2005 OSCC/WTFRC
Cherry Research Review
November 11-12, 2004
Wenatchee, Washington

Time	Pg	Name	Title	Duration
8:30		**McFerson/ Branson**	**Introduction**	
8:40	1	Grove	Modeling and managing cherry PM	04-06
8:45	6	Calabro	Biology and control of fruit infection phase of PM	03-05
9:00	12	Núñez-Elisea	Tree water use, irrigation scheduling, and water management	03-05
9:15	18	Whiting	Alternative water management strategies	02-04
9:30	28	Núñez-Elisea	Cultivars, rootstocks, training systems, and fruit quality	03-05
9:45	34	Azarenko	Horticulture management systems for fresh and brine cherries	90
10:00	40	Whiting	High density orchard systems	04-06
10:05	46	Whiting	Clonal rootstock evaluation	04-06
10:10	53	Whiting	Sweet cherry source-sink relations	04-06
10:15			**BREAK**	
10:30	60	Bush	Cherry leafroll virus	03-04
10:45	65	Eastwell	Virus control strategies to assist cherry production	04-06
10:50	71	Yee	CFF feeding ecology and food-based lures and baits	04-06
10:55	77	Yee	Insecticide effects on CFF biology	04-06
11:00	83	Smith	CFF control options	04-05
11:05	87	Riedl	Phenology models, CFF emergence and oviposition	04
11:20	97	Walsh	Floor management and insecticides for thrips suppression	04
11:35	106	Brunner	Biology and management of bark beetles	04-05
11:40	111	Elfving	Bioregulators to manage growth, flowering, and cropping	04-06
11:45	115	Olmstead	Environmental and genetic influences on cherry fruit size	04-05
1:30	121	Elfving	Induction of branches in sweet cherry trees	02-04
1:45	127	Schrader	Suppressing cherry cracking, stem browning, and water loss	03-04
2:00	135	Bai	Edible coating to improve storage and marketing quality	04-06
2:15	142	Kupferman	Postharvest quality of new cherry varieties	04
2:30	147	Iezzoni	Sweet cherry dwarfing rootstocks (CVRC funding)	04
2:45	152	Iezzoni	Develop seedling populations for future cv selection	04

CONTINUING PROJECT
WTFRC Project: CH-04-406 **WSU Project:** 3361-4795

Project title: Modeling and Managing Powdery Mildew of Sweet Cherry
PI: Gary G. Grove and R.A. Spotts
Organizations: Washington State University and Oregon State University
Cooperators: Mike Bush and Tim Smith

Contract Administrator: Sharon Taff (staff@wsu.edu; 509-786-2226)

Objectives:

I. Develop a risk index model (utilizing rainfall, irrigation, temperature, relative humidity, and pathogen presence/activity) for initiating fungicide spray programs and adjusting subsequent spray intervals. Research in 2005 will focus on disease development over a more broad range of relative humidities at 15-25 C.

II. Develop means of detecting, identifying, and quantifying airborne propagules of *P. clandestina* early in epidemic progress. Proof of concept was demonstrated in 2004. In 2005 this information will be used to guide the initiation of a fungicide spray program. Results will be compared with a standard phenology-driven program.

III. Develop and refine economically viable conventional and organic powdery mildew management programs.

IV. Develop baseline sensitivities for resistance-prone compounds. Preliminary studies focused on the DMI fungicides. Future studies will concentrate on Qol and quinoline fungicides.

V. Determine the effects of temperature and wetness on acute petroleum oil phytotoxicity. Determine the chronic effects of oils on tree health.

Significant Findings:

* Investigations on the temperature *range* where the cherry mildew fungus is active on cherry foliage were continued in 2004. Disease develops between 10 and 27.5 C. Disease did not develop at 7.5 and 30 C.

- Cleistothecia (the primary inoculum supply) viability declined from 50% at bud burst to 0% at pit hardening. The degradation of the ascospore supply required about 150 cumulative degree days > 10 C (50 F).

* The PCR primers developed by the R.A. Spotts research group were found to be highly specific for the cherry powdery mildew fungus. The primers did not react with DNA collected from powdery mildews collected from 46 disparate hosts from 26 plant families.

* The PCR assay was found to be extremely sensitive: it detected DNA extracted from 1-5 conidia of *P. clandestina* in reaction mixtures.

* This PCR assay facilitated the detection of low levels of *P. clandestina* inoculum in air samples within hours of collection in field studies *prior to disease onset*. Results of this study should

represent the initial step in the incorporation of an inoculum availability component powdery mildew risk assessment models. Air sampling results also confirmed the presence of ascospores in the orchard when their presence was predicted by the temperature/rainfall component of the model.

* Oil induced phytotoxicity developed from 3 sequential (at 7 day intervals) oil applications at 5 and 7.5 C, but not at 10-30 C.

- One organic fungicide program provided disease control similar to that obtained using conventional fungicides.

- Stylet Oil/Topsin, Flint/Elite, and Rally/Quintec fungicide programs provided the best control of powdery mildew in the orchard. All effective programs conformed to the new FRAC guidelines for managing resistance to DMI, Qol, and quinoline fungicides.

- Mildew control attained using an AccuTech sprayer was superior to that attained with a conventional airblast sprayer. Disease severity in treatments applied using the AccuTech machine was inversely proportion to spray volume.

- Developed a leaf disk assay designed to develop baseline sensitivities of commonly used fungicides. With the exception of Rally and Rubigan, fungicides evaluated in preliminary tests gave >99.95 % inhibition of powdery mildew at maximum field rates. Inhibition of mildew was lower at 0.25 and 0.5 x rates of the aforementioned fungicides.

Methods:

Objective I. a. Development of risk assessment model. *Effect of temperature and relative humidity on colony expansion and foliar disease severity.* Cherry leaf disks (cv. 'Bing') will be inoculated using a suspension of *P. clandestina* conidia and incubated 21 days at relative humidities of 40-100% at temperatures of 40-95 F (5-35 C). The proportion of disk surface area colonized by powdery mildew will be determined 7, 14, and 21 days after inoculation.

Objective I. b. Development of risk assessment model. *Effect of temperature and relative humidity on spore (conidia) production.* Plants with actively sporulating colonies will be rinsed with water to remove all conidia, placed incubated at 10-35 C for 14 days at 35, 50, 65, 80, or 90, 95, and 100 % humidity. Sporulation will be assessed 7 and 14 days after inoculation as previously described by Chellemi and Marois (1991).

Objective II. a. Development of risk assessment model . *Meteorological factors affecting spring primary inoculum availability.* A degree-day model of spring ascocarp degradation/ascospore load depletion will be developed using historical and new viability and meteorological data from Washington and Oregon. This equation will be used to generate a predicted value of ascocarp viability at given points in phenological time. Ascocarps will be collected from exfoliating bark and senesced leaves in mildew-infested orchard. Ascospore viability will be assessed using FDA fluorescent vital stain. Validation will be accomplished by mathematically evaluating the relationship between observed and predicted values: actual viability numbers will be regressed on predicted viability numbers. An unbiased predictor should have an intercept of 0 and a slope of 1 (Grove, 2002). Coefficients of determination and standard error about the regression curve(s) will also be used to evaluate the relationship between observed and predicted values.

Objective II. b. Development of risk assessment model . *Verifying pathogen presence and activity. Air sampling studies*. Two air sampling methods will be evaluated in the proposed studies. The first group of studies will be conducted using rotary-impaction air samplers fastened to all-terrain vehicles. ATV's will be driven down orchard rows at weekly intervals. At the conclusion of the sampling period, collection rods will be transported to the lab. DNA will be removed from sampling rods. The second group of studies will utilize rotary-impaction devices operated continuously.

Objective II. b. Use of molecular tools for the timely detection of propagules of the cherry mildew fungus. The identification of trapped propagules will require the use of molecular techniques to identify *P. clanestina* trapped from the orchard air. DNA extractions will be performed by modifying manufacturers instructions using a Bio 101 System FastDNA kit. PCR amplification with universal primers will be performed with Pfu polymerase according the recommended instructions. Amplifications will be performed in a total volume of 25µl using three step cycling. PAmplification products will be run on 1% agarose gel at 120 V for one hour, stained with ethidium bromide, and photographed under UV light. Amplification fragment of expected size is interpreted as a positive result. More detailed information extraction procedures have been published.

Objective III. Various fungicide programs will be evaluated using efficacy and relative input cost as measures of usefulness. Various combinations and rotations of DMI, quinoline, strobilurin (Qol), SAR, oil, whey, and sulfur compounds will be applied to Bing, Rainier, Van, Lapins, or Sweetheart cherries and evaluated for efficacy and phytotoxicity. Compounds will be applied in calendar and weather based management programs. Disease incidence and severity will be determined by randomly selecting five terminal shoots from each plot, and picking five leaves from each terminal starting with the last fully open leaf and working down the shoot for a total of 25 leaves per plot. The percentage of the surface area of the underside of each leaf infected by mildew will be estimated and recorded. Data will be subjected to analysis of variance and means separated according to Fisher's PLSD at $P < 0.05$.

Objective IV. Baseline sensitivities for resistance-prone fungicides (eg. Flint, Cabrio, Quintec) will be developed using the methods of Ypema and Gubler. Detached, symptomless, and untreated cherry leaves will be collected from 'Bing' cherry liners. Leaves will be disinfested for 30s in a 50% ethanol solution and rinsed using sterile, distilled water. Leaves will be placed between autoclaved paper towels to dry. Leaves will be dipped in each fungicide treatment and allowed to dry, ventral side-up, on paper towels. Leaf discs will be obtained using a 15 mm cork-borer and four discs will be placed in a 60x20 mm petri dish prepared with one layer absorbent pad (Gelman 47 mm) wetted with 1 ml sterile distilled water and two layers of Miracloth. The discs will be inoculated with *P. clandestina* using an inoculation tower. Disks will be placed in Rubbermaid crispers lined with moist paper towels and incubated 10 days at 28.5C in a 12-hour photoperiod.Inhibition of fungal growth will be determined by assessing the percentage of leaf disc surface covered with sporulating powdery mildew colonies.

Objective V. Oil phytotoxicity studies. Cherry seedlings will be treated with various concentrations of narrow range petroleum oils and incubated 14 days at temperatures of 5-35 C. at 75% relative humidity. Phytoxicity will evaluated by estimating the amount of necrotic tissue per leaf.

Results and Discussion:

Ascocarp degradation model. Ascocarp (primary inoculum supply) viability at bud burst was about 50%. The primary inoculum supply then gradually declined and was depleted shortly before pit hardening. About 150 cumulative degree-days > 10 C was required to deplete the supply. Although this aspect of our research needs to be repeated and conducted in greater depth, these results are significant because the represent an important step in definition of the period of time when the risk of primary infection from internal sources is highest. Sufficient precipitation or irrigation after bud burst, but before the seasonal exhaustion of this primary supply, can result in primary infection and epidemic initiation. Conversely, if the moisture requirements for primary infection are not met during this time period, disease will theoretically develop later if at all.

Controlled environment studies. The results of our controlled environment disease development studies have defined the temperature range over which infection can occur (10 to 28). Multiple regression analyses of the raw data indicated that disease development on cherry foliage was described by the equation:

Disease severity = $=38.9 + 1.3\ T + -0.052\ T^2*RH + 0.008\ T*RH$ (Equation 1)

Where T = temperature and RH = relative humidity. The equationaccounted for about 47% of the variability in the raw data ($R^2 = 0.47$). The most significant aspects of these findings are the identification of the temperatures above and below which the fungus is *not* active and that there is an interaction between temperature and relative humidity. The study also indicated that relative humidity is an important factor over the range of temperatures most conducive for growth of *P. clandestina.*

PCR techniques and air sampling studies. The primers developed by R.A. Spotts were tested for cross-reaction the powdery mildews of 46 other host plants. The powdery mildews of all major crops and susceptible weed species in Eastern Washington were tested for cross-reaction with the primers. Reaction occurred only with DNA extracted from the powdery mildew of cherry indicating that "false positives" due to the presence of other powdery mildews are unlikely. This indicates that the chances for "false positives" in air sampling studies are minimal. The PCR assay was also demonstrated to be extremely sensitive, e.g. DNA extracted from 1 and 5 spores was detected 83% and 100% of the time.

Three different air sampling techniques (used in conjunction with the PCR assay) were evaluated beginning at bud burst. One utilized a Rotorod air sampler that was operated continuously. A second technique involved weekly "spot" sampling utilizing a Rotorod sampler affixed to the front of an ATV. The third technique utilized glass rods affixed to the bark in tree crotches. All three successfully *detected P. clandestina* in the orchard air, but only the first did so early enough to be of practical significance. *P. clandestina* was not detected in the orchard air during March, April, and early May, indicating that "background" DNA from previous epidemics did/will not result in "false positives". The initial detections of the fungus in the orchard air occurred during two rain events in mid-May. The presence of ascospores in the orchard air during these rain events was confirmed using Burkard volumetric air samplers. The first signs of powdery mildew were observed in the orchard 7 days after the second ascospore release. The air sampling/PCR technique confirmed the presence of the fungus in the orchard throughout the growing season (data not shown).

Results of this study should represent the initial step in the incorporation of an inoculum availability component into a cherry powdery mildew risk assessment model. The significance of this component

has several potential benefits. The plant disease triangle dictates that any plant disease results from the interaction between host, pathogen, and environment. If the pathogen were absent, even the most disease-conducive weather conditions would not result in an epidemic. Therefore, the application of this technology could serve to delay the initiation of the fungicide program.

Disease management programs. Several organic programs were tested under low- to moderate disease pressure. Milk and powdered whey did not provide satisfactory disease control. An alternation of Stylet Oil and Microthiol provided control equal to that attained using a conventional synthetic program. However, more applications were required using the organic program. While the compounds used in the organic program were in general less costly than those used in the conventional program, the number of applications required using the former program would significantly increase labor costs.

Fungicide application technology. When fungicides were applied using the AccuTech sprayer, disease control was inversely proportional to spray volume ($R^2 = 0.96$). Disease severity was also higher in treatments where fungicides were applied with a conventional air-blast sprayer.

Budget:

Project Title: Measuring and Modeling Powdery Mildew of Cherry
PI: G.G. Grove and R.A. Spotts
Project Duration: 2004-2006
Current Year: 2005
Project Total (3 years): $137,417
Current Year Request: $ 47,487

Year	Year 1 (2004)	Year 2 (2005)	Year 3 (2006)
	48,678	47,487	48,930

Current year breakdown

Item	Year 1	Year 2	Year 3
Salaries			
[1]Scientific Assistant	17,520	17,409	18,105
Benefits 26% (yrs 2 & 3)	5,606	4,526	4,707
[1]Salaries (hourly labor)	12,000	12,200	12,688
Benefits 16% (yrs 2 & 3)	1,952	1,952	2,030
Equipment	-	-	-
[2]Supplies	6,700	6,700	6,700
Travel	4,700	4,700	4,700
Miscellaneous	-	-	-
Total	$48,678 (funded: $41,000)	$47,487	$48,930

[1] Salaries: Scientific Assistant Jeff Lunden. Hourly Labor: Oscar Garcia
[2] Supplies consist of PCR reagents, glass rods, Petri plates, anhydrous glycerol, plot supplies
[3] Travel - weekly travel to Wenatchee Valley, Roza research unit, and Upper Yakima Valley. Includes partial lease on 4 x 4 truck, fuel and vehicle maintenance charges and occasional overnight travel to Wenatchee for air sampling studies.

CONTINUING PROJECT

WTFRC Project #: OSCC-4
Project title: Studies on the biology and control of powdery mildew on sweet cherry.
PI: Jill M. Calabro and Robert A. Spotts
Organization: OSU Mid-Columbia Ag Research and Extension Center
Cooperator: Gary Grove

2004 Objectives:

1. Determine when fruit infection occurs in relation to maturity,
2. develop an early detection method on cherry fruit,
3. evaluate foliar mildew levels under various management regimes, and
4. study the relationship between powdery mildew (PM) infection and pitting.

Significant findings:

- ✓ Fruit can be inoculated both in the field and in the lab.
- ✓ Fruit remain susceptible to PM throughout the growing season, potentially gaining some resistance after reaching 15 ºBrix.
- ✓ Pm infection levels can be quantified via real time PCR.
- ✓ Management practices are related to PM infection levels. A range of resistance exists among cultivars, and mildew infection levels are related to tree spacing and training system.
- ✓ PM significantly increasing pitting severity.

Methods Employed in 2004:

1. Develop fruit inoculation techniques

Weekly inoculations with a spore suspension were done on fruit clusters of five Lapins trees in an orchard from 16 April to 25 June. Upon harvest, fruit were collected and assessed for PM incidence. To minimize natural PM infections, the trees were sprayed biweekly with Rally, Quintec, Omni Oil, Sulfur, Orbit, or Procure, with the fruit clusters of the study protected with plastic bags. Also at harvest, five border trees were randomly selected for a comparison of foliar PM incidence with the trees of the study to check the effectiveness of the fungicide spray program.

Twenty each of Lapins and Sweetheart fruit were collected weekly from 5 May to 29 June and inoculated with dry spores using a vacuum operated spore settling tower. Fruit were incubated 24 hours, and then glue peels were used to assess percent spore germination.

2. Time of infection of Bing, Lapins, and Sweetheart fruit

New fabric bags made of nylon were used to cover fruit and exclude mildew spores from 8 April to 8 July (harvest). Bags were removed from each fruit cluster for a one-week period throughout the growing season so that fruit were exposed to PM spores. Fruit were assessed for mildew incidence upon harvest. Sensors monitored relative humidity and temperature both within and outside the bags, and an orchard air sampler was used to monitor the daily number of conidia.

3. Optimization of real time PCR to quantify PM

A technique utilizing real time polymerase chain reaction (qPCR) to amplify a segment of DNA unique to the sweet cherry PM fungus was developed to detect and quantify the amount of PM

DNA on both cherry fruit and leaves. Fruit were collected weekly and then washed throughout the growing season. The fruit washes were analyzed with qPCR to quantify PM on fruit surfaces as the growing season progressed.

4. Foliar mildew evaluations comparing the effect of different management regimes and cultivar on mildew infection

Ten shoots of current year's growth were collected per tree, and PM incidence was recorded for the outer most ten leaves. No more than ten trees were selected from three different studies already underway.

Hazel Dell: Cultivar Bing was evaluated for variations in four different rootstocks and three training systems.

Cemetery Block: Five cultivars were evaluated; Bing, Lapins, Regina, Sweetheart, and Staccato.

5. Effect of mildew on pitting

Fruit with a varying degree of mildew (rated as no = 0%, slight = 1-33%, moderate = 34-66%, severe = 67-100% mildew) were selected and cooled to either 1°, 4°, or 20° C, and then a pitting tool was used to deliver a standard impact to the shoulder of each fruit. Fruit were stored for two weeks at either 1° or 4° C and then rated for severity of pitting (1 = none, 2 = slight, 3 = moderate, 4 = severe damage). Twenty-five fruit were used for each temperature regime/PM infection level combination. Three cultivars were included in the study, Bing, Lapins, and Sweetheart. Firmness data were also collected for each PM infection level.

6. Develop protocols for histology

Various stains and tissue clearing protocols were attempted to enable the microscopic examination of PM structures on fruit and leaf surfaces.

Comments: Maturity indices of size, color, and ºBrix were recorded weekly for each cultivar.

2003 & 2004 Results and Discussion:

1. Fruit inoculation techniques. Figures 1.

PM infection was evident among the fruit inoculated in the field trial; however, no differences were seen among the treatments (weeks of inoculation; data not shown). The fungicide spray program was successful at reducing the amount of foliar PM, because the border trees not included in the spray program had significantly more foliar PM infection than the five trees in the study (average 6.4% and 1.5%, respectively.

Spores germinated on detached fruit within twenty-four hours. Statistical differences were evident. Percent germination declined after the fruit reached ºBrix. Glue peels were an adequate method to count percent germination.

These techniques will be useful in 2005 for studies involving the effects of temperature and relative humidity on PM infection.

2. Time of infection of Bing, Lapins, Regina, and Sweetheart fruit. Figure 2, 3, & 4.

The new nylon bags were a significant improvement over the 2003 Typar bags. Fruit developed to a normal size, shape, and color within the bags. The first conidium was collected on 16 April. Fruit were susceptible to PM throughout the growing season. Significant differences were evident between cherries which were never covered by a bag (positive control) and fruit covered with a bag the entire season (negative control) for each cultivar. Fruit infection declined somewhat near the point at which fruit reached 15 °Brix. These studies should be repeated in 2005.

3. Development of a detection and quantification method

A PCR technique was successfully used to identify and quantify the amount of cherry PM DNA on both foliar and fruit tissue. Due to multiple equipment and reagent failures, experiments involving fruit washes collected during the growing season are still in progress. These studies have the potential to allow monitoring of PM populations.

4. Foliar mildew evaluations comparing the effect of different management regimes and cultivar on mildew infection. Figures 5 and 6.

Hazel Dell (Figure 5): Overall, PM incidence was low at this site but greater than 2003. Both rootstocks and training systems varied significantly in terms of observed PM infection, and there is an interaction between the two. Rootstock Edabriz had the least amount of PM incidence. The dwarfing nature of Edabriz is related to significantly less mildew infection. Spanish Bush training system averaged greatest PM incidence. The characteristic dense foliage of Spanish Bush training is related to significantly greater mildew infection. I was advised that the trees trained as Spanish Bush may not be true to form; however, a clear relationship between various training systems and the resulting foliar PM infection has been established. These results are consistent with 2003 data (not shown).

Cemetery Block (Figure 6): PM incidence varied greatly with cultivar; this difference was statistically significant. PM incidence was greatest on Staccato and least on Regina. A range of PM resistance among cherry cultivars is indicated.

Due to the nature of these 2003 and 2004 studies, a causal relationship cannot be established between the different management practices and foliar mildew infection, but there is an association present. These studies have concluded.

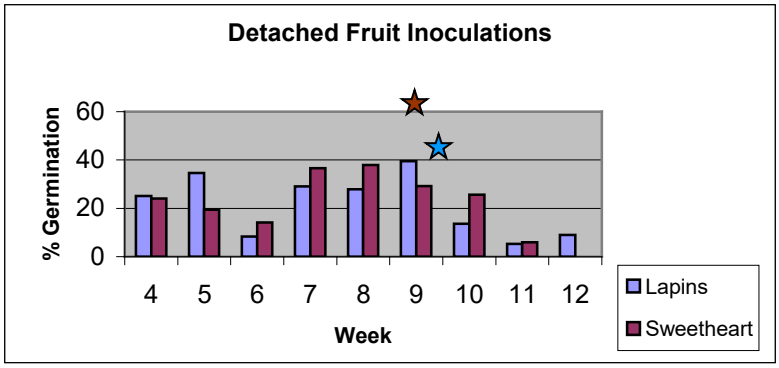
5. Effect of mildew on pitting. Tables 1, 2,& 3

PM significantly increased pitting severity for each cultivar. Sweetheart had the most severe pitting and Lapins the least, with differences being statistically different. Storage temperature had no effect on pitting severity, but the temperature at the time of injury did. For Bing and Sweetheart, pitting was significantly worse when impact occurred at the chilled temperatures of 1 and 4 C. This is consistent with previous studies by other researchers. This trend was opposite for Lapins; injury at the warmer temperature of 20 C resulted in more severe pitting. Interestingly, mildewed fruit were less mature than mildew free fruit, in terms of size, color, and ºBrix. This study should be repeated in 2005.

6. Protocols for histology

A technique was adapted to fix and clear cherry fruit skin tissue to allow microscopic views of PM fungal structures. Most of the color can be removed from small sections of cherry fruit skin submersed in a series of lactophenol, ethanol, and methyl salicylate, and fungal structures can be easily viewed. This will be an important tool enabling the differentiation of the stages of the infection process.

Figure 1. Average percent spore germination on detached Lapins and Sweetheart fruit inoculated weekly with dry spores in the lab. Inoculations began 5 May. The stars indicate the approximate time each cultivar reached 15 ºBrix.



Figures 2, 3, & 4. Average percent fruit infected in the bagging study for each cultivar. Week 1 corresponds to the positive control where fruit were not bagged. Subsequent weeks correspond to period of time when the fruit were exposed (bag removed) and vulnerable to PM infection. PM ratings were done following harvest. Stars indicate when 15 ºBrix was recorded.

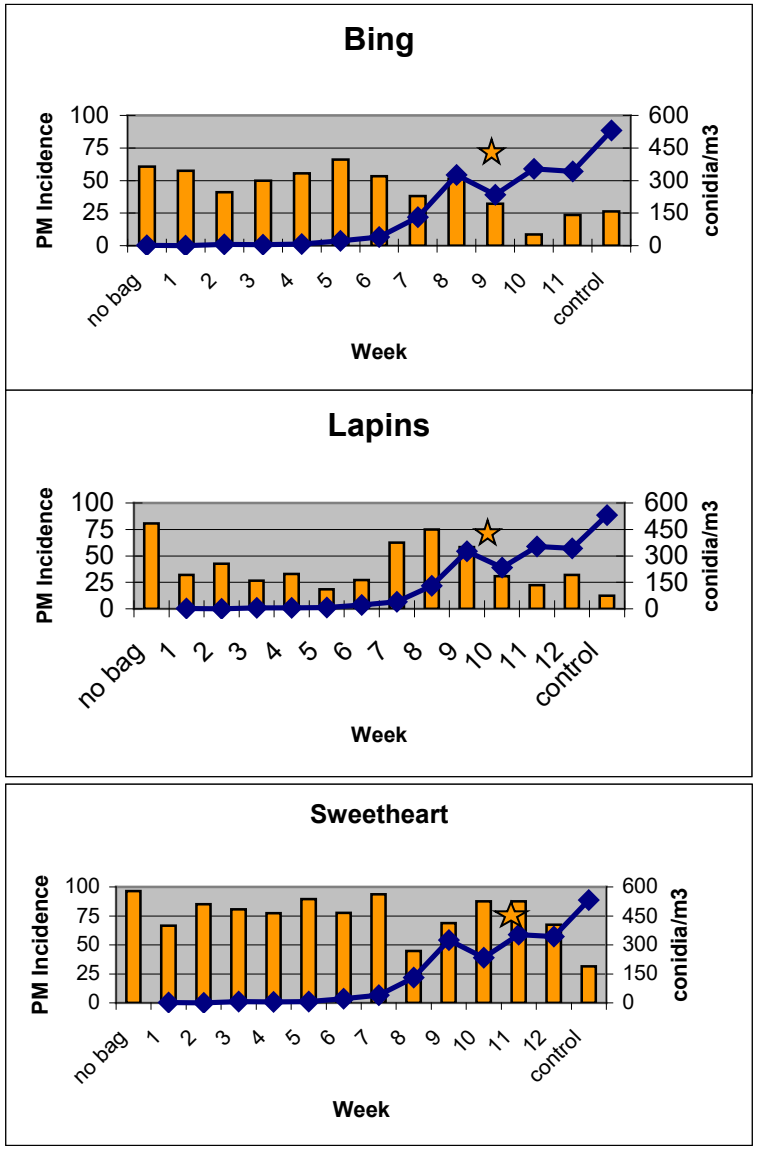


Figure 5. Average percent PM infected leaves observed at the Hazel Dell site. Rootstock abbreviations are as follows: Eda = Edabriz, Mazz = Mazzard, MM14 = Maxima 14, and Pont = Pontileb. Training system abbreviations are as follows: CL = central leader, SB = Spanish bush, and SL = steep leader. Statistical differences at the $\alpha = 0.05$ level are indicated by the lower case letters in parentheses.

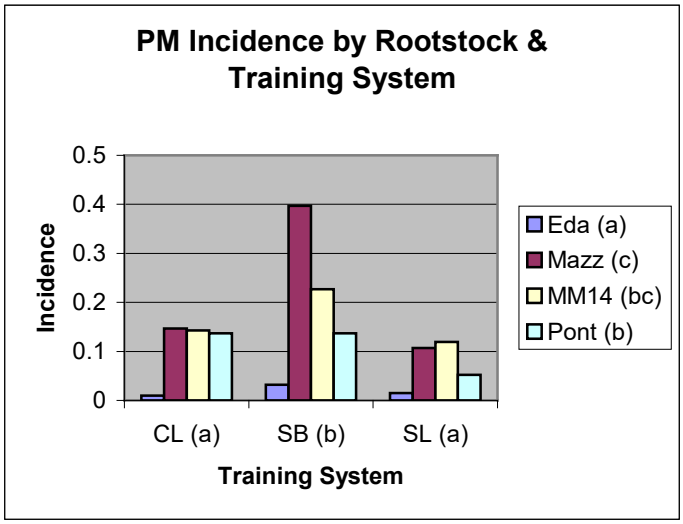
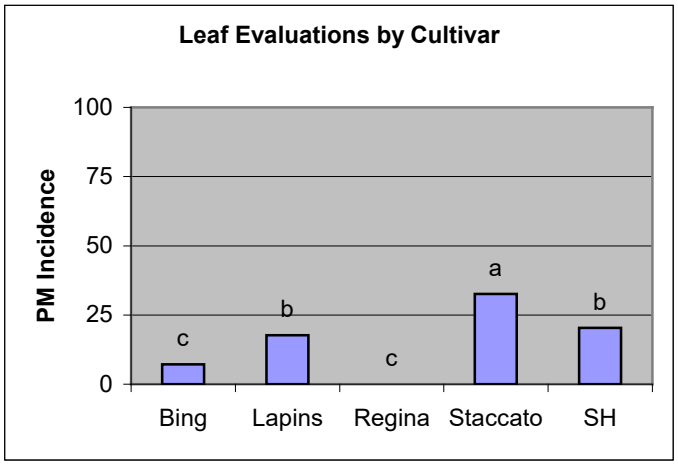


Figure 6. Average percent PM infected leaves observed at the Cemetery Block comparing five cultivars. Statistical differences at the $\alpha = 0.05$ level are indicated by the lower case letters above each bar.



Tables 1, 2, & 3. The average rating of pit development following a standard impact of three cultivars with varying degree of PM infection. A pit rating of 0 = no damage, 1 = slight damage, 2 = moderate damage, and 3 = severe damage.

Bing					
Injury Temp C	Storage Temp C	No PM (a)	Slight PM (a)	Mod. PM (a)	Severe PM (b)
1 (c)	1	2.08	1.72	1.92	2.20
1 (bc)	4	1.48	1.68	1.48	2.52
4 (b)	1	1.52	1.48	1.88	1.92
20 (a)	1	1.08	1.16	1.20	1.36

Lapins					
Injury Temp C	Storage Temp C	No PM (a)	Slight PM (ab)	Mod. PM (bc)	Severe PM (c)
1 (ab)	1	1.28	1.40	1.68	1.96
1 (a)	4	1.32	1.48	1.56	1.40
4 (ab)	1	1.48	1.48	1.68	1.64
20 (b)	1	1.56	1.68	1.72	1.84

Sweetheart					
Injury Temp C	Storage Temp C	No PM (a)	Slight PM (b)	Mod. PM (b)	Severe PM (b)
1 (b)	1	1.56	1.88	1.76	1.96
1 (b)	4	1.56	1.88	1.84	1.88
4 (ab)	1	1.44	1.68	1.68	1.80
20 (a)	1	1.32	1.56	1.80	1.68

Budget: Deviations in the budget are explained by a departmental increase in the appointment percentage (from 0.41 to 0.45 FTE) and a university increase in benefits.

Year	**2003**	**2004**	**2005**
Total	16324	17023	18778

Current Year Breakdown

Item	**2003**	**2004**	**2005**
Salary & Wages	15000	15675	16560
OPE	524	548	1418
Supplies	500	500	500
Travel	300	300	300
Total	16324	17023	18778

2005 Objectives:

1. Determine when fruit infection occurs in relation to maturity,
2. study the relationship between PM and pitting, and
3. evaluate PM resistance to demethylation inhibitor (DMI) fungicides.

Methods to be employed:

1. Time of infection of Bing, Lapins, and Sweetheart fruit

See #2 in "Methods Employed in 2004."

2. Effect of PM on pitting

See # 5 in "Methods Employed in 2004."

3. DMI fungicide resistance

PM isolates were collected in 2004 from ten regional orchards categorized in one of three categories based on the historical use of DMI's as either none/organic, soft, or hard spray program. PM spores were harvested, freeze dried, and stored at –70C. Actively growing cultures will be maintained on live cherry trees, cultivar Sweetheart. Leaf disks will be sprayed with the fungicide Elite, Orbit, Procure, Rally, or Rubigan, at 0, 25%, 50%, 100%, or 200% of the labeled rate and then inoculated with PM. Fungicide resistance will be rated following an incubation period of 14 days. The procedure will be repeated for each orchard, and the entire experiment repeated once in its entirety.

CONTINUING REPORT

Project # OSCC –3

TITLE: Tree water use, irrigation scheduling and water management systems in sweet cherry

PI: Roberto Núñez-Elisea
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C. Seavert, X. Yin, J. Bai, T. Facteau (OSU-MCAREC, Hood River)
Paul Schreiner (USDA-ARS, Corvallis, OR)
Jac le Roux (Irrigation Consultant, Irrinet, The Dalles, OR)

Objectives

- To measure soil/plant water status in sweet cherry to determine active root depth, baseline levels of tree water stress and quantify tree water use.
- To evaluate the benefits of irrigation scheduling based on measurements of soil/plant water status vs. a representative grower irrigation method (i.e., calendar schedule).
- To evaluate the cost/benefits of using a woven polypropylene fabric row cover for water conservation and weed control.
- To evaluate full-season deficit irrigation (from June to September) as a method to promote precocity and control vigor of young trees on Mazzard rootstock.
- To evaluate high-efficiency water management strategies (i.e., regulated deficit irrigation, partial rootzone drying) on bearing trees to conserve water and increase fruit quality.

Significant findings for 2004

- Root systems of 'Lapins'/Mazzard trees irrigated with micro sprinklers were located at 40-60 cm soil depth.
- Fourth-leaf 'Regina'/Gisela 6 trees grown with a woven fabric row cover continued to show greater vigor and branching, canopy spread and higher foliar N content compared to trees growing without cover.
- Yields of trees with row covers were 130% higher and fruit significantly larger compared to trees without row covers.
- Because of significantly larger yields with fabric row covers, orchard establishment costs have begun to be recovered by the 3rd after planting.
- Full-season deficit irrigation of young 'Lapins'/Mazzard trees induced precocity. As in 2003, fruit production in 2004, although still light, was greater for deficit-irrigated trees than controls, with excellent fruit quality.
- Starting in late July, trees subjected to full-season deficit irrigation showed significantly lower stem water potentials than well-irrigated controls; however, in contrast to previous years, vigor of trees under deficit irrigation was similar to that of well-watered trees.

Methods

Measurement of soil and plant water status

Volumetric soil water content is being measured with a portable probe (Sentek Diviner 2000™) or a continuous soil-water monitoring system (Sentek EnviroScan™). Both systems measure soil water content via vertically placed PVC access tubes installed adjacent to trees, within the area explored by root zones. The Diviner 2000™ is manually operated and records data at 10-cm intervals though the

soil profile. The EnviroScan™ consists of a network of eight permanent probes, each with four from sensors at 20, 30, 40, and 60 cm depths. A solar panel and a rechargeable 12-volt battery power the system. Sensors are programmed to collect data at 30-min intervals. A neutron probe will be used in 2005 to measure volumetric soil water content. Diviner access tubes will be used for monitoring soil moisture with the neutron probe.

Tree water status is being measured with pressure bombs, which function on the principle that water inside plants is under tension (negative pressure). Pressure bombs measure the level of water stress by using detached leaves that are inserted in a chamber, with the leaf petiole extruding from the chamber. A portable pressure pump resembling a bicycle pump, or a pressure bomb connected to a nitrogen tank, is used to pressurize the chamber and push water out of the leaf through the petiole cut. A magnifying glass is used to detect the moment at which water appears on the surface of the petiole cut. The pressure required to cause water extrusion is recorded. Leaves with very little water content (from trees under water stress) require a greater pressure to push water out through the petiole cut than leaves from well-irrigated, non-stressed trees. Because pressure-bomb measurements reveal whether trees are under water stress, together with measurements of soil moisture status they offer a powerful strategy to increase the efficiency of irrigation management. Stress can be caused by either over- or under-irrigating, and can be particularly detrimental during the last 2-4 weeks of sweet cherry fruit growth (stage III of the fruit growth curve; its duration varies among cultivars), preventing fruit from achieving their full size potential.

What is stem water potential? When water status of a leaf is measured as described above, the measurement is called 'leaf water potential'. This measurement, however, can vary greatly depending on the position of the leaf in the canopy due to large variations in exposure to sunlight and wind. An effective way of reducing this variability is to select leaves from the inner canopy and enclose them in a plastic/aluminum foil envelope for about an hour before detaching for measurement. Enclosure in the envelope minimizes transpiration and causes the leaf to equilibrate with the water status of the stem, which is highly uniform throughout the tree. This measurement, obtained from leaves whose water potential is in equilibrium with that of the stem, is called 'stem water potential' and is widely used as an indicator of tree water stress. Measurements of stem water potential are most useful when made during the period of highest water demand (between noon and about 3 pm).

Use of a wide polypropylene fabric row cover

A 3-acre plot of 'Regina'/Gisela 6 trees planted at the MCAREC in April, 2001, is being used to evaluate the benefits of using an 8-ft wide woven polypropylene row cover for water conservation and weed control. Trees are planted at 18' *x* 10' (rows *x* trees) and trained to a central leader. Irrigation is being scheduled to maintain soil water content in the top 50 cm of soil profile above 50% of field capacity. Soil moisture content is being measured during the growth season using a portable probe (Diviner 2000, Sentek, Australia). Sensors have been installed to record soil and air temperature in covered and non-covered rows to determine the effect of temperature on tree growth. Measurements of stem water potential are being made to determine the effect of row cover on tree water status. Soil samples have been collected to determine the effect of fabric row covers on root distribution. Establishment and management costs have been recorded since planting. First commercial harvest of this plot occurred in 2004. Tree vigor, yield and fruit quality were determined.

Deficit irrigation of young 'Lapins'/Mazzard trees to control vigor and induce precocity

This experimental block was established in 1999, with trees planted at 14 x 16 feet. The soil is a sandy loam with available water content of about 13%. Irrigation treatments are imposed between May and September. The trial is arranged in a randomized complete block design with 6 replications. Three irrigation treatments are being tested: 100% (control), 50% or 25% replacement of pan evaporation every week (typically). Treatments have been imposed since 2000. The level of tree water stress is determined by measuring stem water potential just prior to each irrigation cycle. Soil

water content is being monitored manually with a portable sensor (Sentek Diviner 2000™). Initial fruit production has been recorded and will continue in 2005.

Partial rootzone drying of young 'Lapins'/Mazzard trees

Trees planted in 1999, now in bearing age, will be used during 2005. Two irrigation rates will be compared: 1 gal/h and 2 gal/h, delivered through pressure-compensated drip emitters placed 20 inches from the tree trunk. For each rate, irrigation will be applied either alternately to each side (PRD) or, for controls, simultaneously to both sides of the root system (full rootzone irrigation, FRI). Irrigation will be applied approximately every 5 days for a period of 24 hours (see Table 1). Two poly-tube lines, each with an independent valve, have been installed at each row to allow applying water to alternate sides of the root system. In the PRD treatments, irrigation will be switched from one side of the root system to the other at approximately 2-week intervals. Growth, yield and fruit quality will be measured in 2005.

Results 2004

Measurement of soil water content and location of active root system

Irrigation during 2004 was applied from mid-June to late September. As observed in 2003, soil water content was consistently higher and around saturation at 60 cm soil depth, gradually decreasing closer to the soil surface. Most water uptake (65% to 85%) of young 'Lapins'/Mazzard and 'Regina'/Gisela 6 trees occurred at 40-60 cm soil depth.

Use of a polypropylene fabric row cover

Fourth-leaf 'Regina'/Gisela 6 trees growing in an 8-ft- wide fabric row cover displayed more vigor and branching than trees without row cover (Table 1). This response was likely influenced by the higher moisture levels and warmer soil temperature (3 to 4ºF) found under the fabric cover. Trees without row cover had a greater canopy spread than those with cover. Leaves of trees with row cover were darker green than leaves of trees without row cover and, as in 2003, had significantly higher N content.

Trees were pruned in April during early bloom. Because of their larger canopies, pruning of trees in row covers was slower than for trees without row covers. The pruning weights for trees with row covers were double that of trees without row covers.

Yields in 2004 were relatively low due to insufficient pollen, as only about 30% of pollinizer trees were functional (a few were lost to disease and most are one year younger and produced insufficient bloom). Yet, trees with row covers produced more than double the average yield of trees without row covers. In row covers. trees adjacent to a functional pollinizer tree ('Sam'/Gisela 6) typically produced more than 30 lbs, whereas trees separated from functional pollinizers produced about 50% lower yields. Without row covers, trees adjacent to pollinizer trees also produced higher yields than trees farther away in the row, but in both cases yields were significantly lower compared to trees in row covers (data not shown).

As in 2003, fruit from row-covered trees were significantly larger than fruit of trees growing without row covers (Table 1). Also, fruit maturity in row-covered trees was delayed by about 2-3 days in relation to controls, which was attributed to more shading, and possibly higher nitrogen content and greater crop load in trees with row covers. Establishment costs have begun to be recovered for the row-covered treatment, but not for the non-covered control (Fig. 1), due to the dramatic increase in yield achieved with row covers.

Measurement of stem water potential showed nearly identical tree water status for trees with and without row covers, indicating that lower production and smaller average fruit size in trees without covers were not due to water stress (data not shown). Rather, higher yields and larger fruit size in row covers are attributed to effective weed control, more uniform moisture and slightly

warmer temperature in the top 4" of covered soil. These factors are believed to have promoted root development and nutrient uptake. Soil samples have been collected to measure root distribution patterns of trees with and without row covers. The impact of row covers on beneficial mycorrhizal fungi will be examined in 2005.

Results of 2004 demonstrate a dramatic positive effects of fabric row cover on growth and production of young 'Regina'/Gisela 6 trees. Tree performance will continue to be evaluated in 2005. In addition, during 2005 we plan to irrigate covered and non-covered trees according to two schedules: (1) based on tree water demand as determined by soil and tree water status, and (2) a calendar schedule representative of commercial sweet cherry orchard irrigation in the Mid-Columbia area.

Deficit irrigation of young 'Lapins'/Mazzard trees

The objective of this study was to reduce vigor and promote precocity of sweet cherry trees on Mazzard rootstock by subjecting trees to full-season water deficit during pre-bearing age. Stem water potential (SWP) levels of control trees (100% irrigation rate) showed minimal water stress just prior to each irrigation event, indicating that trees received very close to their full water requirement. SWP readings of the 25% and 50% irrigation rates were significantly lower (more negative) than controls throughout the study (Fig. 2). SWP differences between the 25% and 50% rates were only detected in the first year of the study. Control trees showed a small (14%) increase in trunk cross sectional area when compared to the two deficit rates (Table 2) and no difference in shoot growth in 2004.

Trees irrigated with 25% and 50% of pan evaporation showed no difference in growth in 2004. Roots are believed to have reached deep soil layers with available soil water, allowing trees to grow at similar rates. Initial yield in 2003 from trees irrigated at the 25% rate was 6 times greater than yield from the 100% and over twice that of the 50% rate. The yield increase between the 25% and 100% rates declined to 3 fold in 2004. Fruit from trees irrigated at the 25% rate averaged 9.8 grams in 2003 and 10.2 grams in 2004. Results show that 'Lapins'/Mazzard trees tolerated full-season deficit irrigation during pre-bearing age without adverse effects on growth and initial production.

The relationship between stem water potential and leaf stomatal conductance (g_s) was explored for 'Lapins'/Mazzard trees in 2004. Stomatal conductance is a measure of the ease with which water vapor moves through stomata (the microscopic openings in leaves through which transpiration takes place) and is, therefore, related to leaf water status. Typically, low g_s values are associated with low water content in leaves and with increasing levels of tree water stress. Measurement of g_s is done with a porometer and is easier and quicker to conduct than stem water potential. The relationship between SWP and g_s was acceptable ($R^2 = 0.48$; Fig. 3), but in practice it was difficult to obtain consistent measurements under windy conditions. More work is planned for 2005 to determine the usefulness of measuring g_s as an indicator of tree water status for cherry trees.

Now that trees have begun production, future work in this plot will consist of testing irrigation techniques such as RDI (regulated deficit irrigation) and PRD (partial rootzone drying) to increase irrigation efficiency. Our goals are to conserve water without affecting tree health, yields and fruit quality.

Budget
Project title: Tree water use, irrigation scheduling and water management systems
PI: Roberto Núñez-Elisea
Project duration: Continuous
Funding in 2004: $25,000
Current year request: $27,500

	Year 2004	**Current year 2005**	Year 2006
Original request			
Total			
Current year request			
Salaries-FRA	16,340	**18,455**	
OPE (49%)	8,660	**9,045**	
Travel			
Total	25,000	**27,500**	27,500

Table 1. Effects of a synthetic fabric row cover on tree vigor, yield and fruit quality of 4th leaf 'Regina'/Gisela 6 trees. Yield data are means of 96 trees per treatment (8 replications, 12 trees per replication). MCAREC, Hood River, 2004.

Treatment	TCSA (cm^2)	Yield (lb/tree)	Fruit wt (g)	Fruit diam. (mm)	Firmness (g/mm)	°Brix
No cover (control)	55.5 a	7.04 a	11.1 a	28.9 a	325.4 a	21.6 b
Fabric row cover	72.3 b	16.3 b	11.6 b	29.5 b	360.9 b	20.4 a
% increase over control	30.3	131.3	10.5	10.2	11.1	- 5.6

Table 2. Effects of full-season deficit irrigation on growth, yield and fruit quality of young (5th to 6th leaf) 'Lapins'/Mazzard trees. MCAREC, Hood River, 2004.

Irrigation regime (% ER)*	Yield (lbs/tree)		Ave. fruit wt. (g)		TCSA (cm^2)	
	2003	2004	2003	2004	2003	2004
25	1.60 a	6.4 a	9.8	10.2 a	70.4 b	108.9
50	0.71 b	1.7 b	9.3	9.2 b	69.6 b	107.9
100	0.26 b	2.1 b	9.6	9.5 ab	77.8 a	119.3
Sign. P ≥ 0.05			*n.s.*			*n.s.*

* ER = weekly evaporation replacement as measured with a USDA class 1 pan evaporimeter

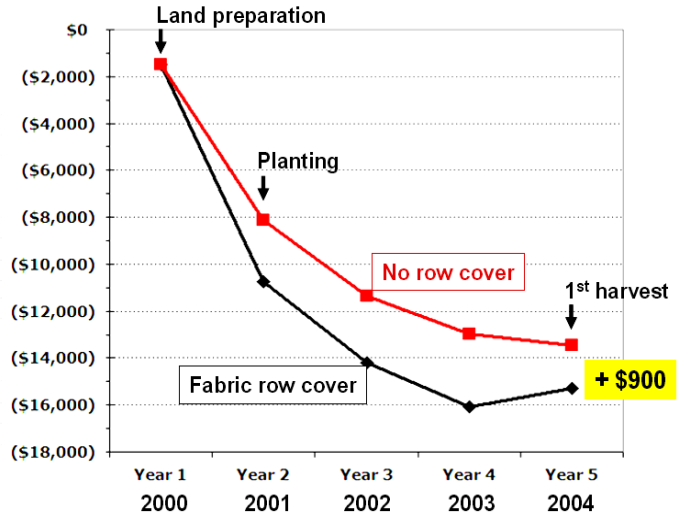

Fig. 1. Cash costs for orchard establishment per acre using wide fabric row covers vs. no fabric row covers. Cost of establishing fabric row covers is beginning to be recovered 3 years after planting. The cost of establishing row covers was $2,140/acre. Economic analysis by C. Seavert. MCAREC, Hood River, 2004.

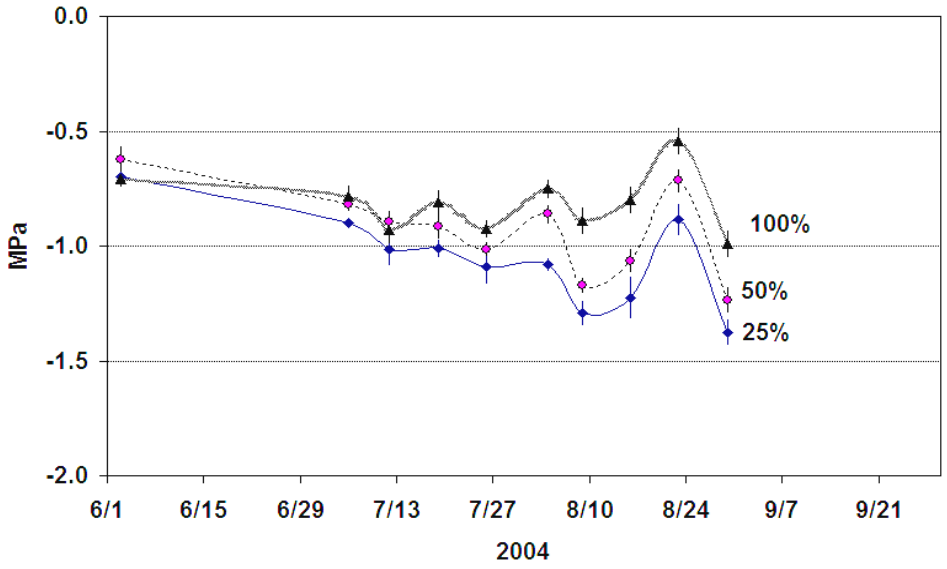

Fig. 2. Stem water potential of 'Lapins'/Mazzard trees as influenced by deficit irrigation treatments. MCAREC, Hood River, 2004.

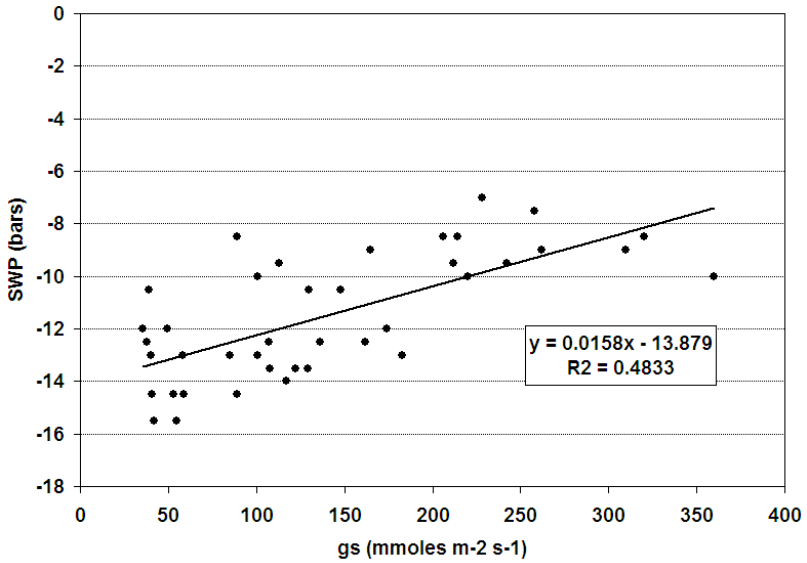

Fig. 3. Relationship between stem water potential and leaf stomatal conductance in 6th leaf 'Lapins'/Mazzard trees. MCAREC, Hood River, 2004.

FINAL REPORT

PROJECT NO.: CH-02-201

TITLE: Alternative Water Management Strategies for Sweet Cherries

Principal Investigators: Matthew Whiting, Assistant Horticult., WSU-IAREC
Roberto Núñez-Elisea, Horticult., OSU-MCAREC

Cooperators: Jim McFerson, WTFRC, Wenatchee
Horst Caspari, Colorado St. U.
Denny Hayden, Pasco

YR INITIATED: 2002 **CURRENT YR:** 2004 **TERMINATING YR:** 2004

OBJECTIVE:

- Elucidate the effects of season-long deficit irrigation and partial rootzone drying on sweet cherry vegetative growth, fruit quality, and leaf and whole-canopy transpiration and carbon assimilation.

SIGNIFICANT FINDINGS:

- across rootstocks, neither deficit irrigation strategy significantly affected fruit quality compared to the control (*i.e*., similar quality fruit were grown using less water)
- PRD provided significant vigor control of Mazzard- and Gisela 5-rooted trees, but not for trees on Gisela 6
- Gisela rootstocks are no more/less susceptible to water stress than Mazzard
- irrigation treatment did not affect trunk expansion of any treatment/rootstock combination
- PRD produced better quality fruit compared to DI in 2 of 3 years
- fruit and shoot growth rates were affected inconsistently and only slightly by reduced water input
- components of gas exchange (*i.e*., net photosynthesis, transpiration, stomatal conductance) were unaffected by irrigation treatment
- DI-treated trees exhibited premature leaf senescence compared to control and PRD which were similar
- shoot leaves senesced prior to spur leaves
- among rootstocks, Gisela 5 trees senesced earliest
- leaf 'greenness' *(i.e*., SPAD meter readings, related to leaf N) varied seasonally and was highest from control, intermediate for PRD, and lowest for DI
- stem water potential declined throughout the season irrespective of irrigation treatment
- stem water potential was highest in control, and lowest for DI but never varied by more than 0.4 MPa among treatments
- for PRD, alternating between rootzones was necessary every 2 – 3 weeks

METHODS:

The effects of two season-long, reduced-input irrigation strategies (deficit irrigation and partial root zone drying) will be investigated. Experiments will be conducted on mature bearing 'Bing' cherry trees at the WSU-Roza experimental orchards, the MCAREC orchards in Hood River, and at grower-collaborator orchards (as identified) in subsequent years.

WSU-ROZA trial:
All treatments will be applied at weekly intervals by under-tree microsprinklers (1/tree).

Control: Water sufficient to replace 100% of that lost by evapotranspiration (Et) will be applied to the entire rootzone. Et is calculated using the Washington Irrigation Scheduling Expert (W.I.S.E.).

Deficit irrigation (DI): Irrigation water will be applied to the entire rootzone but at 50% Et replacement.

Partial root zone drying(PRD): Irrigation water will be applied at 50% Et replacement but only to one half of each tree's root zone (i.e., alleyway) during each irrigation event. Subsequent irrigation events will alternate between root zone halves.

The following data will be collected from treated and control trees at regular intervals throughout the duration of the experiments:

- trunk-cross sectional area, shoot length, leaf area (spur and shoot), leaf water potential, fruit diameter, soil water content

Total water application will be compared among treatments by timing irrigation events. At harvest, tree yield and fruit quality (weight, size, soluble solids, and firmness), will be determined from each tree.

In addition, gas exchange (transpiration and net photosynthesis) within selected trees will be determined. Trials will be continued in subsequent years to examine carryover effects of reduced water inputs.

RESULTS AND DISCUSSION:

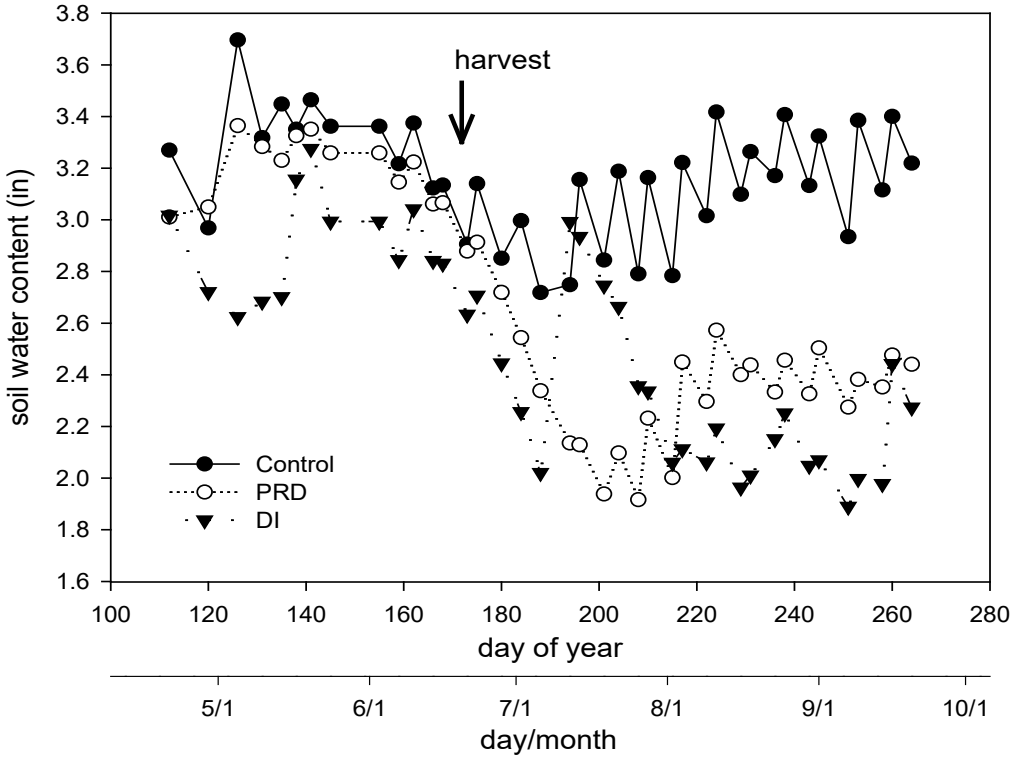

Figure 1. Effect of irrigation regime on the seasonal trend in average soil water content (full profile).

In 2004, soil water content was similar among treatments and high during the preharvest interval (Fig. 1). This is due to several natural rain events that occurred during May and June. As a result, significant water stress was likely not imposed by either deficit treatment. In fact, mean soil water content during the preharvest interval was approximately 3.3″, 2.9″, and 3.2″ for control, DI, and PRD, respectively. High water content of spring soils (essentially saturated due to frost-protection with water), low orchard evapotranspiration during April – early June, and the short interval between bloom and harvest each make a deficit situation difficult to impose. Future trials should more aggressively reduce water inputs during the preharvest interval to study the tree's response.
Following harvest, during periods of greater evapotranspiration without rain, soil water content of DI and PRD declined rapidly. During the postharvest interval, mean soil water content of control was maintained within ca. 75% of field capacity and was approximately 3.1″. In contrast, mean soil water content of DI and PRD were about 25% lower at 2.3″, during the same period. From early August on, soil water content of the PRD treatment was about 10% higher than that of the DI treatment, despite similar volumes of water applied during the period. This is likely due to greater evaporation from the soil surface of DI – water was applied to twice the surface area for DI compared to PRD. This suggests that the PRD technique may improve water use efficiency compared to DI, though this was not determined explicitly.
Similar to results from previous years, across rootstock, fruit quality was not affected significantly by irrigation treatment (Tables 1 & 2, Figure 2). In 2003, fruit soluble solids were highest from control trees and lowest from DI trees, but all were at commercially acceptable levels. Fruit mass was unaffected by irrigation treatment in every year. However, in 2003, fruit yield per tree was reduced significantly (*ca*. 45%) by deficit irrigation, irrespective of the placement of water. This may have resulted from reduced flower bud induction during 2002 or reduced fruit set or increased fruit drop in 2003. In the case of DI, it is possible that reduced postharvest photosynthetic rates limited carbohydrate availability and reduced flower bud quality in 2002. Similar results were not found in 2004, as yields among treatments were within 3 kg. In 2004 PRD-treated trees yielded slightly (≈10%) firmer fruit than DI and C – this improvement in firmness was not apparent previously. Overall, there has been no consistent effect of irrigation regime on fruit quality; only subtle effects in certain years.

Treatment	Tree yield (kg)	Fruit Mass (g)	Soluble solids (%)	Firmness (g/mm)
2002				
Control	21.5 a	6.3 a	19.8 a	288 a
DI	22.2 a	6.4 a	20.6 a	288 a
PRD	23.1 a	5.8 a	20.7 a	268 a
2003				
Control	31.5 a	6.7 a	25.4 a	327 a
DI	16.8 b	6.8 a	21.1 c	338 a
PRD	18.4 b	7.5 a	22.8 b	328 a
2004				
Control	11.2 a	7.4 a	23.6 a	242 b
DI	13.9 a	7.0 a	24.1 a	239 b
PRD	11.0 a	7.0 a	24.4 a	263 a

Table 1. Effect of deficit irrigation (DI) and partial rootzone drying (PRD) on yield and fruit quality of 8-, 9-, and 10-year-old 'Bing' sweet cherry trees. Data is averaged across all rootstocks (Mazzard, Gisela 5 and Gisela 6). Means followed by the same letter within columns and year are not significantly different by LSD ($P < 0.05$).

In 2004, irrigation treatment had subtle effects on yield per row size category (Fig. 2). DI had a slight negative impact on fruit quality of 'Gisela 5' and 'Gisela 6'-rooted trees. On 'Gisela 5', DI trees yielded about 8-fold more cull fruit (i.e., smaller than 12-row) and about half the premium size fruit compared to PRD or control. On 'Gisela 6', DI trees
yielded about 30% (≈ 8.2 lbs) fewer 10.5-row and larger fruit and about 50% fewer (≈ 10.5 lbs) fruit in the 11 and 12-row size category per tree compared to PRD and control. There were no significant effects of irrigation on fruit yield and quality of Mazzard-rooted trees though PRD trees yielded about 40% more fruit in the largest category.

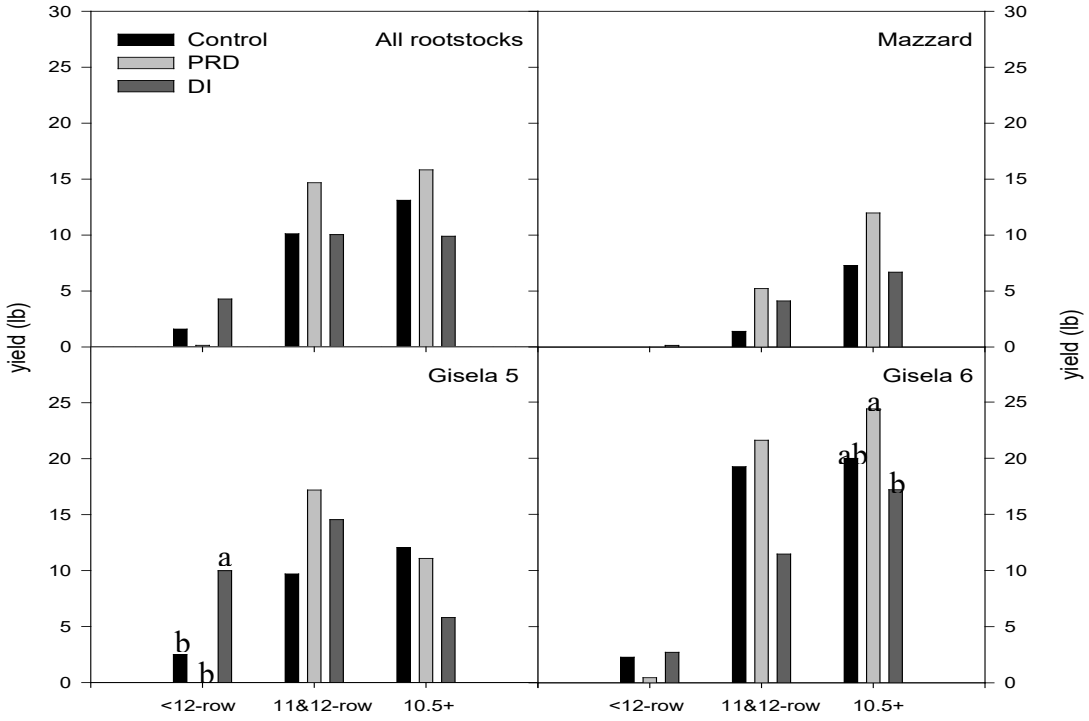

Figure 2. Fruit yield and row size of 10-year-old 'Bing' sweet cherry trees grown on 3 rootstocks (Gisela 5, Gisela 6, and Mazzard) and under 3 irrigation regimes (control, deficit irrigation (DI), and partial rootzone drying (PRD)). Bars with different letters are statistically different ($P < 0.05$).

Interestingly, in 2003 there were significant interactions between rootstock and irrigation regime that did not manifest in 2002 or 2004. Mazzard-rooted trees subjected to deficit irrigation exhibited reductions in yield *and* fruit quality. In 2003 and compared to the control, Mazzard trees subjected to DI had 60% lower yields and PRD had 66% lower yields. In addition, compared to the control trees, DI and PRD produced only about one-quarter and one-third the yield of premium quality fruit, respectively. In contrast, Gisela 5 and 6-rooted trees subjected to deficit irrigation exhibited yield reductions but improved fruit quality compared to the control. In 2003, DI reduced yield by 42% and PRD reduced yield by 31%, compared to the control. However, the yield of premium quality fruit from DI was over 5-fold greater and 8-fold greater from PRD and both deficit treatments nearly eliminated the production of cull fruit (*i.e.*, smaller than 12-row). This response was not seen in 2004.

SPAD meter readings are interpreted as a general indication of leaf health because they are related to leaf nitrogen/chlorophyll content. In 2003/4 we found that leaf SPAD meter readings varied seasonally, increasing from shortly after bloom, peaking near day 170 (19 June), and declining thereafter at a fairly steady rate. On all but one sample date (4 June) control was significantly higher than DI. Early in the season, DI and PRD were similar and generally lower than the control. Later in the season, DI SPAD meter readings were significantly lower than PRD indicating a higher degree of stress in DI trees. In addition, the late-season decline in readings from control and PRD leaves appear to be occurring at a lower rate compared to DI. However, the physiological significance of different SPAD meter readings was not apparent.

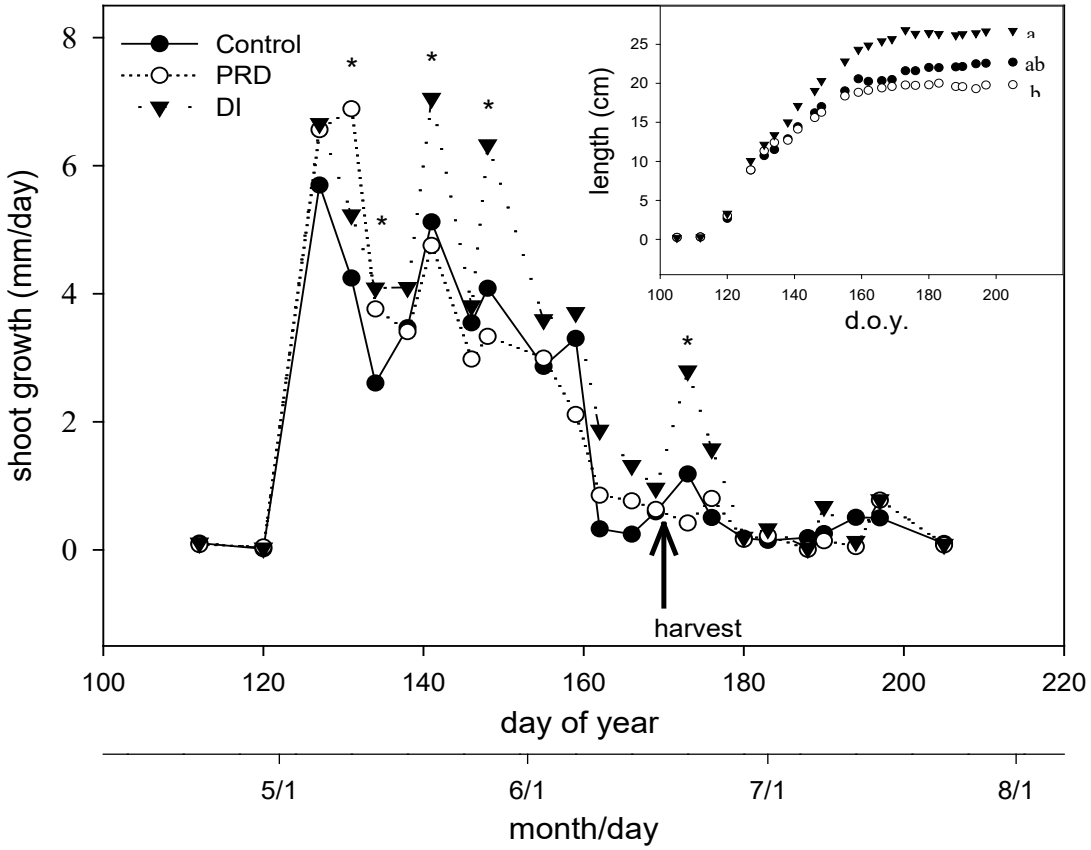

Figure 3. Seasonal trend of expansion rate of shoots and shoot length (inset) within 'Bing' sweet cherry trees subjected to deficit irrigation (DI) and partial rootzone drying (PRD). Asterisks indicate significance ($P < 0.05$).

In 2004, vegetative vigor was significantly higher for DI trees on several sample dates (Fig 3). These higher growth rates resulted in significantly longer shoots compared to PRD, which were the least vigorous (Fig 3 inset). It is not clear why DI exhibited higher growth rates. It is possible that these trees had fewer shoots per tree and therefore reduced whole-canopy sink activity. In addition, high growth rates of DI appear to be related to an increase in soil water content (Fig 1) though this is not consistent. To be sure, the tree's growth response to changes in soil water content remains obscure. However, over the course of this trial, there has been no consistent effect of irrigation regime on vigor and any differences among treatments have been subtle (i.e., not horticulturally significant). Therefore, we have not documented any vigor control using deficit irrigation strategies. This may be due to our inability to induce marked differences in soil water content among treatments during the earliest and most rapid period of shoot growth. This rapid shoot growth has consistently occurred

during May - shoot growth rates decline in June and approach zero by the beginning of July (Fig. 3). Interestingly, the decline in shoot expansion rates coincides approximately with a period of increasing fruit expansion rates (stage III), irrespective of rootstock. This confirms earlier reports from our lab that the preharvest period is one of rapid growth and therefore intense competition for growth resources.

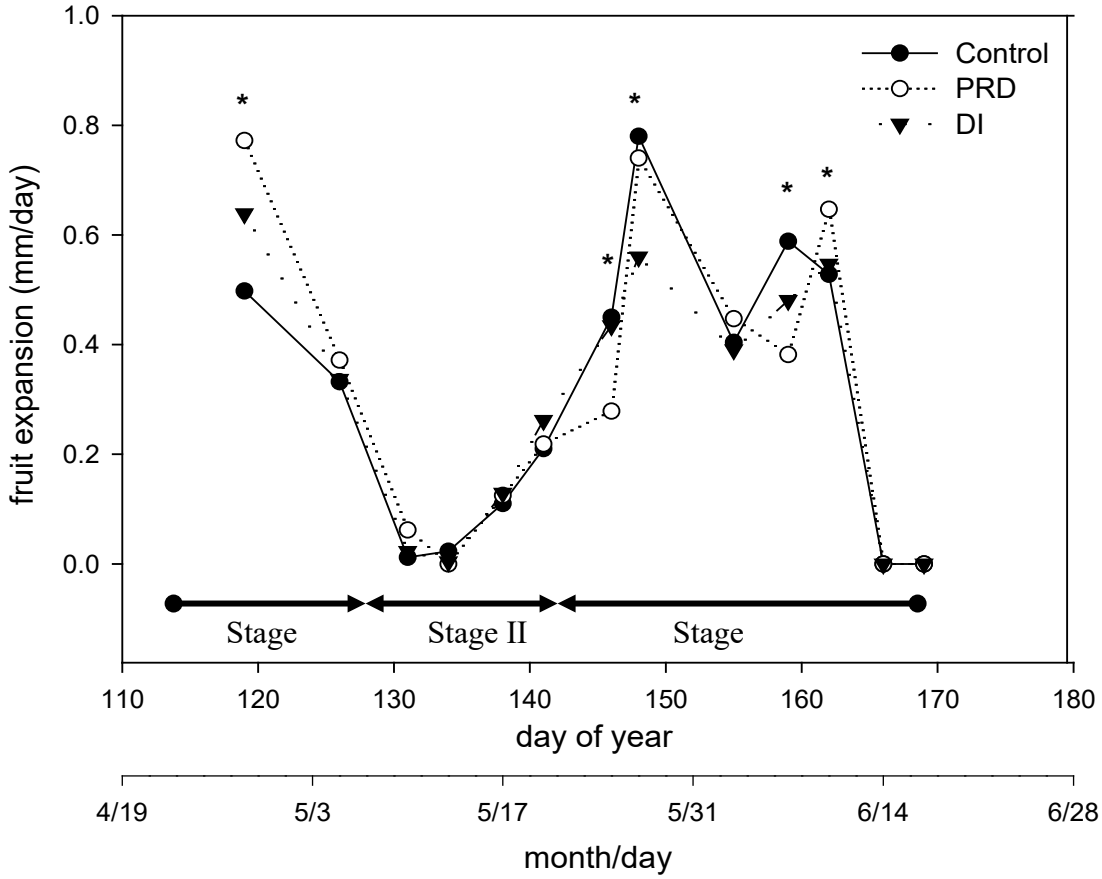

Figure 4. Effect of irrigation regime on the seasonal trend of expansion rate of 'Bing' sweet cherry fruit equatorial diameter. Asterisks indicate significance ($P < 0.05$).

Rates of fruit expansion across all rootstocks were similar (Fig 4). Seasonally, distinct phases of fruit ontogeny were apparent with high rates of expansion during both stage I and III and very little increase in diameter during pit hardening (stage II). Irrigation regime did not affect the transition among, or duration of the distinct growth stages. Differences in daily expansion rate of fruit were evident during stage I and III but not stage II. A similar trend occurred in 2003. We documented no consistent effect of irrigation treatment on fruit expansion despite differences, albeit slight, in soil water content. Therefore, at harvest, fruit size and weight were similar among treatments (Table 1). This may be related again to the lack of a significant drawdown in soil water content during the preharvest interval. It is likely that, the slight reduction in soil water content from deficit irrigation during the preharvest interval, was not sufficient to induce a significant stress response in the trees.

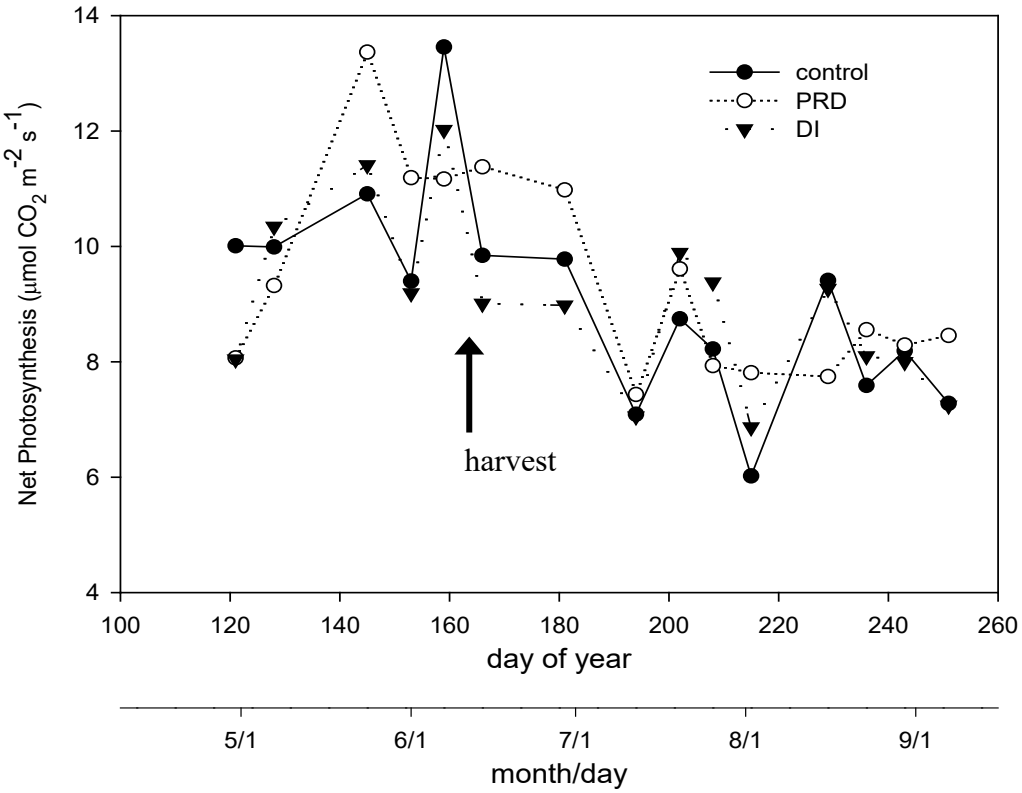

Figure 5. Effect of irrigation treatment on the seasonal trend of leaf net photosynthesis. Measurements were taken on well-sunlit 'Bing'/Mazzard leaves within 1 h of solar noon at 1000 µmols·m^{-2}·s^{-1} PAR.

In 2004 we documented the seasonal trend in leaf net photosynthesis (NCER)(Fig. 5) and midday stem water potential (Ψ_s)(Fig. 6) of Mazzard-rooted trees. There was no consistent effect of irrigation regime on NCER, though differences existed on certain sample dates. The preharvest mean NCER was 10.6, 10.7, and 10.0 µmol·m^{-2}·s^{-1} for control, PRD, and DI, respectively. This is not surprising considering the similarities in soil water content and Ψ_s among treatments and confirms the lack of apparent physiological stress in deficit-irrigated treatments. Postharvest mean NCER declined about 20% irrespective of treatment to ca. 8.1, 8.5, and 8.3 µmol·m^{-2}·s^{-1} for control, PRD, and DI, respectively. This suggests that trees were still not experiencing significant physiological stress during this period, despite lower soil water content of deficit-treated trees (Fig. 1). Therefore, soil water content may not be a reliable tool for assessing physiological stress of sweet cherry trees. Moreover, Ψ_s was often unrelated to NCER and soil water content, though they followed similar seasonal trends. However, Ψ_s of deficit treatments did not differ significantly from the control in this trial. Moderate water stress is suggested to require a reduction of about 1.2 – 1.4 MPa compared to a non-stressed control – in our trial Ψ_s differentials between control and deficit treatment did not exceed ca. 0.4 MPa at any point. Preharvest mean Ψ_s was -0.58, -0.62, and -0.65 for control, PRD, and DI, respectively. Mean Ψ_s declined after harvest, during the period of greater evapotranspiration and declining soil water content, to ca. -0.91, -1.04, and -1.09 for control, PRD, and DI, respectively.

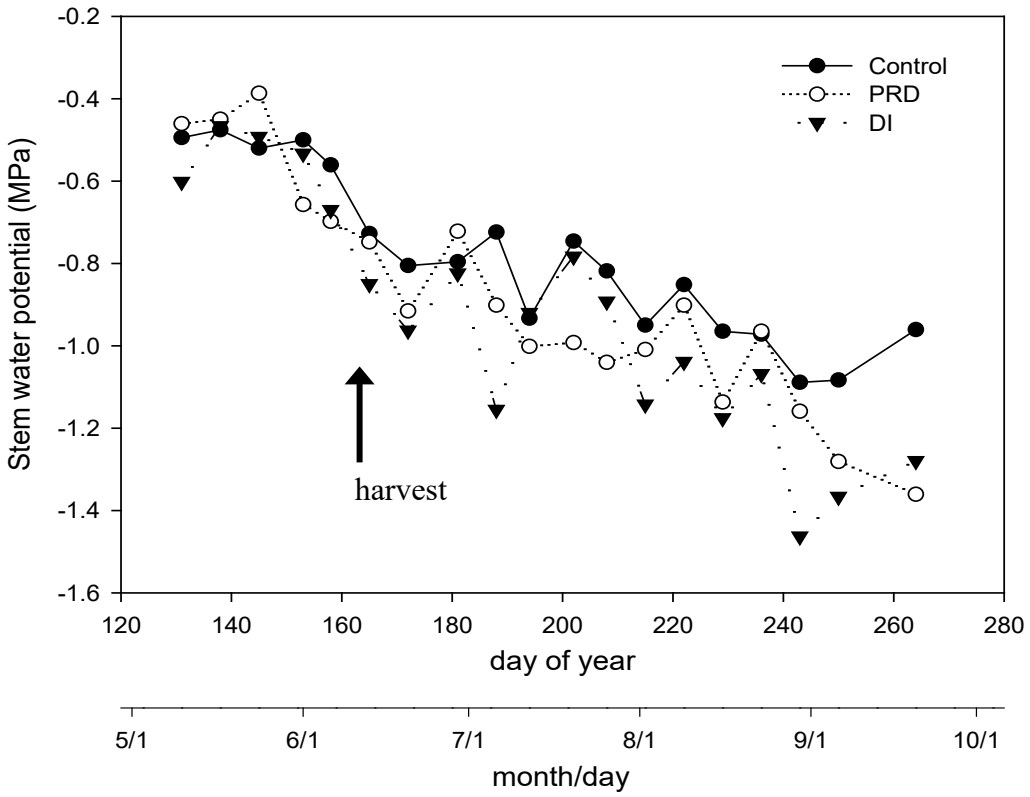

Figure 6. Effect of irrigation treatment on the seasonal trend of midday stem water potential. Measurements were taken on well-sunlit 'Bing'/Mazzard leaves within 1 h of solar noon.

Conclusion Between 2002 and 2004, entire rows of 'Bing' sweet cherry trees grafted on Mazzard, 'Gisela 6', and 'Gisela 5' rootstocks were subjected to season-long irrigation treatments that varied in the volume (by ca. 2-fold) and placement of water applied. We have studied the trees' horticultural and physiological response to these treatments and found no consistent, significant effect of any irrigation treatment. Therefore, we conclude that water resources may be conserved in most commercial orchards without affecting negatively fruit yield or quality. Moreover, sweet cherry trees appear to be physiologically resilient and not particularly susceptible to low soil water content (at least within the range we imposed). Future research should impose a more severe depletion of soil water in order to illicit a physiological response necessary to identify thresholds.

BUDGET

Project: Alternative water management strategies
P.I.: Whiting
Project duration: 2002-2004
Current year: 2004
Project total: $41,920
Current year request: n/a

Year	2002	2003	2004
Total	$20,000	$10,960	**$10,960**

Current year breakdown

Item			
Salaries			
Benefits (30%)			
Wages[1]	6,000	6,000	6,000
Benefits (16%)	960	960	960
Equipment	10,040		
Supplies[2]	1,500	2,500	2,500
Travel[3]	1,500	1,500	1,500
Miscellaneous			
Total	$20,000	$10,960	$10,960

1 Time slip wages for data collection and fruit quality/laboratory analyses.
2 Whole-canopy chamber and laboratory supplies.
3 Travel to plots and transport of shared equipment between MCAREC and IAREC.

Table 1. Effect of rootstock and irrigation regime on yield and quality from 10-year-old 'Bing' sweet cherry trees grown on 3 rootstocks. Data followed by different letters within a column and analysis are different (P > 0.05).

Rootstock	Irrigation	Weight (g)		Brix		Firmness		% < 12-row		% 11 & 12-row		% > 11-row		Yield (kg)	
Gi5		6.8	a	24.1	a	233	a	13	a	46	a	40	a	12.5	b
Gi6		7.4	a	23.2	a	230	a	5	a	40	a	55	a	18.0	a
Mazzard		7.2	a	24.8	a	281	b	2	a	32	a	67	a	5.6	c
lsd		0.8		1.9		16		12		25		27		4.1	
	Control	7.4	a	23.6	a	242	b	5	ab	36	a	59	a	11.2	a
	PRD	7.0	a	24.1	a	239	b	0	b	40	a	60	a	13.9	a
	RDI	7.0	a	24.4	a	263	a	14	a	42	a	44	a	11.0	a
	Lsd	0.8		1.9		16		12		25		27		4.1	
Gi5	Control	7.6	a	22.9	ab	211	e	11	ab	41	a	49	ab	11.0	cd
Gi5	PRD	6.7	ab	25.6	a	234	cde	0	b	49	a	51	ab	12.8	bc
Gi5	RDI	6.0	b	23.9	ab	253	c	29	a	50	a	21	b	13.8	bc
Gi6	Control	7.0	ab	23.7	ab	216	e	5	b	47	a	48	ab	18.8	ab
Gi6	PRD	7.5	a	21.5	b	224	de	1	b	39	a	60	ab	21.1	a
Gi6	RDI	7.7	a	24.5	ab	250	cd	9	ab	36	a	56	ab	14.2	abc
Mazzard	Control	7.5	a	24.1	ab	300	a	0	b	21	a	79	a	3.9	d
Mazzard	PRD	6.8	ab	25.4	a	259	bc	0	b	33	a	67	ab	7.8	cd
Mazzard	RDI	7.2	ab	24.9	a	285	ab	5	b	42	a	53	ab	5.0	d

CONTINUING REPORT

Project #: OSCC-2

TITLE: Cultivars, rootstocks, training systems and fruit quality evaluation in sweet cherry

PI: Roberto Núñez-Elisea
Organization: OSU, Mid-Columbia Agricultural Research and Ext. Center, Hood River, OR
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Co-investigators: Anita Azarenko (OSU Horticulture Dept., Corvallis, OR), Lynn Long (OSU Extension Service, The Dalles, OR), Mathew Whiting (WSU-IAREC, Prosser, WA)
Res. Assistant: Helen Cahn (OSU-MCAREC, Hood River, OR)
Res. Technician: Lilia Caldeira (OSU-MCAREC, Hood River, OR)
Cooperators: Jinhe Bai, Xinhua Yin (OSU-MCAREC, Hood River, OR)

Objectives

- Evaluate new cultivars, rootstocks and training systems for tree and fruit characteristics
- Generate fruit and shoot growth curves to help predict harvest and final fruit size and aid in precision tree management (crop load, irrigation and nutrient management)
- Evaluate fruit quality of promising cultivars and selections
- Develop crop load management strategies to produce large fruit of high quality
- Develop canopy management techniques to advance precocity and control tree size (summer pruning)

Significant findings for 2004

- *Cultivars and rootstocks.* Bloom and harvest in 2004 was notably earlier than in previous years and most cultivars evaluated in The Dalles produced larger fruit during 2004 compared to 2003. 'Bing' on *P. mahaleb* rootstock has produced consistently large fruit since 2002 under a wide range of crop loads, followed closely by Gisela 6.
- *Fruit growth curves.* Growth rates of early and late cultivars were tracked from shuck split to harvest and related to heat unit accumulation (GDH, growing degree hours). Double sigmoidal curves were identified for four cultivars in Hood River and The Dalles. The duration of stage II (pit hardening) was shorter for early ('Cristalina', 'Bing') than late maturing ('Regina', 'Sweetheart') cultivars.
- *Color development/fruit quality.* Color changes in developing fruit were monitored based on the CIELAB color space. Quantitative color measurements of fruit of three maturity stages of 'Regina' and 'Sweetheart' showed changes in fruit quality associated to changes in color parameters.
- *Crop load management.* Fruit size of organically-grown 'Lapins'/Gisela 5 was not increased by chemical bloom thinning sprays of lime sulfur, but significantly larger fruit were produced when an additional 30% of the crop was removed by hand after chemical sprays, 3 weeks before harvest.
- *Canopy management (summer pruning)*. Summer pruning of current-season shoots increased flower production (30% to 40%) in 2nd leaf 'Regina'/Gisela 6.

Methods

- *Cultivar and rootstock evaluation.* A collection of more than 25 sweet cherry cultivars and selections is under evaluation in The Dalles. Trees are on Mazzard rootstock, trained to steep leaders and are treated with GA_3 every year. An NC-140 rootstock trial involving 15 rootstocks was established in 1998 at Orchard View Farms. All rootstocks have 'Bing' as scion, with Van as the pollinizer. Trees are trained to a central leader. Control trees are on *P. mahaleb* rootstock.
- *Fruit and shoot growth curves*. Graphs relating fruit growth and accumulation of heat units were generated for early and mid-season ('Cristalina' and 'Bing') and late ('Regina' and 'Sweetheart')

cultivars in Hood River and The Dalles. Heat units were expressed as growing degree hours (GDH) accumulated when ambient temperatures were between 4C (39°F) and 25C (77°F) and between 25C and 36C (96°F). A temperature of 25C is considered optimum, whereas 36C is considered a critical high temperature, for adequate tree function. GDH accumulation started at ~80% full bloom for each cultivar. Measurements were taken 2 to 3 times a week of the widest point on the fruit, beginning at shuck-split and until fruit maturity.

- *Color development and fruit quality*. A portable spectrophotometer was used to monitor development of fruit color in the four cultivars used for fruit growth measurements in Hood River and The Dalles. Color measurements were based on the CIELAB color system, in which five color parameters uniquely and quantitatively describe each color by its positional coordinates in a 3-dimensional space. These parameters are: L* (lightness position in a white to black axis), a* (position in a green to red axis), b* (position in a blue to yellow axis) C* (chroma or saturation) and h* (hue in angular units from 0° to 360°, where 0°=red; 90°=yellow; 180°= green and 270°=blue). A composite graph was created using fruit of 'Skeena', 'Sweetheart' and 'Regina' at 11 progressive stages of color development to characterize the change in the five color parameters as fruit color progressed from stage 1 ('straw color') to stage 11 (over-ripe). Preliminary data on the relationship between color and fruit quality were produced for 'Regina' and 'Sweetheart'. Fruit harvested at 3 different maturity stages were measured for color parameters, °Brix, firmness and size (diameter and weight).
- *Crop load management*. Chemical bloom thinning treatments were applied on heavily flowering 'Lapins'/Gisela 5 trees during spring 2004 to reduce crop load and increase fruit size. Trees were 9 years old, trained as steep leaders and grown organically. The experimental design was a RCBD with four treatments (tank mixtures of lime sulfur and Crocker Fish Oil) and an untreated control in five blocks. One of the spray treatments was followed by manual fruit thinning, in which an additional 30% of the crop was removed 3 weeks before harvest.
- *Canopy management to promote precocity and control tree size*. We are evaluating summer pruning of young 'Regina'/Gisela 6 and 'Sweetheart'/Mazzard trees. In 'Regina', current-season shoots were pruned early July 2002 (2nd leaf) and growth, flowering and fruiting responses characterized during 2003 and 2004. In 'Sweetheart', current-season shoots were pruned at 2-week intervals between June 24 and August 9, 2004 (2nd leaf). Shoot growth responses to four different pruning dates are being characterized.

Results 2004

- *Cultivar and rootstock evaluation.* First and full bloom, as well as harvest, occurred significantly earlier compared to 2003 (Table 1). Several materials produced notably larger fruit in 2004 compared to 2003 ('Sonata', 'Sandra Rose', '13S-18-15', '4W-11-08', 'Staccato', 'Cristalina', 'Sonnet', '13S-42-49', 'Attika' and 'Regina). These cultivars and selections produced fruit of row size 9 and larger. 'Sweetheart'/Gisela 6 produced notably smaller fruit in 2004 than in 2003 (average 12.8 g vs. 11.4 g). It is possible that larger fruit were produced due to lighter crop loads in 2004. Fruit firmness was very good (usually above 300 g/mm) for all measured cultivars and selections.

  Performance of 'Bing' on salient rootstocks evaluated as part of the NC-140 project is summarized in Figure 1. Yields for all rootstocks increased notably in 2004 compared to previous years. Compared to mahaleb rootstock, all other rootstocks (Giessen 195-20, Gisela 6, Weiroot 158 and 72, and Edabriz) were clearly more precocious. However, mahaleb has produced large fruit more consistently during the past 4 years than the other rootstocks. Thus, it appears that compared to the other rootstocks, fruit size of 'Bing' on mahaleb has been little affected by large crop loads.
- *Fruit and shoot growth curves*. Curves were developed for 4 cultivars in Hood River and The Dalles. Periodic growth measurements were related to cumulative growing degree hours (GDH; Fig. 2). Growth curves from these measurements exhibited a typical double sigmoidal pattern

characterized by an initial period of rapid growth (stage I), followed by a slowing of growth coinciding with pit hardening (stage II), ending with a period of moderate daily growth rate lasting until fruit maturity (stage III). In both The Dalles and Hood River, all cultivars entered stage II at approximately the same GDH accumulation (between 4300 GDH and 4500 GDH). The later cultivars 'Sweetheart' and 'Regina' had a longer stage II than the earlier cultivars 'Bing' and 'Cristalina'. The earliest ripening cultivar, 'Cristalina', had the shortest stage II and harvest at both locations. Observations in 'Regina' suggest that tree age and/or rootstock also impact fruit maturation in this cultivar, as stages II and III were longer for 8th leaf trees s in The Dalles (mazzard) compared to 4th leaf trees in Hood River (Gisela 6). Harvest in Hood River was 10 days earlier than in The Dalles. On the other hand, 'Bing' trees with a similar age gap in The Dalles and Hood River showed similar growth curves. These results indicate that early or late maturity was strongly influenced by the duration of stage II. However, more work is needed to clarify how cultural factors interact with heat unit accumulation in regulating fruit growth and maturation.

- *Color development and fruit quality*. Figure 3 shows how the five color parameters changed as fruit matured. Lightness (L*) decreased as fruit became darker during maturation. Initial red pigmentation (a*) was detected in stage 4, peaked at stage 7 and decreased thereafter with the appearance of darker pigments. Decrease of b* over time indicated loss of yellow color, as red and blue pigments increased gradually. Chroma (C*) decreased sharply after stage 7 as red became less vivid (stage 7 is thought to correspond approximately with the end of stage II of fruit growth). Hue angle was mainly in the yellow/green region during stages 1-4, and gradually moved towards the red/mahogany region as fruit matured. This composite graph resembles the progressive changes in color parameters observed for the four cultivars of dark sweet cherry under study (separate data for 'Cristalina', 'Bing', 'Regina', and 'Sweetheart' not shown). The relation of color to fruit quality parameters is shown in Figure 4 for three maturity stages of 'Regina' corresponding to color stages 9, 10 and 11 of the composite graph. These data show changes in color parameters similar to those seen in the composite graph. All color parameters decreased as fruit ripened, reflecting the change from red to 'mahogany'. Ripe +++ (color stage 11) had the highest average ^{o}Brix (22.1^{o}), but had a tendency for lower average firmness, diameter and weight compared to 'ripe ++' stage (color stage 10). More work is planned to determine the relationship between color and other fruit quality parameters in different cultivars of sweet cherry.
- *Crop load management*. Chemical bloom thinning treatments had no significant effect on tree yield of 'Lapins'/Gisela 5 trees. However, significantly fewer but larger fruit were produced when crop load was further thinned by removing immature fruit by hand after spraying lime sulfur (LS) and Crocker Fish Oil (CFO) during bloom. Fruit obtained from sprayed plus hand-thinned trees had an average row size of 10, whereas all other treatments had fruit of an average row size of 10.5 (data not shown).
- *Canopy management to promote precocity and control tree size.* Summer pruning of current-season shoots of 'Regina' both advanced and increased flower production on the pruned shoots. Nine months after pruning (April 2003) the 'stub' of pruned shoots showed flowers at its base, but commonly also spurs in its middle or distal portion. In addition, the extension growth produced during summer after pruning also produced flower buds. As a result, summer pruning increased the number of flowers by 30% to 40% in relation to non-pruned control shoots, which only produced flowers from single buds at the base of the shoot (data not shown). Late summer pruning of 2nd leaf 'Sweetheart'/Mazzard trees resulted in shorter summer re-growth compared to early pruning (data not shown). The effects of summer pruning on tree structure/size, flowering and fruiting will be assessed in spring 2005 and compared to non-summer-pruned controls.

Table 1. Fruit characteristics of sweet cherry cultivars and selections under evaluation in The Dalles. Trees are on Mazzard rootstock and trained to steep leaders, unless otherwise indicated. All trees were treated with 25 ppm GA_3.

Cultivar or selection	First bloom	Full bloom	Harvest date	Maturity at harvest	Average firmness (g/mm)	Average fruit weight (g)	
						2004	2003
'Lapins'	19-Mar	2-Apr	1-Jul	ripe	-	13.0	13.1
'Bing'/G-6	21-Mar	4-Apr	24-Jun	ripe	-	11.7	9.6
'Sweetheart/G-6	21-Mar	4-Apr	9-Jul	ripe-under	352.0	11.4	12.8
'Bing' (Marchand)	22-Mar	6-Apr	24-Jun	ripe	-	11.7	10.7
'Rainier'	23-Mar	5-Apr	-	-	-	-	-
'Bing'	22-Mar	5-Apr	21-Jun	ripe	-	9.9	10.5
'Early Robin'	23-Mar	5-Apr	17-Jun	ripe	-	10.7	-
'Symphony'	23-Mar	4-Apr	16-Jul	ripe	275.5	13.1	11.2
'Newstar'	26-Mar	6-Apr	17-Jun	ripe	-	12.7	12.2
8S-3-13	26-Mar	5-Apr	17-Jun	ripe	-	13.3	12.4
'Sonata'	26-Mar	6-Apr	28-Jun	ripe-over	-	15.0	13.6
'Sandra Rose'	26-Mar	7-Apr	28-Jun	ripe	-	16.4	14.2
13S-21-07	26-Mar	7-Apr	28-Jun	ripe	-	11.9	11.3
'Skeena'	26-Mar	7-Apr	8-Jul	ripe	339.0	13.2	-
13S-18-15	26-Mar	3-Apr	28-Jun	Ripe	-	16.8	13.6
4W-11-08	26-Mar	8-Apr	14-Jul	ripe-over	328.4	15.0	12.0
'Staccato'	26-Mar	6-Apr	21-Jul	Ripe	340.8	13.8	11.2
13S-21-01	26-Mar	7-Apr	28-Jul	Ripe	337.4	11.9	10.1
'Santina'	27-Mar	7-Apr	17-Jun	Ripe	-	12.3	11.8
'Cristalina'	28-Mar	8-Apr	21-Jun	Ripe	-	13.8	11.0
'Sonnet'	29-Mar	7-Apr	24-Jun	Ripe	-	13.6	11.5
'Gold'	29-MAr	7-Apr	-	-	-	-	-
'Sylvia'	30-Mar	9-Apr	24-Jun	ripe-over	-	12.8	12.1
'Ziraat' 0900*	30-Mar	9-Apr	24-Jun	ripe-under	-	11.1	-
13S-42-49	30-Mar	10-Apr	6-Jul	Ripe	-	13.5	12.3
13S-16-29	30-Mar	12-Apr	12-Jul	Ripe	306.2	10.5	10.1
'Schneiders'	30-Mar	8-Apr	-	-	-	-	-
'Attika'	31-Mar	9-Apr	6-Jul	Ripe	303.1	13.3	12.2
'Regina'	1-Apr	11-Apr	14-Jul	ripe-over	354.2	14.3	11.6
'Regina'/G-6	-	-	14-Jul	ripe-over	283.5	11.7	-
PC 8011-3*	-	5-Apr	17-Jun	Ripe	-	9.0 (5 fruit)	-
NY 252*	-	5-Apr	1-Jul	Ripe	-	7.7	-
NY 304*	-	11-Apr	24-Jun	Ripe	-	13.2	-

*First fruiting year

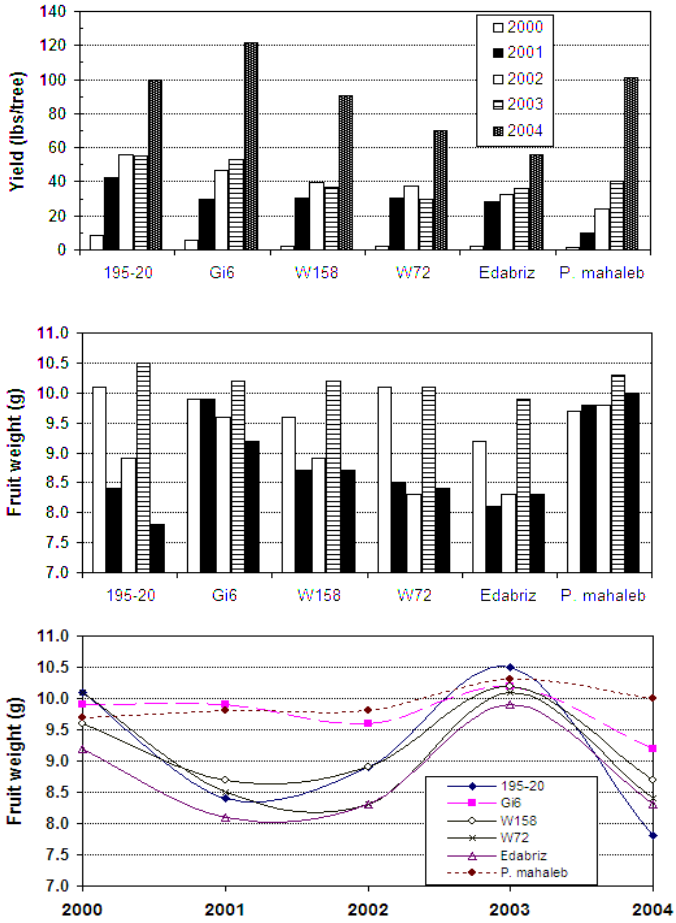


Figure 1. Annual yield and fruit size of 'Bing' on six rootstocks of the NC-140 rootstock evaluation project in The Dalles, Oregon. Trees were planted in 1998 and are trained to a central leader, with 'Van' as pollinizer.

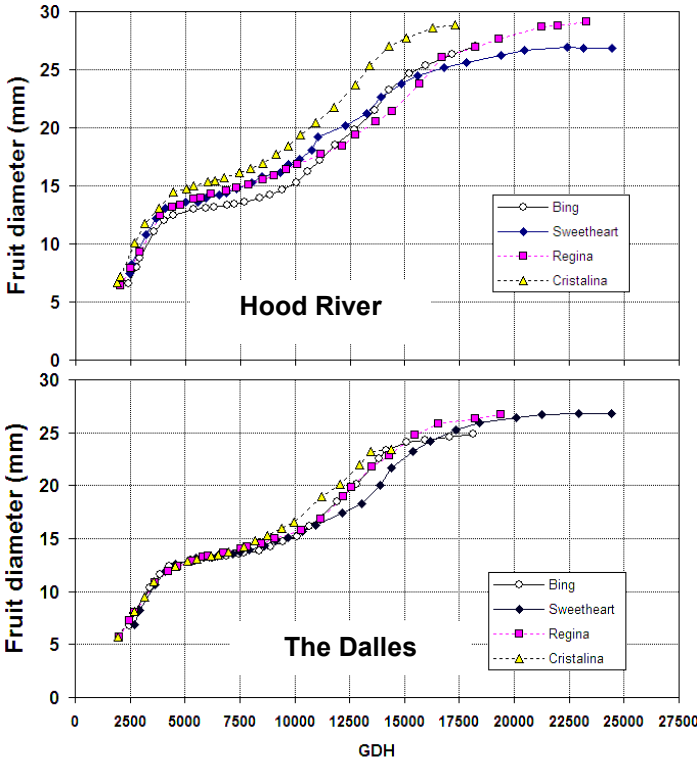
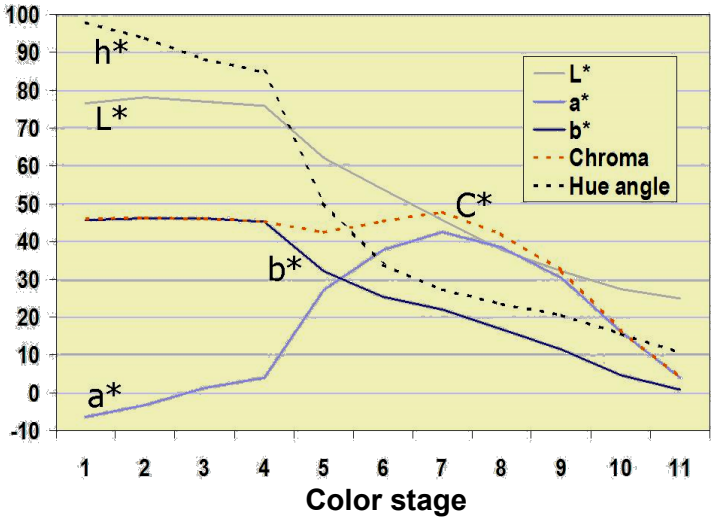


Figure 2. Fruit growth curves of four sweet cherry cultivars in relation to growing degree hour accumulation in Hood River and The Dalles, Oregon. Base temperature was 25C (77° F), biofix was 80% full bloom. Fruit were measured until harvest maturity.

Figure 3. Composite graph of changes in color parameters for 11 progressive color stages, where stage 1 = straw color and stage 11 = over-ripe. Stages 1-5 correspond to fruit of 'Skeena' (Parkdale); stages 6-8 to 'Sweetheart' (MCAREC) and stages 9-11 to 'Regina' (MCAREC). All fruit were harvested July 3, 2004. Measurements were made with a portable spectrophotometer (Konica-Minolta, Japan).



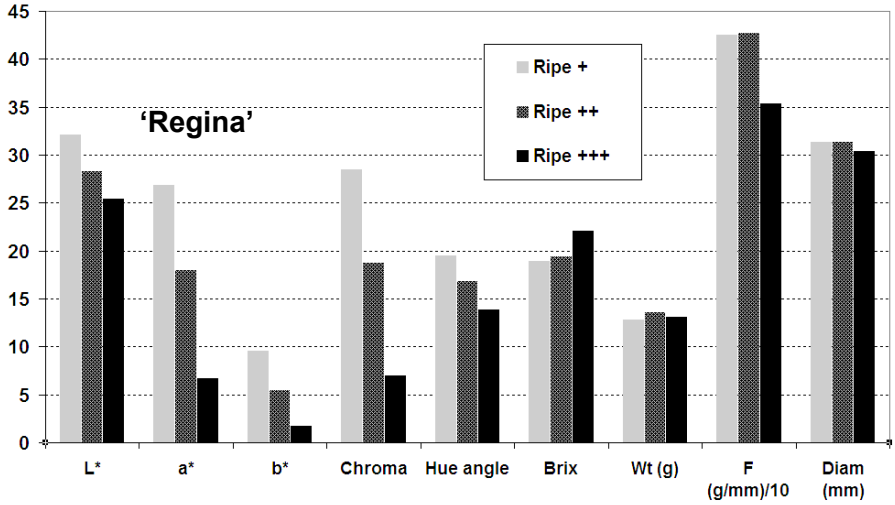


Figure 4. Color parameters and fruit quality for three maturity stages of 'Regina' sweet cherry, where +, ++ and +++ correspond to color stages 9, 10 and 11, respectively. See text for description of color parameters. 'F' represents one-tenth of fruit firmness, as determined with a FirmTech2 instrument.

Budget

Title: Cultivars, rootstocks, training systems and fruit quality evaluation in sweet cherry.
PI: Roberto Núñez-Elisea
Duration: long-term
Funding in 2004: $26,500
Current year request: $27,500

	Year 2004	**Current year 2005**	Year 2006
Original request			
Total			
Current year request			
Salaries-FRA	17,000	18,455	
OPE (49%)	9,010	9,045	
Travel to res. Plots	1,490	0	
Total	26,500	27,500	27,500

CONTINUING REPORT

Project title: Horticulture management systems for high value fresh and brine cherries
Principal investigator: Anita Nina Azarenko
Organization: Dept. of Horticulture, Oregon State University, 4017 ALS, Corvallis, OR 97331-7304
Research assistant: Annie Chozinski, Department of Horticulture, Oregon State University
Cooperators: Dr. Roberto Nunez-Elisea, MCAREC, Oregon State University
Mr. Don Nusom, Nusom Orchards, Gervais, OR
Dr. Frank Kappel, Agriculture Canada, Summerland, BC
Dr. Robert Anderson, Cornell University, Geneva, NY

Objectives for 2005-2006:

- Identify cherry cultivars 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.
- Evaluate new potential rootstocks for commercial acceptability in Willamette Valley sweet cherry production systems.
- Develop and test growing degree models for fruit growth in 7 cultivars of sweet cherry.
- Begin research to determine if rootstock influences susceptibility of a scion cultivar to *Pseudomonas syringae* pv. *syringae.*

Significant Findings and results:

- *1996 Dark cherry cultivar trial*- Best performers: 'Sonata', 'Sylvia', 'Symphony', 13S42-49, and 13S49-24 (Table 1). 13S49-24 is extremely susceptible to brown rot.
- *1998 Blush cherry trial*- Most promising selections for the fresh market remain as NY7690, 13N07-39, 1307-32, 13S21-14, 2N31-19. Genotypes most suited for brine industry are NY518, NY8182, NY9295, 13S20-11, and 'Sweetheart' (Table 2).
- *1998 NC-140 'Bing' rootstock trial*- Least production on Mazzard and Mahaleb trees. Fruit size was small on Gisela 5, Gisela 6, and Edabriz trees (Table 3).
- *Bacterial canker tolerance*-
  Dark cherries with the greatest number of symptoms 'Symphony' and 'Cristalina'. Those with the least: 'Sonata', 'Sylvia', and 'Regina'. A blush cherry genotype with virtually no symptoms is 13N07-39. 'Bing' grafted onto Gisela 4, 5, 6, and 7, Gi195-20, Gi318-17, Edabriz, W53, Gisela 7, had at least two primary scaffolds with cankers, dead bud and blossom blast symptoms. The Weiroots (with the exception of W53), Mahaleb and Mazzard had 0-1.5 scaffolds with symptoms.
- *1999 Interstem trial*- Yield was highest on low-budded MxM60 trees and lowest on Gisela 5 trees with an MxM60 interstem. MxM60 low- or high-grafted trees had the largest TCSA. Low–grafted Gisela 5, regardless of trunk genotype (MxM60 or Royal Ann), were intermediate in TCSA. The smallest TCSA's were found with trees where Gisela 5 as the trunk (interstem or high-grafted).
- *2004 branching trials*- On two year wood of 'Lapins' trees, notching above the bud and painting the notches with promalin induced 89% budbreak of 7.5 or more shoots at or above the treated area and produced an average shoot length of 33cm. Burning and notching resulted in ~60% budbreak with an average shoot number of ~1.2 at or below the treated area. Average shoot length ranged from 28-37cm.
- *Sweet cherry fruit growth curves*- The time to maturation of cherry cultivars is positively correlated with the duration of the pit hardening stage and negatively correlated with the rate of growth during stage III (Figure 1).
- *Stem pull force and retention at harvest and after storage*- MaxCell at 100ppm increased the stem pull force in 'Van' by approximately 8% at harvest.
- *2002 PiKu 1 and 3 trial*- Tree losses occurred only on PiKu 1 rootstocks and bacterial canker symptoms were more prevalent.

- *2002 MxM top-worked mechanical harvest trial*- MxM60 and MxM14 trees yielded 1.9 and 0.3kg of 'Sweetheart' fruit, respectively in the third leaf. MxM60 trees had twice the TCSA than MxM14 trees.

Methods:

- Train, maintain and obtain data on yield, fruit size, tree vigor, bacterial canker tolerance and other relevant data from the existing cherry cultivar trials which include:
  1996 BC dark cherry trial (0.15 ha of low-budded central leader trees)
  1998 Blush cherry trial (0.35 ha of low-budded central leader trees)
  2004 Dark cherry trial (0.15 ha of low-budded central leader trees)
- Train, maintain and obtain data on yield, fruit size, tree vigor and other relevant data from the existing cherry rootstock trials which include:
  1998 NC-140 cherry rootstock trial (0.50 ha low-budded central leader 'Bing')
  2002 PiKu 1 and 3 trial (0.20 ha low-budded trees)
- Train, maintain and obtain data on overall performance of trees in the existing blush cultivar/systems trials. Each planting includes four replicates of three trees of each cultivar, rootstock, and training system combination.
  Top-worked trees: The rootstocks in the top-worked low-density trial are: Gi196-4, MxM14, MxM60 and Mazzard seedling. 'Royal Ann', 'Sweetheart' and 'Stardust' were top-worked onto these rootstocks. The training systems include: free standing, top-worked trees that are trained to a multiple leader tree and central leader (single multiple bud graft) trees. The rootstocks were planted at 18' x 18', in anticipation of mechanical harvest. The total number of trees in this planting are 288 (0.90 ha). Trees were top-worked, pruned and trained in 2003.
  Low-budded- The low-budded high density trial includes Gisela 6, Gi196-4, MxM14 and Mazzard rootstocks. The training systems included in this trial are 1) free standing, multiple leader, 2) free standing, central leader trees, and 3) a multiple wire trellis system. This planting was set at 9' x 16'. The total number of trees planted are 324 trees (0.50 ha). Tree structure is well established.
- Evaluate growth and fruiting of 'Sweetheart' trees in the interstem trial which contains: low-grafted MxM 60, high-grafted MxM 60, low-grafted Gisela 5, high-grafted Gisela 5, Gisela 5 interstem with MxM 60 rootstock, MxM 60 interstem with Gisela 5 rootstock (0.10 ha).
- Prune and train the MxM rootstock trial that were planted in fall 2000 and top-worked in spring of 2002 with 'Sweetheart'. (0.12 ha).
- Distribute experimental trees to orchardists and plant the cultivar x rootstock trial that includes 'Bing', 'Tieton', 'Sunset Bing', 'Sylvia', 'Benton', 13N07-39, 'Early Robin', 'Rainier', 'Sweetheart', and 'Skeena'.
- Order (fall 2005) and produce trees (growing season 2006) for a **new blush trial** with the intent of evaluating 'Early Robin', 'Sonnet', 'Rainier', NY7690, 13N7-39, 13N7-32, 13S21-14, and 2N31-19 on Gisela 6, Gi196-4 and MxM14.
- Order trees for a study on the interaction of scion and rootstock on the susceptibility of 'Sweetheart', 'Bing' and 'Regina' to *P. syringae* pv. *syringae*. Trees will be budded on Gisela 6, MxM14, Mazzard and Gi196-4 in Fall 2005.
- Continue growth measurements and modeling of cherry fruit growth. Compare with Dr. Nunez~Elisea's data. Test models with selected orchardists. Place model on the IFP web-site.

Results: See significant findings and the following tables and figures

1996 Dark cherry cultivar trial-

Table 1. 2004 harvest and bloom dates, yield, TCSA, YE, fruit size, firmness, SSC, fruit color, cracking, and stem pull-force of cultivars and Agriculture Canada selections grafted onto Mazzard rootstock and planted in 1996.

Genotype[z]	Harvest date	First bloom	Peak bloom	Yield (kg)	TCSA[y] (cm^2)	YE (kg/cm^2)	Fruit size (mm)	SSC[x] (°Brix)	Fruit color (1-7)	Crack (%)[w]	Firm. (g/mm^2) Harv.	2 wks	4 wks	Pull force (g) Harv.	2 weeks	4 weeks
Newstar	.	3/18	3/30	.	230.1	.	.	.	.	.	.	.	.	.	.	.
San. Rose	6/21	3/25	4/2	0.7	223.7	0.00	27.2	22.5	3.5	5	178	224	261	670	835	800
Cristalina	6/14	3/26	4/3	1.0	176.6	0.00	26.3	.	4.1	9	338	344	304	963	879	620
Bing[v]	6/21	3/20	3/30	4.1	218.4	0.03	26.0	18.2	5.0	0	225	231	231	916	929	863
8S 03-13	6/15	3/22	3/30	0.8	211.7	0.00	29.0	17.1	4.0	32	231	246	280	1139	885	715
Sonata	6/21	3/21	3/29	14.9	188.5	0.09	26.6	18.8	5.0	1	276	338	348	792	865	730
Sylvia	6/21	3/27	4/3	5.1	253.3	0.02	27.3	19.1	5.0	1	237	269	289	732	870	870
13S 21-07	6/23	3/24	4/1	1.4	217.9	0.01	25.7	.	.	.	253	272	251	692	725	700
13S 49-24	7/2	3/21	3/28	9.3	225.6	0.04	30.8	21.9	6.0	40	290	311	328	665	620	524
13S 17-40	6/23	3/23	3/30	0.4	156.8	0.00	26.6	24.2	6.0	23	220	274	274	645	667	727
13S 18-15	6/23	3/22	3/27	2.1	101.5	0.01	29.5	20.9	6.0	12	223	270	269	673	724	623
13S 42-49	7/2	3/24	4/2	16.2	170.6	0.09	29.2	19.0	6.0	46	419	431	424	598	611	409
Regina[w]	7/8	3/30	4/6	2.8	141.4	0.02	28.1	22.1	6.0	0	286	290	356	1161	1150	1074
Symphony	7/12	3/17	3/25	15.6	245.3	0.06	29.2	18.4	5.0	0	320	374	399	695	534	500
4W 11-08	7/12	3/25	4/3	1.5	202.4	0.01	28.9	23.2	6.0	4	333	336	336	714	713	600
13S 21-01	7/12	3/24	3/30	1.4	143.8	0.01	28.0	20.4	5.0	0	459	483	546	981	920	874
MSD		3 d	2 d	4.4	137.5	0.04	2.9	5.0	0.7	15	45	32	43	132	121	207

[z]Means separation by Waller-Duncan k-ratio t-test, k-ratio = 100.

[y]TCSA=trunk cross-sectional area in September 2003.

[x]Composite sample of 25 fruit.

[w]Fruits with one or more cracks.

[v]Planted one year later.

1998 Blush cherry trial- Table 2. Harvest and bloom dates, yield, trunk cross-sectional area, yield efficiency (YE), soluble solids (SSC), firmness, fruit size, cracking, and pull force of cultivars and blush selections grafted onto Gisela 5 rootstock and planted in 1998. Highlighted numbers are genotypes suitable for brine and bold lettering indicates genotypes potentially suited for the fresh market.

Genotype[z]	First bloom date	Peak Bloom date	Harvest date	Yield (kg)	TCSA[y] (cm^2)	YE (kg/ cm^2)	SSC[x] (°Brix)	Fruit size (mm)	Crack. (%)	Firm. (g/mm^2) Harv.	2 wks	4 wks	Pull force (g) Harv.	2 wks	4 wks
NY518	3/ 17	3/26	6/11	9.1	99.3	0.09	16.8	22.1	35	547	.	.	1062	.	.
R. A.	3/22	3/30	6/11	3.6	112.1	0.03	17.1	25.3	10	275	.	.	973	.	.
NY252	3/21	3/28	6/22	3.0	90.5	0.03	22.7	26.0	5	365	.	465	1203	.	1167
NY7690	***318***	***3/27***	***6/15***	***1.1***	***111.4***	***0.01***	***19.0***	***30.1***	***0***	***415***	***465***	***345***	***1303***	***1307***	***985***
NY6091	3/22	3/29	6/17	0.9	96.9	0.01	20.6	27.7	0	183	213	229	840	755	954
NY8182	3/23	3/29	6/14	4.2	87.7	0.05	17.0	26.6	31	462	.	.	1168	.	.
NY13688	3/23	3/30	6/17	2.1	77.1	0.03	20.2	24.7	1	191	210	228	769	710	812
NY9295	3/23	4/2	6/14	5.5	101.7	0.06	16.5	26.6	24	419	.	.	1233	.	.
NY7855	3/26	4/2	6/14	2.8	84.1	0.03	17.2	25.0	17	351	.	.	1178	.	.
NY307	3/27	4/3	6/17	0.8	100.7	0.01	18.0	27.0	0	219	265	287	900	784	764
13S20-11	3/23	3/29	7/12	1.4	82.3	0.02	21.3	27.6	21	408	477	546	945	1019	920
13N07-39	***3/23***	***3/30***	***6/22***	***8.2***	***107.4***	***0.08***	***25.0***	***26.9***	***33***	***311***	***.***	***380***	***1313***	***.***	***1468***
13S07-50	3/26	4/2	6/17	1.6	58.7	0.04	20.9	25.6	51	179	229	229	795	774	662
13N7-32	***3/24***	***4/1***	***6/24***	***5.7***	***88.2***	***0.06***	***22.3***	***27.8***	***29***	***329***	***384***	***362***	***766***	***743***	***621***
Sweetheart	3/22	3/28	7/7	2.8	88.0	0.03	19.2	27.1	0	445	468	530	1009	901	926
13S 21-14	***3/22***	***3/29***	***7/12***	***1.4***	***62.1***	***0.02***	***21.3***	***25.5***	***3***	***404***	***423***	***489***	***1021***	***1006***	***891***
13S 09-37	3/28	4/2	6/30	9.1	93.8	0.10	21.1	26.6	16	293	326	359	512	545	472
Stardust	3/27	4/3	6/24	6.9	84.3	0.08	22.2	26.1	17	287	318	334	873	972	858
2N 31-19	***3/21***	***3/27***	***6/30***	***4.0***	***76.6***	***0.06***	***19.8***	***29.4***	***18***	***259***	***281***	***317***	***648***	***697***	***687***
MSD	1.4 d	1.3 d		2.1	13.5	0.02	1.8	1.2	15	30	30	31	110	150	200

[z]Means separation by Waller-Duncan k-ratio t-test, k-ratio=100.

[y]TCSA=trunk cross-sectional area in September 2004.

[x]Mean of 25 fruit.

1998 NC-140 'Bing' rootstock trial-

Table 3. Bloom dates, yield, trunk cross-sectional area, yield efficiency, fruit weight, soluble solids, and fruit cracking of 'Bing' trees planted in the 1998 NC-140 rootstock trial at the Lewis-Brown Research Farm, Corvallis, OR. Fruit were harvested on 26-29 June 2004.

Rtstck[z]	First bloom	Peak bloom	Yield (kg)	TCSA[y] (cm^2)	YE (kg/cm^2)	Fruit size (mm)	Fruit wt. (g)	Firmness (g/mm) Harv.	Firmness (g/mm) Stor.	SSC[x] (°Brix)	Fruit Color	Crack (%)	Pull force (g) Harv.	Pull force (g) Stor.
Gisela 4	3/20	4/2	14.9	92.0	.16	24.2	7.2	225	259	16.4	4.8	0.0	925	949
W 53	3/20	3/31	21.3	96.5	.22	23.1	6.1	221	233	14.4	4.0	1.7	791	779
Gi 209-1	3/21	3/31	16.7	89.0	.19	23.3	6.4	222	244	15.1	4.3	0.5	864	890
W 72	3/20	3/31	16.4	123.0	.14	24.3	6.7	215	235	16.1	4.5	0.6	890	860
Gisela 7	3/20	3/30	14.2	111.2	.13	23.7	6.5	234	247	17.3	4.4	2.5	894	883
W 154	3/21	3/30	18.5	161.7	.13	25.4	7.9	208	233	16.6	4.5	1.3	1036	874
Edabriz	3/20	4/1	19.8	135.0	.15	23.0	6.1	222	236	16.1	4.2	5.0	849	807
Gisela 5	3/21	3/30	17.3	115.4	.15	23.9	6.7	219	224	17.1	4.1	1.5	870	946
Mahaleb	3/18	3/29	13.7	160.3	.09	25.2	7.7	227	256	17.3	4.6	6.0	846	893
Gi318-17	3/20	3/30	23.5	149.7	.16	23.7	6.6	222	234	16.3	4.2	1.0	932	913
Gi195-20	3/20	3/31	19.7	149.0	.13	24.0	6.7	235	246	16.4	3.6	4.0	944	888
W 158	3/19	3/31	22.8	161.1	.14	24.3	6.9	210	225	16.5	4.4	1.0	916	875
W 10	3/18	3/31	28.5	194.2	.15	24.8	7.4	199	248	17.2	4.6	0.6	890	907
W 13	3/19	3/31	23.8	191.9	.13	24.4	7.3	216	242	16.2	4.5	2.3	902	908
Mazzard	3/21	3/31	12.4	225.6	.06	25.6	7.0	210	250	18.4	4.6	10.5	953	983
Gisela 6	3/20	3/31	29.9	175.0	.17	23.2	6.2	227	244	15.4	3.6	0.5	905	891
MSD	2 d	2 d	9.9	38.6	.07	1.2	1.5	27	25	1.9	0.8	8.7	195	212

[z]Means separation by Waller-Duncan k-ratio t-test, k-ratio = 100.
[y]TCSA = trunk cross-sectional area in September 2004.
[x]Composite sample of 25 fruit.

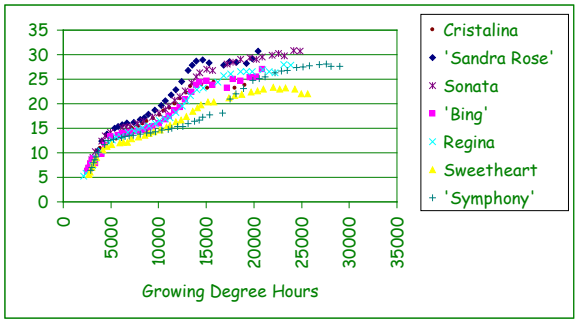


Figure 1. 2004 growth curves of seven genotypes and based on growing degree hours.

Figure 2. Influence of notching and Promalin on 2-yr old wood of 'Lapin' trees.

Budget

Project title: Flowering, pollination and fruit set of 'Regina' and 'Sweetheart' sweet cherry trees
Principle Investigators: Anita Nina Azarenko and Annie Chozinski
Submitted to: Agricultural Research Foundation, Oregon Sweet Cherry Commission and the Washington Tree Fruit Research Commission
Project duration: indefinite
Current year: 2005
Current year request: **$49,500**

Item	2005
Salaries (0.75 FTE)[1]	$24,375
Benefits (59%)[1]	$14,400
Wages[2]	$3,200
Benefits (%)	
Equipment	
Supplies	$325
Travel[3]	$500
Miscellaneous (plot charges)	$6,700
Total	$49,500

[1]Salary and benefits for Annie Chozinski, research assistant. Her base salary is $32,500. The balance of her funding is requested in the "Flowering, pollination and fruit set of 'Regina' and 'Sweetheart' sweet cherry trees"
[2]Wages for an undergraduate student: ~400 hrs at $8.00/hr + $3.12/mo OPE
[3]Travel includes mileage for travel to and from the Lewis-Brown Research Farm.

CONTINUING REPORT

PROJECT NO.: CH-04-410

TITLE: High Density Orchard Management

Principal Investigator: Matthew Whiting
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Co-Investigators: D. Peterson, USDA-ARS, Kearneysville, WV
D.R. Ophardt, Res. Tech. Supervisor, WSU-Prosser
Cooperators: D. Hayden, Pasco, WA
B. Harris, Moxee, WA
D. Allan, Naches, WA

YR INITIATED: 2004 **CURRENT YR:** 2004 **TERMINATING YR:** 2006

OBJECTIVES:

1. Develop and evaluate novel production systems including specific training/pruning strategies, cultivars and rootstocks that improve labor efficiency and yield excellent quality fruit

2. Develop and refine training strategies that facilitate mechanical harvest of sweet cherries for the fresh market.

3. Continue to evaluate the effect of Ethephon on fruit quality, maturity, and retention force of different cultivars

4. Model tree vegetative and fruit growth in relation to genetic and environmental factors

SINGIFICANT FINDINGS:

- Ethephon elicited a reduction in fruit-pedicle retention force in all varieties
- Reductions varied by cultivar (27 – 49% vs. untreated)
- Ethephon-treated Benton, Bing, and Selah fruit were softer than untreated fruit
- Ethephon treatment improved Chelan and Tieton fruit quality compared to untreated fruit
- Early growth of high density orchards is affected by scion variety, training system, and rootstock
- The relative importance related to tree vigor/growth is: scion variety>training system>rootstock
- Bing was the most vigorous, Skeena was the least vigorous
- Gisela 12 is ca. 30% more vigorous than Gisela 5

METHODS:

High density orchard management. A new high density orchard was planted in 2003 at about 5' within row spacing and 14' between row spacing for a density of approximately 580 trees per acre. It is comprised of cultivars that ripen at approximately weekly intervals (Chelan, Tieton, Bing, Skeena, and Sweetheart) on Gisela 5 and Gisela 12 rootstocks. This block is being trained to a y-trellis system in two

different ways: (1) trees headed after planting at approximately 20" and alternately tied to opposite sides of the trellis (*i.e*., three leaders per side in a fan shape) and, (2) trees headed at approximately 30" and split on the trellis (*i.e*., two leaders, one per side in a central leader shape). The interactions among training method, cultivar, and rootstock will be evaluated. In the first few years, tree growth and precocity data will be collected, including, trunk cross-sectional area, shoot length, number of laterals, flowering, fruit yield and quality.

Vegetative and fruit growth (when present) in this new orchard will be monitored weekly and related to locally recorded environmental data. Solar radiation, relative humidity, wind velocity, soil and air temperature, and soil water content will be continuously and intensively monitored in this orchard by three AgWeatherNet weather stations located approximately 100' apart. The ultimate goal of this experiment is to model reproductive and vegetative development of distinct germplasm to environmental phenomena (*e.g*., fruit development, harvest date, and full bloom by degree days/heat units).

A new high density (*ca*. 530 trees/acre) of Tieton on Gisela 5 was planted in 2003. In this block, trees will be trained to either a central leader or multiple leader bush system. Growth, precocity and fruit quality will be monitored and compared between systems. This research program has shown that excellent quality fruit can be grown on a variety of training systems. Therefore, the costs associated with production on these various systems may be an important factor in determining their commercial potential. Each different system will be evaluated for labor efficiency by timing harvest and pruning events on a minimum of 50 trees per system.

Mechanical harvest efficiency. Mature Bing trees trained to various systems (*e.g*., y-trellis, bush, central leader) will be harvested mechanically. Entire rows will be harvested and efficiency will be documented as harvesting time per tree and the number of impacts per tree. In addition, the efficiency of fruit harvest will be evaluated by collecting and weighing: (1) all fruit remaining on the tree (*i.e*., those fruit not removed by the harvester), (2) all fruit on the ground (*i.e*., those fruit removed but not collected), and (3) all fruit in bins (*i.e*., ostensible yield). Quality of fruit subsamples harvested from each system will be evaluated, in comparison to stemless fruit harvested by hand and control fruit (with stems, harvested by hand), by an independent lab (Allan Bros.) for bruising, pitting, mechanical damage, and stem-end tears at the time of harvest and after two weeks in cold air storage.

Ethrel effects. Whole trees will be treated with Ethrel approximately 14 days before harvest. Cultivars to be treated include Chelan, Tieton, Bing, Benton, Lapins, Regina, and Selah. The following data will be collected on each of 40 fruit randomly harvested just prior to application and at 2 – 3 day intervals following application until commercial harvest: fruit retention force, fruit weight, soluble solids, firmness, and color. Fruit from treated trees will be compared to fruit from untreated control trees.

SCHEDULE OF ACCOMPLISHMENTS:

Year 1 (2004):

- Train trees in new orchards
- Monitor growth and environmental variables in new high density blocks
- Evaluate interactions among training method, cultivar, and rootstock
- Apply Ethephon treatments and evaluate effects on fruit quality parameters
- Evaluate effect of training system on efficiency of mechanical harvest and fruit quality

RESULTS AND DISCUSSION:

Varietal response to Ethephon Not all varieties respond similarly to the application of Ethephon (Table 1). However, in 2004, Ethephon reduced pedicel-fruit retention force of every variety. The average reduction, measured about two weeks after application, was 35%. Only Bing and Selah fruit had retention forces below the target of 400 for ideal removal by the mechanical harvester. Tieton exhibited the greatest (ca. 50%) and Chelan exhibited the lowest (ca. 27%) reductions in pedicle retention force. Fruit from Benton, Bing, and Selah trees exhibited a slight but significant decrease (ca. 9%) in fruit firmness in response to Ethephon application. In contrast, Tieton fruit firmness was similar to that of untreated controls and Chelan fruit treated with Ethephon were statistically firmer, albeit only barely (6%), than those from untreated trees (Table 1). Therefore, varieties respond differently to Ethephon. In all cases we elicited a loosening of the fruit, an important response for mechanical harvest, but not all varieties also were softer. Bing fruit exhibited pedicel retention forces low enough for easy removal by the mechanical harvester – ideally this value should be below 400. Bing fruit treated with Ethephon were also the softest in this trial though still above the threshold of 220g/mm that most packing sheds consider too soft to pack.

Table 1. Effect of Ethephon on pedicel retention force and fruit quality of 5 varieties. Statistical differences ($P<0.05$) are within a variety, between treatments, and indicated where present.

Variety	Treatment	Pedicel retention force (g)	Firmness (g/mm)	Color*	Mean row-size	Weight (g)
Benton	Ethephon	0.57 b	251 b	3.8	10.0	9.5
	Control	0.80 a	272 a	4.0	10.0	9.2
Bing	Ethephon	0.39 b	225 b	4.2	10.4	8.4
	Control	0.60 a	243 a	4.2	10.5	8.1
Chelan	Ethephon	0.67 b	282 a	4.1 a	10.6 a	8.0 a
	Control	0.91 a	265 b	3.7 b	11.4 b	6.4 b
Selah	Ethephon	0.37 b	257 b	4.4 a	9.8	9.6
	Control	0.56 a	288 a	3.8 b	9.8	9.6
Tieton	Ethephon	0.49 b	272	4.2	9.0 a	11.8 a
	Control	0.98 a	274	4.0	9.4 b	10.7 b

*color scale: 0=green, 1=pink, 2=light red, 3=red, 4=dark red, 5=mahogany

Interestingly, we found that Ethephon increased Chelan and Tieton fruit quality compared to untreated fruit. Ethephon increased Chelan fruit firmness by 6%, size by almost one category, and weight by 25%. Similarly, Ethephon-treated Tieton fruit were a half row-size larger and more than 1 g heavier, on average compared to untreated fruit. Ethephon-treated fruit were slightly advanced in maturity compared to untreated fruit but that is not likely to have accounted for the quality improvements entirely. These results suggest that Chelan and Tieton are better suited for potential mechanical harvest than the other varieties we tested. It remains to be seen however if Ethephon will reduce pedicel retention force to below 400g without affecting negatively fruit quality.

Mechanical harvest trial In 2004 we negotiated and signed an agreement with USDA-ARS to transport and house their experimental mechanical harvester in Prosser for a 3-year duration. We will continue to consult with Dr. Peterson as we refine orchard systems for maximum harvest efficiency.

Table 2. Quality of hand-picked and machine-picked 'Bing' sweet cherry fruit.

Quality parameter	Hand-picked	Machine-picked
bruising (%)	15	26
total pits (#/fruit)	0.47	0.85
machine cuts (%)	6	11
stem tear (%)	2	1
stem end shrivel (%)	16	15
natural cullage (%)	41	42
with stems (%)	2	12

In 2004 we compared the quality of hand-harvested (HH) fruit with that of machine-harvested (MH) fruit. Analyses were conducted independently on unidentified samples (with respect to harvest treatment) at Allan Brothers packingshed in Naches. Interestingly, we found significantly higher levels of bruising and pitting in the machine-harvested fruit compared to hand-harvested fruit (Table 2). This is the first dataset in which mechanically harvested fruit quality is found to be lower than that hand-harvested fruit. In each of our previous trials, we found similar fruit quality between machine- and hand-harvested fruit. However, in 2004, MH fruit had 11% more bruising, a greater number of pits per fruit, slightly higher machine cuts, and a higher percentage of fruit with stems, compared to HH fruit. Overall, fruit quality was very poor from this block, natural cullage was ca. 42%. This may have contributed to the increased damage to MH fruit. More likely however was the mishandling of MH fruit samples. MH fruit was collected in the machine's bin, filled, and dropped in the field. From this bin, subsamples were collected into bags and delivered to Allan Bros. Unfortunately, it was reported, after sample collection and delivery, that MH fruit samples were mishandled by staff (i.e., aggressively 'shoveled' by hand from the bin into bags). HH samples were not handled similarly and we attribute the higher levels of bruising and pitting to unequal handling of fruit. In subsequent years, greater attention to sample collection will be made and samples will be handled consistently and properly.

High density orchard management In 2004 we measured growth parameters in the new high density orchard planted on Gisela 5 and Gisela 12 rootstocks. Shoot length was measured at weekly intervals until terminal bud set and the total number of shoots and length of wood were determined in September. 2004 was this orchard's second leaf and therefore, trees did not bear fruit (any flowers were removed). We expect to collect fruit growth, yield, and quality data from 2005 and on. From our previous and current studies of training systems for mechanical/pedestrian harvest, we have developed the following principles:

- two single-layer fruiting planes per tree (one/side)
- ca. 75 – 80º between planes (each plane ≈ 50º from horizontal)
- each plane consists of vertical fruiting uprights (4 – 7/tree and side)
- horizontal growth is eliminated
- fruiting limbs are renewed below first wire
- upright growth to a height of at least 50 cm (≈ 20 in) above soil

We documented a significant effect of scion variety on growth characteristics in 2004 (Table 3). Across both rootstocks, Bing, Chelan, Skeena, and Tieton had a similar number of shoots per tree (31 – 38). Sweetheart trees however, had significantly more shoots (47). Growth of Sweetheart was less vigorous than the other varieties though, and therefore, total shoot length per tree among Sweetheart, Chelan, Skeena, and Tieton was similar. Only Bing exhibited significantly greater total shoot length per tree, this

was due to about 30% greater mean length per shoot. High total shoot length per tree is desirable at this stage of orchard establishment because our early goal is to fill the canopy and bring trees into bearing as quickly as possible. The least vigorous combinations were Chelan/Gisela 5, Skeena/Gisela 5, and Sweetheart/Gisela 5, each with less than 11 m total shoot length per tree. The most vigorous combinations were Bing/Gisela 12, Bing/Gisela 5, Sweetheart/Gisela 12, and Chelan/Gisela 12, each with more than 25 m total shoot length per tree.

Gisela 12 was more vigorous than Gisela 5, across all varieties (Table 3). The two rootstocks induced similar numbers of shoots per tree, but Gisela 12 trees had about 40% longer shoots and therefore, greater total length of wood per tree. The greater vigor of Gisela 12 may become disadvantageous in the later stages of orchard maintenance because the spacing of this block does not suit a vigorous canopy. We are very interested to learn whether vigor in this orchard will be diminished by fruiting in the subsequent years.

Training system (alternating trees vs. traditional Y-trellis) had a significant effect upon early growth of trees (Table 3). The more traditional Y-trellis system (Y) produced significantly more shoots per tree compared to the system of sequentially alternating trees down the row (A). Mean shoot length was similar between systems despite their being about 50% more shoots on the Y trees. Therefore, total length per tree was greater for Y trees. Whether these differences in vegetative growth translate into differences in system precocity will be documented in 2005 and on. Early yields within any orchard system will be directly affected by the number of fruiting nodes and productivity of those nodes. Greater shoot length may translate into greater fruiting potential per tree and therefore, greater productivity.

Table 3. Effects of scion variety, rootstock, and training system on vegetative growth of 2nd leaf trees.

Scion	Rootstock	Training system	Shoots/tree (#)	Shoot length (cm)	Total length/tree (m)
Bing			38 b	71.4 a	26.9 a
Chelan			34 b	51.4 b	17.6 b
Skeena			31 b	52.6 b	16.4 b
Sweetheart			47 a	40.2 c	18.9 b
Tieton			35 b	53.8 b	18.7 b
	Gisela 12		35 a	65.9 a	22.8 a
	Gisela 5		37 a	47.1 b	17.4 b
		Y-trellis	44 a	54.9 a	24.1 a
		Alternating	29 b	55.6 a	16.3 b

BUDGET

Project: **High density orchard management**
P.I.: **Whiting**
Project duration: **2004-2006**
Current year: **2005**
Project total: **$58,133**
Current year request: **$19,374**

Year	2004	**2005**	2006
Total	$17,895	**19,374**	20,864

Current year breakdown

Item			
Salaries[1]	6,199	**6,301**	6,553
Benefits (28% yr 1; 31% yr 2 & 3)	1,736	**1,953**	2,031
Wages[2]	6,000	**7,000**	8,000
Benefits (16%)	960	**1120**	1280
Equipment			
Supplies[3]	2,000	**2,000**	2,000
Travel[4]	1,000	**1,000**	1,000
Miscellaneous			
Total	$17,895	**19,374**	20,864

[1] One-sixth annual salary for Mr. Efrain Quiroz.
[2] Time-slip assistance for harvest, data collection, and fruit quality analyses
[3] Field and laboratory supplies
[4] Travel to plots

CONTINUING REPORT

PROJECT NO.: CH-04-412

TITLE: Clonal Rootstock Performance/Evaluations

Principal Investigator: Matthew Whiting
Organization: Irrigated Agriculture Research and Extension Center, WSU-Prosser
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Co-Investigators: W.E. Howell, NRSP5/IR2 Manager, WSU-Prosser
D.R. Ophardt, Res. Tech. Supervisor, WSU-Prosser

YR INITIATED: 2004 **CURRENT YR:** 2005 **TERMINATING YR:** 2006

OBJECTIVES:

1. Continue evaluation of the NC-140 regional project trial ('Bing' on 17 new rootstocks) established in 1998 for horticultural and physiological evaluations and fruit quality. Projected trial duration is 10 years.

2. Continue evaluating vigor and cropping performance of other orchard trials with key PNW cultivars on various rootstocks

3. Analyze the physiology of interactive rootstock/scion horticultural traits (e.g., canopy leaf area, yield efficiency, precocity, graft compatibility).

4. Establish planting of 2005 NC-140 sweet cherry rootstock trial.

SIGNIFICANT FINDINGS:

- rootstock affected scion vigor, yield, and fruit quality
- rootstock altered 'Bing' fruit maturity significantly (ca. 10 days)
- fruit maturity was unrelated to tree vigor
- fruit yield was unrelated to tree vigor
- the Gisela series is very precocious/productive
- the best quality fruit was harvest from Mazzard-rooted trees
- Mazzard had the second lowest yield (8.5 kg/tree)
- the worst quality fruit was harvested from Gisela 209/1 and Edabriz
- Gisela 5 and Gisela 6 yielded the most 10.5-row and larger fruit/tree
- fruit quality is related negatively to yield efficiency
- PiKu 1 is less vigorous and more precocious than PiKu 3
- novel crop load management strategies will need to be developed to grow high quality sweet cherries on precocious and dwarfing rootstocks

METHODS:

The 1998 NC-140 plot was planted at WSU-Prosser's Roza Experimental Unit, with 'Bing' as the scion cultivar and 'Van' as the pollenizer, on the German rootstock series Gisela 4 (GI 473/10), Gisela 5 (GI 148/2), Gisela 6 (GI 148/1), Gisela 7 (GI 148/8), GI 195/20, GI 209/1, and GI 318/17; the German rootstock series Weiroot 10, W13, W53, W72, W154, and W158; Edabriz (France); P-50 (Japan); and Mazzard and Mahaleb seedlings as controls. There are 8 replications/rootstock, with guard tree around the plot perimeter, and tree spacing of 19.5 x 19.5 ft (6.0 x 6.0 m) to reduce the potential influence of neighboring trees. Irrigation by microsprinklers and frost protection by wind machine were installed. A duplicate plot was planted for potentially destructive analyses, such as physiological stress treatments. The effects of rootstock on tree yield, vigor, fruit quality, first and full bloom dates, fruit maturity, and senescence and cold acclimation will be documented annually.

A research orchard was planted in 1998 with WSU-Prosser varieties (including Chelan, Cashmere, Benton, Selah, Rainier and Tieton) and elite selections (including 8011-3, 7147-9, and 7903-2) on several Gisela rootstocks (including Gisela 5, 6, 195/20, and 209/1), Mazzard, Mahaleb, and Colt. In this block, tree vigor, fruit yield and quality, and graft compatibility will be monitored. Several of these newly released cultivars (*e.g.*, Chelan, Tieton, Benton, Selah) and advanced selections (*e.g.*, PC 8011-3, PC 7903-2, PC 7147-9) will be subjected to one of two crop load treatments: (1) unthinned control, and (2) 50% removal of blossoms by hand. Tree growth, fruit yield and quality (weight, row-size distribution, soluble solids, and firmness) will be evaluated for each scion grown on Gisela 6, Gisela 5, Gisela 195/20, and Edabriz, where possible.

Another orchard, planted in 2001, will be utilized to evaluate the effects of two new rootstocks (PiKu 1 and PiKu 3) on growth, precocity, fruit quality, and graft compatibility of Celeste, Benton, Selah, Tieton, Regina, Bing, Skeena, Sweetheart, Attika, Rainier, Lapins, Chelan, Summit, Black Gold, White Gold, Glacier, and Sonata.

In a separate trial in cooperation with Amy Iezzoni of MSU, we have planted 21 MSU rootstock selections, totaling 117 trees, in a test plot at the Roza farm. The control rootstock is GI 6 and the scion is Bing with Tieton/GI6 as the pollinator. An additional 243 trees (84 selections) will be planted in 2004. The effects of rootstock genotype on scion growth habit, precocity, and fruit quality will be documented annually.

SCHEDULE OF ACCOMPLISHMENTS:

Year 1 (2004)

- Evaluate growth, cropping, fruit quality, and graft compatibility of different scion/rootstock combinations
- Characterize effect of rootstock on scion fruit-to-leaf area ratio
- Document effect of blossom thinning on tree yield and fruit quality

Year 2 (2005)

- Evaluate growth, cropping, fruit quality, and graft compatibility of different scion/rootstock combinations.
- Plant new NC-140 rootstock trial at WSU-Roza experimental farm
- Characterize effect of rootstock on scion fruit-to-leaf area ratio

- Document effect of blossom thinning on tree yield and fruit quality

Year 3 (2006)

- Evaluate growth, cropping, fruit quality, and graft compatibility of different scion/rootstock combinations.
- Recommend rootstocks for moderate and high density production systems

RESULTS AND DISCUSSION:

1998 NC-140 trial 2004 was the third fruiting year (6th leaf) for most of the rootstocks in this trial and a great range of fruit yields was recorded (6.4 – 34.2 kg/tree) (Table 1). Rootstock had a tremendous impact on productivity of 'Bing' scion in this trial (Fig. 1). Many trees have reached full production. Fifteen of the 17 rootstocks in this trial have improved productivity compared to the industry standard, Mazzard. In 2004, mean yield was 23.8 kg. The most productive rootstocks were all from the Gisela series: Gi 7, Gi 195/20, Gi 6, and Gi 5, in order of decreasing yield. Each of these rootstocks yielded over 30 kg (66 lbs) of fruit per tree. The least productive rootstocks were P-50, Mazzard, W53 and W154 in order of increasing yield. Trees on each of these rootstocks yielded less than 20 kg (44 lbs) per tree. For W53, by far the most size-controlling of the rootstocks, the poor yields were due to limited canopy size and therefore inadequate bearing surface. We predict that, even at a high tree density, this rootstock is too dwarfing to produce commercially acceptable yields. However, for P-50 and Mazzard, low yields may be attributed to excessive vigor and poor floral bud induction.

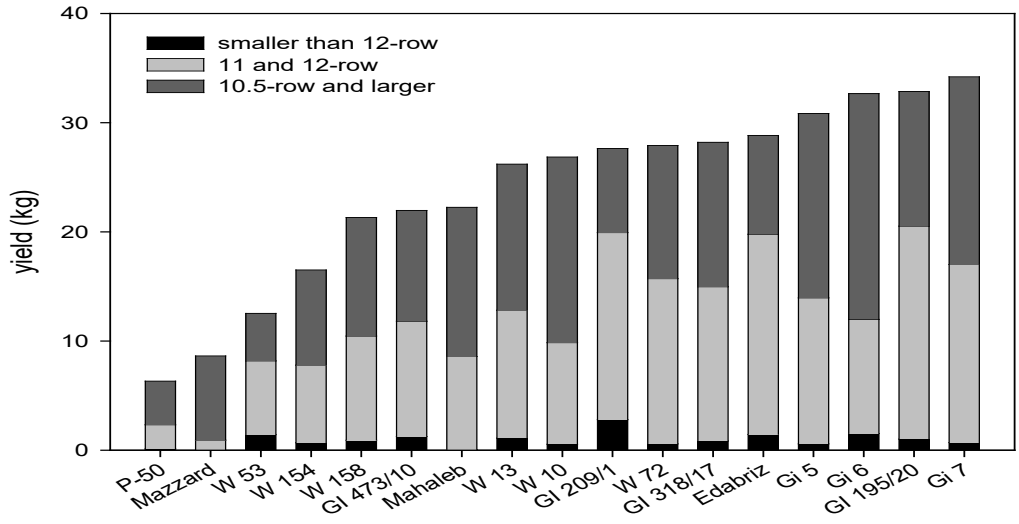

Figure 1. Effect of rootstock on yield and quality of fruit from 6-year-old 'Bing' trees.

As reported previously, yield is unrelated to vigor (Fig. 2). By defining high yield as over 20 kg/tree and high vigor as greater than 250 cm^2 TCSA, we can begin to compare and classify rootstocks. Those which possess high yield and low vigor may be desirable and

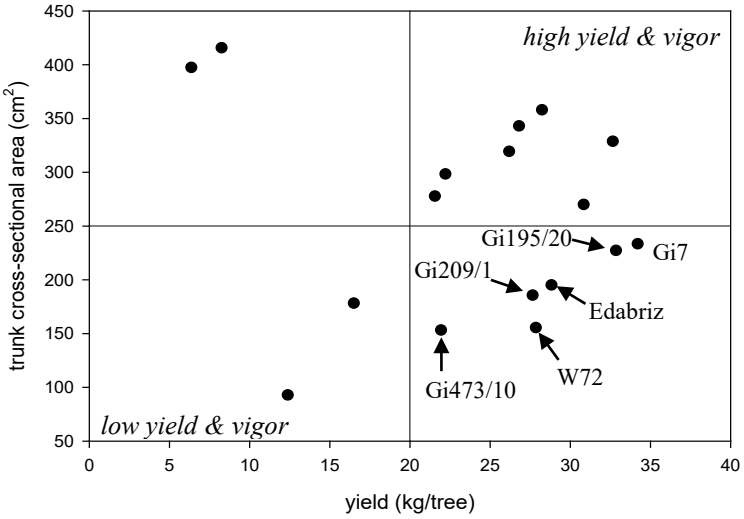

Figure 2. Relationship between yield and vigor (trunk cross-sectional area) of 6-year-old 'Bing' sweet cherry trees grown on 17 rootstocks.

appropriate for high density, more efficient plantings. In our analysis, Gi7, Gi195/20, Edabriz, W72, Gi209/1, and Gi473/10 qualify by falling into the lower right quadrant of figure 2. Unfortunately, most of these rootstocks also produced lower quality fruit. This is because of the negative relationship between yield efficiency (kg/cm^2 TCSA) and fruit quality (Fig. 3). Trees in the lower right quadrant are those which possess high yield efficiency – they are productive and size-controlling. This analysis should not preclude their commercial adoption rather, it highlights the need for different crop load management strategies on trees with high yield efficiency compared to those with low yield efficiency (i.e., Mazzard).

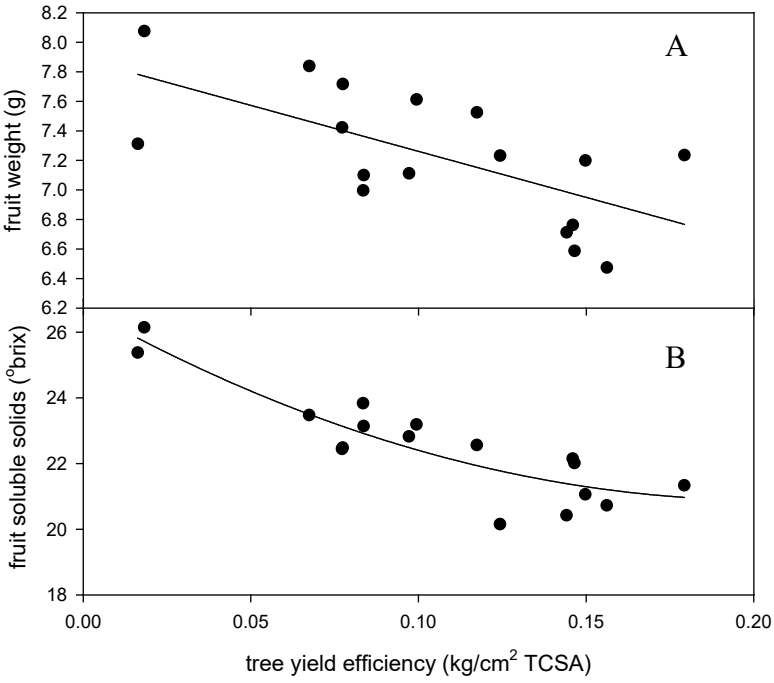

Figure 3. Relationship between fruit weight (A) and soluble solids (B) and yield efficiency (kg fruit per cm^2 TCSA) of 6-year-old 'Bing' sweet cherry trees grown on 17 rootstocks.

A similar comparison can be made between fruit weight and yield. In this analysis we have defined high weight as greater than 7.5 g/fruit. Several rootstocks induce productivity and good fruit quality in the scion (Fig. 4). These include Gi6, Gi5, W10, and Mahaleb. Of these rootstocks, only Gisela 5 is significantly size-controlling compared to Mazzard. Gisela 5 remains the most promising dwarfing rootstock in this trial. Mazzard was the only other rootstock from which fruit weight was greater than 7.5 g but these trees were extremely unproductive. Rootstocks in the lower left quadrant of the figure

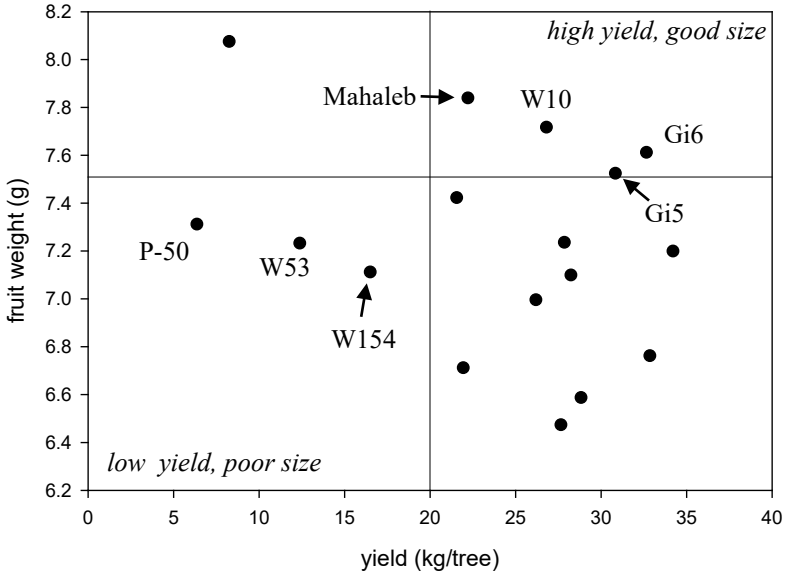

Figure 4. Relationship between fruit yield and weight from 6-year-old 'Bing' sweet cherry trees grown on 17 rootstocks.

are those which are not particularly productive and bear lower quality fruit. P-50, W53, and W154 are in this category.

Overall, in 2004 fruit quality was good – the highest yield of smaller than 12-row fruit was only 2.8 kg on Gi209/1 (most trees yielded less than 1 kg in this size category). However, similar to the past few years, we documented a tremendous effect of rootstock on fruit quality. Fruit weight ranged from 6.5 - 8.1 g, soluble solids ranged between 20.2 – 26.1, and firmness varied between 205 and 272 g/mm. In addition, the yield of 10.5-row and larger fruit per tree varied from a low of 4.0 kg on P-50 to 20.7 kg on Gi6 (Fig. 1). The best quality fruit was harvested from Mazzard (83% 10.5-row and larger, 8.1 g). However, 14 of the 16 other rootstocks yielded more premium quality fruit because of poor yields on Mazzard. Only P-50 and W53 yielded fewer 10.5-row and larger fruit. The worst quality fruit was harvested from Gi209/1 and Edabriz (ca. 6.5 g and <30% 10.5-row and larger).

PiKu trial In 2001 we planted an orchard of 16 scion varieties on both PiKu 1 and PiKu 3 rootstocks. 2004 represented the first year of fruit production on most varieties and therefore, yields were low (Table 1). On PiKu 3, Attika, Benton and Selah trees did not bear any fruit in 2004. On PiKu 1, only Selah was unproductive. PiKu 1 was significantly more precocious, out-yielding trees on PiKu 3 by over 2-fold, though this difference was only ca. 1 lb/tree. In addition, PiKu 1 was about 40% less vigorous than PiKu 3. There were only

Table 1. Effect of rootstock on 'Bing' fruit yield, quality, tree size, and yield efficiency.

Rootstock	Yield (kg/tree)		Weight (g)		Firmness (g/mm)		<12-row (kg)		11 & 12-row (kg)		≥10.5-row (kg)		TCSA (cm^2)		Yield efficiency (kg/cm^2)	
P-50	6.4	f	7.3	abc	272	a	0.1	b	2.2	g	4.0	e	398	a	0.016	g
Mazzard	8.3	ef	8.1	a	255	ab	0.0	b	0.9	g	7.7	cde	416	a	0.018	fg
W 53	12.4	def	7.2	abcd	231	bcd	1.4	ab	6.8	fg	4.4	de	93	k	0.124	bcd
W 154	16.5	cde	7.1	abcd	234	bc	0.7	b	7.1	fg	8.7	cde	178	j	0.097	de
W 158	21.6	bcd	7.4	abc	224	bcd	0.9	b	9.5	def	10.9	bcd	278	def	0.077	e
GI 473/10	21.9	bc	6.7	cd	237	bc	1.3	b	10.6	cdef	10.2	cd	153	j	0.144	abc
Mahaleb	22.2	bc	7.8	a	211	cd	0.1	b	8.5	efg	13.7	bc	298	cde	0.067	ef
W 13	26.2	ab	7.0	bcd	234	bc	1.1	b	11.7	bcdef	13.4	bc	319	bcd	0.083	de
W 10	26.8	ab	7.7	ab	205	d	0.5	b	9.3	ef	13.4	bc	343	bc	0.077	e
GI 209/1	27.7	ab	6.5	d	213	cd	2.8	a	17.1	abc	7.7	cde	186	ij	0.156	ab
W 72	27.8	ab	7.2	abcd	205	d	0.6	b	15.1	abcde	12.2	bc	156	j	0.179	a
GI 318/17	28.2	ab	7.1	abcd	225	bcd	0.8	b	14.1	abcde	13.2	bc	358	ab	0.084	de
Edabriz	28.8	ab	6.6	d	207	d	1.5	ab	18.3	ab	9.1	cde	195	hij	0.147	abc
Gi 5	30.8	a	7.5	ab	214	cd	0.6	b	13.4	abcdef	16.9	ab	270	efg	0.117	cd
Gi 6	32.7	a	7.6	ab	224	bcd	1.5	ab	10.5	cdef	20.7	a	329	bc	0.099	de
GI 195/20	32.9	a	6.8	cd	222	bcd	1.0	b	19.5	a	12.3	bc	227	ghi	0.146	abc
Gi 7	34.2	a	7.2	abcd	219	cd	0.7	b	16.3	abcd	17.2	ab	233	fgh	0.150	abc
lsd	8.9		0.8		28		1.6		7.2		6.3		47.5		0.040	

subtle differences between these rootstocks in fruit quality, with fruit from PiKu 3 being about 8% firmer, and fruit from PiKu 1 having about 8% higher soluble solids.

Table 1. Effect of rootstock (Piku 1 and 3) on yield and fruit quality of 3-year-old sweet cherry trees. Data are means of 16 scion varieties. Means followed by the same letters within a column are not significantly different (P>0.05).

Rootstock	Date	Weight (g)	°Brix	Firmness (g/mm)	%<12-row	% 11 & 12-row	% ≥10.5-row	Yield(g)	TCSA(cm^2)
PiKu 1	6/19	8.0a	22.9a	274b	6a	31a	63a	974a	22.7b
PiKu 3	6/18	8.1a	21.1b	296a	6a	25b	66a	406b	36.9a
lsd		0.4	0.9	19	5	6	8	145	3.6

Fruit quality among scion varieties varied considerably in this first year of production (data not shown). Tieton was the largest cultivar (11.4 g, 96% 10.5-row and larger) and Sonata was the smallest (6.2 g, 28% 10.5-row and larger). Sweetheart was the most precocious cultivar, yielding just over 3 kg per tree.

Project: **Clonal Rootstock Evaluations**
P.I.: **Whiting**
Project duration: **2004-2006**
Current year: **2005**
Project total: **$62,293**
Current year request: **$21,034**

Year	2004	2005	2006
Total	$19,895	**$21,034**	$21,364

Current year breakdown

Item			
Salaries[1]	6,199	**6,301**	6,553
Benefits (28% yr 1; 31% yr 2 & 3)	1,736	**1,953**	2,031
Wages[2]	6,000	**8,000**	8,000
Benefits (16%)	960	**1,280**	1,280
Equipment[3]	1,500		
Supplies[4]	2,000	**2,000**	2,000
Travel[5]	1,500	**1,500**	1,500
Miscellaneous			
Total	$19,895	**$21,034**	$21,364

1. One-sixth annual salary for Mr. Efrain Quiroz (Roza orchard manager).
2. Time-slip assistance for harvest, data collection, and fruit quality analyses
3. To purchase new computer for fruit quality lab
4. Supplies for field work and laboratory analyses
5. Travel to plots and vehicle maintenance

CONTINUING REPORT

PROJECT NO.: CH-04-411

TITLE: Characterizing and Manipulating Sweet Cherry Source-Sink Relations

Principal Investigator: Matthew Whiting
Organization: Washington State University
Irrigated Agriculture Research and Extension Center
E-mail: mdwhiting@wsu.edu
Cooperators: Don Elfving, TFREC
Jim McFerson, TFRC
Roberto Núñez-Elisea, OSU-MCAREC
Mark Roy

OBJECTIVES:

1. To develop and evaluate practical strategies for manipulating sweet cherry crop load and maximizing fruit quality.

2. To investigate whole-tree source-sink relations.

3. Investigate the effects of postharvest defoliation on whole-tree physiology and fruit yield and quality.

SIGNIFICANT FINDINGS:

- Chemical thinning trials in 2004 were unsuccessful – no product reduced significantly fruit set /yield or improved fruit quality
- A double application of GA_3 at 50 mg/l and single applications at 100 mg/l reduced return bloom, yield, and improved fruit quality
- Yield in the season subsequent to GA_3 application was related negatively and closely to [GA_3]
- GA_3 may be an effective crop load management tool for productive orchard systems
- Compared to unpruned trees, summer pruning reduced, by half, whole-canopy NCER
- Summer pruning improved intra-canopy light distribution

METHODS:

Objective 1

Chemical blossom thinning. The efficacy of several blossom thinning agents will be evaluated in multiple locations throughout the PNW. Treatments will be applied in the Yakima valley and Wenatchee region as well as in Hood River/The Dalles. Ammonium thiosulphate (ATS), fish oil + lime sulphur (FO+LS), and vegetable oil emulsion (VOE) will be applied to entire trees at different rates and timings. Treatments will be applied to heavily cropping Bing and Lapins trees on Gisela 5 at the Roza experimental farm as well as other heavily-cropped trees in grower cooperator orchards. Treatments will be compared for their effect upon floral bud induction (both number of reproductive buds per spur/shoot and floral meristems per bud), fruit set, spur and branch F:LA, and fruit yield and

quality. In addition, the tree's physiological response to thinners will be documented by measuring spur leaf gas exchange prior to, and following application, and leaf and shoot expansion rates.

Thinner phytotoxicity will also be evaluated during the winter on trees grown in a greenhouse. Entire potted trees will be sprayed with a wide range of concentrations (0, 1, 2, 4, 8%) of each thinner. Individual leaves will be monitored for rate of expansion, gas exchange, and chlorophyll content (prior to and following treatment).

GA to inhibit floral bud induction. Trees will be treated with GA at varying concentrations (0, 30, 50, and 100 mg a.i./liter) and two stages of flower bud initiation (roughly equivalent to beginning of stage II and III of existing crop). Treatments will be compared for their effect upon fruit quality during the season of application, floral bud induction (both number of reproductive buds per spur/shoot and floral meristems per bud), return bloom density, spur and branch F:LA, and fruit yield and quality. Initial treatments were applied during summer 2003 and consisted of:

1. Control (no treatment)
2. GA_3 30 mg a.i./liter (standard program)
3. GA_3 50 mg a.i./liter
4. GA_3 100 mg a.i./liter

Treatments 3 and 4 were applied as single applications at either the beginning of stage II or stage II, or a double application receiving treatment on both dates.

Objective 2
Potential periods of limiting carbohydrate supply will be investigated by establishing a range of F:LA by thinning fruit buds within Bing trees on Gisela 5, Gisela 6, and Mazzard rootstocks. For each scion/rootstock combination, fruit and shoot growth rates will be monitored weekly and canopy and spur F:LA will be determined at harvest.

Newly released cultivars (*e.g*., Chelan, Tieton, Benton, Selah) and advanced selections (*e.g*., PC 8011-3, PC 7903-2, PC 7147-9) from the WSU sweet cherry breeding program planted in 1998 will be subjected to one of two crop load treatments: (1) unthinned control, and (2) 50% removal of blossoms by hand. Tree growth, fruit yield and quality (weight, row-size distribution, soluble solids, and firmness) will be evaluated for each scion grown on Gisela 6, Gisela 5, Gisela 195/20, and Edabriz, where possible.

Objective 3
Summer pruning. The impact of summer pruning on canopy gas exchange, light distribution, growth, and fruit yield and quality in the subsequent season will be studied. Comparisons will be made between trees subjected to summer pruning (not dormant pruned) and dormant pruned control trees. Prior to pruning, canopy LA and light distribution will be measured for each tree. The LA removed from pruning will be collected and measured. In addition, for both treatments, pruned wood will be dried to a constant weight and weighed. Light distribution throughout pruned canopies will be assessed by ceptometer following pruning. In addition, rates of single leaf and whole-canopy gas exchange will be assessed prior to, and following summer pruning. In the dormant season, wood samples will be collected and analyzed for tissue carbon and nitrogen. In the subsequent spring, rates of vegetative growth (*e.g*., leaves and shoots) growth will be monitored weekly. Tree yield and fruit quality will be determined.

RESULTS AND DISCUSSION:
Blossom thinning

Prosser Roza Trial In 2004, the thinning trial on 'Bing'/'Gisela 5' was completely unsuccessful. No thinning treatment reduced fruit set. Therefore, there were no effects on yield, nor any improvements in fruit quality compared to the unthinned control (Table 1). In fact, fruit set was numerically higher for each thinning treatment. Overall, fruit quality of the Roza trial was very poor with average fruit weight of 5.1 g and ca. 47% of the fruit smaller than 12-row, across all treatments. This is surprising considering the mean yield was not excessive at just under 17 kg/tree. Harvest of these fruit may have been slightly premature (^{o}brix < 17) and therefore limited fruit size. By contrast, in 2003 ATS- and FOLS-treated trees yielded between 11 and 12 kg/tree of which, ca. 83% was 10.5-row and larger. The complete ineffectiveness of each thinning program in 2004 is likely a result of the excellent environmental conditions during and following bloom and highlights the need to better understand the role of the pre- and post-spray microclimate. High fruit set overall supports this contention. Indeed, fruit set of unthinned control in 2004 was nearly double that which we have recorded in the past two years. Moreover, we documented very little phytotoxicity of thinning treatments in 2004. Two days after treatment, leaf net CO_2 exchange rate (NCER) was reduced slightly (≈ 22%) by tergitol, VOE, and FOLS, and unaffected by ATS (Fig. 1). There were no significant differences in NCER on any other date. The seasonal trend in leaf NCER was similar to that reported previously, increasing toward harvest and declining thereafter. The lack of significant and sustained reduction in net photosynthesis suggests that the supply of carbohydrate growth resources was not limiting to fruit development and/or fruit set. This may also explain the lack of thinning in this year's trial – significant reductions in NCER have been related to thinning in other fruit species. We will document thinner phytotoxicity in a separate trial this winter.

Table 1. Effect of thinning treatment on fruit set, yield, and quality of 10-year-old 'Bing'/'Gisela 5' trees. All effects are non significant at P = 0.05.

Treatment	Fruit set (%)	Yield (kg)	Weight (g)	^{o}brix	Firmness (g/mm)	>10.5-row (%)	11 & 12-row (%)	<12-row (%)
Unthinned	50	16.6	4.74	16.5	277.9	1.6	38.9	58.1
1% tergitol	51	14.4	5.31	16.8	264.6	10.6	57.7	31.5
4% VOE	59	15.7	4.67	15.7	272.9	1.0	32.8	66.1
2% FO + 2.5% LS	54	18.7	5.37	16.4	283.5	6.4	54.7	38.0
2% ATS	61	19.1	5.32	15.7	281.8	7.6	51.1	41.2

Hood River Trial This trial was conducted on heavily cropping, 9-year-old 'Lapins'/'Gisela 5' trees. There were no significant differences in average yield per tree, fruit firmness or juice °Brix among treatments. Significantly larger fruit (in diameter) were produced in this study, but only when crop load was further thinned by removing immature fruit by hand after spraying FOLS during bloom (treatment 4). However, the average weight of this fruit was not statistically different from that of controls (at p = 0.0517). Apparently, fruit of control trees had a greater density than fruit of hand-thinned trees, although such possibility requires further examination. The larger diameter of fruit from hand-thinned trees resulted in fruit of an average row size of 10, whereas all other treatments had fruit of an average row size of 10.5. Although FOLS sprays at 2% apparently had no impact on

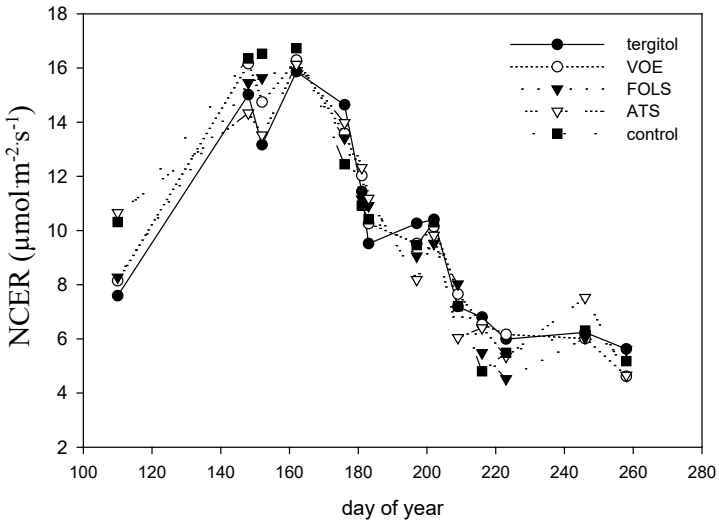

Figure 1. Seasonal trend of leaf NCER (µmol·m^{-2}·s^{-1}) from 10-year-old 'Bing'/'Gisela 5' sweet cherry trees treated with various chemical blossom thinning agents. Harvest was on day 162.

fruit size in this study, an important positive effect of LS was the effective control of brown rot. Sprays of LS were applied to the entire orchard during fruit development, as LS is an approved fungicide in organic production, whereas other fungicides used in conventional sweet cherry production are not.

Treatment	Yield (kg/tree)*	Estimated no. of fruit /tree**	Average fruit wt (g)	Fruit diameter (mm)	Average row size	Firmness (g/mm)	°Brix
1. Control (not sprayed or hand-thinned)	54.5	6610.5	8.3 ab	26.1 b	10.5	291.1	17.7
2. LS + CFO @ 25% and 80% FB	62.1	7802.5	8.0 b	25.8 bc	10.5	300.8	17.5
3. LS + CFO @ 80% and 95% FB	58.9	7374.1	8.0 b	25.7 bc	10.5	296.6	18.0
4. LS + CFO @ 25% and 80% FB + hand thinning	54.2	6124.4	8.9 a	27.1 a	10	296.5	18.1
5. VOE @ 25% and 80% FB	56.8	7264.7	7.9 b	25.5 c	10.5	294.5	17.0
Significance	*n.s.*	*n.s.*	*p=0.0517*	*p<0.001*		*n.s.*	*n.s.*

* Fruit harvest: July 12. 2004; ** No. of fruit per tree estimated from yield/average fruit wt

GA to inhibit floral bud induction The application of high rates of GA_3 to 7-year-old 'Bing'/'Gisela 1' trees inhibited the formation of flower buds, reduced yield, and improved fruit quality significantly (Table 3). There was no inhibitory effect of the standard application

Table 3. Effect of timing and concentration of GA_3 application on yield and fruit quality.

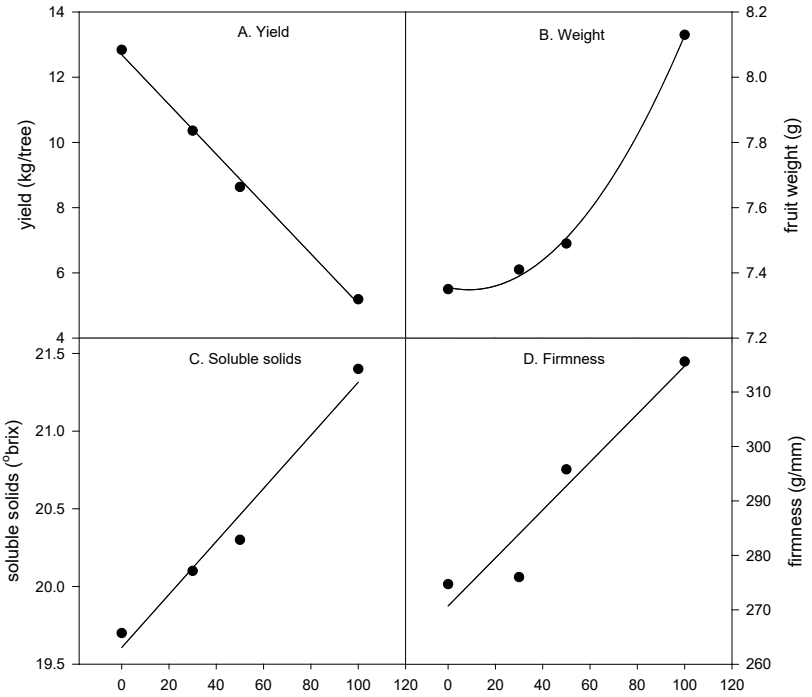

Figure 2. Effect of rate of GA_3 applied to entire 'Bing' sweet cherry trees at 4 rates (0, 30, 50, and 100 mg/l). Data points are mean of all timings.

Treatment	Yield (kg)		Weight (g)		°brix		Firmness (g/mm)		%10.5-row and larger		%11&12-row		%<12-row	
Control	12.8	a	7.35	bc	19.7	bc	275	c	50.6	b	49	a	0.28	ab
30ppm, II	10.4	ab	7.41	bc	20.1	abc	276	c	57.7	b	42.4	a	0	b
50, I	10.4	ab	7.2	c	19.4	c	291	bc	55	b	44.3	a	0.66	ab
50, II	9.66	ab	7.36	bc	20.1	abc	281	bc	52	b	45.7	a	1.01	a
50, I & II	5.84	bc	7.9	abc	21.2	abc	316	ab	77	a	22.9	b	0	b
100, I	4.62	c	8.16	ab	21.6	ab	307	abc	87.3	a	12	b	0	b
100, II	6.3	bc	7.83	abc	20.4	abc	311	abc	77.3	a	22.7	b	0	b
100, I & II	4.65	c	8.39	a	22	a	329	a	86.8	a	13.1	b	0	b

(30mg/l at the end of stage II) on flower bud induction or yield. However, 100 mg/l at all timings and 50 mg/l applied at both stages reduced significantly tree yield and improved fruit quality compared to other treatments. It appears however that yield reductions with those treatments may be too drastic– all others averaged 10.8 kg whereas the 100 mg/l and 50 mg/l applied twice averaged less than half of that at 5.3 kg/tree. Interestingly, the relationship between [GA_3] and tree yield was negative and linear (Fig. 2 A). We also documented a very close positive relationship between [GA_3] and fruit quality (Fig. 2). This response reflects reduced competition among growing points for growth resources and the well documented negative relationship between fruit yield and quality (Whiting and Lang, 2004). It appears that GA_3 applied at 50+mg/l and various timings has potential as an effective crop load management tool. Future research trials will test this response with different isomers of GA, and on different varieties and rootstocks. However, whether applications of GA_3 can be used to effectively moderate crop load and improve crop *value* remains to be seen. Using detailed fruit size and yield data, we intend to analyze treatment effects on crop value – these data will be included in

subsequent reports. In this trial we did not see significant improvements in fruit size without significant reductions in fruit yield (Fig. 2 A & B).

Summer pruning trial We compared light interception, distribution, whole-canopy and single leaf NCER of three pruned and three unpruned 10-year-old 'Bing'/Mazzard sweet cherry trees. Trees were pruned on 8 July, 2004. Pruning reduced canopy NCER (Fig. 3). Whole- canopy NCER on 7 July, the day before half of the trees were pruned, was ca. 121 $\mu mol \cdot tree^{-1}$ for both sets of trees. Three days after pruning, pruned trees had mean daily rates of canopy NCER of less than 18 $\mu mol \cdot tree^{-1} \cdot s^{-1}$ while the unpruned trees had rates of 58$\mu mol \cdot tree^{-1} \cdot s^{-1}$, more than three times higher. Unfortunately we had difficulties with the datalogger and lost the data from 8 July – 10 July. However, we hypothesize that this reduction occurred immediately in response to the pruning treatment. Therefore, the reduction in NCER from summer pruning is not short-lived; it is not known how long-lived the reduction is though. In 2005 we intend to measure tree NCER over a longer period time to better document the tree's response and a potential recovery. It is apparent that lower rates of gas exchange were a result of lower leaf areas in the pruned trees. Leaves contain the tree's photosynthetic machinery and a loss of leaf area will therefore usually reduce the overall capacity of the canopy to photosynthesize. However, in other tree fruit species, depending on the severity of the pruning, canopy NCER is not reduced significantly in response to summer pruning due to improved light

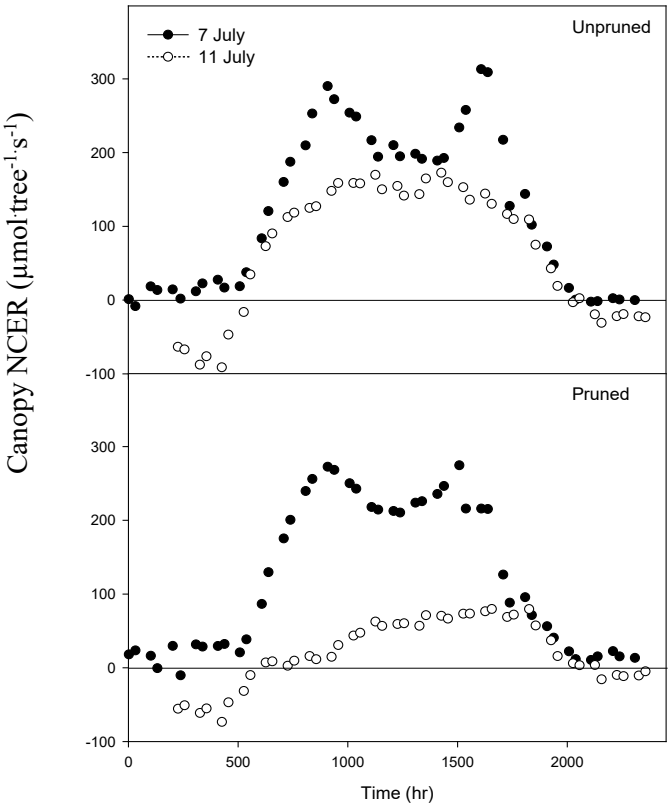

Figure 3. Diurnal trend in canopy NCER ($\mu mol \cdot tree^{-1} \cdot s^{-1}$) of pruned and unpruned 10-year-old 'Bing'/Mazzard sweet cherry trees on the day before pruning (7 July) and 3 days following pruning (11 July).

distribution within the tree. We pruned trees rather heavily to improve light distribution and flower bud induction in the lower regions of the canopy in lieu of dormant pruning. Vigorous water sprouts were removed and in some cases, thinning cuts into larger, older wood were made. Also, in other fruit species, leaves remaining following pruning are able to increase their rate of NCER to compensate for decreased source-sink ratios. However, in the current study we documented no increase in leaf NCER following summer pruning (data not shown).

BUDGET

Project:	**Sweet Cherry Source-Sink Relations**
P.I.:	**Whiting**
Project duration:	**2004-2006**
Current year:	**2005**
Project total:	**$83,373**
Current year request:	**$29,334**

Year	2004	**2005**	2006
Total	$29,015	**$29,334**	$25,024

Current year breakdown

Item			
Salaries[1]	6,199	**6,301**	6,553
Benefits (28% yr 1; 31% yr 2 & 3)	1,736	**1,953**	2,031
Wages[2]	13,000	**13,000**	9,000
Benefits (16%)	2,080	**2,080**	1,440
Equipment			
Supplies[3]	3,000	**3,000**	3,000
Travel[4]	3,000	**3,000**	3,000
Miscellaneous			
Total	$29,015	**$29,334**	$25,024

[1] One-sixth annual salary for Mr. Efrain Quiroz (Roza orchard manager).

[2] Summer support for M.S. candidate Olivia Lenehan (for 2004-2005) plus time-slip labor (April-August) for assisting with chamber studies, collection of canopy physical data (*i.e.*, leaf area, light interception), and fruit quality analyses. $2500 is designated for companion thinning trials in OR (2004-2006)

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

[4] Travel to plots and vehicle maintenance (@$0.375/mile).

FINAL REPORT

WTFRC Project # CH-03-301

Project title: Eliminating Cherry Leafroll Disease from Pacific Northwest Orchards

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Co-PI(s) and affiliation(s): Ken Eastwell, Assoc. Plant Pathologist, WSU-IAREC, Prosser
Bill Howell, Manager NRSP-5, WSU-Prosser

Cooperator(s): Karen Lewis, WSU Coop. Extension, Grant County
Jack Watson, WSU Coop. Extension, Benton/Franklin Co.
Tim Smith, WSU Coop. Extension, Douglas/Chelan Co.
Matt Whiting, Assist. Horticulturist, WSU-IAREC, Prosser

Introduction & Justification
Cherry leaf roll virus (CLRV) is a cherry tree pathogen that is new to the Pacific Northwest. CLRV causes cherry production losses and tree mortality when present in trees that are also infected with other endemic viruses that are known occur at high frequencies in mature cherry orchards. Extensive cherry production losses and tree mortality can be expected if CLRV is allowed spread.

Often producers and fieldmen characterize the symptoms expressed by cherry trees infected with CLRV as a generic tree decline. Some of these symptoms associated with CLRV include delayed bloom and fruit ripening, small cherry size, lack of terminal growth, and premature leaf drop prior to harvest, excessive gumming, shoot tip dieback, loss of fruit-bearing wood, upright leaf growth, leaf enations, and enlarged leaf midribs. Eastwell and Howell have developed an ELISA test and a sampling protocol that allows the WSU ELISA laboratory to screen and detect CLRV in tissue samples of cherry budwood, leaves and fruit.

In previous studies, researchers have observed that within a season or two, CLRV can spread from infected trees to nearby trees through root grafts. They have also found CLRV-infected trees in orchard blocks far removed from known infected sites. The sooner CLRV-infected trees are diagnosed and removed, the less likely the virus will spread to adjacent trees. Previous assessments indicated that CLRV is restricted to a relatively few trees in cherry production areas in Washington. This project intends to contain the virus before it spreads and threatens a larger portion of the PNW cherry industry and evaluate the feasibility of an eradication program.

Objectives:
The objectives of this project are to:
1. Identify and eliminate cherry trees infected with the Cherry leaf roll virus (CLRV) from cherry production areas in the Pacific Northwest.
2. Survey key cherry growing areas in Washington to establish the distribution of CLRV.

Methods:
The leading activities during the winter months of 2003 and 2004 were educational programs to introduce CLRV to cherry producers, agricultural consultants and cherry fieldmen throughout the Pacific Northwest. The goals of these activities were to 1) alert the industry to the threat that this virus poses to cherry production, 2) provide the audience with a "searching image" of the symptoms associated with cherry trees infected with CLRV, and 3) encourage growers and others to submit samples from suspect cherry trees. Interviews and articles on CLRV were given to the Good Fruit Grower, Basin Business Journal, Western Fruit Grower and other trade magazines that target fruit growers in the Pacific Northwest (estimated circulation of 35,000). Many of these presentations and printed articles focused on the impact of several cherry viruses on cherry production. The articles characterized CLRV as highly debilitating disease whose distribution in the Western USA is not fully delineated. Oral presentations were made by project investigators and cooperators at several local grower meetings including the Washington Horticultural Association, the Oregon State Horticultural Association, the Cherry Institute, the Columbia Basin Tree Fruit Spring Meeting, the Sweet Cherry Short Course and other gatherings. These presentations reached an estimated 3,000 to 3,500 meeting participants. Speakers made it clear that CLRV can negatively impact production and that prompt identification and removal of these infected cherry trees will reduce the risk of the disease spreading to adjacent trees, blocks and cherry producing regions in the Pacific Northwest. Field tours were held in CLRV-infected blocks in Prosser and in Kennewick. At these field days, the visual symptoms of CLRV-infected trees, the impact of the disease on tree productivity and the ability of the virus to spread to adjacent trees were demonstrated. Roughly 100 local producers and fieldmen attended these field tours.

The key expenditure during the first quarter of this project was to hire an agricultural consultant to serve as an Industrial Liaison between the project researchers and the cherry industry. The primary role of the liaison is to arrange meetings with representatives from cherry packinghouses and agrichemical supply companies to discuss CLRV, provide their fieldmen with educational material on CLRV and recruit these fieldmen to scout and sample cherry blocks for CLRV-infected trees. The liaison also gave several presentations on CLRV to fieldmen audiences, made field calls to diagnose unhealthy cherry trees, collected cherry samples for fieldmen and transported samples to the WSU ELISA laboratory. Denny Jones was hired for the role and served in this capacity throughout the duration of the project.

Another key activity of this project was to design and assemble educational material on CLRV to distribute among members of the cherry industry in the Pacific Northwest. In the winter months of 2003, the project's investigators and cooperators designed and printed laminated flashcards to provide growers, fieldmen and consultants with color images of the visual symptoms associated with tree infected with CLRV. Approximately 3,700 flashcards were printed and to industry members throughout the Yakima Valley, Columbia Basin, Wenatchee Valley and Hood River Valley in Oregon. In addition, the written material on the flashcards was translated into Spanish and 400 copies were printed and distributed. Information and pictures of CLRV and recommended tree removal

procedure were posted on a County Extension websites as well as at <http://www.nrsp5.prosser.wsu.edu >. Informational notebooks of CLRV were designed and distributed to cherry packinghouses and agrichemical fieldmen. This notebook was to serve to educate these fieldmen about the CLRV threat, provide them with color images of the symptoms associated with CLRV-infected trees and a protocol for taking budwood, leaf or fruit samples to screen for CLRV. The goal of this notebook was to recruit fieldmen to assist in or facilitate the identification and sampling of diseased cherry trees. Roughly 200 notebooks were assembled and distributed.

During the first year of this project we focused our sampling efforts towards the cherry industry along the Yakima Valley and Columbia Basin that we suspected was the "hotspot" for CLRV-infected trees. During the second year, cherry consultants and fieldmen associated with the cherry industry from the Wenatchee Valley and Hood River Valley in Oregon were encouraged to, and did, bring in samples of suspect trees from these areas.

We intend to follow up with fieldmen and growers regarding samples that tested positive in 2004. This will give us another opportunity to promote CLRV eradication, remind fieldmen about the potential of CLRV to spread to adjacent trees or blocks and further assess the distribution of CLRV.

Significant findings:

- CLRV was identified in 460 of the 1,300 cherry samples submitted to the WSU ELISA laboratory. This represents roughly 105 CLRV-infected cherry blocks.
- Nearly all cherry trees that tested positive for CLRV were from Yakima, Benton and Franklin Counties. Twenty-seven percent of all positive samples game from Yakima County (n= 509) and originated from Selah to Grandview. Over 51% of the positive samples were taken in Benton County from Grandview to Richland (n= 457). Another 19% of all positive samples came from Franklin County from Pasco to Basin City (n = 307).
- One positive site (2 samples) was collected near Wenatchee in 2003, but no further samples were collected in 2004 (16 samples in total).
- All samples (45) received from Grant County, Spokane County, Klickitat County, Oregon and Idaho were negative for CLRV.

Results and discussion:

The WSU ELISA laboratory screened over 1,300 cherry tissue samples for CLRV. Many of these samples were taken from unhealthy trees that showed signs of cherry decline, reduced productivity or from trees displayed the symptoms that this program trained fieldmen to associate with CLRV. Nearly 35% of these 1,300 samples tested positive for CLRV. It is important to note that incidence of CLRV in these carefully selected and biased subset of all cherry trees is not a reflection of the actual incidence of CLRV in the field.

Typically multiple tissue samples were submitted by a fieldman to the laboratory to be screened at once; on average five to ten samples originated from each orchard block sampled. We estimate that the number of orchards with at least one tree infected with CLRV rose from 40 orchards in 2002 to 105 orchards in 2004. Nearly all these orchards are found Yakima, Benton or Franklin Counties. We estimate that nearly 35% of the cherry samples that tested positive for CLRV came from the area around Grandview including samples from Yakima County and Benton County. In Yakima County, CLRV infected orchards were scattered from Sunnyside, Wapato, Zillah and Selah. In Benton County, most of the CLRV-infected trees were found between Grandview and Prosser with a few finds around Benton City and Richland/Kennewick area. In the 2003 season, we focused our educational and sampling efforts in this area. We hosted field tours of two cherry blocks with a high

incidence of CLRV to demonstrate the impact the CLRV can have on an orchard operation. The fieldmen who attended these tours were some of our best cooperators in this project.

During the 2003 and 2004 field season, Franklin County Horticultural Pest and Disease Board hired summer interns to walk cherry blocks in the county in search of trees with CLRV symptoms. This agency's proactive response to eradicating CLRV from Franklin County was greatly appreciated and the most successful approach to dealing with CLRV. Over the two years interns covered an estimated 2,500 acres of orchard searching for cherry trees in decline. The Board sent nearly 275 samples to the WSU ELISA laboratory for testing. Over 76 samples representing 21 blocks tested positive for CLRV in Franklin County. All cherry trees that tested positive for CLRV were removed by early 2004 and in most blocks, the stumps were either treated with glyphosate or the stumps were completely removed. In 2004, all orchards that had a positive find in 2003 were resurveyed. Of the 19 blocks with positive finds in 2003, only five blocks were found to still have CLRV-infected trees. In 2004, only two additional sites in Franklin County were found to contain CLRV-infected trees. Representatives from the Franklin County Board were encouraged that they could eradicate CLRV from their County. Their experience has shown that it will take more than one season to accomplish this even in orchards that have already been sampled.

In 2003, two samples from one orchard taken from the Wenatchee Valley tested positive for CLRV. The follow-up survey revealed that this orchard is no longer in existence. Despite efforts to intensify our educational efforts in this area in 2004, few samples came from the area. All samples (25) taken in Chelan/Douglas Counties during the 2004 tested negative for CLRV. While this could be linked to our difficulty in reaching this audience with our educational efforts, fieldmen familiar with this CLRV program and with the symptoms of trees infected with CLRV were confident that CLRV did not exist in their orchard blocks that they routinely monitored.

Throughout this program, our educational efforts were directed towards the cherry grower and towards cherry fieldmen. Both audiences responded well. An estimated 26% of the samples submitted to the WSU ELISA laboratory came from fieldmen and 22% from cherry growers. Roughly 25% of all samples came from Horticultural Pest & Disease Boards, 10% from agrichemical fieldmen and 8% from crop consultants. We did encounter several growers and fieldmen who desired anonymity regarding the location of positive finds. The assistance of our Industrial Liaison as a go-between did recruit samples that we would not have received otherwise.

One major setback to the success of the project is growers who refused to remove trees that the project has screened and diagnosed as positive for CLRV. Often these were small-scale farmers who did not rely on cherries to provide their main means of income. Efforts to convince the grower to remove these trees through adjacent grower peer pressure and Horticultural Pest & Disease Boards did not seem to work outside of Franklin County. We estimate that nearly 10% of the CLRV-infected cherry trees have not been pulled. At the other extreme, we had a few growers either completely remove their orchard blocks badly-infected with CLRV or remove every tree that tested positive for CLRV (accounting for 35% of our positive samples).

Throughout the Yakima Valley, a number of fieldmen did comment that the function of the Industrial Liaison greatly improved their awareness of CLRV and willingness to cooperate with this program. The laminated flashcards that depicted symptoms of trees infected with CLRV were frequently mentioned as another product that was appreciated by fieldmen and we experienced a demand for those flashcards in Spanish that exceeded our supply. The notebook with the sampling kits provided a good reminder and incentive for fieldmen to submit samples to the ELISA lab. When asked about the cost of the ELISA test, many fieldmen did not feel that the cost would deter them from submitting samples in the future. The were some growers and fieldmen that felt comfortable with recognizing

symptoms of trees infected with CLRV and indicated that they would only submit a few samples each season to periodically confirm their diagnosis.

We estimate that over 600 cherry trees have been removed as a result of this project. Four orchards alone accounted for nearly 200 of those trees removed. Not all these trees were tested positive for CLRV, but some showed signs of tree decline and were located in orchards where other trees tested positive. Some growers expressed doubts about receiving mixed results (multiple samples where some samples tested positive and some negative for CLRV) from the ELISA labs and removed all trees in decline regardless of test results. We attribute the removal of these trees to our educational program that convinced growers that CLRV is a highly virulent disease that will significantly impact tree productivity and spread to adjacent trees if the infected tree is not removed immediately. These actions should be interpreted as a positive step towards the containment and even eradication of CLRV in the PNW.

Budget:

Project title: Eliminating Cherry Leafroll Disease from Pacific Northwest Orchards
PI's: Bush, Eastwell & Howell

Project duration: 2003-2005
Current year: 2005
Project total (2 years): $123,000
Current year request: **$0**

Current year breakdown

Item	Year 1 (2003)	Year 2 (2004)	Year 3 (2005)	T
Salaries[1]	35,000	35,000	0	70,000
Benefits (17%%)	5,950	5,950	0	11,900
Wages				
Benefits (%)				
Equipment				
Supplies[2]	4,000	3,000	0	7,000
Travel	9,125	9,125	0	18,250
Miscellaneous [3]	6,340	9,510	0	15,850
Total	60,415	62,585	0	123,000

[1] Industry liaison–was hired through WTFRC and was the equivalent of one full-time position.
[2] The supplies requested are primarily for addition notebooks, flashcards and sample bags.
[3] Screening samples for CLRV at the WSU ELISA Laboratory (~1,500 samples @ $6.34/sample).

CONTINUING REPORT

WTFRC Project #: **CH-04-404** **Organization Project #: 13C-3361-5291**

Project Title: Virus control strategies to assist cherry production in the PNW.

Principal Investigator: Ken Eastwell, Associate Plant Pathologist
Organization: Washington State University – IAREC
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Telephone: (509)786-9385; E-mail: keastwell@wsu.edu
Co-investigators: Bill Howell, Manager NRSP-5, WSU-Prosser
Eileen Perry, Assistant Director, CPAS, WSU-Prosser
Cooperators: Thomas Unruh, YARL, USDA-ARS, Wapato
Narceo Bajet, YARL, USDA-ARS, Wapato
Jerry Reeves, Animal Sciences, WSU-Prosser
Bill Proebsting, OSU, Corvallis
Fran Pierce, Director, CPAS, WSU-Prosser
Lauri Guerra, WSDA, Prosser
James Hansen, YARL, USDA-ARS, Wapato
Many growers and fieldmen

Project Objectives:

1. Develop progressive strategies to control virus diseases that contribute to the decline of sweet cherry productivity in the Pacific Northwest.
   Specific goals for year 2005:
   Determine role of pollen in the spread of *Cherry leafroll virus* so that guidance can be provided to growers on the most cost efficient strategies of virus control in each situation.
2. Develop laboratory tests that will make virus testing accessible to growers.
   Specific goals for year 2005:
   - Evaluate serological assays developed for *Cherry raspleaf virus.*
   - Produce serological reagents for the various little cherry disease-causing viruses in the PNW.
3. Monitor commercial sweet cherry orchards for emerging virus diseases.
   Specific goals for year 2005:
   - Increase our ability to detect the emerging *Foveavirus* genus of pathogens.
4. Evaluate the use of remote sensing to identify areas of declining cherry production that may be associated with virus infections.
   Specific goals for year 2005:
   - Complete the collection of preliminary data collection and evaluation.

Significant findings:

- Showed that root grafting is a major route of tree-to-tree spread of several important diseases of cherry.
- Demonstrated that *Cherry raspleaf virus* is a member of the *Sequiviridae* family; not a nepovirus as previously thought. It has been found by others to be associated with several agronomic crops, and we have demonstrated that its coat protein genes differ significantly across sources.
- Demonstrated that *Foveaviruses* are associated with diseased and declining trees in many orchards.
- The virus that causes little cherry disease in Europe is more widely distributed in the west than previously believed.
- Results suggest that early virus detection might be possible using light reflectance with silicon detectors, an inexpensive technology.

Methods:

Objective 1: Develop progressive strategies to control virus diseases that contribute to the decline of sweet cherry productivity in the Pacific Northwest.

Approximately 50 grams of pollen and anther material were collected from emerging blossoms from trees known to be infected with *Cherry leaf roll virus* and stored at -20C until used. The virus-rich pollen was dusted over the leaf surfaces of young cherry trees and exposed to Western flower thrips. Because of the small amount of virus that could be transmitted by this mechanism, trees are tested for *Cherry leafroll virus* in two successive years after inoculation to allow the virus concentration to increase to detectable levels.

The role of bees in moving viable virus was studied. Pollen sacs were collected from bees and extracts were assayed by ELISA for *Cherry leafroll virus.* Pollen was also collected from the body of bees for a similar test. Infectivity of the virus was assessed by rubbing the pollen sacs or bee bodies directly onto the surface of *Chenopodium quinoa,* an herbaceous host of *Cherry leafroll virus*. After two weeks, the *C. quinoa* plants were assayed by ELISA to confirm any symptoms.

Transmission of *Cherry leafroll virus* through the pollination process is being investigated. Fruit is obtained from a tree that has tested negative for the virus, but is located adjacent to a tree that is a suitable pollinizer, and is infected with *Cherry leafroll virus*. The fruit and pits are tested for virus by ELISA. The pedicels of fruits that contained detectable virus are preserved at -20C for later analysis by molecular assays.

The response of new and important sweet cherry varieties to infection by *Cherry leafroll virus* was determined. Nursery grown trees of several cultivars, including 'Bing', 'Chelan', 'Rainier', Sweetheart', 'Lapins', 'Skeena' and 'Tieton' were grown in 5 gallon pots in our research lath house. Trees were inoculated by chip grafting on July 10, 2003 with a local strain of *Cherry leafroll virus* either alone or in combination with *Prune dwarf virus* or *Prunus necrotic ringspot virus*. The test trees were stored in a cooler over winter and returned to a lath house on April 26, 2004. ELISA confirmed the presence of the viruses, and symptoms were observed and scored in May and September.

Objective 2: Develop laboratory tests that will make virus testing accessible to growers.
Reagents are being developed to assist in rapid diagnosis of diseases caused by viruses belonging to three major families.

There are two viruses that cause little cherry disease – one form predominates in Europe and the other in North America. Because of the low virus titer, coat protein genes of these viruses require amplification by the polymerase chain reaction for further characterization. The genes are then characterized and expressed in bacteria. The bacteria are induced to synthesize relatively large amounts of the protein that are then used to induce antibody production. Antibodies obtained in this manner will be used in ELISA and once the reliability of the ELISA has been confirmed, the reagents will be available for routine, cost-effective testing of orchard trees in the Pacific Northwest. Thus, information required by growers to make informed decisions about the fate of trees in their orchard will become readily available to them.

Isolates of *Cherry rasp leaf virus* were collected in Washington, Oregon and California. The coat protein genes from an isolate obtained in the lower Columbia Valley were cloned and expressed in bacteria. Antibodies are being made. Preliminary tests are underway to evaluate their utility in virus detection.

We are characterizing several *Foveaviruses* associated with diseased blocks that were brought to our attention by growers and fieldmen.

Objective 3: Monitor commercial sweet cherry orchards for emerging virus diseases.
Invited visits to cherry blocks provide a good understanding of the disease concerns that are being faced by growers. This orchard-based survey work continues to provide critical awareness of emerging disease problems. Biological data is being collected to determine the threat each poses and eventually, the means of limiting their economic impact.

Objective 4: Evaluate the use of remote sensing to identify areas of declining cherry production that may be associated with virus infections.

Field measurements were made on 10 September 2004 at an established orchard near Grandview WA where trees have been tested and monitored for *Cherry leafroll virus*. Eight trees consisting of four pairs of adjacent infected and non-infected trees were selected. Five spur leaves with no acute symptoms were selected from each of four infected trees; in addition, symptomatic non-spur leaves were collected from two of the infected trees. Five spur leaves were also selected from each of four uninfected trees. A portable spectral-radiometer was used to measure leaf reflectance on orchard trees that had been tested and monitored for *Cherry leaf roll virus*. Spur leaves from infected trees and symptomatic leaves from infected trees were compared to spur leaves from healthy trees. Leaf samples were collected and tested by ELISA to confirm virus status.

Results and discussion:

Objective 1: Develop progressive strategies to control virus diseases that contribute to the decline of sweet cherry productivity in the Pacific Northwest.

There are likely two modes of transmission by which *Cherry leafroll virus* spreads in our industry. Within an orchard, root grafting likely plays a significant role in tree-to-tree spread. This was illustrated by the number of trees reacting to herbicide treatment after removal of a nearby diseased tree and subsequent herbicide treatment of the stump. A second mechanism responsible for occasional long distance movement between orchards remains elusive. Although thrips-mediated transmission of *Cherry leafroll virus* from cherry pollen to *Chenopodium quinoa* was demonstrated last season, we were unable to achieve transmission from pollen to cherry seedlings via this mechanism.

In walnuts, *Cherry leafroll virus* is transmitted through the pollen to the recipient tree in a small percentage of trees (Adib Rowhani, *Personal communication*). Based on this model, this situation was explored in sweet cherry. With funding from other sources, we demonstrated that *Cherry leafroll virus* can invade tissue in cherry pits on healthy trees growing adjacent to an infected pollinator variety. Pits, flesh, and pedicels were extracted separately and tested for *Cherry leafroll virus*. No virus was detectable in the fruit flesh confirming that the parent tree was not infected with *Cherry leafroll virus*. Virus was detected in up to 22.5% of the pits by ELISA, but none was found in the pedicels (Table 1). If virus was present in the pedicel, this would have provided evidence that the virus moved out of the pit and into the vascular system of the bearing tree; however, no virus was detected in pedicels by ELISA.

Table 1: Fruit was harvested from a tree that had previously tested negative for *Cherry leafroll virus*, but was situated adjacent to an infected pollinator. Fruit flesh, pits and pedicels were tested separately by ELISA

Tree identification	**ELISA results** number positive/number tested (percentage positive)		
	Fruit	Pits	Pedicel
R1T5	0/200 (0.0%)	45/200 (22.5%)	0/200 (0.0%)
R15T10	0/400 (0.0%)	7/400 (1.8%)	0/400 (0.0%)

To increase the number of observations and to increase the likelihood of detecting a minute amount of possible virus in the pedicels, an additional 2,600 pits were tested by ELISA for the presence of *Cherry leafroll virus*; of these samples, 334 or 12.8% were infected. The pedicels from each of the infected fruit were stored at -20C for analysis by the more sensitive RT-PCR test.

During the first two weeks of April, 57 bees were collected from orchard trees and tested to determine their capacity to be carriers of *Cherry leafroll virus*; two bees contained detectable *Cherry leafroll virus* antigen in their pollen sacs and on their bodies. Virus in the pollen sacs was infectious. On

April 22, after peak cherry bloom, 58 bees were collected and tested by RT-PCR. Three bees still bore trace amounts of *Cherry leafroll virus* as detected by RT-PCR.

These experiments indicate that bees are able to transport *Cherry leafroll virus*. Substantial amounts of virus-laden pollen are moved as the bees forage. Based on bee feeding behavior, the greatest potential for tree-to-tree spread of pollen is to nearby trees. The frequency of long distance dissemination by this method is small, but the potential does exist. However, pollen-mediated transmission of virus to cherries still has not been demonstrated.

To date, natural infection of *Cherry leafroll virus* has only been detected on 'Bing', 'Rainier', 'Van' and 'Skeena'. All seven varieties in the virus sensitivity study developed symptoms when inoculated with CLRV. Symptom intensity was rated on a scale from 0 (no symptoms) to 4 (severe symptoms with shoot tip stunting and die back and leaf chlorosis). Dead trees were scored as 5. The ratings are the average of 3 trees:

Table 2: The development of symptoms of young cherry trees representing different varieties in response to *Cherry leafroll virus*.

Variety	Rootstock	Disease Rating			
		CLRV	CLRV+PDV	CLRV+PNRSV	Not inoculated
'Tieton'	Gisela 5	5.0	3.7	1.3	0.0
'Bing'	mahaleb	1.5	1.0	1.7	0.0
'Bing'	mazzard	4.0	5.0	4.3	3.3
'Chelan'	mazzard	0.3	0.3	0.3	0.0
'Lapins'	mazzard	3.7	2.7	3.3	1.7
'Rainier'	mazzard	1.3	4.0	4.0	0.0
'Skeena'	mazzard	3.7	4.3	4.7	0.0
'Sweetheart'	mazzard	4.7	4.3	3.7	0.0

In contrast to observations made in grower orchards, there is little evidence that either of the Ilarviruses (*Prunus necrotic ringspot virus* or *Prune dwarf virus*) significantly increased the severity of disease symptoms at this early stage of infection. Of the varieties tested, 'Tieton', 'Sweetheart', 'Skeena', 'Sweetheart', and 'Lapins' were impacted the greatest by *Cherry leafroll virus* while the response of 'Chelan' was limited. The unexplained death of a number of 'Bing' trees on mazzard rootstock makes comparisons of rootstock difficult.

Objective 2: Develop laboratory tests that will make virus testing accessible to growers.
Substantial progress was made in the development of diagnostic reagents for virus isolates most commonly associated with little cherry disease in North America. Both coat protein genes from this virus have been isolated and used to produce significant quantities of virus coat protein in bacteria. Antibodies are currently being made in response to these bacterially expressed proteins for development of serological assays.

Our studies indicate that the little cherry disease associated virus that is more prevalent in Europe is also well established in western North America. However, extreme sequence variability has thwarted efforts to isolate the coat protein genes from local isolates. We are exploring alternative methods of gene isolation.

Studies by others identified *Green ring mottle virus* and *Cherry necrotic rusty mottle virus* as members of the *Foveavirus* genus. Our research has now shown that cherry rusty mottle, cherry twisted leaf, and Montmorency stem pitting are also caused by closely related viruses. As we accumulate information, it is apparent that there is extensive sequence variability between the different viruses that are associated with these diseases in cherry, but also areas of sequence conservation that is allowing us to develop both broad spectrum and virus-specific molecular assays. Furthermore, we have produced antibodies against the Montmorency stem pitting virus. It is very

effective as a diagnostic aid. The antibodies also react with a number of other *Foveaviruses* of cherry, albeit with lower avidity. This enables a quick response to growers for determining if a *Foveavirus* might be associated with their diseased trees. *Green ring mottle virus*, which is generally regarded as latent in most sweet cherry varieties, does not react with the antiserum that we have developed, thus, its presence does not interfere with efforts to detect disease-causing viruses.

The three coat proteins of *Cherry raspleaf virus* have been isolated from a local strain. Each gene has been expressed separately in bacteria and antibodies are being produced.

Objective 3: Monitor commercial sweet cherry orchards for emerging virus diseases.
Foveaviruses are emerging as an important group of viruses in cherry production. Many different forms of the these viruses are being detected, both in terms of their molecular properties, but also in terms of the degree and nature of symptoms that they cause. Availability of detection reagents is greatly enhancing the ability to identify and react to virus infections.

Objective 4: Evaluate the use of remote sensing to identify areas of declining cherry production that may be associated with virus infections.
Two well known indices of plant vigor, the Normalized Difference Vegetation Index (NDVI) and the Red-edge Vegetation Stress Index (RVSI), were calculated for each leaf. To determine which other wavelengths might be of interest, a sensitivity spectrum was generated for each leaf by dividing the spectrum for that leaf by the spectrum of one of the healthy spur leaves. The resulting ratio values were plotted by wavelength for each leaf. The average ratios for each class of sample (infected spur leaf, infected symptomatic leaf and non-infected spur leaf) are shown (Figure 1). The variability of reflectance among healthy leaves is revealed by an average relative difference that varies from 1.00. The spectra suggest that reflectance values at 582, 697, 1458 and 1975 nm might be sensitive to the plant infection status. The reflectance values at these wavelengths were included in a statistical analysis.

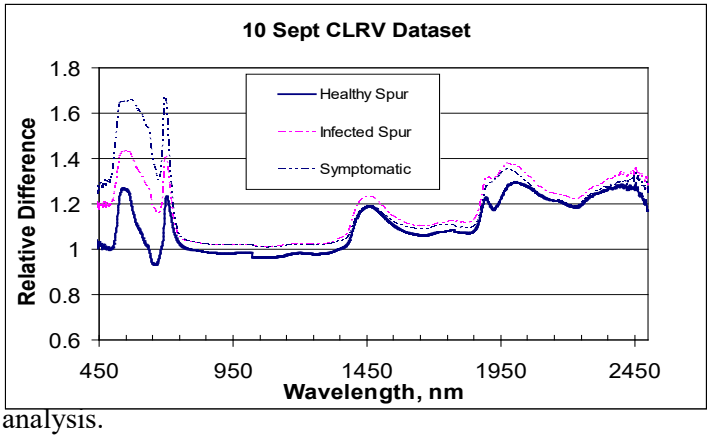

Figure 1. A sensitivity spectrum is shown here for each of the three classes: healthy spur, infected spur, and symptomatic leaves. The greater the resulting ratio (the y scale in the graph) the greater the difference in reflectance measurements at that wavelength. These spectra were generated for each class by dividing the average spectrum for that class by the spectrum of one of the healthy spur leaves.

Analysis of Variance (ANOVA) was used as a tool to estimate the ability of reflectance measurements to discriminate between the three classes of samples: non-infected spur leaves, infected spur leaves and symptomatic (infected) leaves. Analysis was performed using all three classes, and between classes (e.g., between infected and non-infected spur leaves). This assessment revealed that NDVI and RVSI were less effective than single wavelength reflectance values at 582 and 697 nm in distinguishing between infected and non-infected leaves. Furthermore, despite the large difference between the average spectral difference of the symptomatic leaves and the non-infected leaves, the variability between symptomatic leaves was too great to allow this to be used as an accurate measure of infection. The irregular leaf structure characteristic of symptomatic leaves results in erratic measurements, and it is extremely difficult to obtain an average or representative reading. This limitation can be countered by using many readings, or by using the infected spur

leaves that yielded much more consistent measurements. These are preliminary data and confirmatory studies are required. Nevertheless, future work could lead to the design of an inexpensive hand-held meter for detecting virus-infected plants.

Budget:

Project Title: Virus control strategies to assist cherry production in the PNW.
Principal Investigator: Ken Eastwell
Project Duration: 2004-2006 (3 years)
Funding history: FY2004 requested: $29,053 FY2004 received: $26,616
Current year: 2005
Current Year Request: $29,053
Project Total Request (3 years): $91,330

Item	Year 1 (2004)	**Year 2 (2005)**	Year 3 (2006)
Salaries	$14,084	**$14,648**	$15,234
Benefits	$4,084	**$5,292**	$5,503
Wages	$4,000	**$4,000**	$0
Benefits	$640	**$640**	$0
Equipment	$0	**$0**	$0
Supplies	$5,700	**$6,800**	$11,200
Travel	$500	**$230**	$500
Miscellaneous	$45	**$45**	$45
Total	$29,053 (proposed)	**$31,655**	$32,482

Additional funding sources: Nursery License Surcharge research funding managed by the Washington State department of Agriculture has provided funding for several aspects of this program. The Nursery License program contributed $16,410 to initiate characterization of the *Cherry rasp leaf virus* genome and $13,160 to investigate the possible seed transmission aspect of *Cherry leaf roll virus*. Critical support for this research is provided by the National Research Support Project–5. Digital imagery for initial evaluation of remote sensing is provided as an extension to funding currently provided to the Center for Precision Agricultural Systems, WSU-Prosser. A special cooperative agreement with USDA-ARS (Dr. Tom Unruh) is providing $219,000 over the period from 09/25/2003 to 07/31/2008 to investigate vectors and mechanisms of transmission of the little cherry viruses in the PNW.

CONTINUING REPORT

WTFRC Project # CH-04-402
Project title: Fly Feeding Ecology and Food-Based Lures and Baits
PI: Wee Yee
Organization: USDA-ARS
Co-PI(s) and affiliations (s): Pete Landolt, USDA-ARS
Cooperator (s): Various homeowners with cherry trees
Contract Administrator: Pete Landolt, e-mail: landolt@yarl.ars.usda.gov; phone #: (509) 454-6570.
Objectives (2004-2006):
(1) Identify foods of western cherry fruit flies in nature.
(2) Determine when the flies feed, both daily and seasonally, and how much sugar and protein flies feed on in nature.
(3) Determine the most attractive protein and sugar baits in the laboratory and field and that stimulate highest feeding.
Goals and Activities and Anticipated Accomplishments for 2005:
1) Continue studies on foods of flies; identification of substrates most likely used by flies.
2) Continue studies on protein feeding; determination of protein in the environment and in flies.
3) Continue studies of protein and sugar baits; identification of a possible more attractive bait; determination of most effective bait sprays.
Deviations from Schedule:
1) Given the 2004 findings, an addition test is planned for 2005. The test will compare GF-120 with other baits applied on cherry trees to test the hypothesis that any number of baits is equally effective due to random foraging behavior of flies.

Significant findings:
- Flies feed on cherry juice and bird droppings in nature; however, the main sources of sugar and protein foods in nature remain uncertain. In the laboratory, flies feed on aphid honeydew and cherry juice.
- Sugar levels in flies were high throughout day and season, suggesting that within a population, flies constantly on sugars; flies are able to acquire substantial amounts in nature.
- In the laboratory, flies were attracted to the highest label rate (1:1.5 dilution) of the food-based spray bait, GF-120, averaging an 8% response.
- In the field, flies were attracted more to an ammonium hydroxide lure than GF-120 bait, Mazoferm, and NuLure baits; attraction to baits was generally low and was no greater than to the control.
- Adding ammonium carbonate to Mazoferm and NuLure enhanced their attractiveness.
- Studies suggest flies find baits through random foraging behavior rather than by a strong directed orientation towards odors, which seems to be how flies respond to ammonia lures.
- Studies also suggest any number of food-based baits are as effective as the GF-120 bait, as long as spray coverage is sufficiently high to allow flies to find them through normal foraging.

Methods:
(1) *Identification of foods of western cherry fruit flies in nature*. Observations were made of flies feeding on various substances in nature. Cherry trees in backyards in Kennewick or Yakima (and vicinity) as well as at the USDA cherry orchard in Moxee were examined for aphid clumps over the season. Numbers of aphid clumps and bird droppings will be counted. Flies feeding on these sources will be recorded in future studies. Feeding on leaf surfaces, characterized by a grazing behavior, or on fruit will also be recorded. In addition to samples from cherry trees, vegetation around trees that have flies will be examined as a possible source of food. At the Moxee orchard, about 0.5 kg of leaves and 0.25 g of fruit were removed each week from the trees and placed inside sealed bags. Leaves and fruit were brought into the laboratory. Leaves and fruit were dipped in deionized water or

methanol for 1-2 seconds to remove surface materials. The concentrates were dried. Specific sugars and proteins on leaf surfaces will be examined using high performance liquid chromatography (HPLC).

To determine if concentrates from leaves and fruit offer flies nutrition, groups of 10 flies collected from the field were exposed to the concentrates from leaves or fruit. Controls were offered water wicks only and the solvent used to extract the concentrates. Survival was recorded daily.

(2) *Determine when the flies feed, both daily and seasonally and how much sugar and protein flies feed on in nature.* Feeding time of flies within days and over the season were determined at a site with 4 trees in Zillah, WA. On three days during the season (late May, mid June, late June), flies were collected every two hours between 0600 and 2000 hours from trees using glass vials. Flies were quickly frozen in ice in the field. Flies were transported to the laboratory, where they were frozen at –80 ºC. Individual flies were weighed and analyzed for sugars and glycogen. Flies will also be analyzed for proteins, and lipids in future studies.

To test the hypothesis that flies in nature are food-limited, a field cage study at the Moxee cherry orchard was conducted. From 100-200 flies were collected from infested trees and released inside each of nine cages placed over a cherry tree. Five of the nine cages were sprayed with food droplets consisting of sugar and yeast weekly. Four served as controls. Fruit were collected and larval production determined.

(3) *Determine the most attractive protein and sugar baits in the laboratory and field and that stimulate highest feeding.* In the laboratory, three available commercial baits were tested: GF-120, Mazoferm (a corn extract), and NuLure. New bait formulations with various known proportions of proteins, ammonia compounds, sugars, and cherry fruit volatiles (aldehydes, alcohols, and esters) will also be tested against the most effective baits in the future.

In the laboratory, fly responses to baits were tested using treated paper strips or artificial leaves in large plywood cages. About 500 μl of commercial bait was placed on paper strips or artificial leaves. Each bait was tested separately. Flies were released below the strips or leaves inside the cages. Observations of flies landing on the paper or leaves were made every 2 min for one hour. Numbers of flies feeding on bait were also recorded. In support of this objective, fly feeding responses to several dilutions of GF-120 bait were determined using individual flies. Starved flies were exposed to dilutions inside vials and feeding duration and amounts of baits ingested were determined.

In the field, tests were conducted to determine the attraction of flies to ammonia and various baits. Baits were applied on 5 leaves on the south sides of trees between 0900-1500 hours. The ammonia lure tested was a Nalgene bottle with a 0.05 cm hole. The bottle contained 10 ml of ammonium hydroxide saturated in cotton. Baits were Mazoferm, NuLure, and GF-120, with or without ammonium carbonated added to the baits. Within treatments, treated leaves were on the same 15-20 cm stretch of branch, with only the larger leaves used. Bait volumes were 2,500 μl (3 tests) or 5,000 μl (2 tests). Flies seen within a 30 cm distance of the lure or baits were counted.

Results and Discussion:

(1) *Identification of foods of western cherry fruit flies in nature.* Numerous field observations indicated flies fed on cherry juice and bird droppings. However, the main sources of food in nature remain uncertain. In the laboratory, flies fed on aphid honeydew and cherry juice, surviving long periods of time on them, but flies exposed to bird droppings did not survive long periods. Surveys indicated about 30% of trees had aphids, but flies were not seen feeding on honeydew in nature. Other possible food sources besides fruit were not apparent. Flies seemed to acquire little food from leaves, as flies survived only 4 days when exposed to them, suggesting larger numbers of leaves are needed to supply sufficient nutrients, in which case flies need to forage over large areas. Low amounts of sugars were obtained from washings of leaf surfaces in the laboratory, but flies were unable to survive on these concentrates. Further studies will need to be conducted to definitively identify foods used by flies.

(2) *Determine when the flies feed, both daily and seasonally and how much sugar and protein flies feed on in nature*. Flies contained high amounts of sugars and glycogen throughout the day (data not shown) and throughout the season (Fig. 1), suggesting flies feed at all times during daylight and are able to acquire equal and substantial amounts of sugar throughout the 4-5 week cherry season. Given the feeding ecology, flies may feed on bait sprays with sugar at any time, although it has yet to be determined if flies feed on protein sources at the same time as on sugar sources. On a population level, feeding occurred throughout the day and season, but because of the zero tolerance, small proportions of a fly population that have fed and are not hungry may make control more difficult. The field cage study designed to test the hypothesis that flies are food-limited in 2004 did not yield high oviposition and was inconclusive.

(3) *Determine the most attractive protein and sugar baits in the laboratory and field and that stimulate highest feeding.* In the laboratory, preliminary tests with GF-120, Mazoferm, and NuLure using baited paper strips or artificial leaves resulted in low or no responses from flies exposed to food up to testing. However, use of starved flies affected the responses. When GF-120 was tested using starved flies, the response was greatest to the highest label dilution (Table 1). Flies exposed to food up to testing were again non-responsive (Table 1). The effectiveness of bait sprays may depend on the hunger state of the flies. In feeding tests, hungry flies fed immediately on the high GF-120 (1:1.5) dilution. Several tests were conducted using the various baits in the field (Tables 2-4, not all tests shown). In general, none of the baits tested was highly attractive to the flies (attraction = flies approaching $\leq$ 30 cm of the bait or lure). The ammonium hydroxide lure was generally more attractive than baits. When ammonium carbonate was added to Mazoferm and NuLure, the attraction was increased, but no bait supplemented with ammonia consistently outperformed others (Table 4).

***Significance to the Industry and Potential Economic Benefits*:** Cherry fruit flies clearly obtain food from cherry trees. It is important to identify the foods because they may compete with bait sprays intended to control the flies. The early results with Mazoferm, GF-120, and NuLure suggest flies find baits through random foraging behavior rather than by a strong directed orientation towards odors, which seems to be how flies respond to the ammonium hydroxide lure. They also suggest any number of food-based baits are as effective as the GF-120 bait, as long as spray coverage is sufficiently high to allow flies to find them through normal foraging. If inexpensive alternatives to existing baits can be developed, they may reduce costs to growers, who would need to use weekly during the cherry season. Use of effective and long-lasting baits may help reduce spray frequencies and will help reduce costs associated with the negative consequences of finding larvae in fruit.

Table 1. Mean numbers (± SE) of *Rhagoletis indifferens* landing on top and bottoms of artificial leaves per 2 min treated with various dilutions of GF-120 placed on top of leaves in the laboratory over 1 hour.

		Flies Starved 16-20 h prior to Tests			
Dilution	*N*	% on Leaves	No. on Top	No. on Bottom	No. Feeding
0	5	1.8 ± 1.1a	0.05 ± 0.03a	0.65 ± 0.43a	0.01 ± 0.01a
1:160	5	2.2 ± 0.7a	0.54 ± 0.20ab	0.35 ± 0.15a	0.10 ± 0.03a
1:20	5	3.6 ± 0.8ab	1.14 ± 0.27b	0.21 ± 0.11a	0.22 ± 0.04a
1:1.5	5	8.1 ± 3.1b	2.73 ± 0.96c	0.51 ± 0.32a	0.64 ± 0.17b
		Flies Exposed to Food Up to Tests			
Dilution	*N*	% on Leaves	No. on Top	No. on Bottom	No. Feeding
0	5	0.0 ± 0.0a	0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.00a
1:160	5	1.0 ± 0.6a	0.00 ± 0.00a	0.40 ± 0.24a	0.00 ± 0.00a
1:20	5	0.7 ± 0.7a	0.06 ± 0.06a	0.21 ± 0.21a	0.00 ± 0.00a
1:1.5	5	1.2 ± 0.5a	0.08 ± 0.08a	0.38 ± 0.23a	0.01 ± 0.01a

Means followed by same letters are not significantly different (ANOVA, $P > 0.05$).

Fig. 1. Seasonal levels of sugar and glycogen in flies, fly populations, and cherry fruit development.

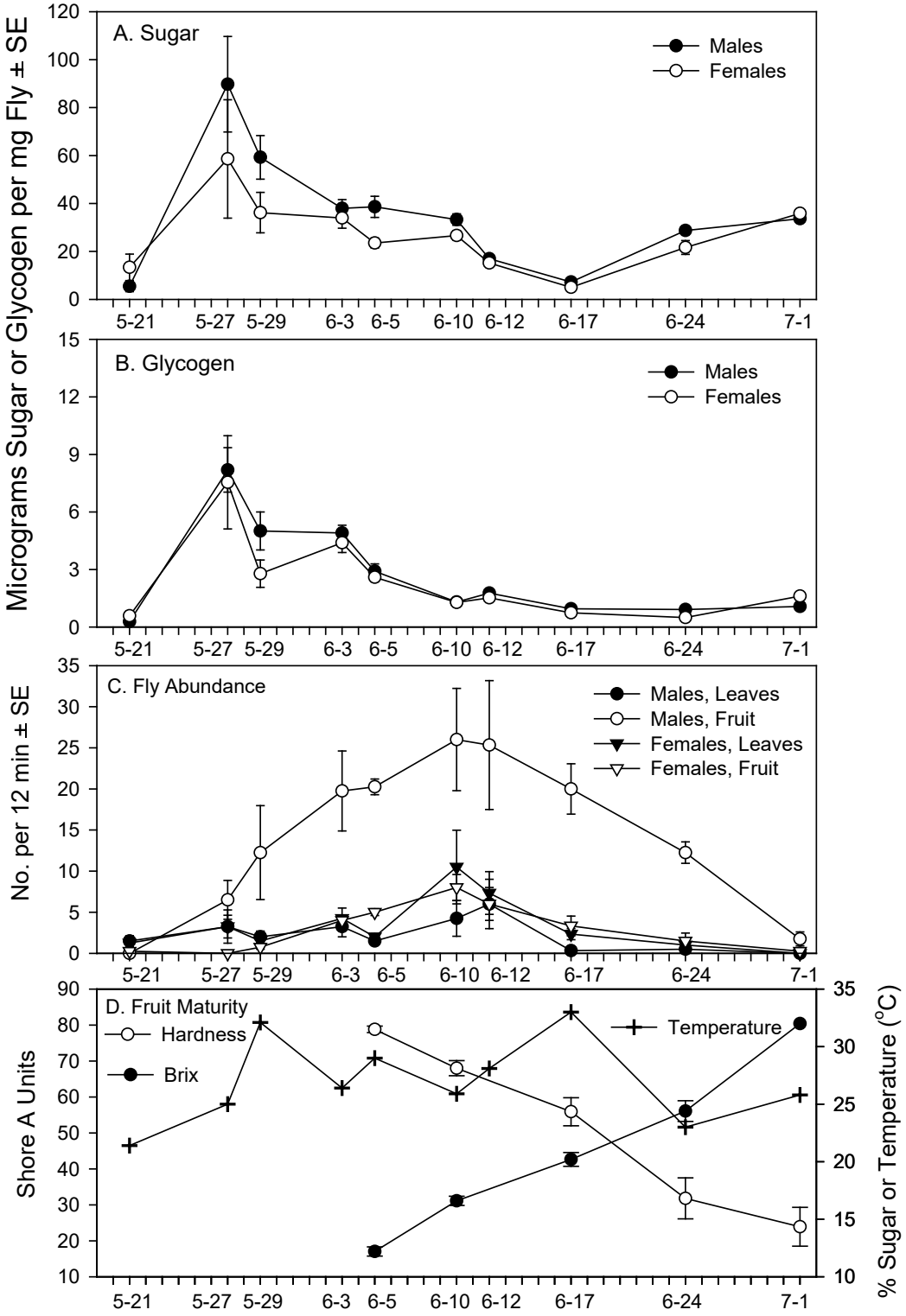

Table 2. Effects of ammonium hydroxide lure and various baits (500 ul per leaf x 5 leaves) with no additional ammonia on numbers (± SE) of flies attracted, Zillah, Yakima County, 2004

Date	*N*	Control	NH_3	Mazoferm	NuLure	GF-120
20 May	3	1.13 ± 0.26a	6.64 ± 1.28b	1.59 ± 0.70a	0.68 ± 0.48a	0.58 ±0.28a
27 May	3	0.00 ± 0.00a	3.22 ± 1.14b	0.42 ± 0.08a	0.53 ± 0.27a	1.20 ± 0.89ab
2 June	3	1.80 ± 0.73a	6.20 ± 3.10a	2.33 ± 1.31a	0.99 ± 0.52a	1.43 ± 0.57a
9 June	3	0.19 ± 0.19a	1.74 ± 0.39b	0.03 ± 0.03a	0.15 ± 0.11a	0.22 ± 0.22a
24 June	3	0.00 ± 0.00a	0.73 ± 0.15b	0.01 ± 0.01a	0.00 ± 0.00a	0.00 ± 0.00a

Means followed by same letters are not significantly different (ANOVA, $P > 0.05$).

Table 3. Effects of ammonium hydroxide lure and various baits (1,000 ul per leaf x 5 leaves) with no additional ammonia on numbers (± SE) of flies attracted, Roslyn, Kittitas County, 2004

Date	*N*	Control	NH_3	Mazoferm	NuLure	GF-120
1 July	4	0.00 ± 0.00a	0.60 ± 0.44a	0.68 ± 0.64a	0.12 ± 0.12a	0.52 ± 0.49a
8 July	6	0.04 ± 0.04a	2.18 ± 0.72b	1.32 ± 0.55ab	0.50 ± 0.25a	0.87 ± 0.62ab
12 July	5	0.00 ± 0.00a	3.09 ± 0.62b	0.40 ± 0.29a	0.17 ± 0.17a	0.25 ± 0.12a
26 July	6	0.17 ± 0.11a	1.49 ± 0.75b	0.07 ± 0.07a	0.01 ± 0.01a	0.00 ± 0.00a

Means followed by same letters are not significantly different (ANOVA, $P > 0.05$).

Table 4. Effects of ammonium hydroxide lure and various baits (1,000 ul per leaf x 5 leaves) with additional ammonium carbonate on numbers (± SE) of flies attracted, Roslyn, Kittitas County, 2004

Date	*N*	Control	NH_3	Mazoferm	NuLure	GF-120
14 July	6	0.02 ± 0.02a	0.35 ± 0.17ab	0.17 ± 0.17ab	0.56 ± 0.22b	0.00 ± 0.00a
19 July	6	0.01 ± 0.01a	0.92 ± 0.52b	0.85 ± 0.33b	0.29 ± 0.22ab	0.07 ± 0.07ab
21 July	6	0.07 ± 0.07a	0.27 ± 0.16a	0.25 ± 0.23a	0.36 ± 0.30a	1.09 ± 0.74a
29 July	6	0.00 ± 0.00a	0.11 ± 0.11a	0.10 ± 0.10a	0.00 ± 0.00a	0.01 ± 0.01a

Means followed by same letters are not significantly different (ANOVA, $P > 0.05$).

Budget:

Project title: Fly Feeding Ecology and Food Based-Lures and Baits
PI: Wee Yee
Project duration: 2004-2006
Current year: 2004
Project total (3 years): $66,000
Current year request: $22,000

Item	Year 1 (2004)	**Year 2 (2005)**	Year 3 (2006)
Salaries	18,000[a]	**18,000**[a]	18,000[a]
Benefits	2,000[a]	**2,000**[a]	2,000[a]
Wages	0	**0**	0
Benefits	0	**0**	0
Equipment	0	**0**	0
Supplies	2,000	**2,000**	2,000
Travel	0	**0**	0
Miscellaneous	0	**0**	0
Total	22,000	**22,000**	22,000

[a]One GS-3 ($6,000), one GS-5, part time ($14,000)

CONTINUING REPORT

WTFRC Project # CH-04-401

Project title: Evaluation of Insecticide Effects on the Biology of Cherry Fruit Flies
PI: Wee Yee
Organization: USDA-ARS
Cooperators: Many homeowners in central and western Washington
Contract Administrator: Pete Landolt, landolt@yarl.ars.usda.gov; phone #: (509) 454-6570.

Objectives (2004-2006):
1) Determine effects of commercial insecticides on mortality, sublethal responses, and behavioral responses of the western cherry fruit fly.
2) Determine relative importance of contact or ingestion mechanisms of kill.
3) Determine residual activity of insecticide formulations in the field.
4) Determine effects of insecticide formulations on larval infestations in the field.

Goals and Activities and Anticipated Accomplishments for 2005:

1) Complete studies on mortality and sublethal effects; identification of most effective insecticides used in different concentrations and determination of systemic/translaminar activity.
2) Continue studies on contact and ingestion; identification of mechanisms of kill for each insecticide.
3) Conduct studies on residual activity; determination of residual activity of each insecticide.
4) Continue studies on insecticides; determination of most efficacious insecticides.

Significant findings:

- Entrust and GF-120 (spinosad insecticides) were the most effective insecticides and caused 100% mortality within 1-4 days, followed by Provado (imidacloprid) and Calypso (thiacloprid).
- There was no clear effect of exposure to any insecticides on fecundity of flies other than through early kill.
- Only GF-120 at the highest label rate prevented oviposition by flies.
- Provado and Calypso did not prevent oviposition, but no larvae emerged from fruit, suggesting some lethal effect on larvae due to systemic or translaminar activtity.
- Observations suggest all materials had some contact activity, but more studies are warranted; for GF-120, ingestion seems to be the main mechanism of kill.
- In the field, all the insecticides tested except for Phloxine significantly reduced larval infestations. GF-120 was the only one that eliminated infestations at one site.
- Further testing of GF-120 at various dilutions indicated the effectiveness of the spray may be site dependent and are affected by environmental factors such as proximity to infested trees. None of the GF-120 dilutions tested reduced infestations to zero and no differences were detected among dilutions at 3 sites.

Methods:

1) Effects of commercial insecticides on mortality, sublethal effects, and behavioral responses of western cherry fruit fly. Initially, experiments using the label rates of and label directions for the following were conducted: (1) Entrust (organic formulation of spinosad, no bait), (2) GF-120 (spinosad mixed with bait containing sugar, protein, attractants), (3) Provado (imidacloprid), Calypso (thiacloprid), and (4) Phloxine (photoactive dye, not tested in the laboratory in 2004). An untreated control was included. These products were tested without sugar (except GF-120).

Groups of 20 or 10 flies were exposed to one treatment per pint-size container. Insecticide solutions of 100 or 500 μl were placed on a dish on the bottom of the container throughout 16 days.

In other tests, cherries were dipped in insecticide solutions and then exposed to flies. Mortality of flies was assessed at 1, 2, 3, and 4 days post exposure. For each treatment, egg production of surviving flies was determined by allowing flies to lay eggs into untreated cherries at days 10-14. In future tests, surviving flies exposed previously to insecticides will be paired with non-exposed mates to observe for mating. Mating frequency will be observed and recorded. Other behavioral responses measured will be time walking on treated surfaces. Repellent effects (avoidance of treated surfaces) will be recorded.

Future tests will involve more treatments, including different concentrations of insecticide and sugar (which is not an attractant but a feeding stimulant). Insecticide concentrations will be 0, the label rate, 10%, 20%, and 50% lower and 25% higher than the label rate. A 20% (wt:wt) sugar concentration was tested with Provado and Calypso in 2004.

2) Relative importance of contact or ingestion mechanisms of kill. Preliminary observations were made of flies placed near GF-120 and Calypso droplets in 2004. The numbers of flies approaching the droplets were recorded. In future studies, the primary mechanism of kill will be determined by feeding individual flies solutions mixed with or without sugar and by placing small measured drops of these solutions onto the dorsa of flies (to prevent ingestion) to simulate contact from sprays. Mortality will be recorded at 1, 3, and 7 days post exposure.

3) Residual activity of insecticide formulations in the field. Selected insecticides will be applied using a handgun on different quadrants of trees at an experimental orchard in Moxee, WA. Controls will be applied with water only. Leaves will be collected 1, 3, and 7 days after applications and brought into the laboratory, where they will be exposed to groups of 10 flies that had been starved for 24 hours. Mortality, time on leaves, and repellent or avoidance effects will be recorded.

4) Effects of insecticide formulations on larval infestations in the field. Applications of Entrust, GF-120, Provado, Calypso (high label rates), and Phloxine + sugar and bait were made at the Moxee orchard every 8 or 10 days in June 2004. Infestation levels of fruit were determined by removing 200 fruit per tree and placing them on wire screens on tubs and allowing larvae to drop from fruit. The most promising product, GF-120, was selected for further testing in 2004 at 3 sites. In the future, additional tests involving the most effective insecticides will be conducted.

Results and Discussion:

1) Effects of commercial insecticides on mortality, sublethal effects, and behavioral responses of western cherry fruit fly. Entrust and GF-120 were the most effective of the insecticides tested when 100 μl was used, with both causing 100% or nearly 100% mortality by day 4 (Table 1). Provado was less effective, and Calypso was the least effective. Females exposed to Provado and Calypso laid eggs at 10-14 days post-exposure. A similar pattern was seen when 500 μl of insecticides was used (Table 2). When cherries were dipped in insecticides and continually exposed to flies for 4 days, a similar pattern emerged again, with Entrust and GF-120 being most effective (Table 3). Both prevented flies from laying eggs, apparently by killing them early, whereas Provado and Calypso did not (Table 3). In a second test, this pattern was followed again, although some eggs were laid in cherries dipped in Entrust. No eggs were laid in cherries treated with GF-120. Although eggs were laid in cherries treated with Provado and Calypso, no larvae emerged from them (Table 3), suggesting some lethal effects to larvae due to systemic or translaminar activity. Mating was not seen in any fly groups, but observations suggested there were no strong repellent effects of the GF-120 and Calypso.

Because Provado and Calypso did not cause 100% mortality, sugar was added as a feeding stimulant to determine if this would increase mortality. Adding 20% sucrose to both products did not increase mortality, at least when other food was present in containers (Table 4).

2) Relative importance of contact or ingestion mechanisms of kill. Preliminary observations suggest all materials had some contact activity. For GF-120, ingestion seems to be the main mechanism of kill. More studies are planned for the future.

3) Residual activity of insecticide formulations in the field. Early results suggest GF-120 has activity against flies up to 14 days post treatment, but that the amounts on leaves after this time are small and that flies may need to feed long periods on them before dying. More studies will be conducted to precisely determine residual activity of all the insecticides.

4) Effects of insecticide formulations on larval infestations in the field. In the field at Moxee, where fly populations in 2004 were unexpectedly low, all the insecticides tested, except for Phloxine, significantly reduced larval infestations. However, GF-120 was the only one that eliminated infestations (Table 5). Because GF-120 was seemingly the most effective product, additional tests using low to high GF-120 dilutions were conducted at Vancouver, Yakima, and at a second set of trees at Moxee in 2004. In Vancouver, where feral trees varied greatly in fly numbers and were scattered, there was no effect of the spray on numbers of larvae per fruit (Table 6). In Yakima, sprays reduced the numbers of larvae per fruit in backyard trees, but did not eliminate infestations, and no dilution effect was seen (Table 6). This was also true in orchard trees at Moxee (Table 6).

***Significance to the Industry and Potential Economic Benefits*:** The results indicate that the cherry industry will benefit most from using the spinosad products, Entrust and GF-120, against the cherry fruit fly. The inability of Provado and Calypso to cause 100% mortality suggests these products may need to be applied differently than that recommended on the label. Use of higher concentrations, greater spray volumes, and other factors may increase their efficacy. This may also apply to the spinosad products. Although GF-120 was the most effective of the products tested, it nevertheless failed to eliminate larval infestations at any of the sites. This suggests that label recommendations for GF-120 need to be modified to include the size of the trees, fly population levels, and the proximity of trees to other infested trees before the product can be successfully used in a broad range of situations. The amounts of active ingredient and the spray volumes used may need to be considered on an individual site or even tree basis. Results of GF-120 tests conducted with feral trees (Vancouver), backyard trees (Yakima), and those in an orchard (Moxee) differ slightly, supporting this statement. The impact of various ecological factors that affect control of flies needs to be better understood. The potential economic benefits of this research are decreased costs for sprays and decreased risks of loss revenue associated with fly infestations. These benefits may be achieved through studies that determine the best ways to reduce the numbers of insecticide sprays and to increase the efficacy of these sprays.

Table 1. Effects of insecticides to 100 μl solutions of insecticides on mean cumulative % fly mortality (± SE) at 1-4 days after exposure and mean numbers of eggs laid/female (± SE) 10-14 days after initial exposures.

Treatment	AI ppm	Day 1	Day 2	Day 3	Day 4	Eggs/female
Control	0	2.5 ± 2.5a	3.8 ± 3.8a	8.8 ± 2.4a	16.3 ± 8.3a	19.2 ± 5.0a
Entrust	32	77.0 ± 9.0b	94.8 ± 2.2b	100.0 ± 0.0b	100.0 ± 0.0b	0.0 ± 0.0b
GF-120	89	57.3 ± 9.1bc	79.3 ± 10.9bc	89.7 ± 8.0bc	96.3 ± 1.9bc	0.0 ± 0.0b
Provado	26	40.5 ± 8.9c	58.5 ± 17.4bc	63.3 ± 16.3c	68.5 ± 17.6c	2.1 ± 2.1bc
Calypso	61	45.0 ± 10.4c	50.0 ± 15.3c	60.0 ± 20.8c	63.3 ± 20.3c	12.4 ± 9.9ac

Three or four replicates, 20 flies/replicate.
Means followed by the same letter within columns are not significantly different (ANOVA, LSD Test, $P > 0.05$).

Table 2. Effects of insecticides to 500 μl solutions of insecticides on mean cumulative % fly mortality (± SE) at 1-4 days after exposure and mean numbers of eggs laid/female (± SE) 10-14 days after initial exposures.

Treatment	AI ppm	Day 1	Day 2	Day 3	Day 4	Eggs/female
Control	0	0.0 ± 0.0a	0.0 ± 0.0a	2.0 ± 1.2a	5.0 ± 2.2a	32.5 ± 7.8a
Entrust	32	75.0 ± 5.7b	88.0 ± 4.9b	99.0 ± 1.0b	100.0 ± 0.0b	0 ± 0b
GF-120	89	70.2 ± 8.8b	86.6 ± 7.5b	93.8 ± 4.1b	97.0 ± 3.0b	0 ± 0b
Provado	26	50.0 ± 9.1bc	65.0 ± 6.9c	87.0 ± 8.9b	89.0 ± 7.1b	0.8 ± 0.8b
Calypso	61	38.0 ± 14.9c	43.0 ± 15.1c	60.0 ± 13.5c	65.0 ± 13.3c	38.7 ± 3.2

Five replicates, 20 flies/replicate.
Means followed by the same letter within columns are not significantly different (ANOVA, LSD Test, $P > 0.05$).

Table 3. Effects of insecticides on mean cumulative % fly mortality (± SE) at 1-4 or 1, 2 and 6 days after exposure to treated cherries and mean eggs/female (± SE) exposed inside cages to insecticides.

Test 1

Treatment	AI ppm	Day 1	Day 2	Day 3	Day 4	Eggs/♀/3 fruit
Control	0	0.0 ± 0.0a	0.0 ± 0.0a	11.7 ± 7.4a	23.3 ± 10.5a	23.0 ± 3.8a
Entrust	32	98.3 ± 1.1b	100.0 ± 0.0b	100.0 ± 0.0b	100.0 ± 0.0b	0.0 ± 0.0b
GF-120	89	94.2 ± 2.4 b	99.2 ± 0.8b	100.0 ± 0.0b	100.0 ± 0.0b	0.0 ± 0.0b
Provado	26	55.2 ± 8.2 c	66.2 ± 8.2c	78.0 ± 6.6c	83.7 ± 5.8c	3.4 ± 1.6b
Calypso	61	46.3 ± 7.8 c	49.7 ± 6.5 d	64.8 ± 5.9c	65.7 ± 5.3c	15.2 ± 4.0a

Test 2

Treatment	AI ppm	Day 1	Day 2	Day 6	Eggs/♀/3 fruit[a]	No. Larvae[a]
Control	0	0.0 ± 0.0a	3.3 ± 2.1a	14.0 ± 2.4 a	9.7 ± 4.8a*	6.7 ± 1.8a
Entrust	32	81.7 ± 5.4b	96.7 ± 2.1b	100.0 ± 0.0b	1.3 ± 0.3b	0.7 ± 0.7b
GF-120	89	93.3 ± 2.1b	100.0 ± 0.0b	100.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b
Provado	26	16.7 ± 3.3 c	40.0 ± 3.7 c	98.3 ± 1.7b	1.7 ± 1.5 b	0.0 ± 0.0b
Calypso	61	10.0 ± 3.7c	21.7 ± 4.8d	45.0 ± 10.9c	2.9 ± 1.2ab	0.0 ± 0.0b

Six replicates; test 1: 20 flies/replicate; test 2: 10 flies/replicate.
Means followed by the same letter within columns are not significantly different (ANOVA, LSD Test, $P > 0.05$). *, P = 0.0598.
[a]Each variable evaluated from three of the six replicates.

Table 4. Effects of adding 20% sucrose to Provado and Thiacloprid on mean cumulative % fly mortality (± SE) at 1-4 days after exposure.

Test 1 Treatment	AI ppm	Day 1	Day 2	Day 3	Day 4
Control	0	0.0 ± 0.0a	0.8 ± 0.8a	0.8± 0.8a	0.8 ± 0.8a
Provado + Sucrose	26	75.0 ± 6.1b	85.0± 3.5b	91.3 ± 3.1b	92.5 ± 2.5b
Provado only	26	66.7 ± 8.8b	86.7 ± 4.4b	88.3 ± 6.0b	88.3 ± 6.0b
Test 2					
Control	0	3.0 ± 3.0a	3.6 ± 3.6a	3.6± 3.6a	8.1 ± 4.2a
Calypso + Sucrose	61	50.8 ± 7.8b	68.2 ± 7.3b	77.4 ± 3.3b	86.2 ± 2.6b
Calypso	61	39.8 ± 12.9b	74.2 ± 14.2b	77.6 ± 15.1b	79.6 ± 15.5b

Test 1: three to six replicates; test 2: five or eight replicates; both 20 flies/replicate.
Means followed by the same letter within columns are not significantly different (ANOVA, LSD Test, $P > 0.05$).

Table 5. Effects of insecticide sprays on mean larval numbers (± SE) in cherry fruit at Moxee, WA 2004.

Treatment	g AI/378	Rate/Tree	No. Sprays	Spray Interval	No. Larvae per 200 cherries + SE	Total Larvae per 1,400 fruit
Control	0	7.56 l water	4	8 days	4.9 ± 1.8a	34
Entrust	13.6	0.34 g/7.56 l	4	8-10 days	0.3 ± 0.3b	2
GF-120	15.1	89 ml in 532 ml	4	8-10 days	0.0 ± 0.0b	0
Provado	11.3	1.2 ml /7.56 l	3	10 days	0.1 ± 0.1b	1
Calypso	28.7	1.2 ml /7.56 l	3	10 days	0.4 ± 0.3b	3
Phloxine+ bait	-----	2.2 g/225 ml	4	8 days	2.6 ± 2.2ab	18

Seven replicate trees per treatment.
Means followed by the same letter within columns are not significantly different (ANOVA, LSD Test, $P > 0.05$).
Entrust, powder; based on weight (1 ounce = 28.350 g).
GF-120, Provado, Calypso, liquids; based on volume (1 ounce = 29.573 ml).

Table 6. Effects of various GF-120 dilution sprays on mean (± SE) no. larvae per fruit at three sites in WA, 2004.

Dilution	Spray Volume	*N*	Vancouver No. Larvae	*N*	Yakima No. Larvae	*N*	Moxee No. Larvae
0	0 ml	31	0.132 ± 0.045a	9	0.743 ± 0.141a	4	0.007 ± 0.003a
1:160	225 ml	8	0.006 ± 0.006a	3	0.158 ± 0.083b	4	0.001 ± 0.001b
1:20	225 ml	8	0.012 ± 0.008a	3	0.053 ± 0.012b	4	0.001 ± 0.001b
1:5	180 ml	8	0.013 ± 0.007a	------	------	------	------
1:5	540 ml	9	0.003 ± 0.002a	------	------	------	------
1:1.5	75 ml	9	0.005 ± 0.003a	------	------	------	------
1:1.5	225 ml	10	0.036 ± 0.026a	4	0.045 ± 0.021b	4	0.0006 ± 0.0006b

Means followed by the same letter within columns are not significantly different (ANOVA, LSD Test, $P > 0.05$).
Vancouver: 120-542 fruit per tree; Yakima: 200 fruit/tree; Moxee: 231-328 fruit/tree.

Budget:

Project title: Evaluation of Insecticides on the Biology of Cherry Fruit Flies
PI: Wee Yee
Project duration: 2004-2006
Current year: 2005
Project total (3 years): $81,000
Current year request: $27,000

Item	Year 1 (2004)	**Year 2 (2005)**	Year 3 (2006)
Salaries	22,050[a]	**22,050**[a]	22,050[a]
Benefits	2,450[a]	**2,450**[a]	2,450[a]
Wages	0	**0**	0
Benefits	0	**0**	0
Equipment	1,000	**1,000**	1,000
Supplies	1,000	**1,000**	1,000
Travel	0	**0**	0
Miscellaneous	500	**500**	500
Total	27,000	**27,000**	27,000

[a]One GS-3 (6,000), one GS-5 (18,500)

CONTINUING PROJECT REPORT

WTFRC Project # CH-04-408

Project title: Cherry Fruit Fly Control Options

PI: Timothy J. Smith
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Research Assistant: Esteban Gutierrez, East Wenatchee.

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

Significant findings:
Objective 1: Product included in this project included Provado, Entrust, GF-120NF Bait, Assail, Calypso, and Aza-Direct.

Objective 2: All products, rates and timings (see Table 1) were tested under pest pressure conditions far in excess of what would be expected in commercial orchards. As higher-level labeled rates worked very well in 2003 efficacy trials, some of these products were tested at lower rates and longer spray intervals to determine product limits. While most tested products controlled cff very well at moderate rates, there were two instances where lowest rates or 14 day intervals resulted in control failures. This information will be used during the development of label directions for these products. Azadirachtin (Neem), often recommended to organic cherry growers in the past, was ruled out as a cherry fruit fly control option.

The GF-120 NF bait was tested far more extensively than in 2003, and proved to be a dependable treatment for this pest. However, when cff adult populations on the tree are very high, and the tree is large, it may take two seasons to bring the infestation level to zero.

Objective 3: There are three new, effective products available for management of cherry fruit fly. (Provado, Entrust and GF-120 NF Bait) It is likely that an additional two will be labeled in the next few years (Assail and Calypso), aided by the research funded through this project.

Methods and materials:
Two small sweet cherry orchards that were documented as infested in 2003 were used as sites for replicated trials.

In addition, sixty "back-yard" situations were included as rate and timing efficacy trials. Each of these sites consisted of one to six cherry trees that were documented or reported as infested with fruit fly, and volunteered by the owners as test subjects, with the understanding that the fruit could not be consumed if treated with unregistered products. In return, the tree owner was assured a "clean" tree next year. Of these sixty-two potential test sites, nineteen proved to be uninfested, proving that some of the public find it difficult to resist a "free" service, even when it is not necessary.

Four isolated abandoned cherry trees were left unsprayed to document the relationship between current season trap catch and fruit infestation. Two of these sites proved to be uninfested.

All test sites were monitored with the standard Trece baited AM yellow sticky 9 x 11 inch traps to document adult presence on the trial trees and potential infestation of fruit. Those sites that were not infested are not reported in the table 1 data.

The trial applications began on May 18, when the first adult was trapped. Sprays were maintained at 7, 10 or 14 day intervals from that date until the normal harvest maturity, which occurred during the last ten days of June. A total of six 7-day, four 10-day, and three 14-day treatments were applied during this time. At harvest-time, a 250 – 500 cherry sample was collected from each replicate and placed into cold storage.

The fruit was then crushed and checked for larva, using the standard brown sugar method for the detection of CFF larvae in large batches of fruit.

Materials included in research: Acetamiprid (Assail) 1.14, 1.71, and 2.28 ounces product/A, 7, 10 or 14 day spray intervals, thiacloprid (Calypso) 2, 4, 6 and 8 fl ounces product/A, 7, 10 or 14 day spray intervals, imidacloprid (Provado) 8 fl. oz. product/A, 10 day intervals, spinosad (GF-120NF Bait), 5, 10, 15, 20 and 40 fl. ounces 0.02% ai product/A, 7 day intervals, and azadirachtin (Aza-Direct 1.2%) 24 or 32 oz. product per acre every 7 days. A wetting agent (Regulade) was added to each spray mixture at a one quart / 100 gallon rate.

Application: All materials except the bait were applied with a backpack air-blast/mist sprayer in about 100 gallons water per acre. The GF-120NF bait was applied in three small orchards with a 12 volt, electric pump, auxiliary sprayer strapped to the back of a "four-wheel" ATV motorcycle. Two adjustable-angle D2 disc nozzles (no cores) were used to direct streams of the bait/water mix across the middle of the tree. Calibration trials proved that 20 fluid ounces of the bait could be mixed 1:4 with water, and then applied to one side of each tree (on alternate row middles) at 6.5 to 7 mph through D2 nozzles. Application took about 2.5 to 3 minutes per acre. The side of the trees treated was alternated weekly, but the row ends and outside rows were treated every week. The fourteen single-tree bait sites were treated with a 1:3 bait to water mix applied with hand-held "window washer" squirt bottles adjusted to apply a solid stream of mixture. Rate per acre was adjusted by varying the amount of mixture that was applied to each test tree. Bait was re-applied after two significant rainfalls.

Results and discussion:

Objective 1: Product included in this project that is newly registered but not extensively tested on cff in Washington: Provado and GF-120NF Bait. Products included in this trial screening at the request of the registrant: Assail, Calypso, and azadirachtin. Product recently registered, but not included in this trial: Actara.

Objective 2: All products, rates and timings (see tables 1 and 2 below) were tested under pest population conditions far in excess of what would be expected in commercial orchards. As adults emerge daily during the season, spraying does not prevent adult trap catch on infested trees. However, effective control products protect the fruit from larval infestation by controlling adults prior to their maturation and egg deposition. Most of the treatments greatly reduced or eliminated infestation. However, no infestation is allowed under quarantine agreements. Under the severe test conditions, some rates and intervals failed to completely control cherry fruit fly.

Larvae were found when rates were dropped to 1/3 of high label rates and spray intervals were increased to 10 or 14 days. Lower rates seem to work well with 7 day spray intervals. Moderate rates appeared to be effective at 7 or 10 day intervals. However, even highest rates of an otherwise effective product failed when spray intervals were increased to 14 days.

Table 1. Conventional Product Results Summary:

Treatment	Ai/A	Product Rate/A	Spray Interval Days	# of Trees	# of Sites	# Fruit	Larvae Found	Percent Larva in Fruit	Adults per Trap in 2004
Untreated	0	0	NA	5	3	950	110	11.6	140
Aza-Direct	.29 fl.oz.	24 fl.oz.	7	5	3	1000	49	4.9	150
Aza-Direct	.38 fl.oz.	32 fl.oz.	7	7	3	1000	53	5.3	177
Assail 70WP	33.7 g	1.71 oz.	10	4	2	1000	0	0	26
Assail 70WP	44.9 g	2.28 oz.	10	6	2	1000	0	0	202
Assail 70WP	22.5 g	1.14 oz.	14	4	2	1000	1	0.1	19
Assail 70WP	33.7 g	1.71 oz	14	4	2	1000	0	0	7
Assail 70WP	67.4 g	3.4 oz.	10	6	1	1200	0	0	23
Calypso 4F	28.3 g	2 fl. oz.	7	2	1	500	0	0	81
Calypso 4F	28.3 g	2 fl. oz.	10	6	2	1000	1	0.2	197
Calypso 4F	56.7 g	4 fl. oz.	10	6	2	1000	0	0	24
Calypso 4F	85.0 g	6 fl. oz.	10	6	2	1000	0	0	182
Calypso 4F	113.4 g	8 fl. oz.	10	2	1	500	0	0	8
Calypso 4F	113.4 g	8 fl. oz.	14	7	3	1050	8	0.76	69
Provado 1.6	45.4 g	8 fl. oz.	10	6	2	1000	0	0	40

Table 2. GF-120 NF Bait Results Summary:

Product	Ai/A	Product Rate/A	Spray Interval	# of Trees	# Fruit	Larvae Found	Adults Per Trap in 2004
Untreated Checks	0	0	NA	5	950	110	140
Ineffective Product	NA	NA	7	12	2000	102	122
Provado Standard	45.4 grams	8 fl.oz.	10	5	1000	0	40
GF-120NF	.0001 oz.	5 fl.oz.	7	2	750	0	16
GF-120NF	.0002 oz.	10 fl.oz.	7	4	650	0	14
GF-120NF	.0003 oz.	15 fl.oz.	7	2	500	0	8
GF-120NF	.0004 oz.	20 fl.oz.	7	11	1500	0	35
GF-120NF	.0008 oz.	40 fl.oz.	7	4	500	1*	110

* Note: The single larva was found in a 250 fruit sample taken from 40 foot tall cherry tree where over 200 cherry fruit fly adults where captured on one trap this season.

Despite as many as five weekly applications at higher than necessary rates, no treatment resulted in leaf marking, yellowing or shedding, fruit marking, or excessive mite flare-ups leading to obvious leaf damage. Some moderate leaf symptoms induced by mite feeding were observable by late summer on some of the trees treated with Provado, Assail, and Calypso.

In organic product trials, weekly GF-120NF bait application proved to be quite practical in both large acreage and single-tree "backyard" applications. Of the 23 trees on 14 highly infested "backyard" situations treated weekly with the bait, one larva was found on the most difficult treatment site in a 250 fruit sample. On this specific site, 204 adult cff were captured on one trap, and the unpruned tree was about 40 feet tall.. No larvae were found in 3650 fruit taken from 20 treated trees on 13 other bait-treated infested sites. No rate effect was found, but most of the low-rate trials proved to be lightly infested, so more research is required to find the low rate at which control failure is likely.

Objective 3:

Numerous "stone fruit" labels for products that are effective on CFF have been recently approved or probably will be registered over the next two to four years. Highly effective spray material options including at least three new (not organophosphate or carbamate) classes of insecticide will be available to growers. The research carried out in this project will be used toward registration of at least three products, and will greatly advance the rate of adoption of three others.

Budget:
Project duration: 2005-2006
Current year: 2005
Project total (2 years): $25,826
Current year request: $12,913

Item	Year 1 Budget	Year 1 Actual	Year 2 (2006)
Salaries[1]	**$8,330**	**$9,492**	**$8,692**
Benefits (34%)	**2,833**	**2,471**	**2,471**
Wages	**0**	**2,240**	**0**
Benefits (16%)	**0**	**311**	**0**
Equipment	**0**	**533**	**0**
Supplies[2]	**400**	**127**	**200**
Travel[3]	**1,350**	**1,620**	**1,550**
Miscellaneous	**0**	**0**	**0**
Total	**$12,913**	**$16,794**	**$12,913**

[1] Technician(s) – three months total salary – to find and secure test trees, help application and assess infestation levels.

[2] Supplies include spray materials, traps, lab supplies and sprayer fuel.

[3] Travel – agent and technician use of own vehicles at 4,130 miles reimbursed at .375 / mile.

FINAL PROJECT REPORT

PROJECT #: OSCC-5

TITLE: Development and Validation of Phenology Models for Predicting Cherry Fruit Fly Emergence and Oviposition in the Mid-Columbia Area.

PI: Helmut Riedl, OSU/MCAREC, Hood River

CO-PI: Y. Song, OSU/MCAREC, Hood River

COOPERATORS: L. Coop, Entomology, Corvallis
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BACKGROUND:

Harvested cherries must be free of western cherry fruit fly (CFF) larvae to be marketable. Because of this 'zero tolerance', cherry growers rely on an intensive control program to prevent infestations of this pest in commercial orchards. Control programs begin shortly after CFF emergence commences in the spring. Traps are widely used to detect CFF emergence. However, in most of the Mid-Columbia cherry-growing districts, CFF populations are at very low levels. As a result, it has become difficult and unreliable to detect first emergence with traps.

As an alternative to traps, temperature-based phenology models have been used to predict CFF emergence and egg laying in Washington, Utah, and the Willamette Valley of Oregon (Jones *et al*., 1991; AliNiazee, 1974, 1979). However, none of these predictive models have proven satisfactory for predicting CFF emergence under local conditions. Therefore, this project was initiated to develop a more reliable method for predicting CFF activity in the Mid-Columbia area.

Detecting and tracking western cherry fruit fly (CFF), *Rhagoletis indifferens*, emergence is critical for successful control. Fluorescent-yellow adhesive traps baited with an ammonia-releasing substance are widely used for monitoring cherry fruit fly. Because of intensive sanitation and control efforts in The Dalles, the principal cherry-growing district in the Mid-Columbia, cherry fruit fly populations are at very low levels. As a result, it has become difficult and unreliable in the last few years to detect first emergence with traps. An alternative to the use of traps for determining when the first fruit flies are present and sprays must be applied is to predict spring emergence of CFF with a degree-day model.

In 1995/96, the cherry research commission funded work to evaluate available predictive CFF models (Jones *et al*. 1991; AliNiazee 1976, 1979) and determine if they can be applied to the local conditions in the Mid-Columbia area. Unfortunately, none of these predictive models proved satisfactory. The probable reason why these models failed to provide accurate information is that they are based on locally collected empirical data which are not transferable to other regions, and because of certain biological assumptions which do not apply to our conditions.

In the fall of 2002, we submitted a research proposal to the cherry research commission to develop a more reliable phenological predictive model for CFF emergence and egg-laying for the Mid-Columbia cherry-growing districts (see

last years proposal for justification and objectives). This proposal was funded and research began in the spring of 2003. A new predictive model was developed which is based on the time-varying distributed delay concept (Manetsch & Park 1974). Unlike the existing degree-day models, the new model can simulate the whole process of CFF phenology including post-diapause pupal development, adult emergence, egg-laying, and larval development. The model also has the capability to simulate the effect of control measures on the CFF population.

While evaluating existing models and organizing/validating the new phenology model, it became apparent that additional biological information, not available from the literature, was needed for inclusion in this model to make it more biologically meaningful and reliable. Therefore, additional data need to be collected about adult longevity, egg-laying as a function of age, larval development, and, most importantly, about the factors influencing development of overwintering pupae. This work needs to be continued and brought to completion so growers have a reliable tool to know with reasonable accuracy when to begin and when to terminate CFF sprays.

A modified and slightly simplified version of the currently developed phenology model will be made available as a degree-day model through the IFP*net* website in The Dalles and through the IPPC web site at Oregon State University. Growers will be able to obtain cherry fruit fly predictions for their orchards by linking the model with temperature data from the established weather networks in The Dalles and Hood River.

The work progressed in two stages: During the first year emphasis was on developing the algorithms for the predictive model, searching the literature for available information on CFF biology in order to parameterize the model, and analyzing historical CFF emergence records. During the second year we began to test the CFF model and collected additional necessary biological data for inclusion in the model in order to improve predictions.

OBJECTIVES:

1. To further develop and improve a predictive phenology model for cherry fruit fly in the Mid-Columbia area.

2. To obtain data from original experiments about adult longevity, egg-laying, and about pupal development in the spring for inclusion in the phenology model.

3. To further validate cherry fruit fly model predictions using trap catch and weather data from The Dalles and Hood River collected in 2003 and 2004.

4. To make the cherry fruit fly model predictions available to all cherry-growing districts in the Mid-Columbia area via the Internet at The Dalles IFP*net* web site and Oregon State University's IPPC web site and link them to weather data from weather networks in The Dalles and Hood River.

SIGNIFICANT FINDINGS:

1. From an analysis of historical records, precipitation during March was found to accelerate first CFF emergence (Fig. 1). On average, CFF emerges 9 days earlier in The Dalles than in Hood River. However, in terms of physiological time it takes on average 128 degree-days (DD Fahrenheit) longer in The Dalles than in Hood River until first CFF emergence (starting point March 1). Possibly, this is due to lower precipitation during March in The Dalles (Table 1).

2. A research model of the western cherry fruit fly phenology was developed based on the time-varying distributed delay concept. The model can simulate the whole phenology system including post-diapause pupal development, adult emergence, egg-laying, and larval development in a user friendly menu driven system (Table 2). The model also has the capability to simulate the effect of control measures on the CFF population.

3. The model was validated using a set of model parameters obtained from various literature sources. The model, run with NOAA weather records from Hood River, generated reasonably good predictions when compared to the trap catch records from the last few years (Fig. 6). However, some essential biological information is still needed for inclusion in this model to make it more biologically meaningful and reliable.

4. Phenological data collected during 2004, indicate a relatively short emergence period for CFF adults of 4 to 5 weeks while trap catches can extend for another 6 weeks into early August. Emergence of CFF larvae from infested fruit began in mid-June, peaked in early July and dropped off markedly after July 15.

5. From the simulations, preliminary heat requirements for first emergence were calculated as 990 DD for The Dalles and 860 DD for Hood River. Site-specific predictions can be obtained through the Internet at The Dalles IFP*net* web site and at the Oregon State University's IPPC web site.

METHODS:

1. **Adult emergence, trap catches and presence of larvae in the field.** Emergence from the soil was monitored with cages, and flight activity with yellow sticky traps. Fruit was examined for presence of larvae. These data will be used for model validation. In addition, a large number of larvae were collected in the field as they were leaving the fruit and allowed to pupate in moist sand. Adults from these pupae will be used for experiments in 2005.
2. **Adult longevity and egg-laying.** Adults will be placed in small cages, provisioned with sugar water and presented with small red wax balls to determine longevity and age-specific egg-laying activity. This experiment will be completed with laboratory-reared adults in 2005.
3. **Pupal development.** Pupae were collected at weekly intervals from infested backyard trees to assess how time of pupation and soil moisture in late winter/early spring affect the timing of emergence the following year. This experiment will be completed in 2005.
4. **Model parameters.** The new model parameters derived from the experiments were incorporated in the new phenology model. Model predictions were validated with trap catch data collected in previous years in the lower Hood River Valley and with historical first emergence records in The Dalles and Hood River. During the 2004 season additional data were collected for model validation.

5. **Phenology predictions and model access.** A web-based predictive CFF model and phenology maps will be developed and linked to real-time weather information provided through the weather station networks in The Dalles and Hood River. Site-specific predictions of emergence dates and other phenological events (e.g., beginning or termination of egg laying) will be available through the IFP*net* website. This part of the project is currently being constructed and will be completed in 2005.

RESULTS AND DISCUSSION:

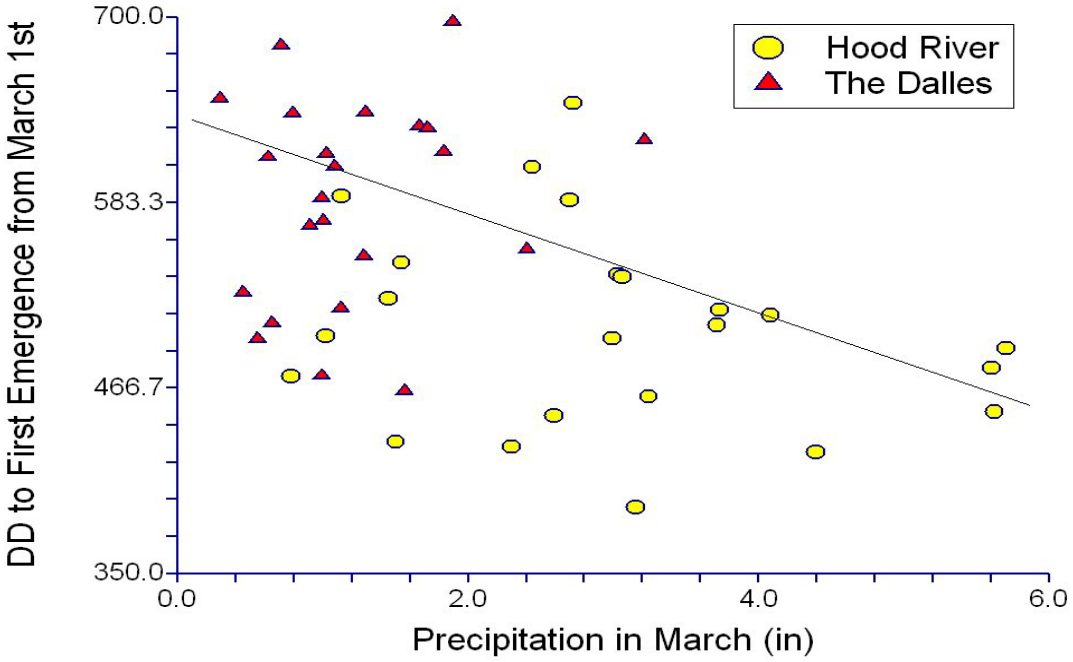
Effect of soil moisture on timing of spring emergence. The analysis of historical records showed no correlation between first emergence and precipitation in late winter/early spring when the two data sets from The Dalles and Hood River were analyzed separately. However, a significant negative correlation was found when the data were pooled (Fig. 1). On average, CFF emerges 9 days earlier in The Dalles than in Hood River due to warmer temperatures during spring (Table 1). However, an additional 128 DD (base 41°F) were required from March 1 until first emergence in The Dalles compared with Hood River. The analysis suggests that rainfall during March accelerates the post-diapause pupal development and advances adult emergence. Therefore, the predictive model should use different heat requirement values for pupal development in the spring depending on the precipitation or soil moisture conditions at a given location. These findings will be validated experimentally in 2005 with pupae collected in 2004.

Table 1. Summary of historical data of first cherry fruit fly (CFF) emergence in The Dalles and Hood River, degree-days are calculated in °F.

	The Dalles (A)	Hood River (B)	Diff.(A-B)
Recorded Year	1950 ~ 1990	1950 ~ 2002	-
First emergence date			
Mean	21 May	30 May	-9 days
Earliest	09 May	15 May	-6 days
Latest	02 June	18 June	-16 days
Degree-days (DD) to first emergence			
Mean	1,054	926	128
Minimum	837	705	132
Maximum	1,255	1,260	-5
CV (%)*	11%	13%	-

*Coefficient of variation %

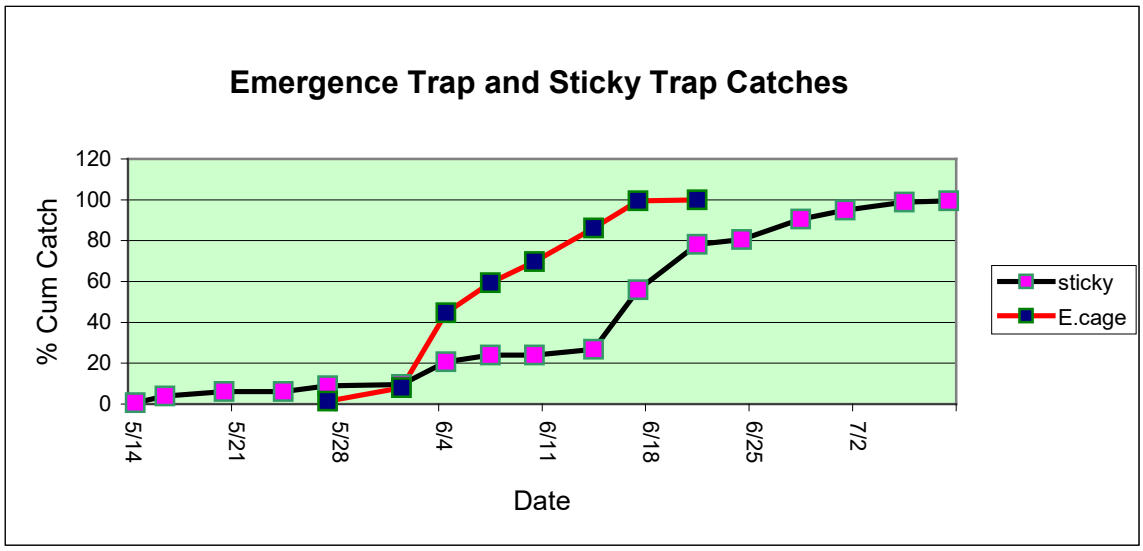
Fig. 1. Relationship between the amount of precipitation in March (X) and the degree-days (Note: DD used in graph are in °C; to convert to °F multiply by 1.8) accumulated from March 1 to first emergence (Y). Regression equation: Y= -21.3X + 589.3 (r=-0.4025**)



Phenological observations.

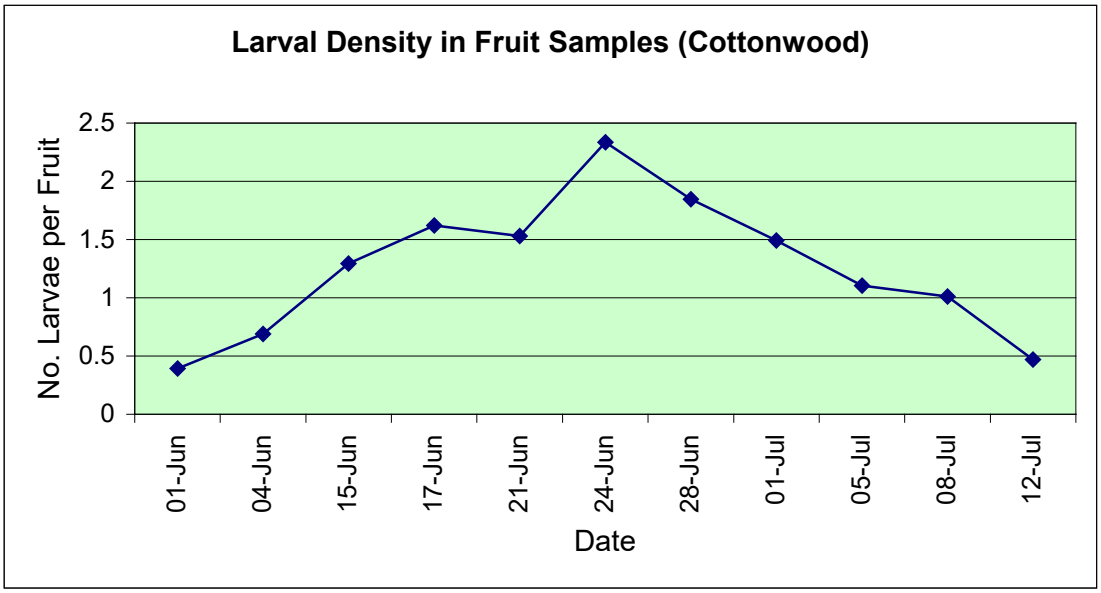
Emergence. CFF adults emerge from the soil underneath cherry trees over a four- to six-week period (Fig. 2). By comparison, trap catches continued for another four weeks after emergence stopped since CFF adults live for a long time. Studies with related temperate fruit flies (i.e., walnut husk fly) have shown that egg-laying closely follows trap catches. That means that egg-laying may occur in the field as long as CFF are caught in yellow sticky traps.

Fig. 2. Emergence of CFF adults from the soil and trap catches on yellow sticky panels; Dillon Street, Hood River, 2004.



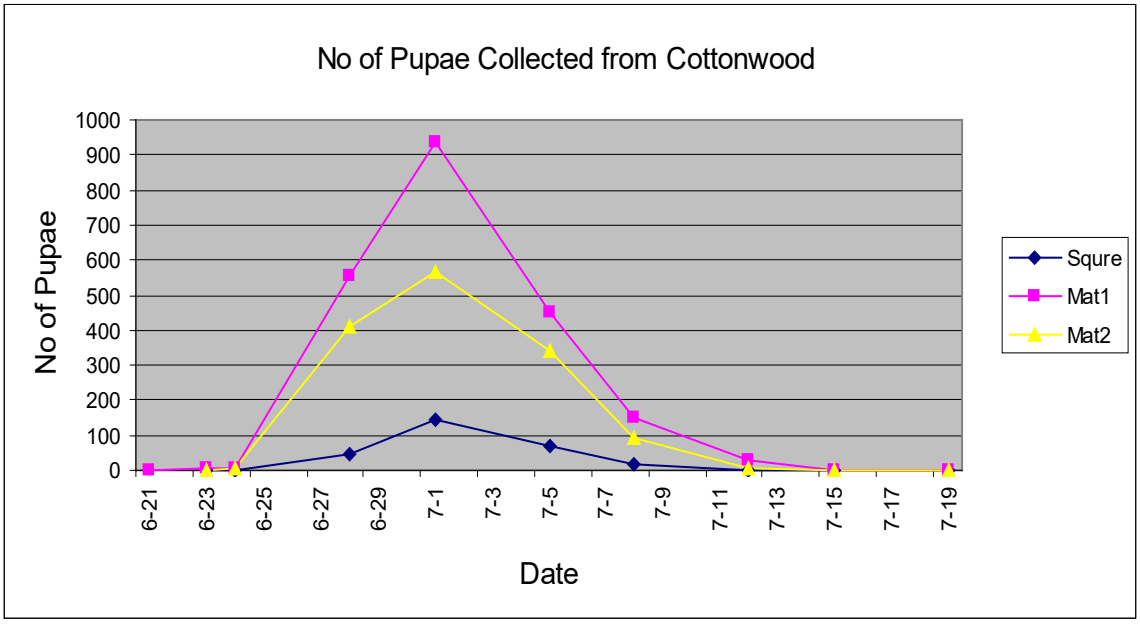
Larval density in fruit. Cherries from one backyard site (Cottonwood) with a very high CFF population were examined weekly to record the number of larvae per fruit. The average larval density per fruit rose from 0.5 in early June to >2 towards the end of June. Thereafter, larval density per fruit declined as the CFF population decreased and fewer and fewer sound cherries were available for egg-laying. Up to 5 or 6 CFF larvae were found in some fruit at the same time. We did not determine whether cannibalism occurs at these high larval densities per fruit.

Fig. 3. Average density of CFF larvae in fruit on heavily infested backyard cherry trees; Cottonwood, Hood River, 2004.



Larval emergence from fruit and pupation in soil. Mature CFF larvae dropping to the ground were collected with large tarps which were spread underneath cherry trees at the Cottonwood and two other backyard sites in the Hood River area. Sand was put on the tarps to provide larvae with a medium for pupation. As soon as larvae dropped onto the tarp they entered the sand and pupated within a short time. Puparia were collected by sifting the sand with a stainless steel screen. Time of pupation was recorded. More than 10,000 pupae were collected in this manner. Adults from these pupae will be used in 2005 in various experiments to determine adult longevity, fecundity and investigate how time of pupation and soil moisture affect emergence the following year.

Fig. 4. Number of CFF pupae collected with three different collection devices under cherry trees in a backyard site (Cottonwood) in Hood River, 2004
(Squre: 3x3 ft cone-shaped funnel; Mat 1: tarp suspended in tree; Mat 2: tarp placed on ground).



Predictive model. The new predictive model is based on the time-varying distributed delay concept (Manetsch & Park 1974) and is written in the Turbo BASIC programming language. Unlike existing degree-day models for CFF, the new model can simulate the whole process of CFF phenology including post-diapause pupal development, adult emergence, egg-laying, and larval development. The model also has the capability to simulate the effect of control measures (i.e., insecticide applications) on the CFF population. The model has a user-friendly menu driven interface (Table 2). Model parameters can be supplied from a separate text file. This makes the model flexible and applicable for other insect phenology systems. The model has other capabilities such as creating/editing weather data files and printing/displaying the results of each simulation.

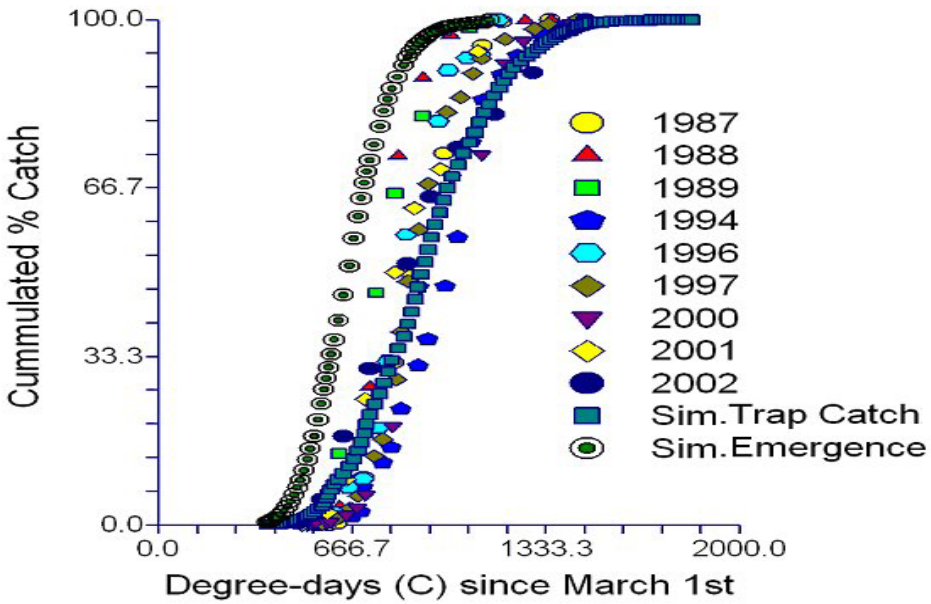
Model validation. The model was validated using a set of model parameters obtained from the literature. However, no information was available from the literature for several key parameters such

as adult longevity, pre- and post-diapause pupal development, pre-oviposition period and larval development and estimates were used instead. The model, run with NOAA weather records from Hood River, generated reasonably good predictions of CFF emergence and flight activity when compared with the trap catch records collected over the last ten years at that location (Fig. 5). Predictions of CFF emergence in 2004 in the Dallesport area where a sizeable CFF infestation occurred the previous year, were very accurate and within a day of the predicted event. While evaluating the CFF phenology model, it became apparent that additional biological information, not available from the literature, was needed for inclusion in this model to make it more biologically meaningful and reliable. Additional data need to be collected about adult longevity, egg-laying as a function of age, larval development, and, most importantly, about the factors influencing development of overwintering pupae. This work needs to be continued and brought to completion so growers have a reliable tool for determining with reasonable accuracy when to begin and when to terminate CFF sprays.

Table 2. The menu structure and related functions of the CFF phenology model

Main menu	Sub menu	Function of the menu
Model	Get Weather File	Select weather data to be used.
	Initial Population	Specify initial population and Biofix days.
	State of Crop	Optional specification of crop status.
	Spray Program	Optional spray records, affected stages and expected efficacy.
	Model Execution	Run the simulation model.
Weather	Create	Create new weather records.
	Update	Update existing weather records.
Setup	I/O Device	Choose I/O device (reserved for future development).
	Model Parameters	Enter and edit model parameters (reserved for future development).
Graph	Get Graph File	Load model output file to be graphically displayed (under construction).
	Display	Graphic display of model output specified.
Print	Get Print File	Load model output file to be printed or displayed.
	Print	Print the simulation results on printer.
	Display on Screen	Display the simulation results on screen.

Fig. 5. Relationship between cumulative percentage of trap catch during various years in Hood River and the simulated trap catch and emergence curves from the CFF model



LITERATURE:

1. AliNiazee, M. T. 1976. Thermal unit requirements for determining adult emergence of the western cherry fruit fly in the Willamette Valley of Oregon. Environ. Entomol. 5: 397-402
2. AliNiazee, M. T. 1979. A computerized phenology model for predicting biological events of *Rhagoletis indifferens* (Diptera: Tephritidae). Can. Ent. 111: 1101-1109.
3. Jones, V.P., D. G. Alston, J. F. Brunner, D. W. Davis, M. D. Shelton. 1991. Phenology of the western cherry fruit fly (Diptera: Tephritidae) in Utah and Washington. Ann. Entomol. Soc. Am. 84: 488-492.
4. Manetsch, T. J. and G. L. Park. 1974. Simulation of Time Delay, chapter 10, *In:* Systems Analysis and Simulation with Application to Economic and Social Systems. Department of Electrical Engineering and System Science, Michigan State University, East Lansing, Michigan.

BUDGET

PROPOSAL TITLE: Development and Validation of Phenology Models for Predicting Cherry Fruit Fly Emergence and Oviposition in the Mid-Columbia Area.
PI: Helmut Riedl
CO-PI: Yoohan Song
DURATION: 2003 - 2004
CURRENT YEAR: 2004
PROJECT TOTAL (two years): $15,000
REQUEST FOR 2005: None

Item	Year (2003)	Year(2004)
Total	$7,500	$7,500

Current year breakdown:

Item	Year (2003)	Year(2004)
Salaries – for research assistant	$6,500	$6,500
Service and supplies: traps, lures, etc.	$500	$500
Travel to experimental plots	$500	$500
Total	$7,500	$7,500

FINAL REPORT

PROJECT NO.: CH-04-409

Title: Orchard floor management and insecticide timing for thrips suppression in stone fruits and cherries.

PI: D.B.Walsh, Agrichem./Environ. Educ. Spec., WSU- Prosser

Cooperator(s): H.J. Ferguson, Extension IPM Coordinator/ Specialist
Mike Bush, County Agent, Yakima County
T.D. Waters, Research Assistant, WSU Entomology

OBJECTIVES:

1. Evaluate the influence of cover crops on the diversity and abundance of pest and beneficial arthropods in cherry and stone fruit orchards.
2. Evaluate the effect of chemical and mechanical treatments to the orchard floor on the spatial distribution and abundance of western flower thrips.
3. Determine the optimal timing of insecticide application for reducing thrips feeding injury to late-bearing cherries.

SIGNIFICANT FINDINGS:

Cover Crops

Sweep Net Surveys: Alfalfa hosted significantly more aphids than any other cover crop studied. Aphids were also abundant in the Bug-n-breakfast and alfalfa/ryegrass blends. Aphid numbers were quite low in the native grass blend, burnett, bared dirt, alsike clover, endemic weedy plants, perennial ryegrass, and native grass blend treatments. Lygus abundance was greatest in the alfalfa, alsike clover, endemic weedy plants, and birdsfoot trefoil cover crops. Lygus numbers were low in the native grass blend, perennial ryegrass, and strawberry clover treatments. The bare dirt and native grass blends hosted significantly fewer leafhoppers than did the other treatments. Spiders were most abundant in the alfalfa, alsike clover, and birdsfoot trefoil treatments. The bare dirt treatment contained the lowest abundance of spiders. Lady bird beetles were not abundant in any of the treatments.

Yellow Sticky Card Surveys: The yellow sticky card traps indicated that the alfalfa, alfalfa/ryegrass, alsike clover, and perennial ryegrass treatments hosted the greatest abundance of thrips. Bug-n-breakfast, bare dirt, and the native grass blend hosted the fewest thrips. Our study also illustrated the change in thrips abundance over time. Two population peaks occurred, one in early July and the other in the middle of August.

Indigenous plants:

The yarrow, salt bush, and Woods rose treatments hosted the greatest abundance of thrips. The Reed canary grass and stinging nettles hosted the fewest thrips.

Thrips also experienced two distinct population peaks in the indigenous plant plots. The first peak of thrips abundance in the indigenous plants occurred in early July directly corresponding to the first peak in the cover crops. Conversely, the second peak was much later than recorded in the cover crops.

Orchard Floor Treatments:
Immediately after the treatments were applied, sticky card data showed that thrips were more abundant in the canopy compared to the orchard floor for all treatments. The following week, thrips abundance was greatly reduced in the canopy of the Roundup treatment and the unaltered control. Two weeks after the treatment, the insecticide treatments still had a lower abundance of thrips on the floor, but the same amount of thrips in the canopy compared to the other treatments.

Lygus were not detected before the treatments were applied. A week following the treatments, Lygus began to inhabit the orchard. The sweep net samples showed that Lygus were significantly less abundant in the mowed plots when compared to the other treatments. The following week showed a reduction in Lygus abundance across all treatments, but the Asana and Roundup treatments hosted fewer Lygus.

Thrips Feeding Damage:
Premature fruit drop at two of the three locations utilized for the thrips cherry cage studies made evaluations of those fruit impossible. For the location where we were able to evaluate a significant amount of the caged fruit, the data indicate that cherries showed more damage when subjected to thrips feeding early during fruit formation (April 26). Another period of damage occurred during three weeks later in development.
The attempt to use spinosad within the cherry orchard to suppress thrips feeding damage was inconclusive.

METHODS:

1. Evaluate cover crops and indigenous plants for their impacts on populations of pest and beneficial arthropods and their effects on disease incidence and severity.

A. Cover crops- In spring 2003 established replicated field stands of several legume type (alfalfa, vetch, & clover) cover crops and several non-legume type (buckwheat, grasses etc.) cover crops. Cultural practices for cover crop management were conducted in a fashion as close to commercial as possible. Sweep net surveys were conducted every 2 weeks and the arthropods present will be quantified based on treatment/ cover crop type. Yellow sticky cards were used to evaluate the population density of thrips pests.

B.** Indigenous plants- In early spring 2000 we established 3 field survey sites of along protected waterways adjacent to apple orchards. From these surveys selected 18 plant species and we have established replicated stands of plants of native and established exotics. We will evaluate these plant species for their ability to serve as hosts for western flower thrips and Lygus bugs.

2. Conduct orchard floor treatments with formetanate hydrochloride and several candidate synthetic pyrethroid insecticides. Replicated blocks of cherry orchards with a history of thrips infestation will be treated 35 days pre-harvest and post-harvest with formetanate hydrochloride, esfenvatlerate, and fenpropathrin. Additional treatments will include the herbicide glyphostate and mechanical mowing. Subsequent assessment of Lygus population abundance will be taken by sweep netting ground cover on 7, 14, 21, and 28 days post treatment. Thrips abundance on the orchard floor and within the canopy will be quantified by placement of yellow 3" by 5" sticky cards. Fruit will be sub-sampled from each treatment at harvest and insect damage will be quantified.

3. Determine the optimal timing of insecticide application for reducing thrips feeding injury to late-bearing cherries. The recent registration of spinosad and imidacloprid will enable us to treat

individual trees with an echo-duster mister sprayer on short time intervals. We will adjust spray timings with these (and other registered) insecticides to suppress thrips populations on trees prior to harvest. We will also cage cherry clusters in cages and introduce thrips at a ratio of 25 thrips per fruit at 30, 20, 15, 10, and 5 days prior to harvest. The thrips cage studies will be conducted on late-bearing cherries in mid-summer.

RESULTS/ DISCUSSION

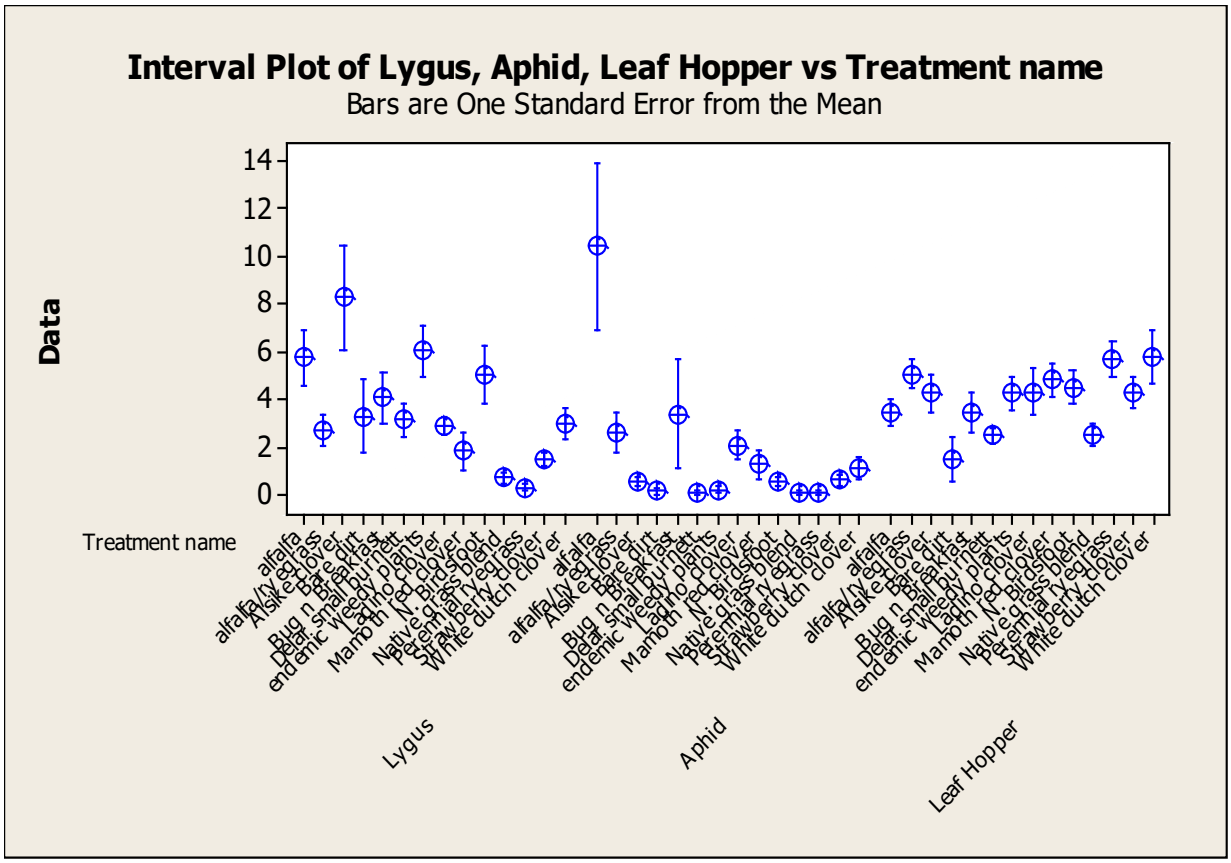
Cover Crops

Fourteen different cover crop blends were established in replicated 900 ft^2 blocks at IAREC in Prosser, WA. Plots were managed to mimic how they would be handled in a commercial orchard in terms of irrigation and mowing regime. Sweep nets were used to monitor arthropods every other week by sweeping each plot five times. Yellow sticky cards were also utilized every other week to assess thrips abundance .As this cover crop study could have broad application among a number of tree fruit crops, the pests we surveyed included Lygus, thrips, aphids, and leaf hoppers.

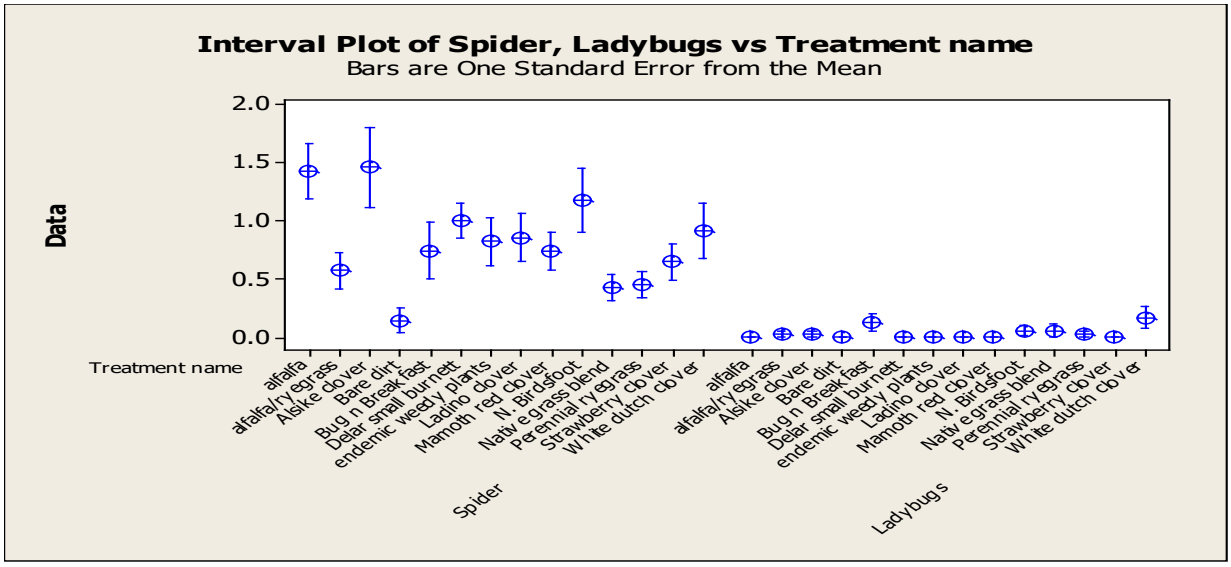
Sweep Net Surveys: Alfalfa hosted significantly more aphids than any other cover crop studied. Aphids were also abundant in the Bug-n-breakfast and alfalfa/ryegrass blends. Aphid numbers were quite low in the native grass blend, burnett, bared dirt, alsike clover, endemic weedy plants, perennial ryegrass, and native grass blend treatments. Lygus abundance was greatest in the alfalfa, alsike clover, endemic weedy plants, and birdsfoot trefoil cover crops. Lygus numbers were low in the native grass blend, perennial ryegrass, and strawberry clover treatments. The bare dirt and native grass blends hosted significantly fewer leafhoppers than did the other treatments. This data indicates that the native grass blend and perennial ryegrass were the treatments least likely to host the pest arthropods we monitored.
Spiders were most abundant in the alfalfa, alsike clover, and birdsfoot trefoil treatments. The bare dirt treatment contained the lowest abundance of spiders. Lady bird beetles were not abundant in any of the treatments.

Yellow Sticky Card Surveys: The yellow sticky card traps showed that the alfalfa, alfalfa/ryegrass, alsike clover, and perennial ryegrass treatments hosted the greatest abundance of thrips. Bug-n-breakfast, bare dirt, and the native grass blend hosted the fewest thrips. Our study also illustrated the change in thrips abundance over time. Two population peaks occurred, one in early July and the other in the middle of August. This data could prove beneficial in timing insecticide applications for controlling thrips on orchard floors.

The cover crop work indicates that the native grass blend host the fewest pests of all of the treatments studied. This study has enabled us to develop a more refined list of possible cover crop blends to be utilized on orchard floors to reduce pest numbers within the orchard ecosystem. Unfortunately, all of the blends that host more beneficial arthropods also host a great abundance of pests making those blends poor choices. The next phase in this study will involve the implementation of the cover crops on this refined list into commercial orchards. Large blocks in commercial orchards will enable us to study how the pests may move from orchard floor to within the canopy and visa versa over time. Studying the spatial dynamics of pests within the orchard will help to further narrow the candidate list of cover crops in order to make specific recommendations on cover crop blends for use in orchards to reduce pest.



Sweep net survey data 2004 (Cover Crops).



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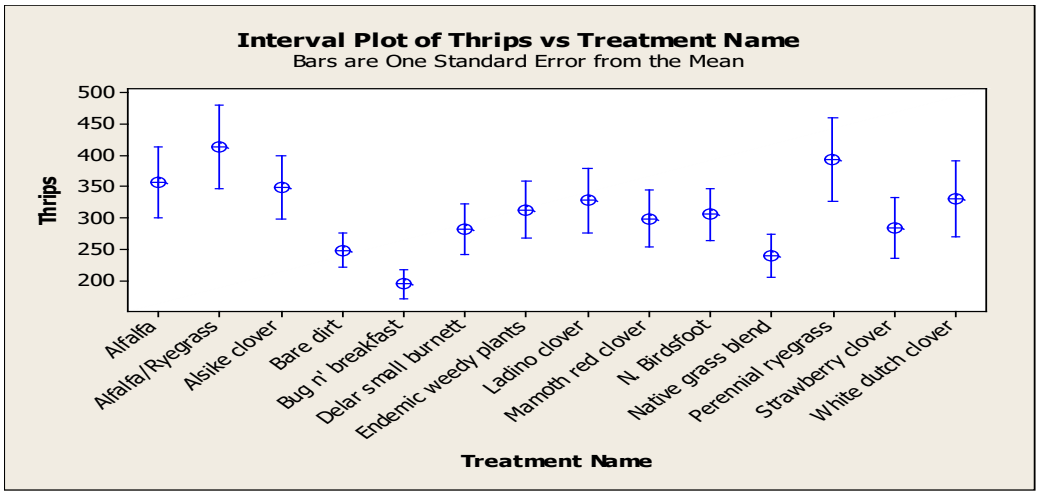
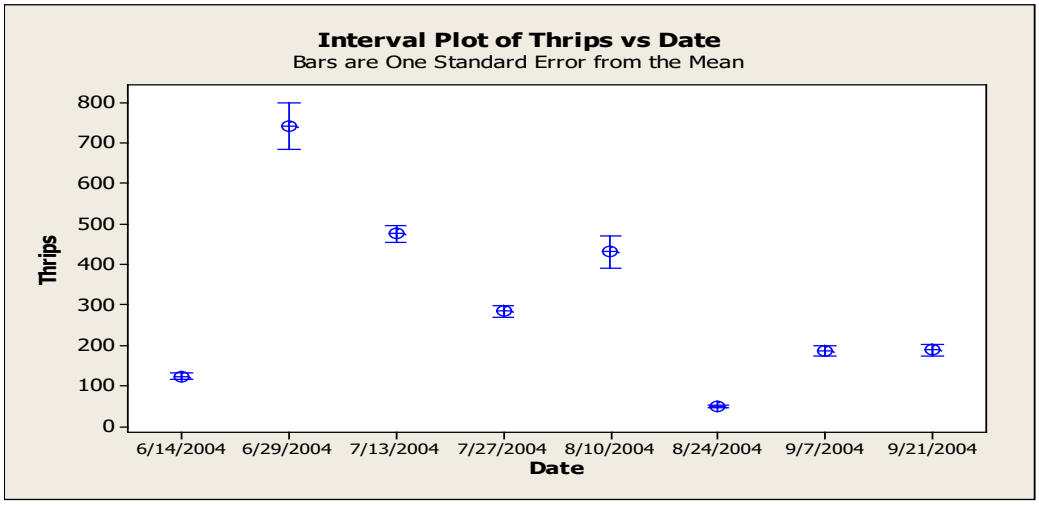


Yellow sticky card data 2004 (Cover Crops).



Yellow sticky card data 2004 (Cover Crops).

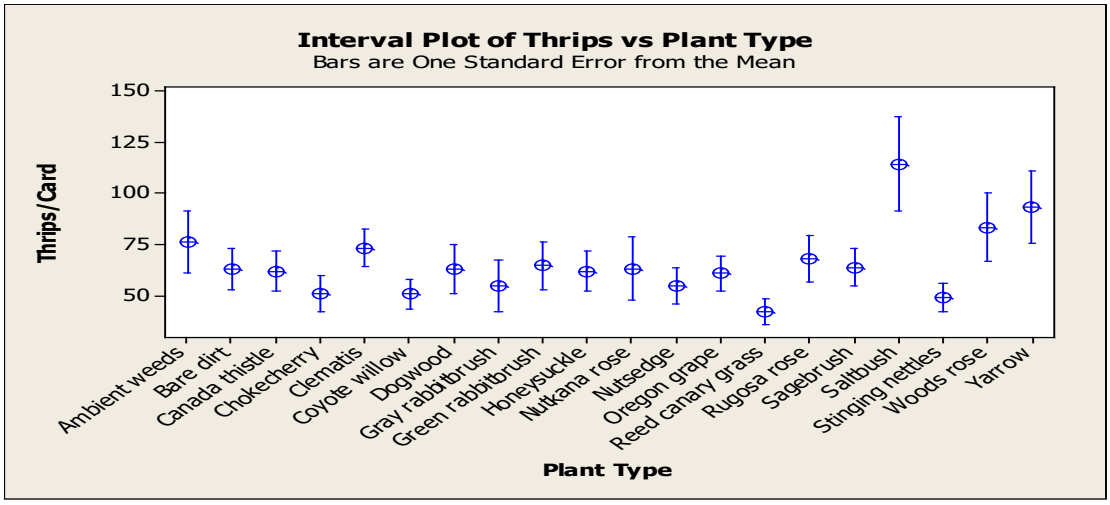
Indigenous plants:

Eighteen different plant species were established in 1 m^2 replicated blocks on the IAREC in Prosser, WA. Yellow sticky cards were placed within each plot every other week in order to assess thrips abundance on the particular plants. Restoration efforts often focus on the establishment of native plant species. These restored areas are often in close proximity to agricultural land. Little work has been done to attempt to determine the pest insects associated with certain indigenous and invasive plant species that can persist in non-crop areas. If not properly maintained, non-crop areas can serve as reservoirs for pestiferous species that can subsequently migrate into agricultural fields.

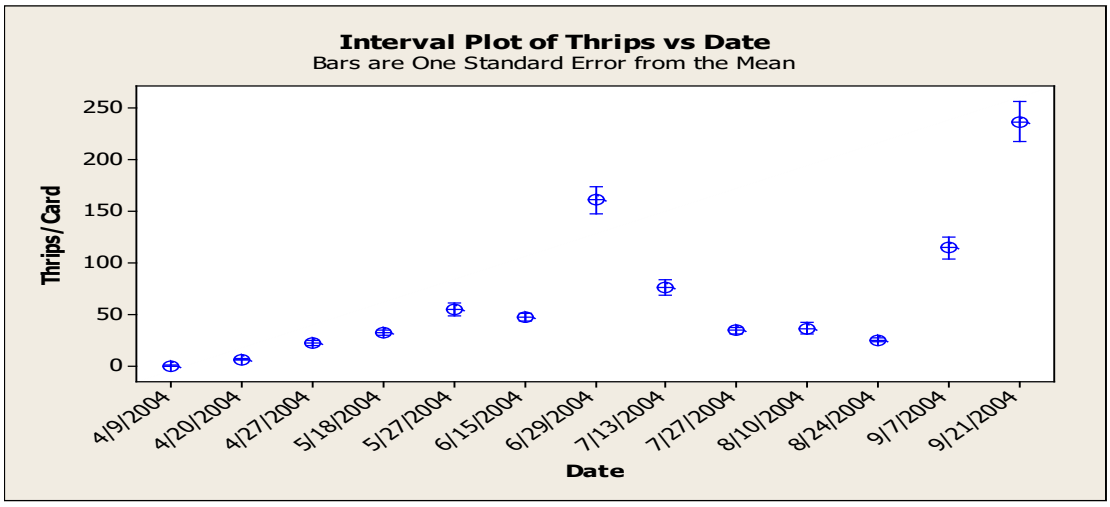
The yarrow, salt brush, and Woods rose treatments hosted the greatest abundance of thrips. The long flowering period of the yarrow and Woods rose creates ideal habitat for thrips. The Reed canary grass and stinging nettles hosted the fewest thrips. The fewer flowers and pollen provided by the Reed canary grass and stinging nettles contributed to the decreased attraction for thrips. Additionally, the stinging trichomes present upon stinging nettles would presumably render them less attractive to most soft bodied insects. Chokecherry and coyote willow were two other plants that hosted fewer thrips and would be good candidates for restoration projects.

Thrips also experienced two distinct population peaks in the indigenous plant plots. The first peak of thrips abundance in the indigenous plants occurred in early July directly corresponding to the first peak in the cover crops. Conversely, the second peak was much later than recorded in the cover crops.

The peak in thrips abundance in late September is most likely associated with the late flowering of a number of the indigenous plants. Most other habitats are void of flowers in late September while the native plants continue to provide flowers. Knowledge of these population peaks should enable growers to increase monitoring for thrips before these peaks are expected to occur so that they can take measures to control thrips when they begin to infest their orchard.



Indigenous plants Yellow Sticky Cards 2004.

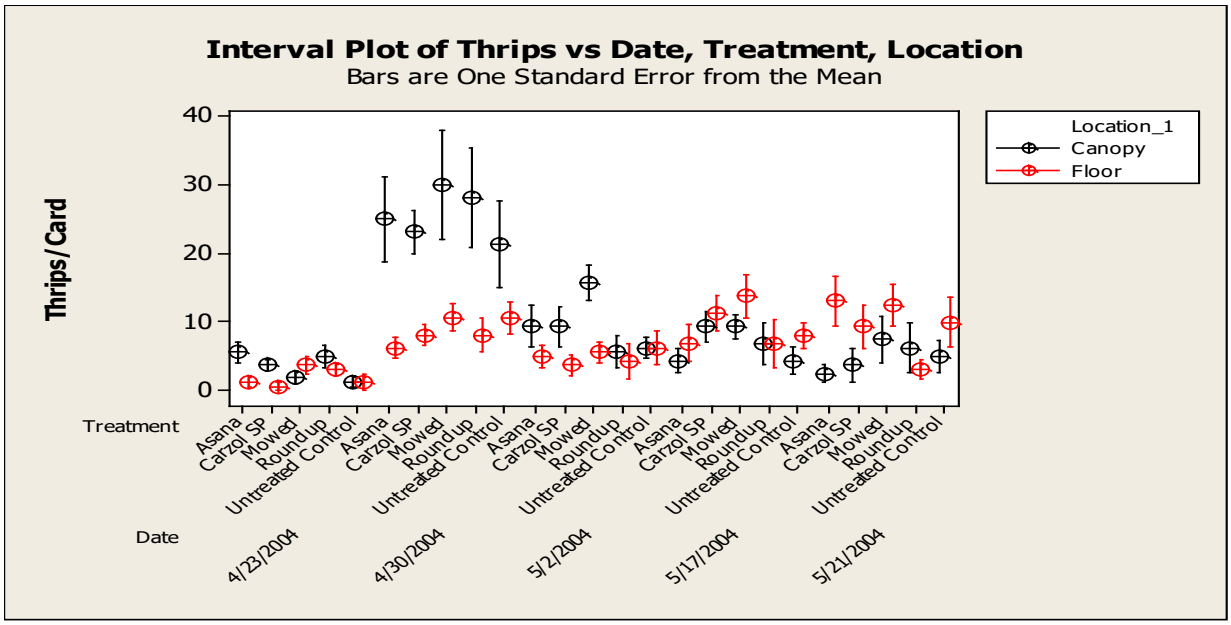


Indigenous plants Yellow Sticky Cards 2004.

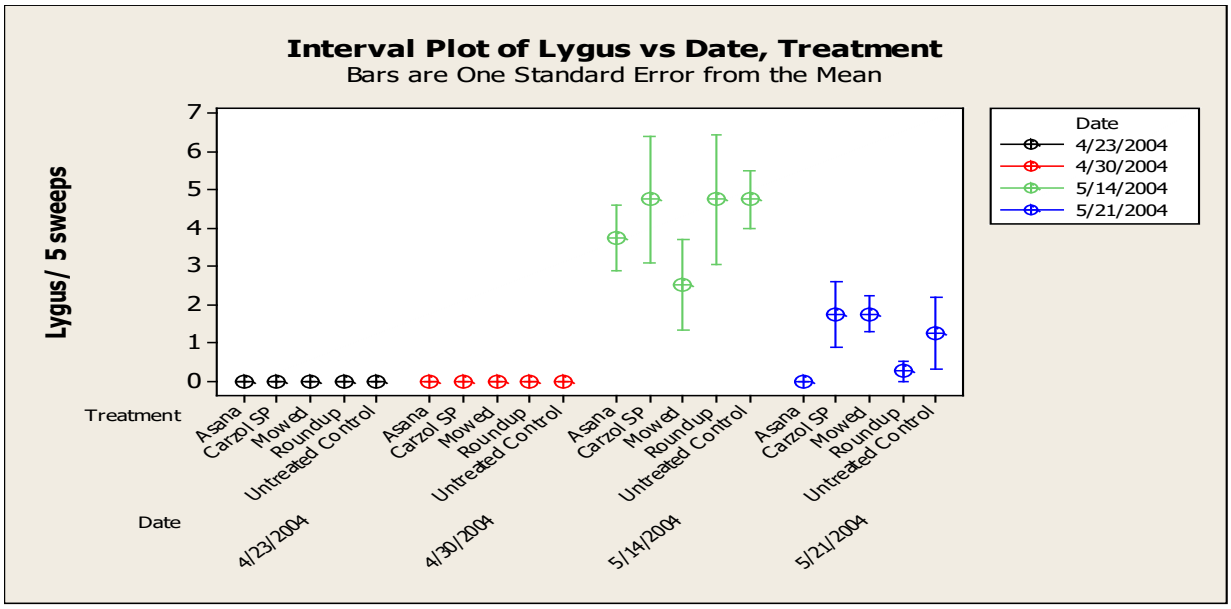
Orchard Floor Treatments:
Replicated 5,000 square foot blocks were established in a commercial orchard. Carzol, Asana, and Roundup were applied at recommended field rates with an ATV mounted boom sprayer. Controls were left unaltered while in the mowing treatment vegetation was cut to four to five inches. Pesticide treatments and mowing were conducted on April 27, 2004 in an attempt to assess how thrips and Lygus would respond. For each sample date, four yellow sticky cards were placed on the orchard floor and canopy in each plot to assess thrips abundance. Lygus were surveyed by sweeping the orchard floor with a sweep net five times per plot.
Thrips have been noted to cause cosmetic damage to a number of fruits and also have the ability to vector a number of plant pathogens. Immediately after the treatments were applied, sticky card data

showed that thrips were more abundant in the canopy compared to the orchard floor for all treatments. It appears that the immediate response of the thrips to all of the disturbances on the orchard floor were to fly to the canopy. Even the control showed an increase in thrips occupying the canopy. This is probably due to the fact that blossoms were present in the canopy at this time. The following week, thrips abundance was greatly reduced in the canopy of the Roundup treatment and the unaltered control. It seems as if the insecticide and mowing treatments discouraged thrips from occupying the floor and encouraged occupancy of the canopy. Two weeks after the treatment, the insecticide treatments still had a lower abundance of thrips on the floor, but the same amount of thrips in the canopy compared to the other treatments.

Lygus are a generalist native pest in the Pacific Northwest. Lygus were not detected before the treatments were applied. A week following the treatments, Lygus began to inhabit the orchard. The sweep net samples showed that Lygus were significantly less abundant in the mowed plots when compared to the other treatments. The following week showed a reduction in Lygus abundance across all treatments, but the Asana and Roundup treatments hosted fewer Lygus. By this time, the vegetation in the Roundup treatments was dead and subsequently unlikely to host Lygus. This data indicates that frequent mowing of the orchard floor may help to reduce Lygus abundance.



Orchard Floor treatments 2004.

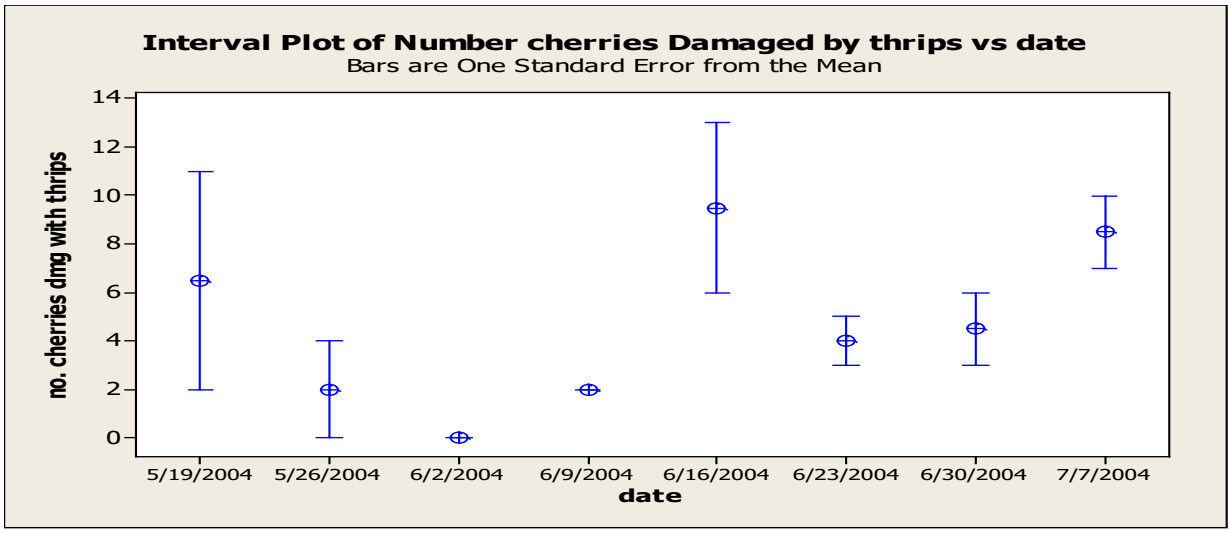


Orchard Floor treatments 2004.

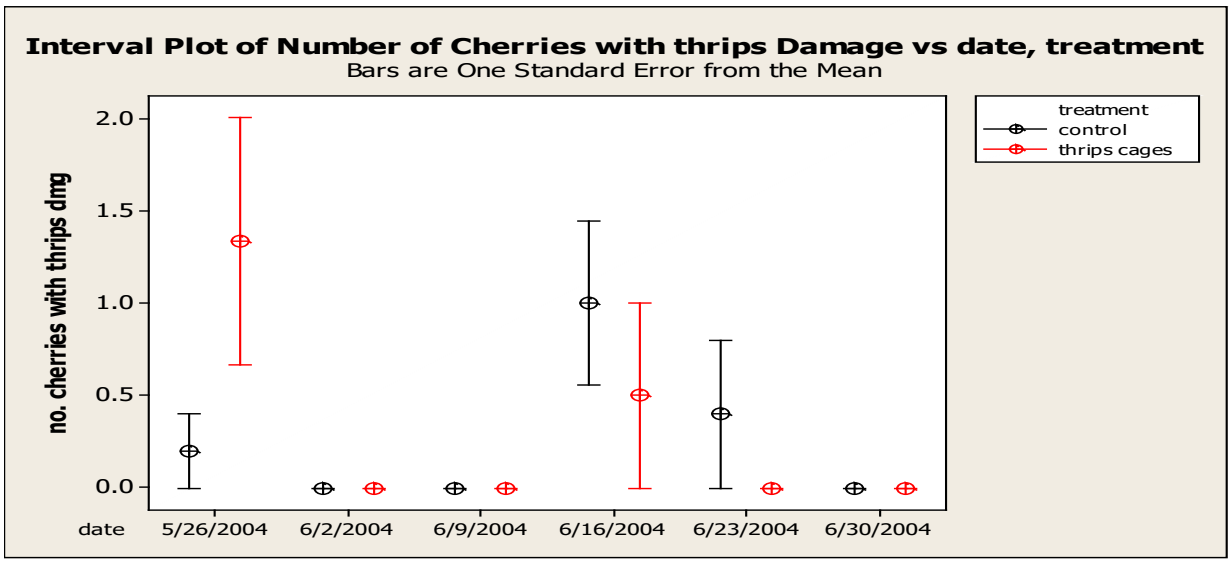
Thrips Feeding Damage:

Cherry clusters were caged weekly and thrips introduced into the cages in an attempt to elicit thrips feeding on the fruit. Controls were also maintained by applying Warrior to fruit clustersto deter thrips. Fruit were harvested during the commercial harvest period and evaluated for cosmetic thrips feeding damage. Premature fruit drop at two of the three locations utilized for the thrips cherry cage studies made evaluations of those fruit impossible. For the location where we were able to evaluate a significant amount of the caged fruit, the data indicate that cherries showed more damage when subjected to thrips feeding early during fruit formation (April 26). Another notable period of damage occurred during three weeks later in development. Using these predictive dates, growers could attempt to focus control efforts at these increments to reduce thrips feeding damage. Refinement of our technique for this experiment could yield more conclusive data.

A backpack air mist sprayer was used to apply spinosad to two trees per week. On subsequent application dates, all trees that had previously been treated were again treated with spinosad. The attempt to use spinosad within the cherry orchard to suppress thrips feeding damage was inconclusive. The trees used for study were treated with azinphos by the grower during late May. Thrips are highly mobile and subsequent immigration coupled with the short residual of spinosad would make its use ineffective or quite expensive to continually reapply. All suppression techniques could be enhanced by using a predictive model on thrips peak abundance. Reducing thrips in other nearby crops or non-crop areas could also improve thrips control in cherry orchards.



Thrips feeding damage spinosad applications 2004.



Thrips feeding damage Cherry Cages 2004

CONTINUING REPORT

WTFRC Project #CH-04-403 WSU Project #13C-3643-3387

Project title: Biology and management of bark beetles

PI: Jay F. Brunner
Organization: WSU Tree Fruit Research and Extension Center

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Co-PIs and affiliations: Tim Smith, Cooperative Extension, Chelan-Douglas County
Mike Doerr, WSU Tree Fruit Research and Extension Center

Contract administrator: Mary Lou Bricker (mdesros@wsu.edu) (509) 335-7667; or Tom Kelly (kellytj@wsu.edu) (509) 335-3691

Objectives:

4. Develop a clear understanding of the seasonal life history of bark beetles in Washington.
5. Develop a degree-day model that will predict beetle activity at any location.
6. Examine methods of monitoring bark beetles.
7. Determine the distance bark beetles move from a source to attack healthy orchard trees.
8. Validate insecticide bioassays against bark beetles and evaluate new candidate insecticides for efficacy and longevity.

Significant findings:

1. It is apparent that two distinct periods of shothole borer (SHB) activity occur in WA. The first begins in late April and peaks in late May to mid-June. The second begins in mid-July and peaks in late July. The pattern first noted in 2003 was observed again in 2004 (Fig. 1).
2. Ambrosia beetle (AB) activity was noted throughout the entire growing season. It is likely that 2-3 generations occur each year, but there is overlap between them making clear demarcation of generations difficult. AB activity was first observed in late March in 2004, with a second activity period occurring in early June, and a possible third in July and August. A similar pattern was noted in 2003, but in that year traps were not in place early enough to detect the first flight (Fig. 2).
3. Yellow sticky traps (unbaited apple maggot traps) seem to be the most appropriate trap to monitor SHB activity but the ethanol-baited funnel traps are necessary to monitor AB activity.
4. Movement of SHB into live orchards was closely associated with emergence from host material.

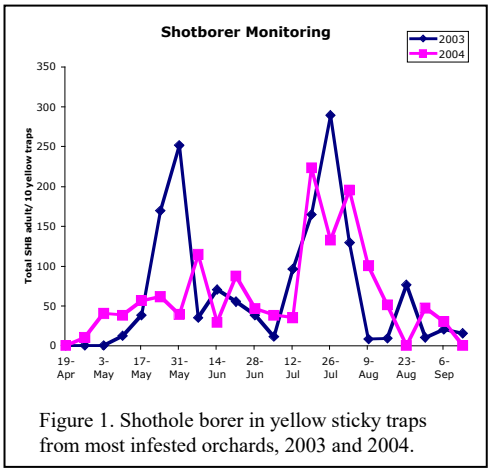

Figure 1. Shothole borer in yellow sticky traps from most infested orchards, 2003 and 2004.

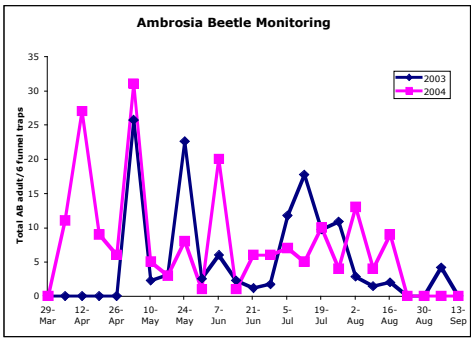

Figure 2. Ambrosia beetles in ethanol-baited traps from most infested orchards, 2003 and 2004.

SHB readily moved distances of 10-50 meters to attack live trees.

5. Host suitability tests showed variability in SHB development and reproductive rates. Cherry appears to be a good host for SHB development, but sap flow and mold development in rearing arenas limited reproduction in the laboratory. Apple and pear were clearly suitable hosts for SHB with reproductive rates being similar. Development was accelerated in apple, and probably cherry, relative to pear.
6. Many insecticides provided control or suppression of SHB in field-aged bioassays. The pyrethroid Asana was the most active through 21 days after treatment. However, the chloronicotinyls, Actara and Assail, were also very effective through 21 days. Avaunt and Guthion provided good suppression through 14 days, with Malathion having even shorter residual control. Proclaim and Success caused mortality but not at levels expected to provide adequate control.
7. Orchard sanitation was again noted as the most important factor in contributing to a reduction in SHB densities and damage in live cherry trees.

Methods:

Seasonal life history and monitoring: The seasonal life history of SHB and AB was monitored at eight locations in north-central Washington. SHB and AB emergence and movement were monitored by rearing adults from infested sources and by trapping adults near the source of infested wood. Infested wood from different locations was collected in the early spring, placed in opaque containers and held under constant temperature conditions. Cages were fitted with glass vials in one side. Emerging beetles (and parasites) are attracted to the light. Beetles entering the glass vial were collected on a regular interval. Traps were placed near the sources of infested wood in orchards. The utility of commercially available intercept traps (Lindgren Funnel Trap, 8-funnels, Phero Tech, Inc.) baited with ethanol lures were compared to unbaited yellow sticky traps (Pherocon AM, Trécé, Inc.) for their ability to monitor adult emergence from a source and subsequent migration into surrounding orchards.

Suitable tree fruit hosts: SHB were reared in limb sections of cherry, apple and pear. These limb sections were recently cut pieces of 2- to 5-yr-old wood (6" long x 1" diameter) from trees that had received no insecticide treatments. Limb sections were exposed to newly emerged adult SHB in 32 oz clear plastic deli cups (Prime Source PS232). Twenty-five cups were set up per host, and 5 SHB were added to each cup. The cups were held at 72°F (±2°F) and 16:8 L:D. The wood sections were examined at regular intervals for SHB survival and the emergence of new beetles. After emergence of the subsequent generation was complete, each egg-laying gallery was examined for gallery length and number of offspring.

Insecticide efficacy and longevity: In 2004, these insecticides were evaluated using newly emerged first generation SHB adults. Mature Delicious apple trees at WSU-TFREC were treated with recommended rates of various insecticides. Treated apple branches were collected at 1, 7, 14 and 21 days after treatment (DAT) and returned to the laboratory. Approximately 6" long x 0.5" diameter sections of 1- to 2-yr-old wood were added to 32 oz. deli cups (Prime Source PS232). Untreated apple branches were used as a control at each evaluation date. Five SHB adults were added to the deli cups, and survival was recorded after 1 and 3 days. Rearing conditions were 72°F, 16:8 L:D.

Activities planned for 2005:

The seasonal life history will be monitored again for SHB and AB from infested locations. We will be working with Vince Jones' laboratory to characterize marking with proteins to use as a method for evaluating dispersal of SHB from infested woodpiles into orchards. We will work with Vince Hebert at the Food and Environmental Quality Laboratory to identify any unique volatiles coming from infested wood that might be developed as possible attractants. Methods for rearing SHB have been refined, and we will rear them at different constant temperatures in an attempt to determine lower thresholds for development and use these data to construct a predictive model for adult emergence.

Results and discussion:

Seasonal life history and monitoring: Two distinct periods of SHB activity occurred in 2004 (Fig. 1). SHB activity was first noted in late April and continued through June. The second adult flight was detected in late July and continued through August and into September. The yellow sticky traps provided better resolution of adult SHB activity than the ethanol-baited traps. The pattern of adult activity was fairly consistent in 2003 and 2004 (Fig. 1). Data from the most heavily infested orchards as monitored by yellow sticky traps indicate two periods of activity. Generally, a first adult generation was noted from late April or early May through June, with a second generation from mid-July through August. Adult SHB were trapped throughout the entire growing season from initial adult emergence through the end of October (2003), but visual observations of laboratory and field behavior suggested that adult dispersal to suitable hosts and subsequent oviposition occurred shortly after emergence and beetle activity from that point on was associated with tending galleries and offspring.

AB activity was initially noted in late March or early April in 2004 (Fig. 2). AB activity was detected throughout the entire growing season, with 2-3 probable generations. It appeared that a second peak of activity might have occurred in early June, with a possible third generation in July and early August. The ethanol-baited funnel traps were more attractive to AB adults than the yellow sticky traps. A similar pattern of summer activity was noted in 2003, but traps were not in place early enough to detect the first flight. It was difficult from these data to determine distinct periods of adult AB activity with the exception of the emergence of overwintering adults. This was expected, as overwintering AB adults become active when the temperature warms enough to allow flight and the adults seem to emerge together. It was possible from that point on that AB oviposition was prolonged with prolonged emergence and overlapping of subsequent generations, or ethanol-baited funnel traps retained their relative attractancy to AB adults throughout their long life.

Movement of SHB into orchards was closely associated with emergence from host material, generally a pile of recently pruned or cut wood. SHB activity was easier to monitor in the host material than in live trees as a very large number of adults emerged from a relatively small area. The first impression was that little activity was noted in live orchard trees. However, plotting adult captures in live trees on a second *y*-axis with a different scale (Fig. 3) showed relative activity in host material and live orchard trees was very similar. These data suggested that recently emerged SHB adults were highly dispersive and readily moved distances of 10-50 meters from host material to live trees. SHB feeding damage in orchards was most commonly associated with movement from infested sources, pointing to sanitation as most important factor in SHB management.

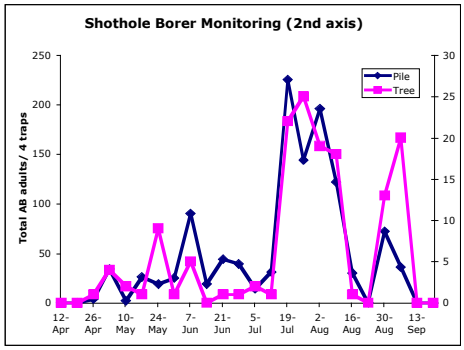

Figure 3. Shothole borer emergence patterns from a woodpile and in nearby trees, 2004.

Host suitability: Host suitability tests showed variability in SHB development and reproductive rates between cherry, apple and pear. Cherry is known to be an excellent host for SHB development, but it is also known that copious amounts of sap flow can inhibit SHB reproduction. Excessive moisture from cherry cuttings in our rearing arenas resulted in significant mold development. This mold apparently reduced SHB reproduction in cherry. Adult survival was high through 14 days but dropped to zero at the 28-day observation. The first emergence of new SHB was noted at 50 days in apple, with emergence from one arena occurring over a 3-4 week period. The first emergence in pear and cherry was noted at 64 days. The emergence pattern in pear was very similar to apple but was delayed by 14 days. It was apparent from this study that apple and pear were suitable hosts for SHB with reproductive rates being similar. Development was accelerated in apple relative to pear in this

study. When adult emergence has ended we will dissect and measure all oviposition chambers and assess reproductive rates by counting larval galleries. It is possible that mold development in some arenas may have arrested larval development. Humidity control appeared to be the biggest obstacle to establishing successful SHB colonies.

Field-aged bioassays: Many insecticides provided control or suppression of SHB in field-aged bioassays. The pyrethroid Asana was the most active through 21 days after treatment. However, the neonicotinyls, Actara and Assail, were also very effective through 21 days (Table 1). Avaunt and Guthion provided good suppression through 14 days, and Malathion had an even shorter residual activity. Proclaim and Success caused mortality but not at levels expected to provide acceptable control. These data support our previous contention that insecticidal controls applied frequently during the first SHB generation for other pests such as cherry fruit fly are coincidentally providing protection of trees from SHB attack. However, after harvest a lack of insecticide applications leaves cherry orchards unprotected from immigrating second-generation adults.

Table 1. Field-aged bioassay data from candidate insecticides, 2004.

	Average corrected % mortality			
Insecticide	1 DAT	7 DAT	14 DAT	21 DAT
Asana	100.0	100.0	100.0	100.0
Actara	100.0	100.0	100.0	90.5
Assail	100.0	100.0	100.0	95.2
Avaunt	100.0	100.0	95.2	61.9
Guthion	100.0	100.0	85.7	42.9
Malathion	90.9	81.3	61.9	47.6
Proclaim	50.0	81.3	100.0	66.7
Success	31.8	43.8	52.4	23.8

Orchard sanitation: In the winter of 2003 we monitored a concentrated effort to clean up a large SHB source that had resulted in significant damage, despite several insecticide applications including repeat applications of methyl parathion and endosulfan (Fig. 4), to young, healthy cherry trees that were located close to the source. The source was a fire woodpile that was replenished each year

Figure 4. Orchard sanitation from 2003 (left) to 2004 (right) in one study orchard. Note the removal of a large firewood pile (upper left) and a large brush pile (lower left).

with new prunings and a brush pile that was not burned each season. The source was identified in September 2003, and a damage evaluation was made at that time. Damage was high but fairly isolated to the rows adjacent to the source. During the winter of 2003-04 the orchard was pruned heavily, removing all weakened or damaged branches. Previous years' prunings (2002-03) and current season prunings (2003-04) were returned to the laboratory and placed in emergence cages. Enough wood to fill a 2' x 2' x 1' (L x W x D) emergence cage was collected from each year's prunings. The 2002-03 prunings produced 191 SHB adults, and the 2003-04 prunings produced 6 SHB adults. These data indicated that the majority of SHB were being generated by older prunings but also that some reproduction was occurring in the live trees. The grower made a concentrated effort to clean up all source material (wood pile, brush pile and prunings) and maintained a clean area near the infested orchard. In 2004 the orchard was monitored with yellow sticky traps, ethanol-baited funnel traps and visual inspection of damaged shoots. Insecticide applications were to be timed with observed trap captures. A total of 4 SHB adults and 9 AB adults were trapped in 5 yellow traps and 2 funnel traps over the entire season. No specific SHB insecticide applications were needed in 2004. No SHB damage was noted at any time in the 2004 season.

Budget:
Project title: Biology and management of bark beetles
PI: Jay F. Brunner
Project duration: 2 years
Current year: 2005-06
Project total (1 year): $32,000
Current year request: $16,000

Year	Year 1 (2004)	**Year 2 (2005)**
Total	16,000	**16,000**

Current year breakdown

Item	Year 1 (2004)	**Year 2 (2005)**
Salaries[1]	4,178	**4,345**
Benefits (29% - 1st yr) (31% - 2nd yr)	1,212	**1,347**
Wages[2]	7,000	**7,000**
Benefits (16%)	1,120	**1,120**
Equipment	0	**0**
Supplies[3]	1,000	**1,000**
Travel[4]	1,490	**1,188**
Miscellaneous	0	**0**
Total	16,000	**16,000**

[1] Mike Doerr – one month salary – conduct bioassays and supervise rearing.
[2] One person for four months to conduct field sampling.
[3] Supplies include rearing materials, traps and preservation materials for beetles. Cell phone charges are allowed under this grant.
[4] Travel – one vehicle for 3-4 months at $350/month plus fuel to collect field samples.

CONTINUING REPORT

WTFRC Project #CH-04-405 **WSU Project #13C-3655-7298**

Project title: Bioregulator uses for managing growth, flowering and cropping and for facilitating mechanical harvesting in sweet cherry

PI: Don C. Elfving, Horticulturist
Organization: WSU Tree Fruit Research and Extension Center, Wenatchee, WA

Cooperators: Eugene M. Kupferman, Extension Horticulturist, WSU-TFREC, Wenatchee, WA
James R. McFerson, Horticulturist and Manager, WA Tree Fruit Research Commission, Wenatchee, WA
Tom Auvil, Horticulturist, WA Tree Fruit Research Commission, Wenatchee, WA
Matthew D. Whiting, Assistant Horticulturist, WSU-IAREC, Prosser, WA
Tory Schmidt, Agricultural Technician, WA Tree Fruit Research Commission, Wenatchee, WA
Dwayne B. Visser, Agricultural Research Technologist II, WSU-TFREC, Wenatchee, WA

Contract administrator: Mary Lou Bricker (mdesros@wsu.edu) (509)335-7667; or Tom Kelly (kellytj@wsu.edu) (509)335-3691

Objectives:

1. Continue to develop improved recommendations for the use of ethephon (Ethrel®, Bayer CropScience) for stimulation of flowering and early fruiting in important sweet cherry cultivars on seedling rootstocks in standard and high-density plantings.
2. Examine the possibility that ethephon treatment for flowering can improve flowering and yield for more than one year after treatment.
3. Explore the potential for use of gibberellic acid (GA_3) as a strategy to reduce flowering the next year on mature sweet cherry trees grown on size-controlling rootstocks where excessive bloom makes crop load control critical for production of fruit of required size and quality.
4. Determine if it is economically feasible to use a single treatment program of GA on cherries to simultaneously obtain both better fruit firmness and quality in the treatment year and also control flowering for the subsequent year as a tool to adjust crop load to benefit fruit quality the next year.
5. Explore in greater detail promising results of preliminary research with SmartFresh® (1-methylcyclopropene, MCP) applied to sweet cherry trees in conjunction with ethephon for loosening fruit for mechanical harvest while reducing negative ethephon effects on fruit quality.
6. If any additional new fruit-abscission products become available, initiate tests for efficacy in loosening sweet cherries while examining effects on fruit quality.

Significant findings:

A. Control of flowering and fruit quality with gibberellic acid and MCP.

1. GA_3 was applied in 2003 to test control of flowering in 2004 as a strategy for crop quality improvement. GA at 30 ppm at straw-color (normal treatment) improved fruit quality in 2003 but did not affect return bloom in 2004.
2. Increasing GA concentration up to 100 ppm decreased return bloom proportionally; maximum reduction in bloom density averaged 40%. Double applications reduced flowering slightly over single applications at either the end of Stage I or Stage II.

3. Yield in 2004 was decreased and average fruit weight increased by higher concentrations of GA in 2003 and by double applications relative to single applications.
4. The percentage gain in fruit weight and brix for lower yields was more than offset by the percentage of loss in yield.
5. GA_3 and GA_{4+7} applied in 2004 twice at 200 ppm a.i. for flowering control reduced mean fruit size by up to 18% while 100 ppm a.i. reduced fruit size only about 4%. Flowering effects will be recorded in 2005.
6. A trial comparing GA_3 with sprayable MCP was established in 2004 to see if sprayable MCP would have any noticeable benefits on fruit quality. GA_3 showed a slight trend toward firmer fruit and lower soluble solids, but this preliminary trial was not large enough to clearly detect the small differences that were observed.

B. Ethephon for stimulation of flowering.

1. In 2003, ethephon at 200, 250 or 300 ppm was applied twice to 4- to 5-year-old 'Bing' and 'Rainier'/Mazzard trees that were physiologically ready to initiate the flowering process but had not borne a crop to that point. In the weeks after the treatments were applied, there was little evidence of gummosis on the limbs and trunks.
2. In spring 2004, the trees came into bloom. There was no beneficial effect of the 2003 ethephon treatments on flowering in 2004.
3. A new trial was established on young 'Lapins'/Mazzard trees to test the use of 3 ethephon applications of higher rates, 300 and 400 ppm, for effectiveness for flower induction in this difficult-to-manage cherry variety. Little gumming was observed in the summer of 2004, although shoot growth was definitely inhibited by the ethephon treatments.

C. Fruit loosening and fruit quality effects from ethephon and MCP.

1. MCP is an inhibitor of ethylene action. In 2003, MCP-treated fruit was firmer than untreated fruit at harvest, and MCP inhibited the flesh softening otherwise normally associated with ethephon treatment.
2. In 2004, an experimental, sprayable formulation of MCP was applied with the Proptec sprayer at three concentrations (54, 135 or 270 ppm active ingredient) in 100 gallons of water per acre. MCP was applied either three days before or on the same day as ethephon (3 pt/acre).
3. Unlike 2003, the sprayable MCP used in 2004 had no effect on fruit loosening, fruit firmness or any other fruit quality parameter, regardless of whether it was applied before or at the same time as ethephon.
4. Sprayable MCP did not affect fruit behavior over a 2l-week air storage period after harvest.
5. Ethephon loosened fruit and reduced flesh firmness in a similar manner to its performance in past years.

Methods:

Two trials from 2003 were carried over in 2004 to evaluate return bloom responses to ethephon applied in 2003. One trial was carried over from 2003 to evaluate the effects of GA on crop load and fruit quality, especially size, the following season. Four new trials were established in 2004 to 1) further explore the use of higher ethephon concentrations as a possible strategy for overcoming the inconsistent flowering response, 2) examine fruiting and return-bloom responses to applications of gibberellic acid, 3) compare GA_3 and an experimental, sprayable formulation of MCP for effects on fruit maturity and quality, and 4) evaluate effects of MCP and ethephon on fruit loosening and fruit quality for mechanical harvest.

Results and discussion:

GA applied during Stage I and/or II of sweet cherry fruit development reduced flowering the following season on 'Bing' trees on G.1 size-controlling rootstock. As one might expect, this effect

was dependent on both GA concentration and number of applications. The reduction in flowering was accompanied by a proportional reduction in yield that was also concentration dependent. Both mean fruit size and brix were increased as yield decreased. However, the proportional increase in both fruit weight and brix (approximately 11% maximum for both) was more than offset by the reduction in yield (approximately 60% maximum). This phenomenon, well documented for fruit thinning of apples, takes place because any amount of fixed carbon that might not be allocated to a larger amount of fruit is not totally reassigned to the remaining crop but is portioned out among fruit and vegetative tissues. Therefore, any reduction in yield is never fully offset by an improvement in the development of the remaining fruit. The point of maximum economic benefit of this form of crop-load adjustment ultimately depends on the comparative value of the composition of larger vs. smaller fruit making up the yield in question. These preliminary results do suggest that it may be possible to incorporate a GA treatment strategy into the management plan for sweet cherries on dwarfing rootstocks to help with crop-load control, a major problem with cherries on size-controlling rootstocks.

On the other side of the question, using ethephon to stimulate flowering in young trees on seedling rootstocks has not proven to be a reliable strategy. Part of this result may well be due to the specific characteristics of the seed sources used for rootstocks. Since each seed is genetically different, the likelihood is that the degree of juvenility varies slightly from tree to tree, which can easily complicate the goal of uniformly stimulating earlier flowering. We are testing higher ethephon concentrations as well as multiple applications in several trials to see if either strategy can improve the reliability of the response.

The results this year with MCP were disappointing. The formulation used this year was an experimental product that was changed again before the apple treatment season arrived, so it is possible that there may have been something about the trial formulation that restricted the potential activity of the active ingredient. Representatives of AgroFresh have agreed that we need to pursue this program for at least one more year to obtain a clearer idea of whether this concept in fact has merit.

Acknowledgments:
The assistance and support of the following persons and organizations is gratefully acknowledged: Noel Adkins, Mark Aldrich, Tom Auvil, Erasmo Avila, Randy Brown, Nancy Buchanan, Felipe Castillo, Dave Chisholm, Brett Franklin, Dennis Hayden, Jeff Henry, Arnoldo Hernandez, Dr. Chris Ishida, Dr. Gene Kupferman, Barbara Lorenz, Dr. Jim McFerson, David Ophardt, Chris Sater, Tory Schmidt, Floyd Stutzman, Dwayne Visser, Dr. Matt Whiting, Bayer Environmental Science, Brewster Heights Packing, Inc., Dovex Orchards, Hayden Orchards, Stutzman Orchards, Valent BioSciences, and the Washington Tree Fruit Research Commission.

Budget:

Project title: Bioregulator uses for managing growth, flowering and cropping and for facilitating mechanical harvesting in sweet cherry
PI: Don C. Elfving
Project duration: 2004-2006 (three years)
Current year: 2005
Project total (3 years): $43,037
Current year request: $14,473

Year	Year 1 (2004)	**Year 2 (2005)**	Year 3 (2006)
Total	$13,210	**$14,473**	$15,354

Current year breakdown:

Item	**Year 1 (2004)**	**Year 2 (2005)**	**Year 3 (2006)**
Salaries (technical) [1]	$ 7,000	**$ 7,280**	$ 7,571
Benefits (27% - yr 1) 31% (yrs 2 and 3)	1,890	**2,257**	2,347
Wages (time-slip) [1]	1,000	**1,100**	1,100
Benefits (16%)	160	**176**	176
Equipment	0	**0**	0
Supplies[2]	1,160	**1,160**	1,160
Travel[3]	2,000	**2,500**	3,000
Total	$13,210	**$14,473**	$15,354

[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. Proposed amount assumes withdrawal of state-funded support for technical support staff.

[2] 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.

[3] Treatment application and frequent data collection in distant sites, e.g. Pasco, Prosser, Yakima, Cashmere, Orondo, Quincy, etc. Includes vehicle lease-to-purchase, operating, repair costs.

CONTINUING REPORT

WTRFC Project # CH-04-400A/B

Project title: Environmental and Genetic Influences on the Components of Fruit Size in Sweet Cherry
PI: Amy Iezzoni
Organization: Michigan State University, Department of Horticulture, East Lansing, MI 48824, (517)355-5191, iezzoni@msu.edu
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OBJECTIVES

Maximizing fruit size is critical for profitable sweet cherry production. For any given variety, (e.g., Bing), the grower's goal is to achieve the fruit's genetic potential for size by using "proper" management practices. New varieties with the genetic capacity to produce larger fruit, such as Selah, provide an additional means to achieve large fruit size.

Both environmental and genetic methods of fruit size increase have been studied in the past. Currently, great strides are being made in the understanding of the physiological "carrying-capacity" of cherry trees (i.e., optimal leaf to fruit ratios for desired fruit size). Cultural manipulations such as blossom thinning, pruning, irrigation, and fertilizer management are also important methods of achieving large cherry size. However, fruit size continues to be a concern, particularly with the adoption of dwarfing rootstocks and the potential for over-cropping. New varieties released in the past decade, in most cases, have been selected for large fruit size (among other selection criteria) and their fruits are considerably larger than those from standard varieties. Despite these advances, the basic genetic and environmental mechanisms that result in large vs. small fruit are not well understood, thus limiting our ability to maximize the number of consistently large fruit.

Our overall goal is to understand the bases for achieving large fruit size in sweet cherry. Our experiments are designed to provide knowledge that will be used to design future management and genetic improvement strategies that would ultimately result in maximized fruit size in grower orchards. Our objectives are based upon the premise that fruit size is maximized using both optimal cultural practices (environment) and large-fruited varieties (genotype).

The specific objectives of this research are to:

1. (a) Determine the effect of cultural practices, such as crop load manipulation, on cell size and cell number in Bing and Regina cherry. (b) Determine the developmental timing of these differences.
2. (a) Determine the differences in cell size and cell number associated with genetic differences in fruit size using three varieties that differ dramatically in fruit size. (b) Determine the developmental timing of these differences.
3. Determine the quantitative trait loci (QTL) that contribute to large fruit size. This is the first step towards the identification of the major genes controlling fruit size in sweet cherry.

SCHEDULE OF ACCOMPLISHMENTS

End of YEAR 1
(1) Completion of the comparison of cell size and number from Bing and Regina fruit from crop load treatments.
(2) Completion of a precise determination of the developmental stage(s) in which differences in cell size and cell number occur in Selah, EF, and NY54.
(3) Initiated the construction of the sweet cherry linkage map.

During the first project year (2004), Bing and Regina fruit from trees adjusted for crop load were sampled from Prosser. Crop load adjustment resulted in significant fruit size differences (see Results and Discussion). Within each variety, the fruit size increase apparent with thinning was due to increases in cell size, not cell number. In contrast, a comparison of fruit from different varieties exhibiting a wide range of fruit sizes confirmed our previous observation that cell number differences are the primary genetic determinant of fruit size. The period between bloom and pit hardening was identified as the developmental period when cell number differences were first apparent (see Results and Discussion). Construction of a sweet cherry linkage map is ongoing, with molecular marker screening and progeny genotyping currently underway.

End of YEAR 2
(1) Completion of a precise determination of the developmental stage(s) in which differences in cell size and cell number occur in Bing and Regina fruit of different sizes subjected to different crop loads.
(2) Completion of the QTL analysis to identify regions containing gene(s) contributing to fruit size in sweet cherry. [This result should provide sufficient preliminary data to apply for USDA/NRI funding.]

During the next project year (2005), Bing and Regina fruit will again be sampled from crop load adjusted trees expected to produce measurable differences in final fruit size. Completion of a sweet cherry linkage map will provide a resource for quantitative trait loci (QTL) mapping of genomic regions important for fruit size in cherry.

SIGNIFICANT FINDINGS

- When comparing different sweet cherry varieties, the most important determinant of final fruit size is the number of cells in the flesh.
- Within the same variety, larger fruit have the same number of cells but the cells are larger than those of smaller fruit.
- Differences in flesh cell number among different varieties are not apparent until after bloom.
- Cell division in the flesh starts and is completed within 6 – 10 days (approx. 50 GDD) after full bloom.
- Cell division in the flesh does not continue past pit hardening.

METHODS

The methodology used for these experiments has not changed from what was originally proposed.

Objective 1 (within genotype): (a) Determine the effect of cultural practices such as crop load manipulation, deficit irrigation, and nitrogen fertilization on cell size and cell number in Bing and Regina cherry. (b) Determine the developmental timing of these differences.

A second year of sampling will be made from Bing and Regina trees in Washington and Oregon subjected to horticultural manipulations expected to generate fruit size differences between treatments. Special emphasis will be placed on sampling dates near key developmental periods identified in Objective 2 of these experiments. Fruit quality measurements will be made prior to sectioning for laser confocal microscopy. Images will be analyzed using digital image processing software.

Objective 2: (a) Determine the differences in cell size and cell number associated with genetic differences in fruit size using three varieties that differ dramatically in fruit size. (b) Determine the developmental timing of these differences.

No additional samples are proposed for the second year of this project.

Objective 3: Determine the quantitative trait loci (QTL) that contribute to large fruit size.

The first fruit should be available for QTL analysis from the fruit size population developed at Michigan State University. We will continue to develop a molecular linkage map using a combination of markers suitable for comparison to other *Prunus* species (RFLP and SSR), as well as "high-throughput" markers (AFLP and SRAP). The goal is to develop linkage maps for both parents that identify 8 linkage groups corresponding to the 8 haploid chromosomes in sweet cherry, with an average distance of 10 cM between adjacent markers.

RESULTS AND DISCUSSION

In our comparison of fruit size between a large size cherry [Selah], a medium size cherry [Emperor Francis (EF)] and a small-fruited mazzard cherry [New York 54 (NY54)], the difference in final fruit size was primarily due to a difference in cell number and not cell size (Table 1). The nearly 11.5 gram difference in size between NY54 and Selah was due to a 74% increase in the number of flesh cells and only a 24% increase in the size of those cells. Clearly, cell number increase was the most important factor in the increased fruit size of Selah.

For the same three varieties, samples taken at different fruit developmental stages indicated that differences in cell number approximating the final cell number count were evident by the onset of pit hardening. More importantly, all three varieties sampled at bloom had similar numbers of cells in the ovary wall, tissue destined to become flesh as fruit development proceeds (Table 2). Using this information, an additional set of samples for EF were collected in Michigan, starting at bloom and continuing every 10-50 growing degree days (base temperature 40 F) until pit hardening occurred. This set of samples further narrowed the time during which fruit cell number increased, to a period of 6-10 days after full bloom (Fig. 1).

Table 1. Comparison of fruit anatomical and morphological characteristics among Selah, Emperor Francis (EF), and NY54.

Variety	Fruit[z] wt. (g)	Fruit dia. (mm)	Cell no. (pit to skin)	Avg. cell size (mm^2)
Selah	12.8 a[y]	26 a	83 a	0.027 a
EF	6.1 b	21 b	47 b	0.024 b
NY54	1.4 c	12 c	27 c	0.020 b

[z]Avg. of 25 fruit for weight and diameter, 5 for cell size and number.
[y]Mean separation in columns by LSD at $P < 0.05$.

Table 2. Comparison of cell number between Selah, EF, and NY54 at different fruit developmental stages.

Variety	Bloom	Pit harden	Harvest
Selah	24 b[y]	70 a	83 a
EF	17 a	40 b	47 b
NY54	25 b	26 c	27 c

[y]Mean separation in columns by LSD at $P < 0.05$.

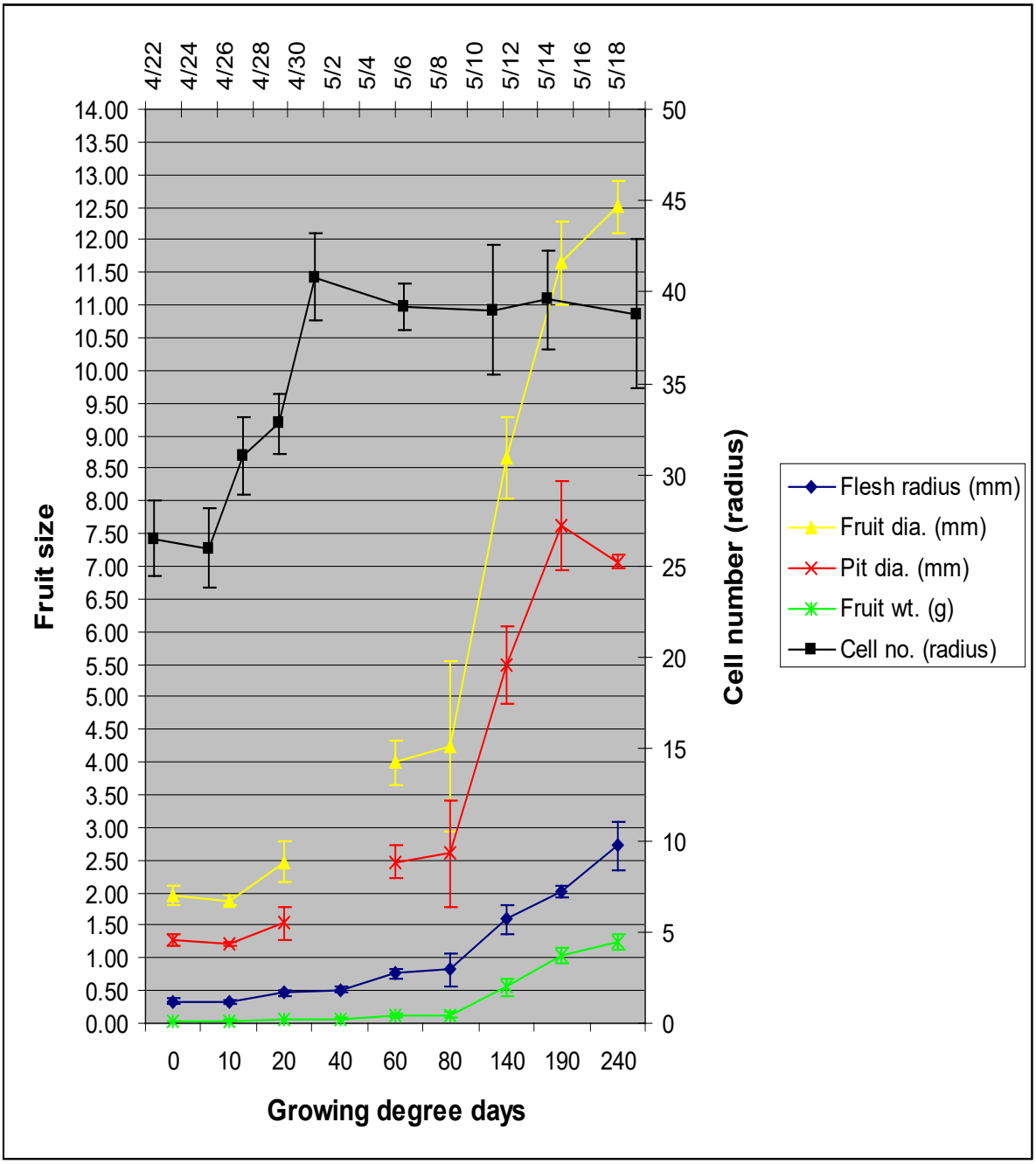

Figure 1. GDD based (40 F base temp.) sampling of EF fruit from bloom (0 GDD, 4/22/04) until pit hardening (240 GDD, 5/19/04)

Figure 2. Representative crop load on Bing trees thinned to one bud per spur (top) and left unthinned (bottom).

Table 3. Comparison of fruit size characteristics between Bing fruit from crop load adjusted trees.

Treatmen	Cell no.[z] (pit to skin)	Flesh length (mm)	Avg. fruit wt. (g)	Avg. fruit dia.	Avg. fruit row	Avg. pit wt. (g)	Avg. pit dia. (mm)
Unthinned control	48.3 n.s.	9.02*	7.65***	24.8***	11	0.50*	7.4**
1 flower bud /	48.5 n.s.	9.58*	9.44***	26.7***	10	0.57*	7.9**

[z]Mean separation in columns by LSD; n.s. = non significant, *, **, *** = significance at $P<0.05$, 0.01, 0.001 respectively

To better understand the environmental influences on fruit size, Bing fruit from Prosser that had been bud-thinned to one flower per spur prior to bloom (Fig. 2) were sampled weekly during the 2004 growing season. Fruit sizes on the thinned trees were nearly two grams larger than the unthinned control at harvest. The use of crop load adjustment provided a method to generate differences in fruit size within a single variety. The pertinent question in this experiment was whether fruit size increase in the same variety was due to cell number increase (as indicated in the comparison of Selah, EF, and NY54), or cell size increase. Our results indicate that the large fruit size resulting from thinning was solely due to an increase in cell size (Table 3). Both treatments had near identical flesh cell numbers.

The final size of cherry fruit results from both an increase in the number of cells in the fruit and the expansion of those cells. Although expansion of the cell volume contributes greatly to overall fruit size, it is the total number of cells in the fruit flesh that sets the stage for eventual fruit expansion. Our results strongly suggest that the average cell number in the flesh is a genetically controlled trait. Variation in cell number was the most significant and consistent difference between a very small size (NY54) mazzard fruit and the very large sized Selah fruit. There are simply fewer cells available for expansion in NY54 than in Selah. Consistent with our hypothesis that cell number is a strongly genetically controlled trait, analysis of Bing fruit revealed similar cell numbers in the flesh regardless of final fruit size. Because all Bing trees are genetically identical, the lack of variation for this trait indicates that variation in fruit size within a single tree is due to environmental influences on cell size.

The stability of the cell number trait when subjected to different physiological conditions will significantly enhance our ability to locate the genes controlling fruit size, one of the Year 2 objectives. The identification of genomic regions controlling fruit size will increase the efficiency of a breeding program by providing an improved method of selecting varieties. In addition, an eventual understanding of the fruit size genes may suggest ways in which one could intervene with cultural practices to maximize cell number.

This year's data illustrates how a better understanding of the cellular development of cherry fruit would allow us to better target cultural practices. For at least the subset of varieties we have tested, the flowers had approximately the same cell number bloom. However, cell division was not affected by our crop load adjustments, even though the bud thinning was performed prior to bloom. Surprisingly, cell division in the developing cherry fruit occurred very early in Stage I growth, within 6-10 days after bloom. This is in contrast to both apple and peach, where cell division can be measured on a weekly timescale. The detailed knowledge provided by these experiments will be an important tool for cherry physiologists in attempts to maximize the fruit size of existing and future cherry varieties.

BUDGET

Title: Environmental and Genetic Influences on the Components of Fruit Size in Sweet Cherry

P.I.: Amy Iezzoni
Project Duration: 2 years (2004-2005)
Current Year: 2005
Project Total (2 years): $50,442
Current Year Request: $25,548

Item	Year 1 (2004)	**Year 2 (2005)**
Salary[1]	$16,344	**16,998**
Wages[2]	500	**500**
User fee – confocal microscope[3]	1,500	**1,500**
Supplies[4]	4,000	**4,000**
Travel[5]	550	**550**
Plot fees at CHES[6]	1,000	**1,000**
Prosser costs[7]	1,000	**1,000**
Total	$24,894	**$25,548**

[1]Salary for Ph.D. student.
[2] Wages for student labor to help with sample preparation.
[3] Fees for the use of the Confocal Laser Scanning Microscope at MSU's Center for Advanced Microscopy. The user fee is $15/hr.[http://www.ceo.msu.edu/Services.htm]
[4] Microscopy supplies are budgeted at $200/yr. Cost of supplies for DNA extraction and marker genotyping is $3,800/yr. This is based upon supply cost to genotype 190 progeny and the two parents using 25 AFLP primer pairs and 32 SSR primer pairs.
[5]Travel to Prosser at sweet cherry harvest to meet with Matt Whiting relative to the cultural experiments.
[6]Starting in 2004, plot fees are charged at all MSU Horticultural Research Stations. These costs are based upon a fee structure that reflects the cost of standard plot maintenance.
[7]These funds are for to Matt Whiting to cover the cost sampling and overnight shipping.

FINAL REPORT

WTFRC Project #CH-02-202 **WSU Project #13C-3655-3298**

Project title: Induction of branches (feathers) in sweet cherry trees in the nursery and orchard

PI: Don C. Elfving, Horticulturist
Organization: WSU Tree Fruit Research and Extension Center, Wenatchee, WA

Cooperators: Matthew D. Whiting, Assistant Horticulturist, WSU-IAREC, Prosser, WA
Dwayne Visser, Agricultural Research Technologist II, WSU-TFREC, Wenatchee, WA

Objectives:

1. Evaluate use of bark-injury techniques (scoring, notching) in conjunction with growth-stimulator bioregulator treatments (cytokinins, gibberellins, cyclanilide, other products) under orchard conditions for improving the effectiveness of branch induction in young trees at the dormant and green-tip growth stages.
2. Assess the relation of timing of green-tip treatments on efficacy of branch development and quality of the lateral branches formed.
3. Assess the effect of cyclanilide on branch development in young, vigorous sweet cherry trees in the orchard. Examine the potential for combining chemical branch induction with later treatments of Apogee and/or Ethrel for stimulation of flowering and cropping.
4. Determine the relationship of cultivar and vigor level to responses to cyclanilide.
5. Evaluate cyclanilide and cytokinin/gibberellin applications to sweet cherry trees in the nursery on overall development of the trees, development of lateral branches (feathers) and occurrence, if any, of phytotoxicity or other negative side effects.
6. Assess the relation of timing of applications in the nursery to development of branching, location of branch development on the tree, number, angle and quality of the lateral branches formed.
7. Relate the height of cyclanilide-induced branching in nursery trees to height of the shoot tip at the time of application to develop a criterion for determining the correct application timing for desired branch height on feathered trees.

Significant findings:

Over the three-year period of this project, 44 trials were undertaken to assess a variety of methods of bioregulator use with or without bark-injury treatments at various times of the growing season to encourage profuse lateral branching in unpruned sweet cherry trees. Unpruned young sweet cherry trees produce virtually all branching from the terminal portion of shoots due to their very strong apical dominance. Trials were initiated to examine the potential of cyclanilide to induce bud development in the spring on buds from the previous growing season as well as buds on 2-year-old wood. Other trials examined the potential for application of scoring and notching with and without supplemental treatment with various bioregulators at the green-tip stage for stimulation of lateral branch formation. Applications of various bioregulators during spring after shoot growth began were made to evaluate the usefulness of those products for breaking apical dominance and induction of branching during the growing season.

Methods:

Over the three-year period of this project, 44 trials were undertaken to assess various aspects of bioregulator use for induction of branching in fall/winter, at the green-tip stage of development in the spring, and during the active growing season. Trials were conducted on young, non-fruiting sweet cherry trees on Mazzard seedling and on Gisela rootstocks. Bioregulators tested included cyclanilide,

Promalin®, Maxcel®, and thidiazuron (TDZ), a powerful cytokinin. Products were applied alone or in combination as sprays or dispersed in latex paint in conjunction with various bark injury treatments, such as scoring, notching, girdling or vertical cuts.

Results and discussion:
During the course of this project, progress was made on all objectives. Detailed results are not available for 2004 projects as of this writing (September 2004) but observations will be reported here. The following results and conclusions have been obtained during the three years of this project:

A. Induction of branching during the dormant period (fall, winter).

1. Cyclanilide at up to 5,000 ppm and/or Promalin® at up to 500 ppm applied in latex paint as bands over 3-4 buds on the mid-shoot to lower-shoot portions of the previous season's shoot growth prior to budbreak on the cultivars 'Bing' and 'Rainier' was ineffective at inducing any bud development that spring, either from treated buds or from any other buds on the treated shoots.
2. Cyclanilide at up to 15,000 ppm mixed with Superior spray oil as an adjuvant was applied to trunks and trunk crowns in either October or March, before budbreak of young trees of 'Bing', 'Rainier', 'Skeena' or PC8011-3 cherry trees to test the potential for translocated effects on branching. Although positive effects of such treatments have been found in pear, no beneficial effects on branch induction in sweet cherry trees were observed.

B. Induction of branching during the bud break period (green-tip).

1. At green tip, painting one-year-old buds on the previous season's shoot growth or painting bands around the bark between buds with up to 5,000 ppm Promalin did not produce any benefit on lateral-branch development in young 'Bing' or 'Skeena' trees.
2. Painting buds at green-tip with cyclanilide at up to 1,000 ppm or painting notched buds with 250 ppm cyclanilide did not produce significant lateral branch development in young 'Bing' or 'Skeena' trees.
3. Scoring vertical, one-year-old vigorous shoots every foot, starting at one foot below the terminal, did not increase the number of shoots but did improve their vertical distribution, assuring that some emerged from the lower portions of the scored shoots.
4. Scoring plus Promalin treatment appeared to be most effective at green-tip. Similar treatments applied two weeks after green-tip did not produce as strong a response.
5. Notching and disbudding improved branching somewhat but did improve the formation of new branches from the lower portions of treated shoots.
6. Scoring one-year-old shoots plus painting the cuts with 5,000 ppm Promalin increased lateral branching up to fivefold in 'Bing', 'Rainier' and 'Lapins' trees while also assuring that good lateral branching took place from the lower portions of shoots, where branching normally does not occur.
7. Promalin only works well as a branch-induction treatment in sweet cherry when the bark barrier is interrupted with some form of injury at the time of Promalin application. Promalin applied to scores, girdles or notches produces a strong branching response in vigorous trees in the total absence of pruning.
8. Treating vertical cuts with Promalin showed that the Promalin branching effect moves mainly downward, only slightly laterally. Thus, the way Promalin is used can influence the location of resultant branching.
9. Applying Promalin along with a bark-injury method also produces branching on horizontal shoots, but the induced branches are less vigorous that those produced on vertical shoots.
10. Notching or scoring plus Promalin applied to two-year-old branch sections did not produce much benefit in terms of lateral branching. There was a tendency to induce the formation of a few strong, vertical, sucker-like shoots, which could only be made useful if careful follow-up management was used to train those shoots before they harden into position.

11. Concentrations of Promalin above 5,000 ppm should either not be used or used with great care. Treatments with 10,000 ppm Promalin produced phytotoxic effects on the cambium in one trial.
12. Care should be taken to use tools for scoring that do not produce a wide cut. In these trials, use of a saw blade of 2.0 mm width produced a girdling effect that resulted in considerable damage. Girdling does not improve the branching response. Scoring should only be done with a sharp knife blade.
13. Notching can be done with a blade of up to 1.0 mm width; a greater width of cut subjects the tree to possible excessive injury.
14. In two years of applying knife and saw cuts to young cherry trees at green-tip, not one infection of bacterial canker occurred as a result, even when rain took place on the same day as the injury treatments were applied. These results should not be interpreted to mean that bacterial canker infection is not a serious risk when using bark-injury methods. More research is needed to assess the level of risk for bacterial canker bark injury poses at this time of year.
15. Notching and disbudding techniques, which do not involve an overall interruption of apical dominance as does scoring, lost effectiveness in the lower portions of treated shoots. Apparently the apical dominance effect in shoots increases with distance from the terminal; this increased effect is most easily overcome with methods such as scoring plus bioregulator treatments that produce a strong interruption of apical dominance.
16. Notching is used commercially to increase branching in young trees. In our trials, notching alone produced a success rate of between 18 and 37% (i.e., only one out of every 3-5 notched buds produced a shoot).
17. To this point in the research program, effective branch induction using scoring and Promalin is very labor intensive. Further work is planned to determine if more efficient ways can be found to obtain the tremendous improvement in branching we have seen without as much investment of time in labor.

C. Induction of branching during the early season (shoot growth just starting).

1. Cyclanilide sprays at up to 100 ppm with or without Promalin (500 ppm) applied to the lower halves of one-year-old, vertical leader shoots of 'Bing' and 'Sweetheart' trees when shoot growth was just beginning had no effect on inducing lateral branching from the treated sections.

D. Induction of branching during the growing season.

1. In trials on young, non-fruiting trees of 'Bing', 'Rainier', 'Skeena' and 'Tieton', cyclanilide at 50-500 ppm applied when new terminal shoots were 18-30 cm in length produced lateral branching from the actively growing new shoots. The new shoot growth occurred from the group of lateral buds that were in the shoot tips at the time of treatment. A single treatment with cyclanilide temporarily interrupts apical dominance, producing a flush of new shoots.
2. Using Promalin alone (250-500 ppm) or combining it with cyclanilide has produced some benefits in some trials and little improvement in branching in other trials. Cyclanilide appears to be a more consistent branching agent for cherries.
3. Preliminary trials with thidiazuron (TDZ, Dropp®) at 100 ppm produced bud activity but did not result in normal lateral branch development. Further work is needed at different concentrations to fully assess the potential benefit of this powerful cytokinin-like bioregulator for branch induction in sweet cherry trees, as well as more work with combinations of TDZ with other branch-induction materials.
4. Applying cyclanilide at 200 ppm did not significantly improve branch formation over 100 ppm but substantially increased phytotoxicity on leaves.
5. Cyclanilide or cyclanilide plus Promalin treatments to older wood of 'Sweetheart' trees when shoot growth was about 19 cm in length did not result in any improvement in branching.
6. Observations indicate that cyclanilide-induced branching is directly dependent on the vigor of the treated shoots at the time of treatment. The best branching response is found in vertical shoots, a

weaker branching response is observed in inclined or horizontal shoots, and a poor response is obtained when trees are not growing strongly.
7. Preliminary trials have been carried out with double applications of cyclanilide to try to improve the branching response under orchard conditions. So far, double applications under orchard conditions have not produced a strong benefit in terms of branching.

E. Nursery applications.
1. Cyclanilide at 50-100 ppm has produced excellent feathering in 'Bing', 'Skeena' and 'Lapins' trees in the nursery.
2. Using Promalin alone (250-500 ppm) or combining it with cyclanilide has produced some benefits in feathering in some trials and little improvement in other trials. Cyclanilide appears to be a more consistent feathering agent for nursery cherry trees.
3. Timing cyclanilide treatments is critical, since the location of induced feathers depends on tree height at the time of treatment. Preliminary work has been carried out to develop a reliable criterion for determining the timing of cyclanilide applications in relation to the height at which lateral branching is desired. Different markets demand branching at different heights, hence the importance of a reliable timing criterion.
4. In 2003, detailed trials suggested that cyclanilide-induced feathering was induced at 10-18 cm ABOVE the height of the shoot tip at the time of treatment. This observation confirms the hypothesis that the buds that are activated by cyclanilide are those deep in the shoot tip at the time of treatment. Hence cyclanilide produces a very localized, as well as temporary, interruption of apical dominance.

Summary:
Effective treatments for interrupting sweet cherry apical dominance and inducing lateral-branch formation have been developed for the early spring (green-tip) timing and for later, after shoot growth has begun. The approaches at these two times are quite different. At green-tip, the objective is to induce pre-existing buds on the previous season's (one-year-old) shoots to develop into branches. At this timing, the most successful branching has been obtained where the bark barrier is interrupted and mixtures of cytokinin/gibberellic acid (e.g., Promalin®) are applied to the wounded area(s). Simple painting of buds or scoring or notching alone is not sufficient to assure an effective branching response. In addition, auxin-metabolism inhibitors such as cyclanilide are ineffective at this time, even when the bark barrier is interrupted. At this point in this research program, the methods that are most effective for green-tip branch induction are very labor intensive. Further research is needed to develop more efficient means of obtaining the same or better results for less cost.

After shoot growth has begun, chemical branch induction is only possible on buds on the new, green shoot growth being produced that season. Treatments applied at this time that are effective on green tissue do not stimulate branch development from older, pre-existing buds on the woody portions of the tree. At this time of year, both auxin-metabolism inhibitors and cytokinin/GA mixtures are effective for lateral branch induction, but the auxin inhibitor cyclanilide appears to be more effective. Because only buds deep in the shoot tip are induced to grow, the timing of the application directly affects where the new branches develop. Because the interruption of apical dominance is temporary, a flush of branches develops, but it has not been possible thus far to produce any kind of sustained branching from one or two applications of either auxin-inhibiting or cytokinin-based growth-promoting bioregulators. Flowering the year following branch-induction treatments in non-fruiting trees has not been increased. It is anticipated that increased lateral branching will benefit productivity over a longer term period.

The growing season-type branching treatments have been most effective and appear to have the most useful application for production of branched trees in the nursery. With the move to size-controlling

roostocks and higher density plantings for sweet cherry, we expect the demand for branched trees from the nursery will increase greatly.

Acknowledgments:
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Summary of total project costs:

Project duration:	Three years
Total project costs:	$25,048

FINAL REPORT

WTFRC Project #AH-03-305 **WSU Project #13C-3655-5326**

Project title: Suppressing cherry cracking and post harvest stem browning and water loss

PI: Larry Schrader
Organization: Tree Fruit Research and Extension Center, WSU-Wenatchee

CO-PIs: Matthew D. Whiting[1] and Eric Curry[2]
Organization: [1]Irrigated Agriculture Research and Extension Center, WSU-Prosser
[2]USDA/ARS Tree Fruit Research Laboratory, Wenatchee

Cooperators: Gordon Brown[3], Leo Jedlow[1], David Felicetti[1], Jianshe Sun[1], Jianguang Zhang[1], Jeong-Hak Seo[1], and David Ophardt[2]
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Contract administrator: Mary Lou Bricker (mdesros@wsu.edu) (509) 335-7667; or Tom Kelly (kellytj@wsu.edu) (509) 335-3691

Objectives:

1. Determine efficacy of spraying a new hydrophobic/lipophilic formulation to suppress cracking of cherries.
2. Optimize timing and rate of application of the new formulation.
3. Investigate fruit cracking with electron and low magnification microscopy to observe formulation effects on cherry cuticle and differences in conductive tissue morphology in various cherry cultivars.
4. Determine whether fruit quality and appearance are altered by the formulation.
5. Determine efficacy of the new formulation for decreasing water loss from harvested cherries and for retention of green stems on cherries after harvest.

Significant findings:

1. A new improved formulation (RainGard, patent pending) suppressed cherry cracking in orchard trials where significant rain occurred during the 2004 growing season. Cracking in 'Bing' cherries was decreased as much as 62% in one Oregon orchard (Fig. 1). Cracking suppression in field trials was comparable to controlled studies conducted earlier in our lab and research orchard.
2. In four trials on 'Rainier' cherries, cracking was decreased significantly ($P<0.05$) in three trials with one or two applications of RainGard (Fig. 2).
3. Even though the first RainGard application was done three weeks before maturity at "straw" color, cracking had already occurred in some orchards. Thus, the first application should have been made earlier in 2004, as cracking occurred as early as four weeks before maturity.
4. In some trials, the first application was as effective as two because no rain occurred after the first application.

5. RainGard caused a significant reduction in cracking of 'Sweetheart' cherries in the lower canopy where irrigation water caused severe cracking. RainGard was significantly better than Vapor Gard or the untreated control (Fig. 3).
6. With 'Rainier' cherries, timing of applications was important. An application at one week before maturity (hours before a rain) was significantly better than an application made three weeks before maturity. These single treatments and a combined treatment (at three weeks and one week before maturity) were all significantly better than the untreated control (Fig. 4).
7. Dr. Brown studied efficacy of RainGard in Tasmania, Australia, in late 2003. Arrival of the formulation was delayed by Customs in Sydney so cracking had occurred prior to the first application. However, cracking was reduced in 'Bing' and 'Van' by one and two applications of RainGard (Table 1) as compared to the control.
8. Using electron microscopy, Dr. Curry compared untreated cherries to cherries treated with 10% (v/v) formulation as well as calcium chloride (Figs. 5 and 6). His micrographs showed a nice coating of the cherries with the formulation without affecting stoma opening (Fig. 6).
9. Microscopic studies done at lower magnification in our lab showed cultivar differences in conductive tissue morphology, especially at the stylar scar. Open channels were observed in cultivars that were more prone to cracking when compared to cultivars that are more resistant to cracking.
10. Fruit quality (e.g., weight, firmness, color and brix) was not changed significantly by preharvest applications of RainGard during 2004. No negative effects on fruit quality or size were observed with RainGard.
11. Although promising results were observed in previous years, green stem retention and moisture loss were not significantly changed by one or two preharvest applications of RainGard in 2004. All fruit maintained in cold storage retained green stem freshness for three weeks but deteriorated quickly as the fruit warmed to room temperature.
12. Stem browning occurred first at the end of the pedicel and progressed toward the cherry as time at room temperature elapsed.

Methods:

Objective 1: The formulation was applied on cherry trees of several cultivars in commercial orchards in central Washington and northern Oregon by spray application at a rate of 10 gallons of formulation per acre. Four uniform blocks of approximately 0.75 acres were selected for three treatments and a control. The protocol called for the formulation to be applied three weeks before harvest in treatment A, one week before harvest in treatment B, and three weeks and one week before harvest (two applications) in treatment C. Treatment D was an untreated control. The three-week application was designed to occur at the "straw color" when cherries were first thought to be susceptible to rain-induced cracking. Growers were advised to use normal practices (e.g., airblast sprayer, helicopter, calcium spray, etc.) to protect their cherries in the event of rain as long as all blocks were treated the same. Growers contacted us if they experienced rain-induced cracking. At sites where cracking was present, four trees were randomly selected for evaluation from each treatment protocol and affected cultivar. All of the fruit from a single limb in the southwest canopy of the selected trees was harvested, and the number of cracked vs. non-cracked fruit and the type of cracking (stem bowl, stylar end, shoulder, suture, other) was recorded for comparison to the control blocks. Data were analyzed statistically.

Objective 2: Cracking frequencies for each treatment were compared to determine when and how often the formulation should be applied. In northern Oregon, rain-induced cracking occurred in some orchards before the first application was made. Rain-induced cracking occurred at only one experimental site in central Washington, but cracking was observed in one orchard due to irrigation water exposure.

Objective 3: Previously submitted reports outline methods used to study formulation effects on the cherry cuticle and morphological differences as seen in microscopic examinations**.**

Objective 4: At harvest, maturity samples were collected from each of the trials. Four trees were selected from each treatment. Five 2-lb clamshells were filled with cherries from each of the selected trees. All fruit was stored at 33°F within four hours of harvest. The following day, sample lots of 25 cherries from each replication were allowed to warm to room temperature before testing for size and firmness with a FirmTech 2. The cherries were then evaluated for color using the CTIFL cherry color comparators (1-6 scale). Finally, the juice expressed from each lot of 25 cherries was tested for brix using a digital refractometer. These tests were repeated at weekly intervals for three weeks post harvest.

Objective 5: Cherries from each of the previously described samples were also used to assess green stem freshness by assigning a value for the stem color from 1-4 based on the amount of browning present (1=25% browning, 2=50% browning, 3=75% browning, and 4 =100% browning). A weighted average for the frequency of observations in each category gave a relative comparison of the effectiveness of each treatment. These assessments were done on cherries at room temperature. Moisture loss was determined by comparing the initial post harvest weights of cherries in two clamshells with the weights of those same cherries at three weeks post harvest.

Results and discussion:

During 2004, the improved formulation, RainGard, was tested in 11 orchards in Oregon and Washington. Rain induced cracking in ‘Bing’ cherries at four orchards near The Dalles and Hood River, OR. Cracking was reduced by one or two applications of RainGard in all four trials (Fig. 1) and was significantly different ($P<0.05$) than the untreated control in orchards 1 and 2. In orchard 4, RainGard was significantly different ($P<0.10$) than the untreated control. Some cracking had occurred in orchards 3 and 4 prior to the first application of RainGard so these efficacy data were compromised. Due to a misunderstanding, the spray applicator made two applications to all cherries except the controls in orchard 1. In the other trials the results shown in Fig. 1 compare treatment A (applied three weeks before maturity) with the untreated control, as there was little change in cracking between treatments A, B, and C.

In ‘Rainier’ cherries, two applications of RainGard significantly reduced cracking ($P<0.05$) in orchards 1 and 2 in Oregon and in orchard 4 in Washington (Fig. 2). In orchard 3, RainGard was significantly better ($P<0.10$) than the control. Cracking in ‘Rainier’cherries was predominantly in the suture of the fruit, whereas cracking in other cultivars was predominantly at the stylar end or around the stem bowl (data not shown).

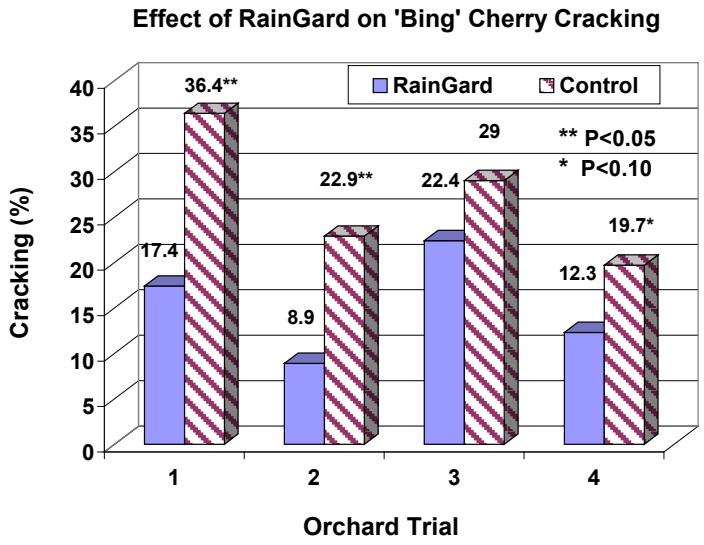

Fig. 1. Efficacy of RainGard for protecting 'Bing' cherries from cracking in four Oregon orchards. Rain caused cracking in all four orchards. RainGard was applied by growers at approximately three weeks and one week before maturity, but the results for only the three-week treatment and controls are shown for orchards 2 through 4.

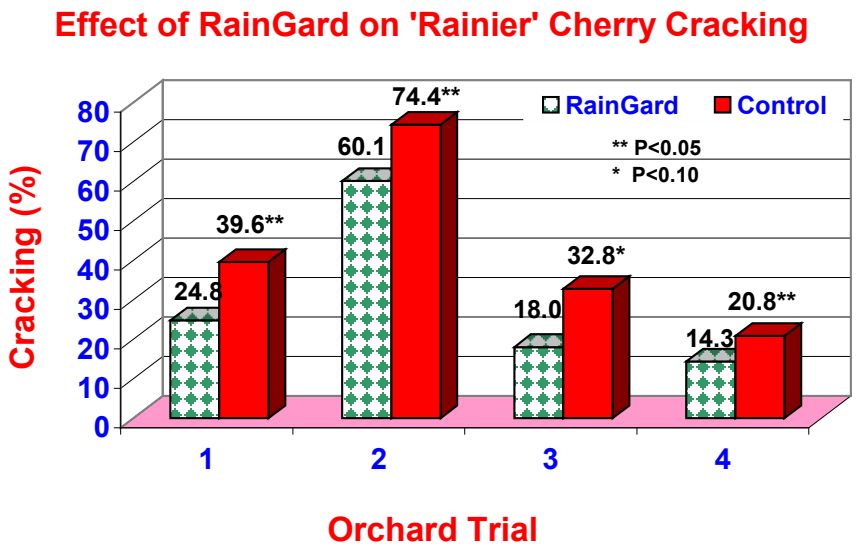

Fig. 2. Efficacy of RainGard for protecting 'Rainier' cherries from cracking in three Oregon and one Washington orchard. Rain caused cracking in all orchards. RainGard was applied by growers at three weeks and one week before maturity.

In another trial near Brewster, WA, two applications of RainGard reduced cracking in 'Sweetheart' cherries in both the upper and lower canopy. Undertree irrigation caused a high level of cracking in the lower canopy, and RainGard significantly ($P<0.05$) reduced cracking as compared to the untreated control or cherries treated with two applications of Vapor Gard (Fig. 3).

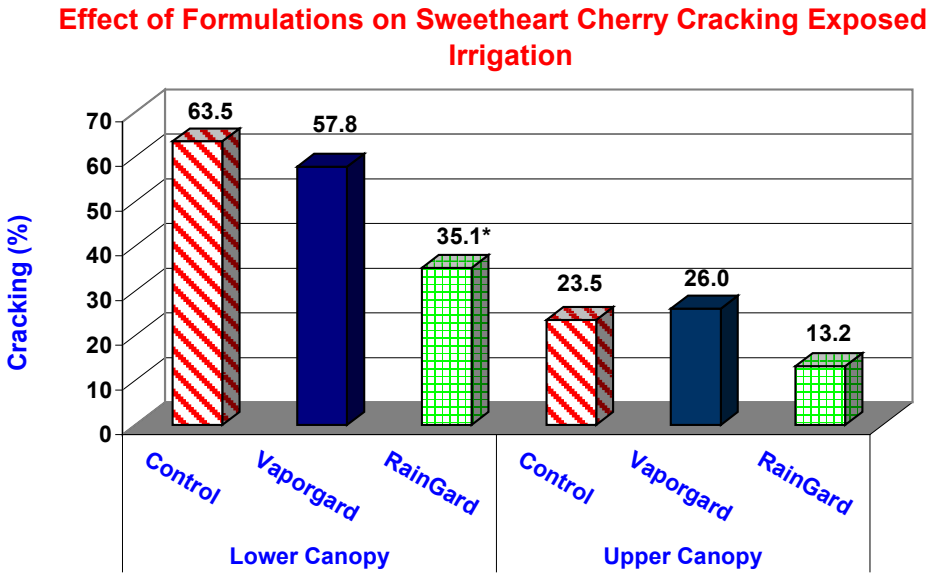

Fig. 3. Efficacy of Vapor Gard and RainGard for protecting 'Sweetheart' cherries from cracking. RainGard was applied by grower at three weeks and one week before maturity. Vapor Gard was also applied twice. Undertree irrigation caused substantial cracking of cherries in the lower canopy.

In a timing study involving 'Rainier' cherries, cracking in treatments A, B, and C was significantly lower ($P<0.05$) than in the untreated control (Fig. 4, treatment D). Treatment B was significantly better than treatment A. Rain occurred within hours after the second application was made (Fig. 4, treatments B and C). Optimal timing of applications is therefore dependent on when rain occurs at that site. Maximal protection from cracking is dependent on maintaining an effective film on the fruit, as fruit surface area doubles (100% increase) each time the fruit diameter increases by only 40%. For example, a cherry that is 0.33 inches in diameter increases in surface area by 300% by the time it reaches a diameter of 0.91 inches. That cherry increases in surface area by 400% if its diameter reaches 1.28 inches by maturity. Therefore, a single application three or four weeks before maturity is not sufficient to provide an effective rain-repelling film until maturity. Two or three applications may be needed to protect the fruit until maturity.

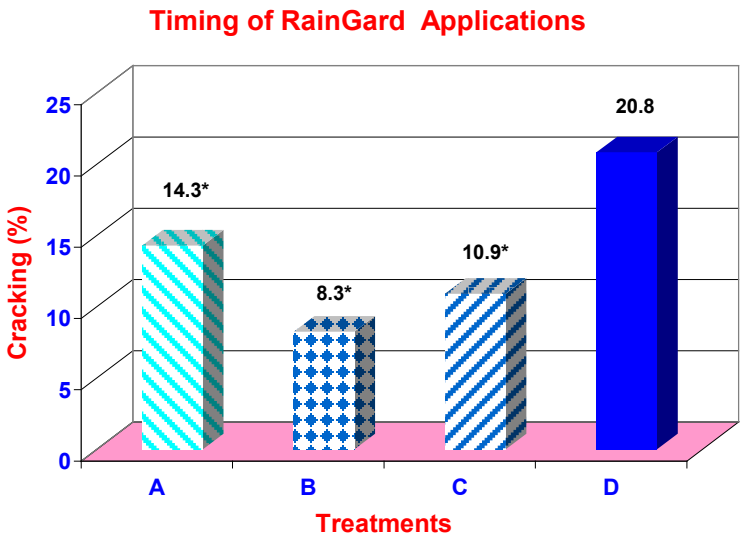

Fig. 4. Effect of timing of RainGard applications on cherry cracking in 'Rainier' cherries (treatment A=one application at three weeks before maturity; treatment B=one application at one week before maturity; treatment C=two applications (three weeks and one week before maturity; treatment D=untreated control).

Dr. Gordon Brown, our cooperator in Tasmania, Australia, also conducted experiments during late 2003. Unfortunately, the formulation was quarantined in Sydney, Australia for at least two weeks so Dr. Brown was unable to apply the formulation as early as desired. Substantial cracking had occurred before his first application. In spite of that, the formulation applied two weeks before harvest (2 wbh) or one week before harvest (1 wbh) had more intact cherries (i.e., less cracking) than the untreated controls (that had rain blown off three times by helicopters). The differences were not statistically different at $P<0.05$.

Table 1. Percent intact 'Bing' or 'Van' cherries in study comparing RainGard with Vapor Gard in Tasmania, Australia. Applications were made one (1wbh) or two weeks (2wbh) before harvest. Study was conducted by Gordon Brown and colleagues in Tasmania.

Treatment	% Intact Bing	% Intact Van
Untreated	75.20	82.00
2 wbh	84.98	85.75
1 + 2wbh	79.58	84.50
1 wbh	84.38	82.50
Vapor Gard	77.73	87.50

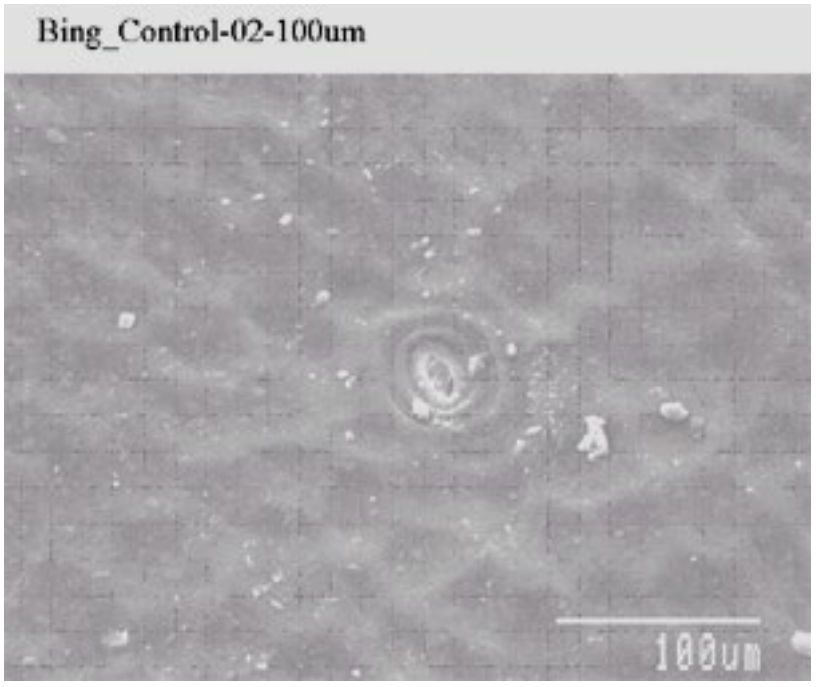

Fig. 5. Electron micrograph of the cuticle of an untreated 'Bing' cherry (provided by Dr. Eric Curry). Note the open stoma near the center of the micrograph.

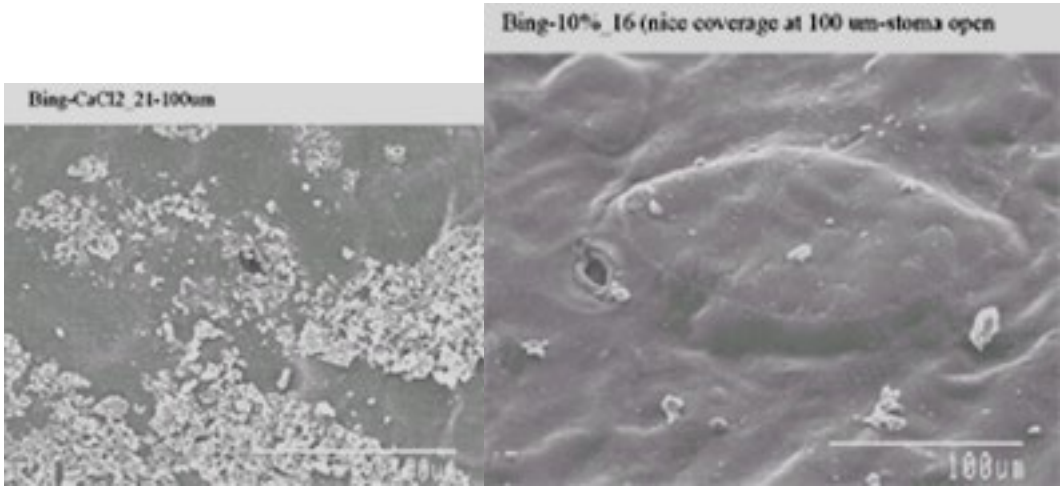

Fig. 6. Electron micrographs of the cuticle of 'Bing' cherries. The micrograph on the left was done on a cherry harvested from a tree sprayed with calcium chloride (1% w/v); the one on the right was from a cherry harvested from a tree sprayed with 10% (v/v) RainGard protectant (provided by Dr. Eric Curry).

Three electron micrographs (Figs. 5 and 6) compare the surface of cherries that were untreated, sprayed with calcium chloride, or sprayed with RainGard. Note the open stoma in each figure and the uniform coating on the cherry sprayed with RainGard.

Budget:

Project title: Suppressing cherry cracking and post harvest stem browning and water loss
PI: Larry Schrader (Co-PIs: M. Whiting and E. Curry)
Project duration: Two years (2003-2004)
Current year: Year 2 (2004)
Project total (2 years): $42,364

Year	Year 1 (2003)	Year 2 (2004)
Total	$19,956	$22,408

Current year breakdown

Item	Year 1 (2003)	Year 2 (2004)
Salaries	$10,000	$10,400 [1]
Benefits (34%)	3,400	3,536
Wages	1,600	1,700 [2]
Benefits (16%)	256	272
Equipment		
Supplies	3,800	3,500 [3]
Travel	900	1,000 [4]
Miscellaneous		2,000 [5]
Total	$19,956	$22,408

[1] Salary for an Associate in Research (25% time) for Schrader's program. The other 75% provided by WSU and other funds.
[2] Time-slip help for Whiting's program.
[3] Supplies included $800 for Dr. Curry to cover supplies needed for electron microscopy. Supplies included additional pumps used in "rain simulation" tests, sprinkler heads, etc., for overhead application of water, Mylar bags to enclose trees, chemicals, cell phone charges, other general supplies and possible payment for "crop destruct".
[4] Travel to experimental plots.
[5] Support for Dr. Gordon Brown in Tasmania, Australia to test efficacy of the cherry matrix in the Southern Hemisphere in 2003-04.

CONTINUING REPORT

Project title: Edible coatings and other postharvest treatments to improve cherry shelf-life and quality
PI: Jinhe Bai
Organization: Oregon State University, Mid-Columbia Agricultural Research and Extension Center
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E-mail: Jinhe.bai@oregonstate.edu
Cooperator: Anne Plotto, USDA/ARS, Citrus and Subtropical Products Lab, Winter Haven, FL 33881
Contract Administrator: Beaton, Dorothy A; Dorothy.Beaton@oregonstate.edu; (541) 737-3228

Objectives (2004):
1. Develop fruit and stem coatings. To develop and evaluate coatings with varying degrees of permeability to water vapor, O_2 and CO_2.
2. To use plant growth regulators and antioxidants to prevent stem shrinkage and stem browning. To add plant growth regulators (gibberellins), antioxidants (ascorbic acid), and minerals (Ca^{++} salts) to edible coatings; to evaluate the additional efficiency of these compounds to extend the postharvest life of cherries.
3. To understand the relationship between the fruit and the stem. After harvest, the fruit may act as a strong sink for the water stored in the stem.

Objectives (2005):
1. Develop fruit and stem coatings. To develop and evaluate coatings with varying degrees of permeability to water vapor, O_2 and CO_2.
2. To use plant growth regulators and antioxidants to prevent stem shrinkage and stem browning. To add plant growth regulators (gibberellins), antioxidants (ascorbic acid), and minerals (Ca^{++} salts) to edible coatings; to evaluate the additional efficiency of these compounds to extend the postharvest life of cherries.
3. To understand the relationship between the fruit and the stem. After harvest, the fruit may act as a strong sink for the water stored in the stem.
4. Optimization of clamshell containers openings to decrease moisture loss of fruit.

Significant findings:
- Efficiency of coatings to reduce postharvest moisture loss of cherries is coating formulation and fruit variety dependent.
- Sucrose fatty acid ester was the only coating that improved significantly shininess of cherry fruit.
- Chitosan coatings maintained fruit firmness and stem retention better than control and other coatings.
- Ca propionate dips helped maintaining fruit firmness but $CaCl_2$ did not.
- For stem coatings, all the film forming formulations except chitosan did not affect stem quality. However, GA3 dips slowed down stem browning of 'Bing' cherries; Chitosan coating slowed down the stem browning of 'Lapins'.
- An experimental clamshell with smaller openings than the commercial clam shell decreased moisture loss of cherry fruits and doubled the shelf-life.

Methods:

Fruit coating formulation: Chitosan coatings and the combination with growth regulator, Ca salts, and antioxidants

Evaluation of commercial and experimental coatings: Evaluate the major cherry coatings from the major industries (Pace, Deco, and FMC), and promising experimental coatings formulated by OUS-MCAREC & USDA/ARS-Winter Haven.

- Stem treatments: Using growth regulators, and antioxidants (carrier: chitosan) to inhibit stem browning.
- Clam shell: evaluating the efficiency of the experimental clam shell with more varieties: Bing, Lapins, Sweet Heart, Rainier, and Skeena.
- Attributes: Water loss, fruit surface color and gloss, fruit firmness, soluble solids content (SSC) and titratable acidity (TA), stem detachment force, and appearance of stem and fruit were determined during storage at 33 °F with two-week intervals. Appearance of stems was scaled using a 5-point scale where 0= clear, 1= <25 % browning, 2= <50% browning, 3= <75 browning, 4= >75% browning of whole stem length. Appearance of fruit was scaled using a 5-point scale where 0= fresh, excellent; 1= fresh, good; 2= fair, market limit; 3= poor; and 4= completely deteriorated. Appearance data were presented as quality index:

  Quality index = $\sum SiFi / 4Fn$

  Where I = 1 - 5, Si is scale, Fi is fruit number and Fn is total fruit number.

  Index > 0.5 is considered a critical point of marketability.

Results and Discussion

Fruit coating: Experimental and commercial coatings were used which contain: 1) Natural film-formers, such as carnauba and resin, which provide an excellent barrier for protecting against moisture loss while moderately modifying fruit internal atmosphere. 2) Special film-forming agents, such as chitosan, which modifies fruit internal atmosphere t and reduces microbial contamination. 3) Plant growth regulators, antioxidants and minerals. Coatings and other dipping solutions were held at 33° F before use.

Sucrose fatty acid esters, resins and vegetable oil emulsions are major commercial coatings for cherries. Most of these coatings prevented moisture loss of fruit, more or less (Table 1). Fruit coated with sucrose fatty acid ester had the highest gloss (Table 2). However, these coatings did not significantly improved shelf life of cherries (Table 3). Chitosan is relatively new as a coating material. Chitosan forms a film when applied on fruit surface, reducing moisture loss, modifying internal atmosphere of fruit, and reducing decay (Bai and Baldwin, 2002). Chitosan decreased loss of fruit firmness and prolonged stem retention (Table 3). A firming agent, Ca propionate also extended stem retention (Table 3). Ca^{++} has been applied in horticultural crops preharvest and postharvest to improve the postharvest stability of produce (Patterson et al., 1983).

El Gaouth (1991, 1992, and 1997) reported that chitosan coating reduce decay for tomato, pepper and strawberries, therefore it could be a promising coating for cherries, too.

Stem coating: Stems of fruits were arrayed and held on a screen net, then were dipped in the coating solutions for 30 seconds. The amount of coating was adjusted to immerse the stem but not the fruit.

For stem treatment, chitosan and GA_3 slowed down stem browning and stem drying (Table 4). Different from other coatings, chitosan is a low pH solution (pH 2.8) with citric or malic acids as solvent. These organic acids could protect stems from oxidation. GA_3 extended stem life probably because of the regulation between source (fruit) and sink (stem). GA_3 stimulated the vigor of stem, therefore, disturbed the source-sink relationship (Table 4). When dipping both stem and fruit in GA_3, the stem life was not extended (data not shown).

Clamshell: We developed an experimental clamshell. The capacity is 4 pints with 7 x 6½ x 3 inches. The opening is 0.37 square inches and the opening ratio is 0.21%. For comparison, a typical commercial clamshell was used which has a capacity of 3.2 pint, 4.82 square inches' opening, and the opening ratio is 3.39% (Table 5).

We compared these two different clamshells for the moisture loss, fruit quality and stem quality of cherries. We packed 'Regina' cherries in these clamshells and stored them at 33° F for 6 weeks. The critical point at which fruits and vegetables deteriorate due to water loss is at 5%. Water loss of cherries packed in the experimental clamshell did not exceed 5% within 6 weeks of harvest. However, the commercial clamshell reached that critical point after 2 weeks (Fig. 1). This was under the cold storage conditions; the water loss would be much higher if clamshells were held under marketing conditions (50 - 70 °F). Because of the water loss, fruits packed in the commercial clamshells lost their shelf-life after 2 weeks, but the experimental clamshells maintained their shelf-life for 4 weeks (Fig. 2 and 3.).

The combination of gases (O_2 and CO_2) in the commercial clamshell is similar to the ambient air (Table 6) because of the huge opening between the top and bottom lids. This opening causes cherry fruits to deteriorate and breakdown after 2-weeks. O_2 is slightly lower and CO_2 slightly higher in the experimental clamshell, which created a favorable environment for the cherries to last up to 4-weeks after harvest. Fruit flavor was not affected by the change in O_2 and CO_2 levels at low and room temperatures.

Bai et al. (1990) reported that Hassaku orange packed in low perforation (0.16%) polyethylene bag had less weight loss, decay and physiological disorder as compared to high perforation (1%) bag.

In conclusion, cherry fruits had a limited shelf-life (2 weeks) in a commercial clamshell with a big opening between the top and bottom lids. An experimental clamshell, with several smaller openings, decreased moisture loss of cherry fruits significantly, and postponed fruit deterioration without creating anaerobic conditions. The experimental clamshell doubled the shelf life of cherry fruits compared with the commercial clamshell. Further research will include continuing to explore the optimal openings of the experimental clamshells for commercial use.

Table 1. Water loss (%) of cherry fruits coated with different formulations after storage for 28 days at 33 °F

	Bing	Lambert	Lapins
Carnauba	-	2.77	3.32
Chitosan I	2.14	-	-
Chitosan II	2.54	3.25	**2.14**
Sucrose fatty acid ester	2.32	**2.20**	**-**
Resin I	-	-	**2.58**
Resin II	-	-	**2.58**
Resin III	-	-	**1.91**
Control	2.32	3.28	3.75

Table 2. Gloss of cherry fruits coated with different formulations after storage for 14 days at 33 °F

	Gloss unit at 60 °		
	Bing	Lambert	Lapins
Carnauba	1.71	1.12	1.03
Chitosan I	1.04		
Chitosan II	1.17	1.14	0.94
Sucrose fatty acid ester	**3.50**	**3.13**	
Resin I			1.06
Resin II			0.99
Resin III			1.03
Control	0.73	1.43	1.15

Table 3. Effect of coating material on stem and fruit quality of sweet cherries after storage at 33 °F

	Bing		Lambert		Lapins	
	Fruit firmness (g force mm^{-1}, d 42)	Stem detatchment force (g force, d 7)	Fruit firmness (g force mm^{-1}, d 14)	Stem detatchment force (g force, d 14)	Fruit firmness (g force mm^{-1}, d 14)	Stem detatchment force (g force, d 14)
Film forming agents						
Carnauba	248	626	284	461		767
Chitosan I	**291**	**655**				
Chitosan II	**285**	**734**	**288**	**593**	**395**	**846**
Sucrose fatty acid ester	237	573	289	346		
Resin I					385	661
Resin II					356	584
Resin III					358	651
GA3						
10 ppm	241	500	310	432	362	650
50 ppm	214	579	293	357	347	545
100 ppm	201	571	271	491	353	748
Firming agents						
CaCI2	250	549	295	371	361	759
Ca Propionate	272	**742**	296	**461**		
Control	241	521	262	328	366	617

Table 6. Combination of atmosphere in commercial and experimental clamshells

Storage condition	Atmosphere combination	Commercial clamshell	Experimental clamshell
Cold storage	Oxygen	> 20%	> 19%
	Carbon dioxide	< 1%	< 2%
Room Temperature	Oxygen	> 20%	> 17%
	Carbon dioxide	< 1%	< 4%

Table 5. Comparison between commercial and experimental clamshells

	Commercial	Experimental
Capacity	3.2 pints (6.5 x 5.2 x 3.2)	4 pints (7 x 6.5 x 3)
Opening	4.82 in2 (3 sides between lid and bottom plus 8 holes on bottom	0.37 in2 (8 holes on side walls and 4 on bottom)
Ratio of opening	3.39%	0.21%

Table 4. Quaity of cherry stems coated with different formulations after storage for 14 days at 33 °F

	Browning index * after storage for 14 days		
	Bing	Lambert	Lapins
Film forming agents			
Carnauba			0.51
Chitosan I	0.45		
Chitosan II		0.49	**0.12**
Sucrose fatty acid ester	0.40	0.53	
Resin I			0.67
Resin II			0.63
Resin III			0.65
GA3			
10 ppm	**0.38**	0.46	0.70
50 ppm	**0.30**	0.53	0.67
100 ppm	**0.35**	0.46	0.40
Firming agents			
CaCI2	0.45	0.52	0.74
Ca Propionate	0.58	0.52	
Control	0.43	0.37	0.32

* Index: 0 = clear; 1 = more than 75% of whole stem length browned.

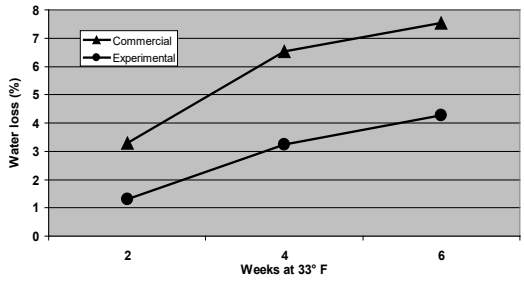

Fig. 1. Effect of clam shell on water loss of sweet cherries stored at 33 °F. Main Point: The critical point at which fruits and vegetables deteriorate due to water loss is at 5%. Water loss of cherries packed in the experimental clam shell did not exceed 5% within 6-weeks of harvest. However, the commercial clam shell reached that critical point after 2-weeks.

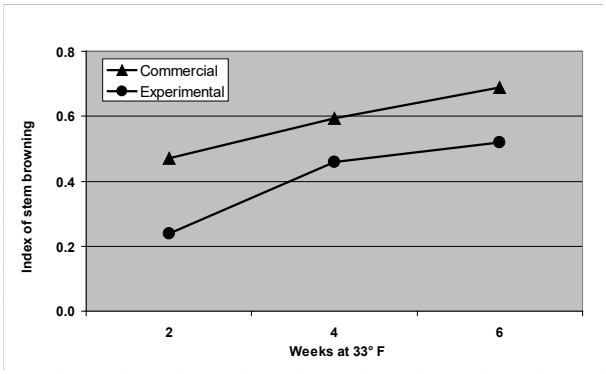

Fig. 2. Effect of clam shell on stem browning of 'Reginar' cherries stored at 33 °F.
Index: 0 = clear; 1 = more than 75% of whole stem length browned
Index > 0.5 is considered a critical point of marketability

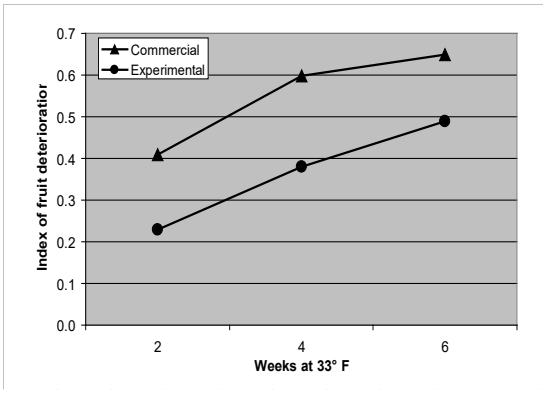

Fig. 3. Effect of clam shell on fruit deterioration of 'Reginar' cherries stored at 33 °F.
Index: 0 = clear; 1 = inedible. Index 0.5 is the critical point of marketability.

BUDGET

Project title: Edible coatings and other postharvest treatments to improve cherry shelf-life and quality
PI: Jinhe Bai
Project duration: 2004-2006
Current year: 2005
Project total (3 years): $42,639
Current year request: $19,198

Item	Year 1 (2004)	**Year 2 (2005)**	Year 3(2006)
Salaries [1]		**10,200**	10,700
Benefits (49%) [1]		**4,998**	5,243
Wages			
Benefits (%)			
Equipment			
Supplies [2]	3,500	**3,500**	3,000
Travel [3]		**500**	1,000
Miscellaneous			
Total	3,500	**19,198**	19,941

[1] OSU-MCAREC: $10,200 – 4-months Faculty Research Assistant time with benefits (49%).
[2] Supplies include fruits, chemical, and equipment supplies.
[3] Travel to Winter Haven, FL.

Literature cited:

Bai, J., Abe, K., Kurooka, H. 2002. Effect of harvest maturity, perforation ratio of polyethylene package and storage temperature on quality of Hassaku (Citrus hassaku hort. Ex Tanaka) fruit. J. Japan. Soc. Food Sci. Technol. 17:971—977.

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El Gaouth, A., Arul, J., Wilson, C., Benhamou, N. 1997. Biochemical and cytochemical aspects of the interactions of chitsan and Botrytis cinerea in bell pepper fruit. Postharvest Biol. Technol. 12:183-194.

El Gaouth, A., Ponnoampalam, R., Castaigne, F., Arul, J. 1992. Chitosan coating to extend the storage life of tomatoes. HortSci. 27:1016-1018

El Gaouth, A., Arul, J., Ponnoampalam, R., Boulet, M. 1991. Chitosan coating effect on storability and quality of fresh strawberries. J. Food Sci. 56.: 1618-1620.

Patten, K., Patterson, ME., Kupferman, E. 1983. Reduction of surface pitting in sweet cherries. Post Harvest Pomology Newsletter, 1 (2): pp6.

FINAL REPORT

WTFRC Project #CH-04-407 **WSU Project #14C-4164-1201**

Project title: Postharvest quality of new commercially grown cherry varieties

PI: Eugene Kupferman
Organization: WSU Tree Fruit Research and Extension Center
Address, phone, e-mail: *1100 N. Western Avenue, Wenatchee, WA 98801*
(509) 663-8181 ext. 239; kupfer@wsu.edu

Contract administrator: Mary Lou Bricker (mdesros@wsu.edu) (509) 335-7667; or Tom Kelly (kellytj@wsu.edu) (509) 335-3691

Objectives:

1. Develop harvest maturity guidelines and determine quality characteristics at harvest and after storage of early ('Chelan') and late ('Lapins', 'Sweetheart' and 'Skeena') sweet cherry varieties as compare with 'Bing'.
2. Determine the effect of growing season temperatures and postharvest treatments on the quality of 'Lapins' cherries.
3. Test the susceptibility to impact force using induced pitting.

Significant findings:

Harvest maturity study:

- Lapins cherries, whether grown at low, medium or high elevations, were less firm than the other varieties at all sampling dates; Skeena and Sweetheart were the firmest (Figure 1).
- The largest cherries were Lapins while Skeena were the smallest. Skeena size was strongly influenced by harvest maturity.
- Chelan was the least acidic and had the lowest soluble solids of the varieties sampled; Bing had the most acidity and soluble solids.

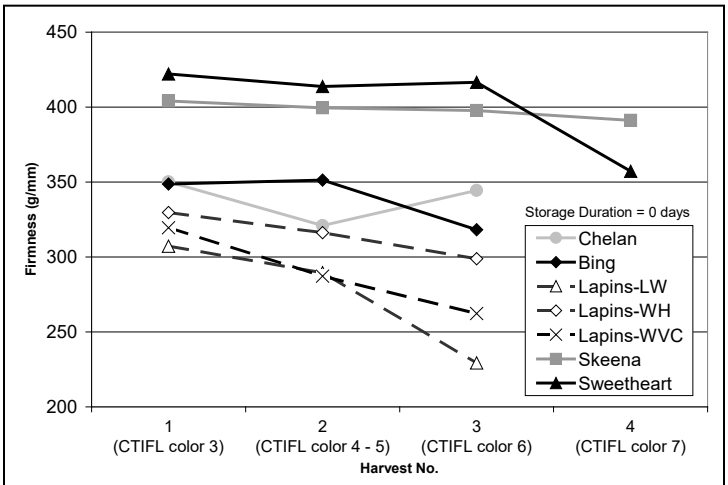

Figure 1. Firmness of Bing, Lapins, Skeena and Sweetheart at different harvest dates.

Storage study:

- All varieties lost acidity gradually, at about the same rate during 28-day storage at 33ºF. Bing cherries had the highest acidity at all storage periods; Lapins generally had the lowest acidity.
- Most varieties retained about the same soluble solids levels during storage except for Sweetheart, which gained soluble solids in each of the storage periods (Figure 2).

- Firmness declined after 7 days from harvest in Bing, Sweetheart, and Chelan. Firmness in these varieties rose above harvest firmness after 14 and 28 days in storage. The firmness of Lapins cherries rose gradually during the storage period.
- Skin color did not change appreciably over the 28-day storage period in any variety.
- Percentage of green stem color was equal to that at harvest after 7 days but declined significantly after 14 days of storage and continued to decline after 28 days in storage. Chelan cherry stems remained green throughout the 28-day period. Sweetheart cherry stem color declined rapidly between 14 and 28 days (Figure 3).
- Percentage of fruit with shrivel rose rapidly in Bing and Lapins, while Skeena and Chelan fruit did not shrivel until after 14 days in storage.
- Percentage of pitted fruit rose dramatically within 7 days of harvest in Chelan and Lapins. In Sweetheart, pitting rose gradually over 7 days, then rapidly with longer duration. In Skeena, pitting was about the same as at harvest after 7 days but then rose at 14 days where it stabilized (Figure 4).

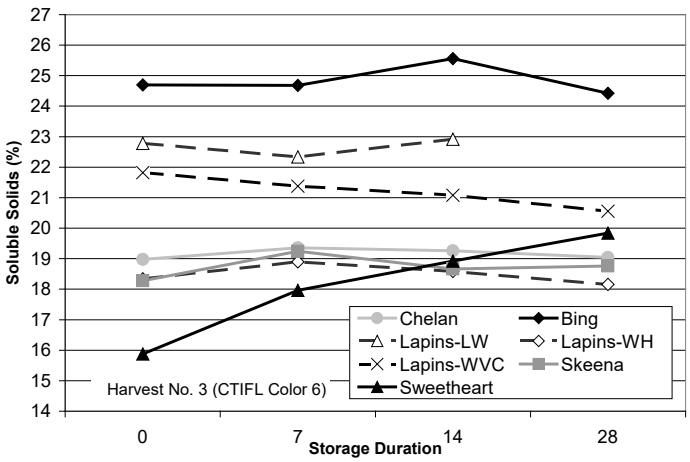

Figure 2. Soluble solids levels of Bing, Lapins, Skeena and Sweetheart after storage.

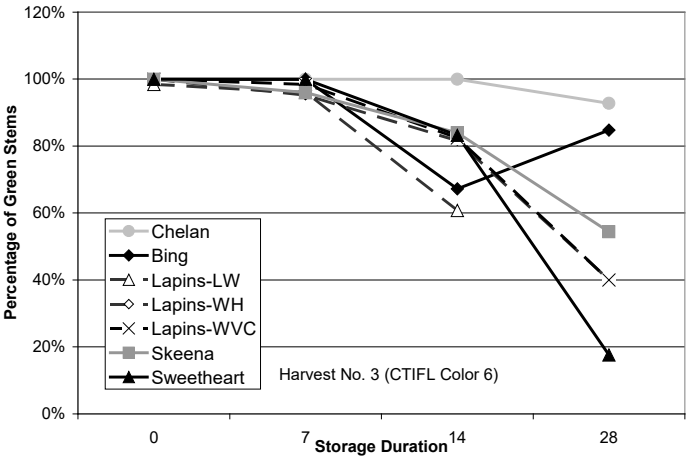

Figure 3. Percentage of fruit with green stems (Bing, Lapins, Skeena and Sweetheart) after storage.

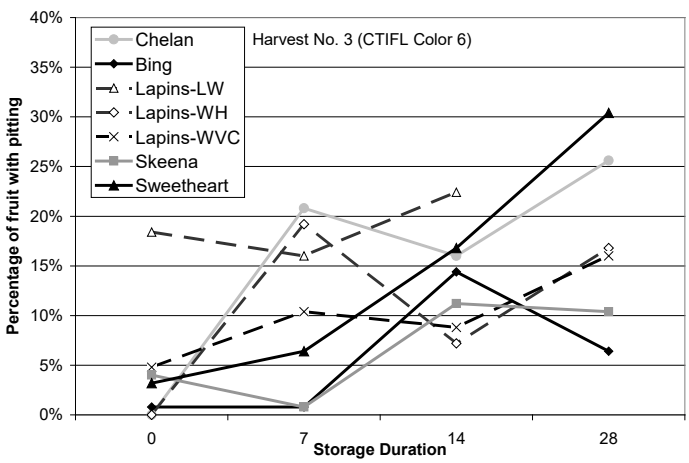

Figure 4. Percentage of pitted fruit (Bing, Lapins, Skeena and Sweetheart) after storage.

<u>Induced pitting:</u>

- When a standard pitting stress using the BC pitting device was applied to fruit from each variety at each harvest, pitting sensitivity from highest to lowest was Sweetheart (82%), Lapins (65%), Bing (62%), Skeena (55%) and Chelan (42%).
- It was unclear whether harvest maturity played a role in the amount of fruit developing pits.

Postharvest temperature and firmness:
In a trial in which cherry firmness was evaluated at different postharvest temperatures (33-116ºF) preliminary data were obtained on Lapins, Bing, Skeena and Sweetheart varieties. Firmness declined linearly in Lapins (r^2=0.81), but there was more variation in Bing (r^2=0.59), Skeena (r^2=0.65), and Sweetheart (r^2=0.23) [see Figure 5]. This work needs to be clarified by additional studies proposed for 2005.

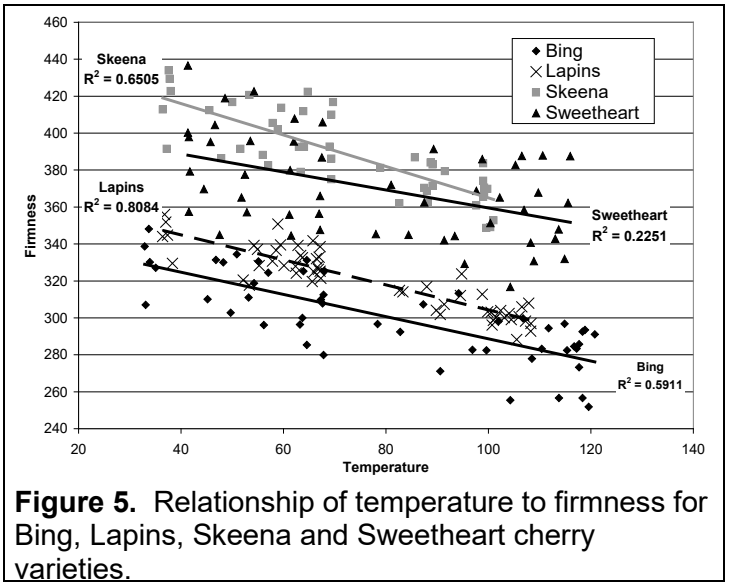

Figure 5. Relationship of temperature to firmness for Bing, Lapins, Skeena and Sweetheart cherry varieties.

Methods employed in 2004:

1. Maturity and storage study:
Chelan fruit were harvested from an orchard in Rock Island. Bing, Skeena and Sweetheart cherries were harvested three or four times from an orchard on Wenatchee Heights. Lapins cherries were harvested from three orchards located at different elevations (Wenatchee River, airport in Wenatchee and Wenatchee Heights) to explore the relationship of accumulated heat units and fruit quality. Harvested cherries corresponded to colors represented on a color scale produced by CTIFL (France) at color ratings of 4, 6 and 8, respectively. A 25-fruit sample taken from each of five trees was analyzed for quality at harvest and after storage for 7, 14 and 28 days at 32ºF. Quality analysis included stem, skin and flesh color, firmness, and size measured on every cherry. Weight, soluble solids (SS) and titratable acidity were measured by pooling all cherries in the sample. Temperature data loggers were placed in each orchard and programmed to monitor temperatures on an hourly basis.

2. Pitting study:
A 25-cherry sample was taken from each of five trees for pitting evaluation. Cherries were held at 38ºF for 24 hours after harvest, then pitting was induced using the device designed at the Pacific Agri-Food Research Centre, Summerland B.C. to induce a standard pitting stress. Cherries were held for 14 days at 33ºF plus 24 hours at 70ºF before evaluating damage. Fruit damage assessed is expressed as the percentage of damaged fruit.

3. Postharvest temperature and firmness study:
Although it is agreed that postharvest temperature affects cherry firmness, the relationship between a specific temperature and cherry firmness is not known. Packers need to know how fruit measured at cold temperature compares with fruit at warm temperature. A preliminary experiment was performed in which Lapins, Bing, Skeena and Sweetheart were removed from cold storage and allowed to warm. Fruit flesh temperature and firmness of 25 cherries were tested at four times between 44 and 69ºF. The fruit were then allowed to continue to warm by being placed directly in the sun, and four firmness measurements were taken between 69 and 110ºF. Firmness was measured using the FirmTech II.

4. Commercial packing study:
At time of commercial harvest for each variety, a sample of fruit was obtained prior to dumping and at the end of the commercial packingline. The sample was evaluated when it was obtained as well as after storage for 14 days.

5. Water study:
A sample of each Lapins harvest and second-harvest Bing was held for 5, 10 or 15 minutes in 33ºF water and evaluated for fruit condition and firmness after 14 days at 33ºF.

Results and discussion:
1. Maturity Study:
Bing – Bing cherries at harvest had the highest acidity and soluble solids during the commercial harvest period of any variety evaluated. Soluble solids rose linearly with skin color (r^2=0.96) and with internal color (r^2=0.99). Bing cherries were not the most firm, but were of high firmness. Bing size was small, peaking on 10 row at commercial harvest. (The orchard was located on Wenatchee Heights and was under the same management as the other varieties.)

Following storage, acidity and soluble solids for Bing cherries harvested at CTIFL color 6 remained high, and firmness did not change in comparison with other varieties. Bing fruit had less pitting than the other varieties during the 28-day storage period (except for the 14-day pullout, at which time it was intermediate).

Chelan – At harvest, Chelan cherries had the lowest acidity and soluble solids of any variety evaluated. Soluble solids rose linearly with skin color (r^2=0.92) and with internal color (r^2=0.99). Chelan cherries were firmer than Lapins but less firm than the other varieties. They were smaller than Lapins but larger than the other varieties.

Following storage of Chelan cherries harvested at CTIFL color 6, the acidity was equal to that of Lapins and Skeena but lower than the other varieties, while soluble solids and firmness were intermediate. Pitting was a serious problem with Chelan at all storage durations, and they had the highest percentage of pitted fruit.

Skeena – Skeena cherries at harvest were intermediate in acidity and soluble solids as compared with other varieties. However, Skeena was almost as firm as the firmest variety at each sampling date. There was not a good linear relationship between the rise in soluble solids and skin color (r^2=0.38) or internal color (r^2=0.45). Skeena cherries were very small at early harvests but intermediate by the third harvest. This variety showed the largest effect of maturity on fruit size.

Following storage of Skeena cherries harvested at CTIFL color 6, the acidity and soluble solids remained intermediate. Firmness remained quite high at all pullout dates. The amount of pitting that developed in storage up to 28 days was low.

Sweetheart – Sweetheart cherries at harvest were high in acidity but intermediate in soluble solids at all dates. Sweetheart cherries were the most firm fruit evaluated at harvest. There was a moderately good linear relationship between soluble solids and skin color (r^2=0.79) but a stronger relationship with internal color (r^2=0.84). Sweetheart cherry size was not influenced by maturity. Fruit were as large, or larger than, all other varieties, except for Lapins, which were larger.

Following storage of Sweetheart cherries harvested at CTIFL color 6, the acidity was high but soluble solids low compared with the other varieties. The cherries were the most firm at all pullout dates. The percentage of pitting of Sweethearts was low after 7 days, but by 28 days it was the highest of all varieties.

Lapins – At harvest, Lapins cherries from the three orchards sampled had low acidity (higher than Chelan) and medium-high levels of soluble solids. There was a linear relationship between soluble solids and both skin and internal color. At harvest and after storage, they were the least firm of all

varieties at all harvest dates; Lapins were the largest fruit sampled. At harvest and after 7 days in storage, Lapins had the highest percentage of pitted fruit. Only after 14 days in storage was fruit from other varieties more pitted.

2. Lapins comparison:
The exploration of the effect of growing season temperature on Lapins quality is currently being explored through the use of temperature models and is not yet complete.

3. Pitting study:
When a standard pitting stressor using the BC pitting device was applied to fruit from each variety at each harvest, the percentage of fruit with severe pitting from highest to lowest was Sweetheart (82%), Lapins (65%), Bing (62%), Skeena (55%) and Chelan (42%). It was unclear whether harvest maturity played a role in the amount of fruit developing pits.

4. Postharvest temperature and firmness study:
This year for the first time, preliminary data was obtained on the relationship of the fruit temperature and firmness on Lapins, Bing, Skeena and Sweetheart varieties. Firmness declined linearly as temperature increased in Lapins (r^2=0.81), but there was more variation in Bing (r^2=0.59), Skeena (r^2=0.65), and Sweetheart (r^2=0.23). This work needs to be clarified by additional studies that are proposed in a new project for 2005.

Budget:

Project title: Postharvest quality of new commercially grown cherry varieties
PI: Eugene Kupferman, Chris Sater (Associate in Research)
Project duration: 2004 (one year)
Current year: 2004
Project total (1 year): $22,380

Current year breakdown

Item	Year 1 (2004)
Salaries[1]	9,700
Benefits (46%)	2,910
Wages	5,100
Benefits (16%)	816
Equipment	0
Supplies[2]	2,854
Travel[3]	1,000
Miscellaneous	0
Total	22,380

[1] Chris Sater, Associate in Research, for 4.5 months.
[2] Supplies include fruit purchase, cherry packing material and lab supplies. Cell phone charges are authorized under this grant.
[3] Travel to obtain fruit samples.

FINAL REPORT

WTFRC Project #: CH-01-02

Title: Identification of sweet cherry dwarfing rootstock candidates from MSU's tart cherry germplasm collection.

PI: Amy Iezzoni
Organization: Department of Horticulture, Michigan State University (MSU)
Co-PI's: none
Cooperators: Matt Whiting (WSU-Prosser), Bill Howell (NRSP5, Prosser) & Ron Perry (MSU)

Objectives: *Identify rootstock selections from MSU's vast cherry germplasm collection that may have commercial potential as dwarfing precocious rootstocks for sweet cherry. MSU selections included as rootstock candidates in field trials at MSU and WSU will have been demonstrated to propagate well and to be virus tolerant.*

Significant accomplishments:

- Virus screening of the rootstock candidates was completed in 2002.
- Test plots for the MSU rootstock trees with Bing and Hedelfingen scions were established at MSU and WSU Research Stations in Clarksville, MI and Prosser, WA, respectively.
- 92 MSU rootstock selections, totaling 363 trees, are under test at Clarksville (Fig. 1).
- 21 MSU rootstock selections, totaling 117 trees, are under test at Prosser (Fig. 2). An additional 35 selections, totaling 126 trees, have been propagated and will be planted in Spring 2005.

Significant findings:

- Approximately 60% of the rootstock candidates were sensitive to PDV and/or PNRSV and eliminated from further testing. This ability to eliminate selections prior to budding proved to be an extremely efficient pre-screening approach.
- In general, the MSU rootstock selections induce precocity with flowering in the second year after planting.
- Observations for the Clarksville plot indicate that some rootstocks confer different levels of freeze tolerance with a few selections appearing to confer increased hardiness compared to GI 6.
- Two rootstock selections have shown symptoms consistent with graft incompatibility at both the Prosser and Clarksville plots and have been eliminated from further testing.

Methods:

*Virus testing***:** Screening for tolerance to PDV and PNRSV was done by Bill Howell at NRSP5. A bud inoculation strategy was used and the symptoms were visually rated.

*Budding and plot establishment***:** Vegetatively propagated rootstock cuttings were planted at Hilltop Nursery and Meadow Lake Nursery for budding. Bing and Hedelfingen scions were budded onto rootstock selections intended for planting in Prosser and Clarksville, respectively. Trees were planted in the test plot with 10 feet between each tree and 18 feet between each row.

Evaluation: The following data was collected: tree survival and health, trunk cross-sectional area, flower number and/or bloom density and fruit number or crop load.

Mother block establishment: Five cuttings of each test rootstock selection were planted in a block at Clarksville. The plot location is distant from the cherry plantings to minimize the possibility that these trees would become infected by the pollen born viruses PDV and PNRSV.

Results and Discussion:
Years 2002 to 2004 represented transition years in which virus testing and budding were sequentially completed. Plot establishment will be completed in 2005. Flower and fruit evaluations began in 2003.

Plot Establishment

There are currently 92 MSU rootstock selections, totaling 363 trees, under test in the plot at CHES (Fig. 1). The control is GI 6. The majority of the scions are Hedelfingen. However, because a decision was made to delay the planting of the Prosser plot until 2002, some of the rootstock selections planted in 2001 have Bing scions. The pollinator is Ulster/GI6. Eighteen additional trees of the MSU rootstock selections will be planted in 2005. These trees were produced from sleeping eye buds inserted in August 2003. In 2004, these trees were grown in a polyhouse at Clarksville.

There are currently 21 MSU rootstock selections consisting of 117 trees planted at Prosser (Fig. 2). An additional 35 MSU rootstock selections represented by 126 trees were supposed to be planted in this plot in 2004. However, extensive deer damage to the trees in the commercial nursery required that the trees remain one more year in the nursery. If tree planting goes as predicted in 2005, the final counts at the Prosser plot will be 56 MSU selections under test represented by 243 trees.

A total of 103 selections totaling 390 trees are planted in the mother block at Clarksville.

Rootstock evaluations

- The vast majority of the MSU rootstock selections induced flowering and fruiting one year after planting. This is similar to GI 6.

- The majority of two-year-old trees exhibited less flowering and fruiting compared to GI 6 (Fig.3). On a scale of 0 being no crop to 5, a very heavy crop, 2 year old trees on GI 6 were rated “3” while the majority of the MSU rootstocks were rated “2”.

- Average yearly trunk growth for the 4 year-old MSU rootstock selections was slightly less than that for the GI 6 (Fig. 4).

- Two MSU rootstock selections exhibited severe symptoms of graft incompatibility at both Prosser and Clarksville and were eliminated from further testing. These selections are I 56 (40) and I 59 (81) (Fig. 5).

- The MSU rootstock selection, III 4 (33) appeared to increase the mid-winter cold hardiness of Bing (Fig.6), however, it also exhibited poor anchorage at the Clarksville plot (Fig. 7).

Recommendation

- Minimal pruning allowed us to evaluate the rootstock’s influence on scion growth habit. However, the minimal pruning also resulted in trees that are not of comparable stature. Therefore, next year we shall evaluated yield using a yield component strategy on paired branches.

Acknowledgements: The contributions of Audrey Sebolt, David Ophardt, and Jim Olmstead are greatly appreciated. Pollinator and rootstock trees were generously donated by Hilltop Nurseries.

Budget

Title: Identification of sweet cherry dwarfing rootstock candidates from MSU's tart cherry germplasm collection.
P.I.: Amy Iezzoni
Project duration: Propagation Phase (1997-2001), Transition Phase (2002-2004).
Project total (3 years): $30,489

Year	Year 1 (2002)	Year 2 (2003)	Year 3 (2004)
Total	$10,600	$9,962	$9,927

Budget breakdown:

ITEM	Year 1 (2002)	Year 2 (2003)	Year 3 (2004)
Salaries[1]	$2,015	$4,010	$4,211
Benefits [2]	621	1,280	1,516
Labor [3]	1,000	800	700
Supplies [4]	200	400	400
Fee for virus screen	3,000 [5]	-	-
Travel	3,000	2,500	1,500[6]
Tree and freight costs	764	972	600[7]
Plot costs at MSU	0	0	1,000[8]
TOTAL	$10,600	$9,962	$9,927

[1] This represents partial funding for technical support to oversee the technical aspects of this project {develop spreadsheets describing each rootstock selection and the status of all the grafted trees, collect data, and manage, analyze, and summarize the data from the 2 field plots}.
[2] Benefits for YRs 2002, 2003 and 2004 are calculated at 30.8%, 31.9%, and 36 %, respectively.
[3] Student labor will assist with planting, data collection and management.
[4] Supplies to include mouse guards and other field supplies, computer diskettes etc, and poster supplies.
[5] Fee from NRSP5 for virus screening 50 selections for PDV + PNRSV @$60 each.
[6] Travel to WSU for field map development, tree labeling and data collection. Besides the obvious benefit of looking at the trees ourselves we are familiar with all the rootstock nomenclature and can more easily verify the accuracy of the labeling, and data collection.
[7] This just represents shipping costs. Trees for the MSU and WSU plots will be generously donated by Hilltop Nurseries and Meadow Lake Nurseries and the pollinator trees will be donated by Willow Drive Nursery.
[8] Starting in 2004, plot fees will be charged at all MSU Horticultural Research Stations. These costs are based upon a fee structure that reflects cost of standard plot maintenance.

Fig. 1. The cumulative number of live MSU rootstock selections and trees currently planted and projected to be planted in Clarksville, MI. The majority of the rootstock selections have Hedelfingen scions while some selections have Bing scions.

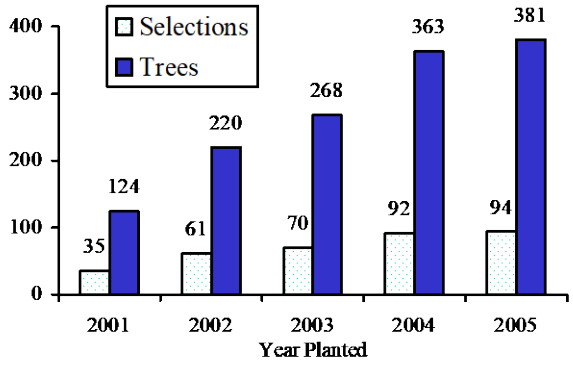

Fig. 2. The cumulative number of live MSU rootstock selections and trees currently planted and projected to be planted in Prosser, WA. All of the rootstock selections have Bing scions.

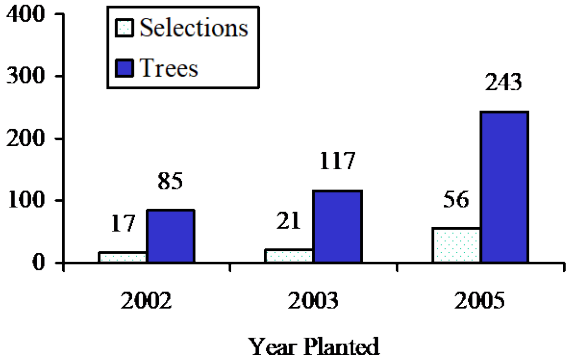

Fig. 3. Average crop rating for MSU selections with Bing as its scion at Prosser, WA. Trees were planted in 2002. *Denotes GI 6. Crop rating is based on 0 being no crop and 5 a very heavy crop.

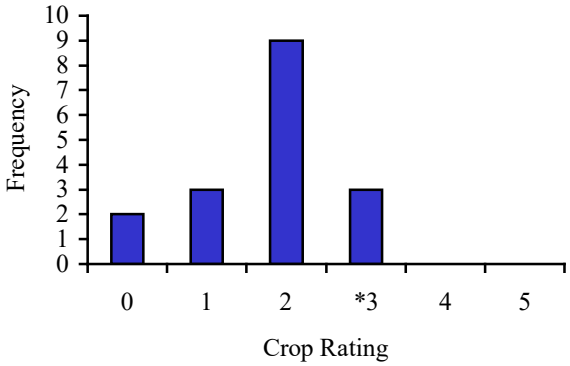

Fig. 4. Average trunk growth (mm) for MSU selections with Bing or Hedelfingen as its scion at Clarksville, MI. Trees were planted in 2001. *Denotes GI 6.

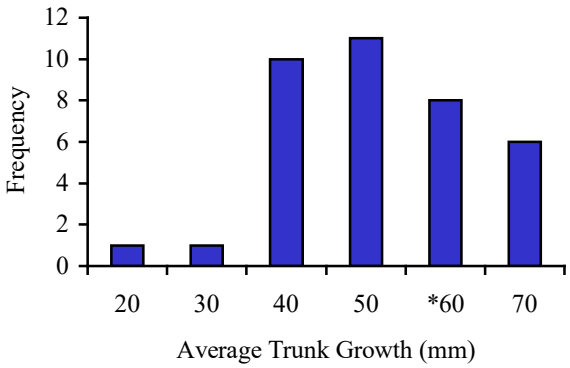

Fig. 5. A grafted Bing/MSU rootstock tree at Prosser, WA exhibiting graft incompatibility.

Fig. 6. Bing scions on two different MSU rootstock candidates illustrating the cold hardiness difference between the two rootstocks.

Fig. 7. Hedelfingen trees grafted onto the MSU rootstock selection III 4 (33) exhibited poor anchorage [YR 2004, Clarksville plot].

FINAL REPORT

Title: Develop seedling populations for future sweet cherry cultivar selection

Consultant: Amy Iezzoni
Cooperator: Matt Whiting, Washington State University

Objective: Conduct sweet cherry hybridizations and seed germinations to result in one-year-old hybrid seedlings from which future cultivars could be selected.

Commercial goal: Develop a full-season series of sweet cherry varieties that exceed current varieties for a range of characteristics desired for current and future domestic and foreign market opportunities.

Rationale: The development of a successful sweet cherry breeding program requires extensive planning and horticultural skill to achieve a potential goal of 5,000 to 10,000 hybrid seedlings. This plan represents a "low-budget" approach towards developing seedling populations that could be evaluated to identify superior selections with cultivar potential.

Plan of work: The proposed plan of work consists of the following seven steps. Steps 1-5 would be conducted in 2004.

1. Develop a crossing plan.
2. Implement the crossing plan
3. Harvest and clean seed.
4. Seed storage.
5. Planting.
6. Seedling growth
7. Dig and store one-year-old seedlings.

1. Develop a crossing plan: A crossing scheme will be designed by the P.I. to achieve the commercial goal stated above.

2. Implementation of the crossing plan: The majority of crosses will be made by Amy Iezzoni in Prosser, WSU, and surrounding locations as necessary. Trees for crossing and pollen will be identified by Matt Whiting and by Amy Iezzoni through direct contacts with growers. Additional labor requirements include: (1) hand labor to collect pollen, (2) a full time assistant during the bloom period who would work with A.I. to become familiar with the crossing process and mother tree locations, continue with pollinations once A.I. is gone if bloom is prolonged due to cool weather, and later in the season conduct fruit collection and seed cleaning, and (3) a crew that can work from 5 to dark if we encounter any really warm days. A.I. shall bring all the necessary equipment and supplies.

Pollen of three parental selections will be purchased through contacts in Europe. This pollen will be sent to A.I. checked for pollen germination percentage and, if viable, used in the Prosser crosses.

3. Harvest and clean seed. Throughout June and July the fruit from the hand crossing will be harvested from all the mother trees by the assistant identified and trained during bloom. The flesh will be removed from the seeds, the seed will be air dried for 24 hours, given a fungicide treatment and then placed in bags for stratification.

4. Seed storage. Seed in stratification bags will be kept in a ~5C cooler at Prosser,WSU, and periodically checked for moisture content and lack of contamination.

5. Planting: The seed will be planted in a seed bed at Willow Drive Nursery in in October. The seed will be hand planted by A.I., M.W., and assistance from the Prosser crew. A.I. shall be responsible for labeling the nursery and making a nursery map.

6. Seedling growth: The seed bed at Willow Drive Nursery will be cared for using standard procedures used at Willow Driver Nursery for obtaining mazzard rootstocks from seeds. A.I. shall visit the nursery to assess seed germination through stand counts and re-label the families to assure that the tags remain intact.

7. Dig and store the seedlings: The seedlings will all be individually labeled with family origin prior to digging. Trees will be dug after one season of growth using standard procedures. The trees will be placed in the storage cooler at Willow Driver Nursery to await delivery to a planting site.

Proposed schedule of accomplishments:

1. Develop a crossing plan: April 5, 2004. .
2. Implement the crossing plan: April – May 2004.
3. Harvest and clean seed: June – July 2004.
4. Seed storage: Summer 2004.
5. Planting: Early October 2004
6. Seedling growth: 2005
7. Dig and store one-year-old seedlings: Fall 2005/Spring 2006. Trees available for planting in Spring 2006.

Budget

Title: Develop seedling populations for future sweet cherry cultivar selection
P.I.: Amy Iezzoni
Project Duration: one year
Current year: 2004
Project total: $ 15,582 ($13,982 for AI and $1,600 for MW)
Current year request: $15,582

Budget breakdown: This budget reflects the actual costs incurred. Receipts are available upon request. The outcome of this project is presented in Appendix 3 of the Breeding Proposal.

Item	Year 1 (2004)
Fee for A.I.	$10,000 [a]
Hourly labor	$1,600 [b]
Imported pollen	$450 [c]
Materials & Supplies	$1,000 [d]
Air travel, rental car, & lodging	$2,532 [e]
Seedling tree cost	0 [f]
TOTAL	$15,582

[a] For P.I. (Amy Iezzoni) to design, organize and conduct the crossing/growing plan outlined in the Plan of Work.

[b] Funds for Matt Whiting to cover the cost of a labor assistant for two weeks during bloom and two weeks during seed collection and harvest, and one day for seed planting.

[c] Three pollen samples were purchased from two locations in Europe. Cost was $100/sample plus the cost of express mail shipping.

[d] Supplies (pollination bags, vials, dessicant, labels etc.) and expenses for A.I. bought from this budget and not MSU supplies (mostly lodging and rental car in Prosser) to conduct the outlined work plan.

[e] This project required 3 trips in 2004: (1) travel to Prosser to carry out the pollinations, (2) travel to Prosser for seed harvest, cleaning and stratification, (3) travel to Ephrata, WA in October to plant seed. This budget request takes into account the funds already granted to A.I. for other projects. These funds cover trips 1 and 2.

[f] Ken Adams at Willow Drive Nursery has generously agreed to grow the seedlings for ~ $1/tree. This charge will appear in 2005.

FINAL REPORT

Contract Title: Develop seedling populations for future sweet cherry cultivar selection

Consultant: Amy Iezzoni
Cooperator: Matt Whiting, Washington State University

Objective: Conduct sweet cherry hybridizations and seed germinations to result in one-year-old hybrid seedlings from which future cultivars could be selected.

Significant Accomplishments:

- 64 crosses were made in April 2004 resulting in 4,466 hybrid seeds.
- The crosses involved 18 parents.
- One European cultivar was successfully used as a parent by importing pollen.
- The seed were planted Oct. 4, 2004 in a nursery row and will be dug Fall 2005 for planting in the Fruit Test Sites.

Discussion:

The success of the crossing done in April 2004 at WSU-Prosser by Amy Iezzoni in collaboration with Matt Whiting validates the feasibility of conducting an accelerated crossing strategy using a collaborative approach.

Details of the actual crosses with seed numbers is provided in Appendix 3 of the Breeding Proposal.