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Fish Oil Plus Lime Sulfur Shows Potential as a Sweet Cherry Postbloom Thinning Agent

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Modern sweet cherry (*Prunus avium* L.) orchard systems based upon size controlling, precocious, and productive rootstocks are inherently more profitable and horticulturally efficient than old systems using vigorous seedling rootstocks (Seavert et al., 2002; Whiting et al., 2005). However, due to their effects on whole-tree source–sink relations, new crop load management strategies must be developed to yield commercially acceptable quantities of high quality (i.e., large diameter, firm) fruit on these rootstocks (Whiting and Lang, 2004). Though it is not currently a commercially used strategy, there is new evidence showing the potential for blossom thinning to reduce fruit set and improve sweet cherry fruit quality (Whiting and Ophardt, 2005; Whiting et al., 2006). Indeed, chemical blossom thinning is beneficial and employed regularly in other tree fruit species, apple (*Malus ×domestica* Borkh.) most notably, for balancing canopy source–sink relations, improving fruit quality, and reducing biennial bearing. Other research has shown potential for thinning blossoms of peach (*P. persica*) (Myers et al., 1993; Southwick et al., 1996) to reduce the need for costly hand thinning. Recent trials within high efficiency sweet cherry orchards have also shown potential to reduce fruit set and improve fruit quality and crop value with caustic bloom thinners (Whiting et al., 2006).

The efficacy of caustic bloom thinners however is often unpredictable and significant variability in thinning may occur from year to year (Robinson and Lakso 2004). Moreover, a potential drawback to any chemical blossom thinning program is over-thinning causing low crop value per tree due to low productivity. Therefore, for many tree fruits (e.g., apple and peach), postbloom fruitlet thinning is a necessary, albeit expensive, follow-up to blossom thinning programs. A significant advantage of fruitlet thinning vs. blossom thinning is having the opportunity to assess crop load (i.e., fruit set) to determine the degree of thinning necessary. Much research is ongoing in the area of postbloom apple fruit thinning, with particular emphasis on modeling canopy carbon balance and its relation to postspray environmental conditions, fruit growth rates, and abscission (D. Greene and A. Lakso, personal communication). Despite their variable efficacy, most apple growers readily use postbloom, fruitlet thinning programs and often follow these with hand thinning to optimize fruit number per tree (i.e., cluster). However, for sweet cherry, hand thinning is not likely practical for dark-fleshed sweet cherries (e.g., 'Bing') due to the relatively small fruit size and high fruit number per tree compared to apple and peach. In addition, there are no published reports on the potential for postbloom sweet cherry fruitlet thinning. The objectives of this research were to investigate the potential for thinning sweet cherry fruit with fish oil and lime sulphur, and to better understand the tree's physiological response to the postbloom thinner.

On 28 Apr. 2005, about 14 d after full bloom, 2% fish oil + 2.5% lime sulphur (FOLS) were applied to entire 12-year-old 'Bing'/'Gisela 5' sweet cherry canopies. Applications were made by an airblast sprayer at 200 gal/acre. The experimental orchard is located about 5 km north of Washington State University's Irrigated Agriculture Research and Extension Center (46.2°N, 119.7°W). Trees were planted in North-South rows, spaced 2.5 × 5.0 m, and trained to a multiple-leader, open-center architecture. Trees were irrigated with under-tree low-volume microsprinklers from bloom to leaf senescence. Typical orchard management strategies (e.g., dormant pruning, fertilization, pesticide application) were carried out.

Fruit set was determined as a percent of available flowers by comparing number of flowers at full bloom on one east- and one west-facing branch (2- to 3-year-old) per tree with the number of fruit on the same branches just prior to harvest. Whole tree yields were recorded in the field at harvest (24 June 2005). Within 24 h of harvest, fruit firmness and equatorial diameter (Firmtech 2, BioWorks, Inc., Wamego, Kans, soluble solids (digital refractometer, Atago Co., Ltd, Japan) and weight were determined at room temperature from 100-fruit subsamples per tree. Crop value per tree was calculated from fruit yield and size relationships. Values are based upon average returns for fresh market quality 'Bing' sweet cherries from 2004 and 2005 (G. Allan, Allan Bros. Packing, personal communication) and include packaging and marketing fees.

Leaf net CO_2 exchange rate (NCER), stomatal conductance (g_s) and intercellular CO_2 (C_i) were measured *in situ* on three sunlit fruiting spur leaves (2 to 4-year-old) per tree within 1 h of solar noon (1200 to 1400 HR). Measurements were conducted with a portable infrared CO_2 gas analyzer (CIRAS-2, PP Systems, Haverhill, Mass.) equipped with a tungsten halogen lamp set to saturating irradiance (1000 $\mu mol \cdot m^{-2} \cdot s^{-1}$ photosynthetically active radiation), with reference (inlet) [CO_2] of about 370 ppm and leaf temperature between 25 to 30 °C. Measurements were taken between day 113 and day 127 (about 14 to 28 d after full bloom) at 2- to 3-d intervals until NCER of treated leaves was statistically similar ($P < 0.05$) to untreated (leaf recovery period).

On the same leaves, chlorophyll fluorescence was measured with a portable pulse-modulated fluorometer (FM.S-2, Hansatech Instruments, Ltd., England). Light fluorescence parameters, ΦPSII (quantum efficiency of photosystem II) and qP (photochemical quenching) were obtained by a saturating light pulse (18,000 $\mu mol \cdot m^{-2} s^{-1}$) followed by a far-red light pulse (735 nm). Dark adaptation clips were then placed on the same leaf for 15 min. To determine initial fluorescence (Fo), dark-adapted leaves were exposed to a modulating beam. Fv was calculated as Fo – Fm. The quantum efficiency of photosystem II (ΦPSII) and photochemical quenching (qP) were calculated by the following standard equations (Hansatech Instruments, England): (Fm' – Fs)/Fm'; (Fm' – Fs)/(Fm' – Fo).

The experiment was arranged in a completely randomized design and consisted of 12 trees of similar vigor with 6 single tree replications. Treatment means were compared by Duncan's test at 0.05 and 0.10 per measurement day and over leaf recovery periods by analysis of variance (Proc GLM) using the statistical analysis system (SAS) program (SAS Institute, Cary, N.C.).

Application of fish oil + lime sulphur (FOLS) about 14 d after full bloom (DAFB) reduced sweet cherry fruit set by 29% compared to the control (Table 1). This reduction is about 15% to 20% less than that previously reported from two applications of the same concentration of FOLS during bloom (Lenahan, 2005; Whiting et al., 2006). This suggests that trees are less susceptible to thinning later in the growing season though it is also likely that FOLS applied during bloom reduces fruit set via interference with fertilization (i.e., a caustic effect directly on flowers), an effect it can not have 14 DAFB. Fruit yield however, was statistically similar to untreated. Fruit quality was unaffected by the postbloom FOLS treatment and very good overall. The greatest differences between treatments were in soluble solids which were about 5% greater from untreated trees, though excellent for both treatments. Crop value from untreated trees was about 17% higher than from FOLS-treated trees. This is because untreated trees were slightly higher yielding and bore similar size fruit to the FOLS-treated trees (Table 1).

We hypothesize the absence of fruit quality improvement from thinning is due to sink-limited conditions of the unthinned trees. This is unusual for this scion-rootstock combination. However, the low yield of excellent quality fruit from unthinned, control trees suggests that their

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Table 1. Effect of a postbloom thinner (28 Apr. 2005) on fruit set, fruit yield, fruit quality (soluble solids, weight, firmness) and crop value of 12-year-old 'Bing'/'Gisela 5' sweet cherry trees in 2005. Means followed by the same letter are not significantly different within a column (n = 6, $p < 0.10$).

Treatment	Fruit set (%)	Yield (kg)	Soluble solids (%)	Wt (g)	Firmness (g/mm)	Crop value ($/tree)
Control	38.3 a	11.2^{NS}	23.8^{NS}	9.2^{NS}	343^{NS}	35.31
FOLS	27.3 b	9.6	22.6	9.2	365	30.29
p values	0.08	0.56	0.12	0.95	0.24	

Table 2. Overall effect of chemical postbloom thinner applied 14 d after full bloom on sweet cherry leaf gas exchange, stomatal conductance, intercellular CO_2 and chlorophyll fluorescence parameters. Letters indicate statistical differences by Duncan analysis of variance test (n = 6, $p < 0.05$). Means followed by the same letter are not significantly different within a column.

Treatment	NCER ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	g_s ($mmol \cdot m^{-2} \cdot s^{-1}$)	Ci (ppm)	Fo	Fv	ΦPSII	qP
Control	12.2 a	115.0 a	154 b	400^{NS}	1902.3^{NS}	0.762 a	0.942 a
FOLS	9.9 b	97.5 b	165 a	404	1835.2	0.707 b	0.902 b
p value	0.0001	0.04	0.041	0.59	0.22	0.01	0.02

growth was not limited by the availability of photoassimilates. This is likely due to low blossom density rather than poor fruit set because fruit set was higher than that reported previously for mature 'Bing'/'Gisela 5' trees (Lenahan, 2005; Whiting et al., 2006). Furthermore, fruit yields in the current trial were about 53% lower than previously reported yields from 'Bing'/'Gisela 5' trees in the same orchard (Whiting and Lang, 2004). We further hypothesize that the reduction in fruit set reported herein would be beneficial for balancing canopy source–sink relations in higher-yielding, over-cropped orchards. Indeed, previous research has suggested that a 50% reduction in the normal fruit density of mature 'Bing'/'Gisela 5' trees is necessary to balance fruit yield and quality (Whiting and Lang, 2004).

Photosynthetic inhibition by chemical means, such as terbacil, or by shading applied after bloom has resulted in apple fruit abscission, due presumably to a reduction in supply of photosynthates to developing fruit (Byers et al., 1985, 1990). Indeed, thinning efficacy is highest during periods of deficit carbon supplies to apple fruitlets (D. Greene, personal communication; Robinson and Lakso, 2004). For the current trial, we specifically targeted 14 d after sweet cherry full bloom because that period corresponds to a period of maximum rate of fruit growth in stage I (i.e., relatively high fruit sink demand; Whiting, unpublished) as well as the approximate switch in carbohydrate source from storage reserves to current-season leaf assimilates (M. Ayala, personal communication). Therefore, we hypothesize that a reduction in net photosynthesis during this stage would deplete assimilate supply to fruit at a vital growth stage. The key benefit to thinning at this stage (fruit diameter about 5 to 7 mm) is the ability to assess fruiting density and therefore the severity of fruitlet removal necessary for balancing canopy source–sink relations.

Application of FOLS suppressed sweet cherry leaf NCER by about 28% within 24 h of treatment (data not shown). Leaf NCER of treated-trees was lower for 6 d, by 7 to 8 d after treatment, leaves had recovered completely (i.e., exhibited NCER similar to that of untreated leaves). The overall effect, was a 19% reduction in leaf NCER (Table 2). This is less in both duration and severity of the NCER reduction recorded from FOLS applications made during bloom (Lenahan, 2005). This suggests that sweet cherry leaves become less susceptible to FOLS applications with age. In apple, Byers et al. (1990) found substantial fruit abscission after shading trees and reducing photosynthesis by about 66% for 10 d. Likewise, shading 'Royal Gala' apple with 80% shade material for 5 d induced fruit abscission (McArtney et al., 2004). Fruit abscission on apple has also been significantly increased after BA application as a result of a 10% to 15% photosynthesis suppression for about 6 d (Yuan and Greene, 2000). In the current trial, a 19% reduction in leaf NCER over 6 d was sufficient to reduce fruit set by 29%.

Very little research has investigated thinner mode of action. In the current trial we evaluated key leaf physiological parameters to better understand the effects of FOLS on leaf NCER and fruit thinning. We recorded an immediate reduction (about 20%), in leaf stomatal conductance (g_s) from FOLS (data not shown). The mean reduction over the recovery period was 15% (Table 2). This is likely due to FOLS causing a reduction in guard cell hydrostatic pressure leading to partial closure of the stomates, though stomatal aperture was not assessed in the current trial. Moreover, we recorded a significant, albeit slight (7%) increase in internal, mesophyll [CO_2]. Together, these results suggest a reduction in photosynthetic efficiency. The postbloom application of FOLS had no effect on Fo or Fv, but significantly lowered (by about 7%) efficiency of photosystem II (ΦPSII). Therefore the fraction of radiant energy absorbed by the light harvesting complexes used to drive the initial light reactions of photosynthesis was lowered by FOLS. FOLS also reduced photochemical quenching (qP) by about 4%, indicating a closing of photosystem II reaction centers and a reduction in photosynthetic efficiency (Maxwell and Johnson, 2000).

Several factors will influence the efficacy of postbloom FOLS applications. First, thinning efficacy of FOLS will likely be influenced by canopy source–sink relations at the time of application. In the current trial, fruit sink demand was not high and it appears as though sink-limited conditions existed. Interestingly however, it appears that a 19% reduction in NCER was sufficient to elicit fruit drop. This suggests that potential exists to thin sweet cherry fruit via reductions in assimilate supply. We hypothesize that in heavier cropping trees (i.e., greater sink demand), an equivalent NCER reduction may lead to greater fruit drop. Secondly, the smaller reductions in leaf net photosynthesis by the postbloom FOLS application versus bloom application suggest that leaves become less susceptible to damage from thinning agents with advanced ontogeny. Thus, higher concentrations of FOLS may be necessary to effect a greater photosynthetic reduction and fruit abscission.

In conclusion, new crop load management strategies must be developed to grow large sweet cherry fruit on precocious and productive rootstocks. Herein we report on the potential for a promising new tactic for thinning sweet cherry fruitlets, presumably via reductions in leaf NCER. However, these results should be interpreted with caution because they are for one variety and year. Much more research is necessary to understand thinner mode of action and develop sound postbloom thinning recommendations.

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