Relationship between Fruit Weight and the Fruit-to-Leaf Area Ratio, at the Spur and Whole-Tree Level, for Three Sweet Cherry Varieties

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Abstract

Fruit weight is the main quality parameter of sweet cherries and leaf area/fruit is the most important characteristic influencing fruit weight. The objective of this study was to determine the relationship between Mean Fruit Weight (MFW) and the Fruit Number to Leaf Area Ratio (FNLAR) for 'Bing', 'Van' and 'Lapins', grown under tatura-trellis and vase training systems, at both the spur and whole-tree level. The research was performed through regression analysis with FNLAR as the independent variable and MFW as the dependent variable. There were no significant interactions between training system and cultivar for the effect of FNLAR on MFW at either the spur or whole-tree level. Also, there were no significant differences between training systems. The R^2 for the relationships per cultivar were higher at the whole-tree level than at the spur level. At both levels, 'Lapins' had the highest fruit weight potential and 'Van' the lowest. At the spur level, the slopes of the regression were similar for the different cultivars, but at the whole-tree level, 'Van' was less sensitive. The better fit at the whole-tree level suggests that fruits of a spur are supplied not only by the leaves on that spur, but also from other less fruit-loaded spurs, from non-fruiting shoots and from reserves.

INTRODUCTION

In sweet cherry (*Prunus avium* L.) production, individual fruit weight *vis-à-vis* size is the main quality parameter for marketing because fruit price is mainly based on size categories. The Fruit Number to Leaf Area Ratio (FNLAR; fruit m^{-2} LA) during the fruit growing period is the most important factor for explaining fruit weight variation (Proebsting, 1990), while previous management has a minor influence (Whiting and Lang, 2004). Leaf area (LA) has a strong relationship with photosynthetic capacity, for a high area per fruit is essential for high quality sweet cherries (Roper and Loescher, 1987). In general, mean fruit weight (MFW; g $fruit^{-1}$) decreases as FNLAR increases (Facteau et al., 1983).

Training system affects canopy light distribution and therefore canopy photosynthetic rate (Goudriaan and van Laar, 1994). For the same LA per tree, a better light distribution may contribute to increased carbohydrate supply to sink organs, resulting in higher MFW. Cultivars differ in potential fruit weight and in the sink strength of individual fruit. Regressions between MFW and FNLAR can be used to analyse production potential of different cultivars (Proebsting, 1990). A better understanding of the relationships between MFW and FNLAR would facilitate development and implementation of cultivar-specific management practices to attain optimum fruit yield and quality. The objective of this study was to determine the relationship between MFW and FNLAR at both spur and whole-tree levels for 'Bing', 'Van' and 'Lapins', growing under tatura-trellis and vase training systems.

MATERIALS AND METHODS

The study was conducted during the 2003/04 growing season, in two commercial orchards: one was trained to a tatura-trellis (1872 trees ha^{-1}) and the other as a vase (937 trees ha^{-1}). Both orchards were planted in 1997 in the lower valley of the Chubut river (43°16' south latitude, 65°25' west longitude), Argentina, with 'Bing', 'Van' and 'Lapins' grafted on 'Mahaleb' (*P. mahaleb* L.) rootstocks. Management and growing conditions were similar for both orchards. Routine horticultural care for commercial fruit production was provided, including irrigation, fertilisation, wind-, weed-, pest- and disease control, and winter pruning. From each combination, ten trees of similar vigour were selected randomly for measurements. From each tree, all leaves and fruits of six 2-year-old spurs were collected at fruit maturity (estimated as 80% of the fruits having attained colour number 3 of the CTIFL colour chart). Each spur leaf was measured with a Hewlett Packard® ScanJet 4C to the nearest 0.1 cm^2, using the "Image Tool 3.0" (UTHSCSA, 2002). All fruits per spur were weighed and counted to calculate MFW and FNLAR. Natural variation of FNLAR was due mainly to pollination failure and spring frosts.

To determine whole-tree LA, all leaves were counted on the date of fruit harvest. A random sample of 60 leaves per tree (between 1 and 2% of the total population, based on a preliminary study showing that 1% was enough to estimate LAI) was collected and mean area per leaf determined, as described at the spur level. LA per tree was calculated from the number of leaves and its mean area. Total yield per tree was determined and MFW was determined from a random sample of 50 fruits per tree. Number of fruits per tree and FNLAR were calculated from yield per tree and MFW.

At both the spur and whole-tree levels, quadratic and linear regression analyses were performed with GenStat 6.1 (Payne, 2002), using FNLAR as the independent variable and MFW as the dependent variable. Within each level, equations for each combination "training system – cultivar" were compared to detect differences ($P<0.05$) in their slopes and Y-intercepts. When either training system or cultivar had no significant effect on the relationship, that factor was removed and a new analysis was performed.

RESULTS

With the quadratic model, no significant relationships were found at the spur level ($P>0.05$). At the whole-tree level, the quadratic model fit better than the linear model (R^2: 0.765 and 0.651, respectively) when cultivars and training systems were not differentiated. With both model types, there were no significant interactions ($P>0.05$) between training system and cultivar for the effect of FNLAR on MFW, neither at the spur nor whole-tree levels. No differences between training systems were found with any of the two model types, and consequently, training system was not considered further in the analyses. When differentiating equations for specific cultivars, relationships did not deviate from linearity. Therefore, simple linear regressions were used thereafter. At the spur-level, 'Lapins' had the highest, and 'Van' the lowest, Y-intercept value (10.12 and 6.72 g/fruit, respectively); MFW decreased at the same rate for all three cultivars with increasing FNLAR (Table 1). Although the relationships between variables were significant, their coefficients of determination (R^2) were low. Mean LAI of individual trees was 2.5. For all three cultivars, MFW decreased with increasing FNLAR at the whole-tree level (Fig. 1). The R^2 values for the relationship between MFW and FNLAR were higher at the canopy level than the spur level. At the canopy level, 'Lapins' had the highest Y-intercept and 'Van' the lowest (10.43 and 7.72 g/fruit, respectively). In contrast to the results at spur level, the slope of the MFW-FNLAR relation ((g/fruit)/(fruit/m^2 LA)) was less negative for 'Van' (-0.0108) than for 'Lapins' (-0.0192) and 'Bing' (-0.0213).

DISCUSSION

Under similar management and growing conditions, cultivar was the main factor affecting the relationship between MFW and FNLAR. In contrast, training system did not affect this relationship. Trees used in this study exhibited a low LAI (2.5±0.7). Training system affects the light extinction coefficient, but at low LAI, this has little effect on light interception (Goudriaan and van Laar, 1994). However, no conclusion can be extracted with this regard because each training system was present in a different orchard.

The results at both spur and whole-tree levels showed a linear negative relationship between MFW and FNLAR, indicating increasing source limitation as FNLAR increased, supporting earlier results at the spur (Roper and Loescher, 1987) and whole-canopy (Whiting and Lang, 2004) level. Most studies of the effect of FNLAR on fruit weight refer to isolated spurs or branches (Facteau et al., 1983; Roper et al., 1987). Facteau et al. (1983) observed strong effects at the spur level when they were isolated by girdling, but no effects (or much weaker) on non-girdled spurs. In our study, results at the whole-tree level were more robust (higher R^2) than at the spur level. As spurs were not isolated, these results strongly suggest that fruits of a spur were supplied not only by leaves on that spur, but also possibly from less heavily-cropped spurs, non-fruiting shoots or reserves, as implied from girdling experiments on fruiting branches (Ayala and Lang, 2004).

The Y-intercepts represent the approximate genetic potential fruit weights (MFW when FNLAR approaches zero) and the slopes represent the sink strength of individual fruits. Thus, under an amply supply of carbohydrates, 'Van' exhibited a lower genetic potential than 'Bing' and 'Lapins', but apparently the sink strength of individual 'Van' fruits promoted relatively high MFW at high FNLAR. Whereas FNLAR appears to be the main determinant of MFW, reserves could also play a role in the data dispersion at the whole-tree level, although Whiting and Lang (2004) attributed a minor influence of crop management history to fruit weight variation.

Reference values of FNLAR, needed to attain certain MFW for specific cultivars, play a fundamental role in designing and implementing correct orchard practices, by either promoting tree vigour when FNLAR is high or by weakening the tree and by trying to increase fruit number when FNLAR is low. Research for quantifying the effect of such practices on LAI and on FNLAR is needed to apply these concepts in commercial orchards.

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Tables

Table 1. Statistical analyses of the models describing Mean Fruit Weight (MFW, g fruit^{-1}) as a function of Fruit Number to Leaf Area Ratio (FNLAR, fruits m^{-2} LA) at the spur and whole-tree levels, for ‘Lapins’, ‘Bing’ and ‘Van’ sweet cherry.

Cultivar	Y-intercept (MFW; g/fruit)	Slope (MFW/FNLAR; (g/fruit)/(fruit/m^2 LA))	R^2
Spur level			
Lapins	10.12^{a} (0.21)	-0.0060^{a} (0.0008)	0.25
Bing	8.30^{b} (0.24)	-0.0041^{a} (0.0010)	0.27
Van	6.72^{c} (0.21)	-0.0028^{a} (0.0006)	0.26
Whole-tree level			
Lapins	10.43^{a} (0.23)	-0.0192^{a} (0.0020)	0.77
Bing	9.20^{b} (0.36)	-0.0213^{a} (0.0042)	0.89
Van	7.72^{c} (0.35)	-0.0108^{b} (0.0022)	0.66

Note: different letters within a single column indicate significant differences ($P<0.05$) among cultivars. Values between brackets are standard errors of estimates.

Figures

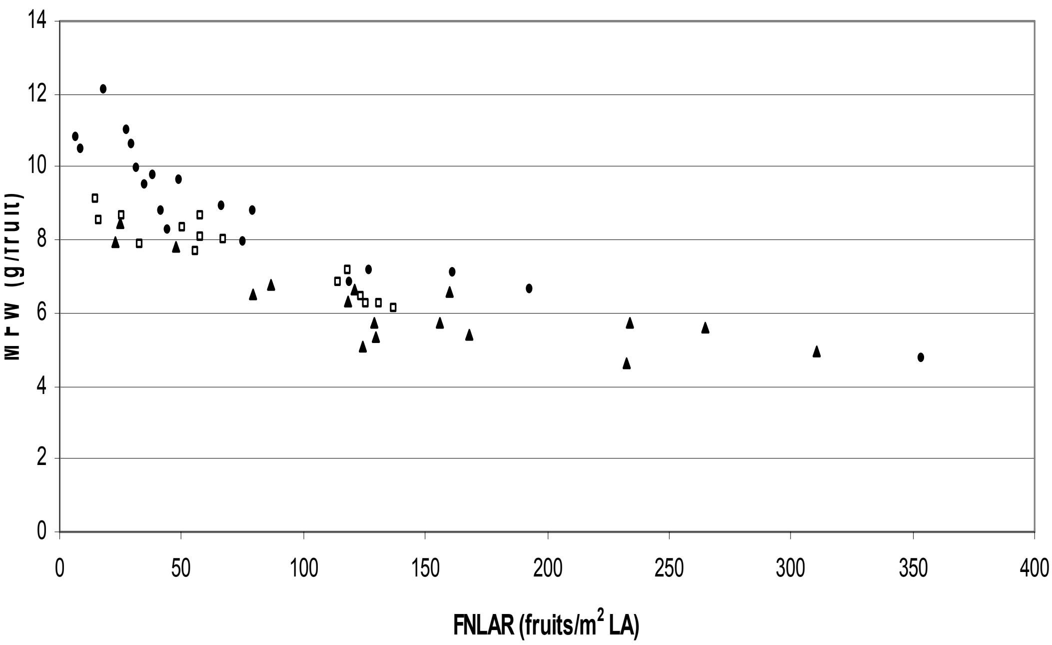

Fig. 1. Relationship between MFW (g fruit^{-1}) and FNLAR (fruits m^{-2} LA) of ’Lapins’ (●), ‘Van’ (▲) and ‘Bing’ (□) sweet cherries at the whole-tree level.