Fruit and Tissue Responses of 'Arauco' Olive Fruits to Crop Load in Arid Argentina

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Abstract
Fruit size at harvest is an important parameter of table olive yield and quality, and is a function of the growth of both major tissues, the fleshy mesocarp (pulp) and the endocarp (pit). High crop loads most often reduce both fruit size and the mesocarp-to-endocarp ratio and delay fruit maturity. Less is known quantitatively, however, about the relationships between olive fruit size and source:sink ratios. Thus, the objectives of the present study were to assess the responses of fruit size and tissue parameters to crop load and to obtain source:sink relationships for these parameters. Fruit samples were taken from low, medium, and high crop load treatments in a commercial orchard (cultivar 'Arauco') located in Bañado de los Pantanos, Argentina, at harvest for green table olives in March 2009. Fruit fresh and dry weight, mesocarp weight, and mesocarp-to-endocarp ratio were at least 35% less in trees with high crop load than those with low crop load. The endocarp showed less response with only a modest reduction of 15%. At the cellular level, mesocarp cell number decreased with increasing crop load, while cell size was not affected. Additionally, a bilinear relationship was found between individual fruit dry weight and the source:sink ratio (canopy volume:fruit dry weight) with fruit weight increasing linearly up to a threshold of about 0.8 m^3 of canopy volume per kg of fruit dry weight, above which no further increase occurred. Similar relationships were also obtained for mesocarp and endocarp dry weights versus source:sink ratio. These results provide original quantitative estimates of olive source:sink relationships and indicate the close integration between fruit developmental processes and whole tree phenomena.

INTRODUCTION

Individual fruit weight and diameter are important parameters for the commercialization of olive table cultivars, and are determined largely by the mesocarp (pulp) and the endocarp (pit) tissues (Rallo and Rapoport, 2001; Hammami et al., 2011). The growth of both tissues is often reduced by increasing crop load, although mesocarp growth is often more strongly reduced by crop load than endocarp growth (Proietti et al., 2006; Lodolini et al., 2011). This differential effect can lead to a large reduction in the mesocarp:endocarp ratio, which is detrimental to consumer acceptance.

The reduction in fruit growth and final size in olive with high crop load may be a function of competition for photoassimilates between fruits (and other organs) as has been

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seen in some stone fruit species such as peach and cherry (Pavel and DeJong, 1993; Whiting and Lang, 2004). This would suggest that fruit growth in olive is regulated by the ratio of source (leaves)-to-sink (fruits and other organs) during some growth stages. In individual shoots, Proietti et al. (2006) observed only minor decreases in fruit growth in 'Frantoio' with decreased leaf-to-fruit ratio, possibly due to carbon importation from neighbouring shoots. However, for entire tree canopies, Trentacoste et al. (2010) found a pronounced threshold in source:sink ratio above which fruit fresh weight did not increase in 'Arbequina'.

The objectives of the present study in the Argentine cultivar 'Arauco' were to: 1) determine the responses of fruit size and tissues to a wide range of crop load; and 2) obtain source:sink relationships for these parameters. 'Arauco' is generally known for producing large fruits (IOOC, 2000), although alternate bearing behavior and accompanying variations in crop load are common.

MATERIALS AND METHODS

The experiment was conducted during the 2008-09 growing season in a commercial olive orchard (*Olea europaea* 'Arauco') located in Bañado de Los Pantanos in La Rioja, Argentina (lat. 28°23'S; long. 66°51'W). The trees were 11 years old and tree spacing was 6 m within rows × 8 m between rows. Tree volume was approximately 16 m^3 at the start of the season. The soil was gravelly sand in texture, deep, and classified as an entisol. Irrigation was based on a crop coefficient of 0.7 using a drip system (Correa-Tedesco et al., 2010) and fertilization (N, P, K, Mg) was provided via the same system. The trees were not pruned during the experiment.

Three experimental groups were obtained at the beginning of the season by categorizing trees as low, medium, or high crop load based on visual observation. At harvest, the average crop loads in fruits per m^3 of canopy volume were 480±94, 759±77, and 1338±60, respectively. The experimental design was a completely randomized block design with six blocks. Each block consisted of one tree from each of the three groups (low, medium, high) for a total of 18 trees in the study.

Samples of 20 fruits per tree were collected on March 16, 2009 during the yearly harvest of green table olives to measure longitudinal and equatorial fruit and endocarp diameters using calipers, and to determine fruit fresh and dry weight. Fruit fresh weights were determined in the laboratory using an analytical balance, and the fruits were dried in an oven at 80-90°C until they reached a constant weight before final re-weighing. A larger sample of 50 fruits was frozen after harvesting for later determination of mesocarp:endocarp ratio.

The total number of mesocarp cells and mean area per cell in equatorial fruit sections was evaluated in 10-15 fruits per tree in three of the experimental blocks using fruits fixed in FAE (formalin:acetic acid:60% ethanol = 2:1:17, v/v) in Argentina and transported to the Instituto de Agricultura Sostenible in Cordoba, Spain for analysis. Details of the histological procedures (paraffin embedding, sectioning, and staining) and image analysis measurements of mesocarp tissue and cells can be found in Hammami et al. (2011).

Statistical analysis was conducted using standard ANOVA models for completely randomized block designs (Infostat Software; Cordoba, Argentina). Fisher's LSD test was employed to determine significant differences between treatments ($p \leq 0.05$). Additionally, the wide range of crop load among the 18 trees was used to assess the source:sink relationships of individual parameters such as fruit, mesocarp, and endocarp weight by fitting the data points with bilinear regressions (GraphPad Software; San Diego, USA). Source:sink ratio was defined as m^3 of tree canopy volume per kg of fruit dry weight. The tree canopy volume was calculated as the average of seasonal measurements, while fruit dry weight was determined at harvest.

RESULTS

Individual fruit weight was approximately 35-40% lower under high crop load on

(2006) in 'Frantoio' and Trentacoste et al. (2010) in 'Arbequina' are 0.7-1.2 and 1.3-1.7 m^2/kg of fresh fruit, respectively. From Figure 1a, it can be observed that individual fruit weight of low (480 fruit/m^3 canopy) crop load trees was generally above the breakpoint, but that fruit weight of both the medium (759) and high (1338) crop load trees was below the breakpoint. This result is similar to Trentacoste et al. (2010), and suggests that individual olive fruit weight is often limited by resource availability. Lastly, the breakpoint for the mesocarp and endocarp were similar to that of individual fruit in our study, but the biological significance of the endocarp breakpoint should be further considered because our source:sink values better reflect the source:sink ratio at harvest than the first 7-9 weeks after flowering when most endocarp growth occurs. Further research is needed to understand cellular processes during fruit growth and the timing of resource limitation.

Literature Cited
Barone, E., Gullo, G., Zappia, R. and Inglese, P. 1994. Effect of crop load on fruit ripening and olive oil (*Olea europea* L.) quality. J. Hortic. Sci. 69:67-74.
Correa-Tedesco, G., Rousseaux, M.C. and Searles, P.S. 2010. Plant growth and yield responses in olive (*Olea europaea*) to different irrigation levels in an arid region of Argentina. Agric. Water Manage. 97:1829-1837.
Dag, A., Bustan, A., Avni, A., Lavee, S. and Riov, J. 2009. Fruit thinning using NAA shows potential for reducing biennial bearing of 'Barnea' and 'Picual' oil olive trees. Crop Pasture Sci. 60:1124-1130.
Grossman, Y.L. and DeJong, T.M. 1995. Maximum fruit growth potential and patterns of resource dynamics during peach growth. Ann. Bot. 75:553-560.
Gucci, R., Lodolini, E. and Rapoport, H.F. 2007. Productivity of olive trees with different water status and crop load. J. Hortic. Sci. Biotechnol. 82:648-656.
Hammami, S.B.M., Manrique, T. and Rapoport, H. 2011. Cultivar-based fruit size in olive depends on different tissue and cellular processes throughout growth. Sci. Hortic. 130:445-451.
International Olive Oil Council. 2000. World Catalogue of Olive Varieties. Madrid, Spain.
Lodolini, E.M., Gucci, R. and Rapoport, H.F. 2011. Interaction of crop load and water status on growth of olive fruit tissues and mesocarp cells. Acta Hort. 924:89-94.
Morales-Sillero, A., Rapoport, H., Fernandez, J.E. and Troncoso, A. 2008. Olive fruit pulp and pit growth under differing nutrient supply. Sci. Hortic. 117:182-184.
Pavel, E.W. and Dejong, T.M. 1993. Source and sink limited growth periods of developing peach fruits indicated by relative growth rate analysis. J. Amer. Soc. Hortic. Sci. 118:820-824.
Proietti, P., Nasini, L. and Famiani, F. 2006. Effect of different leaf-to-fruit ratios on photosynthesis and fruit growth in olive (*Olea europaea* L.). Photosynthetica 44:275-285.
Rallo, P. and Rapoport, H.F. 2001. Early growth and development of the olive fruit mesocarp. J. Hortic. Sci. Biotechnol. 76:408-412.
Trentacoste, E.R., Puertas, C.M. and Sadras, V.O. 2010. Effect of fruit load on oil yield components and dynamics of fruit growth and oil accumulation in olive (*Olea europaea* L.). Europ. J. Agron. 33:132-138.
Whiting, M.D. and Lang, G.A. 2004. 'Bing' sweet cherry on the dwarfing rootstock

'Gisela 5': thinning affects fruit quality and vegetative growth but not net CO_2 exchange. J. Amer. Soc. Hortic. Sci. 129:407-415.

Tables

Table 1. Individual fruit and tissue weights at harvest under different crop loads in *Olea europaea* 'Arauco'. The crop loads were low (480), medium (759), and high (1338) in terms of fruit number/m^3 of tree canopy volume.

Parameter	Crop load		
	Low	Medium	High
Fruit fresh weight (g)	6.7±0.3a	5.7±0.2b	4.4±0.1c
Fruit dry weight (g)	2.8±0.2a	2.3±0.1b	1.7±0.1c
Mesocarp dry weight (g)	2.0±0.2a	1.6±0.1b	1.0±0.04c
Endocarp dry weight (g)	0.69±0.02	0.64±0.02	0.58±0.03
Dry mesocarp:endocarp ratio	2.9±0.2a	2.4±0.1b	1.7±0.1c

Values with different letters indicate significant differences ($p \leq 0.05$) between treatments using Fisher's LSD test. n=6 trees per crop load ± SE.

Table 2. Fruit and endocarp longitudinal and equatorial diameters at harvest under different crop loads in *Olea europaea* 'Arauco'. The crop loads were low (480), medium (759), and high (1338) in terms of fruit number/m^3 of tree canopy volume.

Parameter	Crop load		
	Low	Medium	High
Fruit			
Longitudinal diameter (mm)	28.4 ± 0.5a	27.3 ± 0.5a	25.2 ± 0.2b
Equatorial diameter (mm)	20.0 ± 0.4a	19.0 ± 0.3b	17.0 ± 0.1c
Ratio (Long./Equat.)	1.44 ± 0.01	1.46 ± 0.02	1.49 ± 0.01
Endocarp			
Longitudinal diameter (mm)	19.6 ± 0.2a	19.0 ± 0.4a	18.0 ± 0.3b
Equatorial diameter (mm)	8.9 ± 0.1a	8.6 ± 0.1a	8.2 ± 0.2b
Ratio (Long./Equat.)	2.21 ± 0.03	2.22 ± 0.05	2.21 ± 0.02

Values with different letters indicate significant differences ($p \leq 0.05$) between treatments using Fisher's LSD test. n=6 trees per crop load ± SE.
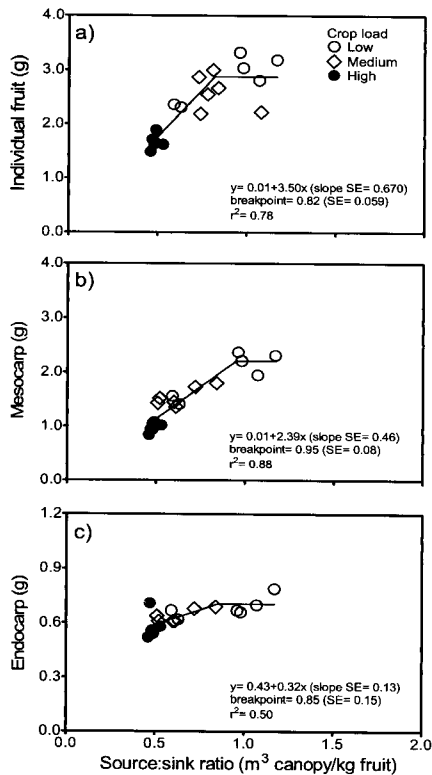
Fig. 1. Dry weight of individual fruit (a) and mesocarp (b) and endocarp (c) tissues versus the source:sink ratio for individual trees of *Olea europaea* 'Arauco'. Tree source:sink ratio is expressed as m^3 of tree canopy volume/kg of fruit dry weight. The crop load group to which each tree was assigned is given as low, medium, and high. A bilinear model was determined for each dry weight parameter including slope, y-intercept, breakpoint, and r^2 value. n=6 trees per crop load group.