of 13.5 °C between October and June) and the lowest elevation location (La Rioja, 420 masl) the highest values (average of 16 °C). La Rioja exhibited higher maximum temperatures than the other locations, especially from October to December during flowering, fruit set and pit hardening. From January to April (fruit growth and oil accumulation), La Rioja was only slightly warmer (average of 31.3 °C) than Chilecito (30.6 °C) and Aimogasta (30.2 °C).

2.3. Fruit growth

A total of 1 kg of fresh fruit was collected monthly from 6 trees per plot from November to June to evaluate fruit growth dynamics over the entire growing season. Each sample included fruit from all