

Fruit Dry Weight and Quality of 'Bing' Sweet Cherries Grown without Source Limitations

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Keywords: *Prunus avium*, source-limited growth, relative growth rate, absolute growth rate, soluble solids, titratable acidity, firmness

Abstract

Understanding the seasonal pattern of potential fruit growth is important for identification and timing of possible management operations, and quantification of this pattern is an important prerequisite to serve as input for crop growth models. 'Bing' sweet cherry trees were heavily thinned at 63 degree-days (DD) (=8 days) after full bloom so weight and quality of the remaining fruit could be monitored under conditions of limiting and non-limiting carbohydrate supply. The effect of fruit thinning on mean shoot growth and trunk cross-sectional area also was analysed to detect possible translocation from reproductive to vegetative growth. Mean Fruit Dry Weight (MFDW) of tagged fruit was estimated weekly, based on fruit diameter, to identify the moment of the onset of competition between fruit within trees. At harvest, Fruit Number to Leaf Area Ratio (FNLAR, fruits m⁻² LA) was 52% lower in heavily-thinned trees than in non-thinned trees. Yield per tree was higher ($P<0.05$) in non-thinned trees, but MFDW and soluble solids content of mature fruit were higher ($P<0.05$) on thinned trees. No significant effects were observed on titratable acidity, firmness and vegetative growth. After 400 DD, differences in relative and absolute fruit growth rates between thinned and non-thinned trees were positive, resulting in a significantly higher MFDW on heavily thinned trees after 578 DD (61 days), which persisted until harvest. Therefore, if any operation to reduce source-limitation is carried out in commercial orchards, it should be done prior to 400 DD after bloom.

INTRODUCTION

In seasons with high yield, the quality of sweet cherry (*Prunus avium* L.) fruit often does not meet international standards (Podestá et al., 2004). In those situations, fruit growth may have been limited by source supply, defined by Grossman and DeJong (1995a) as source-limited growth. Source and sink organs are defined as organs with a net export or a net import of assimilates, respectively. Dry matter partitioning is the result of the flow of assimilates from source organs via a transport pathway to the sink organs and the subsequent (partial) transformation into structural plant material. This transport appears to be primarily regulated by sink strength (Marcelis et al., 1998), which can be defined as the product of sink activity, a measure of the potential rate of assimilate accumulation per individual sink organ, and sink size, a measure of the number of sink organs (Patrick, 1988). Sink demand also is defined as the sum of the carbohydrate requirements for maintenance and growth of the sink organs (Grossman and DeJong, 1995a). However, assimilate partitioning apparently is determined by individual organs competing as autonomous units and not by a set of fixed priorities for resources (Grossman and DeJong, 1995c). During reproductive growth in fruit trees, fruit are the major sinks competing for sugars (Grossman and DeJong, 1994; Marcelis and Heuvelink,

1999). Therefore, the number of fruit that set per tree has a strong impact on dry matter partitioning and fruit growth (Marcelis and Heuvelink, 1999).

Potential growth is the genetically determined maximum rate of biomass increase of an organ growing under optimal environmental conditions with ample supply of carbohydrates and other resources (Grossman and DeJong, 1995c). Fruit growth rate can be expressed in absolute or relative terms. The absolute growth rate (AGR) is the rate of increase in biomass per unit of time (chronological or physiological); relative growth rate (RGR) is the rate of biomass increase per unit of time and unit of biomass.

To understand the growth process of fruit, it is important to know whether the biomass gain of an organ is limited by assimilate supply (source-limited) or by its potential rate of biomass accumulation (sink-limited) (Patrick, 1988). Understanding the seasonal pattern of potential fruit growth is relevant for identification and timing of possible management operations (e.g., summer pruning or fruit thinning). Quantification of this pattern also is a prerequisite for development of crop growth models. Comparison of that pattern with the fruit growth curve also can be used to identify periods of source limitation during cherry development.

Usually, a reduction in crop load (the number of fruit per tree) increases average fruit size as well as the percentage of bigger fruit (Lötze and Bergh, 2004). The effects of reducing fruit number per tree (thinning) depend on its timing (Costa and Vizzotto, 2000) and the weight of the fruit at that time (Lescourret et al., 1998). It is better to intervene before the demand for carbohydrates exceeds its supply and before undesirable competition between fruit and other sinks, or among fruit, occurs (Costa and Vizzotto, 2000). Despite positive effects of reduced crop load on mean fruit weight (MFW), vegetative organs may compete with the reproductive organs (Grossman and DeJong, 1994; Marcelis and Heuvelink, 1999). Therefore, it is possible that at low fruit number to leaf area ratios (FNLAR), not only growth of individual fruit will be stimulated but vegetative growth as well. In apple, vegetative growth is usually more vigorous in years with small crop loads, aggravating the problem of excessive shading in high-density orchards (Medjdoub et al., 2004).

The objective of this study was to determine the seasonal growth pattern of 'Bing' sweet cherry fruit grown with and without source limitations and to identify when competition between fruit starts.

MATERIALS AND METHODS

The study was conducted during the 2004/05 season, in a commercial orchard planted with 'Bing' trees grafted on the rootstock '*P. mahaleb*' in 1997 at 5 x 2.07 m (966 trees ha⁻¹) in the lower valley of the Chubut River, in the Argentinean Patagonia (43°16' SL; 65°25' WL) and trained as a vase. Routine horticultural care for commercial fruit production was provided, including irrigation, fertilisation, wind protection, weed-, pest- and disease control, and winter pruning. Hence, growing conditions were considered near-optimal and were not a factor in the experiment. Air temperature was recorded at the weather station of INTA, in Trelew. Data were registered as cumulative degree-days (DD) after bloom, from air temperature minus a base temperature of 4.5°C (Iezzoni, 1985).

To estimate potential fruit growth rate, individual fruit must be grown under conditions of non-limiting resource availability (Grossman and DeJong, 1995a). Therefore, fruit growth (weight and quality) was followed on heavily fruit-thinned trees, in which about half of the fruit were removed at 63 DD (i.e., 8 days after full bloom). One week later, with fruit set mostly completed, these trees were thinned further, leaving no more than two fruit per cluster, so that carbohydrate supply for the remaining fruits was assumed to be non-limiting. Fruit growth also was measured on non-thinned trees. A total of 14 non-thinned and 14 thinned trees were available for measurements.

On the day of the first thinning, two groups of 10 fruit each per tree were sampled from five non-thinned and five thinned trees, dried at 70°C and weighed. Subsequently, until harvest, fruit dry weight on these trees was estimated each week from fruit diameter,

measured on 8 tagged fruit per experimental tree, with digital calipers (resolution: 0.01 mm). On each measurement day, the relationship between fruit diameter and dry weight was established for each treatment using linear regression analyses of 20 fruit from each of the remaining nine trees, measured as above.

At harvest maturity, determined on the basis of fruit colour (number 4 on the colour chart from the *Centre Technique Interprofessionnel des Fruits et Legumes*: CTIFL), tagged fruit were harvested, measured with calipers, dried at 55°C (to avoid caramel formation in mature fruit) and weighed. All leaves on each of the experimental trees were counted, followed by random sampling of 1% of the leaves. The area of all sampled leaves was measured with a Hewlett Packard® ScanJet 4C scanner to the nearest 0.1 cm², using the “Image Tool 3.0” (UTHSCSA, 2002). Leaf area (LA) per tree was calculated from the number of leaves and the mean area per leaf. The Leaf Area Index (LAI = LA per unit ground area) for each tree was estimated from tree density. Total yield per tree was monitored and mean fresh fruit weight (MFFW; g fruit⁻¹) was determined from a random sample of 100 fruit per tree. The number of fruit per tree and FNLAR were calculated from yield per tree and MFFW.

On each experimental tree, the length of 5 tagged shoots and the trunk cross-sectional area (TCSA) at 30 cm height were measured at full bloom and at harvest. Mean shoot growth (MSG) and TCSA increase (TCSAI) from full bloom to harvest were analysed to determine possible competition between reproductive and vegetative growth. Fruit quality analyses (MFFW, soluble solids content, titratable acidity and firmness) were performed at harvest. Harvest treatments were compared by mean separation using Tukey’s HSD ($P < 0.05$).

Simple regression analyses were performed with GenStat 6.1 (Payne, 2002), using physiological time (DD) as the independent variable and mean fruit dry weight (MFDW; g fruit⁻¹) as the dependent variable. Confidence intervals were used to detect significant differences in MFDW between thinned and non-thinned trees. From the fitted equation, AGR (g dw DD⁻¹) and RGR (g dw g⁻¹ dw DD⁻¹) were derived to detect differences between the two treatments.

RESULTS AND DISCUSSION

LAI at harvest of thinned and non-thinned trees (3.1 and 3.8, respectively) was not significantly different ($P > 0.05$); FNLAR was significantly lower ($P < 0.05$) in heavily thinned trees than in non-thinned trees (30.0 and 62.2 fruits m⁻² LA, respectively), indicating an acceptable treatment set-up of the experiment.

Fresh fruit yield was significantly higher ($P < 0.05$) on non-thinned trees than for heavily-thinned trees (Table 1). MFFW and soluble solids content were higher in fruit from heavily-thinned trees, while no differences were detected ($P > 0.05$) in titratable acidity and firmness. Podestá et al. (2004) found that ‘Bing’ sweet cherries from heavily-thinned trees were heavier, firmer and with higher soluble solids content than from non-thinned trees, resulting in higher exportable yields. MSG and TCSAI did not differ between treatments. This contradicts results from studies on peach trees (Grossman and DeJong, 1995b, 1995c), in which bloom or fruit thinning resulted in significantly greater trunk radial increment and stem length.

The R² for the relationships between fruit diameter and dry weight that were performed for each treatment at each measurement date were higher than 0.7 in all cases.

MFDW vs. time, from heavily-thinned and non-thinned trees, followed a pattern that significantly fitted ($P < 0.001$) a generalized logistic curve (Fig. 1). The difference between fruit RGR of thinned and non-thinned trees was positive until ~ 250 DD and negative between 250 and 400 DD (Fig. 2A); however, these differences in RGR had little effect on AGR (Fig. 2B), which until 400 DD was similar for both treatments, due to the low initial MFDW. Beyond 400 DD (around the start of stage III of fruit development), differences in both relative and absolute growth rate became positive, resulting in significantly higher MFDW on heavily thinned trees at 578 DD (61 days after full-bloom), a difference that persisted until harvest. Furthermore, variation in fruit dry

weights was higher in non-thinned than in thinned trees, suggesting that fruit within a tree respond in an irregular way to source restrictions. Alternatively, the hand thinning operation may have inadvertently resulted in a less variable fruit population, such as by taking off more outside fruit, for example.

This evidence of resource limitation beyond 400 DD (start of stage III), suggests that fruit-thinning in commercial orchards (or any other practice aimed at reducing source-limitation) should be carried out before this time (i.e., 47 days after bloom in this trial).

ACKNOWLEDGEMENTS

We thank J. Evans, A. Curzel, R. Torres, C.A. Iwan, M. Martínez, S. Jara, V. Jara and A.B. Pugh for their collaboration in data collection and processing. We are also thankful to Carlos Paz and Alejandro Catalano, owners of the orchard in which the study was carried out.

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Tables

Table 1. Yield, mean fresh fruit weight, soluble solids content, titratable acidity and firmness of fruits from heavily thinned and non-thinned 'Bing'/'Mahaleb' sweet cherry trees.

	Thinned	Non-thinned
Fresh yield (kg tree ⁻¹)	8.2 a	17.3 b
Mean fresh fruit weight (g fruit ⁻¹)	8.4 a	7.7 b
Soluble solids content (%)	24.2 a	21.0 b
Titratable acidity (ml NaOH)	14.6 a	13.1 a
Firmness (Durofel index; 0-100)	65.2 a	58.6 a

Note: different letters within a single row indicate significant differences ($P < 0.05$).

Figures

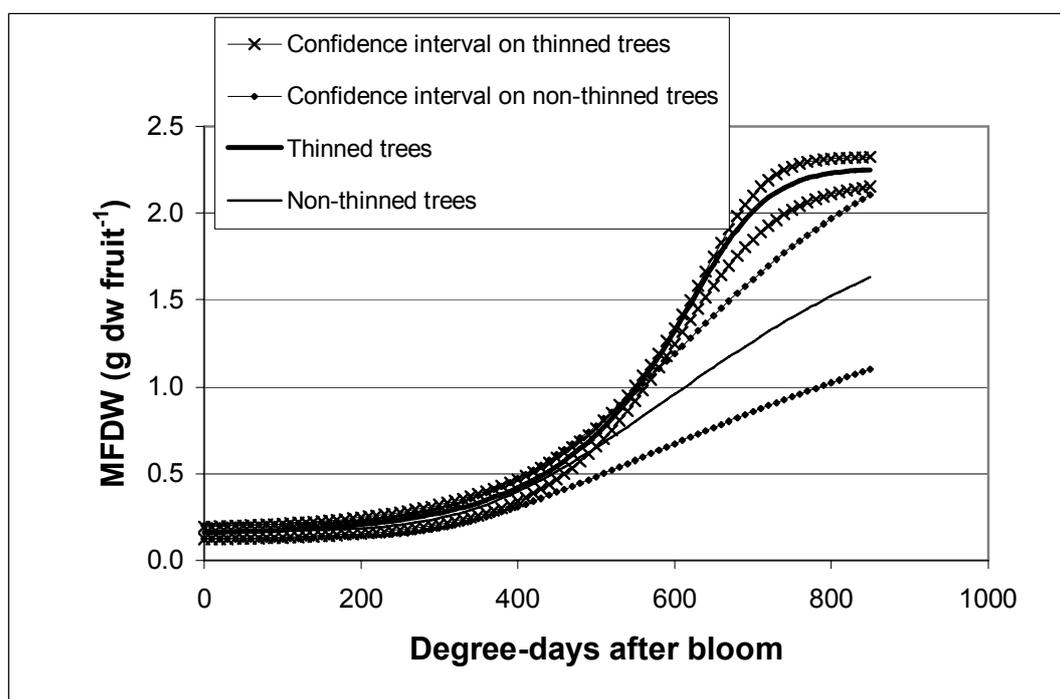


Fig. 1. Estimated mean fruit dry weight (MFDW) ($P < 0.001$) and confidence intervals for thinned and non-thinned 'Bing'/'Mahaleb' sweet cherry trees as a function of accumulated degree-days (DD) after bloom. MFDW (thinned trees) = $0.147 + 2.111 / (1 + 3.18 * \text{EXP}(-0.02416 * (\text{DD} - 622.2)))$ ** (1/3.18). MFDW (non-thinned trees) = $0.171 + 2.030 / (1 + 0.011 * \text{EXP}(-0.00424 * ((\text{DD} - 588.6)))$ ** (1/0.011).

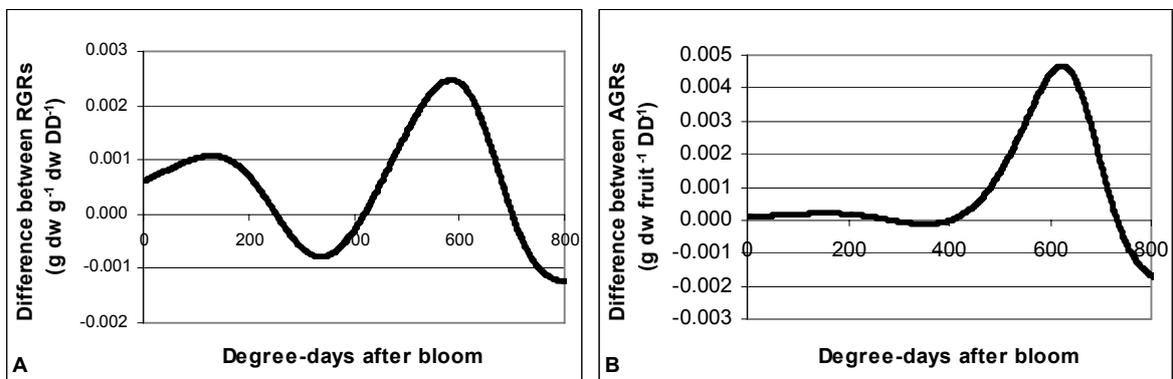


Fig. 2. Differences in Relative Growth Rate (A) and Absolute Growth Rate (B) between fruit grown on heavily thinned and non-thinned ‘Bing’/‘Mahaleb’ sweet cherry trees.