Floral Quality and Inflorescence Architecture in *Olea europaea* 'Arauco' (La Rioja, Argentina)

M.M. Brizuela
PROPLAME PHRIDEB (CONICET)
Facultad de Ciencias Exactas y Naturales
Universidad de Buenos Aires
Argentina

F.J. Fernández
AER INTA-Aimogasta
Ruta Nac. 60 Acceso Norte, La Rioja
Argentina

P.S. Searles
Centro Regional de Investigaciones Científicas y Transferencia Tecnológica de La Rioja (CRILAR-CONICET)
La Rioja
Argentina

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Abstract

Floral quality is often overlooked as being one of the key yield determinants in olive. One aspect of floral quality is the number of perfect hermaphroditic flowers with both male and female reproductive parts relative to imperfect, staminate (male) flowers. We assessed inflorescence density, number of perfect and imperfect flowers, and inflorescence architecture in the cultivar 'Arauco' on the north- and south-sides of six 40-year-old trees growing in a small traditional orchard with a 10×10 m planting density in Aimogasta (La Rioja, Argentina). Some complementary measurements were done in a second orchard. A trade-off was found in the first orchard between inflorescence density and floral quality with inflorescence density being less on the north side of the trees versus the south, while the number of perfect flowers showed the opposite pattern. This phenomenon led to a negative relationship between inflorescence density and percentage of perfect flowers per inflorescence. Comparing the two orchards, the well-irrigated and fertilized first orchard that received flood irrigation every two weeks and manure as fertilizer had the greatest percentage of perfect flowers at the most terminal position on the inflorescence. In contrast, the second orchard received only occasional flood irrigation and no fertilization, had fewer perfect flowers, and the perfect flowers (%) were not greater at the terminal position than more basal branch positions. As a whole, these results show that both biological factors such as inflorescence density and orchard management strongly affect floral quality in the Argentinean cultivar 'Arauco'. Detailed experimental studies are needed to better understand the various influences on floral quality and inflorescence architecture.

INTRODUCTION

Flowering in mature olive trees includes the opening of hundreds of thousands of flowers on paniculate inflorescences during a good production year for a period of about two weeks during the spring (Lavee et al., 1996). Flower quantity depends to a large extent on crop load the previous year (i.e., alternative bearing behavior) and an appropriate numbers of cold hours for breaking dormancy in the winter and subsequent floral differentiation (De Melo-Abreau et al., 2004). Flowering can even vary significantly between trees within an orchard, sides of a tree, or between branches.

In addition to floral quantity, floral quality is an important aspect of olive reproductive biology (Cuevas et al., 1994; Cuevas and Polito, 2004; Moreno-Alías et al., 2012). Olive trees produce both perfect (hermaphrodite) flowers with a bi-locular ovary and imperfect (male) flowers with aborted pistils. At the whole-tree level, the percentage of these flower types can be influenced by overall flower density, while flower position within individual inflorescences can also affect flower type. Genetic differences between olive cultivars are also apparent (Seifi et al., 2008).

As large-scale, commercial olive production has expanded to new regions, there has been renewed interest in traditional olive cultivars. For example, the cultivar 'Arauco' in Argentina is a table olive cultivar with large fruits whose origins arise from the early Spanish settlement of the Americas (Searles et al., 2012). Although this cultivar is catalogued (International Olive Oil Council, 2000), little is known about its floral quality. Thus, the objectives of this study were to assess inflorescence density, the percentages of perfect and imperfect flowers, and the role of inflorescence architecture in the cultivar 'Arauco'.

MATERIALS AND METHODS

Measurements of floral quantity and quality were performed on the north- and south-sides of six 40-year-old trees growing in a small traditional orchard with a 10×10 m planting density in Aimogasta, La Rioja (28.5°S, 66.8°W). This orchard was flood-irrigated every 2-4 weeks, which is a common practice in this area, and fertilized with manure. Four of the six trees had high crop loads, while two trees had low loads. Some supplemental measurements were done on five 50-year-old trees in a near-by orchard located 5 km to the east in the village of Machigasta. This second orchard was infrequently irrigated and received no fertilization. Average monthly maximum and minimum temperatures are 26.5 and 13.3°C, respectively (Correa-Tedesco et al., 2010). Annual rainfall is approximately 90 mm (Searles et al., 2011).

Inflorescence density was measured during full bloom at the beginning of October 2011 by determining the number of inflorescences within a known cubic volume (0.2×0.2×0.2 m) for three positions on both the north- and south-sides of the six trees in the Aimogasta orchard. A one-year-old flowering branch was sampled in the Aimogasta orchard from each side (i.e., north and south) of the trees, while five branches were randomly selected in the Machigasta orchard. These flowering branches were used to observe under 15× magnification the number of perfect and imperfect flowers on selected inflorescences located in the apical, middle, and basal sections of each branch. The percentage of perfect flowers was calculated as the number of perfect flowers divided by the total flowers per inflorescence. The position of the perfect and imperfect flowers was also noted relative to the inflorescence architecture. These positions were categorized as the terminal flower (TF) and inflorescence branch 1 (B1) to branch 6 (B6) with B1 being nearest the TF and B6 nearest the base of the inflorescence.

Statistical analysis of inflorescence density and number of perfect flowers was performed by student t-tests to assess differences ($p \leq 0.05$) between the north- and south-sides of trees in the Aimogasta orchard. Linear regression analysis was used to evaluate the relationship between inflorescence density and perfect flowers (%).

RESULTS AND DISCUSSION

The number of flowers per inflorescence in 'Arauco' averaged 12.3 for the whole tree (north + south) in the Aimogasta orchard (Table 1). This is lower than any of a number of cultivars of Spanish and Italian origin (Seifi et al., 2011; Moreno-Alías et al., 2012; Vuletin Selak et al., 2012). Functionally, this may be related to 'Arauco' being a large-fruited cultivar with only one fruit typically setting per inflorescence. The number of perfect flowers per inflorescence was significantly greater on the N- than on the S-side of trees and inversely there was a tendency for the number of imperfect flowers per inflorescence to be greater on the S-side. However, no difference in overall flower number per inflorescence was apparent for the whole tree.

In addition to perfect flower number, the percentage of perfect flowers per inflorescence (%) was also greater on the N- (56±8%) than on the S-side (27±7%) when considering all trees (Fig. 1a). Because inflorescence density (#/m^3) varied widely from 1000-9000 between the trees, perfect flowers per inflorescence (%) was also assessed for low and high crop loads. There was some tendency for perfect flowers (%) to be greater on the N- than on the S-side under both crop loads, but the differences were not significant (p>0.05) due to low replication numbers (Fig. 1b,c). In comparison to perfect flowers per inflorescence (%), inflorescence density showed the opposite pattern with respect to branch orientation. Inflorescence density was often greater on the S-side of the trees than the N-side (Fig. 1d-f). Thus, a negative linear regression (r^2=0.48) was obtained with perfect flowers per inflorescence (%) decreasing as the inflorescence density increased (Fig. 2).

Differences in perfect flowers (%) per inflorescence due to branch orientation have also been noted by other authors (Dimassi et al., 1999; Seifi et al., 2011). At another Southern Hemisphere location (Australia), Seifi et al. (2011) found more perfect flowers on the N-side of the tree. It could be suggested that greater light levels on the N-side of the tree in the Southern Hemisphere provide more photoassimilates for the flowers and this difference in turn enhances flower quality. In our study, the number and percentage of perfect flowers per inflorescence on the N-side was double that of the S-side. Thus, it is more likely that a climatic event such as a cold southern wind at the end of winter or a hot, dry northern wind known locally as "Zonda" damaged a considerable number of inflorescences in a previous year, and set an alternate bearing behavior based on N vs. S orientation in motion. Cuevas et al. (1994) in the cultivar 'Manzanillo' found that high crop loads resulted in low floral quality in Spain. Our negative relationship between inflorescence density and perfect flowers (%) extends this assessment to positions (i.e., orientation) within individual trees.

The inflorescence architecture was also evaluated. In the well-watered and fertilized Aimogasta orchard, the percentage of perfect flowers was 70-90% at the terminal floral position on both the north- and south-sides of the trees (Fig. 3a,b). The third and fourth branch positions (B3 and B4) also had fairly high percentages of perfect flowers (%), while other positions had lower percentages. This is somewhat similar to the pattern of perfect flowers (%) found by inflorescence position in 'Mission' as reported by Seifi et al. (2008), but 'Mission' did not show such a high percentage of perfect flowers at the apical position. Strong genetic differences between cultivars are often evident (Koubouris et al., 2010).

In contrast to the Aimogasta orchard, the Machigasta orchard that received less water and fertilizer had perfect flower percentages no greater than 30% at any flower position including the terminal flower (Fig. 3c). Rapoport and Martins (2006) have previously reported in 'Picual' that non-irrigated orchards can have few perfect flowers when rainfall is low during the winter and spring months. The very low perfect flower percentages found in the Machigasta orchard may potentially limit fruit set and overall production. Traditional orchards in northwest Argentina are usually irrigated before and during flowering due to low rainfall at this time of year using water from mountain streams or springs, but the amounts available depend greatly on yearly conditions and water rights.

CONCLUSIONS

A trade-off appears to exist between floral quality and quantity in the traditional Argentinean cultivar 'Arauco'. Additionally, orchard management strongly affected the percentage of perfect flowers (%). Detailed experimental studies are needed to better understand the various influences on floral quality and inflorescence architecture. Other local cultivars should also be evaluated.

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Tables

Table 1. Number of perfect, imperfect, and total flowers per inflorescence on the north- and south-facing sides of the tree and both sides (N+S) combined in cultivar 'Arauco'.

Tree section	Flowers (#/infl.)		
	Perfect	Imperfect	Total
North (N)	5.6±0.7a	6.2±0.1a	11.8±1.2a
South (S)	3.3±0.8b	9.6±1.3a	12.9±1.1a
Whole tree (N+S)	4.4±0.6	7.9±0.7	12.3±0.9

Values with different letters indicate significant differences ($p \leq 0.05$) between the north- and south-facing sides using t-tests. The mean is given ± SE (n=6 trees).

Figures

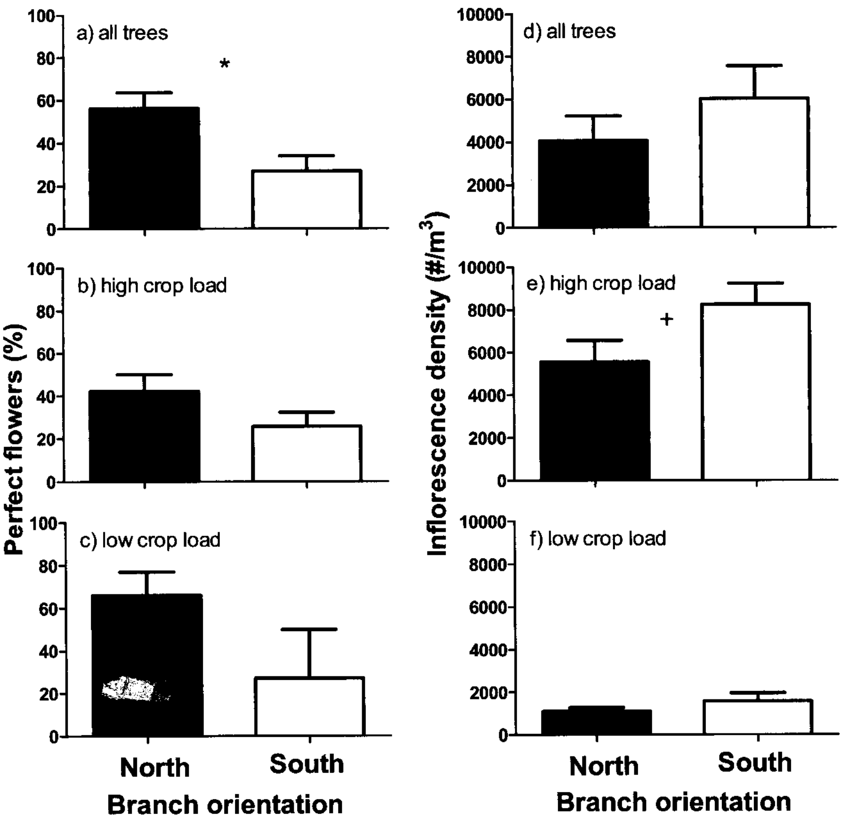

Fig. 1. Percentage of perfect flowers per inflorescence and inflorescence density on north- and south-oriented branches for all trees, high crop load, and low crop load in cultivar 'Arauco' in the Aimogasta orchard. The bars represent means ± SE. n=6 for all trees, and n=4 and n=2 for high and low crop loads, respectively. The symbol * indicates $p \leq 0.05$ and + indicates $p \leq 0.10$.

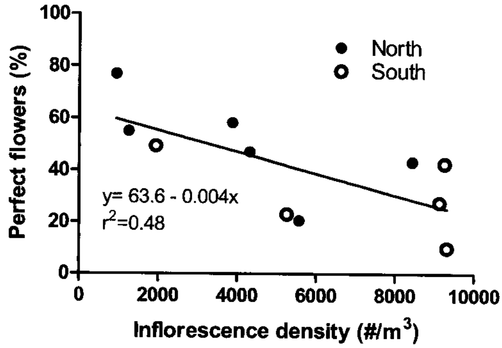

Fig. 2. The negative linear relationship between inflorescence density and percentage of perfect flowers per inflorescence on north- and south-oriented branches.

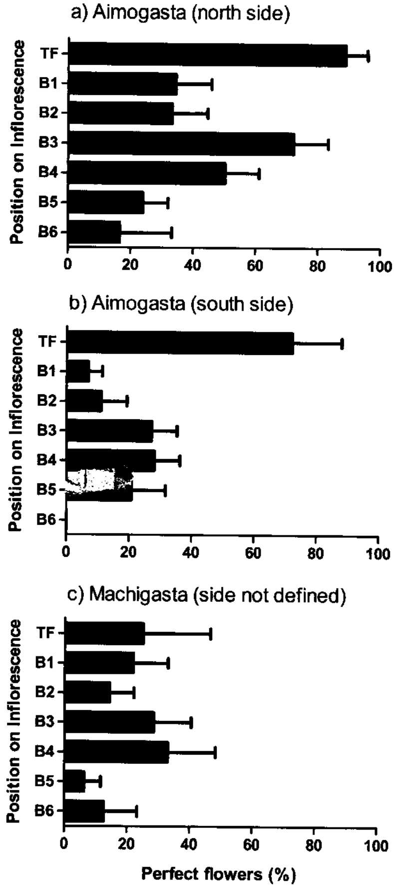

Fig. 3. The percentage of perfect flowers per inflorescence on the north- and south-side of trees in the well-watered and fertilized Aimogasta orchard and for randomly selected branches in the less watered Machigasta orchard. The bars represent means ± SE. n=6 branches per side in the Aimogasta orchard and n=5 in the Machigasta orchard. TF=terminal flower, B# = branch number.