Effect of Fruit-to-Leaf Area Ratio on Fruit Quality and Vegetative Growth of 'Bing' Sweet Cherry Trees at Optimal Leaf Area Index

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Abstract

Fruit yield and quality determine grower income from commercial sweet cherry orchards. The objective of this study was to determine the effect of Fruit Number to Leaf Area Ratio (FNLAR, fruit m^{-2} LA) on Mean Fruit Weight (MFW), firmness (F), soluble solids content (SSC), titratable acidity (TA) and SSC:TA ratio of 'Bing' sweet cherries trees of near-optimal leaf area index (LAI). The effect of FNLAR on Mean Shoot Growth (MSG) and trunk cross-sectional area increment (TCSAI) also was analysed to determine possible competition between reproductive and vegetative growth. Regression analysis was used with FNLAR as the independent variable. While SSC:TA, MSG and TCSAI were not significantly correlated to FNLAR ($P>0.05$), MFW, TA and SSC decreased linearly with increasing FNLAR ($P<0.05$), at a rate of 0.02881 g, 0.0272 ml NaOH and 0.0649% per FNLAR unit, respectively. Firmness showed the same tendency, but the correlation was not significant ($P=0.082$). Knowledge of the relationship between fruit quality and FNLAR on trees of near-optimal LAI allows optimization of high yields with favourable quality.

INTRODUCTION

Fruit yield and quality determine commercial sweet cherry (*Prunus avium* L.) crop value. Yield (kg ha^{-1}) can be calculated as MFW • FNLAR • LAI; where MFW is mean fruit weight (kg $fruit^{-1}$); FNLAR is fruit number to leaf area ratio (fruit ha^{-1} LA) and LAI is the leaf area index (ha ha^{-1}).

Individual fruit weight is the main quality characteristic for market value because fruit price is based mainly on size. However, skin and flesh colour, firmness (F), soluble solids content (SSC) and titratable acidity (TA) also are important quality characteristics for cherry. The relationships between FNLAR and MFW (Proebsting, 1990; Whiting and Lang, 2004), SSC (Roper and Loescher, 1987) and F (Facteau et al., 1983) are negative. For a specific variety, FNLAR of the current year is the most important determinant of fruit weight variation (Proebsting, 1990). Roper and Loescher (1987), studying the relation between leaf area and fruit quality of 'Bing' sweet cherry using isolated spurs, found that in the growing conditions of Washington State, leaf area per fruit accounted for 66, 36 and 53% of the variability in fruit weight, fruit colour and soluble solids, respectively. An increase of 1 g in fruit weight was predicted to require an additional 30 to 32 cm^2 of LA. Leaf area per spur accounted for 54, 27 and 28% of the variability in the same fruit quality parameters.

The objective of this study was to determine the effect of FNLAR on MFW, F, TA and SSC in 'Bing' sweet cherry trees, growing in vase training systems at near-optimal LAI. The effects of FNLAR on mean shoot growth (MSG) and trunk cross-sectional area increment (TCSAI) also were analysed to determine possible competition between reproductive and vegetative growth.

MATERIALS AND METHODS

The study was conducted during the 2004/05 season, in a commercial orchard, planted in 1997 with 'Bing' on 'Mahaleb' (*Prunus mahaleb* L.) rootstock (966 trees ha^{-1}) and trained as a vase, in the lower valley of Chubut river, in Argentinean Patagonia (43°16' south latitude, 65°25' west longitude). Routine horticultural care for commercial fruit production was provided, including irrigation, fertilisation, wind protection, weed-, pest- and disease control, and winter pruning. For defining a target value of LAI at harvest, interception of photosynthetically active radiation (PAR) was calculated (Goudriaan and van Laar, 1994) as: $I_a = (1 - \rho_c) \bullet (1 - \exp(-K \bullet CLF \bullet LAI)) \bullet 100$; where I_a is intercepted PAR (%); ρ_c is a reflection coefficient set to 8% (Goudriaan and van Laar, 1994); K is the light extinction coefficient, set to 0.6 (Gil Salaya, 1999) and CLF is a clustering factor (between 0 and 1) that was calculated with a sub-model (Goudriaan, pers. commun.) to correct for the crop being cultivated in rows. Based on this model, it was estimated that a LAI of 3.2 is necessary to intercept 75% of PAR at harvest, which in fruit tree production is considered a near-optimal situation (Gil Salaya, 1999). Based on data from the same orchard showing a positive relationship between LAI at harvest and TCSA (cm^2) at bud break (data not shown), a minimum threshold for TCSA = 78 cm^2 was defined: 18 homogeneous trees with a TCSA ≥78 cm^2 at bud break were selected.

At fruit harvest (fruit colour number 4 on the Ctifl colour chart; December 10^{th} to 15^{th}), all leaves on each of the experimental trees were counted, followed by random sampling of 1% of the leaves. The area of each sample leaf was measured with a scanner (Hewlett Packard® ScanJet 4C) to the nearest 0.1 cm^2, using "Image Tool 3.0" (UTHSCSA, 2002). LA per tree was calculated from the number of leaves and the mean area per leaf. The LAI of each tree was estimated from tree density. Total yield per tree was monitored and MFW was determined from a random sample of 100 fruits per tree. Number of fruits per tree and FNLAR were calculated from yield per tree and MFW. The same fruit sample was used to estimate F (Durofel index: 0 to 100), TA (ml NaOH) and SSC (%). F was measured non-destructively with a durometer Durofel 25®; TA was measured by adding 10 ml of sample juice to 90 ml of distilled water and titrating with 0.1 N sodium hydroxide (NaOH) to the final point of pH 8.2 and SSC was measured on fruit juice with a refractometer (Atago®). Simple linear regression analyses were performed with GenStat 6.1 (Payne, 2002), using FNLAR as the independent variable and MFW, TA, SSC, SSC:TA, F, MSG (cm) and TCSAI as dependent variables, to detect significant relationships ($P<0.05$).

RESULTS

Mean LAI of individual trees at harvest was 3.6 (standard deviation: 0.74) and estimated PAR interception was ca. 79%. The main source of variability in FNLAR was pollination effectiveness (according to distance from beehives) and fruit-drop, resulting in fruit set between 15 and 56%. While MSG and TCSAI were not significantly correlated to FNLAR (P=0.369 and P=0.092, respectively), all fruit quality variables decreased linearly with increasing FNLAR ($P<0.05$) at rates of 0.02881 g, 0.0272 ml NaOH and 0.0649% per FNLAR unit, for MFW, TA and SSC, respectively (Fig. 1). Firmness showed the same tendency, at a rate of 0.1016 Durofel index units per FNLAR unit, but the relationship was not significant (P=0.082), neither was the relationship (P=0.404) with SSC:TA. The coefficients of determination were rather low, i.e., 0.47, 0.19 and 0.34 for MFW, TA and SSC, respectively.

DISCUSSION

PAR interception was close to the target value, thus near-optimal for sustainable fruit production. Under these conditions, a linear negative relationship between FNLAR and MFW was found, in agreement with the results of earlier studies (Roper and Loescher, 1987; Whiting and Lang, 2004), indicating that source limitation increases as FNLAR increases. Whereas FNLAR seems to be the main determinant of fruit weight, reserves might have played a role. At bud-break, reserves stored in bark, wood and roots provide the carbohydrates for growth until assimilate supply from the leaf area of the tree is sufficient to satisfy sink demand. SSC decreased as FNLAR increased, but it was always ≥17%. Although the negative relationship between firmness and FNLAR was not significant (P=0.082), further study is warranted because of the importance of firmness for export marketing potential. This would be even more important for varieties with softer fruit. The lack of significant effects of FNLAR on vegetative growth (TCSAI and MSG) suggested that, although some competition between vegetative and reproductive growth may occur, fruit are the main sink organs. Thus, low FNLAR stimulates growth of the remaining fruit, rather than vegetative growth.

Knowledge of the relationship between fruit quality and FNLAR on trees at near-optimal LAI allows combination of high yield with favourable quality. Consequently, management practices have to be identified and tested to quantify their effects on LAI and FNLAR, allowing application of this concept in commercial orchards.

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Figures

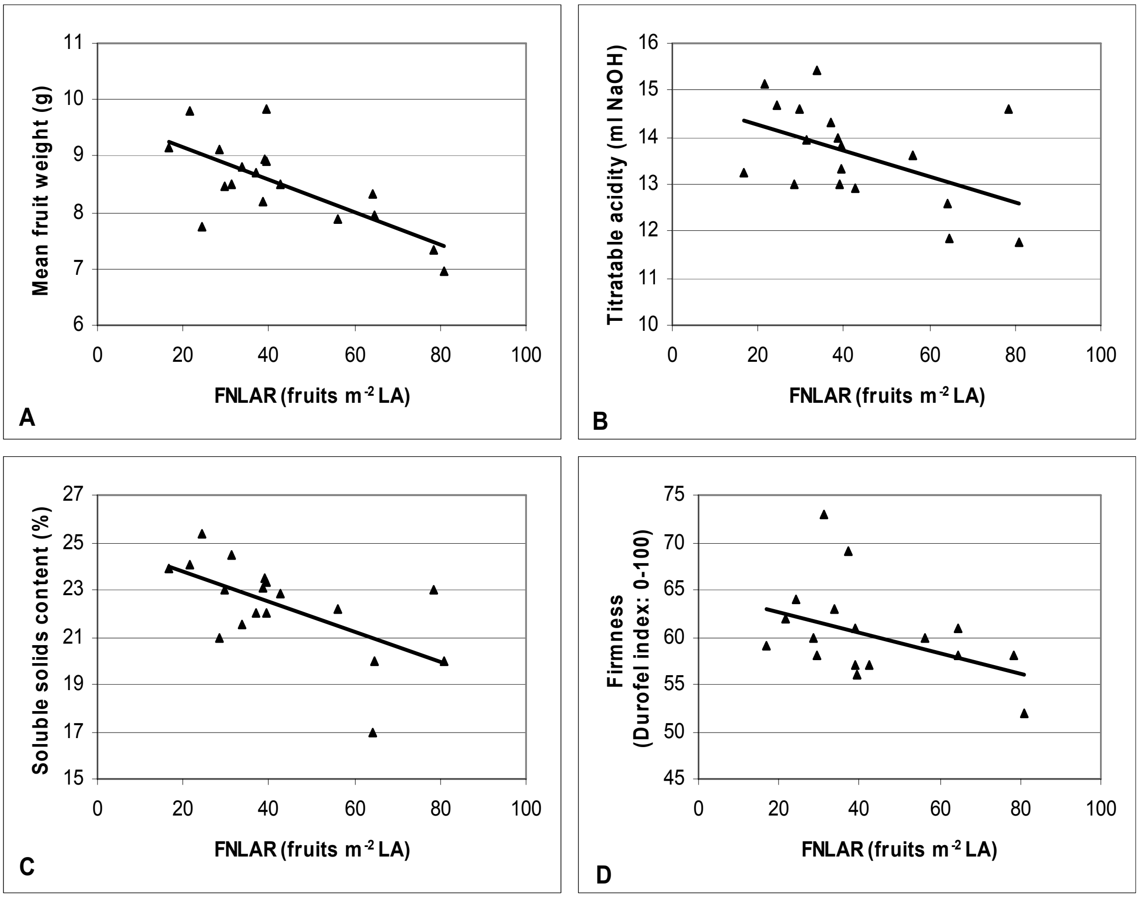

Fig. 1. Effect of sweet cherry fruit number to leaf area ratio (FNLAR) on (A) mean fruit weight (MFW; g $fruit^{-1}$), (B) titratable acidity (TA), (C) soluble solids content (SSC) and (D) firmness (F). A: y = 9.734-0.02881x, R^2 = 0.47, $P<0.001$. B: y = 14.784-0.0272x, R^2 = 0.19, $P<0.044$. C: y = 25.15-0.0649x, R^2 = 0.34, $P<0.008$. D: y = 64.07-0.1016x, R^2 = 0.13, $P<0.082$.