FINAL REPORT

TITLE: Quantifying Limitations to Balanced Cropping

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OBJECTIVES:

To field-validate balanced cropping model and develop and evaluate practical strategies for moderating sweet cherry crop load.

1. To investigate the relationships among tree vigor (i.e., leaf area, shoot growth, trunk expansion, root growth), fruit yield, fruit quality, and yield potential in subsequent years (i.e., flower bud initiation, bloom density, fruit set and yield); in short, investigate whole-tree source-sink relations.
2. To quantify the acquisition and partitioning of cropping resources, such as photosynthates and nitrogen, between the developing tree canopy, flower buds, and fruits to balance yields with optimized fruit size.

SIGNIFICANT FINDINGS:

Canopy source:sink relationships:

- whole-canopy fruit to leaf area ratio (F:LA) is related negatively to fruit size, weight, soluble solids, and unrelated to fruit firmness
- conversely, leaf area per fruit is related positively to fruit quality
- fruit quality declines rapidly at less than 200 cm^2 leaf area per fruit (approximately the equivalent of 5.5 leaves per fruit on a whole-canopy basis)
- crop load is not related to flower bud initiation in ‘Bing’/Gisela 5 trees
- high crop load does reduce the number of flowers *per* reproductive bud and, as a result, fruiting potential in the following year
- flower bud initiation is not related to vegetative vigor
- tree yield is optimized near 100 – 120 fruit/m^2 leaf area in ‘Bing’/Gisela 5 trees (approximately 2000 fruit per full-sized tree)
- shoots, leaves, fruit, and lateral growth (i.e., trunk expansion) all compete for limited growth resources during the preharvest interval
- shoot growth is 85 – 90% complete at harvest in 6- and 7-year-old ‘Bing’/Gisela 5 trees
- spur leaf area is maximized by 35 – 40 DAFB
- spur LA and shoot LA are related negatively to F:LA
- trunk expansion is related negatively to F:LA
- carbon supplies are limiting to fruit yield and quality in ‘Bing’/Gisela 5 trees
- seasonally, net photosynthesis is highest just prior to harvest and declines tremendously (approximately 50%) soon thereafter
- some form of crop load manipulation is required to grow top-quality fruit on precocious

dwarfing rootstocks

In 2002 and 2003 we also studied canopy carbon acquisition and the relative roles of different sweet cherry leaf types (i.e., shoot leaves *vs*. non-fruiting spur leaves *vs.* fruiting spur leaves). This experiment delineated the capacity for (i.e., leaf surface area), and efficiency of net photosynthesis within sweet cherry canopies to better understand whether or not different leaf types are more/less effective as carbohydrate producers. With this knowledge, more informed management decisions can be made, particularly with respect to training and pruning.

- spur leaves expand rapidly in the spring and achieve maximum area ~ 40 days after bud break
- maximum shoot leaf area occurs shortly after terminal bud set (≈ 80 days after bud break)
- leaf area/shoot is ca. 4-fold greater than leaf area/one-year-old non-fruiting spur and twice as great as leaf area/fruiting spur
- leaf net photosynthetic rate increases throughout stages I and II of fruit development and reach seasonal maxima during stage III
- leaf net photosynthetic rate and dark respiration (i.e., daily carbon balance) are similar among leaf types
- the presence of fruit did not affect leaf net photosynthesis
- the relative assimilation potential per annual growth segment is as follows: shoots > fruiting spurs > non-fruiting spurs

Manipulating normal source-sink balance via leaf removal is a convenient, albeit indirect and artificial, means of investigating branch source-sink relationships. In 2002 this project conducted an initial investigation designed to elucidate the potential and relative roles of different annual growth segments (e.g., two-year-old fruiting spurs, one-year-old non-fruiting spurs, and shoots) at supplying photosynthate within heavily-cropped ‘Bing’/Gisela 5 sweet cherry branches. Treatments were imposed by manually removing dormant vegetative buds (5 March, 2001), and consisted of unmodified control (C), and removal of, terminal shoot bud (-SH), vegetative buds on 1YR or 2 YR (-1YR, and -2YR, respectively), and, both SH and 1YR buds (2YRonly).

- the effects of leaf area (LA) removal on fruit quality were subtle and not statistically significant
- fruit quality was not improved in the absence of vegetative extension growth
- shoot growth neither supported nor competed with fruit for growth resources
- LA removal did not influence the number of reproductive buds induced per spur
- leaf net CO_2 exchange rate (NCER) was unaffected by LA removal despite significant induced variability in branch source:sink
- Vegetative components (e.g., LA and shoot length) were not affected by LA removal
- carbohydrates from nearby limbs and/or storage reserves supported both vegetative and reproductive growth in treatments with reduced capacity for carbohydrate production

This project also conducted an initial investigation into the effects of postharvest defoliation on fruit yield and quality in the subsequent season. ‘Bing’ trees on Mazzard and Gisela 6 rootstock were completely defoliated either one or two months after harvest in 2002. Fruit yield and quality in 2003 were evaluated for defoliated and non-defoliated trees.

- defoliation during the postharvest period reduced fruit yield by 63%, fruit weight by 18%, and increased fruit soluble solids by 19% compared to control trees
- fruit quality is substantially affected by growth resources assimilated during the postharvest period of the season prior to actual fruit growth and development

Balanced cropping trials:
In spring, 2002 we imposed different strategies designed to reduce the number of fruit per tree and balance crop load with vegetative vigour (i.e., whole-canopy fruit-to-leaf area ratio) of ‘Bing’ on both Gisela 5 and 6. Based on spur and fruit bud counts of entire trees (see report ‘High Density Orchard Management’) whole-tree thinning was targeted to leave approximately 2000 fruit per tree (≈ 50% of potential). Spur ‘extinction’ (i.e., the removal of complete spurs) was compared to blossom thinning. In 2003 fruit yield and quality was evaluated from the same trees to document carry-over effects from 2002 treatments.

2002

- thinning crop load of ‘Bing’/Gisela 5/6 trees improves fruit quality: high quality fruit (i.e., 68-92% > 11.5-row) can be grown on Gisela series rootstocks
- 50% spur thinning and 50% blossom thinning reduced crop load similarly
- fruit-to-leaf area ratio is higher (i.e., worse) for spur-thinned vs. blossom-thinned
- blossom-thinned trees had higher yields and larger fruit than spur-thinned trees
- number of fruit per tree, fruit soluble solids, and yield efficiency were similar for blossom- and spur-thinned trees
- Both Gisela 5- and Gisela 6-rooted trees had higher yields and fruit quality when blossom-thinned compared to spur-thinned trees
- the best combination of yield and quality was for blossom-thinned Gisela 6 trees which yielded 41 lbs per tree of fruit averaging 21.4 ^{o}brix, 7.8 g, and 85% 11.5-row and larger

2003

- blossom thinning in 2002 had no beneficial carry-over effect in the subsequent season
- trees spur thinned in 2002 had ca. 25% fewer fruit than control in 2003
- spur thinning trees in 2002 improved fruit soluble solids in 2003 but not fruit weight or row-size
- F:LA of individual spurs affects fruit quality more than canopy or branch F:LA
- thinning strategies will need to be employed annually to be effective
- a blossom thinning program for high density sweet cherry production is highly desirable

METHODS:

Acquisition of cropping resources. The laws of supply and demand apply to sweet cherry production. Carbohydrate supply is finite and directly proportional to the rate of photosynthesis and the area of photosynthetically active tissue. This project has already identified the daily and seasonal trend in whole-canopy net photosynthesis, the effects of crop load and fruiting, and developed a model of balanced production (i.e., yield and quality) on Gisela-rooted trees. In the current year we propose to continue investigating practical means of applying our model of balanced cropping on mature heavily-cropped ‘Bing’/Gisela 5 trees. These include spur thinning (‘extinction’), blossom thinning, and modified pruning. In addition, crop load management experiments will be carried out on Gisela-rooted trees in their first year of cropping to examine how early thinning alters our model of balanced cropping in mature trees.

To better understand the role that carbohydrate assimilation after harvest has on yield potential and fruit quality in the following year (2003), entire trees were defoliated completely at approximately 30 and 60 days after harvest. This winter, storage reserves in perennial tissues will be quantified by analyzing for carbon and nitrogen. In 2003, vegetative growth, fruit yield, and fruit quality will be evaluated.

RESULTS & DISCUSSION:

From the past years' results, we now have a better understanding of the temporal and spatial variability in whole-tree growth and development and the nature of competition for carbohydrate resources. Shoot growth, leaf expansion, and fruit growth all occur during the preharvest interval (*i.e.*, full bloom – harvest) and compete for carbon resources produced during the reactions of photosynthesis. Rates of canopy photosynthesis and therefore gross carbohydrate supply appear to be source-limited. Therefore, the supply, and/or partitioning of, carbohydrate resources limit fruit yield and quality. In addition, although it was not a goal of this research to provide thinning recommendations, our results have documented the effect of crop load removal on fruit quality variables that should contribute to a basis upon which potential thinning strategies can be rationalized. The balanced cropping model suggested that 'Bing'/Gisela 5 trees at full canopy are optimized at approximately 2000 fruit per tree. This approximately is the equivalent of 5.5 leaves per fruit on a whole-canopy basis. In 2002 and 2003 we tested two methods of achieving this target: spur thinning and blossom thinning. Both approaches improved fruit quality dramatically compared to the unthinned, control trees. However, blossom thinning was a more effective technique, yielding more and better quality fruit than spur thinning (Table 1). This occurred because spur thinning, while reducing crop load, also reduced canopy leaf area (i.e., those leaves from the fruiting spurs) thereby leaving F:LA of individual fruiting spurs unaffected. In contrast, blossom thinning targeted only carbohydrate sinks, favorably impacting canopy and, most importantly, spur F:LA. From examining tree yield, and fruit quality in subsequent seasons it is apparent that annual application of a thinning strategy is necessary. Neither technique had any beneficial carry-over effect in the year following treatment although spur-thinned trees had about 25% fewer fruit. This suggests that one potential advantage of spur thinning, the need to thin only once every 2 – 3 years, is not practically relevant. This is likely due to the high F:LA of the remaining spurs.

Table 1. Effect of blossom and spur thinning on fruit yield and quality of 8-year-old 'Bing'/Gisela 5/6 sweet cherry trees.

Treatment	# fruit/tree	Tree yield (kg)	Fruit mass (g)	Fruit soluble solids	% ≤12-row	% ≥11.5-row
Control	3827 a	22.8 a	5.9 c	19.9 a	48 a	52 b
Blossom	2250 ab	16.6 b	7.4 a	21.6 a	14 b	86 a
Spur	2053 b	13.4 c	6.6 b	22.0 a	24 b	76 a

We now have a detailed understanding of carbohydrate production within sweet cherry canopies. Among annual growth segments, shoots possess the greatest potential as carbohydrate sources due to their superior leaf area and similar photosynthetic rates (Table 2). In addition, most shoots are situated in the tree's periphery, and therefore in an environment that favors high photosynthetic rates (i.e., well sunlit). This data suggests that each individual fruiting spur (i.e., 2-year-old and older spurs) has the leaf area to support slightly more than one fruit because fruit quality declines at less than 5.5 leaves per fruit (see 2001 Report 'Quantifying Limitations to Balanced Cropping'). However, fruiting spurs usually bear several fruit. Therefore, to maximize fruit quality, one-year-old non-fruiting spur and shoot leaf area must supplement fruiting spur leaf area with growth resources. Pruning strategies that improve branch fruit-to-leaf area ratios and position non-fruiting leaf area (spur or shoot) closer to fruiting spurs must be adopted. Clearly, lengthy, un-pruned shoots with few lateral breaks are undesirable in this regard.

Table 2. Components of the relative assimilation potential of different annual growth segments of 'Bing'/Gisela 5 trees.

Annual growth segment	# leaves/spur or shoot	Leaf area per spur or shoot	Net photosyn. ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	Relative assimilation potential
Shoot	15 a	465 a	10.6 a	100
1-yr-old spur	5 c	115 c	10.3 a	22
2-yr-old spur	6.5 b	195 b	9.9 a	36
≥3-yr-old spur	6 b	216 b	9.9 a	40

The postharvest period may be as lengthy as the period of actual fruit growth and development for sweet cherry. During this interval, fruit buds differentiate and develop prior to the onset of dormancy. These processes affect blossom density and the potential number of fruit per tree (thereby canopy F:LA) in the subsequent, fruiting season. In addition, the growth resources accumulated during the postharvest interval are critically important for early canopy and fruit development in the following spring. To date however, the relative role of the postharvest period in determining fruit quality or yield in the subsequent season has not been researched. In this initial investigation, we found that the removal of the source of photosynthates during bud development reduced fruit quality and yield in the following year (Table 3). This effect may have been a direct result on bud quality or indirect through reductions in carbon and nitrogen reserves utilized in the following spring. The results underscore the importance of maintaining healthy, abundant leaf area after harvest.

Table 3. Effect of postharvest defoliation of 'Bing' sweet cherry trees in 2002 on fruit yield and quality in 2003.

Treatment	Yield (lbs)	Soluble solids (^{o}brix)	Fruit weight (g)	% ≤12-row	% 11- and 12-row	% ≥10.5-row
Control	26.7 a	22.2 b	8.1 a	3 a	33 b	64 a
Defoliated	10.0 b	27.1 a	6.7 b	1 a	70 a	29 b

Carbon acquisition and partitioning within sweet cherry trees remains critical to understand considering its fundamental relation to tree productivity and fruit quality. Practical strategies (e.g., spur and blossom thinning, pruning) for balancing crop load must continue to be sought for the PNW industry to successfully adopt higher density, efficient production systems. The balanced cropping models of this project provide physiological targets. Already this project has provided the first quantitative information integrating photosynthetic activity in PNW sweet cherries across the entire tree canopy and within different canopy architectures (Whiting and Lang, 2001b). This information becomes more critical as younger and smaller trees with limited canopies and resource storage potential are cropped, either via new rootstocks or intensive cultural practices. Information transfer has occurred rapidly through research results reported at industry/extension meetings (*e.g.*, Cherry Institute, Oregon Hort Society, IDFTA), local grower meetings, and publication of results and recommendations in industry (*e.g.*, *Good Fruit Grower*) and scientific (*e.g.*, *Journal of ASHS, Scientia Horticulturae*) periodicals.

Literature cited/Publications:

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BUDGET
Project no.: CH-01-18
Project total: $ 76,566

Year	2001	2002	2003
Total	$15,000	$42,500	$19,066

Current year breakdown

Item			
Salaries[1]		5,797	6,083
Benefits (28%)		1,623	1,703
Wages[2]	5,600	8,000	8,000
Benefits (16%)	900	1,280	1,280
Equipment	4,500	21,800	
Supplies[3]	3,000	3,500	1,000
Travel[4]	1,000	500	1,000
Miscellaneous			
Total	$15,000	$42,500	$19,066

[1] One-sixth annual salary for Mr. Efrain Quiroz.

[2] 4 months student labor (May-August) for assisting with chamber studies, collection of canopy physical data (i.e., leaf area, light interception), and fruit quality analyses

[3] Includes all chamber materials (e.g., mylar, velcro, pvc) and gas analysis consumables

[4] Travel to plots