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FINAL PROJECT REPORT
WTFRC Project Number:

Project Title: Flowering and pollination of 'Regina' and 'Bing' sweet cherry trees

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Cooperators: Mike, Mel and Linda Omeg; John and Karen Carter; Dave, Karen and Stacey Cooper; John McClaskey; Jim Kelly; Rick Derrey; and Don Nusom.

Other Funding Sources

Total Project Funding:

Budget History:

Item	Year 1: 2005	Year 2: 2006	Year 3: 2007
Salaries	8,300	8,300	8,300
Benefits	4,900	4,900	4,900
Wages	2,500	2,500	2,500
Benefits			
Equipment	500	500	500
Supplies			
Travel	1,500	1,500	1,500
Miscellaneous			
Total	17,700	17,700	17,700

Final Report to the Agricultural Research Foundation,
Oregon Sweet Cherry Commission, Washington Tree Fruit Research Commission, and
California Cherry Advisory Board

Project title: Flowering and pollination of 'Regina' and 'Bing' cherry trees

Objectives:

1. Determine ovule longevity of 'Regina' and 'Bing' flowers.

2. Assess pollen viability of 'Attika', 'Sam', 'Sandra Rose', 'Stark's Gold', 'Sylvia', 'Skeena', 'Regina' and 'Schneider's Späte Knorpel'.

3. Compare pollen tube growth rates and fruit set when 2-4 standard pollinizers are used in 'Regina' and 'Bing' plantings.

Significant findings and results:

Below are significant findings to date, however are incomplete because 7 funded months still remain to complete analysis.

- *In situ ovule longevity studies* – The ovules in 'Regina' flowers began declining substantively earlier than 'Bing' flowers in two of the three years (2005 and 2007) that were studied (Figs. 1-3). However, once the ovules began to senesce the rate of decline was relatively similar between each genotype each year. Across the years of study, the rate of decline differs. Ovule viability in 2005 began to decline in 'Bing' flowers after 746 growing degree hours (GDH) (12 days), while in 'Regina' flowers the decline began at 233 GDH (4 days) (Fig. 4). In 2006, flowers of both cultivars began to decline at approximately 350 GDH. This GDH accumulation across both locations occurred at 6 and 3 days for 'Bing' and 'Regina' flowers, respectively. In 2007, ovules began to senesce in 'Regina' flowers at 370 GDH (5 days in Corvallis and 4 days in The Dalles). The ovules in 'Bing' fIowers remained viable over 1000 GDH longer than 'Regina' ovules before beginning to senesce. Senescence began at 1352 GDH (13 days) and 1072 GDH (13 days) at the two Mid-Columbia locations. In 2007, ovules remained viable longer in both cultivars before starting their decline compared to 2006 when ovule decline began much sooner. In general, 'Bing' ovules remained viable longer than 'Regina'.

- *Pollen tube growth and fruit set* - Pollen tube growth in 'Regina' appeared more fragile than in 'Bing'. In 2006, two pollen types never penetrated the style to produce tubes, but in 2007 all pollen types germinated on the style and penetrated but tube growth was slow often stopping in the first 15% of the style. Only 5-10% of all hand-pollinated flowers contained pollen tubes of which a few did reach the base of the style. Length of style and length/width of ovary in 'Regina' was significantly smaller than 'Bing' (Fig. 5 and Table 1). In order to ensure adequate numbers of flowers, the earliest blooming flowers were used. These 'Regina' flowers may be inferior to those maturing later and could potentially explain the poor pollen tube growth, especially since fruit set was very good in both locations where 'Regina' trees were sampled. Generally, pollen tubes in 'Bing' flowers reached the base of the style in less time and lower GDF accumulation (500-750 GDH) than pollen tubes in 'Regina' (700-1500 GDH) (Table 2).

- *Pollen viability* – Pollen viability varies from year to year and by location (Table 3). Adequate germination percentages to develop pollen tubes in hand-pollinated styles were as low as 7%. Pollen collected from open flowers in the field had higher germination percentages than those

forced inside at room temperature. Pollen viability can be ascertained after two hours of incubation in a liquid sucrose solution.

Materials and methods:

- *In situ ovule longevity*- Ovule longevity of 'Regina' and 'Bing' flowers were determined in three locations, The Dalles, Hood River and the Lewis Brown Farm, over a two week period. A branch from each of four trees was covered with a pollination bag to prevent pollen from pollinating flowers during the sample collection period. Flowers were removed every morning for 11 days. Flowers were placed in a fixative. Ovules are excised after rinsing out the fixative, stained with aniline blue, and observed under a fluorescence microscope. Fluorescence of callose at the chalazal end indicates ovule senescence (Fig. 6A). More than 700 ovules were evaluated in 2007 requiring over 75 hours.

- *Pollen tube growth rates*- 'Regina' and 'Bing' flowers were hand-pollinated with pollen from 2-4 standard pollinizers, alone and in combination. Twelve flowers were collected daily, placed into fixative, stained with aniline blue and observed under a fluorescence microscope. The percent of the style traveled by the pollen tube was recorded for each sampling date. Callose plugs and tubes are observed (Fig. 6B). In 2007, over 5000 pistils were collected and 3030 were evaluated (180 hrs). Seed were collected from mature fruit in 'Bing' and will still be analyzed for s-alleles using molecular markers and PCR technologies. The s-alleles in the seed will indicate the pollen parent. No fruit were obtained for 'Regina' in either location.

- *Pollen viability*- Flowers were collected and brought back in garbage bags to prevent dessication. Bases of twigs were cut and put into water. As flowers opened each day, for 3 days, anthers were cut off, induced to dehisce pollen and pollen collected for observing pollen germination and viability. Pollen was collected and put into vials plugged with cotton then placed into the freezer with dessicant in a plastic container. Pollen collection required 96 hours. A simple liquid sucrose medium was used to induce pollen germination and pollen viability was tested prior to placing it in the freezer (45 hrs).

Results: See details of the findings in the following figures and tables.

Fig. 1. Ovule longevity of ‘Bing’ and ‘Regina’ flowers in 2005 at the Lewis-Brown Farm

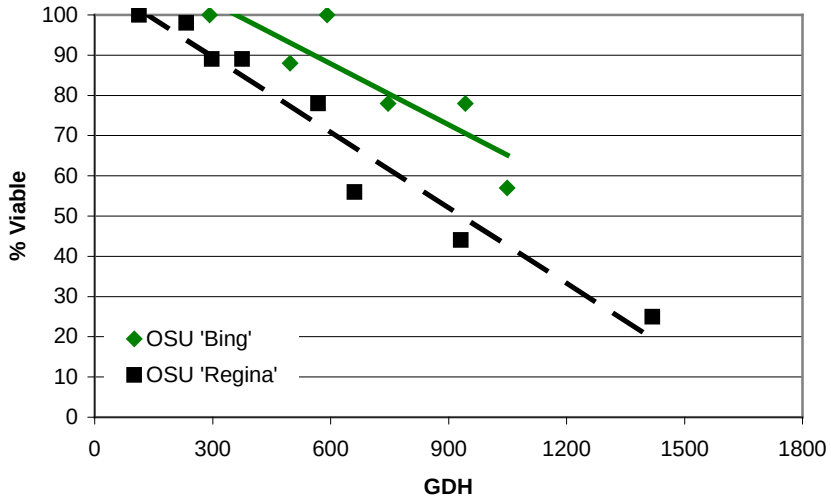

Fig. 2. Ovule longevity of ‘Bing’ and ‘Regina’ flowers in 2006 from 4 different locations

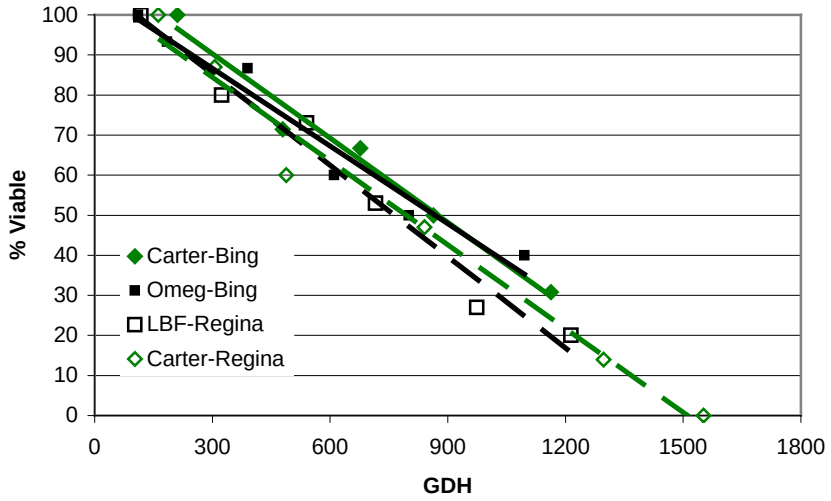

Fig. 3. Ovule longevity of ‘Bing’ and ‘Regina’ flowers in 2007 from 4 different locations

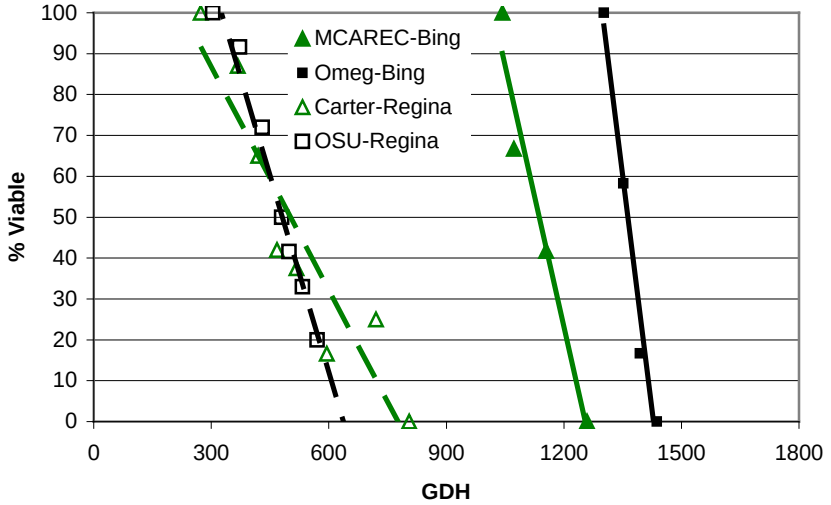

Fig. 4. Growing degree hour accumulation during bloom of ‘Regina’ and ‘Bing’ in 2006 and 2007.

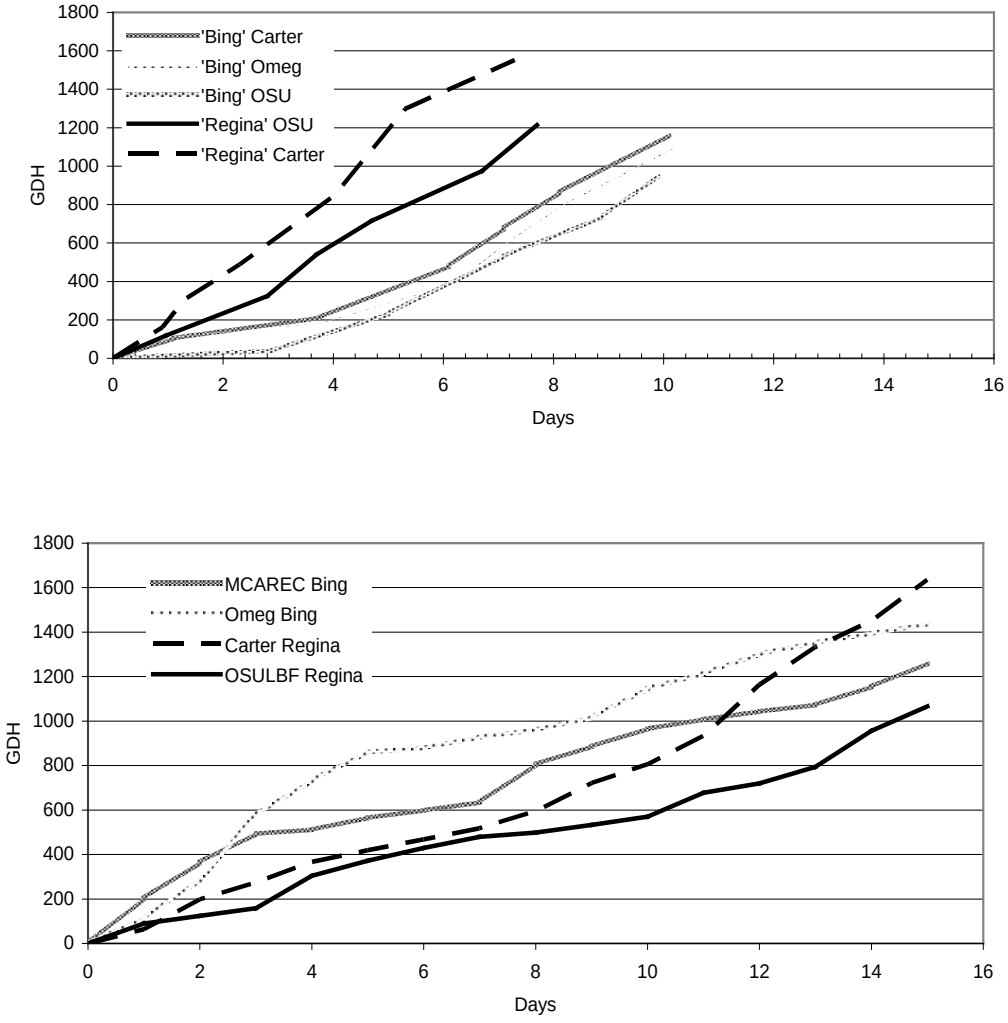

Fig. 5. Pistils of ‘Bing’ flowers (A) and ‘Regina’ flowers (B) in 2007 from The Dalles

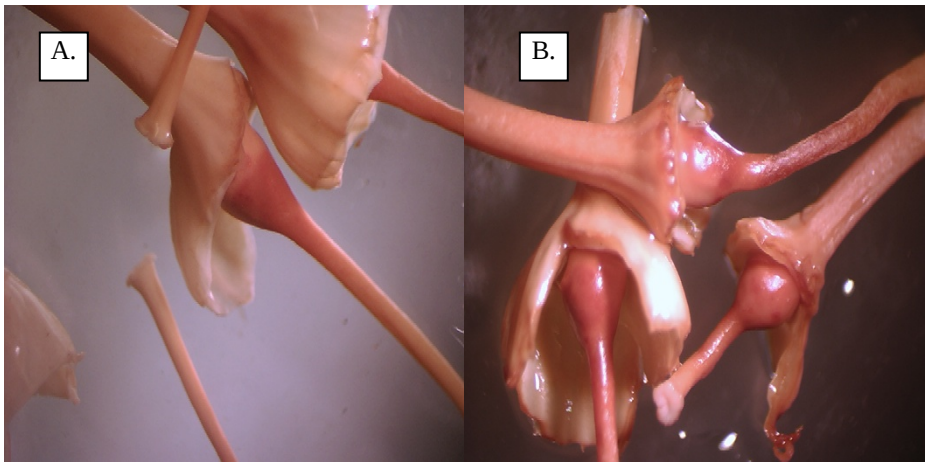

Fig. 6. Senescing ovules (A) and pollen tube growth (B)

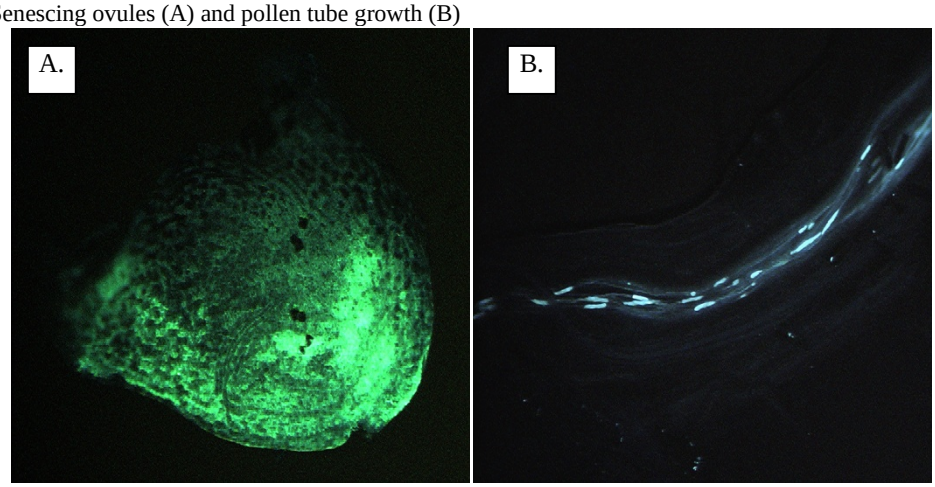

Table 1. Length of style and ovary, and width of ovary of 'Regina' and 'Bing' pistils at time of emasculation.

	Style Length (mm)	SE	Ovary Length (mm)	SE	Ovary Width (mm)	SE
'Regina'	7.3	0.47	2.4	0.07	1.7	0.04
'Bing'	11.0	0.11	2.8	0.06	1.8	0.04

Table 2. Number of growing degree hours (GDH) and maximum observed distance that pollen tubes traveled within the style in 'Bing' flowers pollinated by 'Rainier' and 'Van' in 2007

Pollen source on 'Bing'(s_3s_4)	GDH/Days	Distance of style with pollen tubes (%)
Omeg		
Van (s_1s_3)	734/5	100
Rainier (s_1s_4)	578/4	100
Van + Rainier	734/5	100
MCAREC		
Van	511/5	100
Rainier	493/4	100
Van + Rainier	511/5	100

Table 3. Pollen viability of compatible pollinizers for 'Bing' and 'Regina' in 2005, 2006 and 2007

Pollen genotype	s-alleles	Viability (%)			
		2005	2006	2007 (Range)	2007 (Mean)
Bing	s_3s_4				
Rainier	s_1s_4	69	10	9-33	21
Van	s_1s_3	67	10	25-40	33
Regina	s_1s_3				
Sam	s_2s_4	52	18	6-15	11
Schneider's Späte Knorpel	s_3s_{12}	49	22	8	8
Stark's Gold	s_3s_6		24	20	20
Skeena	$s_1s_{4'}$	28	23	19-28	24
Sandra Rose	$s_3s_{4'}$	11	33	17-33	25
Sylvia	s_1s_4	6	22	21-23	22

FINAL PROJECT REPORT

WTFRC Project Number: CH-05-508 (WSU Project 13C-3655-7299)

Project Title: Induction of branches in sweet cherry trees in the orchard

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Budget History:

Item	**Year 1:** 2005	**Year 2:** 2006	**Year 3:** 2007
Salaries	4,200	4,368	4,543
Benefits	1,302	1,485	1,545
Wages	1,500	2,000	2,400
Benefits	240	220	276
Equipment	0	0	0
Supplies	500	800	1,000
Travel	2000	2,500	3,000
Miscellaneous	500	500	500
Total	10,242	11,873	13,264

Significant findings 2005:

- Scoring/Perlan (2,000 ppm) treatments to one-year-old unheaded leaders of two-year-old 'Sweetheart'/Mazzard trees at various times after green-tip showed best branching at 2-4 weeks after green-tip. This observation coincided with an extensive period of cold temperatures after green-tip.
- Two-year-old 'Sweetheart'/Mazzard tree central leaders were left unheaded and scored once in the middle of the leader shoot. Perlan (2,000 ppm) was equally effective for branch induction when applied to scoring cuts up to 24 hours after the cut was made.
- Thidiazuron, a powerful cytokinin product, was painted on two-year-old wood of three-year-old 'Sweetheart'/Mazzard trees at green-tip. At up to 500 ppm, this treatment was ineffective for producing new branching from the older wood.
- Unheaded leader shoots on second leaf 'Skeena'/Mazzard trees produced significant branching when scraped or notched bark was treated with Perlan (5,000 ppm) at green-tip. A light sanding of the bark plus Perlan paint did not result in additional branch development.
- Leader shoots on second leaf 'Lapins'/Mazzard trees were left intact or lightly headed. Leaders were then scored every 12 inches, notched every 12 inches or disbudded (one left/three removed). Painting scores or notches with Perlan (5,000 ppm) produced much branching, while painting disbudded sites produced no branching response.

Significant findings 2006:

- Where half-score cuts plus cytokinin treatment were made on the outside half of vertical, one-year-old leader shoots, the number of shoots formed was increased by two to five fold, with a large number of those shoots appearing on the lower two-thirds of the treated leader shoots.
- Half-score cuts on the outside portion of the leaders definitely promoted preferential lateral branching on the outside half of the treated leader shoots, mainly on the lower portions of those leaders.
- Shoot development was induced to some extent above a score plus cytokinin application as well as below the point of treatment.
- There was very little movement of the stimulative effect of a partial score or nicking cut plus cytokinin treatment laterally around the treated stem.
- Branch-induction results clearly showed that making cuts every 12 inches along the leader was just as effective for stimulating shoot development as making two or three times as many cuts plus cytokinin treatment (every 4 or 8 inches), thus reducing the labor input required.
- Successful lateral-branch induction did not require any attention be paid to the location of a half-scoring or nicking cut relative to nearby buds.
- Where various mixtures of cytokinin plus adjuvants were applied to unscored bark, no beneficial effect of the treatment on shoot development was observed.
- Scoring plus treatment with 5,000 ppm GA_{4+7} in 'Skeena' cherry was almost as effective for shoot induction as treatment with 6-benzyladenine alone.
- Application of thidiazuron (TDZ) at 1,000 ppm or of chlorophenylurea (CPPU, Prestige) at 500 ppm without added GA produced a weaker shoot induction response than normally observed when Promalin (5,000 ppm) is painted on scoring cuts. When GA_{4+7} was added to either cytokinin and painted on scoring cuts, shoot induction was the same as for the standard Promalin treatment.

- The only shoot-induction treatment with positive results on newly-planted 'Rainier'/G.5 trees was disbudding. The low vigor of their growth in year one did not allow for significant expression of bioregulator-mediated shoot induction.
- When cytokinin was mixed with 10 ppm of fixed Cu and applied to half-scoring cuts, the branch-induction effect was undiminished; thus Cu has no negative effect on the efficacy of cytokinin.

Significant findings 2007:

- Crushing the bark of one-year-old shoots of either 'Sweetheart'/Mazzard or 'Skeena'/G.6 trees with a pair of pliers did not induce branching per se. When Promalin was painted on the crushed bark, branch development was just as effective as if the bark had been scored or notched.
- Most surfactant supplements were not effective in aiding penetration of Promalin through uninjured bark of 'Sweetheart' trees.
- Combining 2,000 mg/liter Promalin with 1.5% v/v Pentra-bark and 2.5% v/v Agri-fos and applying directly to uninjured bark produced branching equivalent to the normal scoring plus Promalin (2,000 mg/liter) treatment.
- Painting the undiluted Promalin formulation (20,000 mg/liter) combined with 0.1% v/v Regulaid or with 1% v/v Pentra-bark on uninjured bark produced the same branching as the standard treatment with no evidence of foliar or bark phytotoxicity.
- Treating scoring cuts in one-year-old wood of second leaf 'Skeena'/G.6 trees with gibberellic acid alone produced as much lateral branching as treating with a cytokinin*/GA* mixture at the same concentration.
- Applied to scoring cuts at 5,000 mg/liter, GA_3 (Pro-Gibb 40) was less effective for inducing lateral branching than either GA_4 (Novagib 10L) or GA_{4+7} (Provide 10SG).

Results and Discussion:

Several points have been confirmed during this project. We demonstrated that if the epidermis on one-year-old wood is broken, the cytokinin product becomes very effective for branch induction. Underlying tissues do not need to be cut or damaged; therefore, large or deep cuts with heavy knives or saws do not improve branching. We showed that crushing bark with pliers was sufficient to breach the epidermis. This approach reduces the risk of personal injury to workers or excessive damage to trees by eliminating the need for knives. Disbudding produces points of injury but these are not sufficient to permit enough bioregulator to enter to achieve additional branching. We further confirmed that epidermal cuts do not need to be located above buds (i.e., notching), since the bioregulator moves from the point of absorption to nearby buds. Placing cuts on one side of a branch (nicking cuts) permits stimulation of branching primarily from one side of the shoot, which is useful if multiple leaders are being trained. The translocation of the cytokinin bioregulator is primarily downward from the site of application, producing the tendency for a directional response. Cu can be mixed with cytokinin bioregulators and applied to cuts without any negative effect on branching response. Since we have never observed a bacterial canker infection associated with branching, we do not know if this approach would eliminate the risk of such an infection. We do know that adding Cu to cytokinin does not affect the branching response. When cuts are made on one-year-old wood for branch induction, there is no reason to apply cuts closer than about 12 inches apart down the shoot. Closer treatments have not proven more effective for branching, since some translocation of bioregulators takes place from the site of the cut. Also heading back the shoot tip does not improve branching in the mid to lower parts of a one-year-old shoot, so heading should be avoided unless there is some other reason to make the cut. We also tried applying thidiazuron (TDZ), a powerful cytokinin, to two-year-old wood to stimulate branching; we did not cut into the bark and we did not see any branching response.

During this project we discovered that gibberellic acid (GA) alone appears to have the ability to stimulate lateral branching. This observation is interesting since GA is not normally associated with the control mechanism of apical dominance. In addition the presence of GA may help explain why cytokinin/GA mixtures work well for branch induction. However, based on the limited data we have acquired thus far, this observation deserves confirmation. Preliminary results from one trial suggest that GA_3, the isomer used routinely in the cherry industry for control of fruit maturity and flesh firmness, is not as effective as GA_4 or GA_7 for vegetative growth stimulation. This observation remains unconfirmed.

We have obtained encouraging results from initial tests of the concept of using apical-dominance-modifying bioregulators for branching without the requirement of injuring the bark. If we could eliminate the bark injury requirement, we could cut the labor cost for this procedure by at least 50%, reduce the risk of personal injury to workers and reduce, or eliminate, the potential for bacterial canker infections. Initial trials have focused on two approaches: 1) using higher concentrations of bioregulators to determine branching efficacy and potential for phytotoxicity and 2) combination of bioregulators with specific supplements known to strongly enhance penetration of products into plant tissues. We have seen initial positive results from using the undiluted formulation of Promalin and from combining regular concentrations of Promalin (2,000 to 5,000 ppm a.i.) with an additive named "Pentra-Bark" (Quest Products Corp). We plan to continue these studies to determine what approach appears to give the best results with the least risk of phytotoxicity. With further research we believe we will be able to eliminate the need for bark injury as a component of the process of lateral branch induction in young sweet cherry trees.

R**eferences:**

Elfving, D.C. and D.B. Visser. 2007. Improving the efficacy of cytokinin applications for stimulation of lateral branch development in young sweet cherry trees in the orchard. HortScience 42:251-256.

FINAL PROJECT REPORT

Project Title: Alternative nutrient, water and floor management strategies

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Clark Seavert, Agricultural Economist, OSU-MCAREC

Total Project Funding

Budget History

Item	**Year 1:** 2005	**Year 2:** 2006	**Year 3:** 2007
Salaries	8,500	6,800	6,800
Benefits	4,165	3,332	3,332
Wages	2,800	2,240	2,240
Benefits	224	179	179
Equipment			
Supplies	2,661	2,129	2,129
Travel	450	320	320
Miscellaneous			
Total	18,800	15,000	15,000

Objectives

1) Study the impacts of drip irrigation on water use efficiency, fruit quality, storability, and yield of sweet cherry relative to micro sprinkler irrigation under different ground cover systems.
2) Compare ground cover [straw mulch or fabric (polypropylene) cover] vs. no ground cover, mulch cover vs. fabric cover, and white fabric cover vs. black fabric cover on water use, fruit quality, storability, and yield of sweet cherry, and on plant nutrition and soil fertility as well.
3) Evaluate the long-term impacts of black fabric ground cover on sweet cherry tree nutrition and soil nutrient supply.
4) Estimate the placement effects of organic fertilizers on sweet cherry tree nutrition and productivity.

Significant Findings

- Drip irrigation significantly increased the percentage of marketable fruit by reducing cherry surface pitting and bruising compared with micro sprinkler irrigation. Straw mulch, black fabric cover, and white fabric cover also increased the percentage of marketable fruit in some years.

- Drip irrigation saved over 70% of irrigation water each season compared with micro sprinkler irrigation averaged over the four ground cover systems.
- Fruit yield under drip irrigation was similar to that under micro sprinkler irrigation. However, there was a trend of yield increase, although statistically insignificant, with straw mulch and fabric covers.
- Fruit quality was generally comparable with drip irrigation relative to micro sprinkler irrigation, and with straw mulch and fabric covers compared with no ground cover.
- Soil available nitrate (NO_3^-) and potassium (K) contents were sometimes significantly lower with black fabric cover relative to no ground cover due to the greater removal of these nutrients by higher fruit yield in 2005-2007. Other nutrients did not differ between the black fabric cover and no cover treatments.
- Leaf nitrogen (N) concentration was enhanced by 9 to 19% with black fabric cover compared with no cover in 2005-2007. However, leaf phosphorus (P) concentration was lowered by 19% in the black fabric cover treatment in 2005; leaf Ca and S concentrations were significantly lower with black fabric cover in some seasons. Reduced leaf P, calcium (Ca), and sulfur (S) concentrations with black fabric cover were attributed to the tissue diluting effects due to greater tree growth and fruit production.
- The total uptake of N, P, K, Ca, magnesium (Mg), boron (B), manganese (Mn), and copper (Cu) nutrients by trees seemed to be significantly increased with black fabric cover relative to no cover. The enhanced uptake of nutrients from soil with the black fabric cover may be due to the larger soil volume penetrated by the root systems of ground-covered trees and increased soil temperature early in the spring.
- From a long-term perspective, more fertilizers need to be applied on black fabric ground-covered sweet cherry trees because of the increased tree growth and fruit production.
- Application of organic fertilizers directly on the top of black fabric cover was equally effective as the application of these fertilizers beneath the fabric cover; application of organic fertilizers directly on the top of black fabric cover could save labor.

Methods

Drip Irrigation and Straw Mulch Trial

A field experiment was initiated on Mel Omeg's orchard in The Dalles, OR in 2005, and was continued in 2006 and 2007. Two irrigation systems (single-line drip irrigation, micro sprinkler irrigation) and four ground management systems [mulch with straw, white fabric cover, black fabric cover, and control (no mulch or fabric cover, but herbicide was used to control weeds)] were evaluated in a split-plot design with four replications. Soil moisture measurements were taken weekly at a soil depth of 12 inches from May to September. Irrigation scheduling for each treatment was based on soil moisture content, and each plot was irrigated separately. Soil sampling was conducted at the depth interval of 0 to 12 inches for each plot each year about one month after fruit harvest. Soil nitrate, available P, K, Ca, Mg, S, B, Mn, and Cu contents were extracted using the Mehlich III method. Soil pH was determined with a 1:1 (soil:H_2O) solution, and organic matter was measured using the loss-on-ignition method. A leaf sample was taken randomly from each plot in August each year. The following nutrient concentrations were determined for these samples. Total N was determined using a combustion method. Total P, K, Ca, Mg, S, B, Mn, and Cu were digested in a CEM MDS 2100 series microwave using nitric acid and hydrogen peroxide, and the digest was analyzed on a Thermo Jarrel Ash 1100 ICP. Fruit yield, firmness, size, color, and sugar were determined for each plot. Visual evaluation of fruit surface pitting was conducted after the fruits had been stored in a cold storage room at 30^{o}C for three weeks. Four categories of excellent, slightly pitted, pitted, and bruised fruit were used in this evaluation.

IFP Cherry Trial

As part of an ongoing long-term research project on the use of black fabric cover, this study was conducted on a Van Horn fine sandy loam soil at the Mid-Columbia Agricultural Research and Extension Center in Hood River, OR from 2005 through 2007. The 1.2-ha orchard used in this study was planted at 18 ft. between rows and 10 ft. within rows in March 2001 with second-leaf Regina sweet cherry on Gisela 6 rootstock. The trees were trained to a central leader. This trial was initiated in 2001 in a randomized complete block design with eight replicates. Two ground management systems were evaluated. One treatment was 8-ft. wide synthetic black fabric, made of black woven polypropylene (DeWitt Co., Sikeston, MO), covering the tree row centers. This water-permeable polypropylene was placed on the ground in April 2001 with 1-ft wide edges buried in the soil on both sides of a tree row. The other treatment was the control (no ground cover, but with herbicide applications in the row area of same width to control weeds). Roundup (glyphosate) at 1388 ml ha^{-1} mixed with 147 liters ha^{-1} of water was sprayed in the control treatment in early June each year from 2005 to 2007. Fertilizer applications were based on shoot growth and nutrient concentrations in leaf and soil for this study. No N, P, or K fertilizer was applied to either treatment during the first three years (2001-2003) of the study. However, N fertilizer was applied to both treatments in April at 8 lb N $acre^{-1}$ in 2004 and 30 lb N $acre^{-1}$ in 2005 and 2006 as ammonium sulfate, and 80 lb N $acre^{-1}$ in 2007 as urea. Soil moisture content was measured weekly and irrigation was conducted during the irrigation season from May to September each year. Soil available nutrients were measured at a depth of 12 inches, and total nutrient concentrations in leaf were measured after harvest. Fruit yield, firmness, size, color, and sugar were determined for each plot. Visual evaluation of fruit surface pitting was conducted after the fruits had been stored in a cold storage room at 30ºC for three weeks.

Organic Fertilizer Placement Trial

A field experiment was conducted from 2005 through 2007 on a 1-acre black fabric-covered adult sweet cherry orchard that was transitioned into organic production in 2003 at MCAREC. Two types of organic fertilizers (fish meal and blood meal) and two placement methods of these fertilizers (broadcast application on the top of fabric cover, broadcast application to the beneath of fabric cover) were evaluated in a split-plot design with four replicates. Leaf chlorophyll concentration was measured during the season in 2005. Soil available nutrients were measured at a depth of 12 inches, and total nutrient concentrations in leaf were measured after harvest. Fruit yield, firmness, size, color, and sugar were determined for each plot.

Results and Discussion

Drip Irrigation and Straw Mulch Trial

In 2005, differences in soil available N, P, K, Ca, Mg, S, B, Mn, Cu, pH, and organic matter were primarily negligible between drip irrigation and micro sprinkler or among no cover, straw mulch, black fabric cover, and white fabric cover (data not presented). However, drip irrigation had slightly lower concentrations of N, P, K, Ca, B, and Mn in leaves than micro sprinkler irrigation after harvest (Table 1); which suggests that the uptake of these nutrients by roots may be slightly reduced due to the switch from micro sprinkler irrigation to drip irrigation in the first year. Unlike the irrigation systems, the four ground cover treatments had similar leaf nutrient concentrations except N (Table 1). Both black and white fabric covers had significantly higher leaf N concentration than the no cover control.

In 2006, drip irrigation plots had significantly higher N and Mn, but lower K concentrations in leaf than the micro sprinkler irrigation plots, about one month after harvest (Table 1). The concentrations of other nutrients were statistically similar between these two irrigation systems. The above results suggest that the uptake of these nutrients, except K, by roots is not reduced due to the switch from micro sprinkler irrigation to drip irrigation in the second year. The four ground cover systems had similar leaf nutrient concentrations except Cu (Table 1).

In 2007, drip irrigation had significantly lower N and Mn concentrations in leaf than the micro sprinkler irrigation in August, about one month after harvest (Table 1). The concentrations of other nutrients were statistically similar between these two irrigation systems. The four ground cover systems had similar leaf nutrient concentrations except P, Mg, and S (Table 1).

Table 1. Effects of irrigation and ground cover systems on leaf nutrient concentrations.

Year	Treatment	N	P	K	Ca	Mg	S	B	Mn	Cu
		%	%	%	%	%	%	ppm	ppm	ppm
2005	Micro sprinkler	2.58	0.26	2.64	1.20	0.31	0.14	81.1	55.2	4.6
	Drip irrigation	2.46	0.21	2.36	1.05	0.31	0.14	67.6	49.1	3.1
	Significance	*	*	*	*	ns	ns	*	*	ns
	No cover	2.40	0.25	2.60	1.14	0.32	0.14	74.8	49.0	4.0
	Straw mulch	2.38	0.22	2.38	1.19	0.32	0.14	69.7	51.7	3.6
	Black fabric	2.75	0.24	2.55	1.12	0.29	0.15	80.0	55.3	4.1
	White fabric	2.55	0.23	2.46	1.06	0.31	0.14	72.9	52.7	3.8
	Significance	*	ns	ns	ns	ns	ns	ns	ns	ns
2006	Micro sprinkler	2.36	0.32	2.64	1.70	0.34	0.18	75.7	52.3	5.0
	Drip irrigation	2.54	0.31	2.31	1.81	0.38	0.18	72.6	62.7	5.5
	Significance	*	ns	**	ns	ns	ns	ns	*	ns
	No cover	2.43	0.33	2.45	1.73	0.38	0.18	74.6	53.9	5.1
	Straw mulch	2.40	0.33	2.54	1.87	0.36	0.18	73.3	58.5	5.2
	Black fabric	2.46	0.29	2.48	1.76	0.35	0.18	75.5	60.4	4.7
	White fabric	2.52	0.33	2.44	1.66	0.36	0.18	73.2	57.2	5.9
	Significance	ns	ns	ns	ns	ns	ns	ns	ns	*
2007	Micro sprinkler	2.74	0.29	2.51	1.34	0.37	0.16	73.2	58.4	5.52
	Drip irrigation	2.43	0.26	2.64	1.18	0.35	0.15	73.0	48.5	4.73
	Significance	*	ns	ns	ns	ns	ns	ns	*	ns
	No cover	2.72	0.28	2.52	1.29	0.40	0.16	72.6	52.3	5.07
	Straw mulch	2.57	0.27	2.49	1.35	0.36	0.15	73.6	52.7	5.17
	Black fabric	2.57	0.26	2.61	1.21	0.31	0.15	73.6	55.9	4.91
	White fabric	2.48	0.31	2.66	1.19	0.36	0.15	73.0	52.8	5.33
	Significance	ns	*	ns	ns	*	*	ns	ns	ns

* indicates the treatment effect is statistically significant at 5% probability level. Non significant effect is denoted by ns.

One of the biggest benefits with drip irrigation was saving water. In 2005, drip irrigation reduced irrigation water use by 74% relative to micro sprinkler during the entire season from May to September (Table 2). Compared with no cover, black fabric reduced water use by 8%, and straw mulch and white fabric had a 1 to 3% reduction in water use. In 2006, drip irrigation saved as much as 79% of the irrigation water relative to micro sprinkler during the entire season. Relative to no cover, straw mulch reduced seasonal water consumption by less than 1% while black and white fabric had a 3 to 5% increase in water use. In 2007, drip irrigation saved 71% of irrigation water relative to micro sprinkler during the entire season. Compared with no cover, straw mulch and white fabric cover has almost the same seasonal water consumption, but black fabric had a 7.1% reduction in water use.

In 2005, fruit yield with drip irrigation was similar to that under micro sprinkler irrigation (Table 2). There was a strong trend of yield increase with straw mulch and fabric covers, particularly with white fabric relative to no cover, although these yield increments were statistically insignificant. Because both irrigation and ground cover treatments were implemented in early May this year, these yield differences may not be fully attributable to the treatment effects alone. Fruit quality including sugar content, firmness, and fruit size did not differ regardless of irrigation or ground cover systems. In 2006, Fruit yield did not differ between drip irrigation and micro sprinkler irrigation when averaged over the four ground cover treatments (Table 2). There was a trend of yield increase, although statistically insignificant, with straw mulch and fabric covers, relative to no cover. Fruit quality was generally similar for the irrigation and ground cover systems. In 2007, Fruit yield with drip irrigation was similar to that under micro sprinkler (Table 2) when averaged over the four ground cover systems. There seemed to be a trend of yield increase with straw mulch and fabric covers relative to no cover. Fruit quality including fruit size and sugar did not differ regardless of irrigation system; but fruit size was larger with drip irrigation than micro sprinkler in 2007. Compared with no cover, straw mulch, black fabric cover, and white fabric cover all had fruit with higher sugar content and greater firmness. Furthermore, white fabric cover seemed to have smaller fruit relative to other ground cover systems.

Table 2. Effects of irrigation system and ground cover systems on irrigation water consumption and fruit yield and quality.

Year	Treatment	Water consumption (gallon/tree)	Yield (lbs/tree)	Sugar (^{o}brix)	Firmness (g/mm^2)	Size (mm)
2005	Micro sprinkler	3427.5	49.9	17.3	290	31.1
	Drip irrigation	893.5	48.9	17.3	298	30.8
	Significance	*	ns	ns	ns	ns
	No cover	2226.3	43.9	17.0	305	31.1
	Straw mulch	2160.0	49.0	17.5	286	31.1
	Black fabric	2042.8	49.3	17.1	299	30.8
	White fabric	2213.0	55.3	17.5	287	30.8
	Significance	ns	ns	ns	ns	ns
2006	Micro sprinkler	4323.8	178.8	17.3	259.7	25.8
	Drip irrigation	928.0	174.0	18.5	268.9	25.5
	Significance	*	ns	*	ns	ns
	No cover	2575.3	170.7	17.9	264.7	25.4
	Straw mulch	2564.0	181.3	18.0	266.6	25.7
	Black fabric	2654.0	175.5	17.5	270.5	25.7
	White fabric	2710.3	178.0	17.9	255.8	26.0
	Significance	ns	ns	ns	ns	ns
2007	Micro sprinkler	5490.0	63.0	19.9	305.6	30.3
	Drip irrigation	1577.5	61.9	20.6	343.2	31.0
	Significance	*	ns	ns	*	ns
	No cover	3590.6	59.8	19.2	310.3	30.7
	Straw mulch	3576.2	64.4	21.7	320.4	31.0
	Black fabric	3335.8	62.4	21.3	340.0	30.8
	White fabric	3632.4	62.1	20.4	326.9	30.0
	Significance	ns	ns	*	*	*

* indicates the treatment effect is statistically significant at 5% probability level. Non significant effect is denoted by ns.

In 2005, it was interesting that drip irrigation increased marketable fruit (clear + slightly pitted) by approximately five percent (absolute value) via reducing cherry surface pitting compared with micro sprinkler (Table 3). No benefits were found with straw mulch or fabric covers in reducing fruit pitting relative to no cover. In 2006, Drip irrigation increased marketable fruit (excellent + slightly pitted) by over four percent (absolute value) via reducing cherry surface pitting compared with micro sprinkler (Table 3). There seemed to be a benefit with black fabric in reducing fruit pitting and bruising relative to no cover. In 2007, drip irrigation increased marketable fruit (excellent + slightly pitted) by over six percent (absolute value) via reducing cherry surface pitting and bruising compared with micro sprinkler (Table 3). There also seemed to be a benefit with straw mulch and white fabric in reducing fruit pitting and bruising relative to no cover.

Table 3. Effects of irrigation system and ground cover systems on fruit surface pitting.

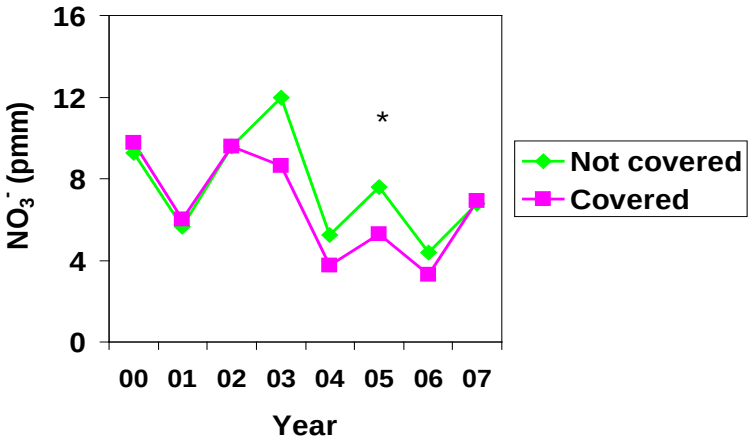
year	Treatment	Clear	Slightly Pitted	Clear + Slightly Pitted	Pitted	Bruised
		(%)	(%)	(%)	(%)	(%)
2005	Micro sprinkler	70.6	6.5	77.1	17.4	5.5
	Drip irrigation	76.2	6.2	82.4	12.6	5.0
	Significance	ns	ns	*	ns	ns
	No cover	75.8	5.0	80.8	14.4	4.8
	Straw mulch	71.5	6.8	78.3	15.8	5.9
	Black fabric	74.0	7.1	81.1	14.5	4.4
	White fabric	72.3	6.4	78.7	15.4	5.9
	Significance	ns	ns	ns	ns	ns
2006	Micro sprinkler	42.0	24.4	66.4	20.3	13.3
	Drip irrigation	44.2	26.6	70.8	19.2	10.0
	Significance	ns	ns	*	ns	ns
	No cover	41.8	24.7	66.4	23.0	10.6
	Straw mulch	41.8	26.7	68.6	18.7	12.7
	Black fabric	48.2	23.7	71.8	16.8	11.4
	White fabric	41.3	26.9	68.2	19.7	12.1
	Significance	ns	ns	ns	ns	ns
2007	Micro sprinkler	15.1	37.2	52.3	28.3	12.4
	Drip irrigation	22.1	36.6	58.6	25.3	9.1
	Significance	*	ns	*	ns	*
	No cover	14.5	38.3	52.8	30.1	10.4
	Straw mulch	24.4	36.3	60.6	21.8	8.7
	Black fabric	15.5	35.6	51.1	29.1	14.3
	White fabric	19.9	37.4	57.3	26	9.8
	Significance	ns	ns	*	ns	*

* indicates the treatment effect is statistically significant at 5% probability level. Non significant effect is denoted by ns.

IFP Cherry Trial

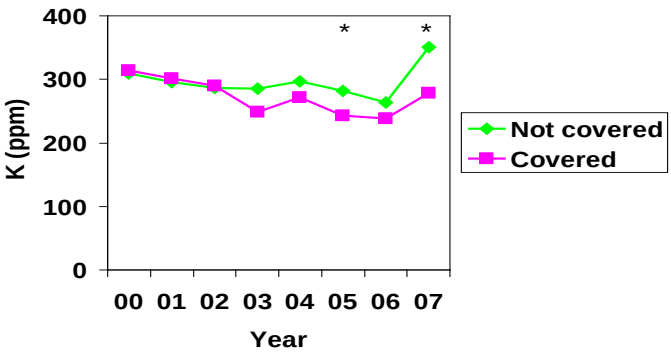
Soil NO_3^- content was statistically similar in the cover and no cover treatments in 2005, when soil under black fabric cover had a 30.3% reduction in NO_3^- compared with the non-covered soil (Fig. 1). However, Soil NO_3^- content was similar under the two treatments in 2006 and 2007. Difference in soil available P was not significant between the cover and no cover treatments regardless of year (data not presented). Soil under black fabric cover had similar soil available K content in 2006, but significantly lower soil K in 2005 and 2007 relative to the non-covered soil. The reduction in soil K was 13.6% and 20.6% in the covered soil over the non-covered soil in 2005 and 2007, respectively (Fig. 2). No significant effects of the black fabric cover on soil available Ca, Mg, S, B, Mn, and Cu, or pH were observed in any of the three years (2005-2007) (data not presented). Although black fabric cover serves as a physical barrier to prevent organic matter additions to the soil, no significant difference in soil organic matter was observed between the two treatments in 2005-2007 (data not presented). This trend may be attributed to the assumption that although tree leaves fall on the top of black fabric cover in the ground-covered treatment, they could still be decomposed by soil microbes and washed down through the black fabric cover and then down to the soil by rain and irrigation water.

Fig. 1. Black fabric ground cover effects on soil nitrate content.



* indicates the treatment effect is significant at $P = 0.05$.

Fig. 2. Black fabric ground cover effects on soil available potassium content.

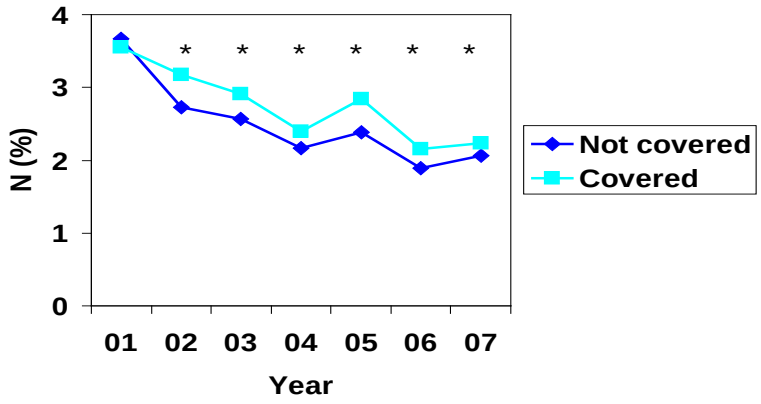


* indicates the treatment effect is significant at $P = 0.05$.

Overall, plots under different treatments had similar available nutrient levels in the soil during the first four years (2001-2004) of experimentation; after that, plots under black fabric cover had lower soil N and K levels in some years. This trend was within our expectation because tree growth and fruit yield were significantly enhanced by over 30% with black fabric cover compared with no cover during 2005-2007. Enhanced tree growth and fruit yield with black fabric cover increased the removal of nutrients from the soil, thus reducing available soil nutrient contents. Meanwhile, our results suggest that increased soil moisture content and soil temperature (data not presented) were both likely attributed to the greater tree growth and fruit yield with the covered trees.

Black fabric cover exerted a consistent effect on leaf N concentration during 2005-2007 (Fig. 3). Leaf N concentrations in August after fruit harvest were 19.3, 13.8, and 8.7 % greater with the covered trees than non-covered trees in 2005, 2006, and 2007, respectively. Because tree size and fruit yield was over 30% greater with cover than without cover treatments (data not presented), this suggests that the total amount of N uptake per tree has been substantially enhanced due to black fabric cover. Our results are different from those in western Canada (Neilsen et al., 2003) in that no significant differences in leaf N concentration were observed on apple trees between in-row black fabric cover and herbicide application in any of the six years from 1994 to 1999. Insignificant differences observed in the study of Nielsen et al. (2003) in western Canada were likely due to the fact that N was fertigated, which probably negated the fabric ground cover effect on leaf N relative to the control.

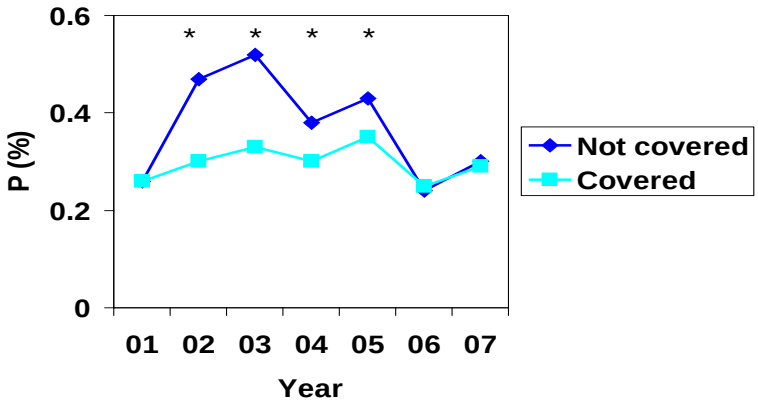
Fig. 3. Black fabric ground cover effects on leaf nitrogen concentration.



* indicates the treatment effect is significant at $P = 0.05$.

On the other hand, leaf P concentration in August after fruit harvest was 18.6% lower with the covered trees than the non-covered trees in 2005 (Fig. 4). However, leaf P level was almost the same for the two treatments in 2006 and 2007. Unlike N and P, leaf K concentrations were always the same for the two treatments during in 2005- 2007 (not presented). Our results generally contrast with those of Neilsen et al. (2003) on leaf P concentrations, but are consistent for leaf K concentrations.

Fig. 4. Black fabric ground cover effects on leaf phosphorus concentration.



* indicates the treatment effect is significant at $P = 0.05$.

Leaf Ca concentration in August was reduced by 9.2% in 2005 in the black fabric cover plots (data not presented). Leaf S concentration was lowered by 7.1, and 8.3% in 2006 and 2007, respectively, with black fabric cover (data not presented). The reduced leaf P, Ca, and S concentrations with the covered trees were attributed to the diluting effects of enhanced tree growth and fruit yield. Neilsen et al. (2003) also reported lower leaf Ca concentrations with black fabric ground-covered apple trees in two out of six years in their study. The effects of black ground cover on leaf Mg, B, and Mn concentrations in August, after fruit harvest, were statistically insignificant in 2005-2007 (data not presented).

Overall, our results suggest that leaf nutrient concentrations respond differentially to in-row black fabric ground cover, and the responses vary with the growing season. The total uptake of N, P, K, Ca, Mg, B, Mn, or Cu per tree per year seems to be significantly increased with black fabric cover relative to no cover because of an over 30% increase in both tree growth and fruit yield in the fabric covered treatment. The enhanced uptake of nutrients from soil with black fabric cover may be attributable to the larger soil volume penetrated by root systems of ground-covered trees, increased soil moisture supply, elevated soil temperature beneath the black fabric cover, and/or reduced competition from other plants such as weeds in the covered treatment. Our results indicate that the availability of all the nutrients in soil generally remains unchanged with black fabric ground cover. From a long-term perspective, more fertilizers need to be applied on black fabric covered sweet cherry trees because of the enhanced tree growth and fruit production.

Similar to leaf nutrient concentrations, the responses of nutrient concentrations in mature fruit to black fabric ground cover were nutrient-specific in 2005, the only year these analyses were made (data not presented). Fruit N concentration was 18.8% greater in the covered plots than non-covered plots. However, fruit P concentration was lowered by 8.3% because of polypropylene cover. Similar to N, fruit S concentration was increased by 33.3% with black fabric cover relative to no cover. No significant difference was observed in fruit K, Ca, Mg, B, Mn, or Cu concentration between the covered and non-covered trees.

Fruit quality, such as sugar content, firmness, and fruit size, generally did not differ between covered and non-covered trees (Table 4). However, fruit pitting evaluation showed that fabric cover increased the percentage of marketable fruit (clear + slightly pitted fruit) by reducing fruit bruising and pitting problems in some years (Table 4).

Table 4. Black fabric ground cover effects on fruit quality and surface pitting.

Year	Treatment	Sugar	Firmness	Size	Clear	Slightly Pitted	Clear + Slightly Pitted	Pitted	Bruised
		(^{o}brix)	(g/mm^2)	(mm)	(%)	(%)	(%)	(%)	(%)
2005	Not covered	18.9a†	333,0a	28.5a	81.5a	4.8a	86.3a	8.4a	5.4a
	Covered	17.6a	335.0a	28.2a	87.5a	4.6a	92.1a	6.2a	1.7a
2006	Not covered	19.2a	245.5a	26.2a	32.4b	31.3a	63.8b	27.2a	9.0a
	Covered	19.6a	245.6a	25.9a	43.7a	29.7a	71.6a	18.5b	9.9a
2007	Not covered	23.8a	286.1a	27.7b	44.6a	26.8a	71.4a	23.8a	4.8b
	Covered	23.3a	288.6a	28.2a	45.9a	26.5a	72.4a	20.2a	7.4a

† Values in column followed by the same letter are not significantly different at 5% probability level.

Organic Fertilizer Placement Trial

Concentrations of soil available nutrients, such as NO_3^-, P, K, etc. after applying fish meal or blood meal on the top of the black fabric cover were similar to those following the application of the same amount of the same type of fertilizer directly to the soil surface by removing the fabric cover away from the tree row areas (data not presented). Leaf nutrient (N, P, K, etc.) concentrations did not differ between the two fertilizer placement methods either (data not presented). Since leaf chlorophyll is a good indicator of tree N nutrition status, we measured leaf chlorophyll content for each treatment from May to July in 2005. We found that leaf chlorophyll content was almost the same under the two placement methods for each of the two fertilizers during the growing season (data not presented), which suggests the placement method does not affect the availability of these applied organic fertilizers. Furthermore, fruit yield and quality (such as fruit firmness, size, color, and brix) were similar for the two placement methods in all three years (data not presented). Overall, our three-year results suggest that there is no need to apply fish meal or blood meal beneath the fabric cover. Application of these organic fertilizers directly on the top of the synthetic black fabric cover is equally effective and could save labor.

FINAL PROJECT REPORT
WTFRC Project Number: CH-05-506

Project Title: Understanding N requirements for sweet cherry production

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Other funding Sources

Agency Name: Agriculture &Agri-Food Canada Matching Investment Initiative (MII) Program.
Amount awarded: Matched Commission funds as below ($15,000US)
Notes: With match, total budget is basically double the numbers below.

Total Project Funding: approx $30,000 US *exact dollar value depends upon the value of the US dollar

Budget History: Washington Tree Fruit Research Commission Funds

Item	Year 1:	Year 2:	Year 3:
Salaries	$4,500 US	$4,500 US	$4,500 US
Benefits			
Wages			
Benefits			
Equipment			
Supplies			
Travel			
Miscellaneous			
Total	$5000 US	$5000 US	$5000 US

SIGNIFICANT FINDINGS

1. A rating system was developed to summarize experience with different sap flow systems as to accuracy, consistency, flexibility, field effectiveness, longevity and system cost (see Table 1).

2. Sap flow measurements are highly sensitive to small changes in environmental conditions and soil moisture content and offer long term, continuous monitoring of tree performance.

3. Sap flow systems were useful for understanding cherry tree response to environmental factors and indicated:

    a. a pronounced daily pattern in tree water use (sap flow) related to increased light and temperature.
    b. reduced sap flow above 95 F (35 C) indicating a high probability of water stress in cherries above this temperature regardless of irrigation strategy.
    c. large decreases in sap flow during precipitation events due to reduced transpiration and low light

4. Sap flow systems were useful for understanding the impact of management practices on transpiration and by inference on fruit growth and development.

    a. Through sap flow monitoring, imposed water deficits were shown to reduce transpiration which affected fruit size in an experiment block of Lapins/Gi.5.
    b. Transpiration limitations associated with a 2-3 day irrigation cycle could be identified through sap flow monitoring in a commercial orchard of Sweetheart/Mazzard where irrigation was not scheduled to meet evaporative demand.
    c. Transpiration limitations associated with a two day irrigation compared with a daily cycle could be identified through sap flow monitoring in an experimental block of Skeena/Gi.6 where irrigation was scheduled to meet evaporative demand.

5. The major advantage of the technique is continuous monitoring which enables the timing and magnitude of the effects of either environmental or management factors on plant performance to be identified

6. There is a pronounced withdrawal of N from cherry leaves in the 6-8 week period prior to leaf loss regardless of tree N status.

7. Disruption of the normal cycle of leaf N removal via premature leaf loss depressed subsequent yield of Lapins on Gisela 5 rootstock until 3 year’s after the triggering event.

RESULTS AND DISCUSSION

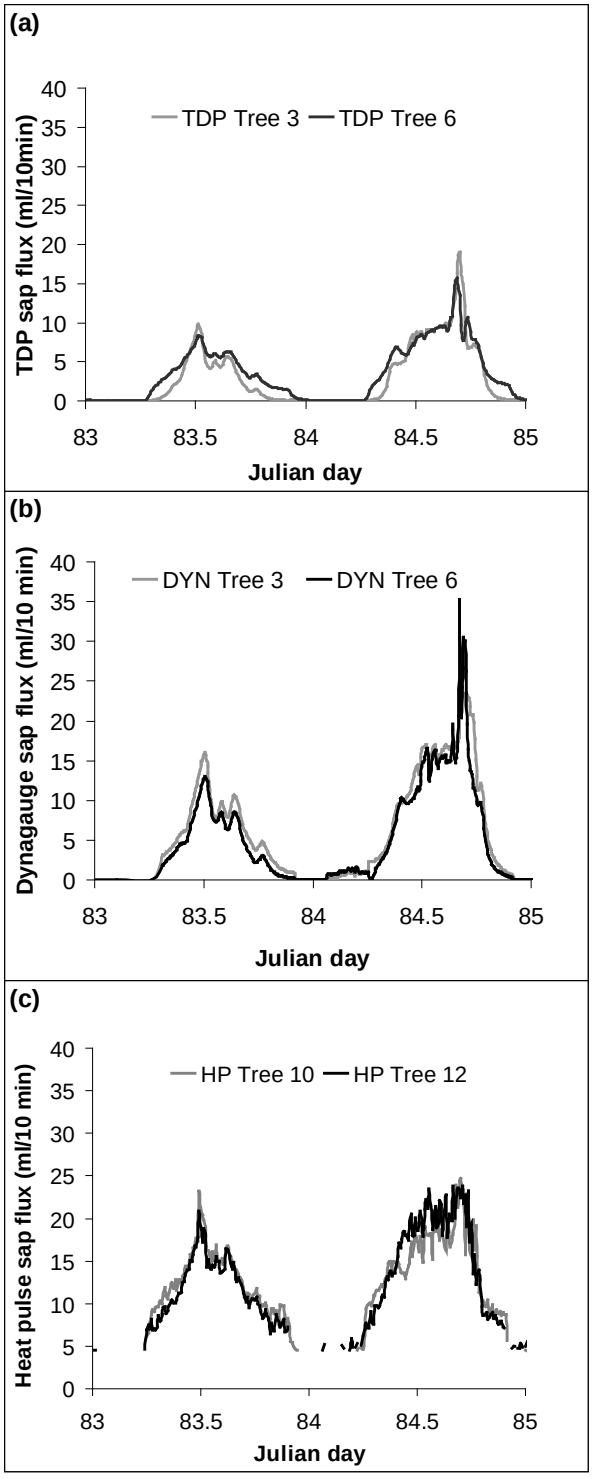

Figure 1. Daily sap flow traces for a) TDP b) Dynagage and c) HP gauges in 2007

accurate, as indicated by how closely the slopes

The initial objectives of this proposal were to determine sap composition and N requirements for sweet cherry, based on xylem N flux and the use of ^{15}N labelled fertilizer. In 2005 funding was re-targeted to a) the assessment of sap flow gauges in greenhouse and field experiments and b) the effects of intervening in Fall N withdrawal and spring remobilization to determine their contribution to cherry nutrition and production.

Assessment of sap flow gauges

Sap flow gauges have been tested to determine:
1. accuracy and precision in the measurement of whole tree transpiration
2. responsiveness to environmental variables
3. usefulness as a tool for irrigation management

1. *Measurement of whole tree transpiration*

Greenhouse tests were carried out in 2005, 2006 and 2007 with consistent results. In the greenhouse, the three types of sap flow gauges tested – PARC thermal dissipation probes (TDP), Dynagage heat balance probes (DYN) and Tranzflo heat pulse probes (HP) had similar responses to tree transpiration requirements over the day. This is illustrated by the similarity in the shapes of the graphs of sap flux, measured every 10 minutes, for representative Stardust/Mazzard cherry trees on two contrasting days (Fig 1). TDP and DYN probes were apparently more responsive to high transpiration demands (Julian day 84.75 - Fig. 1a, b) than HP probes (Fig. 1c). The HP probe signal was 'noisier' than the TDP and DYN probes. The amount of sap flux measured by the probes differed with TDP< DYN < HP.

The accuracy of the different probes was assessed by comparing the calculated sap flux values with weight loss due to transpiration from the pots, which were permanently located on weighing platforms fitted with shear beam force transducers (Omega). The TDP probes underestimated transpiration and were the least

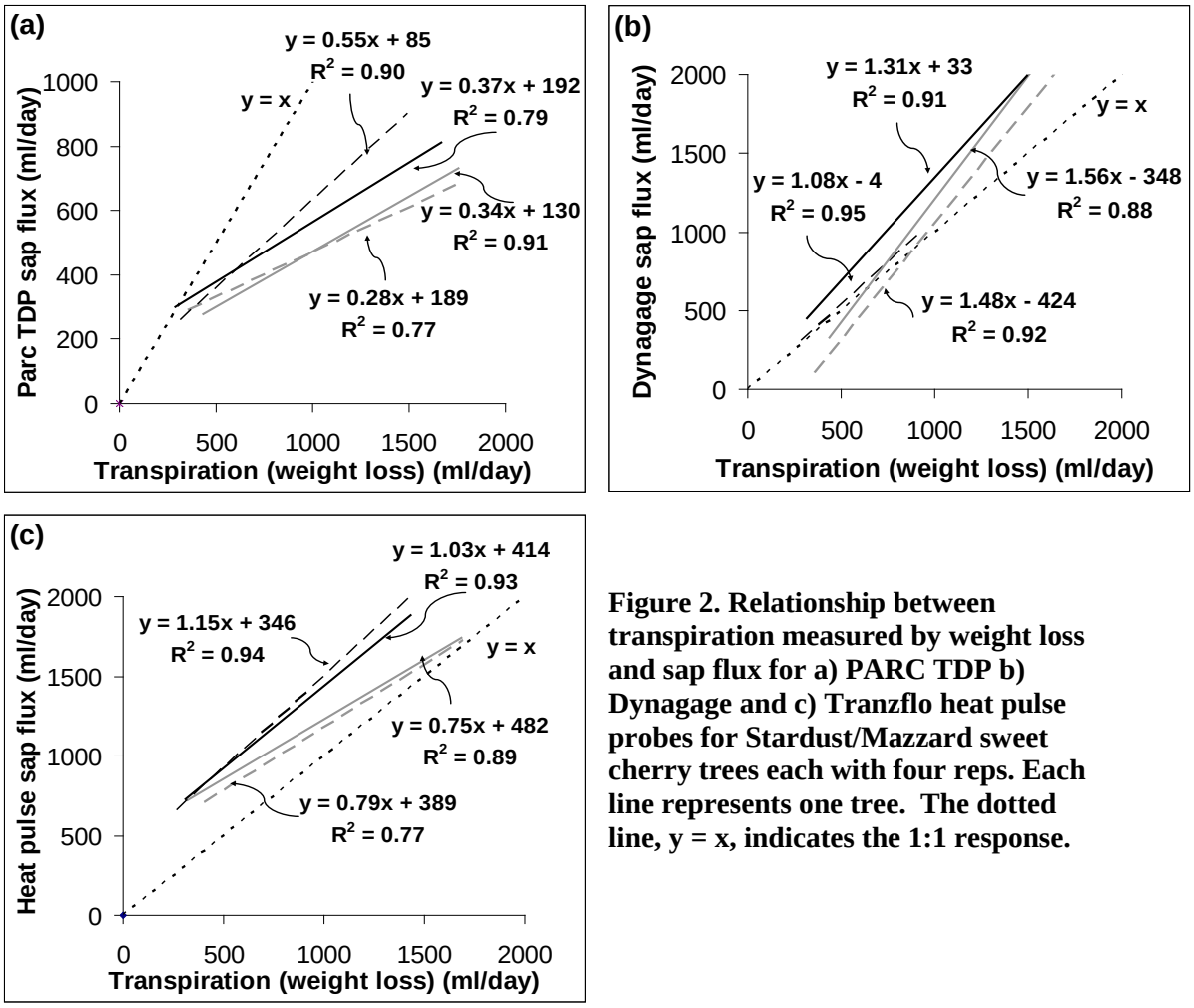

Figure 2. Relationship between transpiration measured by weight loss and sap flux for a) PARC TDP b) Dynagage and c) Tranzflo heat pulse probes for Stardust/Mazzard sweet cherry trees each with four reps. Each line represents one tree. The dotted line, y = x, indicates the 1:1 response.

of the lines for different probes were to the dotted 1:1 line (y = x) (Fig. 2a). The most accurate type of probe was the DYN heat balance probe (Fig. 2b), and the HP probes were intermediate in accuracy, tending to overestimate actual transpiration.

Figure 3. Irregular xylem function in cherry demonstrated using safranin dye solution

The consistency of the relationship between measured and estimated transpiration for individual probes over the course of the experiment is indicated by the magnitude of the R^2 values given on the graphs (Fig. 2). The closer the values are to 1.0 (a perfect correlation) the more consistent the relationship for that particular probe. All of the correlations were strong for individual probes indicating good consistency in their ability to estimate transpiration over time. Between-probe consistency, (similarity in the line equations) was about the same for the replicates of the three different probe types (Fig. 2).

Overall, Dynagage (DYN) heat balance probes are better for estimates of actual transpiration losses than the other two probe types and for xylem N transport studies would be the system of choice. The DYN probes heat the outside of the trunk and measure thermal losses due to sap flow thus sampling the whole of the trunk circumference. The other two probe types are needles

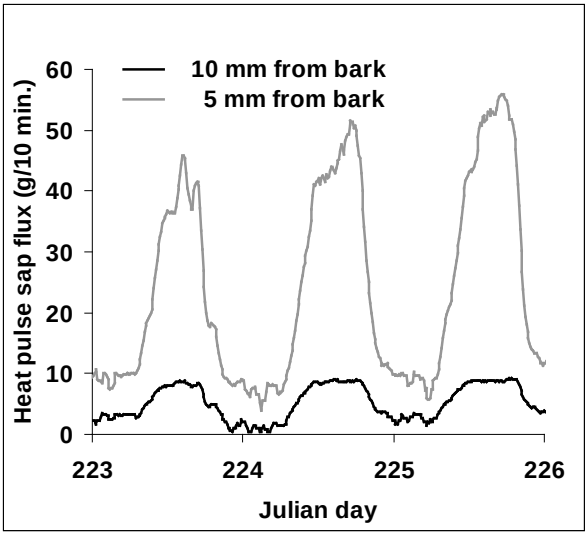

Figure 4. Spatial distribution of sap flow across the trunk measured using Tranzflo probes.

inserted into the xylem and hence only sample a small portion of the total flow. Circumferential xylem inconsistency (Fig. 3) and radial differences in xylem conductive tissue (Fig. 4) contribute to the errors in the TDP and HP estimates of sap flow. This is offset, to some degree in HP probes by ability to take measurements at different depths within the trunk.

Significance to the industry

Given the variation that we have observed among different tree/probe combinations, it is apparent that deriving a universal conversion factor for estimating actual transpiration from sap flow for TDP and HP would not be possible. However, accuracy of measurement (closeness of sap flow estimates to actual transpiration losses) is only important if quantification of xylem flux is required. Below, we will discuss other uses of sap flow gages which are based on relative responses to either environmental or orchard management factors. For this use, given that the probes have similar self consistency, other factors such as cost, robustness and longevity need to be considered (Table 1). We have chosen to use the TDP probes for field studies based on the lower energy inputs required, easier set-up, longevity and lower system cost.

Table 1. Comparison of sap flow measurement systems

Sapflow system	Accuracy	Consistency	Flexibility	Field efficiency	Longevity	System Cost
Parc TDP		✓	✓	✓	✓	✓
Tranzflo HP	✓	✓	✓		✓	
Dynagage	✓	✓				

*accuracy rating based on proximity to y = x for calibration (transpiration/ sap flow)

*consistency based on closeness of R^2 values to a perfect relationship (R^2 =1.0) for calibration

*flexibility based on applicability of the sensor design to a range of tree sizes/shapes. Dynagage collars are specific for trunk size.

*field efficiency based on ease of set up in field, power requirements, maintenance requirements. TDP probes require less set-up and have much lower power requirements.

*longevity based on potential for long-term observations on the same tree (full season or multi-season monitoring). Dynagage heaters damage the bark after 1-2 months.

*system cost - all require datalogger control. Differences in the cost of sensor/systems are significant

2. Use of TDP sap flow probes to understand and measure tree response to environmental factors

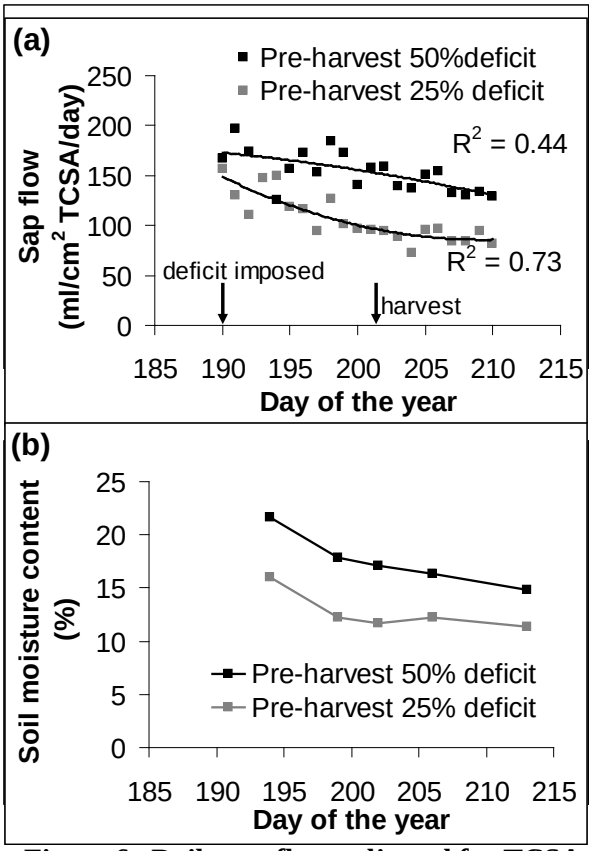

Figure 8. Effects of drought on a) sap flow and b) soil moisture in field grown Lapins/Gi.5

Graphs of sap flow measured over the day (Figs. 1 and 4) indicate that transpiration is primarily governed by the availability of light which controls stomatal opening and carbon acquisition for growth. Even in the greenhouse, where conditions are controlled, daily patterns may vary, largely due to differences in sunlight – e.g. the difference between day 83 and 84 (Fig. 1). However, other factors are also important and these are associated with the ability of the soil/plant system to support the transpiration requirements at the leaf/air interface. In the greenhouse, there was an increase in sap flow in response to increasing temperature up to 35°C (95°F) and decline thereafter (Fig. 5). This indicates that even well-watered soils may not be able to supply sufficient water to meet the high evaporative demand associated with high temperatures. A similar response can be seen in the field when estimates of evapotranspiration, adjusted for canopy development and rainfall, are compared with daily sap flow (Fig. 6). In a well-watered soil there was no increase in sap flow beyond a daily ET of around 7.0 mm (0.28 in).

The daily time course of sap flow in well-watered trees is highly responsive to a number of environmental factors (Fig. 7). In general, sap flow increased in response to increased temperature and ET. Large reductions in sap flow occurred during precipitation events on day 175, 180 and 200. This was likely caused by high relative humidity (low vapour pressure deficits) reducing transpiration requirements and low light conditions reducing stomatal conductance.

3. *Use of sap flow probes to understand and measure tree response to water management*

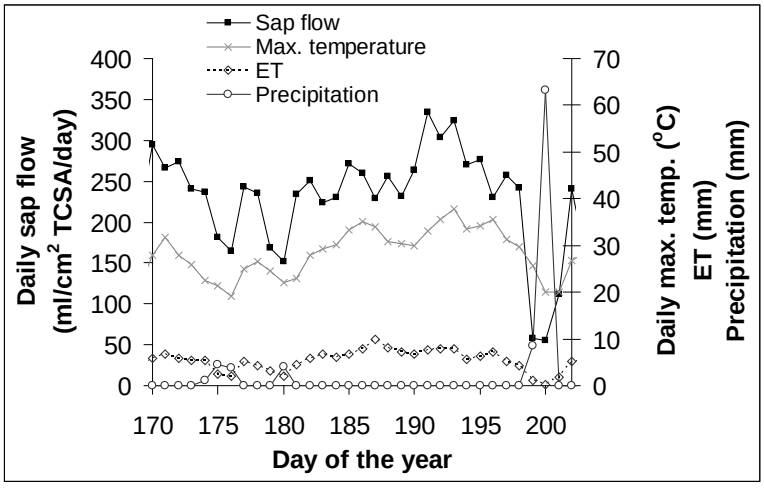

Figure 7. Sap flow as affected by air temperature, calculated ET and precipitation for well-watered Skeena/Gi.5 cherry trees at the PARC lysimeter in 2007 (mean of 4 plants)

Our initial trials examined the effects of imposed moisture deficits on sap flow in an attempt to define a protocol for integrating sap flow measurements into automated irrigation management. The sap flow signal in response to pre-harvest water deficits was quite clear in field grown Lapins/Gi.5 indicating both the timing and magnitude of the drought (Fig. 8a). This was supported by differences in soil moisture content which were evident within three days of the drought imposition in this sandy soil and were cumulative over time (Fig. 8b). The practical outcome of the relative water deficits were significantly smaller fruit (8.2 vs 9.7g) but with greater firmness (71.6 vs 70.4 durometer units) and fewer splits (0% vs 6%) for the more severely droughted trees.

In pursuit of an electronic signal that might be used to control irrigation systems, we examined daily sap flow graphs to identify potential trigger points for watering up. While these signals are quite evident visually (Figure 9), it was not possible to find a pattern that could be reliably used. There were several reasons for this. Sap flow responses to drought were not consistent in shape and varied between the early morning peak followed by a rapid reduction in flow seen for droughted trees in Fig. 9 and an overall reduction in flow with no difference in shape between well-watered and droughted trees. Consequently, a simple mathematical relationship between expected and actual sap flow to be used in a datalogger could not be determined. Similarly, relationships with environmental variables such as maximum daily temperature (Fig. 5) or ET (Fig. 6), although strong, are too variable to be used for calculations of 'expected' daily sap flow.

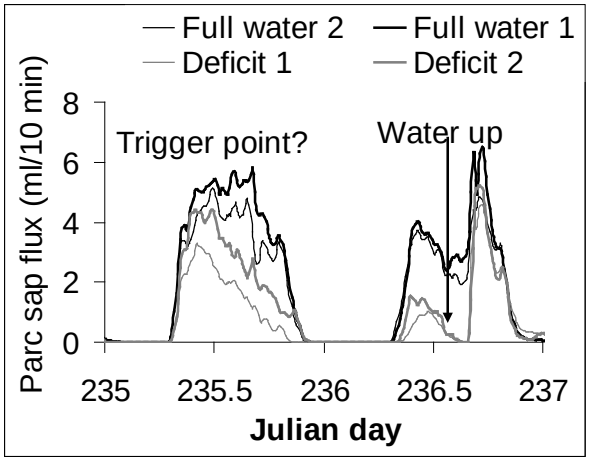

Figure 9. Response of TDP sap flow probes to severe imposed drought.

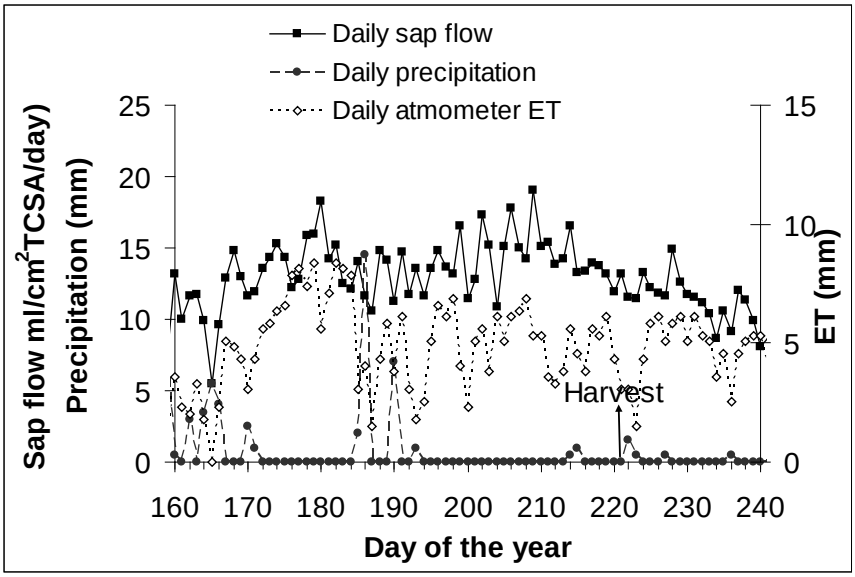

Figure 10. Daily sap flow, precipitation and atmometer ET for field grown Sweetheart/Mazzard sweet cherries. Mean of 5 trees.

The high sensitivity of the probes to instantaneous changes in environmental conditions makes them difficult to use, on a short term basis, to determine soil moisture limitations to transpiration and for automated irrigation control. However, no other method of measurement allows such long term detailed analysis of plant water relations in the field and visual examination of sap flow traces over time can yield valuable information. For example, seasonal water use patterns were identified from sap flow measured in a commercial orchard in 2006 (Fig. 10). The daily sap flow graph varied systematically regardless of ET and precipitation effects. The orchard receives micro-sprinkler irrigation on a 2-3 day cycle and this is reflected in the pattern of sap flow and hence transpiration, particularly in the 30 days before harvest. The decline in sap flow after harvest likely reflects lower stomatal conductance associated with a reduced demand for carbon once the

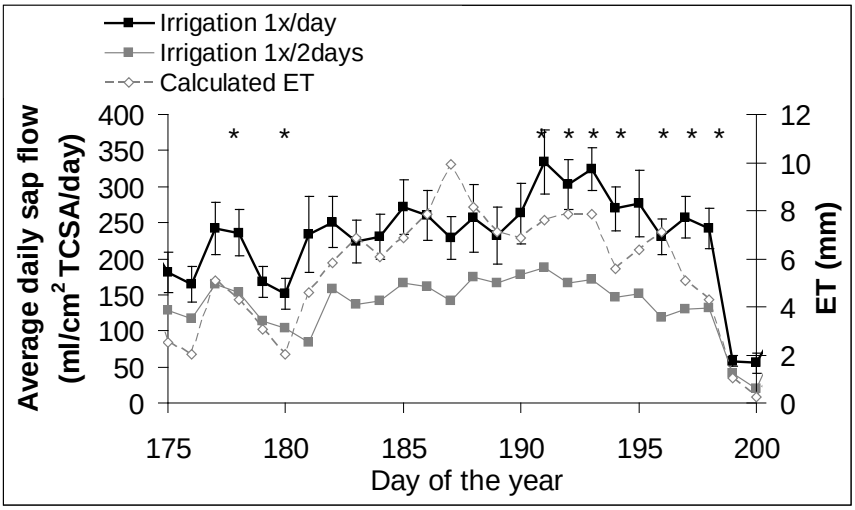

Figure 11. Sap flow in response to ET and two irrigation regimes – scheduled daily drip irrigation and the same volume of water applied every two days for well-watered Skeena/Gi.6 cherry trees at the PARC lysimeter in 2007 (mean of 4 plants).

*** sign. at p<0.05**

fruit has been removed. The implication of the relationship between sap flow and carbon acquisition before harvest is that transpiration limitations on stomatal conductance may affect fruit development and quality as noted earlier for field grown Lapins/Gi.6. These findings suggest that a change in irrigation practice may be warranted and potentially lead to improved fruit size (average fruit weight = 9.8 g).

This type of analysis is useful where irrigation scheduling to meet evaporative demand is not being practiced.

Sap flow patterns can also be used to assess the impacts of new management practices on tree performance. In an experiment at the PARC lysimeter the effect of two irrigation strategies on Skeena/Gi.6 is being assessed. Irrigation was delivered through four 4L/hr (1 gal/hr) drip emitters per tree either daily or once every two days and scheduled to meet evaporative demand. The trees receiving water once every two days had lower sap flow that trees receiving daily irrigation (Fig. 11). The differences in sap flow, between the treatments increased as ET increased (days180-199) indicating that daily irrigation helped to overcome soil moisture limitations to transpiration and potentially stomatal conductance, carbon acquisition and fruit water status. These trees will be cropped for the first time next season. Other management practices that are currently under investigation using sap flow gauges in cherries and other crops include differential crop loads, partial root zone drying, mulching and foliar spray programs.

Significance to the industry and economic significance

Needle type probes such as the PARC-TDP probes which are inserted into the xylem of the tree can provide a continuous record of tree sap flow over multiple seasons. Sap flow measured in this way is an estimate of relative transpiration rates within an individual day or from day to day. The probes are exceedingly sensitive to small changes in air temperature, relative humidity and soil moisture availability. Because transpiration rates are closely linked to stomatal conductance, carbon acquisition and plant water status, factors which limit transpiration may also affect fruit growth and water status. We have identified upper limits for transpiration based on ET (7 mm/day) and temperature (95° F ; 35° C). Sap flow probes may also be used to assess overall tree performance in response to a range of management practices. Experimental water deficits imposed 30 days before harvest caused reduced transpiration and associated reductions in fruit size. In a commercial orchard, sap flow measurements indicated that transpiration was reduced in synchrony with the irrigation cycle, with potential detrimental effects on fruit size. In another trial, with young non-fruiting trees, sap flow was lower when irrigation was applied on a two day rather than a daily cycle.

The potential economic significance of this type of knowledge relates to the ability to identify management practices which may enhance or limit the production of high quality fruit. We have identified irrigation management factors which limit transpiration and fruit growth. Assessment of any current or new management practices with this technique would likely prove beneficial. The major advantage of the technique is continuous monitoring which enables the timing and magnitude of the effects of either environmental or management factors on plant performance to be identified.

Fall N supply and spring remobilization

Seasonal pattern of N remobilization for "Lapins" sweet cherry on Gisela 5 rootstock.

Leaf N concentration of new-year, mid-shoot extension leaves of sweet cherry declines very slowly after harvest until the end of September, as indicated by two sets of trees receiving contrasting N treatments over a two year period (Fig. 12). However for both N treatments there was a rapid decline in leaf N concentration during the month of October, at a rate averaging about 10% (of the

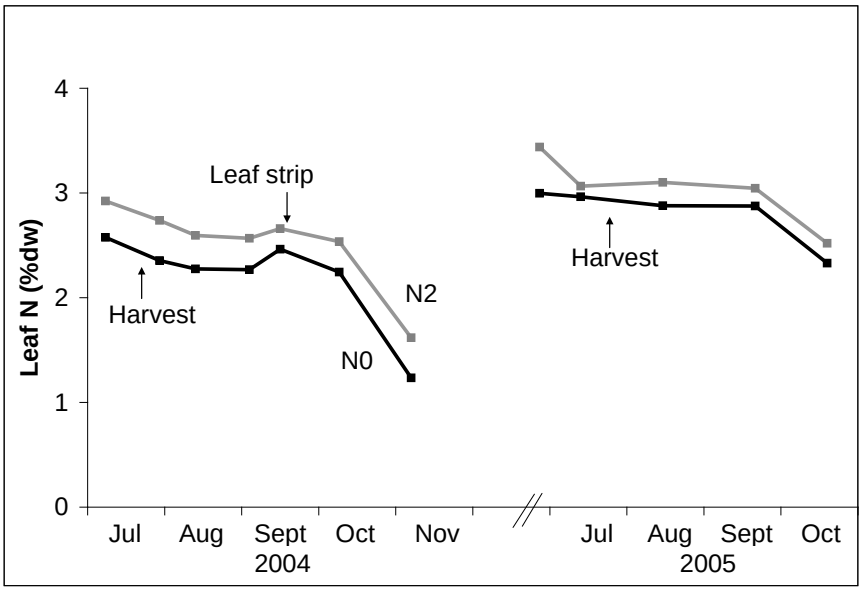

Figure 12. Effect of N application rate and leaf stripping on leaf N concentration of Lapins/Gi.5 cherry trees.

original concentration) per week, which represents the remobilization of nitrogen from leaves to woody storage prior to normal leaf fall. Normally leaf fall is usually completed by December in this region, ensuring sufficient time for the normal processes of nitrogen recycling. This normal process is critical to insure adequate N to support good tree growth the next spring.

Implications of disruption of the normal N remobilization processes

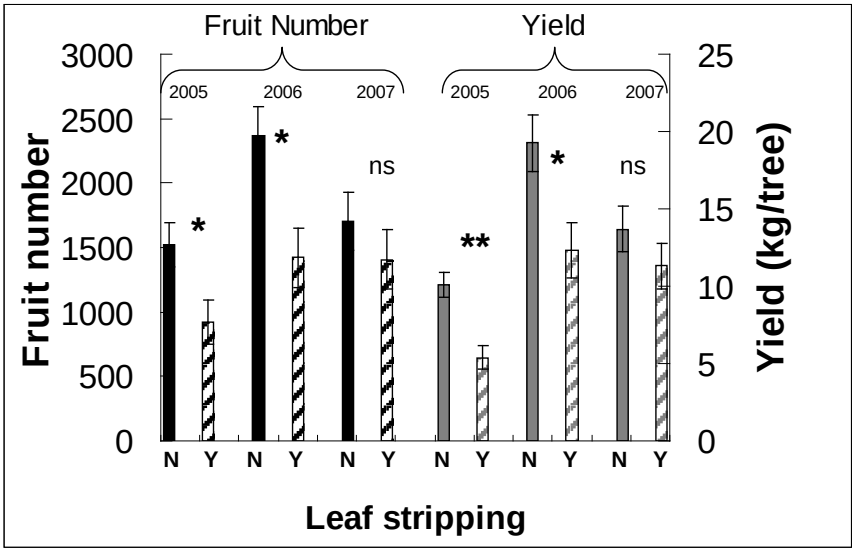

Figure 13. Effect of leaf removal on Sept. 17th, 2005 on fruit number and yield of Lapins/G.5, 2005-2007.

*,**,ns Significant at $p<0.05$, 0.01 and not significant respectively.

In mid September 2004, the normal remobilization cycle was disrupted by imposing a leaf stripping treatment which was enacted to prevent the movement of N from leaves back into storage

(Fig. 12). The importance of effects resulting from disruption of the normal N remobilization cycle was indicated by its pronounced effect on tree yield performance in subsequent years (Fig.13). Yield was significantly decreased in 2005 (46.5%) and 2006 (35.9%). By the third year following the treatment (2007), the effect was no longer statistically significant, although yield was still lower. The yield reduction occurred because of significant reduction in fruit number (2005-2006, Fig. 13) rather than average fruit size which was unaffected (data not shown).

Significance to the industry and economic significance

Disruption of the normal N remobilization cycle for young sweet cherry trees on dwarfing rootstocks, such as these "Lapins" on Gi 5 rootstock, can have large, negative effects on yield performance for several growing seasons. Since fruit size was not statistically affected, the economic impact directly relates to yield reduction and would have decreased income for an experimental block by 46.5 % and 35.9% one and two years, respectively, after the causal event. Trees seem to have the capacity to recover from this stress with normal fertilization and management practices by the third year.

Although the treatment represents an extreme treatment (removal of all leaves), the results suggest that factors leading to premature defoliation of leaves, including insect damage and early freezes could seriously depress fruit production for several years. As the month of October was a critical time for cherry trees to replenish N storage supplies by removing N from leaves, detrimental effects on leaf function during this important time period are particularly serious. It would be prudent for growers with orchards so affected to consider supplementary foliar sprays in the years immediately following the stress event. For example, early spring (in March to dormant trunks) and post harvest urea sprays can augment depleted N storage reserves, as has been previously demonstrated for apple.

FINAL PROJECT REPORT
WTFRC Project Number: CH-06-601

Project Title: Causes and prevention of pistil doubling

PI:	M. Whiting	**Co-PI(2):**	R. Martin
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Cooperators: Del Feigal, AFC; Kent Waliser, Sagemoor Farms; Wild Willow Orchards; John Ferguson and Julie Tarara, USDA-ARS; Bhaskar Bondada, WSU Tri-cities

Other funding Sources

Agency Name: BASF
Amount awarded: $7,000
Notes: additional funding to support doubling research

Total Project Funding:

Budget History:

Item	**Year 1:** 2006	**Year 2:** 2007	
Salaries	18,310	19,508	
Benefits	1,738	1,844	
Wages	5,300	6,000	
Benefits	530	690	
Equipment	1,500	1,500	
Supplies	1,500	1,500	
Travel	1,500	2,000	
Miscellaneous			
Total	30,378	33,042	

OBJECTIVES:

For early-, mid-, and late-season sweet cherry varieties:

1. Elucidate the seasonal trends in flower bud initiation & organ differentiation

2. Determine seasonal susceptibility to pistil doubling

3. Determine seasonal relationship between tissue and air temperature and pistil doubling

4. Compare efficacy of practical means for reducing pistil doubling

SIGNIFICANT FINDINGS:

- cultivars are asynchronous in floral organ differentiation
- early-maturing cultivars exhibit advanced differentiation vs. late-maturing cultivars
- variability in organ differentiation among flowers exists within a tree, spur, and bud
- the system for manipulating tissue temperature *in situ* was able to heat and cool developing fruit buds by ± 5°C from untreated
- both tissue temperature and timing are important factors in pistil doubling
- in 2005, 'Bing' flowers were more susceptible to doubling in late July vs. early July and early August
- buds kept below 34.3 C (ca. 94 F) throughout the 2005 and 2006 trials did not exhibit doubling
- over-tree evaporative cooling shows great potential for moderating tissue temperature (ca. 8.5 F reduction) and reducing pistil doubling
- under-tree microsprinklers are ineffective at reducing canopy tissue temperature
- shade and Surround® are moderately effective at reducing canopy temperature (ca. 3.5 to 4 F reduction)
- in grower cooperator trials, both over-tree evaporative cooling and Surround reflective treatments significantly reduced multiple pistils by about half

RESULTS AND DISCUSSION:

Floral bud initiation and organ differentiation

We documented in 2006 and 2007 the seasonal progression in floral organ differentiation for Chelan, Tieton, Bing, Skeena, and Sweetheart via scanning electron microscopy. We did not observe significant differences among these cultivars for the date of floral bud induction. We observed the initiation of reproductive buds in leaf axils during the first half of May, irrespective of cultivar (data not shown).

In contrast, we observed significant differences among cultivars in the initiation and seasonal progression of floral organ differentiation (e.g., sepals, pistil, stamens). Samples were collected at approximately 3-week intervals between late May and November. Our earliest samples reveal very little difference in organ differentiation among cultivars and buds were comprised primarily of rounded meristems with two to four bracts (images not shown). June samples too revealed buds with largely undifferentiated meristems. By mid-late July however, floral bud initiation was apparent, particularly in Chelan (Appendix A). A pentagonal whorl of sepal primordia was visible in Chelan buds on 31 July. In contrast, on the same sample date buds of other cultivars were less advanced, with Sweetheart exhibiting the least development (no floral primordia). Sweetheart did not exhibit the similar whorl of sepals until the middle of August – more than two weeks later. To our knowledge, this is the first report of asynchrony in sweet cherry flower bud development and organ

differentiation. Interestingly, organ differentiation was related to fruit harvest timing (i.e., Chelan the earliest, Sweetheart the latest), though not as discrepant. This suggests that apparent resistance or susceptibility to MP may be related, in part to variability in the stage of organ differentiation. From our studies of critical timings and temperatures for multiple pistils (MP) (see discussion below), it appears that Bing buds were most susceptible during late July and early August. At that stage, distinct floral meristems are present (Figure 1) though little organ differentiation has occurred. It should be noted that Tieton flower bud differentiation progresses similarly, or slightly advanced, to that of Bing and yet Tieton is significantly more susceptible to MP. This also suggests a strong genetic component to susceptibility/resistance to MP.

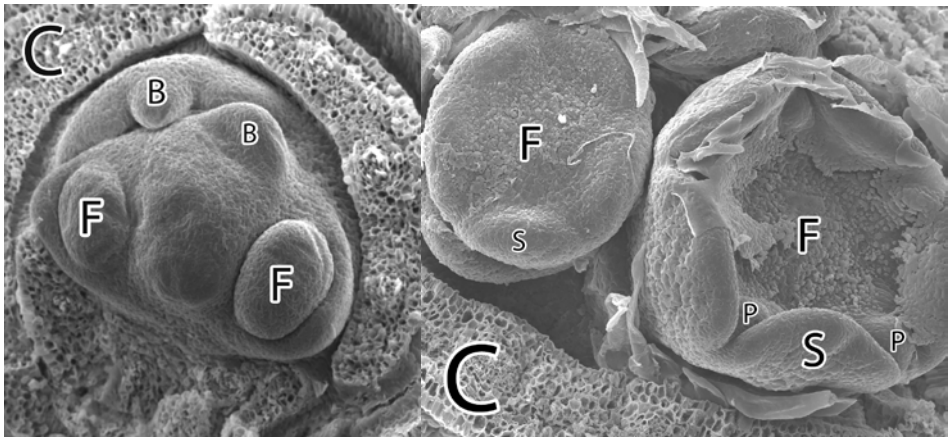


Figure 1. Scanning electron microscope images of Bing sweet cherry flower buds at a stage of high susceptibility to multiple pistils. Bud in left image collected on 31 July (1464 GDU), on right collected 17 August (1750 GDU). F = floral meristem; S = sepal; P = petal; B = bract.

Our histological studies identified variability in the stage of organ differentiation among spurs in a tree, among buds on a spur, and among individual floral meristems in a bud. For example, in the image on the right of Fig. 1, one bud has more developed sepal primordia and is at the beginning stages of petal differentiation whereas the other bud has only begun sepal differentiation. We estimate the floral meristem on the left to be approximately 1 week behind the other. To better characterize the variability among floral meristems in a tree, we initiated an additional trial in 2007 – entire spurs were harvested and each bud is being evaluated for meristem differentiation (i.e., from the oldest to youngest). In addition, we collected spurs from the youngest branches (i.e., one-year-old) and older branches (i.e., 4+ years old) and will compare stages of floral meristem differentiation. Our preliminary results on Bing show advanced differentiation for buds from older wood vs. those from younger wood. We observed a similar pattern for flower buds within a spur (i.e., oldest were further advanced). This variability in the stage of organ differentiation may explain why MP is variable within a spur/tree.

Critical timing and temperatures

This work utilized a novel heating/cooling system to manipulate tissue temperature at ca. 2-week intervals throughout bud differentiation. The heating/cooling apparatus worked well and was able to increase and reduce bud tissue temperature by 5°C (ca. 9°F) from ambient throughout the day (data not shown). These experiments were designed to elucidate the seasonal variability in susceptibility to multiple pistils. Knowing this, we will be able to effectively target preventative strategies.

In 2006, natural MP from 2005 conditions was about 4.5% for Bing. Our trials on Bing in 2005/2006 (heated in 2005 and assessed in 2006) showed that developing flower buds were

susceptible to doubling between 18 and 25 of July (i.e., about one month after harvest, 1079 to 1312 GDU base 50F). Flowers within buds artificially heated during this period exhibited 11% MP (ca. 6.5% more than control) in 2006. Buds were more susceptible between 2 and 14 of August (1435 to 1723 GDU) – we recorded 16% MP (ca. 11% more than control) in response to artificial heating. Timing (i.e., stage of bud differentiation) appears to have an effect because we recorded more MP from heat treatments in early August than from heat treatments in late July despite exposure to similar temperature regimes (58 and 76 $^{o}C \cdot HR$, respectively). However, temperatures were higher during the latter half of July and early August than they were during the earliest interval (July 5 – 14). It is not known how much doubling would have occurred in the early July timing in response to similar high temperatures. What is clear, is the role of high temperature – we did not record a single double pistil from cooled spurs, irrespective of timing. In addition, flowers that were cooler than ca. 37^{o}C (99^{o}F) throughout our trial period did not have doubled pistils – we only observed doubling, albeit variable (0 – 60%), when tissue temperatures exceeded 37^{o}C (data not shown). The variability in doubling above 37^{o}C also reinforces the need to analyze time-temperature threshold rather than a particular temperature alone.

The incidence of MP in 2007 was significantly lower than in the previous year. We recorded less than 2% MP in untreated Bing spurs despite warmer temperatures during key stages of bud differentiation (i.e., late July and August) in 2006 compared with 2005. Indeed, industry-wide, growers observed much less MP in 2007 than was anticipated. Moreover, our heated spurs did not exhibit MP in 2007 as we had expected, based on our results from 2006. Percent flowers exhibiting MP in 2007 never exceeded about 6% and from only two of the five heat treatments in 2006 did we observe an increase in MP vs. the control. Buds heated during 16 Aug to 25 Aug and from 27 Aug to 7 September had ca. 2.5% and 4% more MP than the control, respectively (Figure 2). Despite applying the greatest amount of heat to differentiating buds at a susceptible stage (157 $^{o}C \cdot HR$ in late July, 1230 to 1477 GDU; based on our observations in 2006 from 2005 heat treatments), we were unable to induce MP in 2006. Again, in the subsequent heat treatment (early August), we were unable to induce MP. In contrast, by applying a similar heat treatment in 2005, we induced significant (ca. 11%) doubling. Overall, our data support the general observation across the industry in 2007– that there were far fewer MP than expected. Our hypothesis is that a period of unusually high temperature in late June and early July acclimated the tissue to high temperature stress at a period when differentiating buds were not susceptible to MP. We initiated a trial in 2007 designed to evaluate the effect of a heat treatment applied in late June on incidence of MP (Figure 3). In late June to early July, buds were heated (to mimic the natural heat wave in 2006) or cooled (to avoid the potential natural heat stress). Buds were subsequently heated or cooled in late July to early August to induce or prevent MP, respectively. We will assess MP in dormant flower buds this winter and are particularly interested in the difference between those that received two heat applications vs. those cooled and then heated. The effect of hot temperatures during early stages of bud differentiation on the potential for MP in the subsequent season is an area deserving further investigation, particularly for developing models for predicting susceptibility to MP. Interestingly, we observed an increase, albeit minor, in MP from heat treatments in late August and early September (Fig. 2).

Interestingly, from both 2005 and 2006 experiments, buds treated with cool air for a single interval (e.g., 10 to 14 days) exhibited no multiple pistils, regardless of the timing of the application of cool air. This suggests that MP may be reduced by applying cooling treatments and, furthermore, that precise timing of cooling treatments may not be critical.

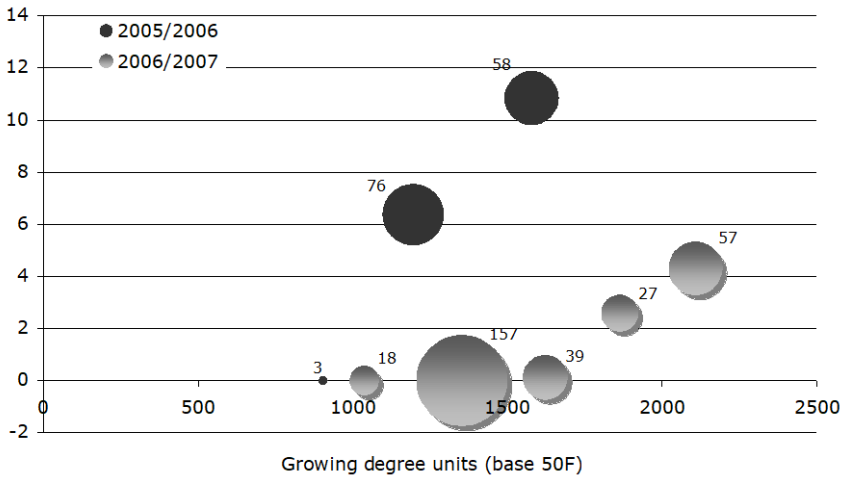


Figure 2. Relationship between timing of heat treatment and effect on multiple pistils in the subsequent season (% greater than for control). Each point is the mean of 8 replicate spurs on 2-year-old wood. The size of the circle is proportional to the hours accumulated at 99F (37C) during the heat treatment ($^{o}C \cdot HR$ indicated beside each circle). Natural (control) multiple pistil incidence was 4.6% in 2006 and 2.0% in 2007.

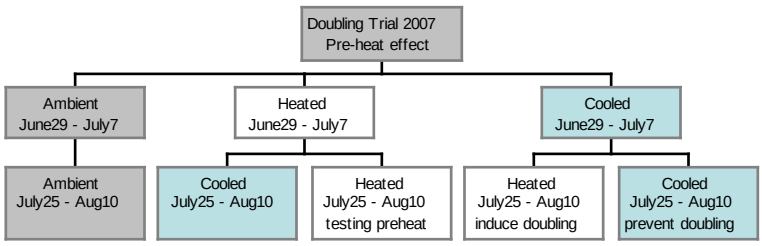


Figure 3. Flow chart outlining trial initiated in 2007 to investigate the effects of high temperature on susceptibility to multiple pistils.

Practical strategies for reducing multiple pistils

In 2006 we initiated several trials with grower cooperators to assess the efficacy of several methods for reducing multiple pistils. In a trial in a 7th leaf Tieton/Gisela 5 orchard, we compared applications of the kaolin reflective Surround® with over-tree evaporative cooling and shading (ca. 20% shade). We observed significant reductions in multiple pistils with each preventative treatment (Fig. 4). Surround, evaporative cooling, and shade were similarly effective, reducing the incidence of multiple pistils by about 45% on a whole-tree level. We also selected one limb per tree (from similar height/orientation in canopy) and counted multiple pistils at bloom and again at harvest. Our data suggest that assessing multiple pistils at bloom may accurately represent final incidence of multiple pistils (on that limb) since we observed little change in multiple pistils between bloom and harvest (Fig. 4). This suggests that fruit with multiple pistils are no more or less likely to drop throughout development than normal fruit. We also observed significantly higher MP (ca. 20% more) on selected limbs vs. the entire tree. Moreover, variability in MP among limbs was much greater than that among trees. These results demonstrate how variable MP can be within a canopy and suggest that further research should continue to assess doubling on a whole-tree basis at harvest. Variability in MP within a tree is likely related to differences in spur microclimate, particularly with respect to light

interception and tissue temperature. The limbs we analyzed in detail were in the upper 1/3 of the canopy and therefore, a high light environment. Potential preventative strategies may be prudently focused on the upper canopy regions where light interception and temperature are relatively high.

Incidence of MP on a whole-tree basis was variable, ranging between 8% and 42% (data not shown). This variability was not related to tree vigor (Fig. 5). Susceptibility to MP may be related to characteristics other than the overall vigor of the tree such as limb and leaf orientation, light distribution and interception, etc. Previous research in Japan had ruled out any role of water stress in MP but this has yet to be investigated for conditions and cultivars grown in the PNW.

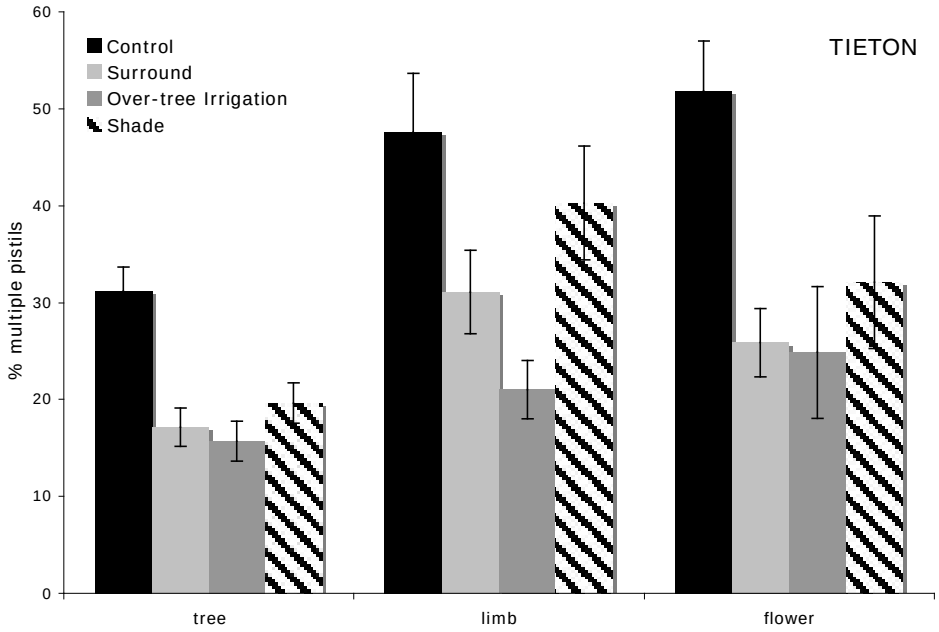


Figure 4. Percent multiple pistils on a whole-tree and limb level (at harvest and full bloom). Assessed on 7th leaf 'Tieton'/'Gisela®5' trees. Each bar is the mean of 8 replications ± standard error.

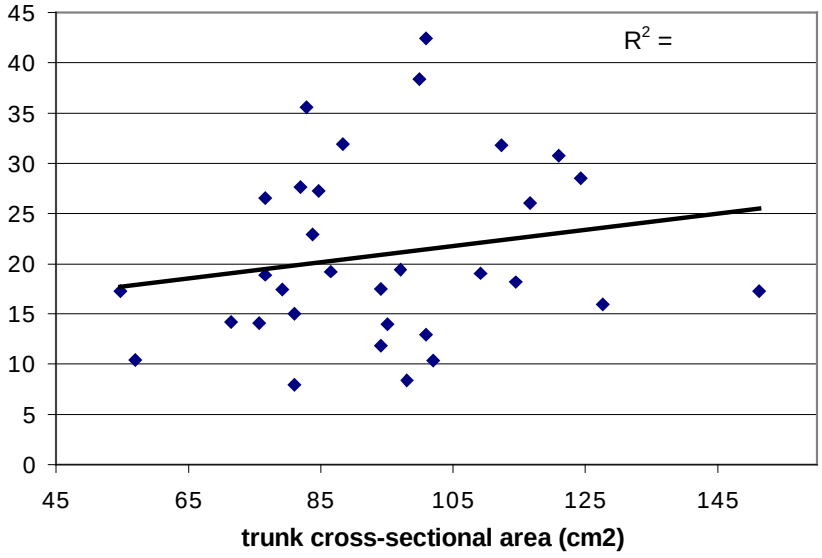


Figure 5. Percent multiple pistils on a whole-tree level in relation to tree vigor (trunk cross sectional area). Assessed on 7th leaf 'Tieton'/'Gisela®5' trees.

In trials on other cultivars, incidence of MP was significantly less than it was for Tieton. In mature Bing and Chelan orchards, we recorded only 4% and 1% MP, respectively on a whole-tree level. Regardless, each preventative treatment we evaluated reduced MP (Fig. 6). In the Bing orchard, both evaporative cooling and Surround treatments reduced MP by about half. In the Chelan trial, Surround and Raynox reduced MP by about 30% and 60%, respectively. Again, our data highlight the need to assess MP on a whole-tree basis – incidence on selected limbs was highly variable and even contradictory to whole-tree results.

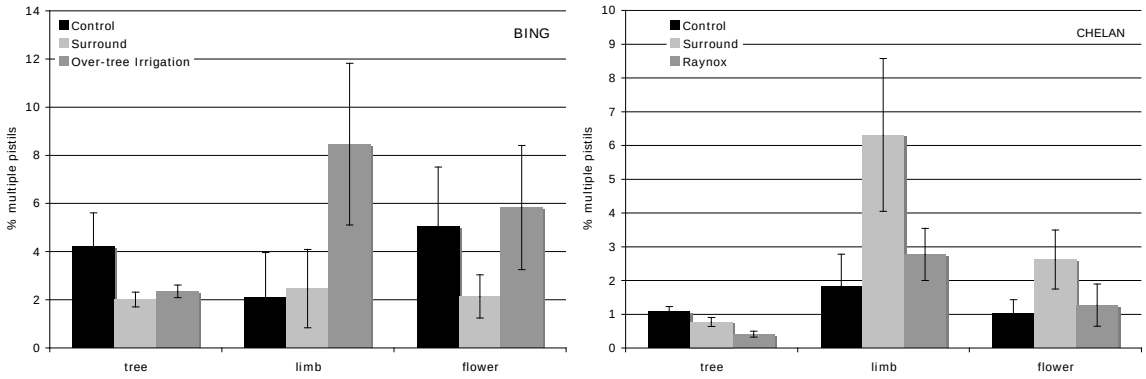


Figure 6. Percent multiple pistils on a whole-tree and limb level (at harvest and full bloom). Assessed on mature 'Bing'/Mazzard and 'Chelan'/Mazzard trees. Each bar is the mean of 4 or 8 replications ± standard error for Bing and Chelan, respectively.

PROJECT OUTREACH:

Presentations:

WTFRC/OSCC NW cherry research review. Richland, WA, November 16, 2006. "Causes and prevention of pistil doubling". Poster presentation. Attendance: ca. 75

Annual Meeting of WA Hort. Assoc. Yakima, WA, December 4-6, 2006. "Causes and prevention of pistil doubling". Poster presentation. Attendance: ca. 50

Cherry Institute Meeting, Yakima WA Jan. 12, 2007. "Blame it on the sun: Preliminary results from research into the causes and prevention of pistil doubling" Attendance: ca. 450

Annual grower meeting. Sambado Packing/Primavera Fruit, Linden CA. March 5, 2007. "Causes and prevention of multiple pistils and deep suture". Attendance: ca. 100

WSU-IAREC Annual Cherry Field Day. June 12, 2007. "Update on pistil doubling research" Attendance: ca. 200

Sunnyside Rotary Club meeting, Sunnyside WA, 22 August. "Research advances in the WSU sweet cherry program". Attendance: ca. 30

Annual Meeting of WA Hort. Assoc. Wenatchee, WA, December 3-5, 2007. "Practical strategies for reducing multiple pistils in sweet cherry". (Poster).

Cherry Institute Meeting, Yakima WA Jan. 11. 2008. "Research update on causes and prevention of multiple pistils"

***Articles in popular press*:**
Hansen, M. 2006. “The causes and cures of doubling”. Good Fruit Grower. Vol. 57

Hansen, M. 2006. “Research aims to help growers prevent doubling”. Good Fruit Grower. Vol. 57 (10)

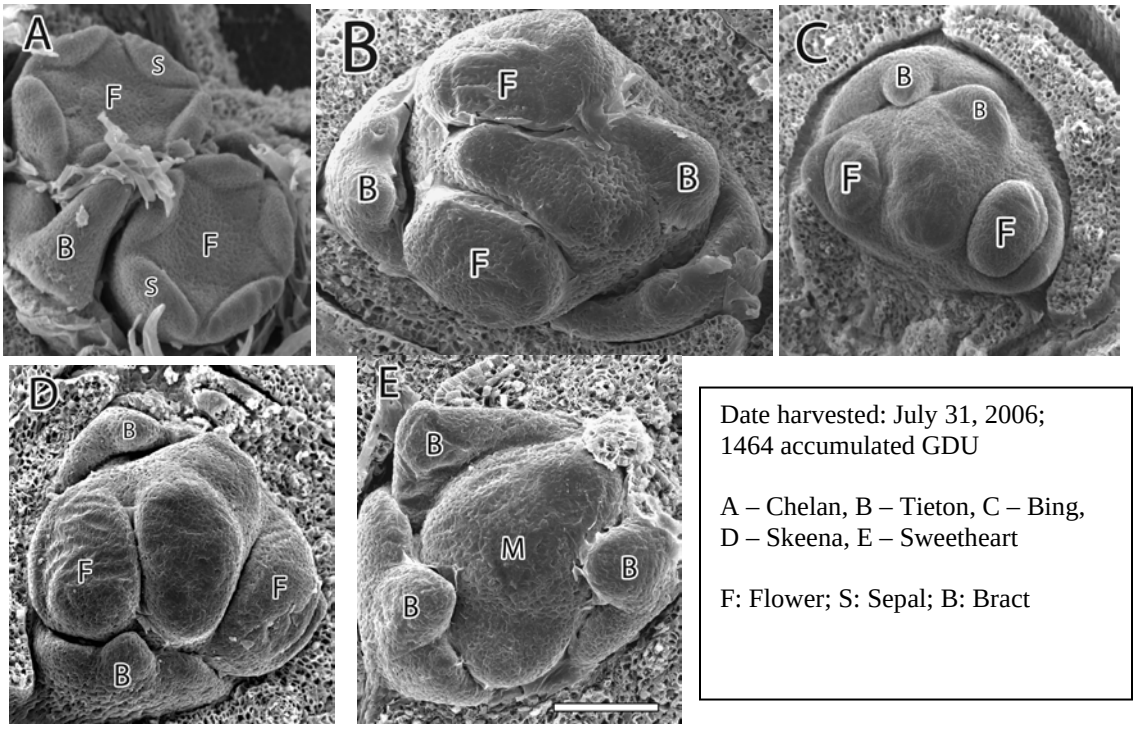
Martin, R. and M. Whiting. 2008. “Practical strategies for reducing sweet cherry pistil doubling”. Good Fruit Grower. Vol 58. Diseases and disorders issue. 15 Feb. (*in preparation*)

***Peer-reviewed manuscripts in preparation*:**
Martin, R. and M. Whiting. 2008. Asynchrony in sweet cherry floral organ differentiation among several cultivars. J. Am. Soc. Hort. Sci.

Martin, R. and M. Whiting. 2008. Susceptibility of ‘Bing’ sweet cherry to polycarpy varies seasonally and with tissue temperature. J. Am. Soc. Hort. Sci.

Martin, R. and M. Whiting. 2008. Practical strategies for reducing multiple pistils in sweet cherry. HortTechnol.

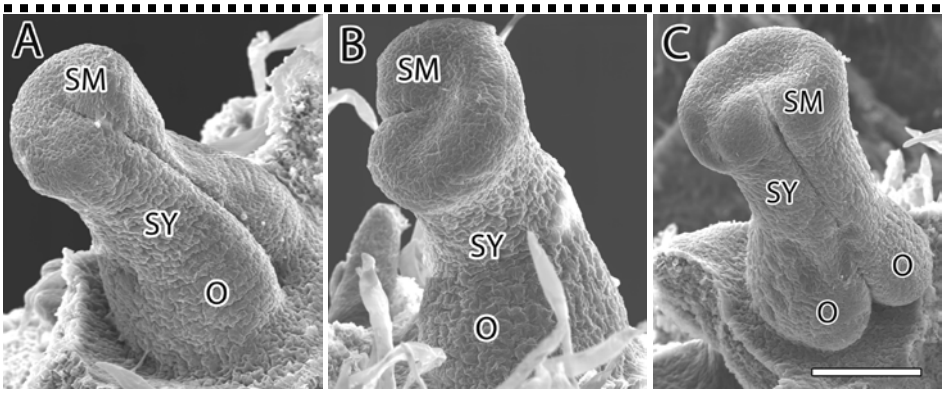
APPENDIX A. Scanning electron images of differentiating cherry flower buds.

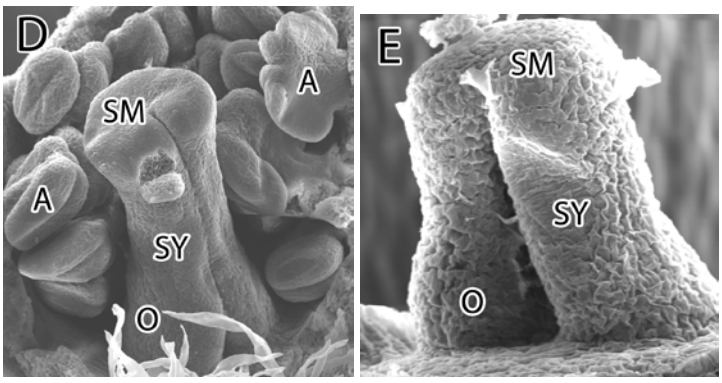


Date harvested: July 31, 2006;
1464 accumulated GDU

A – Chelan, B – Tieton, C – Bing,
D – Skeena, E – Sweetheart

F: Flower; S: Sepal; B: Bract





Date harvested: October 7, 2006;
2446 accumulated GDU

A – Chelan, B – Tieton, C – Bing,
D – Skeena, E – Sweetheart

SM: stigma; SY: style; O: ovary;
A: anther

FINAL PROJECT REPORT
WTFRC Project Number: CH-05-503

Project Title: MSU's sweet cherry dwarfing rootstocks

PI:	Amy Iezzoni	**Co-PI(2):**	Matt Whiting
Organization:	MSU	**Organization:**	WSU
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Address 2:	MSU	**Address 2:**	WSU
City:	East Lansing	**City:**	Prosser
State/Province/Zip:	MI 48864	**State/Province/Zip:**	WA 99350

Other funding Sources

Agency Name:
Amount awarded:
Notes:

Total Project Funding: $ 52,010

Budget History:

Item	**Year 1:** 2005	**Year 2:** 2006	**Year 3:** 2007
Salaries	$4,725	$4,867	$6,343
Benefits	2,183	2,351	3,191
Wages (MSU)	1,500	3,000	1,500
Wages (WSU)	2,000	2,000	2,000
Benefits			
Equipment			
Supplies	400	1,500	600
Travel	1,500	2,500	2,500
Tree & Freight cost	100	500	750
Plot cost at MSU	1,000	1,000	1,000
Greenhouse cost		3,000	
Miscellaneous			
Total	$13,408	$20,718	$17,884

Objective:

Identify MSU rootstock selections that may have commercial potential as dwarfing precocious rootstocks for sweet cherry.

Specific Objectives:

1. Complete the planting of the rootstock candidates at the WSU-Prosser and MSU-Clarksville test sites.

2. Identify the most promising rootstock candidates by evaluating tree health, precocity, trunk cross-sectional area, flower density, crop load, fruiting habit and fruit size.

3. Vegetatively propagate the most promising rootstock selections to provide grafted trees for advanced trials at multiple test locations.

Significant findings:

- The establishment of the first test plots was completed in 2004 with 71 and 41 MSU rootstock candidates planted at MSU-Clarksville and WSU-Prosser, respectively.

- In 2006, 28 of the MSU rootstock selections were chosen for advanced testing based on evaluations of tree health and yield potential.

- Quarantine restrictions were met to permit shipment of these 28 rootstock candidates to nurseries in Washington and California to make trees for the next set of trials.

- In 2006, ~ 4,300 cuttings from these 28 selections were rooted in Michigan. A total of 2,080 rooted cuttings were obtained. These cuttings were shipped to Willow Drive Nursery in March 2007 and planting in one of their nursery rows spring 2007. In August, 1,493 of the cuttings were available for budding.

- In 2006, we reached an agreement with Duarte Nursery for liner increase and eventual tree production. Budwood from each of the 28 rootstock selections was sent to Duarte Nursery and subsequently established in culture.

- Upon transfer to the nurseries, the rootstocks were given Michigan county code names to reduce the likely hood of identity mix ups at the commercial nurseries and throughout the testing process.

- In 2007, the 28 MSU rootstock candidates were narrowed down to 11 selections for advanced testing. See Results and Discussion for a review of these 11 rootstocks.

- DNA markers were identified that can discriminate among the 11 MSU rootstock selections. These diagnostic markers were used to confirm the identity of the rootstock cultures at Duarte Nurseries tissue culture lab (Dry Creek Laboratory) and confirm the 11 MSU rootstock selections in the test plot at MSU-Clarksville.

- Plans for the next phase of testing were developed in collaboration with Matt Whiting and Tom Auvil. This included scion selection and Washington test site selection.

- Tree requests were communicated to Willow Drive Nursery and Duarte Nursery and we are on schedule for planting in spring 2009.

Results and Discussion

Test plot establishment**:**

The rootstock evaluation plot at MSU-Clarksville has 30 more rootstock selections under test than the WSU-Prosser plot. This occurred for two reasons. For the initial planting in 2001, all the trees were planted in Michigan and not split between MSU and WSU as the leadership for the cherry position at WSU was uncertain at that time. In 2004, we were able to add more trees to the MSU-Clarksville plot as these trees were grown at Hilltop Nurseries in Hartford, Michigan, and we personally participated in plant care. Unfortunately quarantine restrictions did not permit us to ship any of the finished trees to Washington. Therefore, the following six advanced selections have only been tested in Michigan: Lake, Iron, Clinton, Cass, Clare and Crawford. Lake and Iron were planted in 2001 and the other four selections were planted in 2004.

The MSU rootstock selections:

GI6 was planted as a rootstock control in 2001 and 2002. Four of the seven MSU rootstock candidates selected for these advanced trials, and planted in 2001 or 2002, confer to the scion lower tree vigor than GI6 (Figure 1). These four rootstocks are Iron, Lake, King and Garfield, and the reduced vigor is apparent from both a reduction in trunk cross-sectional area and lateral and terminal shoot growth. Of these four rootstock selections, Lake has the highest spur density and will likely over-crop with a resulting decrease in fruit size if not managed properly. However, as size reduction is critical to improve harvest efficiency, we will continue to test this rootstock. This potential pit-fall was taken into consideration in the proposed testing strategy (see below). As Iron, King and Garfield, had less fruiting spurs than GI6, crop load management on these small trees may be less challenging. Lincoln, Glen, and Kent, have vigor comparable or higher than GI6 (e.g. Kent); yet, they also appear to induce fewer spurs compared to GI6. However, due to potential over-cropping challenges with self-fertile cultivars we included them in the next testing phase as they exhibited other desirable attributes such as wider branch angles compared to GI6. Kent in particular appears to produce trees with excellent branch angles.

In 2007, there was a spring freeze in Michigan that effectively thinned the flowers. This gave us an opportunity to evaluate fruit size potential without the confounding influence of high crop loads. All the MSU rootstocks selected from the 2001 and 2002 plantings had mean fruit sizes equivalent to or larger than that for trees on GI6, except for Lincoln. However, as the fruit size for Lincoln was significantly greater than that for GI6 in 2006, this selection was still included but for more limited testing (see below). In particular, the fruit sizes from the trees on Garfield, Kent, and Iron have consistently been larger than the fruit from trees on GI6.

Four of the selected rootstocks were only planted in 2004; therefore, limited data is available on their performance. However, Crawford, Clinton, and Cass clearly impart excellent precocity to the scion. Clare does not promote as early fruiting as the other three selections; however, the trunk cross sectional area is extremely small suggesting that it may be a very dwarfing rootstock. Therefore, we will include Clare in more limited trials (see below). Crawford will also only be included in limited

trials (see below) as the mean fruit size was less than that for Clinton and Cass, both of which exhibited excellent scion fruit size.

Liner increase and budding:

To move forward most efficiently and expeditiously with rootstock evaluation and eventual commercialization of any promising selections, it was important to assure that we could generate a sufficient number of uniform rootstock liners. In 2006 we vegetatively propagated the rootstocks in Michigan (Fig. 2); however, the number of liners obtained was still way below that needed for the rootstock trials in the PNW. Therefore, we explored the possibility of having the liners produced by a commercial company. We were able to reach an agreement with Duarte Nursery whereby they would produce liners and eventually trees for the rootstock testing phase. Duarte's Nursery has a tissue culture lab that puts each rootstock into shoot culture and therefore liner number can be ramped up as needed. In addition, they make their trees by budding onto liners that are in pots in the greenhouse, therefore providing very uniform plant material. In addition, having stock plants of the advanced rootstocks at Duarte's Nursery provides a "back-up" mother block to assure that we have access to virus-clean rootstock material that can be sent to any region of the U.S.

In discussions with John Duarte and Javier Castillon (Director of Research, Dry Creek Laboratory), all the 11 selections are doing very well in culture and they anticipate no problems in meeting the liner needs. This result is not surprising as Dry Creek Lab specializes in fruit micropropagation, including cherry, and the MSU selections were pre-selected for their rooting potential.

DNA fingerprinting:

Avoiding clonal mix-ups among different rootstock selections is extremely challenging as the rootstock plant material is below ground. Therefore in 2006 we developed and implemented a DNA fingerprinting strategy to "barcode" all 11 rootstock candidates and use this "barcode" to check clonal identity at critical stages.

We identified four PCR primer pairs that exhibited sufficient polymorphisms in fragment size to discriminate among the 11 rootstock candidates. These four primer pairs are PceGA59, PMS40, PMS67 and the *S*-locus RNase. For example, use of the *S*-locus RNase primer pair is able to distinguish among the majority of the rootstock candidates (Figure 3). With the addition of data from the other three primer pairs, the identity of each of the 11 rootstocks can be easily verified.

As Dry Creek Laboratory is currently increasing the rootstock liners to produce test trees, we requested and received culture tubes from Dry Creek Laboratory so we could do DNA fingerprinting to verify the identity of these cultures. No mix-ups were identified. We propose to continue this quality control fingerprinting at critical stages within the rootstock program, e.g. liner increase, budding, and even verification of planted trees using occasional sucker shoots. In addition, to be 100% certain about identity, we are fingerprinting the test trees of the 11 selections in the MSU-Clarksville plot. This is done using occasional sucker shoots. The MSU-Clarksville plot was purposefully never sprayed with Round-up so that we would have occasional suckers for rootstock verification.

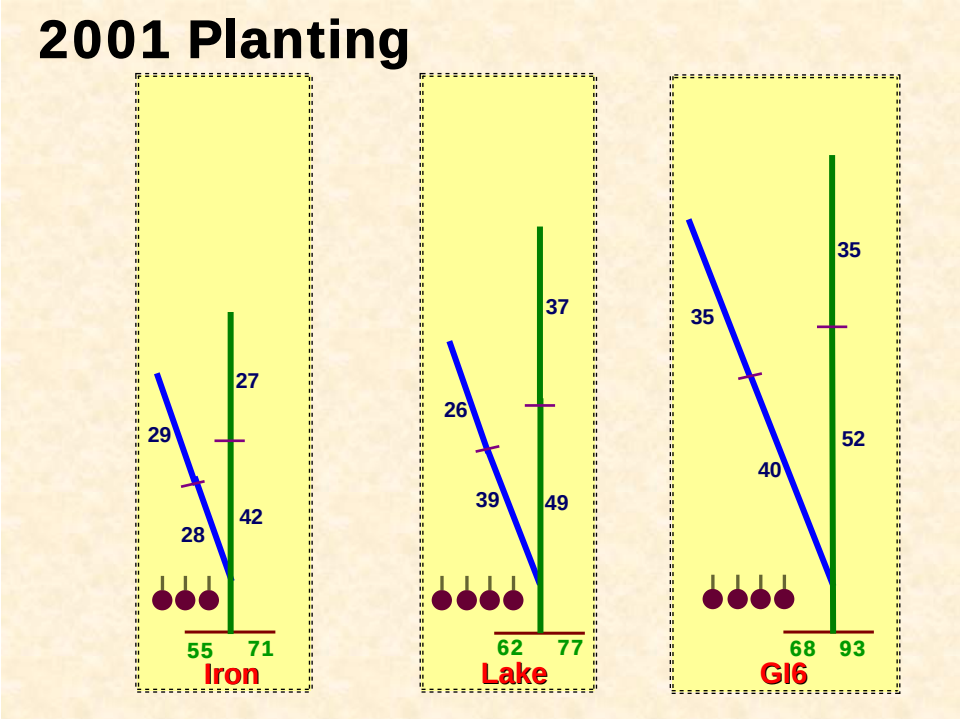
Preparations for the next test sites:

Four test plots are planned for the Pacific North West, one in Oregon and three in Washington. The Oregon plot will be at a grower location that will be determined this winter. The three Washington

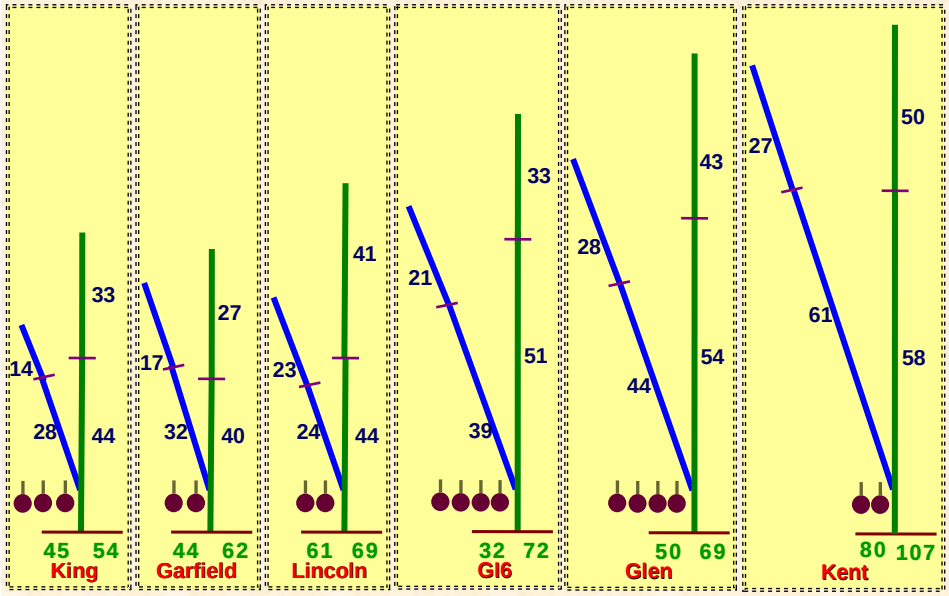
plots include the WSU Roza Farm in Prosser and sites in Manson and Mattawa to represent other environments within the state. There will be one site in Michigan, at MSU's Clarksville Horticultural Experiment Station that will be a much scaled down version of the sites in the PNW. Bing and Sweetheart were chosen as the two scions for the PNW sites. The growth habit of Bing is so well known, that this scion would be a good indicator of rootstock induced scion modifications. Sweetheart was included to represent those self-fertile high fruiting varieties, where reduced stature is required but not a higher spur/flower bud density. Rainier will be the scion for the MSU plot as this cultivar is important in the PNW, yet it is adapted to the Michigan climate.

Of the 11 rootstocks still under test, four are predicted to give very small trees so there is some concern about the fruit size potential, i.e. Clare, Crawford, Lake and Lincoln. These rootstocks may have promise for high density systems, but at this time we are only recommending that these are planted in more limited trials. As a result, these four will only be included in the trials at Prosser and MSU with Bing and Rainier, respectively, whereby the PI and Co-PI can provide the necessary management practices for these rootstocks. The remaining seven selections will be at all sites. Budding requests were communicated to Willow Drive Nursery and Duarte Nursery. In addition, the control trees of GI5, GI6 and mazzard have been ordered from commercial nurseries.

Figure 1. Schematic representation of the 11 MSU rootstocks candidates selected for advanced testing plus Gisela 6 control. The selected rootstocks are grouped by planting year, 2001, 2002 and 2004 and arranged in order of increasing trunk cross-sectional areas. The numbers at the bottom of each frame represent the trunk cross-sectional areas, calculated $\pi(r^2)$, with Fall of 2006 and 2007 values on the left and right, respectively. The numbers of cherries represent the relative predicted cropping potential. The vertical and angled lines represent two years of growth (cm) for terminal and lateral shoots, respectively.



2002 Planting



2004 Planting

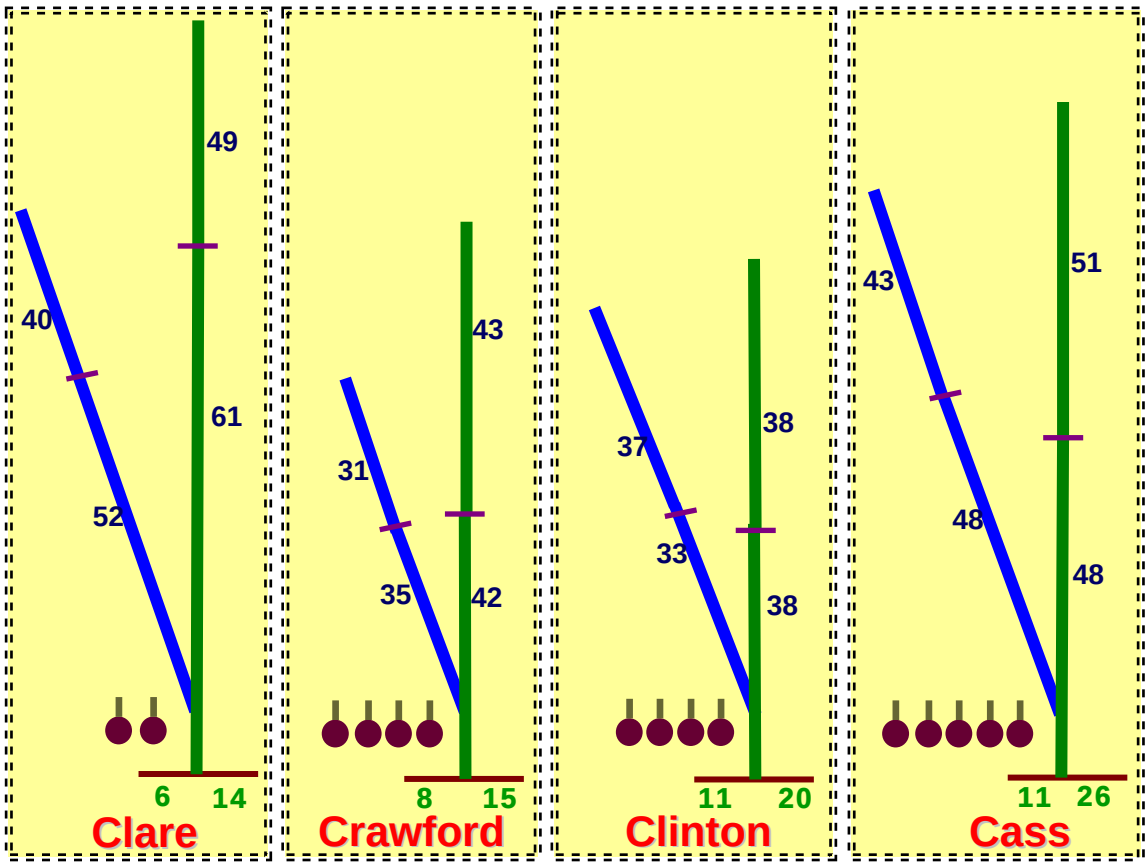
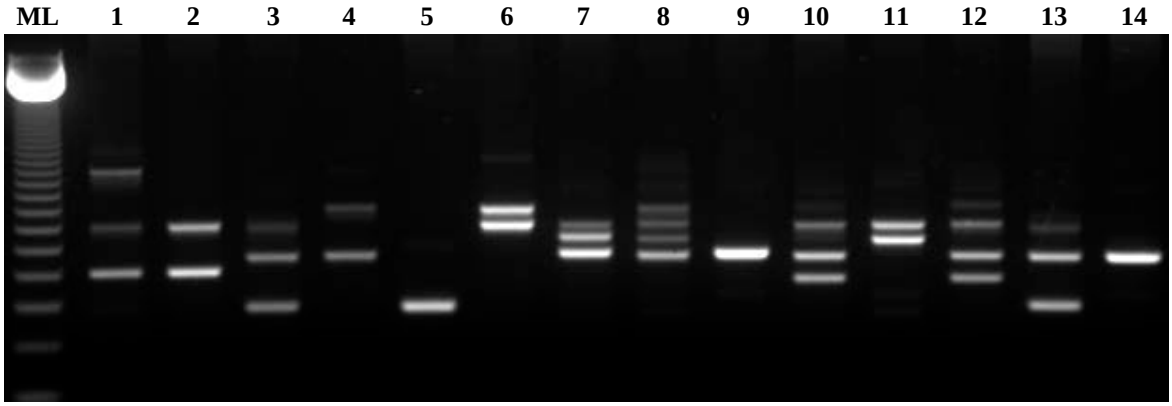


Figure 2. MSU cuttings propagated under mist in June 2006.

Figure 3. An example of one of the rootstock primer pairs that is used to differentiate the MSU rootstock selections. The primer pair used for this figure amplifies the *S-RNase* gene. The samples in the lanes are as follows: ML, size ladder; 1, Cass; 2, Clare; 3, Clinton; 4, Crawford; 5, Garfield; 6, Glen; 7, Iron; 8, Kent; 9, King; 10, Lake; 11, Lincoln; 12, Sherman; 13, GI5; 14, GI6.



FINAL PROJECT REPORT
WTFRC Project Number: CH 07-700

Project Title: Consulting for the Northwest Cherry Improvement Project

PI: Fredrick A. Bliss
Telephone/email: (530) 756-5154 **FBliss@Dcn.org**
Address: 214 Inca Pl.
City: Davis
State/Province/Zip CA 95616

Cooperators: Matt Whiting, Jim Olmstead, Amy Iezzoni, Jim McFerson

Other funding Sources: NA
Agency Name:
Amount awarded:
Notes:

Total Project Funding: $8380
Budget History:

Item	Year 1:	Year 2:	Year 3:
Salaries			
Benefits			
Wages			
Benefits			
Equipment			
Supplies			
Travel	$1,500.		
Miscellaneous	$6,880.		
Total	$8,380.		

Significant Activities and Findings:

Coordinated conference calls with collaborators to evaluate traits for marker assisted selection and other technology applications.

- Approx. 8 group conference calls during the year. Participants included: Jim McFerson, Jim Olmstead, Amy Iezzoni, Amit Dhingra, Yanmin Zhu.

Evaluated and rated the following traits for importance and action regarding marker assisted selection and other activities.

- Tree juvenile period
- Productivity (fruit yield potential)
- Fruit weight
- Fruit texture
- Fruit firmness
- Taste (brix=soluble solids)
- Taste (titratable acidity)
- Fruit doubling (polycarpy)
- Skin (rain) cracking

Traveled to Washington State to evaluate project and assess activities and progress.

- Nov. 15 – 17, 2006. Traveled to Pasco, WA to attend and participate in the WTRFC Cherry Research Review.

- May 8, 2007. Stopped in Prosser, WA to visit research station and the cherry breeding project in conjunction with the Apple workshop in Pullman and Wenachee organized by Cameron Peace.

Provided review of project proposals, plans and results.

- Breeding program progress reports
- Breeding program final (3-year) report
- Various proposals for marker development and marker assisted selection

Identified and compiled references for breeding and genetics of sweet cherry.

- Approx. 30 key references incorporated with trait decision trees

Submitted invoices for expenditures on a quarterly basis.

Quarter one (October 30, 2006 – December 31, 2006)	$3,041.37
Quarter two (January 1, 2007 – March 31, 2007)	$1,440.00
Quarter three (April 1, 2007 – June 30, 2007)	$ 680.00
Quarter four (July 1, 2007– Sept. 30, 2007)	$ 640.00
Total	$5,801.37

Results and discussion:

Cherry team members participated in conference calls to assemble a list of sweet cherry traits which were then evaluated for importance as traits for improved cultivars. This evaluation was used to identify traits having the most value and potential for implementing marker assisted selection (MAS) and related activities to complement classical breeding and selection procedures in the cherry breeding program. Tree juvenile period, fruit weight, taste (brix=soluble solids), taste (titratable acidity), skin (rain) cracking and fruit firmness were ranked as very important; Productivity (fruit yield potential) and fruit doubling (polycarpy) were ranked as moderate importance and fruit texture as limited importance.

Marker assisted breeding can be used to enhance the efficiency of selection, but development and implementation usually have considerable cost. Therefore it is important to choose the most important and valuable traits on which to expend time and resources. This combined exercise has provided guidance to team members as they develop projects related to breeding as well as guidance to the breeding program.

The idea of identifying the current leading cherry cultivar(s) for each target market as well as the desired traits for a new cultivar for that market was introduced to provide a goal and targets for measuring progress in the breeding program. The goal is to replace the market leader in each target market with a new, improved cultivar in a minimum length of time.

Good progress has been made during the first three years of breeding toward reaching the goals for number of crosses and seedlings produced. Considerable attention is being paid to how best to evaluate the seedlings at locations that are most effective in allowing selection and represent the target production areas. The parents of these crosses represent a wide genetic base for sweet cherry, but there is concern about whether there is sufficient genetic variability in the cultivated gene pool of sweet cherry to generate unique new traits for consumer traits.

An excellent team of researchers is becoming available to contribute to the overall breeding effort. The interaction via conference calls and other means is important to optimize collaboration in order to have a productive project.

It is important that a permanent breeder be hired as soon as possible to provide guidance and leadership for the breeding program and assure that the significant momentum to date continues.

CONTINUING PROJECT REPORT **YEAR**: 1 of 3
WTFRC Project Number: CH-07-706

Project Title: Efficient production of superlative fruit

PI:	M. Whiting	**Co-PI(2):**	J. Olmstead
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City:	Prosser	**City:**	Prosser
State/Province/Zip	WA 99350	**State/Province/Zip:**	WA 99350

Co-PI(3): Carolyn Ross
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State/Province/Zip WA 99164

Cooperators: Amy Iezzoni, Clive Kaiser, Auvil Fruit Company, Allan Brothers, Rowe Farms, Roy Farms, Mark Hanrahan, WTFRC, John Verbrugge, Alejandro Antunez, Mauricio Frias Giaconi, Gemalier Lemus

Total project funding request: **Year 1:** 136,138 **Year 2: 137,386** **Year 3:** 140,766

Other funding Sources: None

Budget 1:
Organization Name: WSU **Contract Administrator:** ML. Bricker
Telephone: 509 335-7667 **Email address:** mdesros@wsu.edu

Item	2007	2008	2009
Salaries	20,309	**21,121**	21,966
Benefits	1,856	**1,930**	2,007
Wages	52,980	**55,099**	57,303
Benefits	6,093	**6,336**	6,590
Equipment	5,000	**3,000**	3,000
Supplies	14,500	**14,500**	14,500
Travel	22,500	**22,500**	22,500
Panel Testing	12,900	**12,900**	12,900
Miscellaneous			
Total	136,138	**137,386**	140,766

OBJECTIVES:

1. Improving efficiency (e.g., labor, pesticides, light use) through development of single-plane, compact orchard systems designed to incorporate mechanization and/or mechanical-assisted operations.
2. Develop pragmatic strategies for consistent and balanced cropping through understanding factors limiting fruit set and researching practical thinning strategies
3. Better understand critical fruit sensory attributes, consumers' perceptions of fruit quality, and their willingness to pay for those attributes

SIGNIFICANT FINDINGS:

- a novel tree architecture comprised of upright fruiting offshoots (UFO) shows promise in WSU and cooperator orchards – several cooperative orchards were established
- high yields of quality fruit can be grown in angled fruiting wall architecture (e.g., 15.5 tons/ac 10.5-row and larger from 5th leaf Bing/Gisela12; 10.5 tons/ac 9.5-row and larger from Skeena/Gisela12)
- post-bloom shading (ca 80% shade) reduced significantly Bing fruit set and fruit quality
- 2 – 3% fish oil + 2 – 3% lime sulphur was inconsistent as a post-bloom thinner on Bing, Rainier, and Lapins – we recorded no reduction in fruit set but did see improvements in fruit quality
- Maxcel® was ineffective as a post-bloom thinner at 14 DAFB
- GA_3 applied between 25 and 75 mg/L at straw to Sweetheart did not affect fruit maturity but improved fruit quality compared to untreated fruit
- GA_3 (25 to 75 mg/L) did not reduce no. of flower buds/spur or no. of flowers/bud in Sweetheart
- GA_3 and GA_7 reduced no. flowers/bud but did not affect no. buds/spur in Rainier
- flowers/spur was reduced by 36% (from 25 to 16) with GA_3 and GA_7 at 100 ppm on Rainier
- ATS is an effective pollenicide, reducing pollen germination in a rate-dependent manner
- high fruit set can occur using pollen with extremely low germination potential
- differences in fruit set among cultivars were due to maternal effects
- fruit set in self-fertile cultivars was generally lower than self-incompatible cultivars; emasculating to prevent self-pollination appears to significantly reduce fruit set potential
- ambient temperature at the time of pollination had little effect on fertilization success – fruit set was similar despite variation of up to 15 F in daily high

- a sensory panel trained to recognize attributes of cherry appearance, flavor and texture, was able to differentiate between different varieties of cherries
- trained sensory panel responses showed clear relationships with corresponding empirical data of fruit attributes
- flavor groupings based on perceived sweetness and sourness were used by the trained panel to successfully characterize cherries
- consumers differentiated cherries based on attribute intensity and acceptance of those attributes
- for fruit sweetness, flavor, and juiciness, consumers showed strong positive relationships between intensity and acceptance of the attribute
- consumers showed a negative relationship between length of stem and stem acceptance
- consumers were influenced by the color of the cherry and were more willing to purchase cherries based on color than flavor and texture

METHODS: see below and refer to proposal "Efficient production of superlative fruit"

RESULTS AND DISCUSSION:

Objective 1 Our evaluation of high efficiency fruiting wall architectures continued in 2007. From a 5th leaf orchard at the WSU-Roza experimental farm, we recorded high yields of quality fruit (Table 1). This orchard is planted at a density of 588 trees/acre.

Table 1. Comparison of fruit yield and quality for several cultivar/rootstock combinations in their 5th leaf trained to angled fruiting wall architecture. Means of each attribute for the variety are presented. Within each attribute (column), a different letter indicates a significant difference ($p<0.05$).

Genotype	Yield (kg/tree)	Yield (tons/acre)	≥9.5-row (tons/acre)	≥10.5-row (tons/acre)
Bing/Gi12	28.8 a	17.0	7.1	15.5
Skeena/Gi12	18.1 b	10.6	10.5	10.6
Tieton/Gi5	12.4 cd	7.3	6.8	7.3
Chelan/Gi12	10.5 d	6.2	2.9	5.6
Tieton/Gi12	2.6 e	1.5	1.5	0.0

The most productive combination was Bing on Gisela 12, yielding slightly less than 30 kg (66 lb) per tree, of which, more than 90% was 10.5-row and larger fruit and 42% was 9.5-row and larger. We recorded these high yields despite initiating significant renewal of fruiting wood in the Bing/Gisela12 trees last winter. These results show tremendous potential for fruiting wall orchards. The least productive combination was Tieton/Gisela12, which yielded less than 2 tons/acre. This excessively vigorous combination will be eliminated from the orchard this winter and replaced by a new genotype.

In 2007 we developed a novel approach to creating fruiting wall orchards on precocious productive rootstocks that has been dubbed the UFO system (for Upright Fruiting Offshoots). This system has several potential advantages over traditional systems and may be configured in either upright or angled fruiting walls. We are in the process of developing a guide to the establishment of the UFO system (Figure 1). Briefly, to establish the system, whips are planted at an angle of 30 to 45 degrees from vertical and clipped to a low wire – this wood will become the only permanent scaffold of the tree. Dormant vegetative buds are rubbed by hand from the underside of the tree at planting and well-positioned upright buds about 12 inches apart are selected to develop the fruiting uprights from (this is accomplished by several potential techniques). Renewal of fruiting uprights occurs systematically at the base with aggressive dormant stub cuts. We anticipate minor fruiting in 2nd leaf and significant yields in the 3rd leaf.

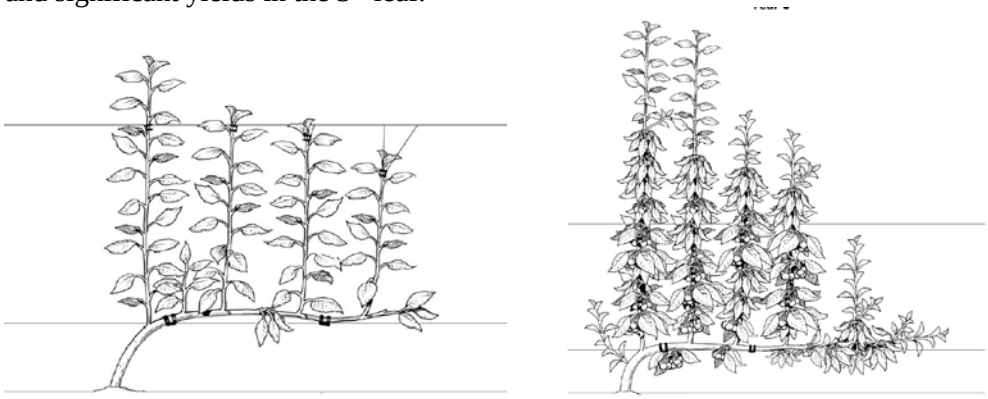

Figure 1. New training system (UFO) for creating compact fruiting walls. Image on the left depicts tree at the end of first year. Image on the right shows tree near harvest in 3rd leaf (images not on same scale)**.**

Objective 2 Pollen germination among the cultivars used for these experiments ranged from 3% to nearly 100%. However, even among pollen with low tested germination ability, relatively high levels of fruit set were achieved. This suggests that maternal factors have greater influence on fertilization than paternal. This will be further tested in 2008 utilizing pollen with variable germination potential from a single source. For germination testing, we used a standard pollen germination media and assessed % germination over time; however, in the coming years we will explore alternative pollen viability testing procedures. In our experiment to assess differences in fruit set potential based on maternal and paternal effects, only fruit set on Regina and Attika flowers was significantly different (lower) from the other female parents tested. Variation in fruit set for Regina and Attika was largely a result of maternal effects; there were no significant differences in average fruit set among the different pollen donors (Table 2). Interestingly, fruit set for hand pollinated crosses tended to be higher than natural (i.e., bee-mediated) fruit set.

These findings were consistent with the results of the experiment to determine whether all sources of the same S-allele are equally effective with respect to fruit set. In this experiment, six different self-fertile cultivars were mated in the field in a scheme that resulted in only the S4' allele from each of the parents being compatible. Again, no significant differences were measured for pollen parent influence on fruit set (Table 3). Celeste and Sonata had significantly lower fruit set compared to the other self-fertile cultivars. Field temperature at the time of pollination appears to have had little effect on fertilization, as variation up to 15 F in daily maximum air temperature resulted in similar fruit set (data not shown).

Two different techniques were used to make the crosses reported here. For the first experiment using predominantly self-incompatible cultivars and fully compatible pollen donors, branches were bagged prior to bloom and pollinated when 50-75% of the flowers were open. In the experiment examining the effect of different sources of the same S-allele, all cultivars were self-fertile. Flowers in this experiment were emasculated when 50-75% of the flowers were at the "popcorn" stage (full white, but unopened). Fruit set tended to be lower in crosses where emasculation was used. This is particularly evident in Sweetheart and Lapins, cultivars that were used in both experiments.

All crosses performed this year consisted of a weighted mix based on pollen germination percentage of the desired pollen type and PC7903-2. PC7903-2 has the S-alleles S5 and S9, which were unique among all the crosses made. We are now in the process of genotyping all the seed resulting from crosses made to determine the successful pollen S-allele in fertilization. The PC7903-2 pollen will serve as a standard control for all crosses during this process.

Table 2. Percent fruit set differences among fully compatible crosses made in April 2007. Statistical comparisons made at 95% confidence for general combining ability.

			Paternal						
Control	**Avg.**	Maternal	B. Tart	NY54	Schneid.	Summit	Attika	Sam	Swthrt
19.0	**14.9 a**	Regina		16.2				13.6	
20.8	**37.3 a**	Attika	28.8			39.6		46.7	
46.0	**74.0 b**	Lapins		86.9	73.7		65.6		70.0
67.0	**74.8 b**	Bing	79.0	48.5		98.4			
53.6	**76.4 b**	Swthrt	74.6	72.8		81.8			
		Avg.	**62.2 ns**	**53.7ns**	**73.7ns**	**75.7ns**	**65.6ns**	**29.4ns**	**70.0ns**

Table 3. Percent fruit set differences among self-fertile crosses with the same S-alleles.

		Paternal					
		S1S4'			S3S4'		
Avg.	Maternal	Celeste	Lapins	Skeena	Selah	Swthrt	Sonata
6.8 a	Celeste	11.3	1.1	8.0			
21.8 b	Lapins	19.5	18.6	27.4			
19.0 b	Skeena	19.5	11.4	26.1			
14.5 b	Selah				17.0	13.0	13.4
16.3 b	Swthrt				20.4	24.2	4.4
1.0 a	Sonata				0.0	1.5	1.6
	Avg.	**16.8 ns**	**10.4 ns**	**20.5 ns**	**12.5 ns**	**12.9 ns**	**6.5 ns**

Objective 3 The overall objective of this work was to determine the sensory properties of importance in Washington State cherries. Fruit samples (cultivars exhibiting a range for various attributes) were identified from among the collection at WSU-Roza. Attributes of these selections were characterized empirically using lab instruments to measure firmness, titratable acidity (TA), pH, color, soluble solids (°brix), stem diameter, and size (i.e., fruit diameter). A trained sensory panel then evaluated the cherries. This sensory panel of 10 was trained to recognize the attributes of cherry appearance (color intensity, uniformity of color, size, stem length, and stem diameter), flavor (sweetness, sourness, and cherry flavor intensity) and texture (flesh firmness and juiciness). Lastly, the same fruit samples were utilized for large-scale consumer preference studies. For these studies, two panels were conducted, one at the sensory evaluation facility at Washington State University and the second panel at a local supermarket (Dissmore's IGA). A total of 117 consumers were evaluated. No significant differences were found between the two locations so the results were combined.

Table 4. Analysis of fruit attributes for the five selections used for subsequent consumer studies. Means of each attribute for the variety are presented. Within each attribute (row), a different letter indicates a significant difference ($p<0.05$).

	Cultivar				
Cherry Attribute	A	B	C	D	E
Brix	19.29b	23.13a	24.16a	18.65bc	17.34c
pH	3.76a	3.40a	3.70a	3.71a	3.65a
TA (mL added)	16.45bc	21.70a	21.55a	18.85ab	15.30c
Firmness	231.50b	245.75b	292.75a	305.50a	182.75c
Average Weight	10.50c	14.05a	12.80b	9.60d	13.30b
Color	4.08a	4.67a	3.74ab	2.96b	3.71ab

The selections utilized for trained panel and consumer panel testing exhibited significant differences within key quality attributes (Table 4). Using these fruit samples, we investigated the possibility of separating them into distinct flavor groups. Our results suggest that consumers may be able to categorize different cherry cultivars based on key flavor attributes such as acidity and sweetness (Table 5). When looking at assigned flavor groupings, results showed significant differences in mean

grouping value among cherry selections. Cherry D was characterized as high sour/low sweet despite having moderate acidity (3.71 pH and 18.9 mL TA) and sugar levels similar to cherry A and E. Cherry C received the lowest overall grouping (i.e., nearest the high sweet/low sour) but was the most difficult for panelists to characterize, having significant classification in each category. Interestingly, cherry E was categorized as high sweet/low sour despite having the least soluble solids among the samples and similar juice pH to other cherries. The ranking of cherries D and E as high sour/low sweet and high sweet/low sour highlights the importance of the combined effect of fruit acidity/tartness and sweetness on the palate – clearly one attribute alone can not be relied upon.

Table 5. Grouping of the five cherries varieties based on their mean sweetness and sourness ratings by the trained panel.

Variety	Mean Sweetness	Mean Sourness	Mean Grouping	Percentage of panelists who placed the cherry in the flavor grouping		
				1 (high sweet/ low sour)	2 (balanced sweet and sour)	3 (high sour/low sweet)
D	9.1	11.1	2.7a	7.5	15	77.5
B	11.1	12.1	2.3ab	35	55	10
A	10.5	9.8	1.9bc	10	50	40
E	10.4	9.2	1.7cd	63.3	30	6.7
C	11.8	8.7	1.4d	33.3	40	26.7

Consumer Panel Evaluations

Our evaluations of consumers' ranking of attributes and acceptance of those attributes is summarized in Table 6. Our results show that panelists perceived the various attributes at a different intensity and also varied in their level of acceptance for the attribute.

Table 6. Tukey's HSD results for the separation of the four varieties of cherries based on sensory attributes and acceptance, as evaluated by the consumer panels. Means of each attribute for the variety are presented and within each attribute (row), a different letter indicates a significant difference ($p<0.05$).

Cherry Attribute	**A**	**B**	**C**	**D**
Color ranking	6.089c	8.354a	6.866b	3.225d
Size ranking	5.439c	7.806a	6.832b	4.909d
Stem length	2.482d	5.901a	5.268b	4.4559c
Sweetness ranking	4.751c	5.499b	6.225a	4.576c
Sourness ranking	4.409b	5.458a	3.330c	5.663a
Flavor ranking	5.128c	6.880a	5.797b	5.549bc
Firmness	6.166b	6.895a	6.485ab	6.741a
Juiciness	5.874b	6.463a	6.181ab	5.856b
Color acceptance	6.957a	6.573ab	6.778a	6.205b
Size acceptance	7.051a	7.214a	7.359a	6.556b
Stem acceptance	6.880a	4.496c	5.043b	5.291b
Sweetness acceptance	5.744b	6.573a	7.077a	5.607b
Sourness acceptance	5.385b	6.034a	6.162a	5.265b
Flavor acceptance	5.803b	6.915a	6.607a	5.692b
Firmness acceptance	6.479b	7.162a	7.068a	6.521b
Juiciness acceptance	6.471c	7.060a	7.009ab	6.487bc

In assessing the correlation between consumers' ranking of an attribute's intensity and their acceptance of that attribute, we saw strong positive relationships for fruit sweetness, juiciness, and flavor and a negative relationship between length of stem and stem acceptance (Figure 2).

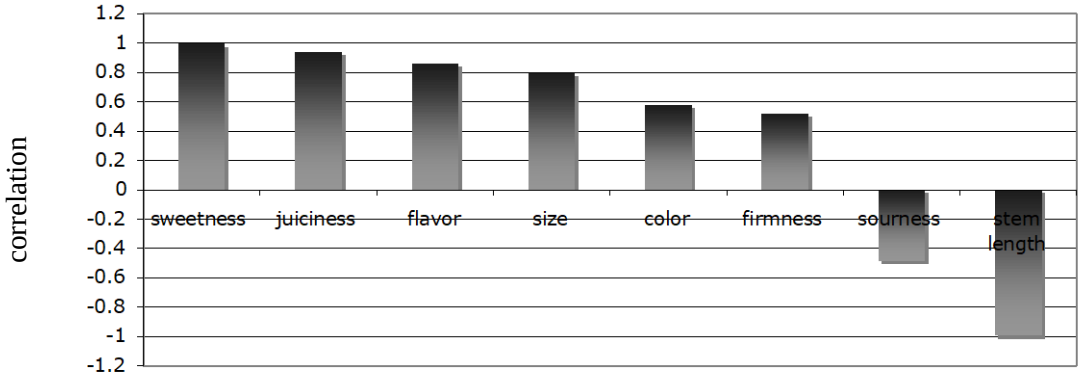

Figure 2. Relationship between attribute intensity and consumers' acceptance of that attribute.

Overall, consumer comparisons of the four cherry samples evaluated showed distinct preferences (Table 7). Based strictly on appearance, samples A and B were rated the most appealing and this was due to color primarily. Color was also the most important attribute for poorly rated fruit. Consumers were more willing to pay for fruit that they found attractive – about 25% more were willing to spend $2.49 per pound for the most vs. least attractive fruit (67% vs. 42%). After tasting the samples, B and C were ranked the highest and A and D the lowest. Consumers cited sweetness and flavor as the most important fruit attributes for high-ranked samples. Poor rankings were a result of flavor for A and sourness for D.

Table 6. Overall evaluation of most and least accepted cherries by the consumer panel.

		Cherry Variety				
Cherry Attribute		A	B	C	D	
Visual Evaluation	Most attractive	30.2	31.9	12.9	25.0	
	Preferred attributes	Color-77.1 Stem-57.1 Size-42.9	Color-89.2			
	Least attractive	5.2	36.2	14.7	44.8	
	Objectionable attributes		Color-59.5 Stem-52.4 Size-31.0		Color-88.5	
	Willing to purchase ($2.49/lb)	67.2	44.8	52.6	42.2	
Flavor/ Texture Eval.	Most pleasant	12.1	32.8	38.8	15.5	
	Preferred attributes		Swt-68.4 Flv-68.4 Jucn-42.1 Firm-36.8	Swt-91.1 Flv-75.6 Firm-55.6 Jucn-51.1		
	Least pleasant	29.3	15.5	20.7	34.5	
	Objectionable	Flv-64.7 Sour-32.4 Firm-29.4 Swt-29.4			Sour-67.5 Flv-35.0 Jucn-27.5 Firm-22.5	
	Willing to purchase ($2.49/lb)	41.4	56.0	56.9	32.8	

CONTINUING PROJECT REPORT **YEAR**: 1 of 3
WTFRC Project Number: CH-07-701

Project Title: Sweet Cherry Regeneration and Transformation System

PI:	Amit Dhingra	**Co-PI(2):**	Amy Iezzoni
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Address 2:	Horticulture and LA	**Address 2:**	Michigan State Univ.
City:	Pullman	**City:**	East Lansing
State/Province/Zip	WA 99164	**State/Province/Zip:**	MI 48824

Other funding sources: None

Total project funding request: **Year 1:** 10,000 **Year 2:** 10,000 **Year 3:** 10,000

Budget 1:
Organization Name: WSU **Contract Administrator:** Mary Lou Bricker
Telephone: 509 335 7667 **Email address:** mdesros@wsu.edu

Item	2007	**2008**	2009
Salaries			
Benefits			
Wages	2250	**1,729**	1,729
Benefits		**271**	271
Equipment			
Supplies	7000	**7,000**	7000
Travel	750	**1,000**	1000
Miscellaneous			
Total	10,000	**10,000**	10,000

OBJECTIVES

Our original objectives for the proposal were:

A. We had proposed to employ a three-pronged approach in the first 18 - 20 months to establish an efficient regeneration system in sweet cherry.
   1. Identify the best media formulation for each variety being tested.
   2. Identify the best line for regeneration.
   3. Monitor the progression of regeneration using known markers of regeneration.

B. Establishment of an efficient transformation system.

In the next year our goal is to finalize the best regeneration conditions for sweet cherry. The activities pursuant to this goal will involve test of different chemicals derived from the chemical genomics project funded by WTFRC to Tianbao Yang. In addition, we will test the unique effect of different wavelengths of light on tissue culture material. The experiments with the chemicals were initiated recently and we are currently constructing special light chambers to test the light effects. This is being done by an Undergraduate student who has brought her own funding to build these chambers. Some of the materials will be procured with support from this project as well. These chambers will be used for other tissue culture projects funded by WTFRC. We are currently on schedule and have actually explored additional avenues beyond what were originally proposed in the initial timeframe.

SIGNIFICANT FINDINGS

The first year has been devoted to Objective A part 1 and partially part 2. We have been involved in standardizing media formulations and also screening the existing varieties. Our findings from the initial efforts are listed here.

1. Standardization of initiating explants in tissue culture
2. Standardization of establishing and multiplying the explants in tissue culture

These findings are explained in greater detail in the Results and Discussion section.

METHODS

Standard tissue culture methods have been used. These include, explant retrieval from the trees in orchards, decontamination and transfer to the media. The explants in tissue culture were maintained at 24 degC/20 deg C for a 16h day/8 h night cycle respectively. We are trying different methods for accelerating plant growth.

1. Media composition
2. Different gelling agents
3. Different light regimes
4. We have also tried using different chemicals that can enhance plant regeneration. This has resulted due to collaboration with another WTFRC funded project on chemical genomics currently being led by Dr. Tianbao Yang. We are currently in the observation mode. This is an extension of the chemical genomics work where we are trying to explore the additional application of chemicals.

RESULTS AND DISCUSSION

We have been successful in establishing sweet cherry tissue culture for Bing, Rainier and Lapins. The next step is to improve the efficiency and improve on the methods established so far. Some of the results are discussed here.

1. Standardization of initiating explants in tissue culture

With sweet cherry tissue culture there are few major problem areas. The first of these is decontaminating explants, as is a problem with all tissue culture. Bacteria and fungi that live on the surface of sweet cherry tissues in the orchard grow vigorously on the sugar containing media the tissue culture utilizes. Surface sterilization is essential and the procedure that we have been using has provided excellent results as far as contamination is concerned. Over-sterilization, however, can result in tissue death. We have successfully standardized this part and are routinely transferring explants into the media directly from trees in the orchard.

2. Standardization of establishing the explants in tissue culture

A second problem with sweet cherry tissue culture is establishing materials in culture. To this point we have been working on initiating shoot cultures on Bing, Rainier and Lapins. A variation of the protocol established for Lapins and Sweetheart is being used to initiate our cultures for Bing, Rainier, and Lapins. We are using this year's growth to obtain plants from the vegetative axial buds for tissue culture (Figure 1A). Bark removal (Figs 1B, 1C) was shown by Elfving and Visser to increase adsorption of cytokinins into woody tissues and improved lateral shoot and bud development on young sweet cherries. The bark removal process, as well as the sectioning of the stem, resulted in production of phenolics at the cut sites. These phenolics compounds act as signals to the rest of the tissues that injury has occurred and can lead to complete tissue death. In our initial trials of this protocol, browning of injured tissues occurred because of the phenolics. Our subsequent trials are utilizing compounds which will adsorb the phenolics thereby preventing browning of the tissues. On an average, results from our initial round of tissue culture had bud initially growing in size and partially opening (Fig 1E) in 5/17 Bing bud sections and 4/22 Rainier bud sections. These are typical results as reported by other researchers. We are in the process of improving on these numbers. We have observed that times greater than one month between subculturing is excessive and will result in damaging the tissues. The fastest growing bud sections produced leaves and have since been subcultured onto the new media (Fig. 1F)

Once the tissues are growing successfully in culture, we will begin micropropagation to increase stocks for further experimentation. Understanding that the initial cultures likely will not be optimized, we will use materials from our cultures to test media modifications and different procedures. Once the media and procedures are optimized, we will begin testing other varieties using them.

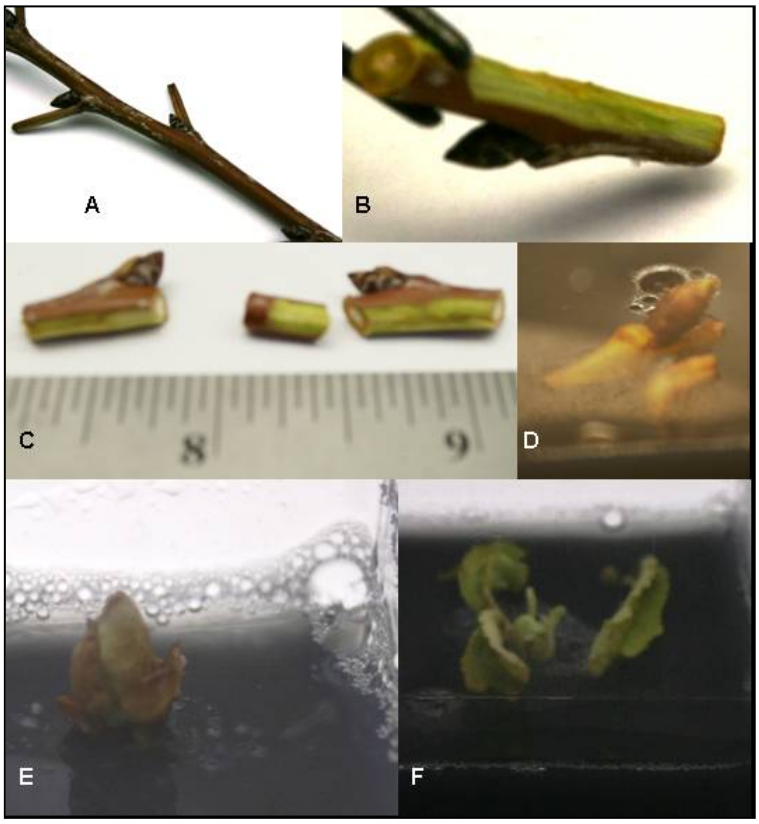

Figure 1: Tissue Culture Overview-Rainier : A)Starting material, B) Bark Removal, C) Outside pieces finalized for placement in media, Middle section removed, D) Bud section after 4 days in culture, E) growing leaves emerging from bud, F)Expanded leaves from culture

This is an important initial step as it will lay down a foundation for establishing micropropagation protocols for these varieties. The procedures developed here will be used for establishing micropropagation protocols for any new variety releases from the WSU sweet cherry breeding program. This will be of potential economic benefit to the industry. There is an immense interest in establishing or improving micropropagation, tissue culture protocols for new rootstock and scion cultivars. Having this platform available will eventually benefit the industry by ensuring timely availability and multiplication of these materials.

CONTINUING PROJECT REPORT **YEAR**: 2 of 3
WTFRC Project Number: CH-07-705

Project Title: Post-Plant Management of Dagger Nematodes in Cherry Orchards in WA

PI: Ekaterini Riga
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Cooperators: **1)** Mr. Don Jagla; Cherry Grower, Wenatchee, WA; **2)** Mr. Jerry Gutzwiler, **3)** Dr. C. Ishida, Field R&D Scientist, Valent Biosciences Co., and **4)** Dr. Ken Eastwell, Virologist, Washington State University, IAREC, Prosser, WA.

Total project funding request: Year 1: $5,495 **Year 2:** $2,000 **Year 3:** 0

Other funding Sources: None

Budget 1: No funds are requested for 2008 – final report will be submitted in 2008
Organization Name: Washington State Univ. **Contract Administrator:** ML. Bricker/S. Brock
Telephone: 509-335-7667 / 509-786-9242 **Email address**: mdesros@wsu.edu / sabrock@wsu.edu

Item	Year 1: 2006	Year 2: 2007	Year 3: 2008
Salaries			
Benefits			
Wages	4,185		
Benefits	460		
Equipment			
Supplies	450	1,000	
Travel	400	1,000	
Miscellaneous			
Total	5,495	2,000	0

Footnotes:
We are not requesting any funds for 2008 as there are enough funds left in the project to continue for one more year of field trials at Mr. Jagla's orchard, and for the subsequent years at Mr. Gutzwiler's orchard. I am responsible for soil sampling and processing the soil for nematodes.

Objectives: The short term objective is to use DiTera as means to control both lesion and dagger nematodes in post-plant cherry orchards. The long term objective is to find alternatives for Nemacur by testing new compounds with nematical properties.

In 2008, Ditera will be tested in two cherry orchards (the 2nd orchard was added in our study in the fall of 2006) with history of dagger and lesion nematodes. In addition, new compounds, green manures and meals are screened in my greenhouses against lesion and dagger prior to field testing.

Significant findings for 2007:

- After 2 years of applying Ditera in one of the cherry orchards, a significant reduction in dagger nematode population was achieved.
- Also, reduction of lesion nematodes in the soil was observed in the second years of treatment; however, there was no reduction odf lesion nematoed inside the roots.

Methods: The methods are the same as in 2006. Soil samples and root samples are collected prior and post Ditera application in the beginning of the season, mid-season and post harvest. Nematodes are extracted from soil and roots, and data from treated trees is compared to untreated controls.

New compounds are tested in the greenhouse on pots infected with lesion and dagger nematodes. The effectiveness of the new compounds is evaluated against untreated controls. The following compounds have been evaluated: *Brassica carinata,* and *Muscodor albus;* these compounsd have been found to be effective in controlling both the lesion and the dagger nematodes.

Results and discussion: After 2 years of applying Ditera in a cherry orchard with high densities of dagger and lesion nematodes, a significant reduction in dagger nematode population was achieved. On average, dagger nematodes were reduced from 400 individuals per 250 cc soil to 21 individuals per 250 cc. Similar reduction was recorded from all soil samples. No significant reduction of lesion nematodes was observed during the two years of treatment in the roots (data not shown), however, reduction of lesion nematodes in the soil has been observed (Fig. 1). Ditera did not have negative effects on the beneficial free living nematodes. Ditera has been applied in a a seocnd cherry orchard, Mr. Jerry Gutzwiler, against dagger nematodes and the nematodes will be monitored over the next 2 years.

The reduction of dagger nematodes will be of importance to the cherry industry as controlling these nematodes will lead to reduction of virus transmission, yield increase and tree survival.

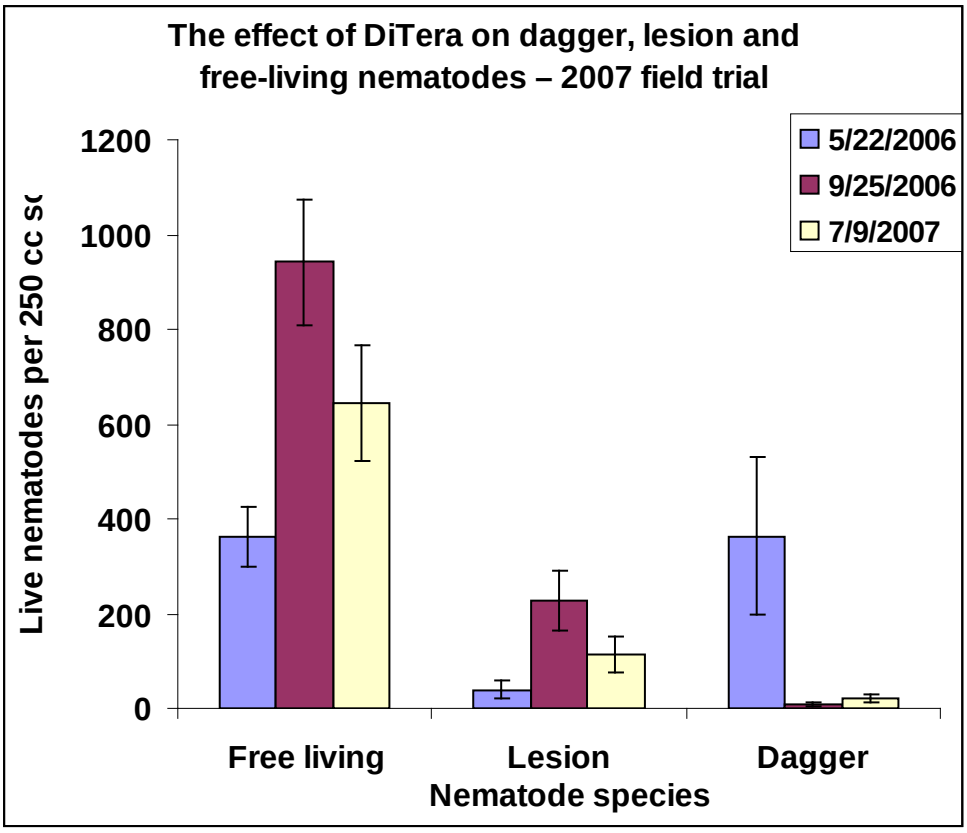

Figure 1. The effect of Ditera on dagger and lesion nematodes – 2007 field trial

CONTINUING PROJECT REPORT **YEAR**: 2 of 3
WTFRC Project Number: CH-06-603

Project Title: Cherry Fruit Fly Control Options

PI: Timothy J. Smith
Organization: Washington State University
Telephone/email: 509-667-6540, smithtj@wsu.edu
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City: Wenatchee
State/Province/Zip WA, 98801

Total project funding request: **Year 1: $17,107** **Year 2: $18,139** **Year 3: $18.776**

Other funding Sources

Agency Name: Bayer, Dow AgroSciences, Cerexagri-Nisso LLC

Amount requested or awarded: $4000, $7000, and $5000
Note: These grants partially support the entirely grant-funded WSU Administrative Professional (Esteban Gutierrez), who is critical to the success of this project, during the 8 months he is not working on cherry fruit fly.

Budget 1:
Organization Name: WSU Extension **Contract Administrator:** ML. Bricker /Jennifer Jansen
Telephone: 509-335-7667/509-335-2867 **Email address:** mdesros@wsu.edu/jjansen@wsu.edu

Item	2006	2007	**2008**
Salaries	$10,773	11,916	**12,393**
Benefits	4,094	4,051	**4,214**
Wages			
Benefits			
Equipment			
Supplies	300	300	**300**
Travel	1,940	1,869	**1,869**
Miscellaneous			
Total	$17,107	18,136	**18,776**

Notes: Salary and benefits are for WSU AP, 4 months - April – July.

Objectives
1: Identify new conventional and organic cherry fruit fly control products and methods.
2: Assess new insecticides and control methods for cherry fruit fly.
3: Work with industry toward the registration of new CFF control products.

Significant 2007 Results Summary:

- Chloronicotinyl (neonicotinoid) class insecticides continued to control larvae of all instars inside of infested fruit. Imidacloprid (Provado) provided post infestation control to a degree similar to that of full dimethoate rates. This "kick-back" effect may demonstrate advantages chloronicotinyl class insecticides offer as part of a pre-harvest control program.

- Entrust was 100% effective at full rates, but showed signs of inconsistency at 1/2 the recommended rate at 10 day intervals.

- Provado and Assail provide excellent control when applied at 10 day intervals even at relatively modest rates.

- This project first recognized and demonstrated the potential of GF-120 Bait as a Cherry Fruit Fly control. In 2007, this control method saved the Pacific Northwest cherry growers about $1.5 million in labor, application and material costs, bringing the total since 2004 to $4.17 million. Judging by the number of acres treated per season, this bait is now the most-used product for cherry fruit fly control in Washington State. The number of larvae detected during WSDA Washington cherry inspections has dropped from an average of 12 per season in 1997 – 2003, the seven seasons prior to bait use, to five larvae in 2006 and two in 2007.

- Reducing GF-120 rate to 10 fl. oz. of product per acre, 1/2 the recommended rate, resulted in a consistent failure of control in lightly infested test trees.

- Full GF-120 rates greatly reduced, but did not completely control CFF infestation on sites with very high numbers of adults emerging during the first season of treatment. A second season of treatment has been required to achieve 100% control on some sites.

- Full GF-120 rates greatly reduced, but did not completely control CFF infestation on sites very near to an untreated source of adult cherry fruit fly, demonstrating the need for sanitation as part of a CFF IPM program

- Assail and Delegate are expected to be registered for use in stone fruits by spring 2008. There are two or three new candidates within two new classes of insecticide that companies have proposed for testing in this project in 2008.

Methods
Pre-harvest efficacy trials: ***Sprayed products:*** In past trials, most products were effective when applied at rates well below those recommended for control of other insects. Companies are not comfortable adjusting rates lower for a pest that requires 100% control, but looking at lower rates gives an indication as to the margin of control. Is the product just on the edge of failure, or do the recommended rates provide for some degree of error? This year, three products, Provado, Assail, and Entrust, all very effective at full recommended rates on 7 – 10 day spray intervals in past trials, were applied at lower than recommended rates at 10 day intervals.

GF-120 Bait: During the past five years, GF-120 bait has been consistently effective, but there are indications that baits have limitations separate from those experienced with sprayed products. Baits have no effect on a population of adult cff at the time of application, as do all other effective registered products. There is a lag period during which the adults must find and feed upon the bait droplets. This does not seem to be a problem when the young target adult emerges from under the bait treated tree, as they must forage for five or more days before laying their first egg. This appears to be sufficient time for orchard-resident adults to find and consume lethal quantities of the bait. This year, we intentionally set up situations to demonstrate possible control problems, so as to lessen the chance of failure under field use. On three sites that have been monitored and treated with GF-120 Bait for at least two previous seasons, and seemed in relatively "clean" neighborhoods, we cut the rate of bait in half. Two sites that we had documented as very highly infested in 2006 were treated weekly with the 20 fl.oz. / acre recommended rate. In one site, we treated one tree, and did not treat another that was about 100 feet away. We succeeded in setting up failure.

After-harvest efficacy trials: Portions of an unharvested, extremely CFF infested cherry tree were treated with the various test products at a fruit development stage that would have been "after-harvest," under normal conditions. The test products were applied in a volume of water that resulted in full wetting, but light run-off, which we judged to be equivalent to about 200 gallons per acre. At the treatment date, some of the larvae in the fruit were late in their third (final) instar, and were soon to emerge, as they had cut the breathing and emergence holes in a low percentage of the fruit. The larva emergence data indicated that there were all stages of larvae and a few eggs in the fruit on the treatment day. Judging by the days to emergence, the treated fruit contained larvae and eggs in the following proportion: egg: 1.8%, 1st instar: 41%, 2nd instar: 28.4%, 3rd instar: 28.8%. One day after treatment, 250 fruit were harvested from each treatment and suspended over sand. The fruit was maintained at room temperature, and emergence of the larvae from the untreated sample was complete at 19 days after the treatment day.

Results & Discussion

Pre-harvest efficacy trials: ***Sprayed products***: Provado 1.6F (imidacloprid), Assail 70 WP (acetamiprid), and Entrust (80% spinosad) all provided 100% fruit protection when applied at 10 day intervals. The only exception was a single larva found in 1000 fruit sampled on a tree treated with Entrust applied at 1.0 oz. / acre, which is almost one-half the recommended rate (see table 1). The equivalent rate of Success 2L was effective when applied on 7 day intervals in past trials. It appears that the apparent residual effect of spinosad products may not be present at lower rates. Provado at full or moderate rates and full rates of Entrust (or Success) have been the most consistently effective treatments of the currently registered products over several years of these efficacy trials.

GF-120 Bait: The treatment of very highly infested trees, while very suppressive of fruit infestation, does not always lead to 100% control in the first year of treatment. We have had reports of this, and have some evidence in our past trials, and documented this once again this year. In every documented instance in past trials, treatment in the second season resulted in 100% control of larvae. It is possible that high numbers of adult flies rapidly find and consume the bait applied to the tree, and there is not enough left to completely control the entire population.

As bait has a lag period required for control, having a near-by untreated infested tree led to the essential failure of control with bait. The treated tree had 0.5% of fruit with larvae. This degree of infestation is far lower than would have been expected on the tree if it had not been treated. However, this demonstrates the importance of sanitation in the region around cherry orchards as a part of the IPM program, especially if you are depending entirely on bait for CFF control.

Product	Rate / A - Days Interval	Number of Trees/Sites	2007 Adult Trap Catch	Total Fruit Inspected	Number of Larvae Found
Untreated	**na**	**3/3**	**340** **827**	**500** **500**	**790** **915**
Provado 1.6	**6 fl. oz. – 10 day**	**4/4**	**11** **30** **6** **20**	**1000** **1000** **1000** **1000**	**0** **0** **0** **0**
	4 fl. oz. – 10 day		**21** **14** **16**	**1000** **1000** **1000**	**0** **0** **0**
	3 fl. oz. – 10 day		**18** **8** **21**	**1000** **1000** **1000**	**0** **0** **0**
Assail 70 WP	**2.3 oz. – 10 day**		**72** **13** **12**	**1000** **1000** **1000**	**0** **0** **0**
Assail 70 WP	**1.7 oz. – 10 day**		**17** **14** **17**	**1000** **1000** **1000**	**0** **0** **0**
Entrust	**1.9 oz. – 10 day**	**6/3**	**17** **7** **17** **10**	**1000** **1000** **1000** **1000**	**0** **0** **0** **0**
Entrust	**1.0 oz – 10 day.**	**4/4**	**12** **10** **20** **57**	**1000** **1000** **1000** **1000**	**0** **0** **1** **0**
GF-120 Bait Normal Site 1st or Re-treatment	**20 fl. oz. – 7 day**	**7/6**	**0** **0** **26** **32** **18**	**1000** **1000** **1000** **1000** **1000**	**0** **0** **0** **0** **0**
GF-120 Bait Very High 2006 Adult Population	**20 fl. oz. – 7 day**	**2/1** **12/1**	**98** **24**	**1000** **1000**	**12** **0**
GF-120 Bait Near an Untreated Tree	**20 fl. oz. – 7 day**	**1/1**	**25**	**1000**	**5**
GF-120 Bait Half Rate on Light Infestation	**10 fl. oz. – 7 day**	**3/3**	**18** **16** **41**	**1000** **1000** **1000**	**3** **10** **14**

Table 1. Results of 2007 Cherry Fruit Fly rate and bait/site situation trials.

A half rate of GF-120 was applied to trees that had been protected by full bait rates fort the prior two seasons, and appeared to be the most likely sites for a successful reduction of rate. All three sites treated with 10 fluid ounces / acre had a significant infestation in 2007, only somewhat lower than the degree of infestation we have seen in similar trees where treatment is suspended for one season

After-harvest efficacy trials: The emergence pattern indicated that CFF larvae were present with all three instars at the treatment date. In the most effective treatments, most of the few larvae that emerged came out during the first nine days after treatment, which indicates that very small percentage of the third and second instar larvae are were not controlled by the insecticide treatment. Judging by the number of larvae that emerged, about 100 percent of the fruit on the test tree was infested, most with more than one viable larva (table 2).

		Emergence Period – Larvae / Interval Day									Total Live Larvae	% of Untreated Control
Product	**Rate/A**	**7/1**	**7/3**	**7/5**	**7/6**	**7/9**	**7/11**	**7/13**	**7/16**	**7/18**		
Dimethoate	4 lb. ai	1.3	1	1	1	0.3	0.5	0	0	0	**11**	**2.4**
Dimethoate	3 lb. ai	1.7	1.5	1.5	1	0.7	0.5	0	0	0	**15**	**3.2**
Provado 1.6	8 fl.oz.	1.3	1	1.3	2	1	0.5	0	0	0	**15**	**3.2**
Provado 1.6	6 fl.oz	2.7	2	2.5	3	0.8	1	0	0	0	**26**	**5.6**
Provado 1.6	4 fl.oz.	2.3	1.3	3	4	2.7	1.3	0.5	0.3	0	**33**	**7.1**
Assail 70WP	3.4 oz.	4	4.5	5.5	6	2.7	2	1	0.7	0	**54**	**11.5**
Assail 70WP	2.3 oz.	3.7	6.5	4	7	4.7	2.5	1.5	0.7	0	**63**	**13.5**
Untreated	0	18	40	46	36	31	29	21	2.7	0	**468**	**100**

Table 2. **After-Harvest Control of Larvae Inside Fruit**. Emergence of cherry fruit fly larvae from 250 fruit treated on separate parts of the same highly infested tree June 28, harvested June 29, 2007.

All products tested appear to be acceptable replacements for dimethoate, the only product currently recommended for controlling larvae in fruit remaining on harvested trees. There was no significant difference of control between dimethoate and the highest rate of Provado (imidacloprid). The "post-infestation effect" observed within the chloronicotinyl insecticide class may give them an advantage as a pre-harvest product, as application may control newly hatching eggs or young larvae that may have slipped through earlier control programs. There is no mention of this effect or spray timing on any label on any of these products at this time.

Dimethoate is not a popular pre- or post-harvest choice, as it sometimes causes leaf yellowing, necrosis and drop. Dimethoate recently passed through a regulatory evaluation by EPA, and data from this trial was used as evidence that dropping the allowed rate from 4 to 3 pounds active ingredient per acre could result in less control. The current 4 lb. after-harvest rate was maintained.

Other effects: Though earlier application timing is recommended**,** Provado and Assail controlled black cherry aphid (Myzus cerasi) when used at rates and timings intended for cherry fruit fly control.

Despite as many as five weekly applications at higher than necessary rates, no treatment in this project has resulted in leaf marking, yellowing or shedding, fruit marking, or excessive mite flare-ups leading to significant leaf damage. Some moderate leaf symptoms induced by mite feeding were observable by late summer on some of the trees treated with up to five weekly applications of Provado, Assail, and Calypso. Many of the candidate products have not yet been tested on all common sweet cherry varieties, so, while there are no indications of these potential problems to date, potential for leaf drop sensitivity in some varieties, or marking of light colored cherries is unknown.

CONTINUING PROJECT REPORT **YEAR**: 1 of 2
WTFRC Project Number: CH-07-704

Project Title: Validation and **i**mplementation of the Northwest Cherry pm model

PI: Gary Grove
Organization: WSU-IAREC
Telephone/email: 786-9283, **grove@wsu.edu**
Address: WSU IAREC
Address 2: 24106 N Bunn Road
City: Prosser
State/Province/Zip WA 99350

Cooperators: Vince Jones

Total project funding request: **Year 1:**$43,419 **Year 2:**$47,167

Other funding Sources
Agency Name: Chemical companies
Amount requested or awarded: $23,000
Notes: DowAgro Sciences, Agra-Quest, Chemtura, BASF, Bayer

Budget 1:

Organization: Washington State University	**Contract Administrator:** ML. Bricker/S. Brock
Telephone:509-335-7667 /509 786 2226	**Email:** mdesros@wsu.edu/sabrock@wsu.edu

Item	2007	2008	
Salaries	28,309	30,657*	
Benefits			
Wages			
Benefits	9,710		
Equipment			
Supplies	1,700	1,700	
Travel	3,700	3,700	
Miscellaneous			
Total	$43,419	$47,167	

Footnotes: * Scientific Asst. @ 35%, Farmer 3 @ 23%

Objectives:

1) Continue model validation work on cv. 'Bing' and 'Sweetheart' and expand validation work to include other cultivars.

a. Determine the accuracy of the secondary infection risk index on Rainer cherries

b. Repeat studies designed to determine whether ascospore release and primary infection could result from the use of irrigation for frost protection.

2) Determine appropriate fungicides for use at critical points during mildew epidemics. In addition to repeating our 2007 work on overall program initiation, our 2008 work will also focus on identification of the most efficacious fungicide class for use at the onset of secondary inoculum production (i.e. when the model indicates disease onset *after* primary infection).

3) Determine optimal spray intervals for various fungicide classes under low, moderate, and high secondary mildew disease pressures as defined by the model's risk index. Identify potential interval variation across cultivars.

4) Establish online training resources for model usage and related powdery mildew management. Develop similar training material for distribution via DVD (and by extension, Podcasts).

Significant Findings (by objective):

1a. Under the weather conditions that characterized the 2007 growing season, the secondary infection risk index was found to be a reasonably accurate and *conservative* predictor of the both the initial occurrence and intensification of mildew in the orchard (Figure 1). The risk index was slightly more conservative on cv. 'Sweetheart' than cv. 'Bing'.

1b. Evidence was collected that irrigation water used for frost protection contributes to ascospore release (Table 1).

2. . The powdery mildew model and/or the results of detection studies were used to initiate and schedule subsequent orchard fungicide applications in 2007. Because of their unique modes-of-action, quinoline, QoI (strobilurin), benzimidazole, DMI, oil, sulfur, carbonate, and biological fungicides were evaluated for their efficacy when used to *initiate* fungicide spray programs upon primary infection. Spray programs were applied according to tree phenology or as specified by the primary infection component of the model and (in the case of 2007) the coincident initial detection using the molecular air sampling techniques. The secondary infection risk index was initiated at primary infection and subsequent spray intervals adjusted accordingly. For example (Figure 2), a DMI program initiated at the first primary infection identified by the model resulted in disease incidence and severity values of 2.4 and 28.4%, while programs initiated according to crop phenology were 4.0% and 27.0%, respectively. Four and 5 fungicide applications were made using the model and phenology based programs, respectively. Disease incidence and severity values in the model- were not statistically different from the phenology/calendar program. As stated in above, the class of fungicide chosen to *initiate* spray programs was not significant.

3. Studies to ascertain the appropriate interval between model-driven fungicide sprays commenced in 2007. In trials under high disease pressure (i.e. high risk indices), QoI, DMI, and sulfur fungicides appeared to provide excellent levels of control at 7- and 14- day intervals and acceptable controls at 21-day intervals (Table 2).

4. The powdery mildew model was incorporated into the AgWeatherNet web site in time for the 2007 growing season. Clients were given the choice of several model outputs ranging from simple to complex. The distribution of summary outputs using text messaging and automated PDF email was tested with user groups and will be utilized during the 2008 growing season. A regional disease

pressure map was also made available. Online training modules was developed using MS PowerPoint, Adobe Presenter, and SnapZ Pro. The basic model coding and model training modules will be provided to the WSU- DAS programmer once established and eventually be available through DAS.

Methods

Objective 1a. An additional year of orchard disease incidence and severity data (over more cherry cultivars) is required to increase the robustness and scope of the model. These studies will be conducted using ten, 3-tree/variety (cvs. 'Bing', 'Rainier', and 'Sweetheart') blocks of untreated trees. Blocks will be separated by at least one row of buffer trees. Foliar disease incidence (per cent of 25 shoots infected per tree) and severity (average % colonization of the terminal five fully expanded leaves on the 25 shoots) of each cultivar. A Burkard volumetric spore trap will be operated continuously in order to determine airborne spore populations. Dataloggers located in each block will provide continuous measurements of temperature, relative humidity, leaf wetness, and soil moisture and will be used to generate block-specific secondary infection risk indices.

Objective 1b. Two IAREC orchards separated by about 500 feet will be used for this study. Rotorod air samplers will be deployed in both orchards and operated continuously. Water will be applied (after bud break) in one of the orchards during a night when the risk of frost is high. The second orchard will serve as a control. Glass air sampling rods will be collected at sunrise, replaced, and the second set of rods collected when tree trunks are dry. Air samples will be evaluated for the presence of *P. clandestina* using specifies-specific primers and PCR.

Objective 2. Prediction-based fungicide programs will be initiated using each of the fungicide classes (DMI, QoI (strobilurin), quinoline (Quintec), benzimidazole (Topsin), sulfur, potassium bicarbonate, and narrow-range petroleum oil) currently available for powdery mildew management. The initial prediction-driven application will be made within 96 hours of the initial primary infection event identified by the model. In a second study, a DMI application will be made in response to predicted primary infection while the various fungicide classes will tested for efficacy at the critical epidemiological point of disease onset (a temperature-dependent lag phase exists between primary infection and disease onset). Applications subsequent to the applications made at primary infection and disease onset will consist of alternations of Quintec (quinoxyfen) and Pristine (pyraclostrobin/boscalid) at 14- day intervals or at intervals recommended by the risk index.

Objective 3. Appropriate application intervals will be determined for representatives of the carbonate, sulfur, QoI, DMI, quinoline, oils, and benzimidazole fungicides. These studies will be conducted on several varieties (Bing and others depending upon availability) in a cherry nursery near Quincy, or Moses Lake, WA. Although we cannot determine at this point in time what sort of weather conditions will be prevalent during the 2008 season, under nursery conditions copious amounts of genetically uniform plant material should be exposed to a high (early season) and low (midsummer) of disease pressures (and mildew inoculum) over the course of the growing season. Fungicides will be applied at 7,14, and 21 day intervals. Disease pressure will be determined by risk indices generated by the secondary infection component of the powdery mildew model. Biweekly evaluations of mildew severity will be obtained by determining the per cent leaf surface area colonized on the first 5 fully expanded leaves beneath the shoot apex on 5 trees per replication. We will use analyses of variance to determine appropriate fungicide application. These nursery studies should significantly accelerate validation and implementation of the model and the development of appropriate management recommendations.

Objective 4. Training models will be developed to familiarize industry personnel with the biological rationale and application of the mildew model and its utility in disease management. Adobe Presenter and SnapZPro will be used to create the web-ready training materials. The WSU-IAREC Viticulture

team has developed an online certificate program using this technology. Adobe Flash Player (a free software application available at http://www.adobe.com) is the only software required on client computers. Among other capabilities, Presenter permits the inclusion of audio and video in PowerPoint presentations and converts them to platform-independent .swf (Flash) files. Screen movies that simulate real-time online model configuration and execution will be made using SnapZ Pro software. Movies will be converted to Flash formats for web distribution.

Results and Discussion

Primary infection was predicted and occurred on 1 May 2007, which initiated the secondary infection component (risk index) of the model. Disease onset was predicted on May 12. The first macroscopic symptoms on cvs. 'Bing' and 'Sweetheart' were observed on May 16. High levels of risk (short spray intervals) persisted from that point through harvest and then declined with the onset of summer heat (Figure 1). The rate of foliar disease increase on 'Bing' was slightly more rapid than increase on 'Sweetheart'. Fruit infections were not observed on either cultivar. The model was *conservative* under the growing conditions of 2007.

Water-based frost protection was applied to some (but not all) IAREC cherry orchards on 2,3, and 5 April (Table 1). Rotorod air samplers were operated continuously through water-application periods and during drying periods the following day. Using PCR, powdery mildew was detected in the air during occasionally during watering but more frequently during the following morning. Powdery mildew was not detected in the orchard air prior to the application of irrigation water or during cold evenings when water was not applied. Although additional work is needed in order to determine the effect of morning temperatures on the ascospore release phenomenon, it appears that irrigation water can promote ascospore release and that temperatures the following morning may be critical.

Weather- and detection-based fungicide programs were initiated on 4 May in response to a (1-2 May) rain event that promoted primary infection (0.15" of precipitation at 54 F). The fungicide mode of action (class) used to initiate fungicide programs had no significant effects on disease incidence and severity (Figure 2) at harvest. Disease severity was 40.5% on the untreated controls and ranged from 2.4% (Rally initiation) to 4.0% (Microthiol). Disease incidence was 86.8% in the untreated control and ranged from 21.5% (Quintec) to 37% (Stylet Oil).

QoI, DMI, and sulfur fungicides provided the best levels of control on cv. 'Bing' and at 7- and 14-day intervals; the best level of control at 21-day intervals (Table 2) was provided by Pristine. QoI, DMI, and sulfur fungicides provided the best levels of control on cv. 'Sweetheart' and at 7- and 14-day intervals; the best level of control at 21-day intervals was provided by Procure or sulfur. Disease severity in the untreated controls was 59.2% and 49% on cvs. 'Bing' and 'Sweetheart', respectively. At 7 day intervals severity ranged from 13.6% (Flint) to 49.4% (Sonata) on 'Bing' and 5.8% (Flint) to 45% (Kaligreen) on 'Sweetheart'. At 14 day intervals severity ranged from 16.3% (Flint) to 57.2% (Sonata) on 'Bing' and 6.4% (Flint) to 39.8% (Kaligreen) on 'Sweetheart'. At 21 day intervals severity ranged from 17.4% (Flint) to 48.0% (Sonata) on 'Bing' and 13.9% (Procure) to 61.3% (Kaligreen) on 'Sweetheart'. A most interesting finding was the relative effectiveness of sulfur on 'Sweetheart' at the longer spray intervals. It is the vapor phase of sulfur that provides fungicidal activity and is possible that in 2007 temperatures that kept the risk index high also provided the proper temperature range for fungicidal activity. However, it is unclear whether it is the temperature at the time of application or afterwards that provides the most effective promotion of the vapor phase of sulfur. Although the excessive use of sulfur may have deleterious effects on beneficial insects, it represents a low-cost organic option for the cherry grower, particularly on later varieties that require more lengthy spray programs. *The relatively poor performance of Quintec at all spray intervals was due to a rate calculation error.*

Due to personnel constraints that precluded timely inclusion of the full 2007 model on WSU-DAS, the model was made available on AgWeatherNet. Based on input from user groups model outputs

were made available in a variety of formats ranging from simple/brief to more complex. A regional summary was also developed (Figures 3 and 4). Coding used for summary outputs will be made available to the new WSU-DAS programmer for inclusion on the site for the 2008 season. All model outputs are hyperlinked to management information on disease biology, model rationale, and disease and fungicide management options. Training modules were developed using Microsoft PowerPoint, Adobe Presenter, and SnapZ Pro. Audio was added to PowerPoint slides and slide shows converted to Adobe Flash movies using Presenter. SnapZ Pro was used to produce screen movies that actual depict real-time configuration of, and navigation through, the web-based model.

Table 1. Effect of early season irrigation (used for frost protection) on ascospore release by *P. clandestina*.

Date	Orchard	Water Applied	PCR Signal Strength	Comments
4/2	D39[1]	Yes	Bright	
4/2	D51[2]	No	Faint	Water applied in adjacent orchard
4/3	D39[1]	Yes	Bright	
4/3	D51[2]	No	Faint	Water applied in adjacent orchard
4/5	D39[1]	Yes	Bright	
	D51[2]	No	Faint	Water applied in adjacent orchard
4/10	D39[3]	No	None	
	D51[3]	No	None	
4/12	D39[3]	No	None	
	D51[3]	No	None	

[1] water used for frost protection within orchard;[2] water not used for frost protection, but was applied in orchard 500 feet away ; [3] water not used in test or adjacent orchards

Table 2. Disease severity on cvs. "Sweetheart' and 'Bing' when various fungicide classes were applied at 21 day intervals. Disease pressure was high. Severity values followed by common letters are not significantly different according to Fischer's Protected LSD.

Fungicide	Class	Severity (Sweeheart, %)	Severity (Bing, %)
Kaligreen	Carbonate	61.3 a	41.4 abcd
Untreated	-	40.0 a	59.2 a
Sonata	Biological	32.2 bc	48.0 abc
Stylet Oil	PDSO	27.1 bc	41.4 bcd
Quintec (see text)	Quinoline	25.1c	52.2 ab
Pristine	QoI (Strobilurin)/anilide	22.4c	17.4 d
Topsin	Benzimidazole	21.4c	38.2 bcd
Flint	QoI (strobilurin)	15.6d	22.6 d
Microthiol	Sulfur	14.8d	30.1 cd
Procure	DMI (Imidazole)	13.9d	23.4 d

Figure 1. Model risk index and disease incidence on cherry cultivars 'Bing' and 'Sweetheart' at Prosser, 2007. Primary infection occurred on May 1.

Cherry Mildew Model Risk Index and Disease Incidence
Bing and Sweetheart Cherries, Prosser 2007

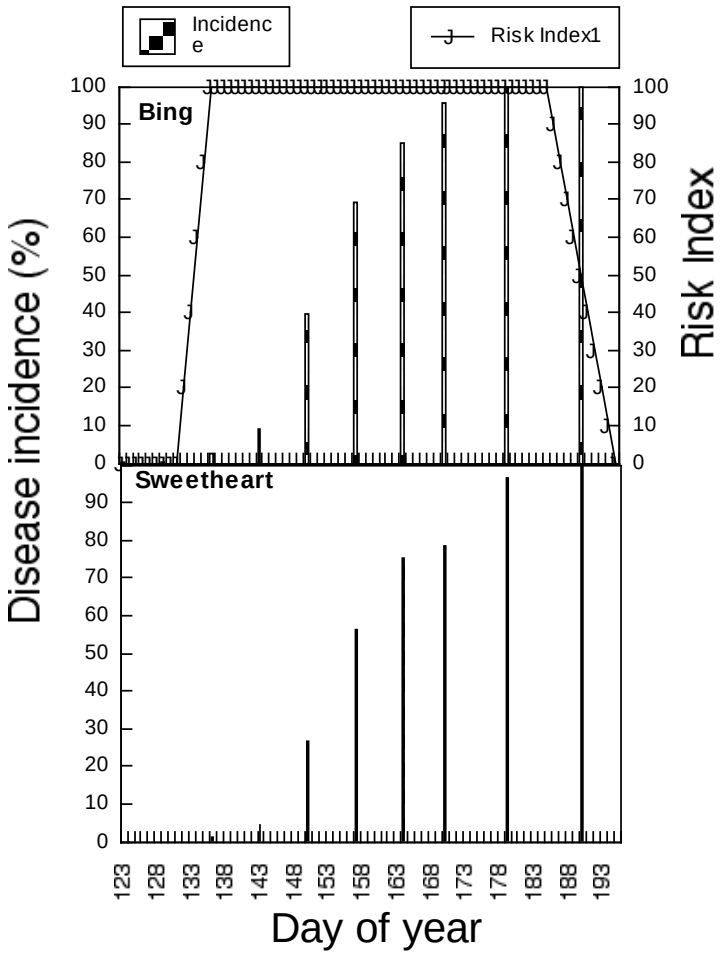
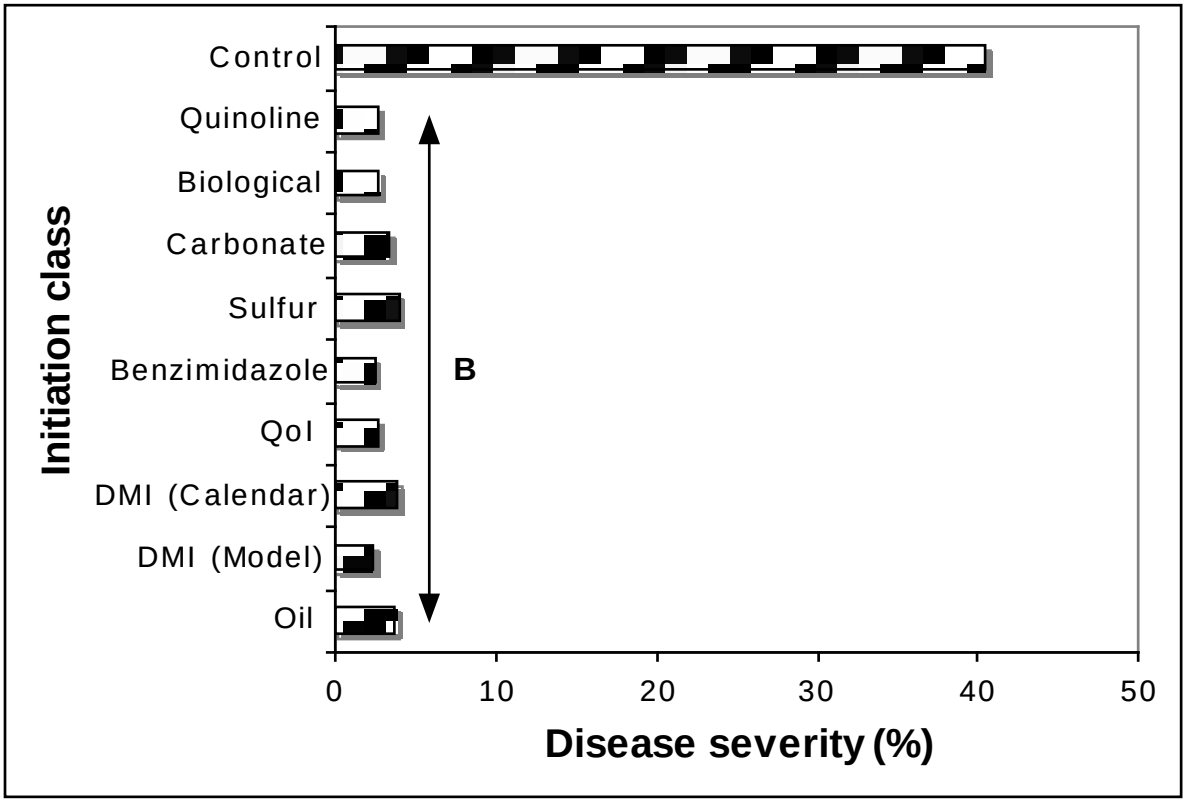


Figure 2. Powdery mildew severity on cv. 'Bing' cherry when fungicide programs were initiated using various fungicide modes-of-action (classes). Compounds followed by common letters are not significantly different according to Fischer's Protected LSD.



CONTINUING PROJECT REPORT **YEAR**: 1 of 3
WTFRC Project Number: CH-07-705

Project Title: Managing virus diseases detrimental to cherry production
PI: Ken Eastwell
Organization: Washington State University
Telephone/email: 509-786-9385/kestwell@wsu.edu
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City: Prosser
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Cooperators: Mr. Bill Howell, Manager, NRSP-5, WSU-Prosser, Dr. Matt Whiting, WSU-Prosser, Dr. Tom Unruh, USDA-ARS, Wapato, Dr. Wee Yee, USDA-ARS, Wapato, Dr. Lauri Guerra, WSDA, Prosser

Total project funding request: Year 1: $36,938 Year 2: $38,823 Year 3: 39,919

Other funding Sources
Agency Name: ANLA/HRI
Amount requested or awarded: $132,000
Notes: WSU is including this information on other funding available for the support of similar research undertaken by the faculty member proposing this research. These resources are listed to identify other support granted for this research and are not included as a commitment of cost-share by the institution.

Budget 1:
Organization Name: Washington State University **Contract Administrator:** ML. Bricker
Telephone: 509-335-7667 **Email address:** mdesros@wsu.edu

Item	2007	2008	2009
Salaries	15,523	**$16,292**	$16,944
Benefits	6,324	**$6,983**	$7,263
Wages	3,400	**$3,536**	$3,677
Benefits	391	**$587**	$610
Equipment			
Supplies	11,000	**$11,125**	$11,125
Travel	300	**$300**	$300
Total	36,938	**$38,823**	$39,919

Footnotes: Itemized cost requirements for Year 2:

The proposed budget for 2008 contains a modest increase from the $38,089 originally proposed for year 2. This reflects a greater than anticipated increase in State mandated salaries and benefits.

Salaries and benefits: 0.3 FTE Associate in Research and 0.2 FTE Nursery Specialist.

Wages: 400 hours of time slip labor.

Supplies: greenhouse and field supplies ($1,000); molecular biology reagents and disposables ($4,800); production of antibodies ($5,325).

Travel: to domestic plots and grower orchards.

Objectives:
Viruses induce losses over the life of an infected tree; recurring annual losses are cumulative and have a significant negative impact on the economic viability of farm operations. Despite past progress, some viruses that affect cherry production continue to challenge efforts to minimize their negative impact on profitability. Those that continue to be problematic from a management perspective include the viruses associated with little cherry disease, cherry leafroll, cherry raspleaf and the rusty mottle group of viruses (foveaviruses). Specific objectives include:

1. Development of laboratory tests to increase grower accessibility to rapid virus diagnosis. The ability to correctly identify the underlying cause of poor fruit production is required in order for growers to take appropriate corrective measures.
2. Development of alternative methods of managing viruses with particular reference to viruses where root-grafting and/or nematode transmission play significant roles in disease epidemiology. Rootstock selection may offer relief from the soil borne viruses.

Significant findings:

- Using sequence information derived from comparisons of North American and Eurasian isolates of little cherry virus 1, we developed and validated a reliable molecular assay for little cherry virus 1 that detects isolates from WA, CA, PA, Canada and Eurasia. This is the first reliable method for detecting this disease agent.
- Evaluation of symptomatic trees in WA indicate that little cherry virus 1 is more common in diseased trees than previously recognized, and little cherry virus 1 was identified in three major cherry producing counties of WA.
- Coat proteins of the virus isolates that cause cherry raspleaf are diverse making reliable detection difficult.
- Four new variants of members of the rusty mottle group of viruses (foveaviruses) were identified. This data confirms the growing incidence of these viruses in commercial cherry production and results indicate that the "universal" foveavirus primers that we developed are able to reliably screen for the diverse members of this family of viruses.
- Data from controlled experiments provide additional evidence that cherry leafroll virus is pollen transmitted in sweet cherry.

Methods:
Objective 1. Working with growers and fieldmen, we examine new disease situations to identify the causal agent, if present. Often, as is the case with little cherry disease, the only "symptom" is poor fruit yield and quality. If a viral agent is suspected based on symptomatology, disease distribution, and orchard data, samples are characterized at the molecular level for the presence of pathogens. This information forms the basis from which assays and management strategies can be developed.

Objective 2. For the management of soil-borne viruses, 'Bing' trees are produced on various rootstocks and rootstock/interstock combinations. The rootstocks and the scions will be inoculated with cherry leafroll virus or cherry raspleaf virus on separate trees. Trees will be evaluated for sensitivity and reaction to the same viruses. Combinations of rootstocks/interstocks/scions will be established to evaluate horticultural performance.

Results and discussion:
Objective 1. Development of laboratory tests to increase accessibility to rapid virus diagnosis.
There is ever increasing emphasis on large fruit size in the sweet cherry marketplace. All viruses divert resources from tree growth and fruit production to virus replication, but the degree to which this affects returns on fruit production depends on the virus and the tree cultivar. There are several virus diseases that directly impact efforts to produce better quality fruit. While the consequences of little cherry virus 2 (LChV2) have been know for many years, the less dramatic negative effects of

little cherry virus 1 (LChV1) may have gone unrecognized. We developed and evaluated a molecular assay for LChV1 to help in the effort to delineate the occurrence of this virus in the PNW. The assay was validated by obtaining samples from CA, PA, Turkey and Canada. As the assay was being developed, several locations were identified in WA that were also affected by this disease. The new assay detected all recognized isolates from these sources. Genetic analysis confirms the diversity of the virus genomes, and partially accounts for the difficulty in developing molecular assays. Prior to our studies, the only sequence information available was derived from Eurasia. Phylogenetic analysis (Figure 1) demonstrates that these virus isolates are quite distinct from those detected in North America. Significant changes in nucleotide sequences defeat molecular assays commonly in use.

Figure 1

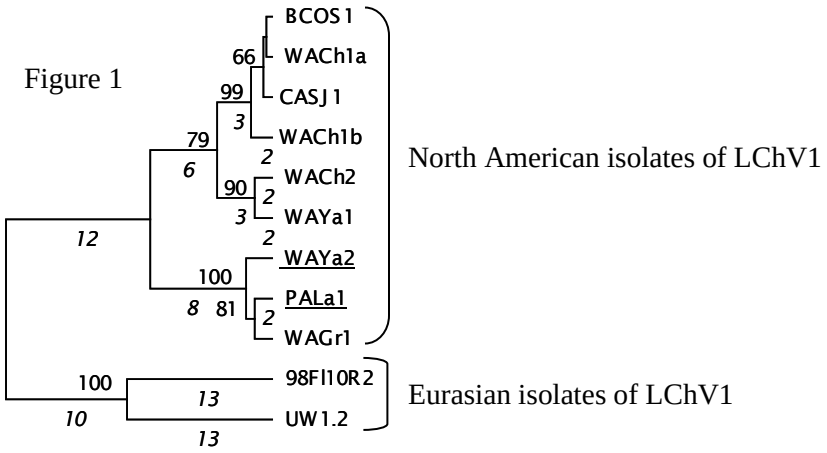

Figure 1. The cladogram of sequences from the replicase region of little cherry virus 1 isolates showing branch lengths in proportion of total sequence difference (italics) and bootstrap reliability estimates. Isolates from WA are identified according to the county in which the isolates were detected.

During the process of scouting for possible virus infections, we identified LChV1 in three major sweet production counties of WA State (Grant, Chelan, Yakima) (Table 1) in orchards operated by five different growers. Significant variability was observed in the sequences obtained from within WA. However, the newly developed molecular assay revealed LChV1 in 21of 48 of the orchard trees assayed and in all of our positive control trees. Note that in two orchards, mixed

Table 1. Incidence of the viruses associated with little cherry disease in orchards with poor production.

Orchard designation and county	**Trees with**		
	LChV-1 only	**LChV-2 only**	**Both LChV-1 +LChV-2**
WAYa1, Yakima Co.	4/4	0/4	0/4
WAYa2, Yakima Co.	3/13	6/13	0/13
WACh1, Chelan Co.	2/10	3/10	1/10
WACh2, Chelan Co.	0/3	0/3	1/3
WAGr1, Grant Co.	10/18	0/18	0/18
Total Positives/Total Assayed	**19/48**	**9/48**	**2/48**

infections of LChV1 and LChV2 were identified in a single tree. The combination of these two viruses had a synergistic effect with very severe reduction in fruit size and reduced tree vigor

Although the RT-PCR assay utilized in the above study was effective, a faster and more economical assay system is needed. A system such as ELISA, where antibodies are used to detect virus protein instead of molecular RT-PCR type assays for detecting the virus RNA, would be very useful. In the process of developing an antibody based method, we produced approximately 150 hybridomas that secreted monospecific antibodies reacting to bacterially expressed coat protein of LChV1. Using tissue from trees identified in the above molecular studies, these antibodies were screened for effectiveness to detect LChV1. Knowledge of the diversity of LChV1 isolates allowed us to screen antibodies for reactivity across the most distantly related strains. Thirteen of the cell lines reacted with leaf extracts of isolates WACh1a from Chelan county, WAYa1 from Yakima county or 98FI10R2 from Turkey. Eight antibodies reacted with all three virus isolates, and 5 others reacted with a subset of these LChV1 isolates. Further development of an ELISA system that capitalizes on these antibodies continues.

In parallel studies, hybridomas were also produced to coat protein of LChV2. We isolated two hybridoma cell lines that produce antibodies that recognize LChV2. The performance of these antibodies in ELISA has been disappointing. While further evaluation continues; another attempt to obtain hybridomas was initiated.

The potential to detect both viruses associated with little cherry disease by relatively economical ELISAs is still very exciting. Further validation and test development is required to insure that diagnoses utilizing these antibodies are reliable. We now have access to virus isolates from diverse sources to evaluate the universality of these assays.

Using strategies as described above, we are developing serological tests for cherry raspleaf virus. Symptoms of cherry raspleaf virus and the rugose strains of Prunus necrotic ringspot can be easily confused. Because these viruses are transmitted through very different mechanisms, it is important to differentiate between these causal agents when such symptoms are observed in commercial plantings. ELISA tests for Prunus necrotic ringspot have been employed for routine screening of orchard trees for many years. However, current serological assays cannot distinguish between mild strains and the severe rugose mosaic strains. A positive test result does not necessarily mean that the rugose mosaic strain is causing the observed symptoms. Consequently, the ability to identify cherry raspleaf virus is important. We evaluated different extraction buffers, plate composition and assay format to discern a protocol that permits accurate detection of cherry raspleaf virus from various sources in cherry leaf extracts. Antibodies produced by four different hybridomas detect multiple isolates of cherry rasp leaf virus when the virus is initially trapped by polyclonal antibodies also produced in our program. One of the antibodies detected multiple isolates in a plate trapped antigen format. The antibodies will be screened further next season to validate their utility for virus detection.

Many of the rapidly expanding numbers of viruses associated with the rusty mottle group of foveaviruses that are being found in Pacific Northwest orchards are associated with redcued productivity of cherry. The diseases include cherry rusty mottle, cherry necrotic rusty mottle, cherry twisted leaf and Montmorency stem pitting. At least some of these diseases spread naturally in cherry orchards, apparently via aerial vectors. It is assumed, although not proven for all members of this group, that reservoirs of these viruses in native vegetation further complicate efforts to control them. Consequently, these viruses can have very serious local consequences on cherry production. In many cases, the symptoms resemble those of adverse physiological conditions. The ability to confirm the presence or absence of the foveaviruses would greatly aid growers in properly ascertaining the underlying cause before initiating a proper response to declining trees. We made great progress in characterizing the sequences of the coat proteins of foveaviruses found in cherry. In the case of Montmorency stem pitting virus, this information has already been used to develop polyclonal antibodies for use in ELISA. Success with the antibodies produced in this manner provides great optimism for further refining and developing robust serological assays for the foveaviruses of cherry.

Impact: All of the virus diseases described above are present in the cherry production areas of the PNW, and generally, the awareness of their presence is increasing. It is unclear whether this is the result of greater market emphasis on premium fruit, increased numbers of infected trees, or better awareness of growers of the potential impacts of virus infection. The diseases associated with these viruses often resemble physiological conditions. Therefore, it is critical to understand the underlying cause of poor cherry production and tree growth. The incorrect diagnosis would result in ineffective and, frequently, costly investments in remedial treatments with little or no relief from poor production. Correct diagnosis of a viral agent allows the grower to make better economic decisions about managing his investment.

Objective 2: Development of alternative methods of managing viruses.

Our research on the epidemiology of cherry leafroll virus demonstrated that transmission through root grafts is an important route of tree-to-tree spread within an orchard. We wish to study the use of genetically diverse rootstocks that may provide field resistance to cherry leafroll virus. This could minimize or even eliminate this significant route of infection. An on-going trial of a small number of 'Bing' planted on 'Colt' rootstocks in cherry leafroll virus-infested orchards have not become infected after five years whereas two-thirds of trees on Mazzard have become infected, some within the second growing season. The difference was not related to bloom because all flowers that developed were quickly removed during the four years of this study. This suggests that 'Colt' offers some protection to root-graft transmission of cherry leafroll virus in the field setting. At this time, it is unknown if the 'Colt' rootstock is immune to cherry leafroll virus, if 'Colt' retards movement of virus from root grafts to the scion, or if 'Colt' is recalcitrant to root grafting. Anecdotal evidence from researchers in Colorado and California suggests that 'Colt' may also offer some field resistance to cherry raspleaf virus. This has not been addressed in a rigorous manor. The movement of cherry raspleaf virus in various rootstock, interstock and scion combinations as described above will be examined using the diagnostic tools developed in objective 1 of this project.

To investigate the potential of rootstocks to offer field resistance to soil-borne viruses, 132 trees on rootstocks and rootstock/interstock combinations were propagated and planted. Rootstocks include 'Colt', 'Krymsk 7', 'Krymsk 6', 'Krymsk 5', Zee-stem interstocks on Citation, Gisela 12, Gisela 5, Gisela 6, and Zee-stem interstocks on Myro plum. Mazzard and mahaleb rootstocks are included for reference. These have been budded with 'Bing' scion. Additional trees will be produced with 'Colt' rootstock and either Gisela 6 or Zee-interstocks. Once established and budded to 'Bing', all rootstocks will be evaluated for sensitivity and reaction to cherry leafroll virus and cherry raspleaf virus. Individual trees will be inoculated on the rootstock or on the scion to indicate field responses that could be expected from root grafting or from aerial transmission. Combinations of 'Bing' on 'Colt' with Gisela 6 or Zee-stem interstocks will also be established in horticultural trials to determine if the interstock counteracts some of the negative production characteristics associated with 'Colt' rootstock.

Potential pollen transmission of cherry leafroll virus is also being examined. Previous research has demonstrated that pollen from virus-infected trees carries infectious pollen particles. During the 2006 growing season, we pollinated 800 blossoms (100 blossoms on each of eight trees) with naturally virus-laden pollen. Molecular assays and immunolocalization assays indicated that cherry leafroll virus was transferred from the pollen grains and could be detected in the stems of developing fruit. Unfortunately, a late frost at the research site damaged the blossom and prevented successful pollination of the flowers. Consequently, the progress of virus infection could only be followed until the unfertilized blossoms were cast off. At shuck-fall, cherry leafroll virus was detected in 50% of the pedicels of blossoms that had been exposed to virus-infected pollen (Table 2). Despite the premature loss of potential infection sites, assays in the spring of 2007 revealed that cherry leafroll virus was transmitted to at least one branch of every tree exposed to virus-infected pollen. Pollen transmission experiments were repeated again in 2007 with much greater success in fruit production.

Pedicels and fruit spurs were collected and extracted for analysis by molecular assays and embedded for immunolocalization by confocal microscopy; samples are still being analyzed.

Table 2. Detection of CLRV by RT-PCR in pedicels at shuck fall stage after hand pollination. Samples were collected May 9, 2006 from the USDA Moxee orchard.

Treatment	**RT-PCR results** ***pedicels positive / pedicels tested***
Uninfected 'Van' flower pollinated with CLRV-infected 'Bing' pollen	11/20
Uninfected 'Bing' flower pollinated with mix of CLRV-infected 'Bing' and healthy 'Van' pollen	9/20
CLRV-infected 'Bing'	5/5
CLRV-free 'Van'	0/5

Impact: Cherry raspleaf virus is a nematode transmitted virus of sweet cherry trees with a wide host range. Its distribution is quite restricted; however, where it does occur, it is devastating. The host range includes apples and a number of weedy plants common in orchard flora. In combination with the nematode vector, this means that options are very limited to the grower. The identification of rootstocks that offer field resistance to nematode transmission will provide the growers with the first real option for disease management. The use of interstocks to improve the horticultural production on the virus resistant rootstocks is an important component of this project.

Cherry leafroll virus continues to be a challenge in Washington's cherry production areas. Information obtained in our project has already had a large impact on industry-wide operations in an effort to control this virus. However, much more information is needed to allow growers to respond to the threat of this virus. Minimizing transmission via root grafting will slow the spread of the virus and its associated economic losses within infested orchards. Awareness of the potential aerial transmission of this serious virus also aids in management of the disease. Results from the first year of detailed studies provide very strong evidence that pollen is an important aerial route for transmission of cherry leaf roll virus.

CONTINUING PROJECT REPORT **YEAR**: Continuous

Project Title: Horticultural management systems for high value fresh and brine cherries

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Cooperators: Don Nusom; John and Karen Carter; David, Karen and Stacey Cooper; Mike, Mel and Linda Omeg; John McClaskey; and Wayne Worby.

Budget 1:
Organization Name: Agricultural Research Foundation **Contract Administrator:** Dorothy Beaton
Telephone: 541-737-3228 **Email address:** dorothy.beaton@oregonstate.edu

Item	**Last Year :** 2006	**Year 2:** 2007	**Year 3:** 2008
Salaries (1.0FTE)		25,350	35,600
Benefits (67%)		17,000	23,852
Wages (1 students)			
Benefits			
Equipment			
Supplies			
Travel			450
Miscellaneous (plot charges)		7,800	7,625
Total	45,000	50,150	67,527

Footnotes:

Objectives:

1. Identify cherry cultivars and rootstocks suitable for the processing cherry industry (e.g. brine, freezer) and those that may have potential for fresh market production in the Willamette Valley and cooler cherry growing districts.
2. Evaluate the effects of training system, rootstock and variety on tree performance, fruit quality and yield.
3. Refine and test growing degree hour (GDH) model for fruit growth in 'Bing', 'Sweetheart' and 'Regina' sweet cherry using information solicited from Washington and Oregon growers. Participate in a larger scale data collection and distribution system that alerts growers to crucial production dates.
4. Evaluate alternative cherry cropping systems (ie. protected culture and alternative orchard floor management) for orchard performance and profitability.

Significant findings and results

1. *Rootstock and varieties*

a. *2002 PiKu 1 and 3 trial*- Many PiKu 3 trees did not come into production until the fourth leaf (2005) while PiKu 1 trees began bearing in the third leaf. In 2006, PiKu 3 trees had higher yields than PiKu 1 in all varieties except 'Royal Ann', 'Skeena' and 'Sweetheart'. Mid-bloom freezing temperatures and frosts resulted in no measurable yields during 2007. *Pseudomonas* incidence was very high and PiKu 1 trees began dying in spring followed by later season death in PiKu 3. Cumulative mortality on PiKu 1 was 70%. 'Skeena', 'Sonata' and ' Black Gold' had 100% mortality on PiKu 1. PiKu 3 trees died only in 2007 and had a final mortality of 23%. There was no mortality in 'Royal Ann'. This trial was removed as a result of disease incidence and unacceptable growth and performance of the trees.

b. *2002 'Sweetheart'/MxM trial*- MxM60 and MxM2 trees have the largest trunk cross sectional area (TCSA) (Table 1.) MxM14 has 55% of the girth of MxM60. Yields were similar, while yield efficiency was lowest for MxM60 trees. Fruit firmness and stem pullforce was not affected by rootstock. Seventy seven percent of fruit was graded as 'Fancy', 2% 'Choice' and 21% 'Stemless'. Trees exhibit only few symptoms of bacterial canker.

c. *2002 Top-worked mechanical harvest trees* – The greatest change in TCSA occurred on MxM60 for all cultivars, followed by MxM14, Mazzard and Giessen 196-4 (Table 2). Only 'Stardust' yielded enough fruit for harvest and firmness evaluation. The 'Stardust' packout was 86% 'Fancy', 11% 'Stemless' and 3% 'Choice'. There were no culls. Firmness ranged 354 to 371 g/mm with no significant difference between rootstocks. Although MxM14 had the lowest stem pull force, all fruit had a stem pull force greater than 1.1 kg/cm^2. Cracking was predominantly on the nose ranging from 7-11%. Average fruit size was 24 mm with soluble solids ranging from 17.1 to 18.3 Brix. 'Sweetheart' packout was 70% 'Fancy', 24% 'Stemless' and 6% culls. Stem pull force was not as high as 'Stardust' but still at least 1 kg.

d. *2003 'Skeena'/Krymsk rootstock trial* – Krymsk 6 trees had the largest TCSA (107.8cm^2) and a loss of one tree. Krymsk 5 (88.8 cm^2) trees have a similar TCSA as Gisela 6 (93.0 cm^2), had 60% mortality, and trees sucker. Mazzard (83.6 cm^2) trees have similar TCSA to both Gisela 6 and Krymsk 5 trees.

e. *2005 'Regina' rootstock trial* – Although there was no significant difference between vigor, Gisela 5 and 12 had the greatest increase in TCSA (13-14 cm^2) followed by Mazzard and Gisela 6. Mortality, due to cool spring temperatures during bloom and increased *Pseudomonas* pressure, occurred in three Mazzard and one Gisela 6 tree.

f. *2006 NY blush and variety trial on Gisela 6* – The 10 numbered Cornell (NY) selections, 'Rainier', 'Regina' and 'Skeena' grew well in their second season. TCSA and annual increase in TCSA were measured at three locations: Lewis-Brown Farm, OSU, Corvallis; Cooper Orchards; and Omeg Orchard in The Dalles. Although some trees flowered and data was taken on bloom time, we have limited confidence that the data will reflect performance as trees mature. NY2068 will, however, be interesting to observe as it appears to bloom after 'Regina'.

g. *2006 Dark cherry cultivar and rootstock trial*- Trees grew well but again it is too early to determine substantive differences between rootstocks at the three locations, Corvallis (1) and The Dalles (2). Trees at the Cooper Orchards grew significantly larger than at the other two locations.

h. *Pseudomonas trial*- Trees of 'Sweetheart', 'Sylvia', 'Bing', 'Regina' and unbudded on Mazzard, Gisela 6, Giessen 196-4 and unbudded controls were planted at Mid-Columbia Agricultural Research and Extension Center (MCAREC). Robert Spotts, Professor of Botany and Plant Pathology, will maintain, inoculate and continue observing for symptoms of infection.

2. *Training systems*

a. *2003 Training systems and rootstock trial trees* – In their fifth leaf, all three cultivars trained to a multiple leader had greater vigor and yield than central leader trees (Table 3). Central leader trees have a larger TCSA on MxM14, while multiple leader trees are larger on Gisela 6. Central leader

'Stardust' trees yielded more on MxM14 while Gisela 6 trees produced the highest yields on multiple leader trees. Stem pullforce did not differ significantly at harvest but after two weeks in storage, fruit from Gisela 6 trees had higher stem pullforce measurements for both CL and ML trees (data not shown). There was mass mortality among Gisela 6 and Giessen 196-4 trees, especially in 'Stardust' which led to the removal of this cultivar from the trial. The modified Tatura trellis does not fare well in Willamette Valley conditions. This is primarily due to the incidence of bacterial canker that occurs where trellis wires rub the trunk. A frost at bloom severely affected the flowers of 'Sweetheart' resulting in no crop.

b. *2006 On-farm training systems trial* – Steep leader trees of 'Early Robin' on Gisela 6 were more vigorous than central leader trees, followed by multiple leader trees (Table 4). 'Rainier' steep leader trees grew more in girth in 2007 than central leader trees. Trees are well established at both on-farm trials.

3. *Growing degree hour model*- Producers made gibberellic (GA) applications close to our predicted "beginning of stage III" biofix for 'Bing', 'Regina' and 'Sweetheart' (Fig. 1). Although harvest continues to be a more difficult value to agree upon partly due to the window of harvest that is influenced by threat of rain and prices, the data collected from actual harvest dates from 3-5 different orchards per cultivar indicates a potential to better predict harvest. The range of GDH from peak bloom to harvest for 'Bing', 'Regina' and 'Sweetheart' were 19,000-20,500 (~5 days); 20,500-22,500 (~7 days); and 21,000-23,000 (~5 days), respectively. Although grower cooperation is present, work demands near bloom time often precluded recording crucial peak bloom dates for our model verification.

4. Alternative cropping systems

a. *Protective culture and spectral light management*- A windstorm during November 2006 destroyed the tunnels which were rebuilt by March 2007 (Fig.2). 'Early Robin', 'Rainier', and 13N07-39 trees on Gisela 6 rootstock completed their second growing season under the tunnels. Ten 'Royal Rainier' trees were planted as additional pollinizers and for observation for suitability under protected culture. Three different colored nets of red, blue and pearl were installed in March 2007 to alter light quality. Another application of 10cm of bark mulch was applied in April 2006. Plastic and net were removed October 5, 2007. There was no significant difference in TCSA for any cultivar under any color except 'Rainier' exhibited a slightly higher vigor without color netting. Leaf area and greenness were highest under blue shadecloth. There was no statistical difference for number of leaves, internode length or shoot length for any treatment. 'Rainier' was the only cultivar to show a difference in TCSA which was highest under no netting, the control. Temperature data under the different colored netting reveals pearl and control to be hottest from 7 am to 6 pm, while red is coolest during these hours and blue is coolest from 8 pm to 6 am. Powdery mildew became a problem in late summer to upper branches.

b. *Alternative orchard floor and fertility management* – There was a significantly higher number of fruiting spurs in the spring on trees grown on the landscape cloth. Although trees on landscape cloth were larger at the beginning of the season, there were no differences in TCSA at the end of the growing season between the landscape cloth and the compost treatments. Particulate organic matter (POM)-C is increased at both depths under bark mulch treatments compared to the landscape cloth. Higher nitrogen mineralization potential was observed on compost treated rows while soil nitrate concentrations decreased (Fig. 3 and 4). Sensitivity of POM to detect management changes is dependent upon "quality" (i.e., C:N ratios) of organic amendment. The value of POM as an indicator of N mineralization potential was weakened when using low quality (high C:N) materials. Enzyme responses were more sensitive to POM but enzyme dependent, supporting multiple-enzyme analyses. Application of bark or straw mulch may immobilize N (tree data support this). Application of straw mulch did not result in increased soil organic carbon (SOC) nor POM-C and results suggest a stimulation of microbial activity (priming?).

Materials and methods:

- Train trees, maintain orchard and obtain data on yield, fruit size, tree vigor, bacterial canker tolerance and other relevant data from the existing cherry trials (3.05 ha) which include:

  Lewis-Brown Farm Trials
  2002 'Sweetheart'/MxM rootstock trial (0.12 ha)
  2002 Topworked mechanical harvest trial (0.90 ha)
  2003 Training systems and rootstock trial (0.33 ha)
  2003 Skeena/Krymsk rootstock trial (border planting)
  2005 'Regina' rootstock trial (0.10 ha)
  2006 Dark cherry cultivar and rootstock trial (0.20 ha)
  2006 NY blush and dark cherry cultivar trial (0.20 ha)
  2005 Alternative fertility management trial (0.60 ha)
  2006 Protective culture and light spectral management (0.60 ha)
  On-Farm Trials
  2006 Dark cherry cultivar and rootstock trial- Omeg and Cooper
  2006 NY blush and dark cherry cultivar trial- Omeg and Cooper
  2006 Training systems trial- Carter and Morgan

- Continue testing and refine *Growing Degree Hour* model of cherry fruit growth. Test models over several sites where weather stations are located. Collaborating orchardists in Oregon and Washington will provide peak bloom, GA application and harvest dates.

- *Alternative cropping systems-*
  - Alternative orchard floor and fertility management- The USDA competitive grant is covering the cost of all activities and services and supplies with the exception of the plot charges for 0.6ha and the in-kind match of 0.25 FTE of Annie Chozinski's salary. Biological and economic effects of two different methods of orchard floor and fertility management during orchard establishment and early production are being compared. The research orchards of 'Regina' on Gisela 6 were established in 2005. Geotextile cloth and straw/bark mulch followed by compost are used in the tree row. Plots are planted in two locations: Lewis-Brown (LB) Farm (Corvallis) and MCAREC (Hood River). Trees are being pruned and trained to a central leader system. Soil water content and quality are being measured at the LB Farm; leaf analyses performed; soil chemistry, physics, and biology (organic matter, nematode, enzymes and molecular) characterized; and tree performance evaluated at both locations. In addition, 13 commercial orchard sites are being sampled to determine if soil community structure is an indicator of the effects of different management practices on soil health and orchard performance via the collection of soil chemical, physical and biological (nematode, enzymes and molecular) data.
  - Protective cultivation with light spectral management- Three different colored, 30% shadecloth of red, blue and pearl overlay greenhouse plastic on three 400 ft long high tunnels. The control is a standard film. Trees will continue to be trained as central leaders (Fig. 3). Temperature data will be collected inside and outside of the tunnels. Leaf color, size and specific weight will be measured under each treatment. Light quality will also be measured and tree performance continues to be evaluated. We anticipate fruit set in 2007 and will bring bees into the tunnels for pollination.

Results: See detailed findings in the following figures and tables.

Table 1. Effect of rootstock on tree performance and fruit quality in 2007 of 'Sweetheart' trees top worked onto M x M rootstocks

MxM Rootstock [z]	Yield (lb)[x]	TCSA (cm^2)	Fruit size (mm)	Firmness (g/mm)	SSC (°Brix)	Pullforce (g)	Yield efficiency (kg/cm^2)
14	64.7	115.8 c	20.2 b	360	14.8 b	962 a	24.9 a
46	83.4	136.4 c	20.9 b	356	16.6 a	886 a	26.9 a
2	99.0	188.0 ab	21.4 b	347	15.5 ab	1162 a	22.7 a
39	87.8	148.6 bc	21.4 b	335	14.9 b	957 a	26.2 a
60	66.0	208.2 a	23.0 a	58	16.5 a	987 a	14.6 b
MSD[y]	ns	41	1.4	ns	1.5	ns	6.3

[z]Rootstocks were planted in 2000 at a 18' x 18' spacing in a completely randomized design with 6 replications and topworked in 2001.
[y]Means separation is by the Waller Duncan k-ratio t-test, k-ratio=100.
[x]Packout as a composite: 77% fancy, 21% stemless and 2% choice.

Table 2. Effects of rootstock on the tree and fruit characteristics of topworked 'Sweetheart' in 2007

Rootstock [z]	Yield (lb)[x]	TCSA (cm^2)	Fruit size (mm)	SSC (°Brix)	Pullforce (g)	Yield efficiency (kg/cm^2)
MXM60	6.6 ab	141 a	24.2	17.2 b	1147	2.0 b
MXM14	8.8 ab	123 b	24.2	17.1 b	1195	3.4 b
Mazzard	2.6 b	76 c	24.1	18.6 a	1006	1.1 b
Giessen 196-4	13.6 a	63 c	24.2	17.2 b	1197	9.3 a
MSD[y]	7.3	17.6	ns	1.0	ns	2.9

[z]Rootstocks were planted in 2002 at an 18' x 18' spacing. Trees were topworked in 2003. Trees were mechanically harvested.
[y]Means separation is by the Waller Duncan k-ratio t-test, k-ratio=100.
[x]Packout as a composite: 70% fancy, 24% stemless and 6% culls.

Table 3. Effect of training system and rootstock on the performance of 'Sweetheart', 'Stardust' and 'Royal Ann' trees planted in 2003

	TCSA (cm^2)			Yield (lbs)
	'Sweetheart'	'Stardust'	'Royal Ann'	'Stardust'
Training system: Central leader				
MxM14[z]	83	79 a	93 a	8.1
Mazzard	80	.	75 b	.
Gisela 6	75	50 b	67 b	7.0
Gi196-4	66	52 b	70 b	2.9
MSD[y]	ns	16	9	ns
Training system: Multiple leader				
MxM14[z]	107 a	93 a	98 a	7.9
Mazzard	88 b	.	82 b	.
Gisela 6	73 b	58 b	76 b	18.3
Gi196-4	79 b	62 b	75 b	15.0
MSD	18	21	12	ns

[z]Rootstocks were planted fall 2003 at an 9' x 16' spacing.
[y]Means separation is by the Waller Duncan k-ratio t-test, k-ratio=100.

Table 4. Effects of training systems on tree growth (TCSA) of two blush cultivars in 2007

	'Early Robin'/Gisela 6 (Carter)		'Rainier'/Gisela 6 (Morgan)	
	TCSA (cm^2)	ΔTCSA	TCSA (cm^2)	ΔTCSA
Steep leader	31.5 a	20.6 a	16.3	10.3 a
Central leader	26.7 b	16.6 b	14.4	8.4 b
Multiple leader	23.3.c	16.9 b	16.3	9.7 ab
MSD	2.4	2.4	ns	1.6

Fig. 1. Fruit Growth Model developed by OSU targeting GA spray and harvest dates (GDH) compared to average grower dates in 2006 (solid line) and 2007 (dash line) for these events. OSU model (dotted line) indicates the beginning and ends of Stage III.

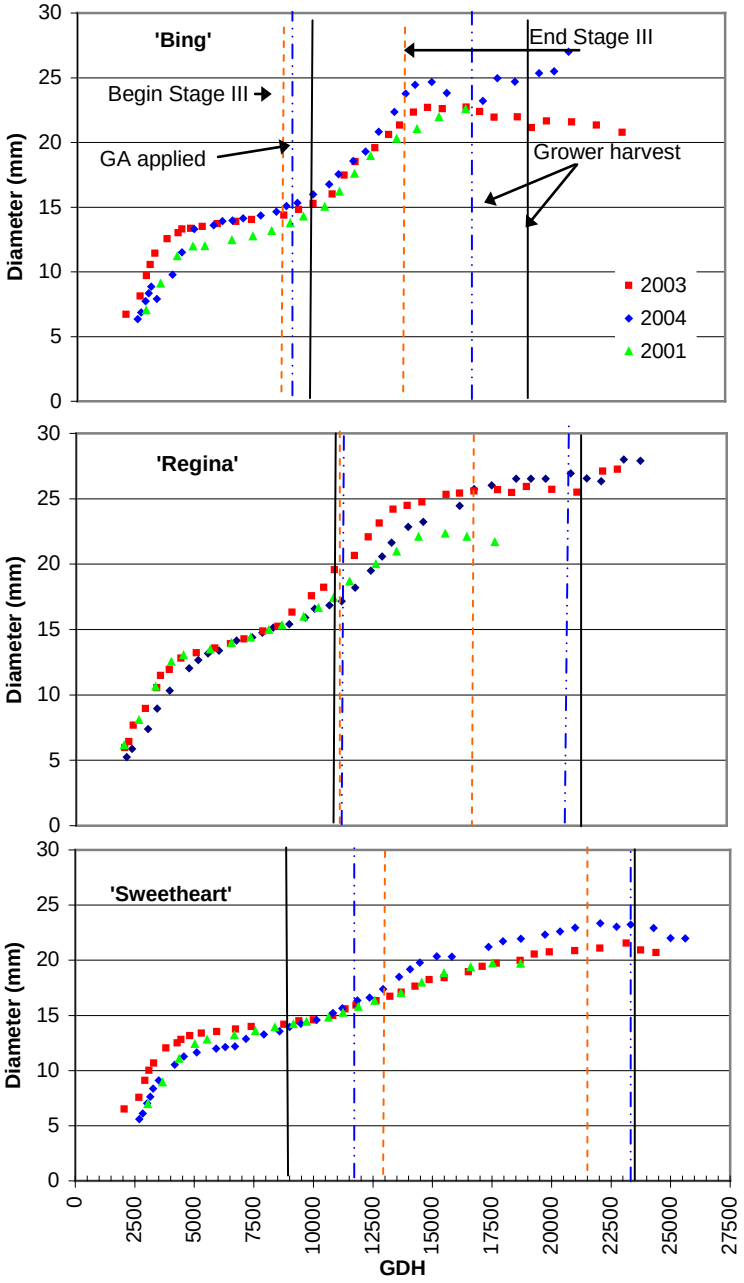
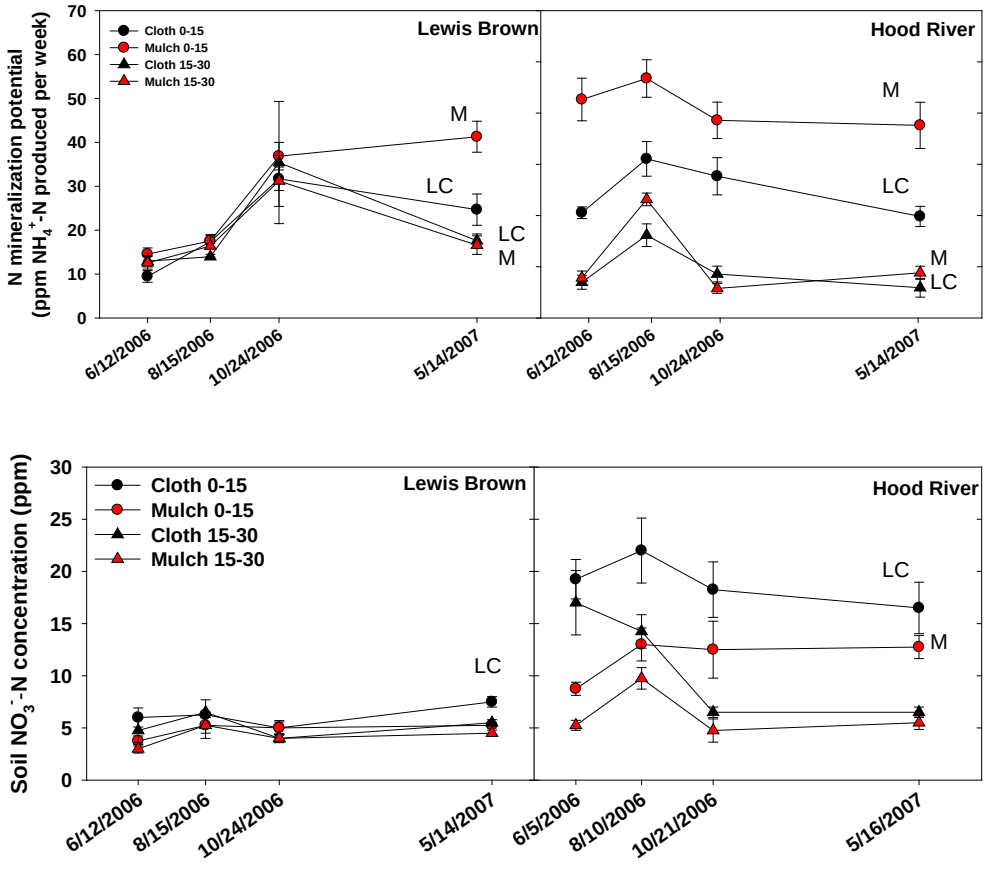


Fig. 2. Wilson high tunnels planted in 2006 with colored shadecloth growing three high value blush cherries according to certified organic standards at OSU-Corvallis.

Tunnel Color	Leaf Area (cm^2)	Leaf Greenness[z]
Blue	75.8 a	36.7 a
Red	71.0 a	32.5 b
Pearl	64.8 b	31.2 b
Control	69.2 ab	32.2 b
MSD	6.8	3.5

TCSA '07	'Rainier'	'Early Robin'	13N7-39
Control	16.8 a	14.5	12.8
Blue	16.4 a	17	12.4
Pearl	15.8 ab	17.5	12.6
Red	13.4 b	15	11.1
MSD	2.6	ns	ns

Fig. 3. The effect of landscape cloth and mulches on N mineralization potential and soil nitrate concentrations at 0-15 and 16-30cm depths at the Lewis Brown Farm and MCAREC



CONTINUING PROJECT REPORT **YEAR**: 2 of 3
WTFRC Project Number:

Project Title: Improve and predict fruit quality in late-season cherries

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City: Hood River
State/Zip: Oregon 97031

Cooperators: Bob Bailey, Orchard View, 4055 Skyline Rd., The Dalles, OR 97058

Total project funding request: **Year 1: $19,549** **Year 2: $20,526** **Year 3: $21,553**

Budget 1: (*Required information – please complete all information***)**
Organization Name: Oregon State Univ. **Contract Administrator:** Peggy S. Lowry
Telephone: 541-737-4933 **Email address:** sponsored.program@oregonstate.edu

Item	Year 1: 2007	Year 2: 2008	Year 3: 2009
Salaries[1]	7,200	**7,560**	7,938
Benefits[2]	3,600	**3,780**	3,969
Wages[3]	4,050	**4,253**	4,465
Benefits[4]	1,012	**1,063**	1,116
Equipment			
Supplies[5]	2,880	**3,024**	3,175
Travel[6]	395	**415**	435
Miscellaneous[7]	412	**431**	455
Total	$19,549	**$20,526**	$21,553

1. Two months of salary for a research assistant who will oversee the technical aspects of this project (plot establishment and maintenance, sample collections, field measurements, data entry, harvest, and fruit evaluations).
2. Benefits for a research assistant are calculated at 50% according to 2007 OSU regulations.
3. Hourly help for field measurements, fruit evaluations, and harvest at $15 per hour in 2007.
4. Benefits for hourly help are calculated at 25% according to 2007 OSU regulations.
5. Nutrient analysis in fruit, leaf, and soil samples. There are 192 samples in total each year. The cost for analyzing a sample for N and Ca will be $15.
6. Travel to plots: 15 round trips to The Dalles (65 miles each), the total mileage will be 65*15= 975 miles. Each mile costs 40.5 cents.
7. Costs on purchasing chemicals and supplies for fruit quality evaluations, etc.

Objectives

1) Assess the impacts of nitrogen (N) fertilizer rates, foliar calcium (Ca) applications, and packingline on cherry fruit surface pitting.
2) Estimate the correlations of cherry pitting susceptibility with fruit chemical and biochemical properties (such as Ca/N ratio, firmness, etc.), and thus predict and reduce cherry pitting.
3) Evaluate the effects of N fertilizer rates, foliar Ca applications, and packingline on cherry fruit quality, such as fruit size and firmness.

Significant Findings

- Sweetheart cherry pitting during cold storage can be reduced by lowering the N fertilizer application rate on the field during the growing season.
- Five applications of Ca spray does not improve cherry pitting compared with the two applications of Ca spray later during the growing season; which suggests that foliar spraying Ca twice late in the growing season could provide adequate Ca nutrition for fruit.
- Packingline (both cluster cutter and full packingline) have a huge impact on cherry pitting.
- Cherry pitting increases sharply and marketable fruit decreases accordingly during the 3-week cold storage period.
- Cherry pitting seemed to be negatively related to fruit titratable acidity; which means the more acidic the cherries are, the less pitting there is.

Methods

This study was designed to evaluate the impacts of nitrogen (N) application rates, foliar calcium (Ca) spray practices, packingline, and their respective interactions on Sweetheart cherry pitting. The field trial was conducted using a split plot experimental design with four replicates each at the Orchard View farm in the Dalles, OR in 2007. The two N application rates were low (40 lb/acre applied on April 10) and high (80 lb/acre in total, first half applied on April 10, and the other half applied on May 14); the foliar calcium spray practices were two applications and five applications. The three packingline treatments included: (1) the fruit did not run through a packingline at all (no packingline), (2) the fruit ran through a cluster cutter (post cluster cutter), and (3) the fruit ran through an entire packingline (full packingline). The trial was harvested on July 19. At harvest, one box of fruit was collected from each combination of the three treatment factors and taken to MCAREC. Fruit firmness, size, brix, titratable acidity, and color were measured for each box of fruit. In addition, leaf and soil samples were analyzed. Leaf sampling was conducted on a split plot basis at harvest; N and Ca concentrations in these samples were determined.

Visual evaluation of fruit surface pitting was conducted when the fruit arrived at MACREC, and again three weeks after the fruit had been stored in a cold storage room at 32^{o}C. Six categories of excellent (no pitting), slightly pitted (but marketable), moderately pitted (not marketable), severely pitted (not marketable), bruised (not marketable), and pitted and bruised (not marketable) fruit were used in this evaluation. Overall, the marketable fruit included excellent and slightly pitted fruit; the unmarketable fruit, due to pitting, included moderately pitted, severely pitted, and pitted with bruised fruit. Correlations of cherry pitting with fruit chemical and biochemical properties were analyzed.

Results and Discussion

I. Effects of Nitrogen Rates, Calcium Rates, and Packingline on Fruit Pitting after Three Weeks Cold Storage

The two foliar Ca spray practices (two applications vs. five applications), three packingline treatments (no packingline vs. post cluster cutter vs. full packingline), and low N application rate (40 lb/acre) averaged 29.7% marketable fruit (excellent fruit plus slightly pitted fruit) after 3-weeks cold

storage. That is statistically higher than the 25.8% marketable fruit with the high N rate (80 lb/acre) (Table 1). In contrast, unmarketable fruit due to pitting (moderately pitted fruit plus severely pitted fruit plus pitted fruit with bruise) was 66.0% with the low N rate, statistically lower than the 70.8% unmarketable fruit due to pitting with the high N rate. Our results suggest raising the N application rate during the growing season significantly increases cherry pitting.

On average, the two N application rates (40 lb/acre vs. 80 lb/acre) and three packingline treatments indicated no significant influence from the two foliar Ca spray practices on cherry pitting after 3-week cold storage (Table 1). Our results show that foliar spraying of Ca twice late in the growing season could provide adequate Ca nutrition for fruit, and there is no need to foliar spray Ca five times late in the growing season.

Averaged over the two N application rates and two Ca spray treatments, the packingline had a huge impact on cherry pitting (Table 1). The marketable fruit was 43.7% with no packingline, however, was only 26.9% with post cluster cutter and 12.6% with full packingline. In contrast, unmarketable fruit due to pitting was 49.8% with no packingline, but 71.6% with post cluster cutter and 83.7% with full packingline. Our results strongly show that both full packingline and cluster cutter have a huge impact on cherry pitting.

Overall, there were no significant interactive effects among N application rates, Ca spray practices, and packingline treatments on Sweetheart cherry pitting (data not shown).

II. Effects of Nitrogen and Calcium Rates on Fruit Pitting after Full Packingline and Three Weeks Cold Storage

Averaged over the two Ca spray practices, the low N application rate (40 lb/acre) had 14.2% marketable fruit after the fruit had been run through the full packingline and cold stored for three weeks, which was higher than the 11.0% marketable fruit with the high N rate (80 lb/acre) (Table 2). In contrast, unmarketable fruit due to pitting was 82.1% with the low N rate, statistically lower than the 85.3% unmarketable fruit due to pitting with the high N rate. Our results suggest raising N application rate increases Sweetheart cherry pitting.

On average, the two N application rates indicated no statistically significant influence of the two Ca spray practices (two applications vs. five applications) on pitting after the fruit had been run through the full packingline and cold stored for three weeks (Table 2). Our results show that foliar spraying of Ca twice late in the growing season could provide sufficient Ca nutrition for fruit, and there is no need to foliar spray Ca five times late in the season.

Overall, there was no significant interactive effect between N rates and Ca spray practices on pitting after the fruit had been run through the full packingline and cold stored for three weeks (data not shown).

III. Effects of Nitrogen Rates, Calcium Rates, and Packingline on Fruit Pitting at Harvest

Averaged over the two foliar Ca spray practices and three packingline treatments, the low and high N application rates both had 61% marketable fruit at harvest (Table 3). On the other hand, the unmarketable fruit due to pitting was 22 to 23% for the two N rates at harvest. Our results suggest N application rate does not significantly influence cherry pitting at harvest.

On average, the two N application rates and three packingline treatments indicated no significant influence of the two Ca spray practices on pitting at harvest (Table 3). Our results show that foliar spraying of Ca twice late in the growing season could provide adequate Ca nutrition for fruit, and there is no need to foliar spray Ca five times.

Averaged over the two N application rates and two Ca spray practices, the packingline had a huge impact on pitting at harvest (Table 3). Marketable fruit was 79.4% with no packingline, however, only 56.9% with post cluster cutter and 48.3% with full packingline. In contrast, unmarketable fruit due to pitting was 11.0% with no packingline, but 25.4% with post cluster cutter and 31.4% with full packingline. Our results strongly show that both full packingline and cluster cutter have a huge impact on cherry pitting at harvest.

Overall, there was no significant interactive effect among N application rates, Ca spray practices, and packingline treatments on Sweetheart cherry pitting at harvest (data not shown).

IV. Effects of Nitrogen and Calcium Rates on Fruit Pitting at Harvest after Full Packingline

Averaged over the two Ca spray practices, the percentage of marketable fruit at harvest after the fruit had been run through the full packingline did not differ significantly between the low and high N rates (Table 4). On the other hand, unmarketable fruit due to pitting was 31 to 32% for the two N rates. Our results show N application rate does not affect Sweetheart cherry pitting at harvest.

On average, the two N application rates indicated no statistically significant influence of the Ca spray practices on pitting at harvest after the fruit had been run through the full packingline (Table 4). Our results show that foliar spraying of Ca twice late in the growing season could provide sufficient Ca nutrition for fruit, and there is no need to foliar spray Ca five times late in the season.

Overall, there was no significant interactive effect between N rates and Ca spray practices on Sweetheart cherry pitting at harvest after the fruit had been run the full packingline (data not shown).

V. Comparison of Fruit Pitting at Harvest and after Three Weeks Cold Storage

Averaged over the two foliar Ca spray practices and three packingline treatments, the high N application rate had 61.6% marketable fruit at harvest, but had only 25.8% marketable fruit after 3-week cold storage (Tables 1 & 3). In contrast, the unmarketable fruit due to pitting was 22.4% at harvest, but was as high as 70.8% after 3-week cold storage. These trends were also observed with the low N rate.

On average, the two N application rates, three packingline treatments and five applications of Ca spray had 60.0% marketable fruit at harvest, but had only 27.5% marketable fruit after 3-week cold storage (Tables 1 & 3). On the other hand, the unmarketable fruit due to pitting was 24.0% at harvest, but was increased to 68.4% after cold stored for 3 weeks. These trends were also detected with the two applications of Ca spray.

Averaged over the two N application rates and the two Ca spray treatments, full packingline had 48.3% marketable fruit at harvest, but had only 12.6% marketable fruit after 3-week cold storage (Tables 1 & 3). In contrast, the unmarketable fruit due to pitting was 31.4% at harvest, but was 83.7% after 3-week cold storage. These trends were also observed with no packingline and post cluster cutter. Overall, our results suggest cherry pitting increases sharply, and thus the marketable fruit decreases accordingly during the 3-week cold storage.

VI. Effects of Nitrogen and Calcium Rates on Fruit Quality at Harvest

Fruit quality including fruit firmness, size, sugar, titratable acidity, and color did not differ from any of the N application rates or Ca spray strategies (Table 5).

VII. Effects of Nitrogen and Calcium Rates on Leaf Concentrations of Nitrogen and Calcium at Harvest

Raising N application rate from 40 lb/acre to 80 lb/acre significantly increased N concentration, but reduced Ca concentration, and thus enhanced N/Ca ratio in leaf at harvest (Table 6). There was no significant difference in leaf Ca concentration between the two Ca spray strategies (two applications vs. five applications).

VIII. Correlations of Fruit Pitting after Full Packingline and Three-Week Cold Storage with Fruit Quality Attributes at Harvest

Linear regression analyses showed that cherry pitting (total percentage of pitted and pitted + bruised fruit) was not related to most of the fruit quality attributes, such as fruit firmness, size, sugar, or color. Our results indicate that fruit quality attributes, such as firmness, size, sugar, or color at harvest can not be used to predict cherry pitting during cold storage. However, cherry pitting was negatively related to fruit titratable acidity; which means the more acidic the cherries are, the less pitting there is. In addition, there was no correlation of cherry pitting with leaf N or Ca concentration or N/Ca ratio at harvest. Our results indicate that leaf N or Ca concentration or N/Ca ratio at harvest may be not valuable indicators of cherry pitting during cold storage.

CONTINUING PROJECT REPORT **YEAR** 1 of 3
WTFRC Project Number: CH-07-702

Project Title: Prevention of cherry fruit cracking using soluble potassium silicate

PI:	Clive Kaiser	**Co-PI(2):**	Lynn Long
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City:	Milton Freewater	**City:**	The Dalles
State/Province/Zip	OR**,** 97862	**State/Province/Zip:**	OR, 97058
Co-PI(3):	Matt Whiting	**Co-PI(4):**	Anita Azarenko
Organization:	WSU	**Organization:**	OSU
Telephone/email:	5097869260	**Telephone/email:**	5417379877
Address:	24106 North Bunn Rd	**Address:**	4017 ALS Building
Address 2:		**Address 2:**	Oregon State University
City:	Prosser	**City:**	Corvallis
State/Province/Zip	WA, 99350	**State/Province/Zip:**	OR, 97331-7304

Cooperators: Annie Chozinski

Total project funding request:	**Year 1:**	**Year 2:**	**Year 3:**
	$6000	**$6500**	

Other funding Sources

Agency Name: **NONE**
Amount requested or awarded:
Notes:

Budget 1: (*Required information – please complete all information***)**
Organization Name: OSU **Contract Administrator:** Dorothy Beaton
Telephone: 5417373228 **Email address:** Dorothy.Beaton@oregonstate.edu

Item	**(2007)**	**(2008)**	**(type additional year if relevant)**
Salaries	2000	2250	
Benefits			
Wages			
Benefits			
Equipment	1000		
Supplies	1500	1750	
Travel	1500	2000	
Miscellaneous		500	
Total	6000	6500	

Footnotes:

Objectives for 2007

1 To test the effects of soluble silicon on cherry fruit cracking

- This research project has a main objective to control fruit splitting (Priority 4).
- In addition, it may have an impact on postharvest fruit quality (Priority 1).

Significant findings and results:

Hood River 2007

- There were no significant differences in % fruit cracking between treatments at Hood River of 'Bing'/'Mazzard' (mean for cracked fruit = 23.6% $\pm$ 4.47%). Throughout the growing season in Hood River, there were no significant differences in 'Bing' fruit diameter (figure 1) however on the day of harvest, fruit from untreated control trees were 0.64 mm in diameter larger than those from trees treated with soluble potassium silicate (F. pr. <0.001).
- In Hood River, 'Bing' fruit from trees on Mazzard rootstock, treated with soluble potassium silicate were significantly firmer (409.4 $mm.g^{-1}$) than untreated control fruit (385.5 $mm.g^{-1}$) (F pr.<0.001).
- In Hood River, the TSS levels of 'Bing' fruit treated with soluble potassium silicate were significantly lower (19.15% Brix) compared to control fruit (19.99% Brix) (F. pr. <0.001).

Corvallis 2007

- There were no significant differences between treatments of 'Stardust'/'Gisela 6' (mean for cracked fruit = 14.7 $\pm$ 5.08) . However there was a major treatment difference for 'Stardust'/'MM14', where the application of potassium silicate (mean = 34.7%) actually resulted in more cracking than on control trees (mean = 14.7%) (Figure 5).
- 'Stardust' fruit from trees treated with soluble potassium silicate were significantly larger than control fruit (Figure 6) regardless of the rootstock cultivar.
- Furthermore, 'Stardust' fruit from trees on 'Gisela 6' rootstock were the firmest of the all the treatments (Figure 7). Those from trees on 'MM14' rootstocks were the least firm. Clearly rootstock effects are having a major impact on role of soluble potassium silicate.
- The incidence of disease in the fruit at harvest in Corvallis was such that postharvest disease assessments were not deemed necessary. It was concluded that the silicon soil applications had no effect on these diseases.

Prosser 2007

- There was no rain-induced fruit cracking however, the immersion stress test resulted in more fruit cracking in fruit from trees treated with soluble potassium silicate than untreated control fruit (Figure 8). There were no differences in fruit firmness between treatments at harvest.

Materials and Methods:

Hood River

In a completely randomized block design, ten eight-year-old 'Bing' on 'Mazzard' trees in Hood River were drenched four times with soluble potassium silicate at periods of 3 weeks apart during the growing season from flowering until harvest and compared against similar untreated control trees. Fruit diameter of 100 fruit per tree was measured on a monthly basis up to the day of harvest. On the day of harvest, the total number of cracked fruit per tree were counted and expressed as a percentage of the total number of fruit on the trees. A sample of 25 fruit were harvested from each tree and fruit diameter, TSS, pH and fruit firmness were recorded and analyzed by one-way anova using Genstat 10.1

Corvallis
Six trees each of 'Stardust' on either 'Gisela 6' or 'MM14' were selected from a completely randomized block design at the Lewis Brown Research Farm and treated identically to those in Hood River and at harvest, the incidence of fruit disease was noted. Fruit diameter, TSS, pH, fruit firmness and stem pullforce were recorded.

Prosser
In a completely randomized block design, ten nine-year-old 'Bing' on 'Gisela 1' trees at IAREC, Prosser were treated with potassium silicate as above and compared against ten similar untreated control trees. At harvest, fruit mass, fruit firmness, TSS and row sizes were recorded for 100 fruit per tree. Since no fruit cracking was observed in any of these fruit, an immersion stress test was performed over time. Here fruit were immersed in deionized water from 11 am and the incidence of fruit cracking recorded at 1:15 pm, 3:00 pm, 4:45 pm and 6:00 am the next day.

Results

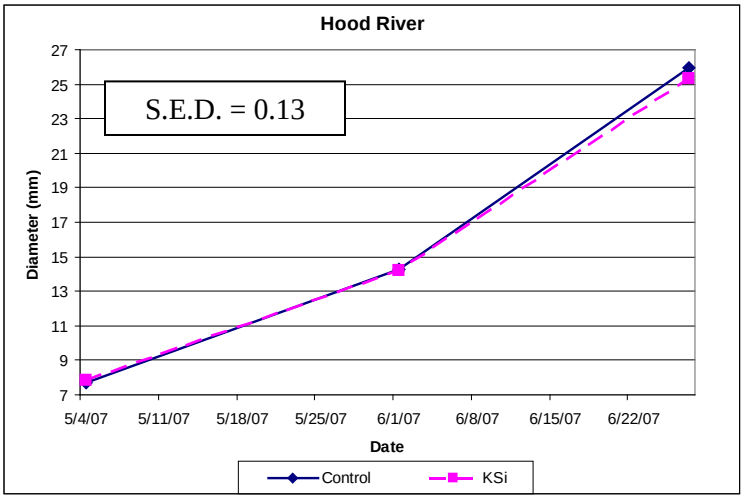

Figure 1. Change in average fruit diameter (mm) of 'Bing' / 'Mazzard' from 5/4/07 till harvest (06/27/07) from trees treated with or without soluble potassium silicate (KSi) at Hood River.

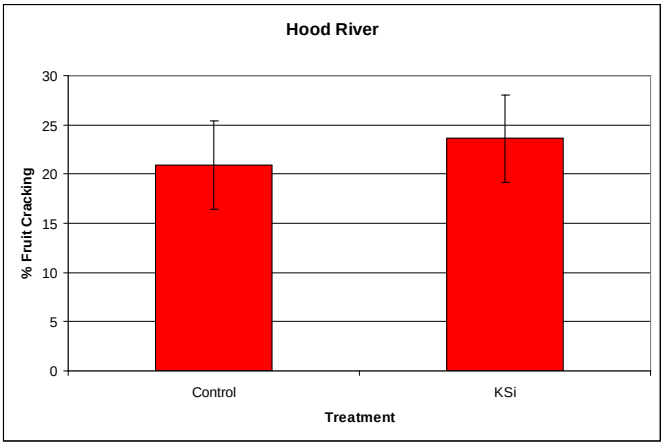

Figure 2. Average percentage fruit cracking of 'Bing' / 'Mazzard' at harvest (06/27/07) from trees treated with or without soluble potassium silicate (KSi) at Hood River.

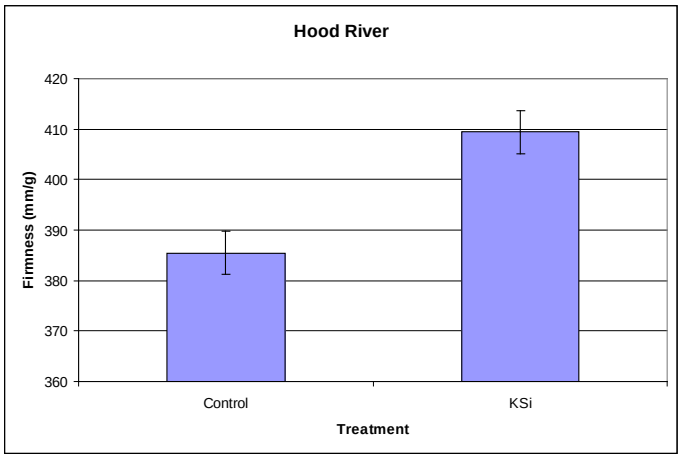

Figure 3. Average fruit firmness (mm.g^{-1}) of 'Bing' / 'Mazzard' at harvest (06/27/07) from trees treated with or without soluble potassium silicate (KSi) at Hood River.

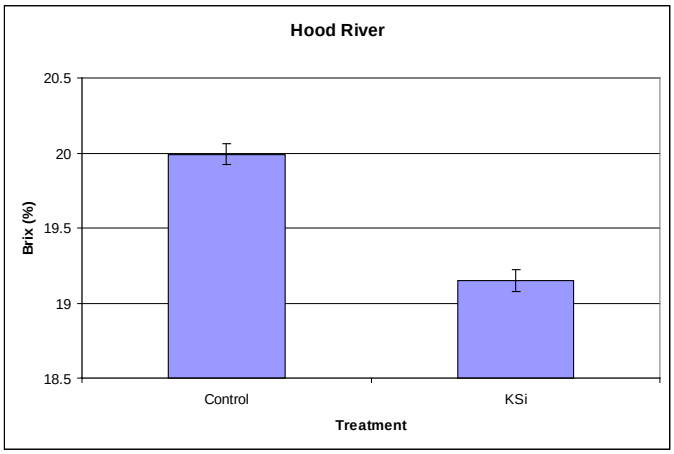

Figure 4. Average fruit TSS (% Brix) of 'Bing' / 'Mazzard' at harvest (06/27/07) from trees treated with or without soluble potassium silicate (KSi) at Hood River.

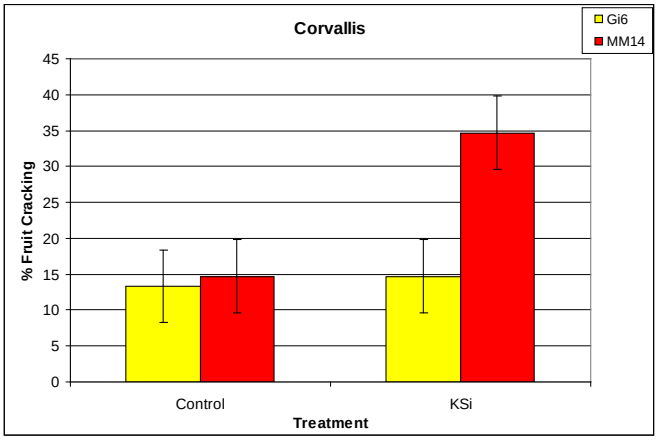

Figure 5. Average percentage fruit cracking of 'Stardust' / 'MM14' or 'Stardust'/ 'Gi6' at harvest (06/25/07) from trees treated with or without soluble potassium silicate (KSi) at Corvallis.

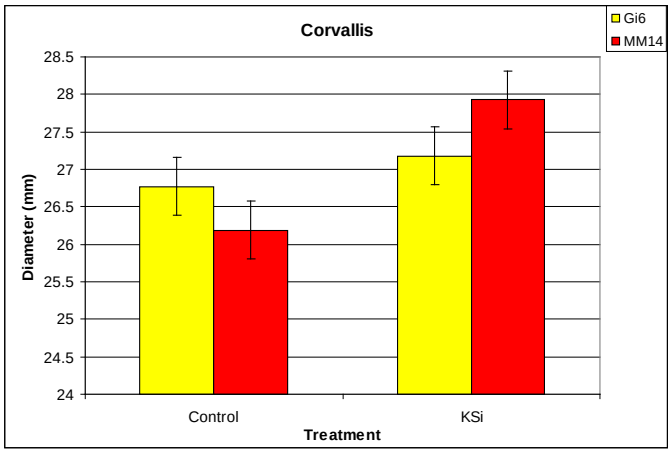

Figure 6. Average fruit diameter (mm) of 'Stardust' / 'MM14' or 'Stardust'/ 'Gi6' at harvest (06/25/07) from trees treated with or without soluble potassium silicate (KSi) at Corvallis.

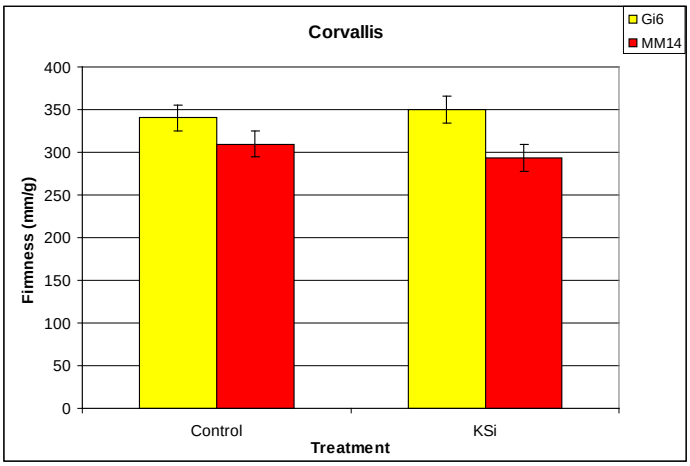

Figure 7. Average fruit firmness ($mm.g^{-1}$) of 'Stardust' / 'MM14' or 'Stardust'/ 'Gi6' at harvest (06/25/07) from trees treated with or without soluble potassium silicate (KSi) at Corvallis.

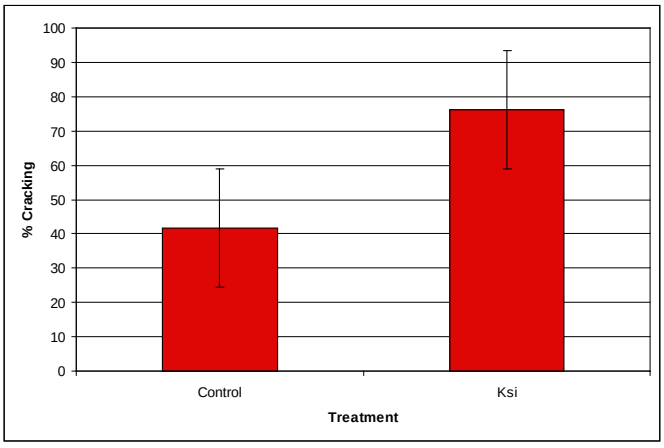

Figure 8. Percentage cracking of 'Bing'/ 'Gisela 1' after immersion stress test at harvest from trees treated with or without soluble potassium silicate (KSi) at IAREC, Prosser.

Discussion & Conclusions

Clearly, soluble potassium silicate is having an impact on fruit quality. Unfortunately, there was no significant improvement in percentage fruit cracking at either Hood River or Corvallis and natural rain induced cracking did not occur at Prosser. The immersion stress test on three fruit from each tree however, resulted in 34% more cracking in fruit treated with soluble potassium silicate than without.

Interestingly, addition of soluble potassium silicate resulted in a significant improvement in fruit firmness of 'Bing' fruit on 'Mazzard' rootstocks at Hood River and of 'Stardust' on 'Gisela 6' rootstock at Corvallis but had an inverse effect on 'Stardust' on 'MM14'. At Prosser, there was no significant difference in fruit firmness in any of the treatments at harvest.

An inversely proportional relationship was observed with respect to firmness and fruit size when assessed against the addition of potassium silicate, suggesting that silicon is playing a structural role in pericarp cell walls when fruit were not fully enlarged. Similarly, there was an inverse relationship between TSS concentrations and soluble potassium silicate, suggesting that potassium silicate may be delaying fruit maturity, where crop load and fruit size are implicated. There were no significant differences in pullforce of 'Stardust' nor in pH of the fruit from any of the treatments at either Corvallis or Hood River.

Consequently, although the effects of soluble potassium silicate with respect to fruit cracking were inconclusive, it is imperative that a second years data be accumulated to determine whether there is a cumulative effect of soil applied potassium silicate over time. Furthermore, the rootstock effects observed in 2007 must be confirmed over a second year of study as this will surely impact on soil amelioration e.g. mulching of sandy soils, which are known to have higher silicon concentrations than other soils e.g. loams and clays. Furthermore, the results of this study will also impact heavily on future site and soil selection for new orchards.

CONTINUING PROJECT REPORT **YEAR**: 1 of 3
WTFRC Project Number: CH-07-703 **(WSU Project #13C-3655-3296)**

Project Title: Bioregulators, fruit loosening, mech. harvest of sweet cherry

PI: Don C. Elfving
Organization: WSU-TFREC
Telephone/email: 509-663-8181, ext. 252**,** delfving@wsu.edu
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City: Wenatchee
State/Province/Zip: WA 98801

Cooperators: Dr. M.D. Whiting, WSU Prosser; Dr. E.M. Kupferman, WSU Wenatchee

Total project funding request: **Year 1:** 15,518 **Year 2: 17,723** **Year 3:** 19,427

Budget 1:
Organization: WSU Tree Fruit Research and Extension Center
Telephone: 509-335-7667 and 509-663-8181 x221, respectively

Contract Administrator: ML. Bricker and Kevin Larson
Email: mdesros@wsu.edu and kevin_larson@wsu.edu, respectively

Item	2007	2008	2009
Salaries[1]	7,000	**7,500**	8,000
Benefits[2]	2,380	**2,550**	2,720
Wages[1]	1,200	**1,500**	1,800
Benefits[2]	138	**173**	207
Equipment	0	**0**	0
Supplies[3]	800	**1,000**	1,200
Travel[4]	4,000	**5,000**	5,500
Miscellaneous	0	**0**	0
Total	15,518	**17,723**	19,427

[1] Technical and time-slip help is essential to collect the volume of data needed to evaluate growth, flowering, yield, fruit loosening and fruit quality responses to the various bioregulator applications involved.
[2] Salaries benefit rate is calculated at 34% for Dwayne Visser. Time-slip benefit rate is calculated at 11.5%.
[3] This category includes miscellaneous supplies, non-capital equipment, consumables, repairs, etc. that are needed to carry out the research project. Cell phone charges are allowed under this grant.
[4] Treatment application and frequent data collection at distant sites, all off-station. Includes vehicle lease-to-purchase, operating, repair costs.

Objectives:

1. GA may provide a tool for crop-load adjustment in sweet cherries by reducing return bloom, but it also affects the current season's crop quality. Explore the possibility of finding a suitable GA program that both contributes to reduced return bloom and favorably affects current season's fruit quality.
2. Alternative approaches to loosening sweet cherries for mechanical harvest will be explored using new bioregulator products that directly inhibit auxin transport from the fruit. When auxin transport is reduced, abscission layers are supposed to become active and loosening should occur. Such products might also be useful in conjunction with reduced rates of ethephon. Reducing the ethephon rate reduces its negative effects on fruit quality.
3. Alternative products will be examined for potential activity to offset or negate the negative effects of ethephon on fruit quality.

Significant findings:

1. Ethephon again effectively loosened 'Bing' cherries when applied approximately 14 days before harvest. However, only the lower concentration of ethephon (150 mg/liter a.i. or 0.5 pint/100 gallons) combined with "Pentra-Bark" penetrant reduced flesh firmness significantly. The factors that influence the relation between fruit loosening and firmness loss are unknown. No visible effects on defoliation were observed with any ethephon treatment.
2. Two known auxin transport inhibitors, cyclanilide and diflufenzopyr (DFFP), were tested on limbs of 'Bing' cherries for efficacy in loosening and effects on flesh firmness loss.
3. Cyclanilide at 500 mg/liter destroyed the crop due to phytotoxicity; this product does not appear promising.
4. The potent auxin transport inhibitor DFFP at 0.5-5 mg/liter a.i. did not induce fruit loosening, flesh firmness loss nor defoliation.
5. Methyl jasmonate (MJ) has been proposed as a possible fruit loosener for sweet cherries. At 1000 mg/liter a.i., MJ did not loosen fruit, stimulate flesh firmness loss or induce defoliation.
6. Applications of GA_3 and GA_7 to 'Rainier'/G.5 trees in 2006 produced a small reduction in flower buds per spur in 2007. In addition, GA_3 reduced flowers per bud in proportion to concentration, while GA_7 did not.
7. GA treatments on 'Rainier'/G.5 trees in 2006 did not produce significant effects on mean fruit size, brix, percent red color or percent of crop in fruit-size classes in 2007 at any of three harvests. Compensating fruit set on differential bloom may have accounted for this observation.
8. GA_3 at up to 75 mg/liter improved mean fruit size but had no effect on fruit firmness or total yield when applied in 2007 to 'Sweetheart'/G.5 trees. Bloom and crop characteristics data will be taken in 2008.
9. Cytokinin products applied to 'Bing'/G.1 trees 6 days after full bloom (fruit diameter 4.8±0.1 mm) failed to improve fruit size. The cytokinins were thidiazuron (TDZ, Dropp, Bayer Crop Science), forchlorfenuron (CPPU, Kim-C1 Co.), and 6-benzyladenine (BA, Maxcel, Valent Biosciences), each applied at either 10 or 50 mg/liter. These concentrations may not have been high enough to stimulate cell division in sweet cherry fruit.
10. The high rate of TDZ reduced fruit red color rating at harvest. The other cytokinin treatments had little effect. There were no significant effects of any treatment on fruit firmness at harvest.

Methods:

Three trials were initiated in 2007 to examine effects of various bioregulators on fruit loosening for mechanical harvest, for control of return bloom as a possible strategy for crop load management in size controlled sweet cherry fruit and for possible effects on fruit cell division, and fruit size, at harvest. One trial from 2006 was carried into 2007 to explore effects of GA applications in 2006 on fruit size and other fruit characteristics in 2007.

Results and discussion:

Since the repeated absence of beneficial effects of sprayable MCP (e.g., "Harvista") on control of fruit firmness loss in ethephon treated cherries (2003-2006), we have been exploring other possible options for loosening fruit. A main direction in 2007 was the examination of auxin-transport inhibitors, based on the physiological principle that auxin transport to an abscission zone keeps that group of cells healthy, preventing abscission. Once auxin flow is reduced, or eliminated, the abscission zone begins to deteriorate, which ultimately should lead to the separation of the fruit from the tree.

In 2007 we tested methyl jasmonate, diflufenzopyr (a powerful anti-auxin from Chemtura) and cyclanilide (another anti-auxin from Bayer) in comparison to ethephon alone or supplemented with the cytokinin forchlorfenuron (CPPU). Ethephon produced the same results as it has every year since 2001, namely, loosening of fruit with, in the case of 2007, little effect on flesh firmness except where the penetrant "Pentra-bark" was combined with ethephon. The factors that influence the relation between fruit loosening and firmness loss in ethephon treated fruit are unknown. At the concentrations used, the anti-auxins were ineffective for loosening fruit. Cyclanilide at 500 mg/liter produced substantial phytotoxicity to both leaves and fruit, but no loosening. The physiological activity in sweet cherry trees of methyl jasmonate is not understood, but it was also ineffective for loosening fruit. Since, with the notable exception of cyclanilide, there were no symptoms of any kind of phytotoxicity or defoliation due to any other treatment, it is possible that product concentrations were too low to produce abscission in sweet cherry fruit.

GA trials oriented toward managing crop load have so far not proven to produce as dramatic results as we had hoped. Because GA applications affect the current season's fruit maturity, as well as bloom formation for the next year, the concentration range must be chosen such that neither goal is unfavorably affected. So far, our results have been inconsistent, which may be a reflection of the differential effects of one season vs. another on factors that influence flower-bud induction and formation. More trials are needed to determine whether a sufficiently predictable response can be achieved.

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