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Influence of altered irradiance on fruits and leaves of mature pear trees

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Abstract

The response of pear fruit and leaf parameters to shade imposed during development was studied. Whole branches of mature trees of *Pyrus communis* L. cv. Bartlett growing in the High Valley area of Argentina were covered with a shade cloth (80 % reduction in irradiance) from 6 to 18 weeks after full bloom (WAFB) during the 1995-96 growing season. Fruit diameter was measured at two-weekly intervals; flesh firmness, soluble solids concentration, and leaf area were determined 18 WAFB. Prolonged shading significantly reduced fruiting spur specific leaf mass and consequently resulted in 20.79 % less final fruit fresh mass. However, flesh firmness was 8.07 % lower under full irradiance.

Additional key words: fruit quality, *Pyrus communis*, shading, specific leaf mass.

Introduction

Shading can be a major stress in many crop species; it frequently occurs in tree canopies and has marked effect on fruit quality. This is a particularly difficult subject to study since fruit growth covers a long period and involves numerous physiological changes, each of which may be influenced in different ways, depending on environmental conditions and orchard management. Since tree training systems and techniques such as winter and summer pruning and fruit thinning can alter irradiance in the canopy, more knowledge in this respect could usefully be applied to increase orchard efficiency (Mika 1986, Loreti *et al.* 1993). As the leaves of a tree develop during the spring, interception of photosynthetically active radiation (PAR) increases.

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Abbreviations: FD - fruit diameter; FM - fresh mass; LA - leaf area; PAR - photosynthetically active radiation; SLM - specific leaf mass; SSC - soluble solids concentration; WAFB - weeks after full blossom.

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However, leaves shade each other, and that shading is detrimental to photosynthesis. Many of the effects of microclimate on fruit development appear to be related to the variations in irradiance across the canopy, although there have been many reports showing the positive influence of high irradiance on final fruit size. The clarification of when and how the fruit growth is affected is still needed. Additionally, the effects will likely vary depending on the environment, the different shading methods and the fruit crops used. Studies with other crop plants indicate that shade (Boardman 1977), defoliation (Garriz 1980) or insect damage (Francisconi *et al.* 1995) decrease photosynthesis and yield.

Cultivar Bartlett is currently the most extensively planted pear cultivar in Argentina. Our research was undertaken to determine if shading imposed after full bloom affect leaf characteristics and fruit quantity and quality.

Materials and methods

Mature *Pyrus communis* L. cv. Bartlett trees trained as palmette leader were grown at the experimental farm of the Comahue National University (latitude 38°56'S longitude 67°59'W) on a sandy loam soil. The experimental site was located in an arid region, with average annual rainfall of 250 mm. Daily maximum irradiance was 1525 W m^{-2} (8 November 1995). The growing season 1995-96 was hot, particularly in December, with maximum air temperature of 31.8 °C (Fig. 1). The trees were

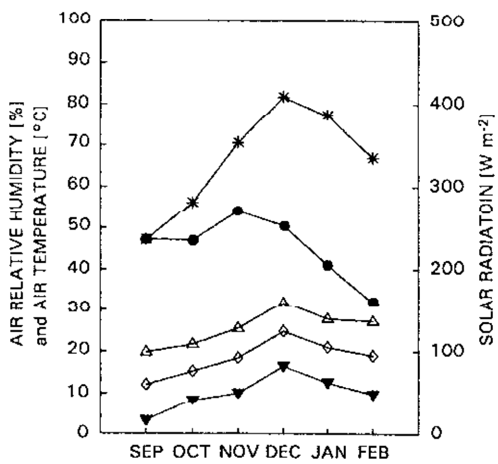

Fig. 1. Monthly solar radiation (*asterisks*), maximum (*open triangles*), mean (*rhombs*) and minimum (*closed triangles*) air temperature and relative humidity (*circles*) in orchard during 1995-96 growing season.

spaced 4 × 4 m and row orientation was north-south. Crop load was 1.36 fruits cm^{-2} trunk cross sectional area. The orchard was kept weed-free, fertilized, hand thinned and sprayed for pest and disease control according to the local standard programme for pears; surface flooding irrigation was applied. Two comparable branches on each of five uniform trees were selected for good exposure and one branch of each pair was randomly shaded. Whole branches were covered continuously with a 20 % transmission (*i.e.*, 80 % reduction in irradiance) black saran neutral density shade cloth, starting in November 1995 (6 WAFB) and ending in January 1996 (18 WAFB); full blossom was on 25 September 1995. On each branch, four fruits were tagged and fruit diameter (FD) was measured at two-weekly intervals with a Vernier caliper (model *30-410-5*, *General Supply Corporation*, Jackson, USA) (n = 20 per treatment and date). FD was the maximum width perpendicular to the main axis. On 31 January 1996, fruit firmness was measured by means of a penetrometer (model *FT 327*, *R. Bryce*, Alfonsine, Italy) equipped witn an 8 mm plunger and soluble solids concentration (SSC) was determined using a hand-held refractometer (*Brix 0 - 32 %*, *Erma*, Tokyo, Japan). Simultaneously, the fully expanded spur leaf which was the closest to each tagged fruit was collected. Leaf area (LA) was assessed from measurements of the length and width of leaves (Garriz *et al.* 1996). Discs were excised between the midrib and leaf margin, using a cork borer of 13 mm diameter. They were subsequently dried at 80 °C for 48 h and weighed to obtain specific leaf dry mass (SLM). Meteorological data were continuously monitored at the experimental farm, using a weather station (model *93V2*, *Metos-DAT*, *Gottfried Pessl*, Weis, Austria). All data were tested for significant differences using analysis of variance (*SAS Institute*, Cary, USA).

Results and discussion

Fruit growth pattern: Initially, there were no differences in FD between the fruits exposed to full sun and 80 % shade but from 10 WAFB, the effect of the shading treatment became apparent (Fig. 2). Significant ($P \leq 0.05$) differences were found between the final FD of the exposed (66.40 mm) and shaded fruits (61.05 mm). In order to express the results in fruit fresh mass, FM [g], FD [cm] was converted to FM

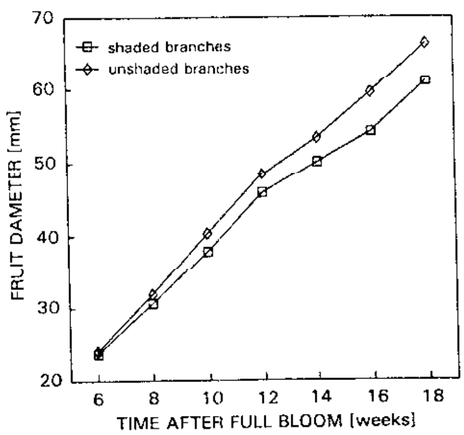

Fig. 2. Seasonal changes in pear fruit diameter as affected by shade beginning at 6 WAFB.

using the following equation: FM = 0.8236 $FD^{2.775}$; r^2 = 0.98 (Garriz *et al.* 1995). Reducing the production of photoassimilates by shading of branches during 12 weeks resulted in 20.79 % less final FM (Table 1). Lakso and Corelli Grappadelli (1992) found that moderate shade (65 % reduction in irradiance) had negative effects on apple fruit growth rates at 4 WAFB and just before harvest. However, in areas with high irradiance and air temperature, some negative effects of high irradiance may occur; Bravdo (1986) showed that moderate shade under such conditions may increase photosynthesis and stomatal conductance in apples. Loss of a source of assimilate can be partially compensated for by increased photosynthesis in other organs (Garriz 1980). The transport of assimilates may be changed by the rate of growth of developing organs which, in turn, may be affected by the level of phytohormones, changes in the rate of photosynthesis and by the export of assimilates from leaves (Šebánek 1992). For instance, shading of young grape shoots could completely alter carbohydrate partitioning (Quinlan and Weaver 1970).

Fruit maturity: Fruits which were exposed to full solar radiation were softer and *flesh firmness was decreased by 8.07 %, compared with the shade treatment* ($P \le 0.05$), whereas no marked changes were detected in the SSC (Table 1). There are several attributes that constitute fruit quality, including flesh firmness, skin appearance, size, taste, aroma, anthocyanin and starch content. Shading experiments conducted in the past resulted in reduction of fruit quality in pears (Kappel and Nielsen 1994) and other horticultural crops (Jackson 1968, Proctor and Lougheed 1976). Luminosity in pear skin was highly affected when the fruits were wrapped in aluminium foil to obscure all light (Dussi and Sugar 1995). Although radiation interception is never totally blocked throughout a canopy, very low irradiance can be reached in the innermost parts. Radiation interception is determined by the amount and arrangement of leaves, fruits and branches within the tree crown, the tree shape and size, spacing, row orientation and the angular distribution of light from the sun and sky (Palmer 1981).

Table 1. Effect of shade (80 % of full irradiance) on pear fruit firmness, soluble solid concentration, mean fruit fresh mass, specific leaf mass and leaf area. Means with the same letter in each column did not differ significantly at $P \le 0.05$.

	Firmness	SSC [%]	Fresh mass [g]	SLM [mg cm^{-2}(LA)]	LA [cm^2]
Unshaded	80.61 a	10.35 a	157.48 a	11.36 a	11.19 a
Shaded	87.69 b	10.65 a	124.74 b	7.86 b	11.39 a

Leaf characteristics: Changes in sun exposure induced leaf morphological differences (Table 1); statistically higher SLM was recorded in unshaded fruiting spur leaves in comparison to spurs exposed to shade ($P \le 0.05$). Fruiting spur LA was lower in the sunlit branches than in the shaded ones (11.19 cm^2 *vs.* 11.39 cm^2, respectively); however, the differences were small. According to Salisbury and Ross (1991), sun leaves have less area per leaf, but they are thicker (often have more layers of palisade mesophyl consisting of longer cells) than shade leaves. The present study with pear leaves of cv. Bartlett confirms the general trend for increased SLM with higher irradiances found in cv. Forelle (Dussi and Huysamer 1995) and shows that the response can occur from 6 WAFB onwards. In cvs. Bartlett and Anjou a positive correlation was found between SLM and irradiance up to 10 weeks prior to leaf analysis (Kappel and Nielsen 1994). Barden (1978) reported that SLM was affected by shade and might be used as a tool to determine net photosynthetic potential. SLM was also influenced by the origin of the leaves within the spur and by both the previous and the current irradiances (Porpiglia and Barden 1980, Tustin *et al.* 1992). Furthermore, it appears that later in the season a substantial quantity of carbohydrates are provided by the shoot leaves to the fruits (Faust 1989). Apple leaves that develop in the sun contain more nitrogen and exhibit higher photosynthetic rates than those developing in the shade (Lakso 1994). Positive correlations between leaf N content and irradiance was found in pears (Kappel and Nielsen 1994) and peaches (Dejong and Doyle 1985). However, N nutrition would have to be used in moderation, since lush growth resulting from high-N fertilization increases shading within the tree. Shading induces differences in foliage temperature, transpiration and the patterns of root-supplied hormones (*e.g.*, cytokinins) and/or nutrients (Botos-Bálo *et al.* 1994). In our study, the increment in fruit size in the exposed fruits would appear to depend on carbohydrate availability, since leaf thickness (*i.e.* SLM) in the sun-lit leaves was increased relatively more than in the shaded ones. The present results indicate that shading imposed from 6 to 18 WAFB had negative effects on fruit growth and maturity and only small positive effect on fruit firmness under the climatic conditions of this experiment. The results reinforce the need to maximize light penetration by improving different management practices in the future.

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