2004 OSCC/WTFRC
Cherry/Soft Fruit Research Review November 6, 2003
Pasco, Washington

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6:30	163	Whiting	Apricot and peach scion and rootstock evaluation	04-06
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CONTINUING PROJECT
Project #: OSCC-2

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

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Cooperators:	Lynn Long, Anita Azarenko, Matthew Whiting

Objectives

- Evaluate new promising cultivars, rootstocks and training systems for tree growth and fruit characteristics (branching and fruiting habit, yield, disease tolerance, and bloom and harvest season).
- Evaluate postharvest quality of different cultivars (firmness, size, ^{o}Brix, color, pedicel quality and detachment force).
- Generate fruit and shoot growth curves for promising cultivars to help predict harvest and final fruit size and aid in developing new tree management strategies.
- Evaluate manual crop load regulation strategies as options to produce larger fruit.

Significant findings for 2003

- Cultivars and selections showing promise include 'Santina' and 'Cristalina' for the early season and 13S-16-29 (showed good tolerance to powdery mildew) for the late season. 'Regina' showed very good overall quality. 13S-42-49 continues to show promise as a stemless cherry.
- Alternative rootstocks identified as most promising so far include Pontaleb, Maxma 14, Giessen 195-20 and Weiroot 158.
- Postharvest quality analysis based on fruit maturity revealed quantitative differences in firmness, ^{o}Brix and stem detachment force (plus subjective evaluation of color and stem quality) among under-ripe, ripe and over-ripe fruit of 8 cultivars.
- Preliminary developmental growth curves have been generated for fruit and shoots of 'Bing', 'Regina', 'Lapins' and 'Sweetheart'.

Methods

- A collection of sweet cherry cultivars and selections is under evaluation in The Dalles and Hood River. Trials are currently being carried out on rootstocks from France and Germany (Weiroot series) in plots in The Dalles with 'Bing' as the scion cultivar. An NC-140 rootstock trial involving 15 rootstocks was established in 1998 at Orchard View Farms. All rootstocks are evaluated on 'Bing' scion, with Van as the pollinizer.
- A postharvest study involving 8 cultivars was initiated in 2003 to assess average fruit weight, size and firmness (FirmTech 2 firmness instrument), ^{o}Brix, pedicel detachment force. Fruit quality was assessed immediately upon harvest and periodically after exposure to 14 and 28 days periods of cold storage.
- Fruit and shoot growth curves are being developed for 4 cultivars. Periodic growth measurements are related to cumulative growing degree hours (GDH) rather than growing degree days (GDD). A base temperature of 25^{o}F was used with biofix at ca. full bloom. Fruit equatorial diameter measurements made between May 12 and July 14.

Results

Sweet cherry rootstock evaluation, Hazel Dell, The Dalles

French section (7th leaf):

Results for 2003 are summarized below for both sections of the Hazel Dell plot (Table 1). Pontaleb and Maxma 14 continue to produce excellent yields in the French section, and all rootstocks produced fruit of the same caliber as Mazzard during 2003. No differences in fruit size could be determined among rootstocks.

Weiroot section (6th leaf):

Inadequate replication in the Weiroot section does not allow a proper statistical analysis to conclusively evaluate performance of the 3 rootstocks harvested in 2003. Although both W158 and W72 produced numerically higher yields than Mazzard, such differences were not statistically significant. Fruit size was good and not influenced by rootstock or training system. Mazzard production is still low with relatively high fruit weights. Weiroot 72 and 158 as a central leader had numerically higher yields than open vase. Fruit size of W72 as a central leader was not satisfactory in 2003, an observation also made at the NC-140 rootstock evaluation trial.

Sweet cherry cultivar collection, The Dalles

Cultivars that offer potential for the early season include 'Santina' and 'Cristalina'. 'Santina' fruit had good firmness, flavor and acceptable size. Several cultivars from this plot have shown potential for the late season (13S-16-29, 'Sweetheart' 'Symphony', 'Staccato' and 13S-21-01). Unfortunately, most have shown high incidence of powdery mildew on the fruit (see Table 2). 13S-16-29, although with relatively small fruit, ripened after 'Sweetheart' this year and offers potential as a late material and showed minimal powdery mildew damage. Selection 13S-42-49 continues to display potential as a stemless and/or mechanically-harvested cherry. Observations on pitting incidence using fruit stored at 10C and treated at 4C with a pitting tool showed none to slight damage for treated fruit of 'Bing' (Dufur), 'Sonnet', 'Sonata', 'Regina', 'Sandra Rose', 'Attika' and 'Lapins'. Fruit were stored July 10 and evaluated on July 23. 'Sonata' and 'Sandra Rose' had small proportions of fruit (<15%) with severe pitting.

NC-140 rootstock trial, Orchard View Farms, The Dalles

Trees of this trial are trained to the central leader training system. Yield and fruit size trends in 2002 and 2003 suggest that the trees in this plot are approaching mature bearing age. Fruit size for all rootstocks was very good in 2003, whereas in 2000, 2001 and 2002 there were significant differences among cultivars, ranging from 8.1 g/fruit to 10.0 g/fruit in 2002. Giessen 195-20 has produced the best yields throughout the study, although fruit size in previous years has not been optimal (10.5 row average in 2002). Yield of Weiroot 72 during 2003 was lower than in 2002 and 2001, and fruit size was unacceptable in both years. Based on results obtained so far, the best performing rootstock in this plot is Giessen 195-20 (Table 3).

Post-harvest evaluation of modified-atmosphere packaged (MAP) 'Regina' fruit

A preliminary study conducted in 2002 revealed that more than 60% of 'Regina' fruit exhibited darkened pulp spots when packaged in MAP. Symptoms suggested damage by elevated CO_2 levels inside MAP bags (Dr. Paul Chen, personal communication). An experiment was conducted to compare fruit quality of Regina fruit packaged in View-Fresh bags with and without a CO_2 scrubber pad (filled with 500 g of hydrated lime powder) to absorb CO_2. Fruit samples were harvested and packaged July 21, and evaluated after 25, 32 and 39 days of storage (Table 4). The damage observed in 2002 was not seen in either treatment tested in 2003, therefore the cause of the 2002 damage remains unclear. However, this recent trial revealed that 'Regina' fruit stored for up to 39 days in MAPing maintained very good visual and physical quality.

Postharvest fruit quality parameters as influenced by maturity stage at harvest

Postharvest quality traits (firmness, ^{o}Brix, color based on MSU 4-tone scale, overall fruit appearance where 1= best and 4=worst, and stem detachment force) are summarized for 4 cultivars in Table 5. Fruit considered ripe, under- or over-ripe based on external color, were separated per ripeness stage. Samples (n=25) were analyzed 0, 14 and 28 after storage at 31^{o}F. All measurements were performed on individual fruit to allow cross-correlations among quality parameters, although only means and corresponding standard errors are presented. Additional cultivars not shown include ‘Sylvia’, ‘Sandra Rose’ and ‘Lapins’. Additional measured variables include fruit weight and diameter.

Fruit and shoot growth curves

A study to generate developmental curves for fruit and vegetative shoots of 4 cultivars was initiated in 2003 in Hood River and The Dalles. Curves relate incremental growth to time and growing degree hours (GDH; Fig. 1) for fruit growing in Hood River (MCAREC). Measurements were made between May 12 and July 14 using a digital caliper. Fruit were about mid Stage 1 at the start of measurements. Although preliminary, these curves reveal differential growth rates among cultivars, with ‘Regina’ showing greater growth rates (steeper slope) during early development (part of Stage 1 Fig. 1). Reductions in growth rate corresponding to Stage 2 (hardening of the pit) are discernible for all cultivars, with ‘Bing’ and ‘Regina’ showing a more defined lag period than ‘Lapins’ and ‘Sweetheart’. This information can be potentially useful in fine-tuning the timing of cultural practices such as irrigation, nutrient management and GA_3 sprays. This type of information may also help predict reproductive and vegetative developmental events (as well as harvest date and final fruit size) by tracking accumulation of temperature-related parameters such as GDH. This study will continue during 2004.

Budget

Title: Cultivars, rootstocks, training systems and fruit quality evaluation.
PI: Roberto Núñez-Elisea
Duration: long-term
Funding in 2003: $26,500
Current year request: $27,500

	Year 2003	**Current year 2004**	Year 2005
Original request			
Total	41,000		
Current year request			
Salaries-FRA	17,153	**17,000**	
OPE (53%)	8,847	**9,010**	
Travel to res. plots	500	**1,490**	
Total	26,500	**27,500**	30,000

Table 1. Yield, vigor and fruit size of ‘Bing’ on promising alternative rootstocks at Hazel Dell orchard, The Dalles, OR, 2003.

French (7th leaf)	**2003 yield (tons/acre)**		**Fruit weight (g)**		**TCSA (cm^2)**	
Rootstock	**Central leader**	**Open vase**	**Central leader**	**Open vase**	**Central leader**	**Open vase**
Pontaleb	6.67 a	4.38 a	10.3	10.1	263.0	250.1
Maxma 14	4.26 b	4.98 a	9.6	9.5	232.0	279.3
Edabriz	2.90 b	3.80 a	8.5	8.9	113.7	123.9
Mazzard	3.12 b	1.33 b	9.6	9.7	221.4	250.7
			ns	ns	ns	ns
Weiroot (6th leaf)	**2003 yield (tons/acre)**		**Fruit weight (g)**		**TCSA (cm^2)**	
Rootstock	**Central leader**	**Open vase**	**Central leader**	**Open vase**	**Central leader**	**Open vase**
W158	7.06	5.66	8.3	9.0	158.8	218.6
W72	8.47	5.20	8.3	7.4	71.5	74.5
Mazzard	2.69	0.51	8.6	9.6	180.2	262.7
	ns	ns	ns	ns	ns	ns

Table 2. Fruit characteristics of sweet cherry cultivars and selections under evaluation in The Dalles. All trees were treated with 25 ppm GA_3.

Cultivar/selection	Date	Ripeness status	Fruit wt. (g)	Fruit diam. (mm)	Firmness (g/mm)	% of fruit (n = 50 fruit) 10-row and larger	9-row and larger
Newstar	26-Jun	ripe-over	12.2	30.7	253.2	100	66
8S-3-13	26-Jun	ripe	12.4	31.7	318.3	100	82
Cristalina	26-Jun	ripe-over	11.0	30.4	339.7	98	74
Santina	26-Jun	ripe	11.8	30.7	380.9	100	80
Bing (Marchand)	30-Jun	harvest	10.7	29.2	321.1	100	34
Bing/Mazzard	30-Jun	harvest	10.5	28.9	287.1	96	26
Bing/G-6	30-Jun	harvest	9.6	28.1	339.9	90	10
Sylvia	30-Jun	ripe-under	12.1	29.9	292.6	96	60
Sonata	7-Jul	ripe-over	13.6	31.9	400.7	100	90
Sandra Rose	7-Jul	ripe-over	14.2	32.6	358.7	100	88
13S-21-07	7-Jul	ripe-over	11.3	30.5	270.0	100	70
Sonnet	7-Jul	ripe-over	11.5	29.8	260.4	90	56
13S-18-15	7-Jul	ripe	13.6	32.3	298.5	100	94
Attika	10-Jul	ripe	12.2	30.1	309.0	100	56
Lapins	14-Jul	ripe	13.1	31.5	364.9	100	82
4W-11-08	17-Jul	ripe	12.0	30.3	409.1	100	64
Regina	17-Jul	ripe	11.6	28.9	353.3	82	34
13S-42-49	17-Jul	ripe	12.3	30.9	389.2	94	76
Sweetheart/G-6	17-Jul	harvest	12.8	30.7	348.0	100	66
Sweetheart/Maz	17-Jul	harvest	10.1	28.5	368.9	96	8
13S-16-29	23-Jul	ripe	10.1	28.9	306.6	98	28
Symphony	28-Jul	ripe	11.2	29.1	261.9	100	32
Staccato	4-Aug	ripe	11.2	-	-	-	-
13S-21-01	4-Aug	unripe	10.1	-	-	-	-

Table 4. Effect of a CO_2 scrubber on MAPed 'Regina' fruit quality. Fruit samples harvested July 21, 2003 and stored at 31^{o}F.

MAP treatment	Fruit wt. (g)	±Std error	Firmness (g/mm)	±Std error	^{o}Brix	±Std error	Color (1-5; 5= darkest)	±Std error	Stem qual. (1-4; 1 = best)	±Std error
15-Aug (25 days postharvest)										
MAP + CO_2 scrubber	12.21	0.25	355.0	8.3	20.9	0.36	4.72	0.03	2.1	0.17
Control (MAP only)	12.82	0.23	349.9	8.2	22.2	0.64	4.79	0.03	1.3	0.11
29-Aug (39 days postharvest)										
MAP + CO_2 scrubber	12.36	0.26	349.5	7.8	21.5	0.34	4.75	0.05	1.6	0.10
Control (MAP only)	12.86	0.22	364.7	10.9	21.6	0.50	4.70	0.04	1.6	0.12

Table 3. Performance of 'Bing' sweet cherry on 15 rootstocks at the NC-140 evaluation trial, Orchard View Farms, The Dalles, 2003.

Rootstock	Yield (lbs/tree)	TCSA (cm^2)	Fruit quality: Weight (g)	Diam. (mm)	Firmness (g)	Fruit appearance
195-20	55.0 a	124.1 de	10.5	29.40	308.41 efg	variable/ripe-underripe
Gi-6	52.8 ab	171.8 abc	10.2	28.82	327.44 cdef	uniform/ripe
Gi-4	46.4 abc	79.5 h	9.5	27.45	297.98 fg	uniform/ripe-overripe
Gi-5	45.9 abc	111.3 ef	10.0	28.58	337.08 cde	uniform/ripe
318-17	44.4 abc	163.5 bc	10.2	28.92	327.79 cdef	uniform/underripe
Gi-7	42.8 bc	111.0 efg	10.6	29.01	341.28 cd	uniform/ripe-underripe
P. mahaleb	40.6 cd	180.3 ab	10.3	29.24	338.36 cd	uniform/ripe-underripe
W-158	36.6 cde	146.0 cd	10.2	29.14	381.57 a	variable/underripe
W-53	36.1 cde	72.5 h	9.9	28.91	313.8 defg	uniform/ripe-overripe
Edabriz	36.0 cde	93.2 fgh	9.9	29.04	323.70 cdefg	variable/ripe-overripe
209-1	30.9 de	68.5 h	10.0	28.69	296.63 g	uniform/ripe-overripe
W-154	30.6 de	161.7 bc	9.7	28.80	351.64 abc	variable/underripe
W-72	29.5 de	85.0 gh	10.1	29.27	335.40 cde	uniform/ripe
W-13	29.3 de	194.9 a	9.9	28.94	348.93 bc	uniform/ripe-underripe
W-10	25.8 e	175.7 ab	9.9	28.75	377.56 ab	variable/underripe
			n.s.	n.s.		

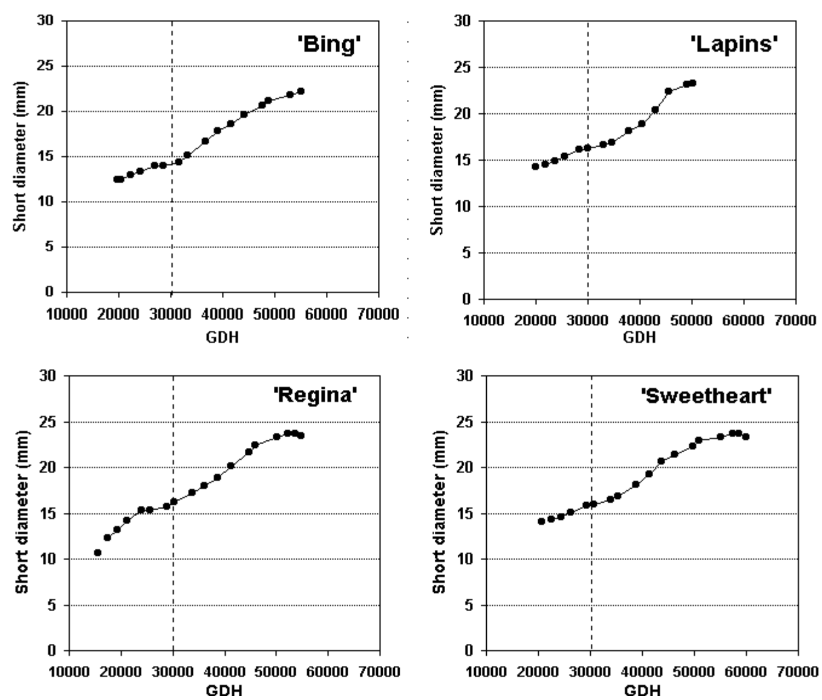

Figure 1. Fruit growth curves for 4 sweet cherry cultivars in relation to cumulative growing degree hours (GDH; base temperature 25°F, biofix at ca. full bloom). Fruit equatorial diameter measurements made between May 12 and July 14. MCAREC, Hood River, 2003.

Table 5. Postharvest quality of 4 sweet cherry cultivars harvested at 3 maturity stages. Fruit samples collected from The Dalles cultivar evaluation plot. OR = over-ripe; UR = under-ripe; n = 25 fruit.

Cv.	Stage	Days posth.	Firmness (g/mm)	±Std. error	°Brix	±Std. error	Color (1-5; 5= darkest)	±Std. error	Stem qlty. (1-4; 1= best)	±Std. error	Stem detach. force (g)	±Std. error
		0	323.3	*50.6*	23.9	*3.1*	4.2	*0.4*	1.0	*0.0*	585.4	*255.2*
	OR	14	372.0	*50.5*	22.8	*3.1*	4.3	*0.4*	2.4	*0.8*	416.8	*263.6*
		28	--	--	22.1	*2.3*	4.5	*0.3*	2.5	*0.8*	440.6	*246.7*
		0	307.9	*44.3*	21.4	*2.9*	4.3	*0.4*	1.0	*0.0*	676.4	*148.5*
'Bing'	Ripe	14	361.3	*72.4*	21.4	*2.8*	4.1	*0.4*	1.8	*0.7*	668.7	*283.3*
		28	445.9	*97.2*	20.1	*2.8*	3.9	*0.4*	2.4	*0.6*	646.6	*206.6*
		0	371.0	*30.2*	18.3	*1.6*	2.7	*0.5*	1.0	*0.0*	611.5	*121.3*
	UR	14	419.6	*50.2*	17.5	*1.4*	2.1	*0.6*	1.8	*0.6*	627.2	*177.4*
		28	458.6	*72.2*	17.6	*1.6*	2.6	*0.5*	2.2	*0.6*	472.1	*236.2*
		0	353.5	*51.1*	19.2	*2.1*	4.7	*0.3*	1.0	*0.0*	351.2	*166.5*
	OR	14	--	--	20.5	*3.2*	4.6	*0.3*	2.6	*0.6*	385.8	*185.1*
		28	410.9	*76.8*	20.2	*2.4*	4.5	*0.4*	2.6	*0.6*	301.5	*188.2*
		0	338.3	*42.0*	19.1	*2.5*	4.3	*0.3*	1.0	*0.0*	512.8	*209.6*
'Lapins'	Ripe	14	398.7	*66.7*	18.4	*2.0*	4.4	*0.3*	2.3	*0.7*	491.0	*228.8*
		28	--	--	18.8	*2.5*	4.4	*0.3*	2.3	*0.8*	411.7	*255.3*
		0	386.4	*41.9*	20.0	*1.6*	3.6	*0.3*	1.0	*0.0*	604.0	*139.3*
	UR	14	423.2	*65.8*	19.1	*1.9*	3.7	*0.2*	2.4	*0.6*	550.6	*210.4*
		28	--	--	19.2	*1.6*	3.9	*0.3*	2.3	*0.9*	533.4	*233.7*
		14	--	--	23.4	*2.8*	4.9	*0.2*	2.8	*0.6*	1109.5	*369.4*
	OR	28	448.6	*77.3*	22.6	*2.3*	4.9	*0.1*	3.8	*0.4*	1058.2	*431.9*
		0	331.8	*46.5*	22.5	*3.0*	4.4	*0.2*	1.0	*0.0*	1005.4	*179.4*
'Regina'	Ripe	14	358.2	*47.0*	22.7	*2.4*	4.8	*0.3*	2.0	*0.7*	1070.5	*304.7*
		28	--	--	22.1	*2.4*	4.7	*0.4*	1.8	*0.7*	1052.1	*307.4*
		0	346.2	*66.3*	17.9	*2.1*	3.9	*0.4*	1.0	*0.0*	888.7	*185.1*
	UR	14	361.5	*46.0*	18.2	*3.1*	4.1	*0.6*	1.8	*0.8*	943.5	*150.3*
		28	--	--	18.2	*2.8*	4.2	*0.4*	1.6	*0.8*	945.6	*249.9*
		0	405.1	*43.0*	20.5	*2.1*	4.3	*0.4*	1.0	*0.0*	441.2	*200.5*
	OR	14	--	--	20.6	*1.4*	4.5	*0.3*	1.8	*0.6*	369.5	*192.7*
'Skeena'		28	487.5	*59.2*	19.8	*1.8*	4.5	*0.3*	2.3	*0.6*	287.6	*199.3*
		0	381.5	*38.3*	20.1	*2.1*	4.1	*0.2*	1.0	*0.0*	420.2	*226.0*
	Ripe	14	458.7	*53.1*	19.5	*1.5*	4.2	*0.3*	1.8	*0.7*	434.7	*223.3*
		28	--	--	19.5	*2.6*	4.3	*0.4*	2.4	*0.9*	431.4	265.6

FINAL REPORT

Title: Chemical bloom thinning of sweet cherry to increase fruit size

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David Ophardt, Prosser, WA

Objectives
This project is a collaborative effort involving research in commercial and experimental orchards in Washington and Oregon. The main objectives are to (1) determine the efficacy of chemical bloom thinning agents in reducing crop load and to (2) determine to determine the effect of crop load reduction on fruit size and quality. Trials were conducted in 2001, 2002 and 2003.

Significant findings

- The effect of chemical bloom thinners varied greatly among locations. Treatments that effectively reduced crop load did not consistently increase fruit size.

- The strongest responses to chemical treatments appeared to occur when with high initial crop loads. Crop load reductions have often been excessive, resulting in larger fruit but production of yields too low to be economically attractive.

- Data generated to date indicates that ATS is an effective bloom thinner, but it has not consistently resulted in a significant increase in fruit size.

- It was observed that in some cases, larger fruit was produced without significant chemical bloom thinning, suggesting an alternative mechanism for fruit growth stimulation independent of crop removal. It seems possible that sink strength has been enhanced in these cases, allowing fruit to compete more favorably for resources.

- Fruit firmness and soluble solids content (^{o}Brix) were often increased by the chemical bloom thinners tested.

- More research is needed to clarify the causes of the highly variable responses obtained among years, products and experimental sites and often within experimental sites.

Methods
This project was conducted in grower or experimental orchards in Oregon and Washington. During 2002 and 2003, work focused on testing the following treatments in 'Bing' trees:

1. Control trees, not sprayed.
2. Crocker fish oil + lime sulfur 2% (CFO + LS, sprayed at 25% FB and again at 85% FB).
3. Vegetable oil emulsion (VOE; 4% a.i., sprayed at bloom stage 6 and again at 75% FB).
4. Ammonium thiosulfate (ATS; 2% v:v; sprayed at 25% FB and again at 85% FB).

In addition to the above treatments, a combination spray of 2% ATS plus an experimental bioregulator (20 ppm) was tested in The Dalles on 6^{th} leaf 'Bing'/Gisela 5 trees. A single combination spray was applied at ca. full bloom.

One branch per tree was chosen for data collection. Measurements included basal diameter at branching point, total branch length, number of individual flowers, number of green fruit when fruit measured 1 cm diameter, number of harvested fruit per branch and weight of fruit harvested from whole branch. Total yield per tree was recorded and a random sample of 25 fruit was collected from the tagged branch per tree to determine diameter, firmness and average fruit weight.

Results

Prosser, WA ('Bing'/Gisela 5)

All spray treatments significantly reduced crop load compared to controls. Yields of control trees averaged 68 lb/ whereas sprayed trees produced ca. 20 lb/tree. All spray treatments increased average fruit weight from 5.4 g in controls to ca. 7.3 g in sprayed treatments; however, this size increase is insufficient to offer increased profitability. Chemical bloom thinning resulted in ca. 85% 11½-row fruit, whereas controls produced 47%. Average fruit firmness was significantly increased by CFO + LS. ATS and CFO + LS significantly increased total soluble solids to 24^{o} Brix compared to 20^{o} Brix in controls.

Results for 2003 show that ATS and CFO+LS significantly increased fruit size in relation to VOE, while yields were similar for all treatments at ca. 12 kg/tree (Fig. 1). Fruit weights achieved in this trial ranged from 7 to 9 g, with controls producing fruit of statistically equal weight as ATS and CFO+LS. Fruit weights obtained in The Dalles (see below) exceeded 10 g/fruit, suggesting that the experimental microenvironment was more favorable for fruit development.

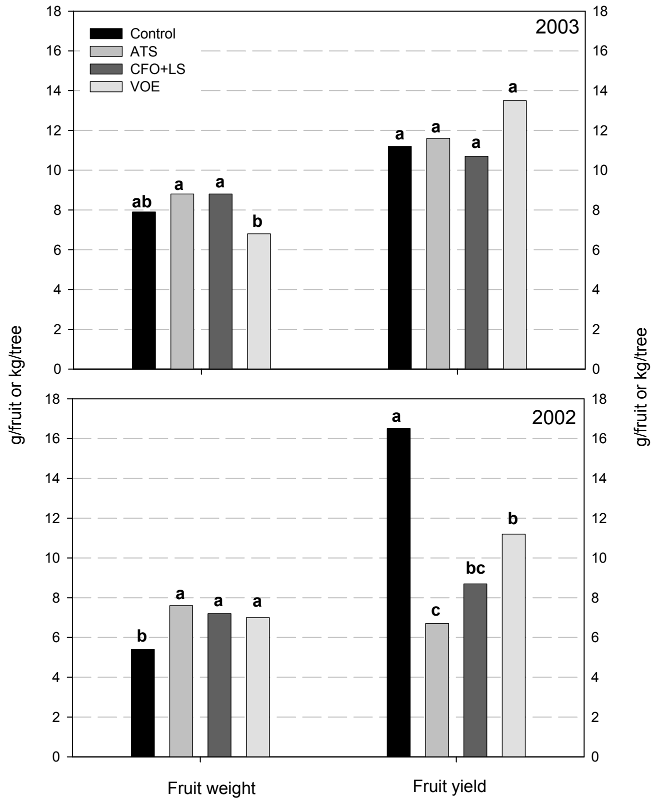

Figure 1. Effect of blossom thinner on individual fruit weight (g) and tree yield (kg) from 8- and 9-year-old 'Bing'/Gisela 5 sweet cherry trees in Prosser, WA. Bars with different letters are statistically different within year and parameter (P<0.05, n = 8). Data from M. Whiting.

Wenatchee, WA ('Bing'/Gisela 5)
Average yield for control trees was 50 lb/tree, compared to 36 lb/tree to 45 lb/tree for the spray treatments. Significant increases in average fruit weight were obtained with all treatments. Average fruit weight for controls was 6.6 g compared to >8.0 g for VOE and ATS, and 8.9 g for CFO+LS.

Yakima, WA ('Bing'/Gisela 6)
Chemical bloom thinning treatments showed no significant effects on fruit set, crop load reduction or fruit size. Average fruit size for all treatments at this site ranged from 8.6 g to 9.7 g

The Dalles, OR ('Bing'/Gisela 5)
Average tree yields for all treatments were ca. 40 lb/tree. Fruit set of controls was 52%, vs. 39% to 42% fruit set for sprayed trees. Compared to Prosser, average fruit weight in The Dalles was large for all treatments (10.0 g to 10.8 g), including controls (10.4 g), corresponding to an average row size of 9½ in all cases. Fruit firmness ranged from 314 g/mm in controls to > 323 g/mm for the chemical spray treatments.

In a separate trial, it was observed that the 2% ATS/bioregulator combination spray produced a large proportion of fruit exceeding 10 g without significantly reducing tree yields. This response suggests the possibility that the competitive ability of young sweet cherry fruit can be stimulated at this early stage, when they are still ovaries in development.

Hood River, OR (‘Lapins’/Gisela 11)

Tree responses were very variable, resulting in no significant effects on fruit set, crop load reduction or fruit size. Fruit set varied from 27% to 30%, with average yields ranging from 28 lb/tree (ATS) to 46 lb/tree (control and LS). Average fruit weight ranged from 12.0 g to 13.4 g (30.3 to 31.6 mm diameter).

Future work

Crop load management via bloom thinning offers great potential as a management tool to increase grower profitability. However, consistent and predictable increase of sweet cherry fruit size by chemical bloom thinning still eludes us. It is suggested that tree and environmental conditions be monitored more closely in future work to help explain the highly variable responses observed to date. Generating fruit growth curves during each trial would also be very helpful. Periodic assessment of tree stress level is necessary to determine whether a lack of response is due to product or tree condition. For example, a practical determination of tree water status involves measuring leaf or stem water potential with a portable pressure bomb. Focusing future work on more detailed tree, fruit and environmental monitoring with very few treatments (only control vs. ATS, for example, may be sufficient to begin) and with more replication would increase our ability to interpret results of experimental chemical bloom thinning treatments.

Budget

Title: Chemical bloom thinning to increase fruit size in sweet cherry.
PI: Roberto Núñez-Elisea
Duration: 3 years
Project total (3 yrs): $17,000

Item	Year 1 (2001)	Year 2 (2002)	**Year 3 (2003)**
Salaries - FRA	$4,000	$4,398	**4090**
OPE (51.58 %)		$352	**2110**
Supplies		$500	**300**
Travel to orchards		$750	**500**
Total	$4,000	$6,000	**7,000**

CONTINUING PROJECT REPORT **YEAR 3/3**

Project Title: *Influence of Blossom Thinners in Commercial Peach Cultivars on Fruit Set and Effects of Training and Crop Load Adjustment on Fruit Quality in 'Snow Giant' Peach*

Personnel: **Project Leader**: **Dr. Essie Fallahi**, Professor and Director of Pomology, University of Idaho, Parma Research and Extension
Technical Support: Bahar Fallahi and Benito Morales, University of Idaho.

Organization: University of Idaho, Parma Research and Extension Center 29603 U of I Lane, Parma, Idaho 83660

Cooperators: **Dr. Jim McFerson,** Washington State Tree Fruit Research Commission (will be Co-investigator in the blossom-thinning portion).

OBJECTIVES

Thinning of pome and stone fruit is a necessary but costly practice. Apples are chemically thinned to increase fruit size and to assure a return crop in the following season. In 2003, we experimented with soybean oil as a prebloom control agent on peaches. In 2003, we also used a **NEW chemical called Tergitol-TMN 6** (a surfactant) extensively in several orchards in different regions, and blossom thinning results on peaches and plums were **outstanding, with up to 55 to 60% saving in hand thinning**. No one has looked at this chemical for blossom thinning of any fruit in the PNW before. Thus, we would like to continue our work with Tergitol TMN-6 in 2004. We would also like to continue our research to find out how far apart the "hangers" on 'Snow Giant' peach should be to produce optimum fruit size and quality. Thus, our main objectives are:

1) To experiment with Tergitol TMN-6 blossom thinner in peaches. This experiment will be in conjunction with Dr. Jim Mc Ferson on peaches and perhaps with other stone fruit growers in Washington.

2) To study the effects of different numbers of "hangers" (crop load) on fruit yield, color, and quality in 'Snow Giant' peach.

Significant Findings:

1. Tergitol at all tested concentrations effectively thinned blossoms in peaches and plums in different orchards in 2003.
2. When trees were in about 75 to 80% bloom, Tergitol at 1% (at 200 gal/acre) and above caused over thinning. Under this condition, concentrations of 0.5% or perhaps 0.75% were sufficient.
3. When Trees were at 100% blooms, and flowers had a chance for good pollination/fertilization, Tergitol at 1% resulted in excellent thinning, and very small amount of hand thinning was needed (at least 60% saving in hand thinning).
4. Fish Oil at 3% also caused blossom thinning in peaches but it was not as effective as Tergitol.
5. No Fruit russetting was observed with Tergitol applications at any concentrations.
6. Water volume (spray volume) seems to be important and deserves further study.
7. Pre-bloom application of soybean oil did not affect blossom or fruit density.
8. Tergitol could have the potential to be an excellent blossom thinner for stone fruit.

Methods:

<u>Blossom Thinners and SoyBean applications For Year 2003 and 2004:</u>

a) **<u>Soy Bean Oil Spray:</u>** Three peach orchards (Elberta and August Lady) were selected in Sunnly Slope, Idaho for prebloom soybean oil spray. The treatments were 6%, 8%, or water spray (control). The trees were sprayed with soybean oil about 7 weeks before anticipated bloom time at 200 gal/acre with an air-blast sprayer in 2003.

b) **<u>Blossom Thinners:</u>** Several peach and two plum orchards were selected in Idaho for 2003 blossom thinning experiment. In each orchard in Sunny Slope (Elberta and August Lady) peaches 4 rows were selected for the experiment with two buffer rows in between. In each of the two adjacent rows, 10 trees (total of 40 trees per treatment) were tagged and sprayed with Tergitol at 0.5%, 1%, 2%, 3% or with Fish Oil at 3% at the rate of 200 gal/acre. The same number of trees was left unsprayed (control) on each row. The procedures were the same for Elberta, Red Globe, and Blazing star orchards in Fruitland Idaho, except only 6 trees per segments were sprayed. We also left unsprayed (control) for each cultivar. Between three to four limbs per tree were selected and number of fruit and branch cross sectional area were measured. After fruit set was complete (in June), number of fruit in those limbs were also counted and fruit set was measured (fruit No/branch cross sectional area). The same method will be used in 2004. In 2003, Trees were sprayed at 200 gal/acre rate at about 70-80% bloom in Sunny Slope and at Full-bloom (100% open) in Fruitland, Idaho**.** In general, our blossom thinning methodology in 2004 will be similar to those in 2003.

Crop Adjustment with Selecting Certain Number of Hangers: For this experiment, 'Snow Giant' peach trees on Lovell rootstock were planted at the University of Idaho Pomology orchard at 8 x 16.5 ft spacing. Trees were trained as a Y or QAD Vase shape in 2001, 2002, and 2003. In this portion of proposal, we have one of the three levels of hangers (one-year old branches) per limb. These treatments consist of removing the runners out to one runner every 5, 10 or 15 inches apart in 2003 and 2004. Fruit quality, maturity, color and size will be evaluated in each treatment.

<u>Results and Discussion:</u>

<u>Blossom Thining 2003:</u>

In all locations, Tergitol significantly reduced blossoms and fruit set in peaches in all different orchards (Figures 1-5).

Application of as low as 0.5% significantly reduced fruit set in Sunny Slope. Application of more than 1% was too much and resulted in over thinning (see Figures 5-9). Application of 1% Tergitol showed excellent results in Fruitsland, perhaps because we applied at 100% bloom. However, trees with 1% application had light crop in Sunny Slope because we sprayed at 70-80% bloom. In Sunny Slope, based on conditions of our experiment (about 80% bloom), it seemed that somewhere between 0.5% and 1% (perhaps 0.75%) is sufficient for effective bloom thinning. In Fruitland, however, 1% resulted in excellent results, perhaps because we sprayed at full bloom. We would like to continue our experiment with Tergitol, as it seems to be THE BEST Blossom thinner we have ever tested for peaches and plums in many years.

We sprayed ‘Empress' plums with 3% Tergitol in two locations. This concentration resulted in over thinning but not as drastic as in peaches.

Application of 3% Fish oil also reduced fruit set, but effects were not nearly as significant as Tergitol effects ; please see figures of 2003.

TERGITOL IS VERY CHEAP!! And we think it has the potential to be an outstanding blossom thinner for stone fruits after registration. The cost will be about $15/acre!!

No one has experimented with this new blossom thinner in the PNW and we are hoping to be able to receive the requested funding and to continue our experiment with this chemical in both Washington and Idaho.

Soy Bean Oil Spray: Three peach orchards (Elberta and August Lady) were selected in Sunnly Slope, Idaho for prebloom soybean oil spray. The treatments were 6%, 8%, or water spray (control). The trees were sprayed with soybean oil about 7 weeks before anticipated bloom time at 200 gal/acre with an air-blast sprayer. Number of blooms per certain length of hanger was counted at "popcorn" bloom stage. We did not observe a significant effect with soybean application. This chemical in some years shows effective thinning in the South Eastern states of the US. However, perhaps because of a different dormancy cycle in our area, we may not see an effective thinning of this chemical. We will not continue our work with soybean oil in 2004 and will only focus on Tergitol.

Crop Adjustment:

The crop load adjustment experiment showed that removal of hangers down to 10 or 15 inches apart on a leader will result in larger fruits but lower yields (Table 1). Type of training (2-leader vs. 4-leaders) did not affect yield or fruit quality (Tables 2). We would like to continue this experiment in 2004 when trees are mature.

Budget Page

Title: ***Influence of Blossom Thinners in Commercial Peach Cultivars on Fruit Set and Effects of Training and Crop Load Adjustment on Fruit Quality in 'Snow Giant' Peach***

Project Leader: **Dr. Essie Fallahi, University of Idaho**

Project Duration: **2002-2004**

Current Year: **2004**

Project Total: **$15,375**

Current Year Request: **$6825**

Year	**Year (2002)**	**Year (2003)**	**Year 3 (2004)**
Total	$6600.00	$1950.00	$6,825.00

Item	Year 1(2002)	Year 2(2003)	**Year 3 (2004)**
Salaries	2800	500	**1000**
Benefits(%) 45%	1260	225	**450**
Wages	1500	300	**2100**
Benefits (%) 0.25%	375	135	**525**
Equipment	0	0	**300**
Materials& Supplies	465	380	**1480**
Travel	200	410	**970**

Figure 1. Effect of Blossom Thinners on Fruit Set of 'Elberta' Peach, Sunny Slope, Idaho, 2003

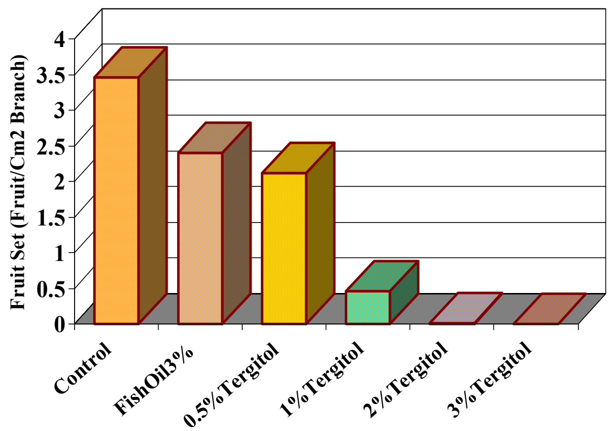

Figure 2. Effect of Blossom Thinners on Fruit Set of 'August Lady' Peach, Sunny Slope, Idaho, 2003

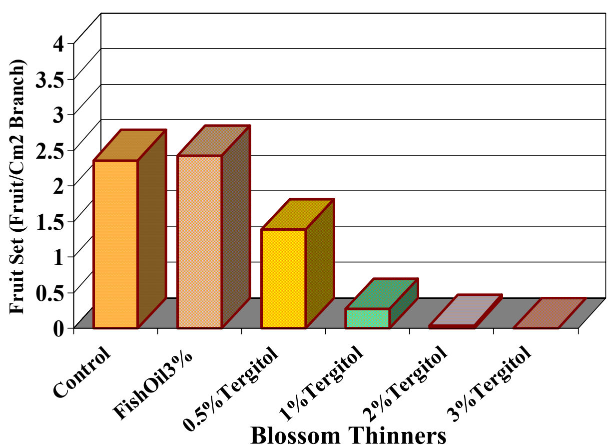

Figure 3. Effect of Tergitol on Fruit Set of 'Elberta' Peach, Fruitland, Idaho 2003

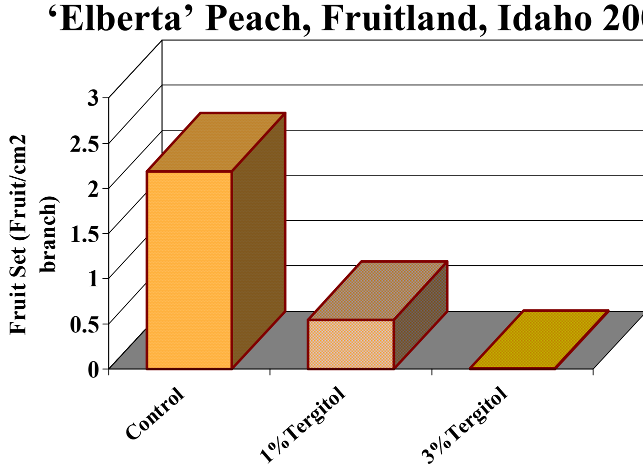

Figure 4. Effect of Tergitol on Fruit Set of 'Red Globe' Peach, Fruitland, Idaho 2003

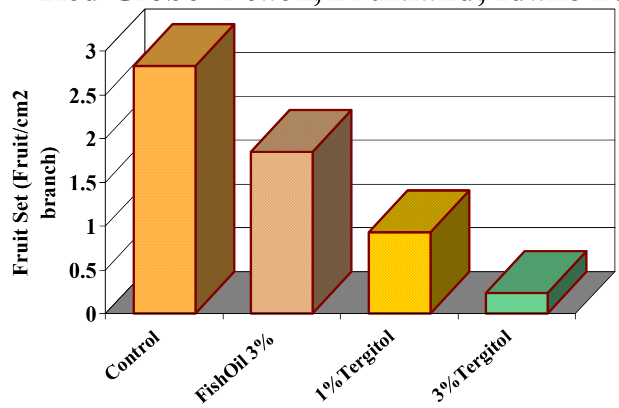

Figure 5. Effect of Tergitol on Fruit Set of 'Blazing Star' Peach, Fruitland, Idaho 2003

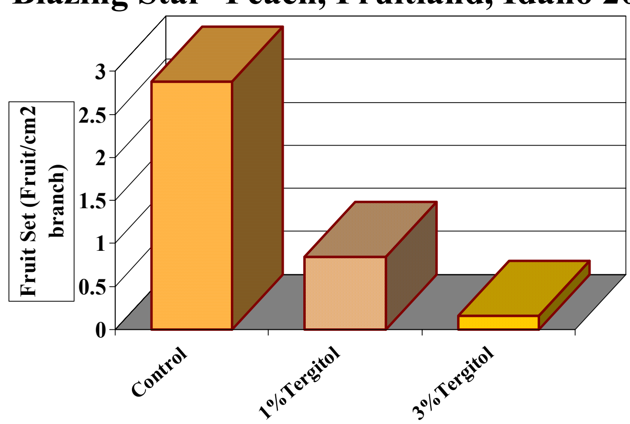

Table 1. Effects of Different "Hanger" Spacing on 'Snow Giant' Peach Quality and Yield, 2003.

Crop load	Avg net yield (Boxes/tree)	Avg sugar (Brix)	Color (1-5)	Avg fruit wt (g)
Light (Runners 15 inches apart)	0.83 c	11.58 a	3.76 a	259.9 a
Medium (Runners 10 inches apart)	1.05 b	11.96 a	3.58 a	264.7 a
Heavy(Runners 5 inches apart)	1.38 a	11.7 a	3.68 a	234.6 b

Values followed by different letters are significantly different at 5% based on LSD mean separation.

Table 2. Effect of Training on 'Snow Giant' Peach Quality and Yield, 2003.

Crop load	Avg yield (Boxes/tree)	Avg sugar (Brix)	Color (1-5)	Avg fruit wt (g)
4 Leader Training	1.11 a	11.86 a	3.65 a	251.8 a
2 Leader (V shape) Training	1.04 a	11.62 a	3.70 a	256.7 a

Values followed by different letters are significantly different at 5% based on LSD mean separation.

CONTINUING PROJECT 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
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 2004-2005:

1. 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.
2. Appraise new potential rootstocks for commercial acceptability in Willamette Valley sweet cherry production systems.
3. Assess the influence of burning alone and in combination with other branch inducing agents to induce budbreak on 2-yr and older wood and evaluate the treatment's effects for the presence of bacterial canker.
4. Evaluate GA, cytokinin and Retain treatments for their influence on fruit maturity and quality, and stem retention and quality.

Significant Findings:

- *1996 Dark cherry cultivar trial*-

Best performers: 'Sandra Rose', 'Sonata', 'Sylvia', 'Regina', 13S21-07, 'Regina', and 'Staccato'. Firm fruit but lesser stem pull force at harvest or after two weeks: 'Symphony', 13S49-24, 4W11-08, 13S21-01, and 'Skeena' (stemless cherries?)

- *1998 Blush cherry trial*-

Most promising selections for the fresh market: NY7690, 13N07-39, 1307-32, 13S21-14, 2N31-19. Most suited for brine industry: NY518, NY8182, NY9295, 13S20-11, and 'Sweetheart'.

- *1998 NC-140 'Bing' rootstock trial*-

Gi5 and Gi6 are 2-3.5 times more productive than Mazzard and have similar fruit size and stem pull force.

- *Bacterial canker tolerance*-

Dark cherries-
Most symptoms: 'Staccato', 'Symphony' and 'Cristalina'
Least symptoms: 'Newstar, 'Sandra Rose', 'Bing', 'Sonata', 'Skeena', 'Sylvia', 'Regina', 'Symphony', 13S17-40, 13S18-15, 13S42-49, 8S03-13, 4W11-08, 13S21-01.
Blush cherries-
No to few symptoms: 'Stardust', NY13688, 13N07-39, 13N 07-32, NY9295, 13S 09-37, NY518, 2N31-19, NY8182, NY252, 'Royal Ann'.
'Bing'-
Most symptoms: Gisela 6, Gi195-20, Gisela 5, Edabriz, Gi318-17, W53, Gisela 7, Gisela 4, Gi209-1.
Least symptoms: Remaining Weiroots, Mahaleb and Mazzard.

- *1999 Interstem trial*-

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 is the trunk (interstem or high-grafted).

- *2003 branching trials*-

Burning and notching above the bud, and disbudding at green tip on one-year old wood resulted 6-9.5 budbreaks per branch. Covering promalin treated buds with clear plastic increased the number of branches (4.25) and consistency of branching when compared to promalin alone (3). No gumming was observed at the site of the burns.

- *Sweet cherry fruit growth curves*-

The different maturity times of cherry cultivars is positively correlated with the duration of the pit hardening stage and negatively correlated with the rate of growth during that stage.

- *Stem pull force and retention at harvest and after storage*-

'Van' (Stuart Olson):
MaxCel (100ppm) had the highest stem pull force at harvest. SSC accumulation appeared to be delayed in ReTain, MaxCel (200ppm), Accel and ABG3207 (20ppm) treatments.
'Van' (OSU):
Stem pull force was greatest in fruit treated with GA after 2 weeks in storage.
'Lapins' (OSU):
ProGibb and Accel treatments had the greatest stem pull force after 2 weeks in storage. Tendency towards a delay in color development with MaxCel and ProGibb treatments.
'Royal Ann' (OSU):
Greater firmness and stem pull force after 2 weeks in storage with 'ProGibb' treatment. ABG-3207 (20ppm) also increased stem pull force after 2 weeks in storage.

Methods:

1. 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)
2. 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)
3. 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 were 324 trees (0.50 ha). Tree structure was well established in 2003 and trees grew well.
4. 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).
5. 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).
6. Order (fall 2004) and produce trees (growing season 2005) for a new blush trial with the intent of evaluating 'Royal Rainier', 'Sunrise', 'Early Robin', 'Sonnet', 'Rainier', NY7690, 13N7-39, 13N7-32, 13S21-14, and 2N31-19 on Gi196-4 and MxM14.
7. Evaluate the response of older wood to burning with and without promalin treatment on bud-break, shoot growth, branch angle and the presence of bacterial canker (0.05 ha).

8. Apply a reflective mulch to determine its influence on the coloring and quality of blush cherry fruit.
9. Apply Entry + CAN17 to 'Regina' trees to determine bloom enhancement capacity.
10. Apply ProGibb, ReTain, Accel, Maxcel, and ProVide to Van and Lapins trees to determine the influence on stem pull force and quality.

Results:

- *2000 MxM rootstock trial*- Trees grew extremely well.
- *2001 Sweet cherry systems/cultivar trial-*

Higher density planting: Trees were planted in the fall of 2002. Tree training and pruning commenced to develop central leader, multiple leader and trellised tree structure.
Low-density top-worked planting: rootstocks were top-worked in spring 2003 with 'Royal Ann' 'Sweetheart' and 'Stardust', either as two bud grafts or as multiple scaffold grafts.

- *2002 PiKu trial*- Ten cultivars, 'Sweetheart', 'White Gold', 'Sonata', 'Royal Ann', Skeena', 'Lapins', 'Regina', 'Black Gold', 'Attika' and 'Bing' are being evaluated on PiKu 1 and 3. Four tree replicates were trained as central leader trees.
- *1999 Interstem trial*–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 is the trunk (interstem or high grafted). Trees should bear significant crops in 2004.
- *2003 'Sweetheart' leader burning trial*- Burning, notching and disbudding induced the greatest amount of branching. Promalin alone was erratic but when coverd with plastic, more breaks occurred and were more consistent in length.
- *Sweet cherry fruit growth curves*- During the 2001, 2002, ands 2003 growing seasons, fruit diameter measurements were taken for eight genotypes that matured over a range of ripening times. The cultivars included 'Bing', 'Cristalina', 'Regina', 'Sandra Rose', 'Sonata', 'Staccato', 'Sweetheart' and 'Symphony. Growth curves were evaluated by calendar date and growing degree-hours. Transition points in the double sigmoidal growth curves and slopes of the lines during the three growth phases were determined. The different maturity times of cherry cultivars are influenced by the duration of the pit hardening stage and the rate of growth during that stage. Harvest will be more easily predicted than the beginning of pit hardening and final swell. (Poster is on display.)
- *Bacterial canker*- NY6091, 13S20-11, NY7690, 13S21-14, and Sweetheart trees, and 'Bing' trees on Gisela 6, Gi 195-20, Gisela 5, Edabriz, Gi318-17, W53, Gisela 7 and Gisela 4 had the highest incidence of symptoms. Of the varieties, Symphony, Staccato and Cristalina had the worst symptoms.

Proposed Title: Horticulture management systems for high value cherries
Project Leader: Anita Nina Azarenko **Project duration:** Indefinite
Current year: 2004 **Previous year funding:** $46,000

ITEM	2003	2004
Salaries	**$22,500**	**$32,500**
Benefits (54%)	**11,700**	**16,575**
Wages	**4,420**	
Benefits (5%)	**221**	
Plot charges	**6,213**	**6,700**
Supplies	**446**	**425**
Travel	**500**	**500**
Total	**$46,000**	**$56,700**

1996 Dark cherry cultivar trial-

Table 1. 2003 harvest and bloom dates, yield, TCSA, YE, fruit size, firmness, SSC, pH, 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	6/23	3/28	3/8	9.2	195.4	0.05	27.9	18.5	.	8	257	286	.	925	868	.
San. Rose	6/23	3/6	3/14	9.2	204.7	0.05	27.7	19.6	.	5	255	287	233	717	685	585
Cristalina	6/23	3/6	3/13	5.0	141.2	0.05	27.0	18.5	.	1	287	267	.	685	437	.
Bing[v]	6/30	3/30	3/9	2.2	163.9	0.02	26.5	23.5	6.0	4	230	282	298	816	926	727
8S 03-13	6/ 24	3/29	3/5	4.4	177.0	0.02	28.6	19.0	.	6	295	195	.	922	363	.
Sonata	6/ 30	3/29	3/3	7.0	149.7	0.05	28.5	19.5	5.1	1	284	286	261	803	617	466
Sylvia	7/2	4/8	3/16	17.8	215.1	0.08	26.7	16.4	4.9	0	254	242	220	725	608	553
13S 21-07	6/ 30	3/31	3/11	7.5	188.4	0.05	27.3	14.2	6.0	1	266	317	305	594	643	524
13S 49-24	7/2	3/31	3/9	4.7	180.7	0.03	29.2	20.1	4.5	20	272	277	213	863	489	214
13S 17-40	6/ 30	3/4	3/11	9.0	137.9	0.07	26.5	20.4	5.6	1	206	227	199	530	530	336
13S 18-15	7/8	3/26	3/3	10.5	91.1	0.09	28.3	20.5	5.7	10	220	220	193	555	539	297
13S 42-49	7/10	3/5	3/15	4.8	143.7	0.03	29.9	19.5	5.7	40	349	393	305	642	437	80
Regina[w]	7/3	3/8	3/17	3.3	113.4	0.03	26.4	19.8	5.6	0	246	273	293	829	749	731
13S 16-29	7/14	3/6	3/16	3.8	150.3	0.03	27.0	22.9	5.5	0	262	285	272	.	462	280
Symphony	7/18	3/29	3/9	7.0	210.0	0.03	26.8	18.7	4.5	0	351	.	327	651	.	184
Staccato[w]	7/18	3/28	3/11	4.3	163.7	0.03	25.4	22.4	5.0	0	379	.	413	758	.	673
4W 11-08	7/10	3/5	3/13	2.5	168.1	0.02	28.8	19.2	4.4	71	280	327	.	633	518	.
13S 21-01	7/18	3/4	3/9	1.8	127.2	0.01	26.6	17.9	4.4	0	414	.	321	658	.	268
13N 14-22	.	3/7	3/13	.	115.0	.	.	.	.	.	.	.	.	.	.	.
11W26-58	7/14	3/8	3/15	0.4	124.7	0.01	.	.	.	.	.	.	.	.	.	.
Skeena[w]	7/3	3/12	3/19	5.2	.	.	27.9	19.0	5.0	0	341	267	301	723	365	306
MSD		3 d	2 d	3.8	100.4	0.02	1.5	4.9	0.5	7	57	30.9	25	176	180	73

[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), pH, firmness, fruit size, cracking, pull force and stem weight 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	Peak Bloom	Harvest Date	Yield (kg)	TCSA[y] (cm^2)	YE (kg/ cm^2)	SSC[x] (^{o}Brix)	Fruit Size (mm)	Crack. (%)	Firm. (g/mm^2) Harv.	2 wks	4 wks	Pull Force (g) Harv.	2 wks	4 wks	Stem[x] wt. (mg)
NY518	3/ 27	3/7	6/ 25	6.6	82.6	0.08	18.4	22.0	2	525	318	.	974	481	.	118
R. A.	3/ 30	3/11	6/ 24	14.2	92.8	0.15	16.3	21.3	0	280	211	.	931	500	.	89
NY252	3/ 30	3/8	7/2	7.6	79.3	0.10	19.4	25.1	0	319	335	257	963	832	436	88
NY7690	*3/ 25*	*3/8*	*6/ 25*	*3.6*	*96.9*	*0.04*	*19.8*	*28.6*	*13*	*414*	*402*	*338*	*1028*	*866*	*771*	*116*
NY6091	3/1	3/10	6/ 25	6.8	85.1	0.08	17.1	25.8	0	220	200	157	1026	841	690	123
NY8182	3/ 30	3/10	7/2	9.3	71.9	0.13	19.5	23.8	0	299	357	.	884	856	.	94
NY13688	3/5	3/13	6/ 25	6.2	65.3	0.10	18.7	25.7	3	235	213	190	756	607	461	110
NY9295	3/7	3/14	7/2	6.1	85.3	0.07	22.5	25.6	0	347	441	.	1096	1119	.	119
NY7855	3/8	3/16	7/2	6.5	72.0	0.09	.	.	.	.	253	.	.	840	.	.
NY307	3/9	3/15	7/2	5.5	86.3	0.07	19.3	27.0	0	207	251	227	774	718	633	96
13S20-11	3/ 31	3/9	7/14	3.7	70.3	0.05	18.8	25.0	1	355	329	.	950	.	.	107
13N07-39	*3/5*	*3/10*	*7/3*	*13.6*	*89.4*	*0.15*	*19.2*	*26.8*	*3*	*333*	*350*	*346*	*1264*	*1265*	*1097*	*102*
13S07-50	3/2	3/16	7/3	5.1	50.5	0.10	22.9	25.4	6	198	167	.	530	274	.	150
13N7-32	*3/8*	*3/15*	*7/3*	*11.2*	*78.5*	*0.15*	*18.2*	*26.7*	*9*	*281*	*277*	*296*	*900*	*801*	*832*	*127*
Sweetheart	3/ 29	3/9	7/14	3.5	76.6	0.05	21.1	26.0	0	353	429	.	700	752	.	97
13S 21-14	*3/ 30*	*3/9*	*7/14*	*0.6*	*54.7*	*0.01*	*19.5*	*26.5*	*0*	*363*	*354*	.	*981*	.	.	*130*
13S 09-37	3/5	3/16	7/3	10.9	81.1	0.13	18.8	24.9	2	322	270	.	691	258	.	102
Stardust	3/7	3/15	7/8	11.3	73.0	0.16	19.0	25.5	1	239	263	210	527	590	574	101
2N 31-19	*3/ 24*	*3/8*	*7/14*	*4.3*	*66.1*	*0.07*	*19.1*	*27.6*	*1*	*230*	*267*	.	*669*	*708*	.	*97*
MSD	3.3 d	1.7 d		2.0	11.2	0.03	0.8	0.7	5	18	21	17	101	104		118

[z]Means separation by Waller-Duncan k-ratio t-test, k-ratio=100.
[y]TCSA=trunk cross-sectional area in September 2003.
[x]Mean of 25 fruit.

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 Jun.

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/ 29	4/11	4.4	76.5	.06	27.3	9.6	210	258	25.2	5.8	8.0	909	859
W 53	3/ 29	4/11	5.0	77.5	.06	27.6	9.6	250	300	22.2	5.7	6.5	787	777
Gi 209-1	3/ 30	4/10	4.5	82.1	.06	28.0	10.0	249	307	21.9	5.6	5.5	856	834
W 72	3/ 29	4/10	4.3	97.4	.05	27.8	9.7	250	309	21.8	5.7	6.3	844	785
Gisela 7	3/29	4/10	5.2	96.1	.05	27.8	9.8	264	336	22.6	5.8	7.5	912	960
W 154	3/29	4/10	4.0	130.0	.03	27.9	9.9	248	293	21.6	5.4	4.0	899	855
Edabriz	3/29	4/11	3.1	110.7	.03	27.9	10.1	249	303	22.3	5.6	10.5	859	816
Gisela 5	3/30	4/10	4.9	99.8	.05	27.4	9.5	247	315	22.0	5.5	6.0	881	848
Mah.	3/31	4/11	3.4	133.0	.03	27.7	9.6	227	270	22.0	5.6	8.0	900	892
Gi318-17	3/30	4/10	4.7	124.6	.04	27.8	9.6	240	293	21.3	5.7	11.5	922	902
Gi195-20	3/29	4/10	4.5	125.6	.04	28.1	10.0	256	318	22.7	5.6	5.5	949	974
W 158	3/29	4/10	4.0	137.6	.03	27.9	9.8	247	314	22.7	5.7	5.5	953	1014
W 10	3/29	4/10	4.8	155.1	.03	27.7	9.7	237	295	21.8	5.6	5.1	885	835
W 13	3/30	4/10	5.8	155.0	.04	27.2	9.3	232	263	21.9	5.5	4.6	801	761
Mazzard	3/31	4/10	2.3	167.3	.01	27.0	9.0	242	291	22.4	5.5	5.5	893	795
Gisela 6	3/30	4/10	8.1	151.4	.05	27.6	9.7	248	293	21.5	5.4	5.0	936	951
MSD	2.2 d	1.5 d	3.7	23.3	.03	0.9	0.7	33	41	2.2	0.5	4.8	167	179

[z]Means separation by Waller-Duncan k-ratio t-test, k-ratio = 100.
[y]TCSA = trunk cross-sectional area in September 2002.
[x]Composite sample of 25 fruit.

CONTINUING PROJECT **YEAR 3**

Title:	Tree water use, irrigation scheduling and water management systems in sweet cherry
PI:	Roberto Núñez-Elisea
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Cooperators:	Matthew Whiting, WSU-IAREC, Prosser, WA Clark Seavert, OSU, Mid-Columbia Agric. Res. and Ext. Center John Selker, OSU Bioengineering Dept., Corvallis, OR

Objectives

- To measure soil water content in sweet cherry orchards to determine active root depth and quantify tree water use.
- To conduct trials comparing irrigation scheduling based on soil water content vs. a calendar schedule.
- To evaluate a woven polypropylene fabric row cover for water conservation and weed control.
- To investigate different water management strategies to conserve and improve tree water use.
- To characterize growth and physiological responses of sweet cherry trees under water stress.

Significant findings

- Continuous measurement of soil water content within root systems of young 'Lapins'/Mazzard trees irrigated with micro sprinklers shows that the bulk of the root system is located at 40-50 cm soil depth.
- Use of a woven polypropylene row cover in 3rd-leaf 'Regina'/Gisela 6 trees has caused greater vigor, improved branching, more spreading growth habit and higher foliar N content compared to trees growing without cover. Also, fruit were slightly larger for trees with row cover.
- Deficit irrigation (micro-sprinkler) of young 'Lapins'/Mazzard trees is showing promise as a technique to reduce vigor and induce precocity of this scion/rootstock combination. Fruit production in 2003 was greater for deficit-irrigated trees than controls, with similar fruit size.
- Initial results of partial rootzone drying (drip irrigation) of young 'Lapins'/Mazzard trees show adequate growth responses in trees irrigated with substantially lower amounts of water compared to standard practice.
- Prolonged water stress (2 months without irrigation) of young 'Lapins'/Mazzard trees caused clear reductions in stem water potential compared to irrigated trees, although visual foliage appearance was not dramatically different. Results suggest the presence of deeper roots than previously thought.

Methods

Measurement of soil water content

Volumetric soil water content is 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 collects data at 10-cm intervals though the soil profile. The EnviroScan™ consists of a network of eight permanent probes, each with four 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.

Use of a polypropylene fabric row cover
A 3-acre plot of 'Regina'/Gisela 6 trees was planted at the MCAREC in April, 2001, to evaluate the benefits of using a woven polypropylene row cover for water conservation and weed control. Upon reaching bearing stage, irrigation scheduling based on soil water content vs. a calendar schedule will be compared. Further details on the experimental setup and methods can be found in last year's report. Irrigation during 2003 was applied uniformly at weekly intervals to all trees. Approximately 100 gal of water were applied per tree/week. Upon reaching the bearing stage, fruit yield and quality will be determined. Evapotranspiration rates will be calculated during the different growth stages including bloom, shoot elongation, early fruit development and pre-harvest stage. An automated soil moisture monitoring system (Sentek EnviroSCAN™) was installed in late 2002 to continuously record soil moisture content at 20, 30, 40 and 60 cm depths. Sensors were 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 will be made to determine the effect of row cover on tree water status.

Deficit irrigation of young 'Lapins'/Mazzard trees to control vigor and induce precocity
The experimental block was established in 1999, with trees planted at 14 x 16 feet. All trees are being trained to multiple (steep) leaders. 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. Further experimental details are found in the 2002 report. Three treatments are being tested: control trees are irrigated to replace 100%, 50% or 25% of pan evaporation during the period preceding irrigation. Measurements of tree vigor include trunk cross sectional area (TCSA), shoot length and weight of pruned wood. The level of tree water stress is determined by measuring stem water potential just prior to each irrigation cycle. Soil water content is monitored manually with a portable sensor (Sentek Diviner 2000™) and automatically with a permanent, continuous soil moisture monitoring system (Sentek EnviroSCAN™).

Partial rootzone drying of young 'Lapins'/Mazzard trees
This trial was initiated in June 2002 at the MCAREC in Hood River using planted in 1999 and trained to a steep leader. Two irrigation rates are compared: 1 gal/h and 2 gal/h, which are delivered through pressure-compensated drip emitters placed 20 inches from the tree trunk, in the direction of the row. For each rate, irrigation is applied either alternately to each side (PRD) or, for controls, simultaneously to both sides of the root system (full rootzone irrigation, FRI). Irrigation was applied every 5-6 days for a period of 24 hours (see Table 1). Two poly-tube lines, each with an independent valve, are installed at each row to allow applying water to alternate sides of the root system. In the PRD treatments, irrigation was switched from one side of the root system to the other at ca. 15-day intervals.

Physiological responses to severe water stress
Fifth-leaf 'Lapins'/Mazzard trees were deprived of water for 2 months at the MCAREC. Control trees were irrigated periodically during that period based on soil water content. Whole-canopy and single-leaf gas exchange, and chlorophyll fluorescence measurements were performed during the first week of drought (Matt Whiting, WSU-IAREC, Prosser). Stem water potential was monitored periodically for 2 months using a portable, pump-up pressure bomb (PMS Instruments, Corvallis, OR). Soil moisture was continuously monitored for irrigated and non-irrigated trees using an automated EnviroSCAN system.

Results and discussion

Measurement of soil water content and location of active root system
Irrigation was applied from mid-June to late September, 2003. As observed in 2002, soil water content was consistently higher and around saturation ($\approx$ 40 mm, equivalent to 40 %) at 60 cm soil depth, gradually decreasing closer to the soil surface. Root activity was concentrated within 40-50 cm depth.

Use of a polypropylene fabric row cover
Third-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 2). This response was possibly influenced by the higher moisture levels and warmer soil temperature (3 to 4^{o}F) found under the fabric cover.
Row covers modified tree shape. Trees without row cover had a more columnar shape than those with cover. Leaves of trees with row cover were of a darker green color than leaves of trees without row cover. Foliar analyses revealed significantly higher N content for leaves of trees in row cover. Initial bloom and fruiting occurred during 2003. Yields were low due to insufficient pollen availability. A small but significant increase in fruit size was detected for trees growing in row covers. These initial results demonstrate a dramatic impact of fabric row cover on growth of young 'Regina'/Gisela 6 trees. Trees will continue to be evaluated in 2004 to determine whether these growth responses have a favorable impact on next year's fruit yield and quality.

Deficit irrigation of young 'Lapins'/Mazzard trees
Irrigation replacing 25% or 50% of pan evaporation reduced vegetative vigor of young 'Lapins'/Mazzard trees by ca. 15% during 2003 in relation to control trees irrigated by replacing 100% of evaporation rate. Flower and fruit production increased during 2003, although yields per tree were still low (<100 fruit per tree). Deficit-irrigated trees produced twice and up to six times (for 50% and 25% evaporation replacement, respectively) the number of fruit per tree compared to trees receiving 100% weekly evaporation replacement. Fruit size was similar among treatments (ca. 9.5 g). Fig. 1 shows the generally lower stem water potential for trees subjected to deficit irrigation throughout the growing season, increasing notably as of early August. These results are of particular interest because it indicates that water stress imposed through deficit irrigation has increased precocity.

Partial rootzone drying in young 'Lapins'/Mazzard trees
Fruit production in this trial was negligible in 2003; however, differences in vegetative growth were detected among treatments (Table 3). Shoot length was significantly shorter for PRD low rate compared to the corresponding control (FRI low rate), but this response was not observed with the high irrigation rate. The dynamics of shoot extension were similar for all treatments (data not shown). Final leaf area was similar for all treatments, although the increment occurring in the low rate PRD and FRI treatments from late June to late July was numerically lower compared to the high rate PRD and FRI treatments.
These results provide initial evidence of a growth-reducing effect caused by reduced water availability through both PRD and FRI applied through a drip irrigation system. Within the same irrigation rate, end-of season stem water potentials were lower (greater water stress) for trees irrigated in both halves of the root system (Fig. 2). This response suggests that trees receiving alternating irrigation gradually adjusted to water deficit. It is possible tat transpiration rates of PRD-treated trees was reduced by the influence of drying roots, whose chemical signals are known to induce partial closure of leaf stomates.

Physiological responses to severe water stress
Long-term impact of water stress on stem water potential is shown in Fig. 3. Stem water potential of non-irrigated trees was clearly lower than that of irrigated trees, particularly by late September. Stem water potential decreased (trees were less stressed) in response to both irrigation and a reduction in temperature. A comparison of soil moisture content in the 0-60 cm soil profiles for an irrigated a non-irrigated tree shown in Fig. 4. Trees deprived of water for 2 months, although showing lower stem water potentials, did not appear excessively dehydrated in the field and had similar, low levels of leaf drop compared to irrigated trees. A common observation in these trials (Figs. 1-3) is the fact that stem water potentials of all treatments gradually decreased over time and did not recover to levels observed early in the season despite adequate irrigation in controls. Measurements will continue in

2004 and will be related to dynamics of vegetative growth to determine base levels for growth reduction and cessation, as well as effects on reproductive growth.

Budget

Project title: Tree water use, irrigation scheduling and water management systems
PI: Roberto Núñez-Elisea
Project duration: Continuous
Funding in 2003: $18,500
Current year request: $28,500

	Year 2003	**Current year 2004**	Year 2005
Total	41,000		
Current year request			
Salaries-FRA	12, 205	**17,000**	
OPE (53%)	6,295	**9,010**	
Travel		**2,490**	
Total	18,500	**28,500**	32,000

Table 1. PRD treatments tested on 5th-leaf 'Lapins'/Mazzard trees. MCAREC, Hood River, OR, 2003.

Treatment*	# emitters/tree	# emitters open during irrigation	Emitter delivery rate (gal/h)	Total water applied in a 24-hr set (gallons)
PRD 1x	2	1	2.0	48
FRI 1x	4	2	1.0	48
PRD 0.5x	2	1	1.0	24
FRI 0.5x	4	2	0.5	24

* PRD = partial rootzone drying; FRI = full rootzone irrigation.

Table 2. Impact of a fabric row cover on vigor, branching and production of 3rd-leaf 'Regina'/Gisela 6 trees. MCAREC, Hood River, 2003.

Variable (per tree)[1]	Fabric row cover	Control (no cover)	% increase	Sign. level [2]
No. of main branches (2001 wood)	34.1	34.5	--	ns
No. of shoots (2002 wood)	41.4	28.6	44.8	*
Total number of branches (2001 + 2002)	**75.5**	**63.1**	**19.6**	*
Length of all main branches (cm)	2908.4	2013.3	44.5	**
Length of all shoots (cm)	2244.6	1111.4	101.9	***
Total wood length (2001 + 2002; cm)	**5153.0**	**3124.6**	**64.9**	***
Length of central leader (cm)	367.3	343.6	6.9	*
TCSA (cm^2)	43.7	32.7	33.6	***
Yield (g)	932.1	1005.8	--	ns
Ave. fruit size (g)	10.6	10.3	3.0	**

[1] Measurements taken Jan 13/14, 2003;
[2] * = 0.05; ** = 0.01; *** = 0.001

Table 4(3). Effects of partial rootzone drying (PRD) and full rootzone irrigation (FRI) in vegetative growth of 5th-leaf 'Lapins'/Mazzard trees. MCAREC, Hood River, 2003.

Treatment	Shoot length (cm)	Leaf area (cm^2) 26-Jun	28-Jul	Increment (cm^2)
PRD 1x (2 gal/hr)	65.4 a	70.2	82.7	12.5
FRI 1x (2 gal/hr)	57.0 b	65.5	83.7	18.2
PRD 0.5x (1 gal/hr)	55.7 b	69.2	80.3	11.1
FRI 0.5x (1 gal/hr)	64.3 a	67.4	79.3	11.8
		ns	ns	

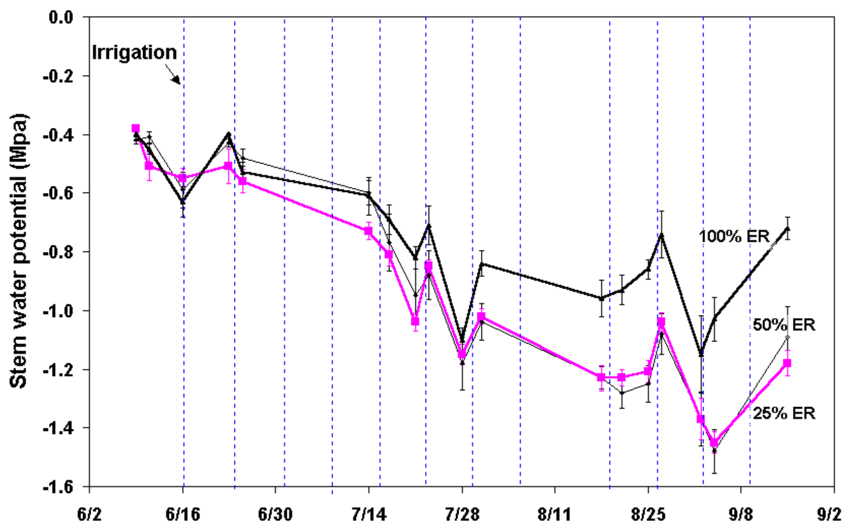
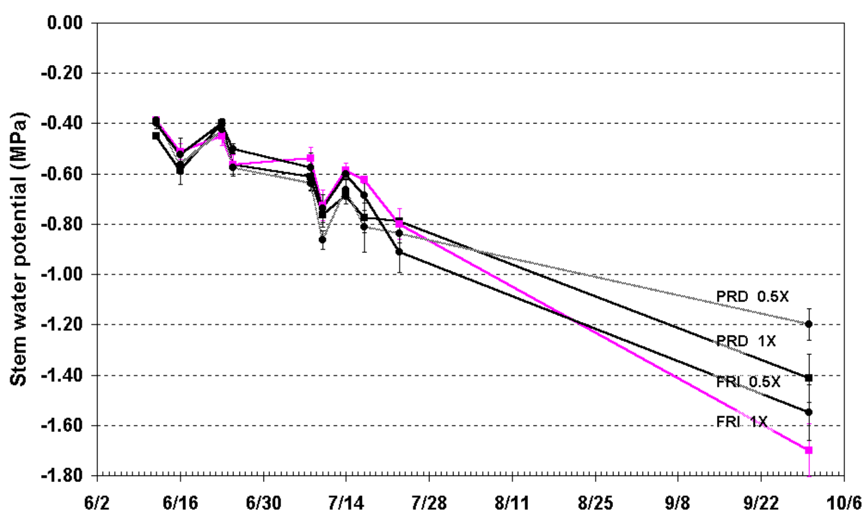


Fig. 2. Stem water potential of 'Lapins'/Mazzard trees as influenced by deficit irrigation treatments. MCAREC, Hood River, 2003.

Fig. 3. Stem water potential of 5th-leaf 'Lapins'/Mazzard trees as influenced by 2 rates of partial rootzone drying (PRD) or full-rootzone irrigation (FRI). MCAREC, Hood River, 2003.



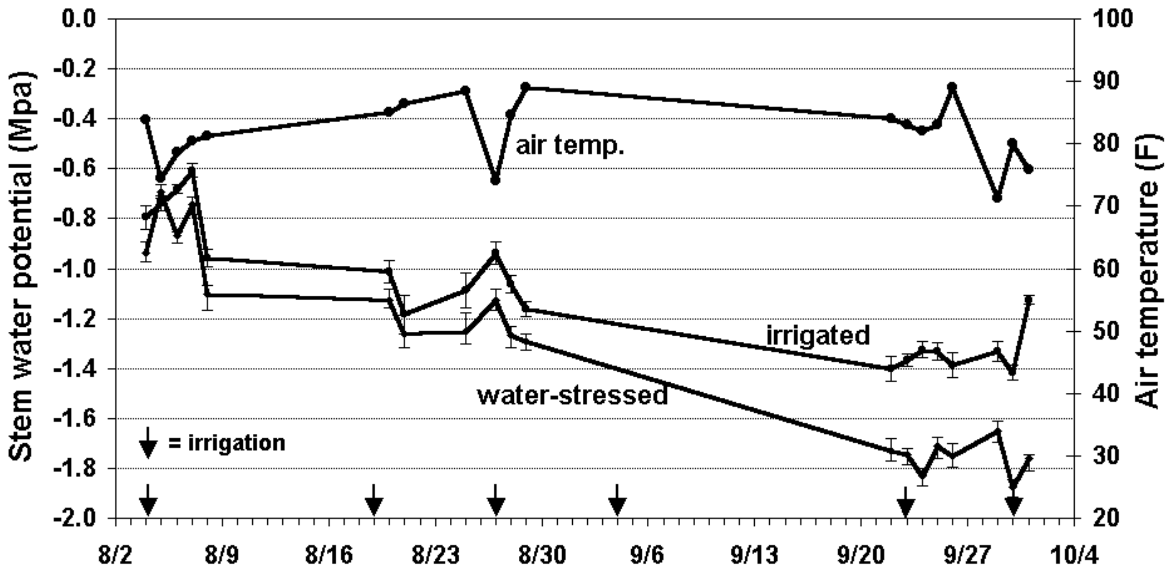


Fig. 4. Effect of water stress on stem water potential of 5th-leaf 'Lapins'/Mazzard trees (n = 4 trees). MCAREC, Hood River, 2003.

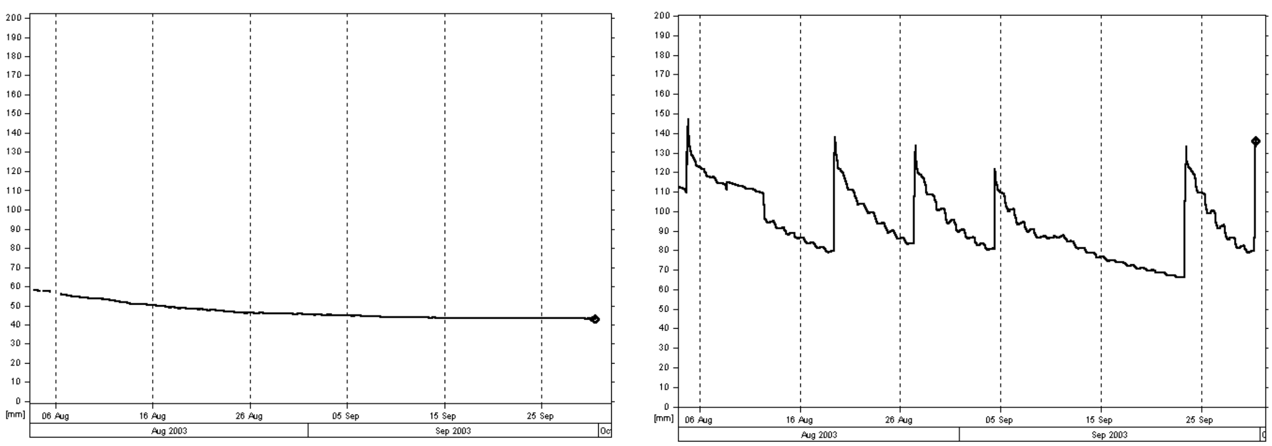


Fig. 5. Soil moisture content of a 5th-leaf non-irrigated (left) and irrigated (right) 'Lapins'/Mazzard tree. Curves represent the water content of the 0-60 cm soil depth as measured by sensors placed at 20, 30, 40 and 60 cm soil depths. Peaks indicate irrigation events. Staircase pattern indicated daily water uptake by active roots.

CONTINUING PROJECT REPORT **YEAR 3/3**

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, Horst Caspari, Colorado St. U.
Denny Hayden, Pasco

OBJECTIVE:

- Elucidate the effects of 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)
- deficit irrigation reduced yield and quality of Mazzard-rooted trees
- deficit irrigation reduced yield but improved quality of Gisela-rooted trees
- PRD produced better quality fruit compared to DI
- fruit and shoot growth rates were affected by reduced water input
- final shoot length was significantly less from PRD trees
- components of gas exchange (*i.e.*, net photosynthesis, transpiration, stomatal conductance) were unaffected by irrigation treatment during stage I or III of fruit development (Table 3)
- postharvest net photosynthesis was reduced by DI (*ca*. 50%) but unaffected by PRD
- stomatal conductance was similar for control and PRD and about 20% lower for DI
- water use efficiency (g CO_2/g H_2O) was highest for control and PRD and lowest for DI
- 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 were highest from control, intermediate for PRD, and lowest for DI
- leaf water potential in August was highest in control, and lowest for DI
- 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, whole-canopy gas exchange (transpiration and net photosynthesis) of selected trees will be determined. Trials will be continued in subsequent years to examine carryover effects of reduced water inputs.

RESULTS AND DISCUSSION:
Similar to results from 2002, across rootstock, fruit quality was similar, albeit poor, among treatments (Table 1, Figure 1). Fruit soluble solids were highest from control trees and lowest from DI trees, but all at commercially acceptable levels. Fruit firmness and mass were unaffected by irrigation treatment. However, fruit yield per tree was significantly reduced (*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. This counter-intuitive response to deficit irrigation will be investigated more thoroughly in 2004. These results suggest deficit irrigation may have a role in cropload management on Gisela rootstocks if the yield reduction and quality improvements we observed in 2003 are sustainable.

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

Table 1. Effect of deficit irrigation (DI) and partial rootzone drying (PRD) on yield and fruit quality of 8- and 9-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 ($P < 0.05$).

Interestingly, in 2003 there were significant interactions between rootstock and irrigation regime that did not manifest in 2002. Mazzard rooted trees subjected to deficit irrigation exhibited reductions in yield *and* fruit quality (Table 2). 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. Comparing deficit treatments, DI was worse than PRD (47% vs. 73% 10.5-row and larger fruit from DI and PRD, respectively). The fact that both fruit quality and yield were reduced is troublesome and implies little commercial relevance of deficit irrigation strategies (at least not as severe as 50% replacement) for mature, bearing Mazzard-rooted orchards.

Rootstock	Treatment	Smaller than 12-row (%)/(lbs/tree)	11- and 12-row (%)/(lbs/tree)	10.5-row and larger (%)/(lbs/tree)
Mazzard				
	Control	0/0	17/6	83/30
	DI	1/0.2	52/7	47/7
	PRD	1/0.3	26/2	73/10
Gisela 6				
	Control	34/31	62/59	4/4
	DI	1/1	59/33	40/21
	PRD	3/2	48/31	49/32
Gisela 5				
	Control	48/37	50/40	2/4
	DI	36/16	57/24	7/3
	PRD	21/9	67/30	12/6

Table 2. Interactions between rootstock and irrigation regime on 'Bing' sweet cherry fruit quality (percent and yield of fruit per row-size category).

In contrast, Gisela 6-rooted trees subjected to deficit irrigation exhibited yield reductions but improved fruit quality compared to the control (Table 2). In 2003, DI reduced yield by 42% and PRD reduced yield by 31%, compared to the control. However, compared to the control, the yield of premium quality fruit from DI was over 5-fold greater and 8-fold greater from PRD. Similar to trees on Mazzard, PRD produced better quality fruit than DI. However, both deficit treatments nearly eliminated the production of cull fruit (*i.e.*, smaller than 12-row).

Trees on Gisela 5 responded similar to those on Gisela 6 – yield was reduced but quality was improved by both deficit irrigation regimes. Compared to control, DI had 46% lower yield and PRD had 43% lower yield. However, fruit row-size was favorably shifted to larger size fruit. As a percentage of yield, DI trees produced 25% less smaller than 12-row fruit and 3.5-fold more premium quality fruit. Similarly, as a percent of yield, PRD trees produced 56% less smaller than 12-row fruit and 6-fold more premium quality fruit.

Treatment	Net photosyn. ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	Transpiration ($mmol \cdot m^{-2} \cdot s^{-1}$)	Stomatal conductance
	2 May, Stage I		
Control	9.1 a	3.8 a	166 a
DI	9.4 a	4.1 a	171 a
PRD	8.6 a	3.4 a	139 a
	5 June, Stage III		
Control	13.7 a	4.8 a	224 a
DI	13.8 a	5.9 a	246 a
PRD	12.2 a	5.6 a	207 a

Table 3. Effect of deficit irrigation (DI) and partial rootzone drying (PRD) on leaf gas exchange of 'Bing' sweet cherry trees on 3 rootstocks. Data were collected on fully sunlit leaves on two dates. Means followed by the same letter within columns and sample date are not significantly different by LSD ($P < 0.05$).

In 2003 vegetative vigor of DI and control were similar (Figs 1 and 3) and greater than vigor of PRD. In general, shoot growth rates increased throughout the season, peaked near day 150 (30 May), and declined thereafter, nearing zero close to harvest. Daily expansion rate of control was significantly higher than that of both DI and PRD on several sample dates (Fig. 3). Interestingly, shoot expansion rates began to decline as fruit expansion rates neared their seasonal maxima. Fruit expansion rates across all rootstocks were similar but final fruit diameter was highest for PRD and lowest for control (Figs. 1 and 3). 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). Differences in daily expansion rate of fruit were evident during stage I and III but not stage II.

SPAD meter readings are interpreted as a general indication of leaf health because they are related to leaf nitrogen/chlorophyll content. In 2003 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 (Fig. 2). 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. The physiological significance of different SPAD meter readings will be further investigated in 2004.

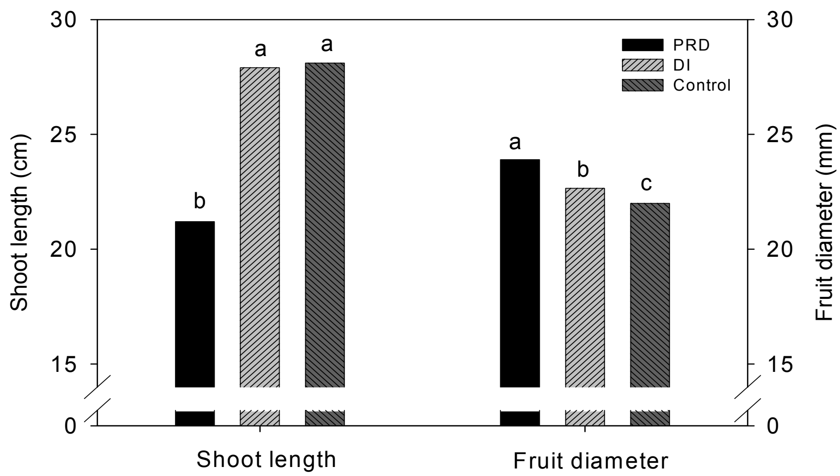


Figure 1. Effect of irrigation treatment on final shoot length (cm) and equatorial fruit diameter (mm) of 'Bing' sweet cherry trees grown on 3 rootstocks.

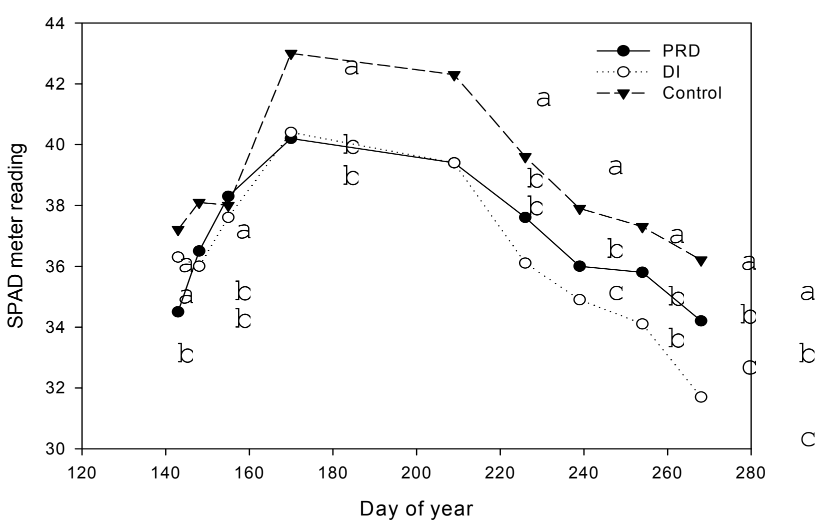


Figure 2. Effect of irrigation treatment on seasonal trend of leaf SPAD meter reading. Each point is the mean of all rootstocks (n=3). Data points followed by different letters are significantly different within sample date by LSD (P < 0.05).

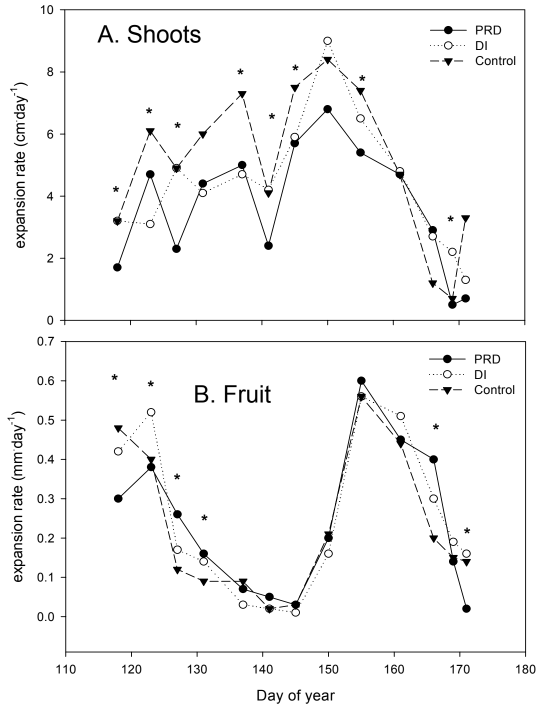


Figure 3. Seasonal trend of expansion rate of shoots (A) and equatorial fruit diameter (B) within 'Bing' sweet cherry trees subjected to deficit irrigation (DI) and partial rootzone drying (PRD). Asterisks indicate significance ($P < 0.05$).

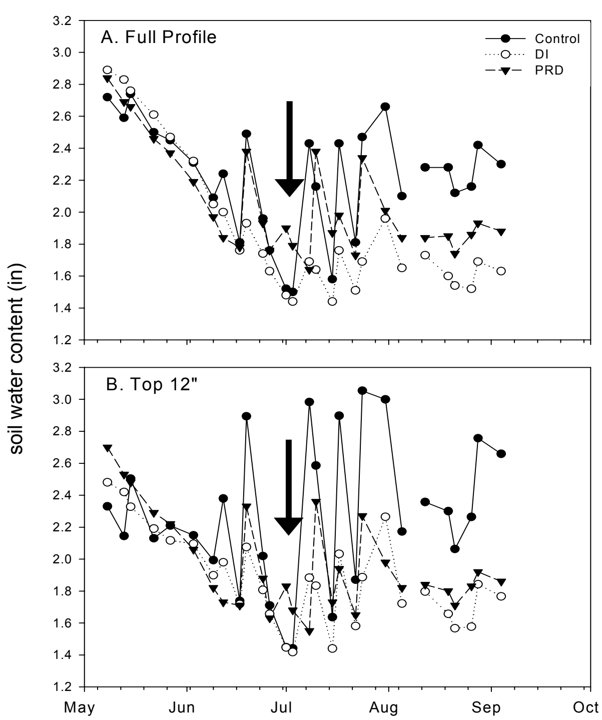


Figure 4. Effect of irrigation regime on the seasonal profile of soil water content within (A) - total profile, and (B) - top 12". Arrow indicates harvest date.

BUDGET

Project:	Alternative water management strategies
P.I.:	Whiting
Project duration:	2002-2004
Current year:	2004
Project total:	$55,106
Current year request:	$24,776*

Year	2002	2003	2004
Total	$20,000	$10,960	**$24,776***
Current year breakdown			
Item			
Salaries1			**7,672**
Benefits (30%)[2]			**2,384**
Wages[3]	6,000	6,000	**6,000**
Benefits (16%)	960	960	**960**
Equipment[4]	10,040		**3,537**
Supplies[5]	1,500	2,500	**2,500**
Travel[6]	1,500	1,500	**1,693**
Miscellaneous[7]			**30**
Total	$20,000	$10,960	**$24,776***

1 Steve Link (1 mo. @ $6,267); Engineering tech III (1 mo. @ $4,013 x 35% FTE)
2 Link salary @ 32%, Engineering tech salary @ 27%
3 Time slip wages for data collection and fruit quality/laboratory analyses.
4 Supplies for construction of 18 strain gauges, solar panel, multiplexer
5 Whole-canopy chamber and laboratory supplies.
6 Travel to plots and transport of shared equipment between MCAREC and IAREC. Travel from WSU-TC to Roza ($193)
7 copies and postage for Link

* budget is greater than originally requested by $13,816. This additional funding would be used to construct and test 18 strain gauges (9 on fruit and 9 on shoots) to monitor fruit and shoot expansion/contraction in relation to irrigation regime.

PROGRESS REPORT **YEAR 3/3**
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. Determine the effect of various concentrations of cyclanilide applied to sweet cherry trees on size-controlling rootstocks in the nursery on overall development of the treated nursery trees, development of lateral branches (feathers), and occurrence, if any, of phytotoxicity or other negative side effects.
2. 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.
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.

Significant findings:
Shoot growth is ending as this is written (September, 2003); therefore, final assessments of shoot growth effects are not yet available. General observations are reported below.

a. Dormant and green-tip cyclanilide applications
Applications of cyclanilide at concentrations of up to 15,000 mg a.i./liter to trunks and soil around the crowns in October, 2002, or March, 2003, were made to trees of PC8011-3, 'Bing,' 'Rainier' and 'Skeena' on Mazzard rootstock in orchards located in Wenatchee, Bray's Landing or Chelan Falls to evaluate the possibility that cyclanilide might translocate upward and affect bud development in spring, 2003. Preliminary assessments indicate no effects of any of the treatments on stimulation of lateral branch development anywhere in the canopy.

b. Other green-tip applications
One-year-old or two-year-old intact, unpruned shoots were scored every foot starting one foot below the terminal bud; a ring of Promalin (5,000 mg a.i./liter in 50% v/v latex paint) was painted every foot in place of the scores; shoots were scored as described and then painted with Promalin after scoring; every fourth bud down the shoot was notched; every fourth bud down the shoot was painted with the same Promalin mixture; or three buds were removed and every fourth bud left intact on the shoot. Control shoots were untreated. The objective was to determine if it is possible to overcome the strong apical dominance of sweet cherry and induce strong lateral branching with desirable crotch angles in the absence of heavy heading-back pruning, which would otherwise be the only method of choice for stimulation of lateral branching.

On last year's shoots in 'Skeena' and 'Bing,' scoring every foot plus painting the score with Promalin produced a very significant increase in lateral branch development. Branching in all other treatments was equivalent to the branching produced by controls in terms of numbers of shoots and their lengths.

Scoring every foot with or without Promalin paint, disbudding and notching significantly altered the distribution of shoots, with many more shoots being produced from the lower portions of the original, upright branches. The improvement in lateral branch distribution along the original shoots was best for scored treatments. Where mechanical means were used in the absence of scoring (i.e., disbudding or notching), the increasing impact of apical dominance in reducing bud development lower on the original shoot was only partially overcome by notching or disbudding. No treatment significantly affected the crotch angles of induced shoots compared to the lateral shoots from control trees.

Branch induction from two-year-old wood is much more difficult than from one-year-old wood. On two-year-old wood only scoring, either with or without Promalin paint, increased the development of new shoots from that limb section. Notching buds, painting buds with Promalin or painting a ring of Promalin around the limb every foot had no effect.

Bud notching is used commercially in the cherry industry as a means to increase branching in young trees. In the trials reported here, notching produced a success rate of between 18 and 37% (i.e., only one out of every 3-5 notched buds produced a shoot), while painting buds with 5000 ppm Promalin was much less successful, 0-5%.

c. In-season applications

When terminal shoots were approximately 18-30 cm in length, cyclanilide at 50 or 100 mg a.i./liter with or without Promalin (250 mg a.i./liter), Promalin alone, cyclanilide with or without thidiazuron (Dropp, 100 mg a.i./liter) or Dropp alone were applied to second- or third-leaf trees of ‘Bing,’ ‘Rainier,’ ‘Skeena,’ and ‘Tieton,’ cultivars, all on Mazzard rootstock. In some cases a second application was made approximately one month later. Generally, the early season applications of cyclanilide produced new branch development from actively growing shoots. The later applications were much less successful in branch induction. Branching response to cyclanilide was variable from orchard to orchard in 2003. Preliminary observations suggest that new shoots must be in very active growth in order to obtain satisfactory branching from cyclanilide. Promalin alone produced some lateral branch development from current season’s buds on new shoots, but the branching was inconsistent from shoot to shoot. Thidiazuron was tested for the first time this year. With no previous experience, we started with an application at 100 mg a.i./liter. Thidiazuron displays strong cytokinin-like activity, and hence it would be expected to induce lateral bud activity. However, even though treatment with thidiazuron did induce lateral bud activity, few of the activated buds produced normal shoots. The reason(s) for the absence of shoot formation from buds stimulated by thidiazuron is unknown.

d. Nursery applications

Cyclanilide at 50 or 100 mg a.i./liter with or without Promalin (500 mg a.i./liter) or Promalin alone were applied to nursery trees of ‘Bing,’ ‘Skeena’ and ‘Lapins’/Mazzard in mid-June to induce feathering. The products were sprayed across the tops of the trees to treat the shoot tips and upper portion of the newly developing shoots. Cyclanilide induced lateral branch formation in all three cultivars. Timing of branching treatment depends on where lateral branches are formed in response to cyclanilide treatment. Cyclanilide appears to induce branching in a different manner from Promalin. It appears that only very immature buds deep in the shoot tip at the time of treatment respond by growing into feathers. Thus timing treatments to obtain proper height of feathers has become an important issue to examine. This year the nursery trees in each plot were treated such that the relation between height of the shoot tip at the time of treatment and heights of the induced lateral shoots (feathers) can be precisely determined when the trees are evaluated this winter. These results will permit much more precise treatment timing recommendations to be made.

Methods:
Seventeen trials were initiated in the 2003 growing season to test effects of cyclanilide and other treatments on stimulation of lateral branch development in sweet cherry trees. Four tests were begun in October 2002, while trees were in the late stages of hardening off and beginning to lose leaves prior to winter 2002-2003. Those four trials were continued, and three new trials were initiated when bud development had reached the green-tip stage (late March). Seven trials were started in May soon after shoot growth began, and three new trials were begun in the nursery in mid-June. The trials started in fall, 2002, had the objective of determining whether cyclanilide could be used to stimulate branch development in 2003 from pre-existing buds on shoots that grew in 2002. Trials at green-tip compared various methods for stimulation of lateral bud growth on previous season's wood and on two-year-old wood, from which obtaining bud activity is much more difficult. The in-season and nursery trials were primarily focused on the stimulation of branching from newly formed buds on current season's shoots.

Results and discussion:
Cyclanilide appears to be effective for stimulation of branching only when shoot growth is strongly active. The variability in branching responses observed in 2003 may be due in part to effects of plant vigor on the growth response. Cyclanilide has no apparent role in inducing dormant buds to become active and shows no translocatable effects in sweet cherry at concentrations used. However, cyclanilide has a very definite potential role in the production of feathered trees in the nursery. It is likely that the demand for feathered cherry trees will grow as the popularity of size-controlling rootstocks and higher density plantings for sweet cherries increases.

Mixtures of benzyladenine (BA) and gibberellins (such as Promalin) have not proven very effective for inducing lateral branching in sweet cherry when applied to buds on shoots at green-tip. Our results this year strongly suggest that this observation has more to do with lack of uptake or penetration of the bioregulator products with conventional application methods than with a natural lack of responsiveness of the sweet cherry tree to such treatments if the bioregulators are provided a path of entry into the tree. Combining scoring with Promalin paint not only produced a strong interruption of apical dominance in cherry but also provided a ready means of entry for bioregulators, which probably explains the significant increase in both branching and the improved distribution of branching in that treatment. Interestingly, treatments such as disbudding or notching, which do not involve the overall interruption of apical dominance produced by scoring, lost effectiveness in the lower portions of shoots, suggesting a cumulative apical dominance effect further down the shoot. This increase in apical dominance lower in shoots likely explains why cherry trees naturally branch virtually exclusively from the tips of pre-existing shoots. This inhibitory effect on bud development can be very strongly overcome with a program that includes scoring at intervals down the shoot.

There appear to be varietal differences in branching response to cyclanilide; further trials with other cultivars are needed to clarify the effects of genetics on the response to cyclanilide treatment. Similarly, cultivars may respond somewhat differently to other branch manipulations designed to induce lateral branching. Future trials will be oriented to develop a better understanding of the apical dominance control system and to seek more cost effective ways to overcome apical dominance.

Acknowledgments:
The assistance and support of the following persons and organizations is gratefully acknowledged: Noel Adkins, Erasmo Avila, Jeff Cawood, Mike Cawood, Dave Chisholm, Dan Fulbright, Chris Ishida, Kyle Mathison, Chris Olsen, Byron Phillips, Pete Van Well, Rick Van Well, Jim Wade, Mike Wade, Bayer Environmental Science, Cawood Orchards, Dovex Orchards, Mathison Orchards, Mountain View Orchards, Oregon Sweet Cherry Commission, Van Well Nursery, Valent BioSciences and the Washington Tree Fruit Research Commission.

Budget:

Project title:	Induction of branches (feathers) in sweet cherry trees in the nursery and orchard
PI:	Don C. Elfving
Project duration:	2002-2004 (up to three years)
Current year:	2004
Project Total:	(3 years) $26,488
Current year request:	$9,820

Year	**Year 1 (2002)**	**Year 2 (2003)**	**Year 3 (2004)**
Total	8,288	8,380	**9,820**

Current year breakdown

Item	**Year 1 (2002)**	Year 2 (2003)	**Year 3 (2004)**
Salaries (technical)[1]	3,100	4,000	**4,500**
Benefits (28%)	868	1,120	**1,260**
Salaries (time-slip)[1]	2,000	1,000	**1,000**
Benefits (16%)	320	160	**160**
Equipment	0	0	**0**
Supplies[2]	500	800	**800**
Travel[3]	1,000	1,300	**2,100**
Miscellaneous	500	0	**0**
Total	8,288	8,380	**9,820**

[1]Technical and time-slip help is essential to put out the large number of treatments and collect the volume of data needed to evaluate growth, flowering, fruiting, fruit loosening and fruit quality responses to bioregulators.

[2]This category includes a variety of miscellaneous supplies, non-capital equipment, consumables, etc. that are needed to carry out the many trials in this research project. Cell phone charges are specifically authorized on this grant.

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

CONTINUING PROJECT REPORT **YEAR 2/2**
WTFRC Project # CH-03-305 **WSU Project # 13C-3655-5326**

Project title: Suppressing cherry cracking and postharvest 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]
Affiliations: [1] Irrigated Agriculture Research & Extension Center, WSU-Prosser
[2] USDA/ARS Tree Fruit Research Laboratory, Wenatchee
Cooperators: Jianshe Sun,[1] Leo Jedlow,[1] Jeong-Hak Seo,[1] and David Ophardt[2]
[1] Tree Fruit Research and Extension Center, WSU-Wenatchee
[2]Irrigated Agriculture Research & Extension Center, WSU-Prosser

Objectives:
1. Determine efficacy of spraying a new hydrophobic (lipophilic) formulation to suppress cracking of cherries.
2. Optimize timing and rates of application of the new formulation(s).
3. Investigate fruit cracking with electron microscopy. Compare fractures of the cuticle in different cherry cultivars and determine the effect(s) of calcium and the hydrophobic formulation on these fractures and other features related to integrity of the cuticle.
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. The new formulation (matrix) suppressed cherry cracking significantly. With a single application (10% v/v) two weeks before harvest, cracking in ‘Bing’ cherries was decreased from 39% in untreated control to 8% in the treated cherries (a 79% reduction in cracking). When 10% (v/v) matrix was applied one week before harvest, cracking of ‘Bing’ cherries was decreased from 42% in untreated control to 16% in the treated cherries (a 62% reduction in cracking).
2. A 10% (v/v) dilution rate of the formulation was superior to using a 20% dilution rate. An application two weeks before harvest appeared to be more effective than an application one week before harvest.
3. Dr. Curry used electron microscopy to examine dozens of cherries to compare control (no treatment) with cherries sprayed with 10% or 20% matrix or with calcium chloride one or two weeks before harvest. Interesting differences were seen and provided some insight into why the 10% matrix was superior to the 20% application.
4. Water absorption by cherries immersed in deionized water (similar to rainwater) showed that water uptake differed by cultivar. Total uptake of water during six hours was highest for ‘Bing’ (3.89% increase in weight), lowest for ‘Van’ (3.10%), and intermediate for ‘Lapins’ (3.26%). However, when water uptake by different parts of the fruit was examined, striking differences were observed at the stylar scar end. ‘Bing’ absorbed 12% of the water through the stylar end, ‘Van’ absorbed 6% and ‘Lapins’ absorbed none of its water through the stylar end. This trend in water absorption through the stylar end corresponds with cracking resistance of these three cultivars (i.e., ‘Lapins’ more resistant than ‘Van’ with ‘Bing’ being least resistant of the three) (King and Norton, 1987).
5. Lower magnification microscopy revealed that anatomy of ‘Bing’ differs from that of ‘Rainier,’ ‘Van,’ and ‘Lapins’ cherries and may help explain why ‘Bing’ is more susceptible to cracking than ‘Lapins’ or ‘Van.’

6. Cherries sprayed preharvest with calcium (0.5%) followed by a matrix application were firmer (12 days after storage at 33ºF) than untreated controls or cherries sprayed with calcium alone.
7. Matrix applied alone did not improve firmness in this experiment, but increased firmness was observed in a larger orchard trial with 'Bing' and 'Van.' The cherries sprayed with the matrix were very attractive as compared to the untreated controls.
8. Preharvest application of matrix (10 and 20%) decreased stem browning, after 12 days in storage at 33ºF, by 23 and 28%, respectively, as compared to the control.
9. Postharvest applications of matrix (10%) and Semperfresh (product of Pace International, diluted according to label) reduced water loss by 50% and 40%, respectively, after 12 days storage at 33ºF. Stem browning was only slightly decreased by postharvest applications of matrix or Semperfresh.

Methods:

Objective 1—We sprayed the new formulation (matrix) on cherry trees of several cultivars using the Proptec low volume sprayer (50 gal/acre) or an air-blast sprayer (100 gal/acre). Because no rain fell during the two weeks preceding cherry maturity, there was no cracking. Therefore, we enclosed trees in large Mylar bags designed for photosynthesis studies with cherry trees (courtesy of Matthew Whiting). In the first experiment done two weeks before maturity (June 17-19, 2003) four treatments were applied with a hand sprayer (at a rate comparable to 50 gal/acre) to different branches on a tree. After drying, the tree was enclosed in a Mylar canopy system supported by air pressure generated by an electric fan. A sprinkler system was installed inside the canopy and oriented to allow deionized water to be misted throughout the tree canopy. The water was cycled on/off to keep the cherry fruit surfaces wet as well as maintain high humidity and temperature within the Mylar canopy. A Campbell Scientific CR10 datalogger was used to collect fruit surface temperature and ambient temperature inside and outside the canopy. A Hobo datalogger was used to record humidity inside the canopy. The canopy system was inflated during the day from early morning until sunset for three days. The deflated canopy was left in place over the cherry tree to maintain humidity overnight. Cherries were harvested from each treated branch the morning after the day when cracking was noted and the frequency for cracking was recorded. The second experiment done one week before maturity (June 24-25) was conducted using the same procedures as in the first experiment. However, cherry cracking occurred during the first day. Fruit was harvested the next morning and percent cracking was recorded for each treatment.

Objective 2—Studies on timing and rates of application were conducted to optimize the efficacy of the matrix. We scaled up our studies to larger plots at two sites and compared different cultivars, as earlier reports indicated cultivar differences in cherry cracking (King and Norton, 1987; Lang et al., 1997). Dr. Whiting, co-PI, also conducted experiments at Prosser. Unfortunately, his canopy was destroyed by wind, and no rain was received at any of the sites during the two weeks preceding maturity. Next year we will expand the studies to many sites to increase the likelihood that rain will occur.

Objective 3—Dr. Curry, co-PI, examined dozens of cherries with electron microscopy. He examined different cultivars to see if the differing susceptibility to cracking is related to differences among cultivars in cuticular cracking or other anatomical changes. He also examined fruit treated with the matrix to see if the cuticular cracks are filled with the matrix and also whether the stem bowl is protected by the formulation. He also compared cherries sprayed with the 20% (v/v) and 10% (v/v) rates of matrix.

Objective 4—The effect of the formulation on fruit appearance and quality was assessed using conventional techniques. Soluble solids, osmolality, water potential, fruit weight, firmness, color and cracking were evaluated.

Objective 5—Fruits were harvested and dipped in the matrix or Semperfresh for less than a minute. Fruits were dried and placed in cold storage at 33ºF. Treated and untreated cherries were weighed to determine water loss. The appearance of the stem also was assessed at intervals to see if the matrix or Semperfresh decreased stem browning.

Results and discussion:

In the first experiment, two weeks before harvest maturity, all the formulations reduced cracking frequency compared to controls (Fig. 1). The 10% matrix showed the best result (80% reduction), followed by the $CaCl_2$ (77% reduction), then the 20% matrix (38% reduction).

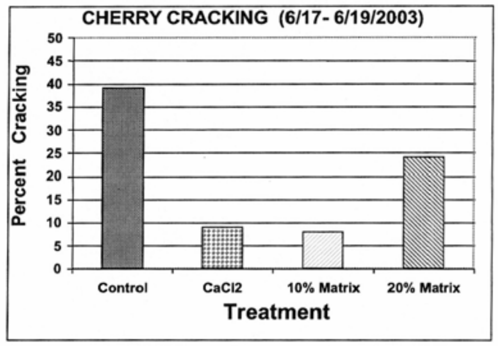


Fig. 1. Cherry cracking when treatments were applied two weeks before maturity.

In the second experiment, one week before harvest maturity, the matrix again reduced cracking frequency compared to controls, but the effect was lower (Fig. 2). The 10% matrix again showed the best result (62% reduction), followed by the 20% matrix and $CaCl_2$ (40% reduction each). It is not known why $CaCl_2$ was so effective in the first experiment. The matrix at 10% was superior to 20% in both experiments.

In studies to better understand the relationship between cracking and water absorption by cherries, cherries were immersed in deionized water, and weighed at two-hour intervals to determine the amount of water absorbed. After six hours, 'Bing' had absorbed more (3.89% increase in fresh wt.) than either 'Van' (at 3.1%) or 'Lapins' (at 3.26%) (Table 1). To determine which parts of the cherries absorbed water, an experiment was conducted in which only the pedicel (stem) was immersed, pedicels and stem bowls were immersed, stylar ends only were immersed, and total fruits were immersed. No significant water uptake was recorded at the stylar scar end for 'Lapins,' whereas water uptake at the stylar scar end of 'Van' and 'Bing' was 6% and 12%, respectively. This trend in stylar scar end water uptake corresponds with cracking resistance for these three cultivars with 'Lapins' more resistant than 'Van' and 'Bing' least resistant of the three (King and Norton, 1987). Other regions of the fruits' surfaces showed differences as well in water absorption and are presented in Table 1.

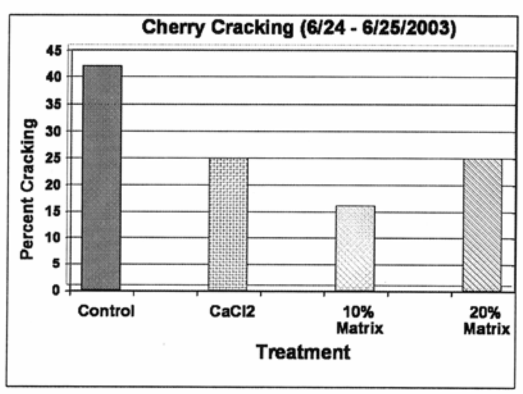


Fig. 2. Cherry cracking when treatments were applied one week before maturity.

Table 1. Water absorption by cherries immersed in water. Cherries were totally immersed in water (Column 2), only the stylar end was immersed (Column 3), only the pedicel or stem was immersed (Column 4), only the stem and stem bowl were immersed (Column 5). The values in Column 6 for other surfaces of the cherry cuticle were calculated.

WATER ABSORPTION BY CHERRIES					
Cultivar	(2)	(3)	(4)	(5)	(6)
	Total uptake	Stylar end	Stem	Stem & bowl	Other surfaces
	% increase in wt.	% of total	% of total	% of total	% of total
'Bing'	3.89	12	3	16	69
'Van'	3.1	6	11	14	69
'Lapins'	3.26	0	13	9	78

Digital images taken with a Nikon SMZ-U dissecting microscope showed differences in the structure of the stylar scar end of each of the three cultivars (data not shown). The junction between the stylar scar tissue and the cuticle appears to be open in the 'Bing,' partially open in the 'Van' and closed in the 'Lapins.' "Conductive" tissue appears to be more pronounced in 'Bing,' somewhat less in 'Van' and even less apparent in 'Lapins.' 'Rainier' cherries were also examined in this manner and also showed a tight junction between the stylar scar and the cuticle. Stylar scar appearance may change relative to maturity. However, these samples were representative of mature fruit at harvest.

The data from this study suggest that cherry cultivars have varying degrees of vulnerability to cracking depending on the location of the water/fruit surface interface. Fruit surface absorption was comparable in all three cultivars. Stylar scar end water uptake was higher in 'Bing' followed by 'Van' and 'Lapins.' The same trend is apparent in the stem bowl. During sustained rain exposure, the two regions of the cherry fruit that carry the highest water load are the stem bowl and the stylar scar end. Despite the closed appearance of the stylar scar, 'Rainier' cherries are thought to be highly susceptible to cracking (King and Norton, 1987). We were unable to test this in any of our studies this year.

Published studies of 'Sam' cherries treated with silicone to block water uptake showed no absorption from the stylar scar when the entire fruit was sealed except for the stylar scar (Beyer et al., 2002). The 'Sam' cherry is a relatively crack-resistant cultivar (King and Norton, 1987), which may have a stylar scar similar to other crack resistant cultivars, i.e. 'Lapins.' While these are not the only paths for water uptake in the cherry fruit, the specific differences in the cultivars described suggest an explanation for cracking susceptibility.

The effect of the new matrix (10% v/v) sprayed on cherries after spraying calcium chloride (0.5% w/v) was an increase in firmness observed after 12 days of cold storage (at 33ºF) (See Fig. 3). Calcium applied alone was nearly as effective, but both treatments were better than no treatment.

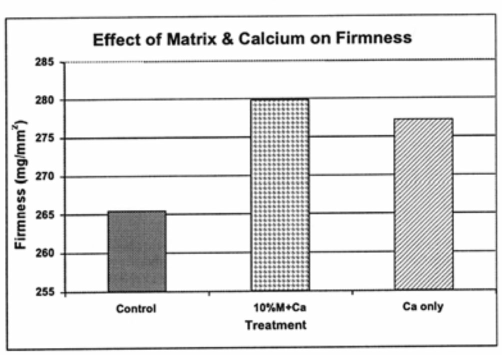


Fig. 3. Firmness after 12 days of storage at 33ºF of cherries sprayed two weeks preharvest with calcium chloride (0.5% w/v) alone, calcium chloride (0.5% w/v) followed by 10% matrix, or water (control).

‘Bing’ cherries were sprayed two weeks prior to harvest with 10% or 20% matrix. They were stored at 33ºF for 12 days, and then evaluated for stem browning. The 10% and 20% matrix reduced stem browning by 23 and 28%, respectively, as compared to the untreated control (Fig. 4).

Cherries were treated with 10% matrix or Semperfresh (according to label) shortly after harvest and placed in cold storage for 12 days (33ºF). Water loss and stem browning were evaluated and compared to the control (Fig. 5). Water loss was reduced 50% with the matrix. Semperfresh reduced water loss by 40%. Stem browning was reduced slightly by both treatments as compared to the control.

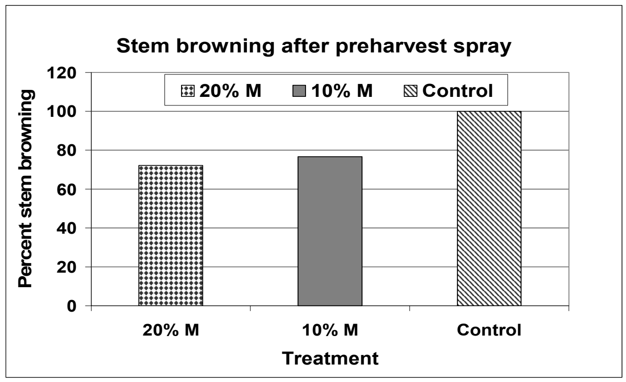


Fig. 4. Effect of 10% and 20% matrix on cherry stem browning after 12 days at 33ºF.

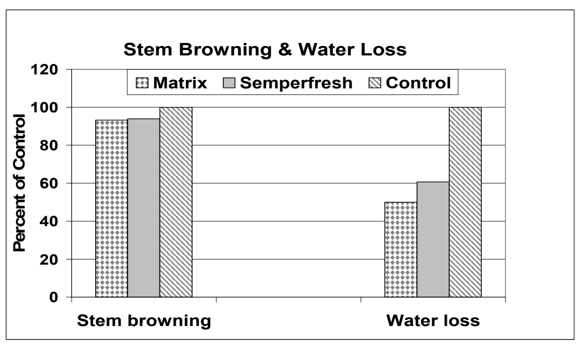


Fig. 5. Water loss and stem browning with Matrix and Semperfresh applied postharvest and then evaluated 12 days later after storage at 33ºF.

Literature cited:

Beyer, M., S. Peschel, M. Knoche, and M. Knorgen. 2002. Studies on water transport through the sweet cherry fruit surface: IV. Regions of preferential uptake. Hort Sci. 37(4): 637-641.

King, J. and R.A. Norton. 1987. Cracking resistance in certain cherry cultivars and selections. Fruit Varieties J. 41:83-84.

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Budget:
Project title: Suppressing cherry cracking and postharvest stem browning and water loss
PI: Larry Schrader (Co-PIs: M. Whiting & E. Curry)
Project duration: 2 years (2003-2004)
Current year: Year 2 (2004)
Project total (2 years): $42,364
Current year request: $22,408

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 requested for an Associate in Research (Leo Jedlow) (25% time) for Schrader's program. The other 75% is provided by WSU and other funds.
[2] Time-slip help for Whiting's program.
[3] Supplies include $800 for Dr. Curry to cover supplies needed for electron microscopy. Supplies include additional pumps to be 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] We can gain a season by testing efficacy of the cherry matrix in the Southern Hemisphere this winter. We plan to develop collaborative efforts with one or more scientists in Tasmania, Chile, New Zealand or Australia.

FINAL REPORT

TITLE: Quantifying Limitations to Balanced Cropping

Principal Investigator: Matthew Whiting

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Julie Tarara, Research Horticulturist, USDA-ARS

OBJECTIVES:

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

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

SIGNIFICANT FINDINGS:

Canopy source:sink relationships:

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

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

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

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

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

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

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

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

2002

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

2003

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

METHODS:

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

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

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

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

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

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

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

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

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

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

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

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

Literature cited/Publications:

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

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

Current year breakdown

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

1 One-sixth annual salary for Mr. Efrain Quiroz.
2 4 months student labor (May-August) for assisting with chamber studies, collection of canopy physical data (i.e., leaf area, light interception), and fruit quality analyses
3 Includes all chamber materials (e.g., mylar, velcro, pvc) and gas analysis consumables
4 Travel to plots

FINAL REPORT
PROJECT NO.: CH-01-16

TITLE: Intensive Sweet Cherry Orchard Management

Principal Investigators: Matthew Whiting
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D.R. Ophardt, Res. Tech. Supervisor, WSU-Prosser
Cooperators: D. Hayden, Pasco, WA
B. Harris, Moxee, WA

OBJECTIVES:

1. Plant a new orchard for the development and evaluation of management practices (e.g., specific training/pruning strategies and growth regulator applications) that facilitate mechanical harvest of sweet cherries for the fresh market.
2. Continue to evaluate the interactions between high density pruning/training systems and trees on various rootstocks for precocity, yield efficiency, fruit quality and other horticultural characteristics. Remaining trial duration is two to three years.
3. Refine high density orchard management techniques (e.g., pruning/training systems) for 'Bing' and 'Rainier' trees established in 1995 on dwarfing and non-dwarfing rootstocks. Remaining trial duration is two to three years.
4. Develop and apply cultural techniques, such as developmental bud and branch management, growth regulator applications, to achieve smaller trees on non-dwarfing rootstocks in new WSU or cooperators' orchards.

Significant findings:

Rootstock x Training System:

In 2003 we compared vegetative characteristics and fruit quality of 'Bing' trained to 4 distinct systems: the free-standing central leader (C) and Spanish bush (B) with the trellised palmette (P), and Y-trellis (Y).

- Among training systems and across rootstocks:
  - fruit quality was lowest for P-trained trees (6.6 g/fruit, ~ 31% ≥ 10.5-row), and similar among the other systems (7.7 g/fruit, ~ 51% ≥ 10.5-row)
  - fruit quality was negatively related to tree yield
  - fruit yield was highest from C and P trees, intermediate from Y trees, and significantly lower (ca. 35%) from SB trees
  - trees trained to B and Y were the most vigorous and CL and P trees were the least vigorous
  - yield efficiency (kg/cm^2 TCSA) was lowest for SB trees, intermediate from Y trees and highest from C and P

- Among rootstocks and across training system:
- fruit quality was best on Mazzard and worst on Gisela 5
- yield was highest on Gisela 6 (~ 27 kg/tree, 9 tons/acre) and ca. 21 and 70% less from Gisela 5 and Mazzard, respectively
- despite producing less than half of the total yield of Gisela 5 trees, Mazzard-rooted trees yielded a similar quantity of ≥ 10.5-row fruit per tree
- Mazzard was the most vigorous followed by Gisela 6 (20% less) and Gisela 5 (45% less)
- yield efficiency was greatest on Gisela 5, 17% less on Gisela 6, and 70% less on Mazzard
- Across all rootstock/training system combinations, yield efficiency and fruit size were correlated closely (r^2=0.83) and negatively
- The top three system/rootstock combinations for yield and quality were: Gisela 6 trained to either Spanish Bush or Central Leader, and Gisela 5 trained to Spanish Bush

Fundamental Cropping Components:
In 2002 and 2003 we studied how canopy architecture affects fundamental components of cropping and fruit quality including number of spurs per tree, flower buds per spur, length of wood per tree, and trunk cross-sectional area. From these data, spur/bud density (spurs/buds per cm wood) and potential cropping density (fruit per tree) were estimated. With this knowledge, we will better understand the effects of training system on tree productivity and be able to develop system-specific management techniques.

- Across all rootstocks, Y-trellis had the highest number of spurs per tree (~750), SB and P were similar (~700), and CL had the fewest (~650)
- CL trees had the highest number of buds per spur (3.2) and SB had the fewest (2.1)
- Therefore, potential fruit per tree was highest for CL (due to high buds/spur), intermediate for P and Y, and lowest for SB (due to low # buds/spur)
- Y trees had the most wood, SB was intermediate, and P and CL had the least
- Spur density was therefore highest for P and the lowest was for Y trees
- Among all combinations, CL Gisela 6 is potentially the most productive and Mazzard trained to SB was the least productive

Methods:
A new high-density orchard (3 acre) will be designed and planted specifically to facilitate mechanical harvest of fruit. Several cultivar/rootstock combinations will be planted including Bing, Chelan, Columbia, Liberty Bell, Sweetheart, and Tieton on Gisela 5, 6, and 3 (209/1), Edabriz, Weiroot 72 and 158. Different high density orchard strategies will be applied, including training (e.g., variations of the Y-trellis, non-trellised) and the use of plant bioregulators. These orchard system variables will be studied for their influence on tree/system precocity, fruit quality, ease/cost of maintenance, efficiency of harvest, and long-term productivity.

A 4-acre (2ha) high density orchard (360tress/acre) of 'Bing' and 'Rainier' on Mazzard (full size), and Gisela 5 (50% size), Gisela 6 (Full size), Gisela 7 (55% size), and Gisela 11 (75% size) was established in 1995 at WSU-Prosser's Roza Experimental Unit with microsprinkler irrigation and wind machine frost protection. Eight training systems, four trellised (single-plane palmette, double-plane "Y", single-plane oblique leader, and single-plane central leader) and four self supporting (multiple leader bush, central leader spindle, central leader axe, and standard multiple leader), were imposed in a randomized block design. Size control, precocity, yield efficiency, fruit quality and other horticultural characteristics are being evaluated relative to both rootstock/scion combinations and rootstock/training system interactions.

Several smaller high density orchards have been planted at the Roza Experimental Unit for short-term studies of specific intensive management practices as trees have been available. These include: 'Bing' and 'Rainier' on Mazzard and Gisela 5, Gisela 6, Gisela 7, and Gisela 11 rootstocks, planted in 1995 on a single plane trellis at trunk angles that vary by 15° increments from 30° to 90°, to examine specific training vs. cropping responses (precocity, fruit quality, and flower bud development vs. shoot growth); a very high density orchard of 'Bing' on Gisela 1 (GI 172/9), planted in 1996 and trained to a central leader spindle to examine canopy architecture as influenced by selected bud or shoot removal, as well as renewal pruning on fruit quality since Gisela 1 is prone to severe overcropping and poor vigor. In addition, high density orchard plots of 'Chelan', 'Attika', 'Lapins', and 'Regina' planted in 1998 on standard rootstocks and trained to either a multiple leader bush or central leader spindle training system to examine growth and precocity responses of these new cultivars to high density training systems. Selective bud removal strategies on young trees in these, and in grower/cooperator orchards will continue to examine the potential for non-Promalin branch development, enhancement of precocity on standard rootstocks, and balancing of reproductive vs. vegetative vigor on precocious rootstocks.

Results and Discussion:
Sweet cherry orchards are being planted at higher tree densities to improve orchard efficiencies (labour in particular) and economic returns. Very little research has investigated the interaction between canopy architecture and rootstock in high density sweet cherry production systems. In addition, the prospect of mechanical harvest of sweet cherries for sale in a premium, fresh market, creates the need for novel orchard systems trials to better understand key growth and cropping components (*e.g.*, cultivar, rootstock, and training system and their interactions). This project provides critical, practical information relating sweet cherry cropping performance to specific intensive training and orchard management decisions under PNW conditions.

Our results show that training system (across all rootstocks) can significantly affect yield and fruit quality (Table 1). Spanish Bush-trained trees were less productive (total tree yield) and yielded the best quality fruit compared to the other architectures. This training system yielded fruit with the highest weight, soluble solids, firmness, and % premium quality. Indeed, almost 56% of fruit from B trees were in the largest category compared to 52% from Y, 46% for CL, and 31% from P trees. However, despite producing a lower % premium quality fruit, other systems with higher total yields (e.g., C and Y) produced significantly more 10.5-row and larger fruit per tree. Central leader trees yielded the most premium quality fruit at 8.6 kg per tree. This is roughly equivalent to 3.25 tons per acre of 10.5-row and larger fruit.

Rootstock (across all training systems) significantly affected fruit quality and yield (Table 1). These results support data from previous years. In general, trees on Mazzard were larger and yielded fewer, higher quality fruit compared to Gisela 6 and 5. In 2003 individual fruit weight from Mazzard trees was about 1 g higher than Gisela 6 trees whose fruit were about 1 g heavier than fruit from Gisela 5 trees. Fruit soluble solids were similar among rootstocks (e.g., 21.1 – 22.8 ^{o}brix). Trees on Gisela 6 yielded significantly more fruit of slightly better quality than trees on Gisela 5. Clearly the implementation of 'standard' management practices in 'Bing'/Gisela 5/6 trees can lead to high yields of poor quality fruit. In 2003, less than 45 and 20% of harvested fruit were 10.5-row or larger for Gisela 6 and 5, respectively. In 2002 fruit were slightly better quality. These general trends reflect the negative relation between fruit quality and crop load (see report on Quantifying Limitations to Balanced Cropping) because tree yields were lower for Mazzard-rooted trees and in 2002.

Tremendous interaction exists between training system and rootstock (Table 1). Trees on Mazzard rootstock performed the best when trained to a central leader system. For Mazzard, this combination produced the highest yields and the best quality fruit (12.5 kg/tree, 85% 10.5-row and larger).

Palmette trained trees were the second highest-yielding but they only produced about half the quantity of premium quality fruit as C. For trees on Mazzard, B was the worst training system because yields were low and fruit quality was poor in comparison to other architectures. In contrast, trees on Gisela 6 rootstock performed the worst when trained to P and were similar among the other systems. However, best individual fruit quality was harvested from B trees but the C and Y systems yielded the most premium quality fruit. The Spanish bush was the best training system for trees on Gisela 5 because yields were lower and fruit quality was better. Similar to Gisela 6, the palmette system was the worst for Gisela 5, yielding just over 1 kg of premium quality fruit per tree.

Rootstock	**Training System**	**Fruit yield (kg)**	**Yield ≥ 10.5-row (kg)**	**Fruit mass (g)**	**Soluble solids (°brix)**	**Firmness (g/mm)**
Central Leader						
	Mazzard	12.5	10.8	8.6	22.6	369
	Gisela 6	29.9	12.0	7.2	20.6	285
	Gisela 5	25.7	3.1	6.5	21.0	295
	Mean	22.7 a	8.6 a	7.43 a	21.4 b	316 b
Spanish Bush						
	Mazzard	4.5	2.6	7.8	23.3	383
	Gisela 6	19.0	9.7	8.2	22.4	313
	Gisela 5	16.1	4.8	7.1	23.8	319
	Mean	13.2 c	5.7 b	7.7 a	23.17 a	338 a
Palmette						
	Mazzard	10.7	5.6	7.8	22.3	358
	Gisela 6	31.4	6.7	6.5	20.1	284
	Gisela 5	20.1	1.1	5.6	20.4	308
	Mean	20.73 ab	4.5 b	6.63 b	20.93 b	317 b
Y-Trellis						
	Mazzard	4.3	4.0	9.6	22.8	332
	Gisela 6	27.7	12.2	7.5	21.3	287
	Gisela 5	23.3	4.5	6.7	21.3	308
	Mean	18.43 b	6.9 ab	7.93 a	21.8 ab	309 b

Table 1. Effect of training system and rootstock on fruit yield and quality of 9-year-old Bing sweet cherry trees. Means followed by different letters are significantly different by LSD ($P < 0.05$).

Fruit row-size distribution also was tremendously variable among training systems and rootstocks (Fig. 1). Among all combinations, the worst quality fruit were harvested from palmette-trained Gisela 5 rooted trees (>30% smaller than 12-row, <10% 10.5-row and larger) and the best quality were harvested from y-trellised Mazzard rooted trees (0% smaller than 12-row, 90% 10.5-row and larger). In general, Gisela 5 rooted trees had the highest percent of smaller than 12-row fruit and the lowest percent of 10.5-row and larger fruit. For Gisela 5, P was the worst with about 30% in the smallest size category. Bush was clearly the best system for Gisela 5 yielding about 40% in both the 11 and 12-row category and the 10.5-row and larger category. Gisela 6 and Mazzard trees yielded fewer cull fruit (smaller than 12-row) than Gisela 5, generally 5 percent or less. Mazzard produced a higher proportion of premium quality fruit compared to Gisela 6 though. For all rootstocks, palmette was the worst system by yielding the lowest proportion of premium quality fruit and highest proportion of cull fruit.

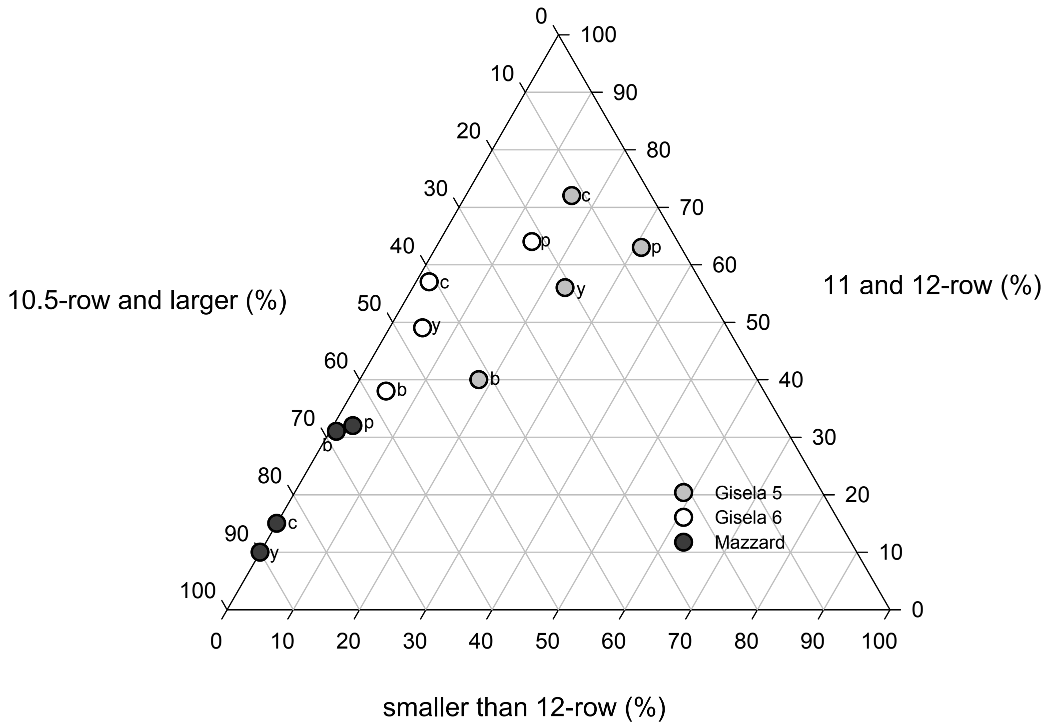

Figure 1. Effect of training system and rootstock on row-size distribution from 9-year-old Bing sweet cherry trees. c = central leader, p = palmette, y = y-trellis, b = bush.

Vigor and yield since planting

Rootstock genotype affected tree vigor (Fig 2). Gisela 5 was the most vigor-controlling rootstock reducing tcsa to 54% of Mazzard-rooted trees. Gisela 6 was intermediate reducing tcsa to 80% of Mazzard-rooted trees in 2002. Very little research has examined the cause of dwarfing in sweet cherry but in apple, restricted conducting tissue may play a role. The size-controlling properties of the Gisela rootstocks did not become apparent for several years after planting. Not until 1999, in the trees' five year in the orchard, did significant variability in tcsa manifest. Gisela 6 and Mazzard-rooted trees exhibited similar vigor until 2000 after which point trees on Gisela 6 were about 20% less vigorous. Differences among rootstocks became more pronounced thereafter as crop load increased significantly. Whiting and Lang (2003) showed that crop load was related negatively to trunk radial expansion. It is not known whether a similar relationship would hold across rootstock genotypes.

Differences in tree vigor among training systems were less pronounced than rootstock. Only subtle differences were evident in the years following planting. Significant trends began to emerge in 2000 as CL and P trained trees were less vigorous than B and Y trees which were similar. However, by 2002, CL and P trees were only about 15% less vigorous than B and Y. Early training of both B and Y involved more branch heading cuts which may have caused greater trunk expansion in these systems.

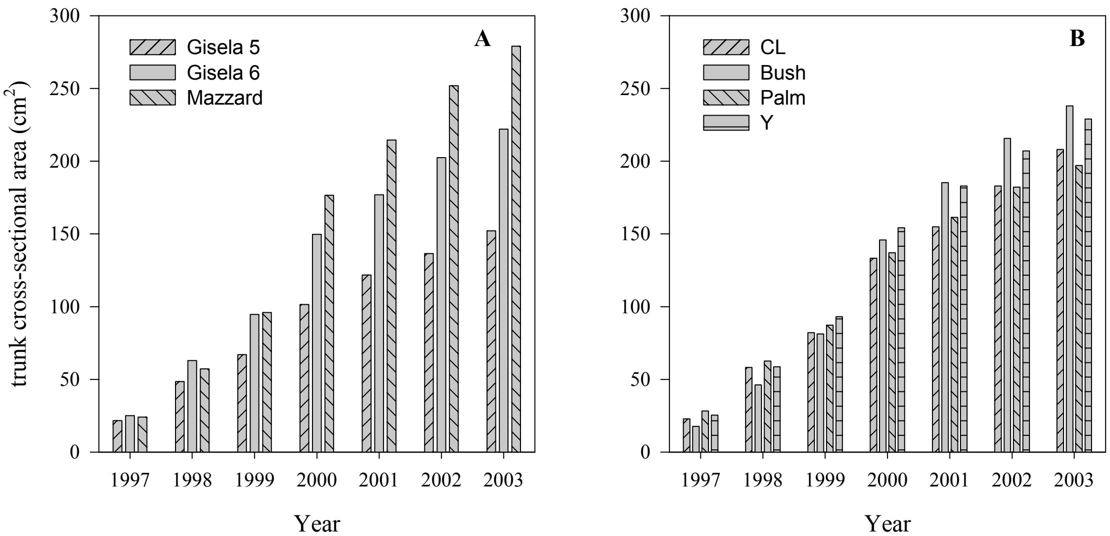

Figure 2. Effect of training system and rootstock on tree vigor (tcsa, cm^2) of Bing sweet cherry trees. Trees were planted in 1995 at 8.5' x 14'.

Rootstock had a tremendous effect on fruit yield (Fig. 3). Overall, Gisela 6 was the most productive rootstock yielding between 12 and 25% more fruit than Gisela 5-rooted trees and 50 to 85% more than Mazzard-rooted trees, depending on the year. Both Gisela 5 and 6 were significantly more precocious than Mazzard and induced fruiting two years after planting. Early yields of Gisela series rootstocks were about 4.5 to 6-fold higher than Mazzard-rooted trees. This trait is of particular interest to sweet cherry growers because the revenue from early fruit sales allows growers to pay off the high costs of orchard establishment. Preliminary estimates indicate that due to the precocious nature of Gisela 5 and 6 rootstocks, growers may break even 7 years before they would with Mazzard-rooted trees (Seavert, pers. comm.).

Training system exhibited less of an effect upon fruit yield compared to rootstock (Fig. 3). Through the first 3 years of production, P was the most productive system and B was the least. In the past 3 years, B remains the least productive system (~ 20 – 25% lower yields) while the other three are similar. However, by mitigating the precocity of the Gisela series rootstocks with repeated heading cuts, the B system yielded higher quality fruit at full production (Fig. 1).

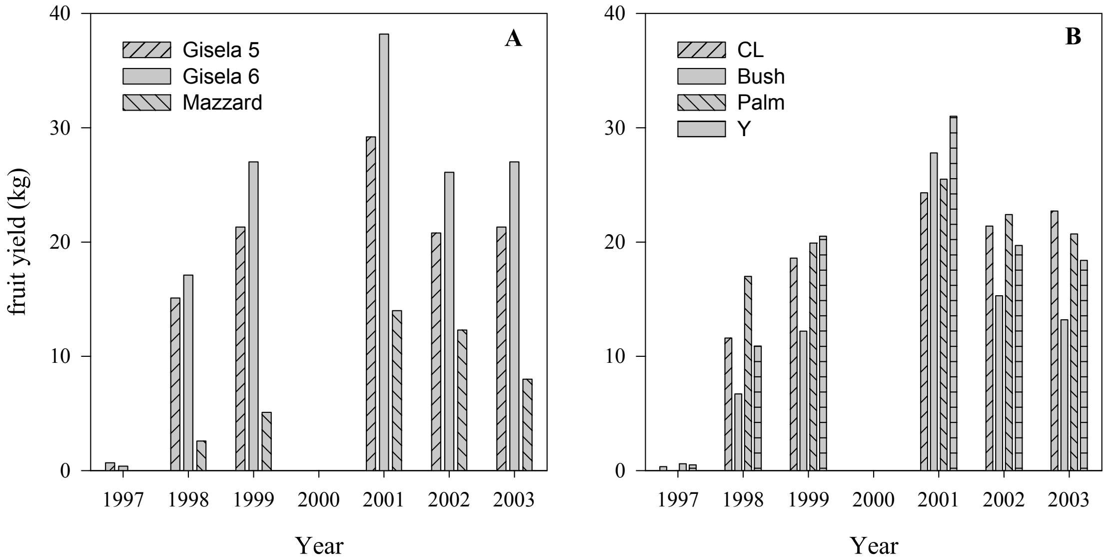

Figure 3. Effect of training system and rootstock on tree yield (kg) of Bing sweet cherry trees. Trees were planted in 1995 at 8.5' x 14'.

Budget:
Project duration: 2001-2003
Project total: $47,926
Current year request: n/a

Year	2001	2002	2003
Total	$10,500	$19,180	$18,246

Item			
Salaries[1]		5,797	6,083
Benefits (28%)		1,623	1,703
Wages[2]	6,000	6,000	6,000
Benefits (16%)	960	960	960
Equipment		1,800	
Supplies[3]	3,000	2,500	2,500
Travel[4]	540	500	1000
Miscellaneous			
Total	$10,500	$19,180	$18,246

FINAL REPORT
WTFRC Project #CH-01-20 **WSU Project #13C-3655-3298**

Project title: Bioregulator uses for controlling vegetative growth, stimulating precocity and managing fruit quality in sweet cherry

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Reporting period: 2001-2003

Objectives of original project:
1. Evaluate effects of Apogee and ethephon alone and in combination on vegetative growth, flowering, fruiting and fruit quality in young sweet cherry trees. Include the cultivars 'Bing.' 'Lapins,' 'Rainier,' and others as appropriate in trials.
2. Compare single vs. multiple application strategies of Apogee and ethephon for effectiveness in control of vegetative growth under southern Washington and north-central Washington environmental conditions. Develop application combinations and timing strategies that produce effective growth control in different cherry growing environments.
3. Determine the propensity for treatment with Apogee and/or ethephon to induce regrowth and application methods that minimize regrowth.
4. Examine effects of growth-control applications to non-fruiting cherry trees on stimulation of precocity in flowering and fruiting.
5. Evaluate Apogee effects on cherry fruit size, color, firmness, solids content and quality. Determine the potential for use of Apogee in management of growth and cropping in fruiting cherry trees.
6. Examine canopy structure in relation to whole-tree photosynthesis of young sweet cherry trees treated with Apogee and/or ethephon. Characterize the changes in canopy structure and document tree photosynthetic behavior through the growing season. Assess the relationship, if any, of whole-tree carbon-fixing capacity to flowering, fruiting and crop quality.

Significant findings:
Over the three-year period of this project, 23 separate trials were undertaken to assess various aspects of bioregulator use for management of vegetative growth, flowering, fruiting and fruit quality in sweet cherry trees. Some of the trials were established to assess the potential for prohexadione-Ca (Apogee®, BASF Corp.) and ethephon (Ethrel®, Bayer CropScience) for control of vigor and induction of flowering in young, non-fruiting sweet cherry trees on Mazzard seedling rootstock. Other trials examined the effects of ethephon on loosening of 'Bing' cherries for mechanical harvest and the potential for either aminoethoxyvinylglycine (ReTain®, Valent BioSciences) or 1-methylcyclopropene (MCP, SmartFresh®, AgroFresh, Inc.) to reverse or offset some of the negative side effects of ethephon on cherry fruit quality. One trial in 2003 explored the potential of three chemicals showing promise in the citrus mechanical harvesting project in Florida for possible loosening of sweet cherries. Another trial in 2003 initiated a new phase of research into the potential

for using gibberellic acid on size-controlled sweet cherry trees for both fruit quality improvement and reduction in flowering, with the goal of producing another grower tool to facilitate the management of such trees for improved fruit quality. This GA program is planned for expansion in 2004 and for continuation for several years to allow the proper assessment of efficacy on cropping and crop quality in subsequent years from GA applications.

Results:
During the course of this project, all objectives have been met except for the evaluation of effects of bioregulators on canopy photosynthesis. This objective was of significantly lower priority and was not addressed. Early on in the project it became obvious that control of vegetative growth was not nearly as important a priority as control of flowering. Both stimulation of flowering and reduction of flowering became more important priorities in the later phases of the project. The following results and conclusions have been obtained during the three years of this project:

A. Vegetative growth

1. Apogee can be successfully used to control vegetative growth in sweet cherry under Washington conditions, but the cost effectiveness of this approach has not been demonstrated.
2. No benefit in growth control has been observed when Apogee doses in excess of 6 oz./100 gallons (dilute basis) have been used, even under high vigor conditions.
3. Reduced vegetative vigor is a prerequisite for improved flowering in young cherry trees, but reduction in vegetative vigor alone is NOT sufficient to encourage flower bud initiation. Apogee reduces vegetative growth but does not supply whatever else is needed to increase flowering.

B. Flowering and fruiting

1. Sweet cherry cultivars differ in their growth responses to Apogee, Ethrel and tank mixes of these products, but only ethephon improves flowering. The cause(s) for variable flowering responses to ethephon is (are) unknown at this time.
2. Apogee has no beneficial effect on induction of flowering in young, non-fruiting sweet cherry trees, either when applied alone or in combination with ethephon.
3. During the course of this project, ethephon increased flowering in 'Rainier'/Mazzard trees, increased bloom and yield in 'Bing'/Mazzard and slightly increased flowering and fruiting in 'Tieton' trees, but at concentrations used ethephon did not improve flowering of 'Lapins' sweet cherry.
4. Trees of 'Attika'/Mazzard planted on the same date in the same orchard and sprayed with Apogee and/or Ethrel on the same dates as the two other cultivars listed below showed increased flowering and yield in response to ethephon, 'Bing'/Mazzard trees showed a small increase in bloom that did not translate into improved yield, and 'Regina'/Mazzard trees did not respond to either Apogee or Ethrel with any improvement in flowering or yield.
5. Ethephon increased the number of flower buds per spur and number of flower buds borne on previous season's shoots in 'Bing'/Mazzard trees.
6. The flowers induced by ethephon treatment are capable of producing fruits of normal quality.
7. Ethephon at concentrations up to 200 ppm produced up to threefold improvement in 'Bing' yield in the year following application. Unfortunately, this response was not observed in all trials.
8. Where yield was increased by ethephon, fruit size was not reduced.
9. Three applications of ethephon did not appear to be superior to two applications of a higher concentration. Substituting concentration for number of applications can improve the cost effectiveness if the gain in flowering and fruiting is sufficient and injury to the tree can be avoided. The relation between ethephon concentration and number of applications still needs further exploration.

10. Gummosis severity was proportional to ethephon concentration in most trials. Where little or no flower-bud formation occurred as a result of ethephon application, little gummosis was observed as well.
11. Ethephon-induced gummosis has not been associated with any negative effects on cherry tree or fruiting behavior. Gummosis may in fact be another sign of a successful ethephon treatment.
12. In one trial, ethephon treatment resulted in increased flowering for two years following treatment. This observation has not been confirmed in other trials to this point.
13. Ethephon treatment of young sweet cherry trees increases flowering by increasing flower-bud density on spurs and on previous season's shoots.
14. Where ethephon has been effective for increasing flowering, the trees have been at least in their third leaf. Treatment of second-leaf trees had no beneficial effect on flowering. A body of spurs needs to be produced before ethephon treatment can be maximally effective because the largest effect of ethephon is on increasing spur flower buds.

C. Fruit loosening and fruit quality

1. Ethephon-based loosening of sweet cherries depends on amount of active ingredient per acre; the amount of water applied per acre appears relatively unimportant as long as good coverage is achieved.
2. Similarly, ethephon-induced gummosis depends primarily on quantity of product per acre and only to a small extent on concentration in the spray solution.
3. Ethephon is highly buffered; only extremely poor quality water is likely to increase the pH of the spray solution. Ethephon was equally effective in loosening cherries at spray solution pH values of 3.2, 6.0 or 8.2 as long as the mixture was sprayed immediately after preparation. Alkaline pH can degrade ethephon performance but only after enough time has elapsed for significant hydrolysis to occur.
4. Ethephon application preharvest reduces the force required to remove the cherry from its pedicel but also increases fruit flesh softening. Ethrel has less effect on soluble solids, acids, fruit size, fruit color and incidence of pitting and tears, but there appear to be important effects of season, which are likely related to temperature after Ethrel treatment.
5. Half rates of Ethrel applied twice are equally effective as twice the amount of Ethrel applied once for fruit loosening and for flesh softening.
6. Applying Ethrel when fruit are more mature (closer to harvest) does not result in greater reduction in fruit removal force. The amount of Ethrel per acre, environmental conditions and time after application are the principal factors that influence the amount of loosening from an Ethrel application.
7. Preharvest ReTain application to sweet cherry trees near harvest has no noticeable effects on fruit removal force, fruit flesh firmness or any other quality parameter. ReTain applied before or at the same time as Ethrel does not alter the Ethrel effects on fruit loosening, softening and other quality parameters. This outcome might be expected, since an ethylene biosynthesis inhibitor would not be expected to have much effect in a system in which ethylene is not being synthesized.
8. MCP is an inhibitor of ethylene action. MCP sprayed on sweet cherry trees near harvest had no discernible effect on fruit removal force, but MCP-treated fruit was firmer than untreated fruit at harvest.
9. When MCP was applied to the same trees at the same time as Ethrel, the ethephon loosened the cherries as normal, <u>but MCP inhibited the flesh softening otherwise normally associated with ethephon treatment</u>. This exciting observation definitely deserves further research attention.
10. Delaying the MCP application 3 to 5 days after the ethephon treatment eliminated the MCP-based control over fruit softening.
11. Three candidate products that loosen citrus for mechanical harvesting were tested for the capability to loosen sweet cherries. The chemicals were Release, LA-139 and Atrimmec

(dikegulac). The same concentrations that are effective in citrus were used. None of these candidate products produced any loosening effect on ‘Bing’ sweet cherry.

D. Control of flowering and fruit quality with gibberellic acid

1. Gibberellic acid appeared to retard color development and maintain higher flesh firmness in relation to concentration and to number of applications. Double applications were firmer and less red-colored in general than single applications at either the end of stage I or stage II of development.
2. Effects on flowering will be assessed in spring, 2004.

Summary:
Flowering in young cherry trees was improved, sometimes substantially, by treatment with Ethrel, but the results varied from year to year. Cherry cultivars show surprisingly different responses to both Apogee and Ethrel. It appears likely that growers interested in improving flowering in specific cultivars will have to evaluate recommended procedures to be sure they are effective under their specific conditions and cultivars. Apogee does NOT improve flowering in sweet cherry, even though it can reduce vegetative vigor. Without an improvement in flowering, Apogee treatment of sweet cherry does not appear to be cost effective in young trees. Ethrel may produce an improvement in flowering for two seasons after treatment, but this observation needs confirmation.

Perhaps the most exciting observation in the mechanical harvesting project was made in 2003. Combining preharvest Ethrel with an application of MCP at the same time resulted in the normal loosening typically produced by Ethrel but without the loss of flesh firmness that otherwise always accompanies Ethrel application. If this observation can be confirmed with more study, it may pave the way toward being able to use Ethrel effectively for fruit loosening for mechanical harvest while better preserving fruit quality, both during and possibly after the harvest process.

The newest project involves the potential use of gibberellic acid in cherry to reduce the excessive flowering induced by size-controlling rootstocks, such as the Gisela series rootstocks. Size-controlling rootstocks will become much more popular for commercial cherry growing if the problems of excessive flowering and fruit set can be effectively managed. Chemical blossom thinning techniques may be developed but are not available at present. Using the tree’s own physiology to control flowering by controlling the initiation of flower buds offers an exciting possibility for a new tool for growers of dwarf cherry trees. This project is only in the beginning stages and requires further study to verify its potential benefit as a tool for cherry growers to manage fruit quality on small trees.

Acknowledgments:
We gratefully acknowledge the support and assistance provided over the past three years by the following individuals and organizations that helped made this project possible: Tom Auvil, Bob Bailey, Diana Bailey, Bart Brinkman, Felipe Castillo, Rommel Corral, Dan Fulbright, Jake Gutzwiler, Dennis Hayden, Randy Hayden, Dr. Chris Ishida, Richard Janney, Dr. Gene Kupferman, Dr. G.A. Lang, Edgar Letkeman, Lynn Long, Dr. Jim McFerson, Kent Meline, David Ophardt, Byron Phillips, Len Pugsley, Pete Savage, Tory Schmidt, Dr. Eliot Scull, Matt Smith, Kevin Sullivan, Dwayne Visser, Dr. Matthew D. Whiting, Bayer CropScience, BASF Corp., Hayden Orchards, Mountain View Orchards, Orchard View Farms, Oregon Sweet Cherry Commission, Scull Orchards, Stemilt Management, Valent BioSciences and the Washington Tree Fruit Research Commission.

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Drake, S.R., D.C. Elfving, T.A. Eisele, M.A. Drake, S.L. Drake and D.B. Visser. 2003. Effects of ethephon and aminoethoxyvinylglycine on the carbohydrate and acid contents of 'Scarletspur Delicious' apples (*Malus domestica* Borkh.). Poster, Proc. Inst. Food Technol. Annual Meeting, July 12-13, Chicago, IL.

Summary of total project costs:

Title:	Bioregulator uses for controlling vegetative growth, stimulating precocity and managing fruit quality in sweet cherry
PI:	Don C. Elfving
Project duration:	three years
Total project costs:	$40,520

FINAL REPORT

TITLE: Epidemiology and control of cherry powdery mildew (CPM)

Principal Investigator: **G. G. Grove**, Plant Pathology, WSU-IAREC, Prosser, WA

Co-investigators: **C.L. Xiao**, Plant Pathologist, WSU-TFREC, Wenatchee, WA
D.C. Elfving, Pomologist, WSU-TFREC, Wenatchee, WA
Tom Auvil, Washington Tree Fruit Research Commission, Wenatchee, WA
Matt Whiting, WSU-IAREC, Prosser, WA

OBJECTIVES:

* Determine if irrigation management can be used to delay the onset of cherry mildew epidemics and/or reduce disease severity.

* Develop oil-based conventional and weather driven cherry powdery mildew management programs.

* Continue evaluating various sprayer technologies and spray volumes

* Investigate the influence of weather variables and current irrigation practices on disease prgoression and aerial conidia populations of conidia of the cherry fungus.

* Continue field evaluations of various "soft" fungicides for efficacy against stone fruit mildews and as components of antiresistance strategies for maintaining the effectiveness of "at risk" fungicides.

SIGNIFICANT FINDINGS:

* Modeling studies. <u>Controlled environment studies</u>. Infection of cherry foliage occurred between 10 and 25 C at relative humidities of 90-100% (Figure 2). *There was no infection at 5 or 30 C.*

<u>Field Studies.</u> Primary infection resulted from natural precipitation in three orchards and the initial irrigation set in 3 orchards. Delayed irrigation resulted in lower disease severity at harvest (Figure 1).

* CPM epidemics at 3 sites intensified during the first two weeks of June (Figure 3). Although more data needs to be collected, it appears that epidemics intensified after several consecutive days with average temperatures > 60 F.

• Irrigation delays of 2-4 weeks had no effects of fruit size, weight, or soluble solids. Some effects were noted after a 6 week delay (Table 2).

• In an orchard where irrigation was delayed in 2001 and 2002, but received normal irrigation in 2003, there were no significant differences in fruit weight (with the exception of the 6 week delay), firmness, and soluble solids. Vegetative growth was also normal (Table 3).

* Qualitative air sampling/early detection studies. Powdery mildews were detected in the field using Innovatek Bioguardian and Rotorod rotary impaction air samplers, and identified using PCR.

-Molecular identification methods. Primers for cherry powdery mildew (*developed by R.A. Spotts*) were tested for cross-reactivity to apple, hop, peach/nectarine, Cosmos, lilac, pea, and rose powdery mildew. No cross-reaction occurred. The primer is currently being tested for cross reaction with DNA collected from the powdery mildews from 47 disparate plant hosts from 25 different vascular plant families.

* Organic fungicides applied at 7- and 14- day intervals failed to provide statistically significant control of CPM in a high disease pressure cv. 'Bing' orchard (Table 4).

* Oil programs were compared with conventional fungicide programs. The former programs provided savings of $30-60 per acre without compromising disease control (Table 5).

* Quinoxyfen, petroleum oils, neem oil, applied alone or in combination, provided mildew controls equal to that obtained using conventional fungicides.

• Two new compounds (Pristine and a numbered compound from Valent) provided excellent control of CPM in the orchard.

METHODS:

Effect of temperature and relative humidity on colony expansion and foliar disease severity. Cherry leaf disks (cv. 'Bing') were inoculated using a suspension of *P. clandestina* conidia and incubated 21 days at relative humidities of 90-100% at temperatures of 40-95 F (5-35 C). The proportion of disk surface area colonized by powdery mildew was determined 7, 14, and 21 days after inoculation.

Verifying pathogen presence and activity. Air sampling studies. Two air sampling methods were evaluated in preliminary field studies. The first study was conducted using rotary-impaction air samplers.
In a second study, a custom-built air sampler (manufactured by Innovatek of Richland, WA) 50-100 times more efficient than other types currently available was tested through the summer of 2003.

<u>Use of molecular tools for the timely detection of propagules of the cherry mildew fungus</u>. DNA extractions were using a Bio 101 System FastDNA kit. PCR amplification with universal primers was performed with Pfu polymerase according the recommended instructions. Amplifications were performed in a total volume of 25µl using three-step cycling. Amplification products were 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 about extraction procedures has been published (Falacy et al 2003).

Various fungicide programs were evaluated using efficacy and relative input cost as measures of usefulness. Various combinations and rotations of DMI, quinoline, strobilurin, SAR, oil, whey, and sulfur compounds were applied to Bing and Rainier cherries and evaluated for efficacy and phytotoxicity. Compounds were applied in calendar and weather based management programs. Disease incidence and severity was 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 was estimated and recorded. Data were subjected to analysis of variance and means separated according to Fisher's PLSD at $P < 0.05$.

Preliminary baseline sensitivity studies for resistance-prone fungicides (eg. Flint, Cabrio, Quintec) were conducted using the methods of Ypema and Gubler (1997). Detached, symptomless, and untreated cherry leaves were collected from 'Bing' cherry liners. Leaves were disinfested for 30s in a 50% ethanol solution and rinsed using sterile, distilled water. Leaves were placed between autoclaved paper towels to dry. Leaves were dipped in each fungicide treatment and allowed to dry, ventral side-up, on paper towels. Leaf discs were obtained using a 15 mm cork-borer and four discs 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 were inoculated with *P. clandestina* using an inoculation tower. Disks were 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 was determined by assessing the percentage of leaf disc surface covered with sporulating powdery mildew colonies.

Results and Discussion:

Irrigation timing was compared in two neighboring Yakima Valley orchards with histories of powdery mildew epidemics. The initial irrigation set was applied April 28 and May 10 in the two respective orchards. The first powdery mildew symptoms and signs were observed on May 12 and 20, respectively, *indicating that the beginning of the epidemic was delayed about 2 weeks when irrigation was delayed*. Disease severity at harvest in the "normal" and "delayed" irrigation orchards was a 47.4 and 10.7% indicating that the "intensification" phase of the CPM epidemics was delayed by the irrigation delay (Figure 1; Table 2). The implications of this shift on fruit infection require further investigation. The results of the 2000-2003 studies have improved our understanding of the primary infection process in sweet cherries. We have documented two moisture events that can result in ascospore release and primary infection: 1) impact sprinkler irrigation and 2) natural precipitation (0.1" or greater). In all test orchards, the appearance of primary mildew required about 50 cumulative degree-days > 50 F after a primary infection period.

Irrigation delays were shown to have little effect on tree and fruit horticultural characteristics in 2001-2003 studies. For the third year, irrigation delays of 2-4 weeks had no significant effects on fruit size, soluble solids, and weight (Table 2). This years' studies also included fruit and tree analyses in an orchard where delays were practiced in 2001 and 2003, but irrigated normally this year. Irrigation delays in 2001 and 2002 had no residual effects on fruit size, weight (with the exception of the 6 week delay in 2002), firmness, or soluble solids at harvest in 2003 (Table 3). Average leaf area, shoot number, and shoot length were also not affected. The conclusion drawn from our irrigation studies is that in the absence of natural (precipitation induced) primary infection periods, *irrigation delay offers a safe means of delaying the onset of cherry powdery mildew epidemics.*

The development of a technique for determining the effects of temperature and relative humidity on powdery mildew infection of, and sporulation on, foliar tissue will expedite the development of a risk assessment model. The general high- and low- temperature limits were found to be between 26-30 C (79-86 F) and 5-9 C (41-48.2 F). The optimum temperature for tissue colonization was 25 C (Figure 2). In preliminary stepwise regression analyses, infection of cherry foliage was best predicted using a model containing temperature and temperature*relative humidity interaction terms (R^2 = 0.85) The expansion and continuation of these studies is discussed in the new project proposal. Disease progression studies in the field indicated that foliar incidence and severity increased significantly with the onset of warmer weather in early June (Figure 3).

Although extensive further testing is required, the PCR primer developed by R.A. Spotts did not cross-react with the powdery mildews of apple, hop, and peach. Early indications are that this primer is as specific as the grape, hop, and peach powdery mildew primers developed in our laboratory. The latter routinely amplified *U. necator* DNA, but did not amplify DNA from powdery mildew species collected from 47 disparate plant hosts from 25 different families. The cherry primer is being tested against the DNA of this same group of powdery mildews is in progress and should be complete by March 2004.

The utilization of these air sampling devices to detect airborne *P. clandestina* conidia and ascospores coupled with molecular identification techniques could possibly be utilized to pinpoint the onset or intensification of CPM epidemics and to study the long-distance dispersal of *P.clandestina*. However, because of the presence of numerous other powdery mildews (e.g. hop, apple, grape, peach, nectarine, apricot) that may be in orchards and hop yards in close proximity to Eastern Washington orchards the discrimination of *P. clandestina* in air samples containing mixed fungal populations is imperative. Identification of *P. clandestina* using designed species-specific PCR primers could be utilized to differentiate Erysiphaceous fungi that are difficult to distinguish using conventional labor-intensive and time-consuming microscopic techniques.

Early detection and identification of spores in low concentrations could provide a safe means to associate the initial fungicide applications with the initial occurrence of airborne pathogen propagules, rather than assumed or predicted activity. Conversely, verification of inoculum availability could enhance a CPM risk assessment model. These approaches could be extremely useful in reducing fungicide applications in the absence of the pathogen or during years of late epidemic onset and thereby enhance our current approach to CPM management.

Several new fungicides were registered, and a new approach (utilizing the fungicidal properties of petroleum oils) for disease management has resulted from this program (Grove, 2001). The efficacy packages for Procure, Flint, Cabrio, Pristine, and Quintec were developed as a portion of this grower-funded research program. The benefits of the oil program are evident in Table 5. The spray regimes containing oil provided the same level of disease control as other approaches, conformed to the APS Fungicide Resistance Action Committee resistance management guidelines, were free of any phytotoxicity, and provided a monetary savings of $31-62 per acre (based on a 4 application program).

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Tables and Figures

Table 1. Primary infection, disease progression, and disease severity at harvest in orchards where natural and irrigation-induced primary infection events occurred. Pasco trees were treated with fungicides every 14 days.

Location	Primary Infection	Moisture Source	First Symptoms	Disease severity at harvest
Halstead	28 April	Irrigation	12 May	47.4
Pasco*	30 April	Precipitation	12 May	18.0
Zillah	10 May	Irrigation	20 May	10.7

Table 2. Effect of 2001 and 2002 irrigation delays on selected fruit characteristics at harvest, 2003.

Irrigation Delay (2002)	Fruit Weight (2003)	Fruit Firmness (2003)	Soluble Solids (2003)
0	11.48A	297.6A	16.9A
2	10.9AB	295.7A	16.7A
4	10.8AB	303.6A	16.8A
6	10.2B	300.3A	16.9A

Table 3. Effect of 2001 and 2002 irrigation delays on selected vegetative characteristics of ‘Bing’ cherries at harvest, 2003.

Irrigation Delay (2002)	Number of sucker shoots per limb	Sucker shoot length (inches)	Leaf Area (cm^2)
0	2.3A	26.5A	715.4A
2	1.9A	24.6A	697.2A
4	2.5A	23.3A	629.5A
6	1.3A	21.0A	638.7A

Table 4. Effect of organic fungicides on powdery mildew severity on cv. 'Bing' cherries, Orondo, WA. Disease pressure was extremely high.

Treatment	Program/ Interval	Disease severity
Untreated		89.9 a
Oil Kaligreen	first symptoms 7 day interval following oil	70.7 ab
Oil CalSup	first symptoms 7 day interval following oil	73.9 ab
Oil Serenade	first symptoms 7 day interval following oil	66.1 ab
Oil Microthiol	shuck fall-pit hardening 7 day interval after pit hardening	82.1 a
Oil Kaligreen	shuck fall-pit hardening 7 day interval followingoil	73.0 ab
Oil Kaligreen/CalSup	shuck fall-pit hardening 7 day interval following oil	75.9 ab
Oil Kaligreen/Serenade	shuck fall-pit hardening 7 day interval following oil	61.1 abc
Oil Serenade/CalSup	shuck fall-pit hardening 7 day interval following oil	66.0 ab
Oil Flint	shuck fall-pit hardening 14 day intervals following oil	32.2 c
CalSup	shuck fall-harvest (7 day intervals)	72.3 ab

Table 5. Comparison of oil-based and conventional fungicide programs on powdery mildew of sweet cherry.

Treatment	Timing[1]	Disease severity[2]	Disease severity [3]	Cost/A	FRAC Guidelines[4]
Untreated		56.4A	52.7A		
Procure	Full season	9.6C	6.6BC	$94.72	No
Procure + Flint	SF, SF+14 1C, 2C	1.5C	2.1C	$126.44	Yes
Oil Flint Procure	SF, SF + 14 1C 2C	13.1BC	5.9BC	$63.98	Yes
Oil Procure Flint	SF, SF + 14 1C 2C	7.9C	9.2BC	$63.98	Yes
Cabrio	Full season	1.0C	0.1C	-	No
Pristine	Full season	0.3C	3.8BC	-	No

[1] = SF (shuck fall), SF +14 (14 days after shuck fall), 1C (first cover), 2C (second cover)
[2,3] = percentage of leaf surface area infested
[4] = APS Fungicide Resistance Action Committee (FRAC) recommends no more than three applications of any single fungicide mode of action per season

Figure 1. Effect of irrigation delay on disease onset and intensification Yakima Valley cherry orchards. First symptoms were noted 12 and 20 May in Halstead and Zillah orchards, respectively. Note comparative disease severity at harvest.

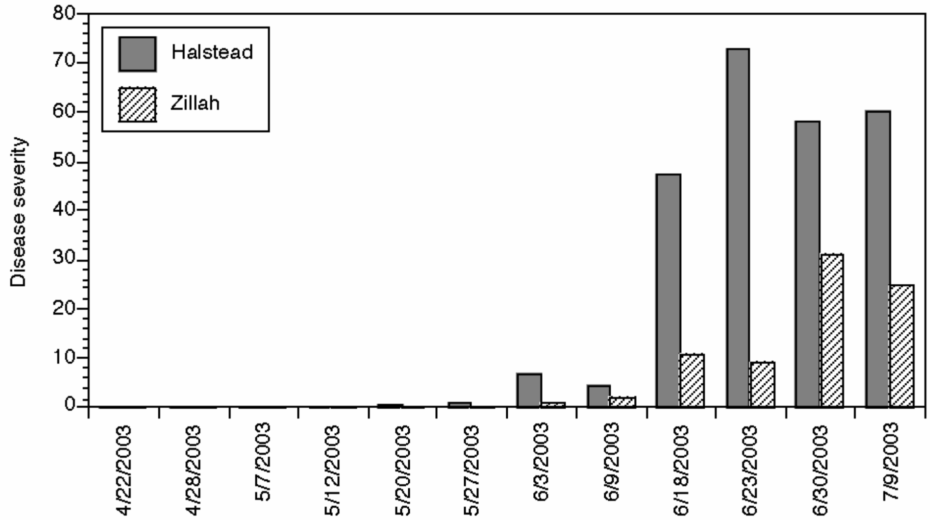


Figure 2. Influence of tempeature and relative humidity on colonization of cherry leaf disks by *Podosphaera clandestina.*

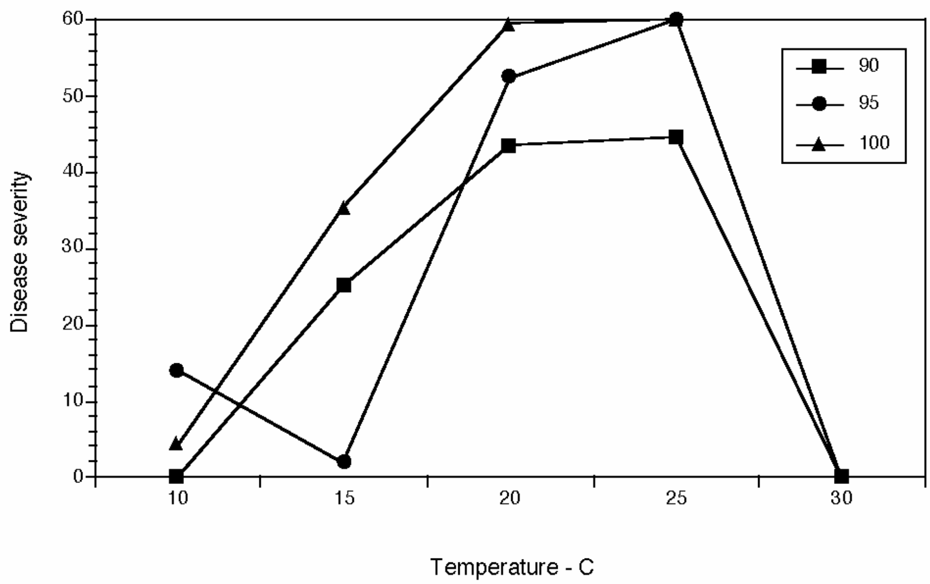
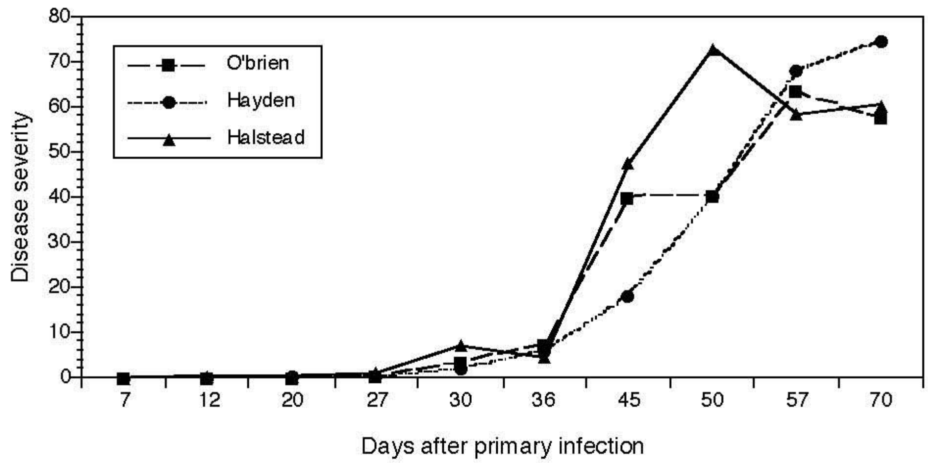


Figure 3. Progression of CPM following primary infection in the Yakima and Columbia Valleys, 2003. Large increase in severity (days 30-40 after primary infection) corresponded with onset of warm weather.



CONTINUING PROJECT REPORT **YEAR 3/3**

TITLE: Epidemiology and control of powdery mildew of peach and nectarine

Principal Investigator: G. G. Grove, Plant Pathology, WSU-IAREC, Prosser, WA

Cooperators: Mike Bush, Area Extension Agent, IPM, Yakima County
Dana Faubion, Area Extension Agent, Pomology, Yakima County
Doug Walsh, Entomologist, WSU-IAREC
Heather Galloway, Associate in Research, WSU-Prosser

Justification:

Powdery mildew (PM) is the most serious disease of peaches and nectarines in Eastern Washington. In recent years, PM has been managed through the intensive use of DMI and sulfur fungicides. The availability of new organic products (e.g. narrow range petroleum oils and carbonates) offer a means to enhance fruit marketability while at the same time lowering fungicide input costs. However, improvement of conventional programs and implementation of organic programs requires a better understanding of PM epidemiology and the development of innovative tools for study and detection of the causal organism. The sources and production of primary inoculum are the principal epidemiological questions about peach/nectarine mildew. We can detect primary inoculum in volumetric spore traps, but tentative identification of *Sphaerotheca pannosa* is usually not made for at least 1 week after the actual spore trapping. One method that has potential benefits for the grower is the use of indicator plants (in this case, cultivated roses) for detection of *S. pannosa*. Early symptoms on rose may be useful for signaling the beginning of the "mildew season" in the peach or nectarine orchard.

Another possible way to indicate the first presence of the pathogen and beginning of the powdery mildew epidemic is the use of molecular biology for indentification of *S. pannosa* propagules. Due to the presence of many different powdery mildew species in the orchard air, this method of detection is subject to error. Furthermore, it is unclear how the spore trap detection threshold correlates with inoculum concentration and the implementation of chemical control measures. The polymerase chain reaction may provide a means for detection of this pathogen in the orchard air, but the potential application of this technology will take several research steps. It must be determined if this method can be used to detect and amplify DNA extracted from conidia that may be present in spore traps. If this is possible, the next step will be to determine the detection threshold of the technique, i.e. does the technique detect *S. pannosa* at levels that would enable the timely application of chemical control measures.

It is currently thought that fruit are susceptible to infection from shuck fall to pit hardening, but this phenomenon has never been conclusively demonstrated in temperate climates and could vary according to cultivar. Studies of the ontogenic resistance of grape berries to grape powdery mildew (GPM) indicates that fruit are susceptible to infection for much shorter periods of time than previously thought. This knowledge is significantly reducing the expense of GPM fungicide programs and could also apply to the PM/nectarine/peach pathosystem. The period of fruit susceptibility and timing of fruit infection in Eastern Washington could be elucidated through "bagging" experiments and/or by using PCR to detect *S. pannosa* on the fruit surface.

The nectarine/peach orchard planted at IAREC in 20001 is severely infested with powdery mildew and ready for extensive epidemiological and chemical research beginning in 2004. Access to an experimental orchard where fungicide applications can be minimized should ensure rapid progress on all aspects of this project.

<u>Objectives</u>

I. Develop an epidemiological-based method of timing fungicide sprays for managing peach/nectarine powdery mildew.

* Determine if irrigation management can be used to delay the onset of peach mildew epidemics and/or reduce disease severity.

* Continue large plot (on-farm) testing of oil-based weather driven peach/nectarine powdery mildew management program.

*Investigate the influence of weather variables and current irrigation practices on aerial conidia populations of conidia of peach mildew fungus.

*Evaluate Rotorod, volumetric, and low (Burkhard) and high-efficiency (Innovatek) cyclonic air samplers for trapping propagules of *S. pannosa*. Evaluate the efficiency of ATV- mounted rotary impaction air samplers for detecting *S. pannosa*.

*Perfect techniques for extraction of DNA from *S. pannosa* mycelia; continue investigations of primer specificity. Determine if primers developed for *S. pannosa* on rose can be used in investigations of *S. pannosa* on soft fruit. Techniques will be used for epidemiological investigations in upcoming years.

*Continue testing primers for cross-reaction with other powdery mildews.

*Determine the fruit infection window through bagging experiments and/or application of PCR techniques.

II. Practical Disease Management

*Continue field evaluations of various "soft" and organic fungicides for efficacy against stone fruit mildews and for effect on beneficial insects.

*Continue the development and implementation of practical fungicide resistance management programs.

*Develop fungicide programs that complement overall sound IPM strategies.

*Evaluate tower and electrostatic sprayer technologies on peaches and necatarines.

Significant findings/developments:

- The large peach/nectarine orchard established at WSU Prosser is now in its 3rd leaf and ready for experimentation. A large population of *S. pannosa* has been established in the orchard, which should alleviate research problems encountered in commercial orchards.

- The orchard is comprised of highly susceptible varieties and is surrounded by mildew-susceptible roses. Epidemiological studies at the site commenced in 2003 and will expanded significantly in 2004.

- Relationship of irrigation sets to orchard spore loads: 2003 data is still being collected and will be analyzed in October-November 2003.

- A primer designed to amplify DNA of *S. pannosa* did not amplify DNA from apple or hop powdery mildew.

- The soft fruit degree day model provided a means to identify the onset of primary and secondary inoculum dispersal, but due to lack of powdery mildew pressure in 2002, field validation experiments were repeated in 2003. Spore data is still being evaluated as of September 30.

- For the fourth year, *S. pannosa* infection of cultivated roses occurred early enough in the epidemic to warrant the use of indicator plants in management experiments.

- Organic fungicide program evaluation: testing still in progress in Quincy, WA nursery (30 September).

- Conventional fungicide program evaluation: testing still in progress in Quincy, WA nursery (30 September).

Methods:

Detection of airborne S. pannosa. See spore trapping above. We obtained the Innovatek air sampler in late March and began "debugging" experiments during 2002-2003. Powdery mildew DNA was successfully detected (using PCR) in air samples collected using the Innovatek and rotary-impaction air samplers.

In order to maintain and collect specific isolates of *S. pannosa* a horsehair attached to a needle probe will be used to transfer single conidial chains to surface-disinfested peach leaf disks or stem cuttings. PM isolates will be maintained on inoculated plant material maintained in a Burkhard isolation plant propagator. Conidia and mycelium of various isolates will be collected using previously described techniques (Evans, 1996); *S. pannosa* DNA will also be obtained from researchers throughout the world. Other airborne fungi common in the vineyard air will be collected. Fungi will be isolated and maintained in pure culture. In order to determine specificity, primers developed for *S. pannosa* will be tested for cross reaction to other powdery mildew mildews and unrelated airborne fungi.

Our identification approach uses nested primers in order to detect DNA in very low quantities (Stark 1998, Williams 2001). The ITS region was chosen for amplification because there are several hundred copies of this region per genome, allowing for detection of smaller amounts of spores than with other genomic areas (Zhou 2000). The first universal primers (ITS 1, ITS4) amplify most of the ITS region of the DNA present. The second species-specific primers were designed to only amplify *S. pannosa.* Species -specific primers have been created by our lab utilizing internal transcribed spacer (ITS) sequence data already available on NCBI submitted mostly by Saenz et al (1999).

Genomic DNA will be extracted using a Bio101 FastDNA using the manufacturer's recommendations (with minor adjustments) for fungal DNA extraction.

The chances for successful implementation of the sampling/ identification technology are good. However, there are several possible pitfalls for the proposed detection and identification approach. The primers may lack the specificity required to positively identify *U. necator* in a mixed aerial population of fungal propagules. If the identification portion of the technique is successfully developed, the detection threshold may be not be low enough to facilitate early warning, i.e. detection may not occur early enough in the epidemic to be of practical use to the grower. The cost of the air sampler required to successfully implement the strategy may remain high. However, the sensitivity of our assay is such that detection may be accomplished using far less expensive means.

Irrigation studies. Investigations will commence in the new nectarine orchard at WSU-IAREC in 2004. Volumetric and rotary impaction spore traps will be operated continuously. Once mildew is established, day or night irrigation sets of various lengths will be applied. Correlation, time series, and regression analyses will be applied to determine irrigation effects on airborne spore populations. The effect of irrigation type on orchard microclimate and airborne spore concentrations will be studied using CR-21X Dataloggers and volumetric spore traps.

Sprayer Technology. Mildew control using electrostatic and tower sprayers will be evaluated the new WSU-IAREC orchard. Conventional spray technology will serve as controls. Initial studies will focus on the influence of spray volume on efficacy.

Oil phytotoxicity issues. Expand investigations on control of mildew with oils. The potential phytotoxic effects of petroleum and vegetable oils on peach/nectarine fruit will be evaluated in field trials.

Forecasting. Continue field testing the oil-based mildew management program. A local orchard will be used for this portion of the study. Portions of orchards will be treated using conventional spray programs while separate portions will be treated using the model/oil programs. Foliar disease incidence/severity and fruit phytotoxicity at harvest will be determined as described previously.

Timing of fruit infection. Fruit of cv. 'Jupiter' will be bagged beginning at petal fall. Bags will be removed at 7- day intervals and disease incidence and severity (the proportion of infected fruit and severity of infection will be noted in midsummer. Soluble solids, firmness, and color will be noted on each sampling date. If a species-specific primer can be employed, PCR will be used to detect *S. pannosa* on the fruit surface in 2004 studies. The latter data would supplement that obtained in bagging experiments. On 9 April ten blossoms on each of ten Jupiter cultivar nectarine trees were covered with Nitex cloth bags to protect the developing fruit from exposure to powdery mildew conidia. (Nitex pores allow necessary gas exchange for normal photosynthetic processes but are too small for mildew conidia entry.) Beginning 16 April ten bags were removed for one week and then replaced each week until 9 July; creating ten sequential exposure periods.

On 9 July all bags were removed and each remaining fruit was examined for signs of powdery mildew. Table 1 contains the results of this evaluation.

In addition, on three dates ten fruit on each of ten trees in an adjacent row to the above trial were examined for the presence of mildew infected fruit.

Continue developing practical fungicide resistance management strategies. Various combinations and rotations of quinoline, strobilurin, SAR, oil, and sulfur compounds will be applied nectarines and evaluated for efficacy and phytotoxicity. Compounds will be applied in calendar programs and in conjunction with the new degree day model. 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 $P < 0.05$.

Results and Discussion

The technique developed in late 2002 to remove powdery mildew from plant surfaces and to extract and amplify DNA was further refined in 2003. The former involves the use of a small handheld cyclonic air sampler that deposits mycelia and conidia of S. *pannosa* into a small via. The DNA extraction technique involves the use of the FastDNA commercial extraction tool. Two PCR techniques were tested. A nested primer technique was used to detect minute amounts of powdery mildew DNA contained in a air sampler, but was found to be plagued with contamination problems. Standard PCR techniques were found to be the most consistent for detection of small quantities of powdery mildew. Specifity studies using the S. pannosa primer commenced in 2003 and will continue: the primer will be tested for amplification of DNA of about 50 other powdery mildews.

Spore and weather data permitted the development of a degree day model that can be used to identify the onset of primary and secondary inoculum production. The most appropriate threshold for the historical spore data appears to be cumulative degree days >60 F past bud break. CDD values of 0 and 20 identify critical events in the disease cycle and may be the most appropriate times for fungicide applications. This requires further study because the results of large 2002 and 2003 trials were inconclusive due to lack PM (oversprayed). This study will be continued in the new WSU-IAREC orchard in 2004.

The infection of roses during the early stages of fruit susceptibility may offer an alternative means of signaling the beginning of the spray program. However, this observation needs to be verified using expanded fruit bagging experiments and the aforementioned PCR techniques.

Studies on the temporal susceptibility of fruit were conducted in Mattawa. As result of poor pollination, damage during bagging or a combination of both, not all exposure periods had ten test fruit. The remaining fruit did not show any obvious symptoms of infection trend (Table 1). However, the degree of mildew infection in the orchard was quite low in general. Infection rates observed were 5, 4, and 1 percent on 18 June, 25 June, and 2 July respectively.

References

Evans, K.J. 1996. An experimental system for characterizing isolates of *Uncinula necator*. Mycological Research 100(6): 675-680.

Stark, K.D.C., Nicolet, J., Frey, J. 1998. Detection of Mycoplasma hyopneumoniae by Air Aampling with a Nested PCR. Applied and Environmental Microbiology 64: (2) 543-548.

Stummer, B.E., Zanker, T., Scott, E.S., 1999. Cryopreservation of air-dried conidia of *Uncinula necator*. Australasian Plant Pathology 28:82-84.

Stummer, B. E., Zanker, T., Scott, E.S., Whisson, D.L. 2000. Genetic diversity in populations of *Uncinula necator*: comparison of RFLP and PCR-based approaches. Mycological Research 104(1): 44-62.

Williams, R. H., Ward, E., McCartney, H.A. 2001. Methods for integrated Air Sampling and DNA analysis for Detection of Airborne Fungal Spores. Applied and Environmental Microbiology 67: (6) 2453-2459.

Zhou, G., Whong, W.Z., Ong, T., Chen, B. 2000. Development of a fungus-specific PCR assay for detecting low-level fungi in an indoor environment. Molecular and Cellular Probes 14: 339-348.

Budget:

Title: Epidemiology and control of powdery mildew of peach and nectarine
Principal Investigator**:** G. G. Grove
Project duration: 3 years
Current year: 2004
Project total: $49,068
Current year: $16,192

Item	**Year 1 (02)**	Year 2 (03)	**Year 3 (04)**	**Total**
00 Salaries				
Graduate Research Assistant Associate in Research	7,557	12,360	**12,854**	32,771
01 Wages	5,000	0	**0**	5,000
03 Goods and services	1,000	0	**0**	0
07 Benefits				
Graduate Research Assistant Beneftis Associate in Research	1,480	3,832	**3,985**	9,297
Total:	16,037	16,192	**16,839**	49,068

CONTINUING PROJECT REPORT
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
Project Duration:	2003-2004
Project Total:	Please refer to the original proposal for budget information.

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 infection may occur before mildew is observed.
- ✓ Mildew can be detected on fruit using micro techniques.
- ✓ Tree spacing and training system may affect mildew infection levels.
- ✓ Mildew infected fruit were no more sensitive to pitting than fruit not infected with mildew, under the conditions of study.

Methods:

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

Typar bags were used to cover fruit and exclude mildew spores from 15 April to 17 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 and severity upon harvest. Sensors monitored relative humidity and temperature both within and outside the bags.

2. Development of a detection method

A technique utilizing polymerase chain reaction (PCR) to amplify a segment of DNA unique to the sweet cherry PM fungus was developed to detect the presence of mildew on both cherry fruit and leaves.

3. 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, five spacings, and three training systems.
Cemetery Block: Five cultivars were evaluated.
Water Deficit: Three irrigation regimes were evaluated.

4. Effect of mildew on pitting

Fifty fruit with a varying degree of mildew (rated as 1 = 0%, 2 = 1-33%, 3 = 34-66%, 4 = 67-100% mildew) were selected and cooled to about 1° C. Twenty-five of the fruit were wounded using a pitting tool near the stem; the remaining twenty-five were wounded on the side. All fruit were stored for two weeks at about 3-4° C and then rated for severity of pitting (1 = none, 2 = slight, 3 =

moderate, 4 = severe damage). Four cultivars were included in the study, Bing, Lapins, Regina, and Sweetheart.

Results and Discussion:

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

The number and quality of fruit development was much lower when covered with the Typar bags. In some cases, entire treatments were lost. No consistent pattern emerged, and the results were considered inconclusive due to lack of data. The sensors indicated a consistently higher relative humidity within the bags than in the tree canopy; thus, the Typar material was concluded as being inappropriate. A more suitable bagging material is being sought for the 2004 growing season.

2. Development of a detection method

A PCR technique was successfully used to identify cherry PM in both foliar and fruit tissue. This technique is specific enough to delineate cherry PM from other PM fungi and will be vital for future studies.

3. Foliar mildew evaluations comparing the effect of different management regimes and cultivar on mildew infection. Figures 2, 3, and 4

Hazel Dell (Figure 2 & 3): Overall, PM incidence was low at this site. Rootstock was found not statistically important in mildew incidence and therefore concluded to have no impact on PM incidence at this site. Both spacing and training system seem to impact PM incidence. The Spanish Bush training system averaged greatest PM incidence, and Central Leader averaged the least. Interestingly, tree spacing of nine feet apart within a row averaged the greatest PM incidence; while twelve foot spacing averaged the least. Both training system and tree spacing impact environmental conditions necessary for PM development, such as airflow and relative humidity in the canopy. Future studies on the ideal conditions for cherry PM development should conducted.

Cemetery Block (Figure 4): 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.

Water Deficit: Disease pressure was very high in this plot. The three treatments, 100%, 50%, and 25% recommended irrigation, were found to be statistically the same in terms of PM incidence. Mildew incidence did not vary statistically between these three treatments; thus water deficit does not seem to affect PM incidence in this plot.

4. Effect of mildew on pitting. Figures 5, 6, 7, & 8

No difference in pitting severity was found among the four levels of PM infection in all cultivars tested, but pitting severity was related to the location of the wound. Wounds made on the side of fruit were statistically more severe than wounds made on the top of the fruit near the stem. However, conditions of this study were not consistent with typical commercial cherry packing operations. In this study fruit were stored at 3-4º C as opposed to 1º C in commercial operations. This slight change in temperatures may have greatly influenced pitting development. This study will be repeated next year with modifications in the storage temperature.

Figure 1. Average percent fruit infected in the bagging study for each cultivar throughout the growing season. Week 1 corresponds to the control treatment where fruit were not bagged. Subsequent weeks correspond to period of time when the fruit were exposed (bag removed) and vulnerable to PM infection. Ratings were done following harvest.

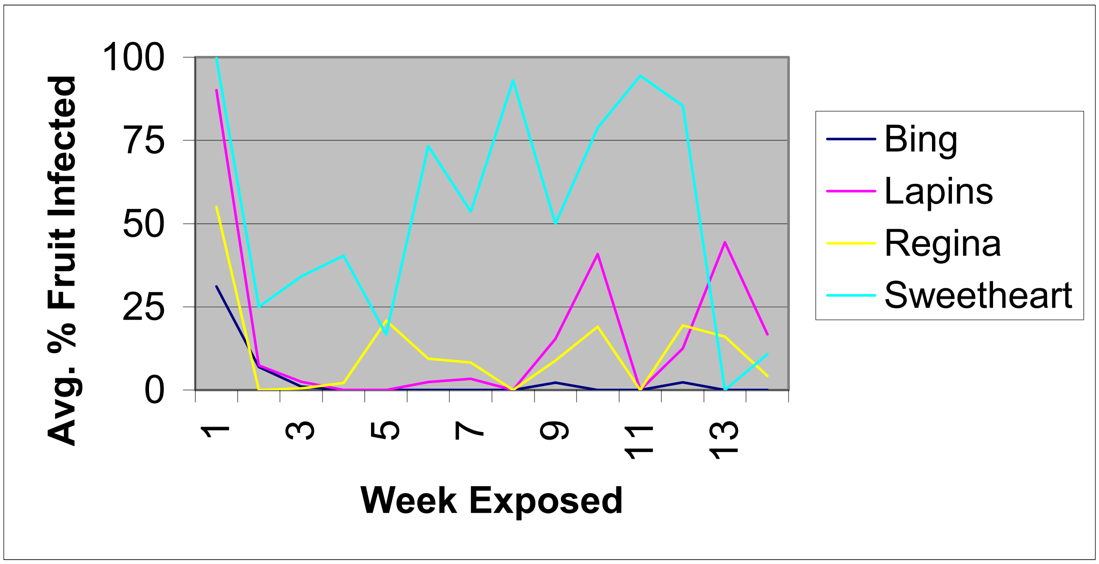


Figure 2. Average percent PM infected leaves observed at the Hazel Dell site for different training systems. SB = Spanish Bush, SL = Steep Leader, and CL = Central Leader.

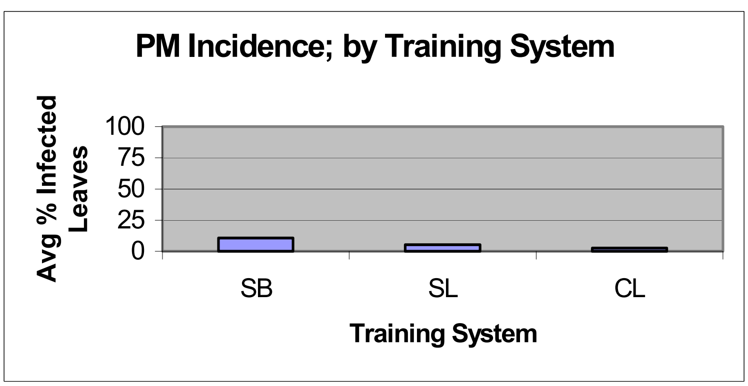


Figure 3. Average percent PM infected leaves observed at the Hazel Dell site for different tree spacings within a row.

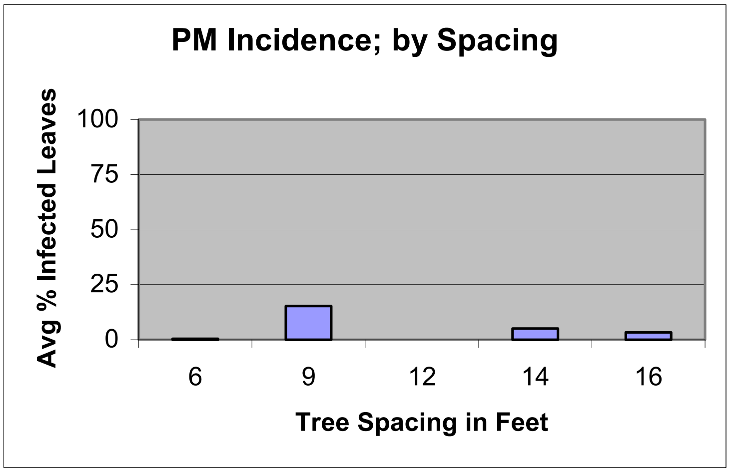
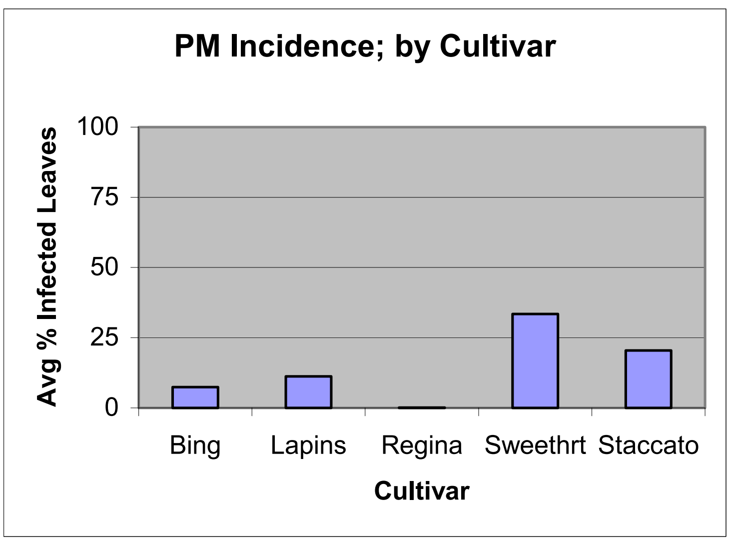
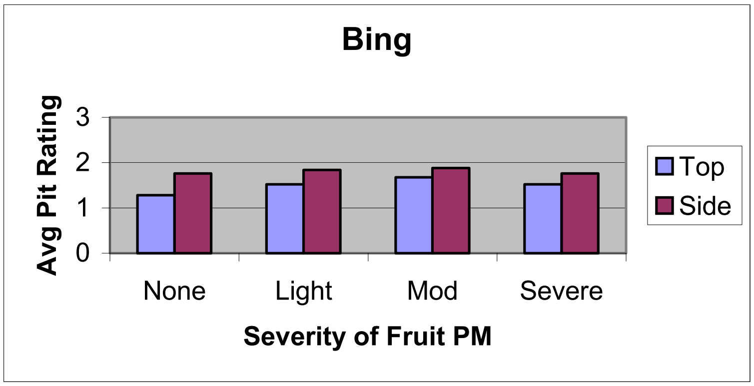
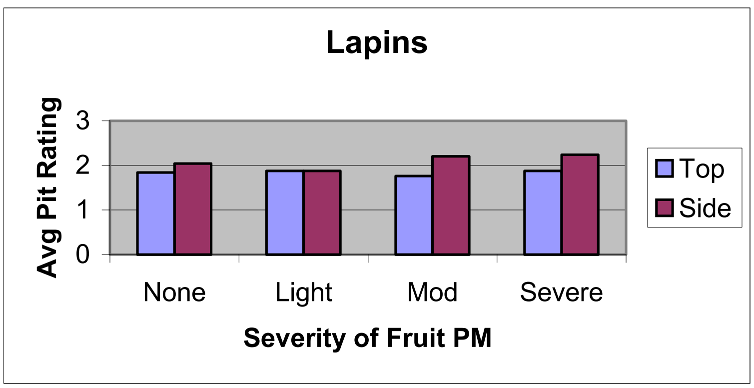


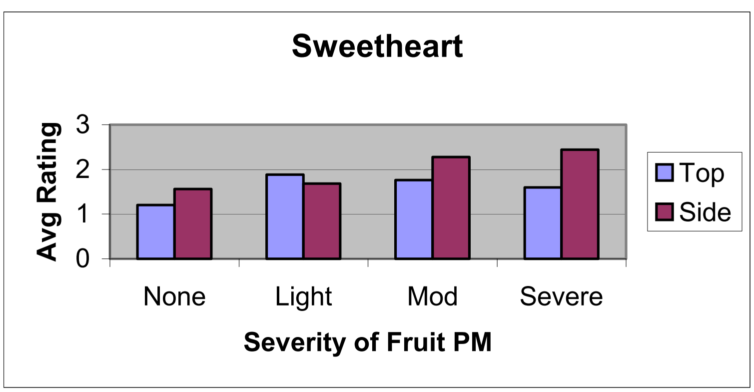
Figure 4. Average percent PM infected leaves observed at the Cemetery Block comparing five cultivars.

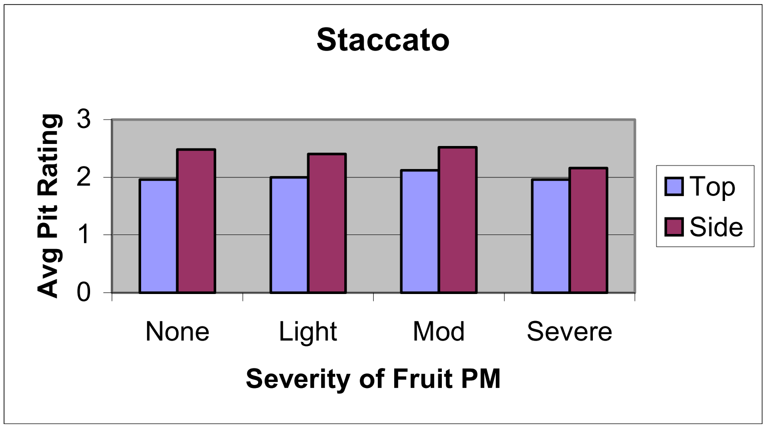


Figures 5 through 8. The average rating of pit development following a controlled wound of four cultivars with varying degree of PM infection. A pit rating of 0 = no damage, 1 = slight damage, 2 = moderate damage, and 3 = severe damage. Fruit were wounded either near the stem (Top) or on the Side.









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
Project Duration: 2003-2005
Project Total: $51,099
Current Year Request: $17,023

Year	2003	2004	2005
Total	16324	**17023**	17752

Current Year Breakdown

Item	2003	2004	2005
Salary & Wages	15000	**15675**	16380
OPE	524	**548**	572
Supplies	500	**500**	500
Travel	300	**300**	300
Total	16324	**17023**	17752

PROJECT REPORT

Title: Aureobasidium rot in sweet cherry, 2003

PI: P.G. Sanderson
Staff: M.S. Aldrich
Organization: Washington Tree Fruit Research Commission

No information exists on the ability of *Aureobasidium pullulans* to infect fruit postharvest. This study was conducted to determine the frequency of occurrence of *A. pullulans* in cherry packing water systems and if fruit could be infected after exposure to *A. pullulans* in those systems. *Aureobasidium pullulans* colonizes stylar tissue of sweet cherries during the growing season, and may remain latent until fruit senesces at which time it may spread to healthy tissue causing a lesion to develop (Dugan and Roberts, 1994). In studies on the effects of MAP liners on extension of shelf life of cherries in 1999 and 2000, *A. pullulans* was the predominant cause of decay in commercially packed fruit (45% and 50.3% of fruit decayed in 1999 and 2000, respectively) (Kupferman and Sanderson, 2001).

The water systems at a packinghouse were assessed for microbial contamination in 2002. A relatively high density of *A. pullulans* was present and few other fungi were found (unpublished data). This packinghouse had a shipment of fruit rejected due to decay. Although the predominant disease in that rejected lot of fruit is not known, our previous experience suggests that *A. pullulans* was the most likely cause.

Significant findings

- *Aureobasidium pullulans* was found in cherry water systems in all 7 packinghouses surveyed
- In each water system, *A. pullulans* was recovered about 45% of the time.
- Highest population densities were found in dump tanks.
- Population densities diminished in succeeding water systems.
- *Aureobasidium pullulans* was not recovered in water systems with total chlorine >50 ppm.
- Both wounded and unwounded fruit were susceptible to infections caused by *A. pullulans* in water systems at densities >100 CFU/ml.
- Stemless cherries were less susceptible to infection than stemmed cherries.

Materials and methods

Packinghouse survey

Water samples were collected from each independent water system at seven Washington State cherry packinghouses. Chlorine in the water was neutralized with sodium thiosulfate. Water temperature, pH and total chlorine were measured in each water system at the time of sampling. Water samples were cultured on potato dextrose agar (PDA) containing antibiotics (chloramphenicol and gentamycin sulfate) and fungal colonies enumerated to determine the amount of *Aureobasidium* spp. and other pathogenic fungi present in each water system.

Fruit inoculations

Treatments were applied to commercially harvested Bing cherry fruit obtained from three North Central Washington packinghouses. Fifty fruit from each of the packers were used for replicates. Fruit were surface disinfested by dipping them in 100-ppm chlorine for 5 min. Cherries were either wounded (0.5mm diam x 2mm deep) a single time on the equatorial axis or unwounded. Stems were removed from an additional subset of fruit just before inoculation.

Three isolates of *A. pullulans* that had been previously recovered from cherry fruit were grown for 7 days on PDA at room temperature for inoculum. Fruit were inoculated by dipping them into aqueous suspensions of *A. pullulans* (0, 100, 1000, and 10,000 cfu/ml). Following inoculation the cherries were placed into aluminum pans lined with a damp paper towel, covered with plastic lids and stored for 2 weeks at 40°F before being assessed for lesion development. Isolations were made from lesions to assure that *A. pullulans* was the causal agent. The trial was repeated once. Results were similar for each experiment so data were combined for statistical analyses.

Results and discussion

Packinghouse survey

Aureobasidium pullulans was found in about equal occurrence (about 45%) in each of the waters systems sampled (Table 1). The only type of water system in which *A. pullulans* was not recovered was a single sample taken from a flume into which Captec had been added. However, dump tanks were the most heavily contaminated followed by hydrocoolers (Table 2). Each succeeding water system following the dump tank tended to be less contaminated. *Penicillium* spp., especially *P. expansum* was the only other fungus recovered frequently from water systems. *P. expansum* was the second most frequent cause of decay in previous experiments with MAP in 2000 (35% of decayed fruit).

Aureobasidium pullulans population densities varied widely among packinghouses and among sampling times within a packinghouse (Table 2). This variation was most closely correlated with the use of chlorine in the water systems, which ranged from no chlorine to 80-100 ppm in each system (Table 3). Temperature and pH of water systems also varied markedly among packinghouses. Highest populations of both *A. pullulans* and *Penicillum* spp. were recovered from water systems with no chlorine. Neither fungus was recovered from water that contained >60 ppm total chlorine (fig. 1).

Fruit inoculations

Fruit inoculated with *A. pullulans* in water developed Aureobasidium rot lesions. Fruit treatment had a differential effect on disease development. Disease incidence in fruit with stems increased with inoculum density >100 CFU/ml in both wounded and unwounded fruit (fig. 2). The incidence of decay in fruit inoculated with 0 and 100 CFU/ml was not significantly different. About 90% of lesions developed in the wounds of wounded fruit (Table 4). In unwounded fruit, most lesions developed at the stylar end, but about 29% of lesions developed on the sides.

In fruit with stems removed, most lesions developed at the point of stem attachment (Table 4). However, in stemless fruit, the incidence of decay was very low and there was no significant difference in the incidence of decay with inoculum dose (fig. 2). It is possible that removal of the stem caused a resistance response in the fruit, but the reason for this phenomenon is unclear.

Conclusions

This is the first report of sweet cherry spoilage caused by postharvest inoculation by *A. pullulans*. Inoculum loads >100CFU/ml in packinghouse water systems may cause significant decay losses. Chlorine at >60 ppm was effective at eliminating *A. pullulans* inoculum from water systems.

Literature cited

Dugan, F. M. and Roberts, R. G. 1994. Etiology of preharvest colonization on Bing cherry fruit by fungi. Phytopathology 84:1031-1036.

Kupferman, E, and Sanderson, P. G. 2001. Temperature management and modified atmosphere packing to preserve sweet cherry quality. Postharvest Information Network, July 2001. 9 pp.

Table 1. Frequency of occurrence of *Aureobasidium pullulans* and *Penicillium* spp. found in cherry packing water systems.

Water system	*Aureobasidium pullulans*	*Penicillium* spp.
Hydrocooler (n=12)	41.7 %	25.0 %
Dump tank (n=18)	44.4 %	38.9 %
Cluster cutter (n=15)	46.7 %	46.7 %
Flume (n=12)	41.7 %	8.3 %
Fungicide TRT (n=1)*	0.0 %	0.0 %

* Captec in flume water at full label rate

Table 2. Density of *Aureobasidium pullulans* and *Penicillium* spp. in Washington State cherry packinghouse water systems.

	Aureobasidium pullulans		*Penicillium* spp.	
Water system	cfu/ml	(± s.d.)	cfu/ml	(± s.d)
Hydrocooler (n=12)	222.2	655.9	5.0	12.0
Dump tank (n=18)	1284.8	3810.4	67.8	234.1
Cluster cutter (n=15)	106.4	202.4	7.3	9.6
Packing water (n=12)	11.1	15.3	0.6	1.9
Fungicide TRT (n=1)*	0.0	0.0	0.0	0.0

* Captec in flume water at full label rate

Table 3. Physical characteristics of Washington State cherry packinghouse water systems.

Water system	Total chlorine (ppm)	pH	temp °C
Hydrocooler (n=12)	33.3 (0 – 80)*	5.8 (2.8 – 7.1)	4.9 (0.2 – 16.0)
Dump tank (n=18)	38.4 (0 – 102)	7.1 (6.2 – 7.6)	8.9 (2.2 – 15.0)
Cluster cutter (n=15)	32.6 (0 – 100)	7.2 (6.8 – 7.5)	7.9 (1.8 – 16.8)
Packing water (n=12)	34.2 (0 – 90)	6.4 (4.0 – 7.5)	4.0 (0 – 17.9)
Fungicide TRT** (n=1)	0.0	7.2	3.0

* Mean and range
** Captec in flume water at full label rate

Table 4. Locations of *Aureobasidium* rot lesions on cherry fruit surfaces.

Fruit treatment	Cheek	Stem end	Stylar end	Wound
Stemless/unwounded	11.1 %	82.2 %	6.7 %	--
Stem/unwounded	28.6 %	8.4 %	63.0 %	--
Stem/wounded	5.4 %	1.5 %	3.5 %	89.6 %

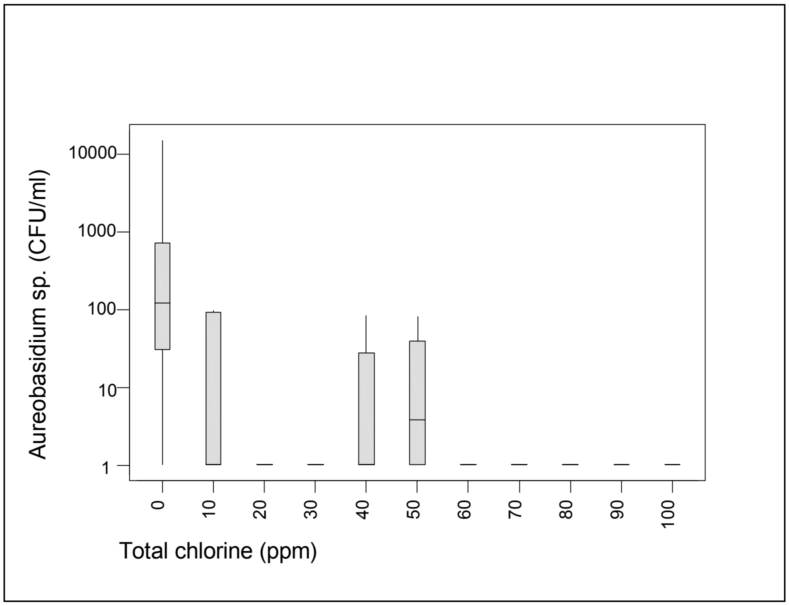


Figure 1. Effect of chlorination on inoculum loads of *Aureobasidium pullulans* and *Penicillium* spp. in cherry packinghouse water systems.

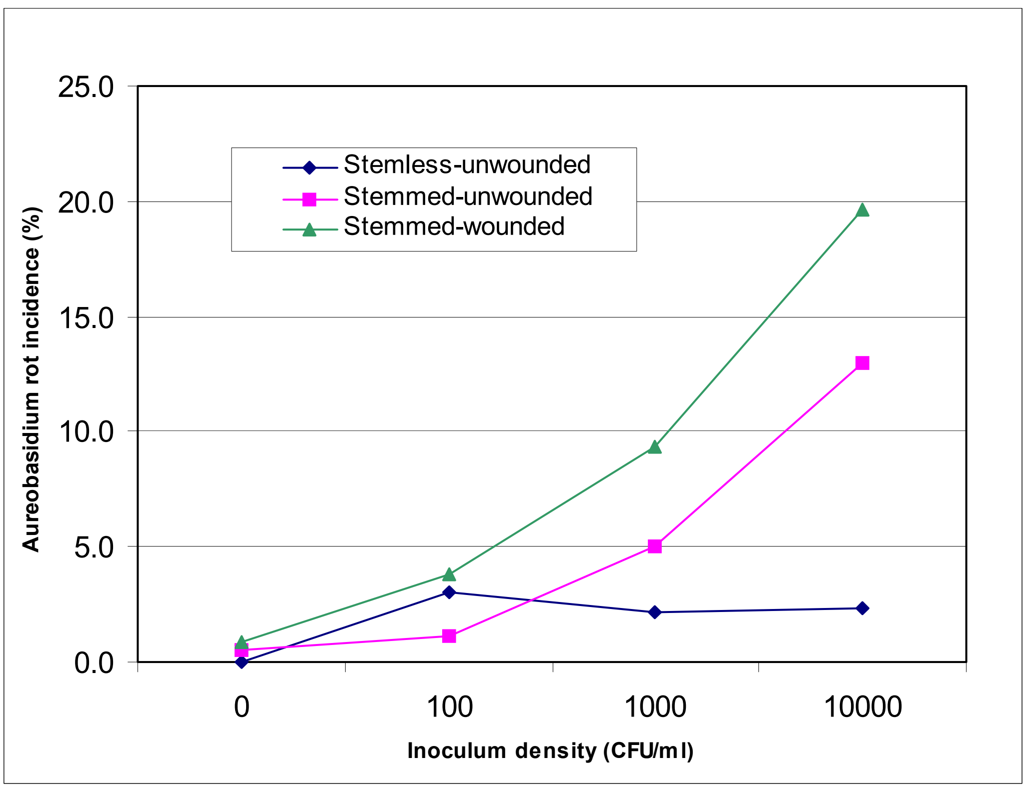


Figure 2. Incidence of decay in sweet cherry resulting from inoculation with increasing doses of *Aureobasidium pullulans*

FINAL REPORT
WTFRC Project # CH-03-300 **WSU Project # 13C-3643-3387**

Project title: Bark beetles (shot hole borer) in pome and stone fruit

PI: Jay F. Brunner
Organization: WSU Tree Fruit Research and Extension Center
Address, phone, e-mail: 1100 N. Western Avenue, Wenatchee, WA 98801
(509) 663-8181 ext. 238; jfb@wsu.edu

Co-PI and affiliation: Tim Smith, Cooperative Extension, Chelan-Douglas County

Objectives:
1. Identify the bark beetle species attacking pome and stone fruit throughout the state.
2. Compare the seasonal life history of bark beetles with current information.
3. Develop methods of rearing bark beetles in the laboratory.
4. Examine methods of monitoring bark beetles.
5. Assess efficacy of new insecticides against bark beetles.

Significant findings:
- The dominant bark beetle found throughout the state was the shothole borer (SHB), *Scolytus rugulosus* Müller. An ambrosia beetle, the European shothole borer (AB) (*Xyleborus dispar* Fabricius) and/or the lesser shothole borer (*Xyleborus saxeseni* Ratzeburg), was present in high numbers at only one location, a cherry orchard that had been abandoned for several years. At many locations more than one species of scolytids was detected.
- The life histories as determined in 2003 indicated one prominent flight of SHB that peaked in June and possibly two flights of ambrosia beetle. These data were inconsistent with some of the reported literature. Beetles appear to live a long time or emerge from various hosts over a long time.
- Woodpiles of apple and cherry are the main sources of high beetle densities that cause injury to commercial orchards. Cherry trees are most heavily attacked, and severe injury can result to trees adjacent to woodpiles. Injury accumulation continued well after peak flight, with damage occurring through September.
- Traps can be useful in identifying peak activity periods, but it is not clear whether they would be useful in setting thresholds for treatments. Available attractants enhanced trap captures, but it seems likely that with some effort better attractants could be found.
- Laboratory rearing of multiple generations was not successful. Adult SHB survived a short time on an artificial diet, but no reproduction occurred. Adults were reared and collected in large numbers from infested wood in the laboratory. Rearing of beetles on cherry or apple wood should present no problems, but this takes a lot of space to rear numbers needed to conduct additional studies of development or pesticide screening.
- A preliminary protocol was developed for screening insecticides against SHB adults. The method seemed to work well when tested against older adults but needs to validated against reproductively active adults.

Methods:
Species identification:
Bark beetles were reared from infested stone and pome fruit. Infested fruitwood was collected from many SHB infested areas throughout central Washington. Care was taken to record the plant host and describe the galleries, as these can be important characteristics in identifying scolytids. Adult SHB

and associated natural enemies were collected from the infested wood by laboratory rearing in darkened cardboard cages having a vial to catch emerged beetles and parasitoids that fly toward the light. Adult beetles were preserved and identified using established keys. Samples were collected from spring through fall and from all locations of the state. Verification of the identifications will be done by submitting specimens to experts. In addition to beetles, the natural enemies collected from the beetles or emerging from galleries will be identified.

Life history/monitoring methods:
At selected locations, the seasonal life history (adult activity) was examined. Beetle emergence from wood was monitored by collecting infested wood and rearing SHB to the adult stage in a cage. Cages were examined at regular intervals and beetle adults collected. The beginning of new beetle egg-laying galleries was recorded and tagged. Any second-generation emergence was followed in these cages. The timing and longevity of adult beetle activity was compared to historical information on bark beetles.

There are established monitoring methods for bark beetles. These are generally associated with monitoring in forest systems but could have some potential for use in orchards. We monitored infested sites with yellow sticky traps (unbaited Pherocon AM Trap, Trécé, Inc.) along with commercially available interception traps (Pane Intercept Trap, IPM Technologies; 8-funnel Lindgren Funnel Trap, Phero Tech, Inc.). Several side-by-side comparisons were made with the available trapping systems to determine the most effective way of monitoring SHB infestations. All traps were placed when beetles began to emerge in the spring (April) and were checked at regular intervals throughout the season. The sites used for species identification described above were also used for monitoring studies.

Distribution of feeding damage from a source adjacent to a cherry orchard was monitored at one orchard with a particularly severe infestation. The situation was a burn pile started in the spring of 2003 next to a firewood pile that was added to annually. A five-year-old Rainier cherry orchard was planted adjacent to this source. The cherry orchard was narrow, only five rows deep. Ten trees from each row were sampled in September, and the percentage of shoots with visible signs of SHB adult feeding was recorded.

Laboratory rearing:
In order to make progress on the understanding of bark beetle control and biology it will be very helpful to establish a laboratory colony. This would allow for year-round research activity and the possibility of developing an insecticide screening method for beetles. Various sources of wood types and conditions will be used to initiate colonies. SHB adults were collected from infested wood as described in the *Species Identification* section. The majority of adults were collected following peak flight noted in June. Adults were exposed to both drying wood in a cage and cups of artificial scolytid diet (southern pine beetle diet # F9761B, Bio-Serv, Inc.). The rearing arenas were examined regularly for SHB feeding activity and any sign of reproduction.

Insecticide screening:
Adult SHB, presumably from the early summer flight, were collected from infested wood that was returned to the laboratory in August and September. The insecticide screening methodology was designed to analyze the efficacy of field-aged residues. Mature Delicious apple trees at WSU-TFREC were treated with recommended rates of various insecticides commonly used in apple and cherry production. An effort was made to screen candidate insecticides from as many classes of insecticides as possible. Treated apple branches were collected at 1, 7, 14 and 21 days after treatment (DAT) and returned to the laboratory. Approximately 6-inch sections of 1- to 2-year-old wood were added to 32 oz deli cups (Anchor Packaging, Inc.). Untreated apple branches were used as a control at each

evaluation date. SHB adults were added to the deli cups, and survival was recorded at one day and three days. All of the chemicals screened were neuroactive insecticides with relatively quick modes of action. Therefore, consistent data were collected at the three-day evaluation, and it was not necessary to run the test for a longer time period. Five cups with five SHB adults were set up for each insecticide at each evaluation period (25 SHB adults/treatment).

Results and discussion:
Species identification:
Infested fruitwood was collected from 10 sites ranging from the Wenatchee valley to Oroville. Several hundred adult scolytids were collected and preserved for identification. At the time of this report, verification of our initial identifications has not been completed.

The dominant bark beetle found throughout the state was the shothole borer (SHB), *Scolytus rugulosus* Müller. An ambrosia beetle, the European shothole borer (AB) (*Xyleborus dispar* Fabricius) and/or the lesser shothole borer (*Xyleborus saxeseni* Ratzeburg), was present in high numbers at only one location, a cherry orchard that had been abandoned for several years. At many locations more than one species of scolytids was detected. Further, many other wood-decomposing beetles were reared from infested wood. In fact, the majority of beetles collected were associated with dry, dead wood. Buprestids, bostricids and powderpost beetles (Lyctidae) were the primary families of beetles associated with dry, dead wood. The SHB and AB appear to be the primary attackers of live and weakened trees. Initial observations at the time of collection show that there was fairly significant parasitism (up to 50%) of SHB larvae by hymenopteran parasitoids. These have been submitted for identification.

Life history/monitoring methods:
It was believed that AB overwinter as adults while SHB overwinter as mature larvae or pupae. Thus, it would be expected that AB adult flight would be detected first as temperatures warmed and the adults became active. This appeared to be the case in 2003, as AB adults were detected in the traps prior to SHB (Figure 1). AB activity began in early May and peaked in mid-May. A possible second flight was observed during July. The life histories as determined in 2003 indicated one prominent flight of SHB that peaked in June. Adult activity was noted with both species throughout the entire summer. These data were inconsistent with some of the reported literature for both species. It should be noted that our traps were not placed until the middle of April, and it is known that some scolytids, and possibly SHB, could be active during March. It is not known if this is the case in Washington, but initiating trapping earlier in 2004 should resolve that question. Beetles appear to live a long time or emerge from various hosts over a long time. The exact biology and life history of these insects is difficult to determine with one year's research. It is possible that a portion of the summer SHB larval population emerged during the late summer while the majority of larvae ceased development, remaining in a diapause-type condition. These individuals will likely overwinter and emerge next spring or early summer.

Woodpiles of apple and cherry are the main sources of high beetle densities that cause injury to commercial orchards. Cherry trees are most heavily attacked, and severe injury can occur to trees closest to woodpiles (Figure 2). Injury appeared to be closely associated with the population source and extended only a short distance into an orchard. Younger trees were more susceptible to severe injury, as high numbers of attacks to a young tree would be more damaging. Injury accumulations from SHB, as noted by adult feeding at the base of buds, began during the peak flight in June and continued through September.

Traps were useful in identifying peak beetle activity periods, but it was not clear whether they would be useful in setting thresholds for treatments (Figure 3). There did not appear to be any significant difference in commercially available trap types. Either the Pane Intercept trap (IPM Tech, Inc.) or the Lindgren Funnel Trap (Phero Tech, Inc.) was a suitable trapping system to monitor both SHB and AB adult activity. Available ethanol attractants enhanced trap captures, but the lure system seemed to be a limiting factor in the monitoring system (Figure 4). It is likely that better attractants could be found.

Laboratory rearing:
Laboratory rearing of multiple generations was not successful. Adult SHB survived a short time on an artificial diet, but no reproduction occurred. Adults were collected and reared in large numbers from larval infested wood in the laboratory. Rearing of beetles on cherry or apple wood should present no problems, but it would take a lot of space to rear numbers needed to conduct additional studies of development or pesticide screening. An efficient means of rearing insects in the laboratory or under controlled environments would make precise observations of phenology possible.

Insecticide screening:
A preliminary protocol was developed for screening insecticides against SHB adults. The average survival of SHB adults introduced to rearing arenas with untreated sticks was above 80% through the three days of observation. This level of survival indicates that any significant mortality noted in the rearing arenas could be attributed to pesticide exposure and not a problem with the protocol. The method seemed to work well when tested against late summer adults but needs to be validated against reproductively active adults collected during peak flight.

Preliminary results indicate that the most active insecticide against SHB adults was the pyrethroid, esfenvalerate (Asana XL) (Table 1). It is likely that other products from this same class of insecticides would be active as well. There was some evidence that the organophosphate insecticides tested may not give the control that a grower would like. Survivors were detected at each bioassay interval with azinphos-methyl (Guthion). Malathion was very active early as one-day residues, but older residues showed reduced mortality. It appeared that the chloronicotinyls [acetamiprid (Assail) and thiamethoxam (Actara)], the carbamates [formetanate hydrochloride (Carzol) and carbaryl (Sevin)], endosulfan (Thiodan), indoxacarb (Avaunt), and spinosad (Success) were not highly effective as controls for SHB. However, significant mortality was noted with many of these products for up to seven days, and their repeated use during the growing season may be responsible for maintaining SHB and AB populations below damaging levels in most commercial orchards. Cherry orchards may become susceptible to injury in the postharvest period when insecticide programs for cherry fruit fly and leafroller have ceased.

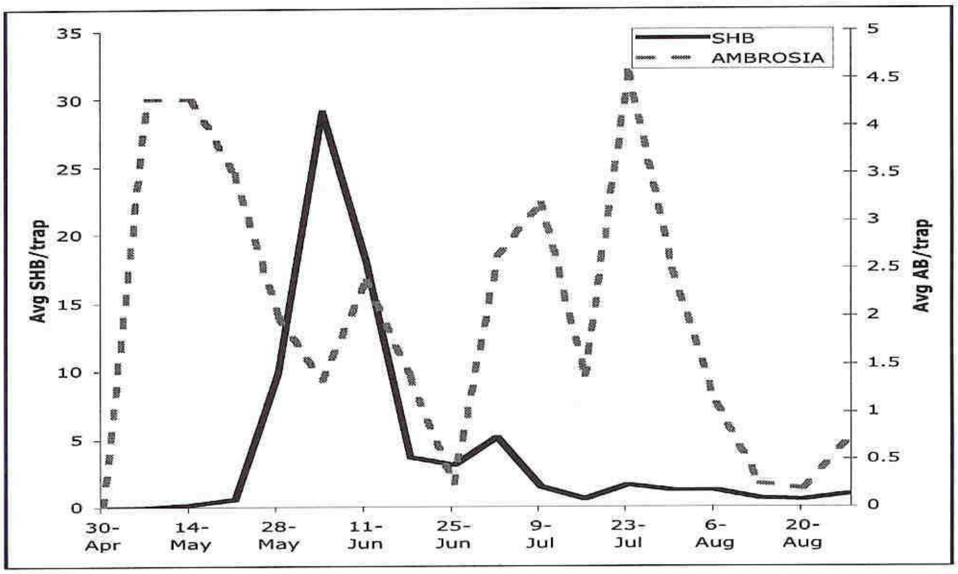


Figure 1: Average adult scolytid captures in ethanol-baited traps, 2003.

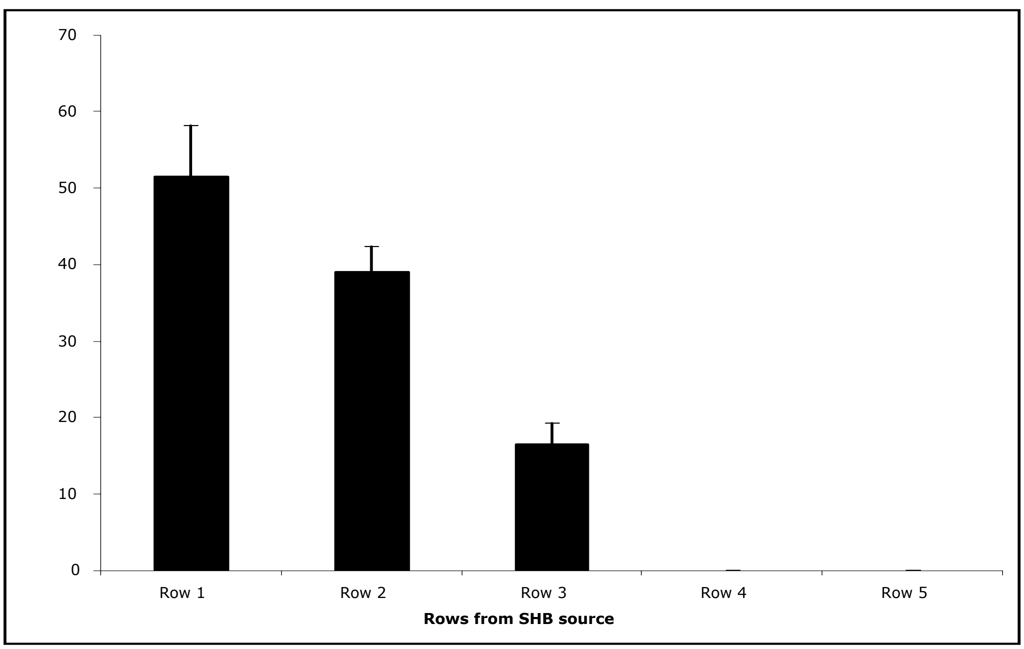


Figure 2: Distribution of adult SHB feeding damage by distance from a source adjacent to a cherry orchard, 2003.

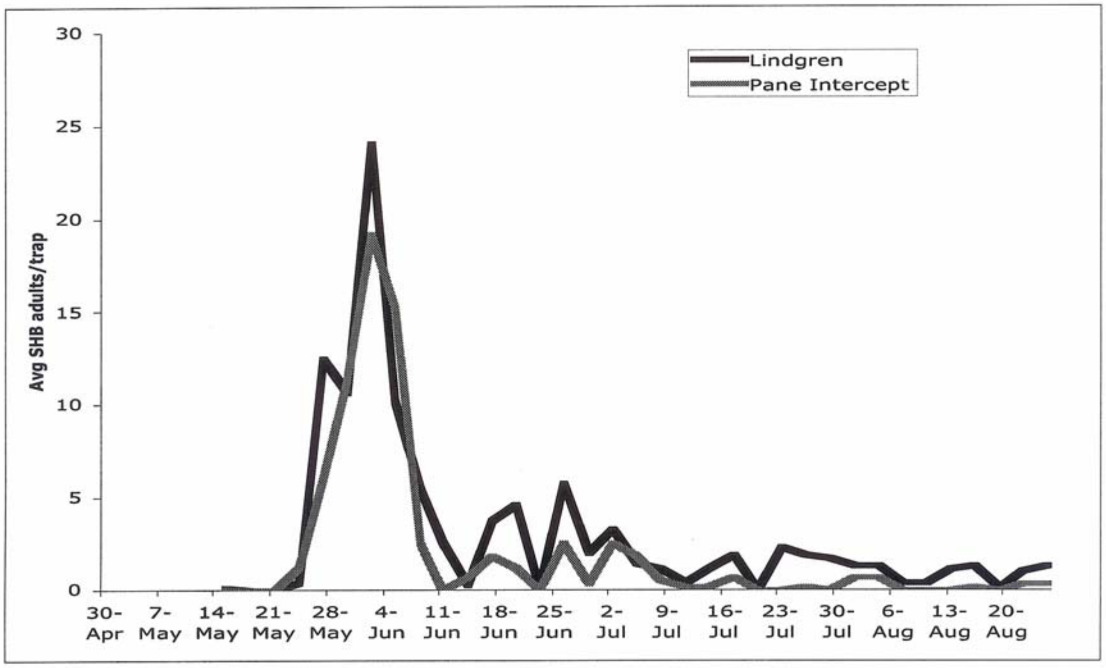


Figure 3: Adult SHB trap captures in commercially available scolytid traps, 2003.

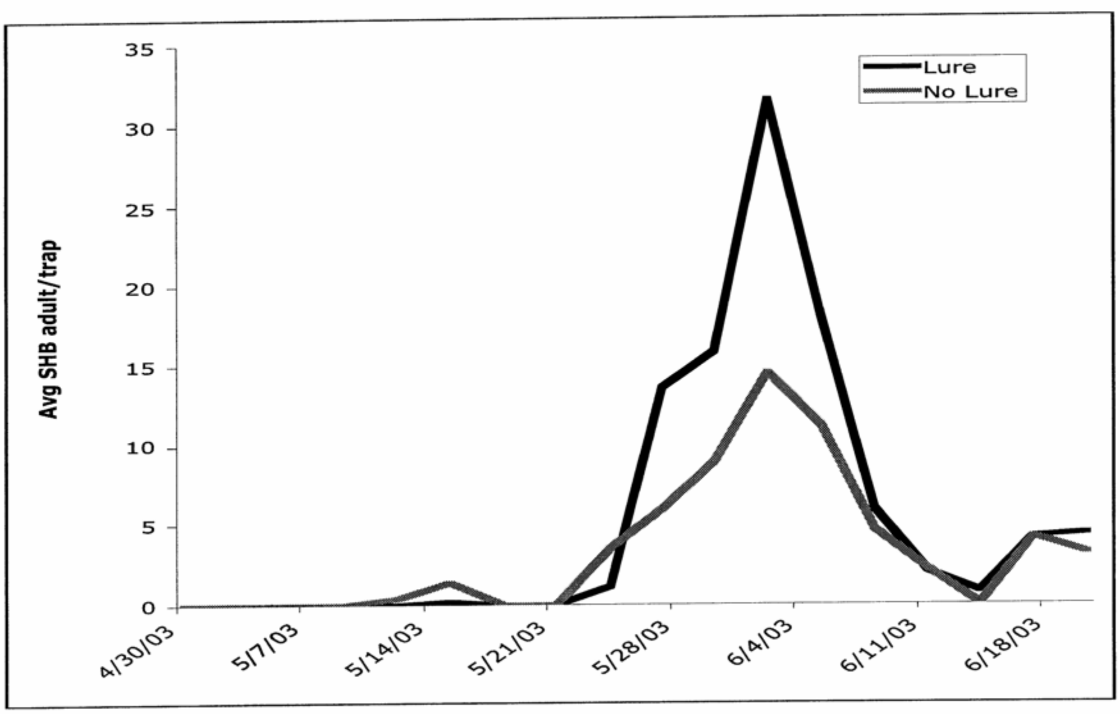


Figure 4: Relative effect of an ethanol lure on adult SHB trap captures, 2003.

Table 1: Relative effect of field-aged insecticide residues against SHB adults, September 2003.

Insecticide	Rate (form/a)	Avg corr % mort. (3-day evaluation) 1 DAT[1]	7 DAT	14 DAT	21 DAT
Guthion 50WP	2 lbs	87.5	75.0	25.0	75.0
Malathion 50%	1.5 qt	100.0			
Assail 70WP	3.4 oz	50.0	50.0	25.0	25.0
Actara 25WDG	4.5 oz	100.0			
Asana XL	8 fl oz	100.0	100.0	100.0	100.0
Thiodan 3E	3 qts	87.5	25.0	25.0	25.0
Carzol 92SP	1.25 lb	62.5			
Sevin XLR	1 qt	25.0			
Success 2SC	6 fl oz	87.2	62.5	75.0	0.0
Avaunt 30WDG	6 oz	75.0	12.5	0	50.0

Summary of total project costs:
Bark beetles (shot hole borer) in pome and stone fruit
Jay F. Brunner
Project duration: one year (2003)
Total project costs: $20,040

CONTINUEING 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 L. E. Long, OSU Extension, The Dalles Mike Omeg, Wy'East RC & D, The Dalles

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.

OBJECTIVES:
1. To improve a predictive phenology model for cherry fruit fly in the Mid-Columbia area from historical observations on first emergence, rainfall and temperature data.

2. To validate cherry fruit fly model predictions using trap catch and weather data from The Dalles and Hood River collected during the last five years.

3. To extend cherry fruit fly model predictions to all cherry-growing districts in the Mid-Columbia area and with GIS technology compute maps for emergence and egg laying which can be displayed at the users request.

4. To make the cherry fruit fly model predictions and phenology maps available via the Internet at The Dalles IFP 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 71 degree-days (DD Celsius) 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. 2). However, some essential biological information is still needed for inclusion in this model to make it more biologically meaningful and reliable.

4. From the simulations, preliminary heat requirements for first emergence were calculated as 550 DD for The Dalles and 480 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. Data on first emergence collected since 1950 at The Dalles and Hood River were analyzed together with degree-days to calculate the heat requirements for first emergence dates. We also evaluated the effect of precipitation on first emergence, specifically the amount of precipitation during the months prior to emergence. The NOAA weather stations at The Dalles and Hood River provided temperature and precipitation data for the analysis.

2. The time-varying distributed delay concept (Manetsch and Park 1974) was used for organizing the CFF phenology model. The model was written in the Turbo BASIC programming language and can be accessed through a user-friendly menu driven interface. Model parameters can be changed from a separate text file. Therefore, the model can be used for insects other than CFF.

3. The model uses parameters obtained mainly from the literature. The NOAA station records from The Dalles and Hood River were used for the simulations. To validate the model, outputs were compared with actual trap catch data collected in the Hood River area during the last few years.

RESULTS AND DISCUSSION:

From the analysis of historical records, there was 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 71 DD 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 at a given location.

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. The menu structure and function of the CFF model is shown in Table 2. 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. 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.

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. 2). 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.

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: 2003
PROJECT TOTAL (two years): $17,500
CURRENT YEAR REQUEST: $7,500

Item	Year (2003)	Year(2004)
Total	$7,500	$10,000

Current year breakdown:

Item	Year (2003)	**Year(2004)**
Salaries – for research assistant	$6,500	**$9,000**
Service and supplies: traps, lures, etc.	$500	**$500**
Travel to experimental plots	$500	**$500**
Total	$7,500	**$10,000**

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

	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	585.3	514.4	71.0
Minimum	465.0	391.7	73.3
Maximum	697.1	699.8	-2.7
CV (%)*	11%	13%	-

*Coefficient of variation %

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.

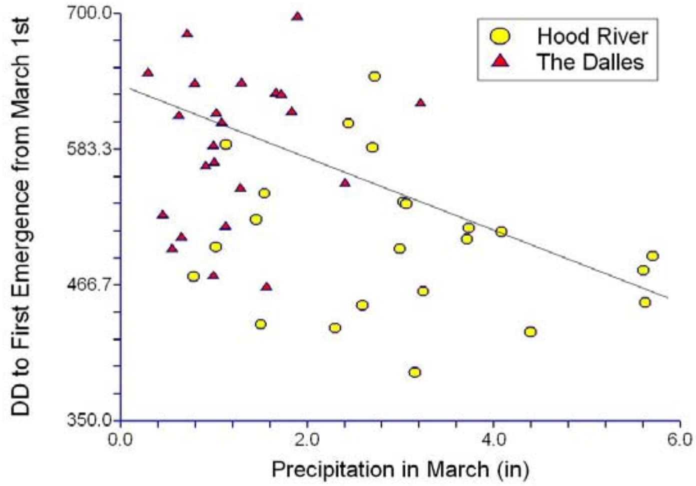


Fig. 1. Relationship between the amount of precipitation in March (X) and the degree-days (DD in °C) accumulated from March 1 to first emergence (Y). Regression equation: Y= -21.3X + 589.3 (r=-0.4025**)

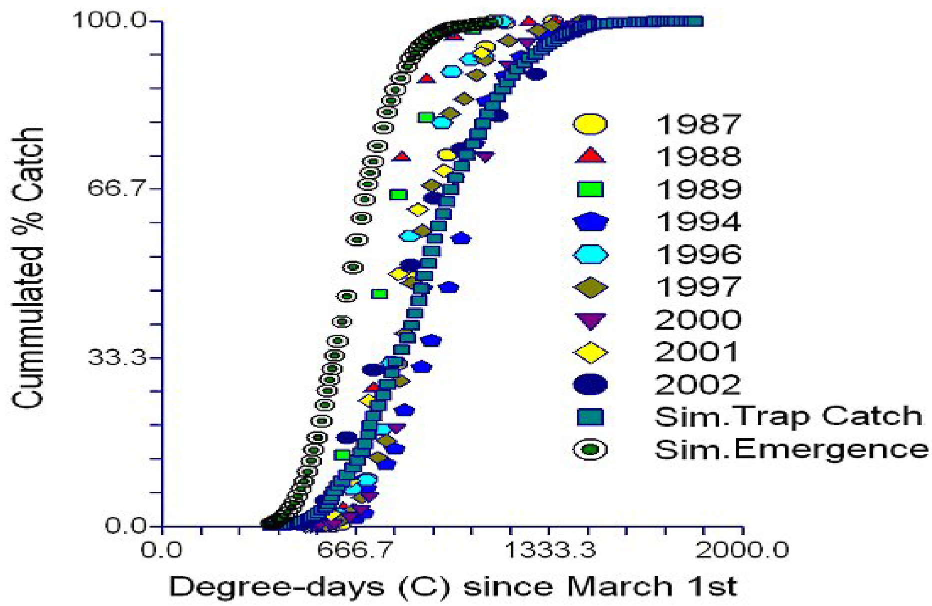


Fig. 2. Relationship between cumulative percentage of trap catch during various years in Hood River and the simulated trap catch and emergence curves from the CFF model

FINAL REPORT
WTFRC Project # CH-01-12

Project title: Factors Affecting Mating By Cherry Fruit Flies
PI: Wee Yee
Organization: USDA-ARS, Wapato, WA

Objectives:
2001
- Document and describe mating behaviors of the western cherry fruit fly in the laboratory.
- Determine effects of age on mating success and fecundity.
- Document mating behaviors of flies in the field.

2002
- Demonstrate the presence of a mating pheromone in the fly using laboratory wind tunnel and field bioassays.
- Compare the ability of laboratory- and field-collected males to attract females.
- Characterize the chemicals responsible for attraction of females to males.

2003
- Continue to establish presence of pheromones or odors involved in mating behavior.
- Determine visual factors involved in successful mating by flies.
- Determine effect of nutrition on mating success.
- Effects of age on mating and egg hatch success in the laboratory and field.

Significant findings:
2001
- Flies displayed no true courtship behavior; mating was initiated by males that leaped onto females when they were within 1-2 cm.
- Flies that were 3-9 days old mated less frequently than 17-43 d old flies; females exposed to males laid an average of 250 eggs, but mating did not increase egg production.
- Mating was initiated while males were on fruit, and was often completed on leaves; mating occurred frequently whenever temperatures were $\geq$ 80 ºF.

2002
- Extensive laboratory and field bioassays using male flies as a source of odor suggested the females do not respond to chemicals released by males (but further work is needed).
- Neither laboratory nor field-collected males (which may be exposed to different nutrients in the field) attracted females in the absence of visual cues in the laboratory or field.
- Flies mated infrequently during the first 14-19 d after emergence in the field.
- The numbers of eggs in unmated flies were lower than in mated flies, suggesting older flies with higher egg loads are more likely to mate.

2003
- Sex odors did not seem involved in mating success.
- Fruit presence was a visual factor essential for high levels of mating.
- Orange wax cherries attracted more male flies (presumably for mating) than real dark purple fruit, probably because of high substrate (wax) firmness and color.
- Males in the field seemed to prefer orange over green fruit for mating.
- Presence of (dead) males on fruit had no effect on female mating, suggesting the sight of flies on fruit does not stimulate female responses to land on fruit.
- Nutrition in the form of protein did not increase mating, suggesting mating success can be achieved without high protein intake.
- Flies greater than 9 days old showed greatest mating propensity

Methods (2003):

1. Further laboratory studies to determine the presence or absence of a mating pheromone were conducted. Larger tunnel designs and changes in temperatures, light intensity, and wind speed inside tunnels were tested to improve conditions that promote greater or more natural behavior.
2. To provide evidence for visual attraction by females to males, tests were conducted with 20 virgin female flies and 20 males inside screen cages. Sixty cherries were hung from the ceiling of the cages. Fruit were unbaited, baited with dead flies (pinned or glued to fruit), or with live males (that will naturally cling to the fruit). Two-minute observations were made every hour over 8 hours to determine whether females preferential visit fruit with live males. A second test was conducted with artificial red and orange fruit to determine the interaction between color and male presence on mating.
3. Male and female flies were fed diets of sucrose only, sucrose-yeast, and cherry juice only. They were paired in all combinations and exposed to wax domes for egg laying and observed for mating. Eggs were collected, placed on moist filter papers, and hatch rate determined. Egg hatch was used as an indication of successful insemination.
4. Final work was conducted on age-related mating effects in the laboratory and field by pairing males and females of known ages in the lab and by pairing flies collected over the season in the field inside cages.

Results and Discussion:

<u>2001-2003 – Mating Behaviors and Age</u>

Extensive analyses of video recordings indicated that mating behaviors did not involve true courtship. The mating is initiated by males, which wait until females are 1-2 cm away before leaping on them. It appears mate finding is based largely on vision. No evidence of wing fanning or abdominal movement that could be interpreted as dispersing of pheromone was seen in many hours of videotape recordings. A female often resisted the attempts of a male to couple. Once coupled, though, mating lasted up to 73 min (Table 1). The mating pair stayed motionless or walked slowly inside cages. The end of mating occurred when one or the other partner kicked, causing disengagement. No differences were seen in the mating behaviors of 3-9 day old or 17-43 day old flies, although young flies mated less frequently than older flies (Table 1). Mating in the laboratory occurred throughout the day, but mostly during the second half (Fig. 1).

In the field, mating occurred frequently throughout the day in the trees and inside cartons (Fig. 2), whenever temperatures were $\geq$ 80 ºF. Mating in the field was initiated on fruit only, but was often completed on leaves. Males waited on fruit for 2-13 minutes for females to arrive before leaving for other fruit. Males watch as other flies arrive on the fruit or fly by the fruit. In many cases, males did not distinguish between the sexes and attempted to mate with other males. Males often defended the fruit against other males with pawing actions of the forelegs. Mating in the field lasted 18-50 minutes. This long period of coupling may represent a period of increased vulnerability for the flies. Flies were easier to collect when they were coupled than when they were single. In addition, low-dosages of toxic chemicals can perhaps be mechanically transmitted from fly to fly during this process. Such chemicals warrant examination in the future.

Final laboratory work on the effects of age on mating indicated that the average day for first mating is about 10 days (Fig. 3). Age has an effect on mating propensity, but only up to about this age. There was no increase in mating as flies aged.

The laboratory suggested age-related patterns should also be seen in the field. Season-long mating incidence was determined from emergence until flies disappeared in 2002. Mating by flies was determined by observing trees and by pairing males and females that were caught in the field inside cages in Zillah and Roslyn (Fig. 4), WA. In Zillah, mating propensity as determined by observations in trees and inside cups was < 20% for the first 14 days after first fly detection, when fruit were small, hard, and green. At Roslyn, mating tendencies were <25% for the first 19 days after flies were seen. These results suggest that during the early part of the season, flies do not mate frequently and thus have a lower chance of bearing fertile eggs than later in the season. If flies are controlled before mating incidence increases, this may reduce the numbers of fertile eggs laid into fruit.

When placed inside pint-size cups in the field, mating usually occurred within 10 min. As supported by earlier laboratory and in-tree observations, no wing fanning or movement of the abdomen by the male, which would suggest the release of a pheromone, was seen. Females also were not agitated or "excited", which would have indicated they were stimulated by an odor. However, males clearly responded to the sight of females inside cups. Upon seeing a female, a male made jumps to mount her. A pair often struggled momentarily on the bottom of the cage before coupling was complete. In many cases the females resisted the attempts made by the male. However, once coupled, mating was prolonged. Observations were consistently with previous ones.

In Zillah, females that mated had higher numbers of eggs than females that did not throughout most of the season, but especially during the early part. By the end of the season mated and unmated females had about equal numbers of eggs. A similar overall pattern was seen in Roslyn. Flies in Zillah had higher egg loads throughout the season perhaps because these flies had better nutrition, which in turn resulted in greater mating tendencies. This hypothesis was tested in 2003 (below).

2002-2003, Pheromones and Other Factors

Female flies did not respond to male odor in experiments in which males were held inside cages and air was passed over them in experiments conducted in 2002. When the sliding door on the cage holding males was opened, the females did not fly upwind, but rather stayed on the sides of the cages and walked very slowly for hours. The response of female western cherry fruit flies thus were different than that of the European cherry fruit fly, which responded to male odors inside tunnels within 1 hour. A field experiment conducted in an infested backyard cherry tree in June 2002 in which 30 males were held inside paper cups with food and water also yielded the same conclusions. The results suggest female flies are not responsive to odors of males or that the males need to be in a specific physiological or behavioral state to release a pheromone. Because males were kept inside cages or spheres for bioassays and were not hanging on fruit waiting for females (the natural behavior), they may not have been in the right state to release any sex attractants. The background environment may need to be very specific for this to occur. Clearly further work is needed to provide evidence that a pheromone exists, as it does in other fruit flies. If a pheromone is absent, mating may depend mostly if not solely on vision. The question is how flies find one another using vision only; perhaps repeated flights to fruit by females needing to lay eggs are sufficient to achieve successful mating. Further laboratory studies in 2003 to determine the presence or absence of a mating pheromone were conducted. Flies again did not respond strongly to odors despite changes in tunnel designs and temperatures, light intensity, and wind speed inside tunnels.

Several non-chemical factors involved in mating success were tested. One was the presence of fruit. Fruit presence was essential for high levels of mating. When no substrates were present, numbers of matings averaged 1.0; with wax domes on the cage floor, 1.3; with cherries hung from the cage ceiling, 9.3 (4 replicates). Low fruit loads, such as near the end of the season, may cause flies to leave trees in search of mating sites This indicates that sphere traps lure in males that are ready to mate. Another factor was the color of the fruit or fruit-like substrate. Males preferred to rest on wax cherries over real, ripe sweet cherries (Table 2, Experiments 2 and 3). Females tended to visit real cherries more often, perhaps to lay eggs. From this experiment, at least, it appears males and females may not necessarily prefer the same color fruit. If orange sphere traps are more attractive for males, this may help reduce fly populations in the field. Field studies were conducted to determine if males showed evidence for a fruit color preference. Digital pictures were made of 4 trees in Roslyn in July 2003. Images were analyzed and fruit categorized into different colors. Fruit on which males were seen were collected, taken to the laboratory, and placed in the same color categories. Even though most fruit were green, most males were found on fruit that were yellow/orange or orange/red (Fig. 5), suggesting a preference for riper fruit. This preference may be related to visitation by females. If females also prefer these fruit, then the probability of mating is increased. Female numbers were low, but the available data suggest this was the case.

Although the fruit presence and fruit color are two factors that may affect mating, presence of males on fruit seemed to have no effect on female responses to fruit. The numbers of females that were attracted to wax cherries baited with dead male flies and control cherries were nearly the same (286 versus 279 total female visits for 3 replicates).

Surprisingly, nutrition seemed to have little effect on mating frequency. Male and female flies fed diets of sucrose only, sucrose-yeast, and cherry juice only mated equally (Table 3, Experiments 2 and 3). Total numbers of matings ranged from 0-123 over the 30-day tests. Interestingly, in one sugar-only replicate, there were 123 matings that resulted in a 61.9% egg hatch (n = 113 eggs). However, when this replicate was dropped, the hatch rate of sugar-fed flies was lower than of sucrose-yeast fed flies, partly because the latter ones laid more eggs. The overall hatch rate of this group was 37.4% (total of 463 eggs sampled), compared with 12.4% (total of 114 eggs sampled) in the sugar-only group. Although the numbers of matings in the two groups were equal, but these results suggest insemination of flies with few eggs is lower than when flies produce many eggs.

Overall Conclusions

The results indicate that mating in cherry fruit flies is governed mostly by vision and the flight of females to fruit, where males congregate and where egg laying occurs. There, the males wait for females that visit the fruit for feeding or egg laying. No evidence for a sex pheromone in this process was found. Mating is often completed off the fruit on leaves. It is likely females do not seek the males, but that males detect the females by vision alone. These visual factors may include fruit presence and color. The ingestion of protein with sugar appears to have little effect on mating propensity, but clearly has an impact on egg production. Further research into factors that disrupt the ability of males to mate with females (and vice versa) will aid in managing the fly. The current work indicates that orange sphere traps should be effective in removing large numbers of male flies, especially if fruit loads are low. Trap densities in trees would need to be fairly high to remove large fly numbers. The work also lays a foundation for work on more intensive control methods such as the sterile male technique. Enough is known about the mating behaviors and ecology of the cherry fruit fly to take advantage of advances in this technology. For example, irradiated flies should perform as well as normal flies for this technique to work. Whether this expensive technique will be implemented is question of economics rather than biology.

Table 1. Frequency of mating and mean numbers of matings/day and mean mating duration (minutes) of single male-female pairs of flies different ages in the laboratory.

Age (days) Male	Age (days) Female	No. Pairs	No. Pairs Mated	% Pairs Mating	No. Matings per day ± SE	Mating Duration ± SE
3-9	3-9	32	5	15.6	0.08 ± 0.03a	40.12 ± 17.50a
3-9	17-29	25	8	32.0	0.27 ± 0.09a	60.95 ± 13.68a
17-29	3-9	15	4	26.7	0.20 ± 0.12a	73.05 ± 7.48a
17-29	17-29	47	11	23.4	0.44 ± 0.22a	36.76 ± 9.43a
30-43	30-43	16	8	50.0	0.33 ± 0.14a	26.85 ± 11.44a

Means followed by same letters within columns are not significantly different ($P < 0.05$).

Table 2. Effects of nutrition on numbers of mating pairs + SE of cherry fruit flies.

Expt 1	N	No. Matings	Expt 2	N	No. Matings
Yeast + Sugar + Cherries	5	5.8 + 3.2	Yeast + Sugar + Domes	5	9.2 + 4.7
Sugar Only + Cherries	5	1.6 + 1.4	Sugar Only + Domes	5	26.0 + 24.3

Table 3. Use of orange wax cherries and real dark purple cherries by male and female cherry fruit flies in the laboratory. Twenty of each and 19-35 females and 8-35 males per replicate (N = 5).

	Mean total no. of visits + SE over 30 days				
	Diet: Sugar Only			Diet: Sugar-Yeast	
	Wax Cherries	Real Cherries		Wax Cherries	Real Cherries
Females	192 + 52	51 + 22	Females	275 + 126	41 + 16
Males	28 + 6	1 + 1	Males	89 + 63	1 + 1

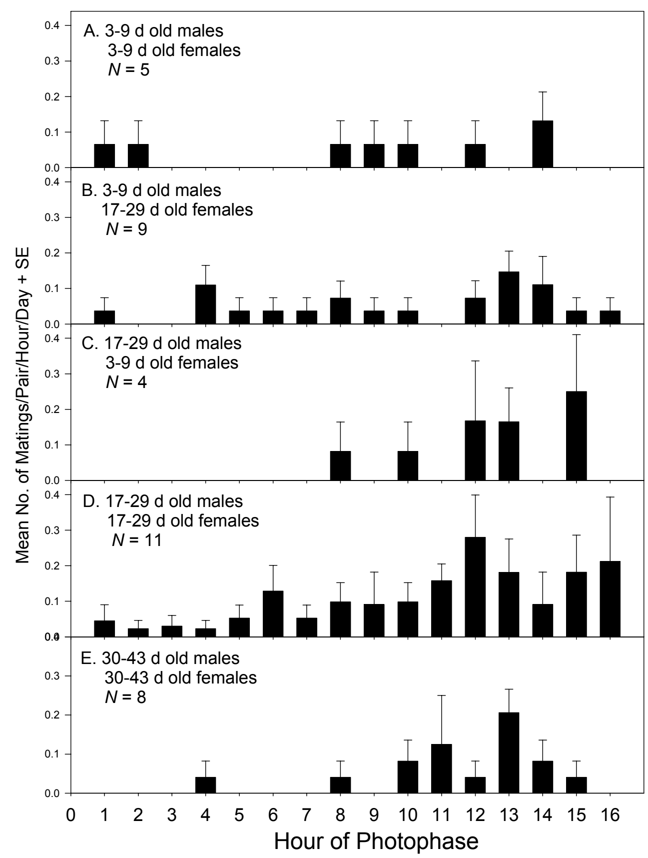


Fig. 1. Time of day effects on mating by cherry fruit flies in the laboratory.

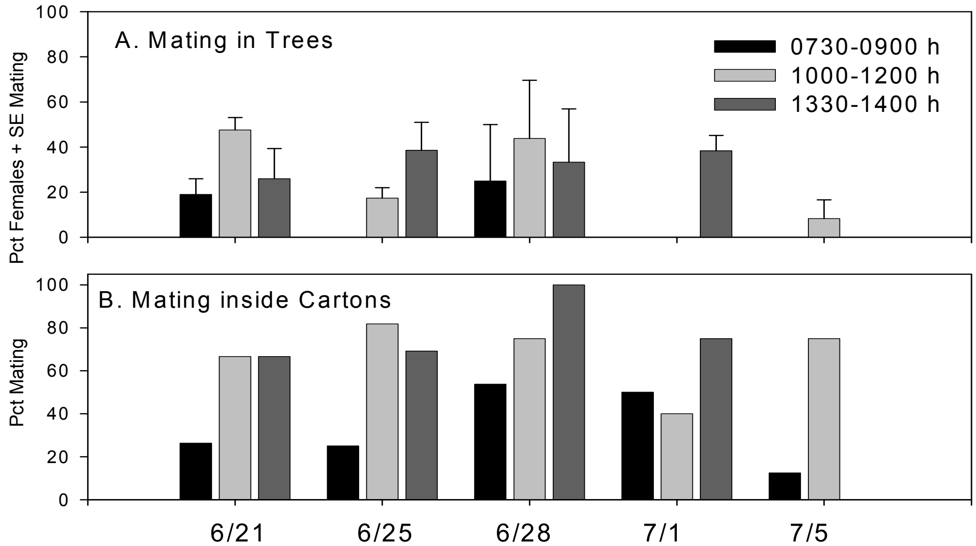


Fig. 2. Field mating incidence by cherry fruit flies in relation to time of day, 2001.

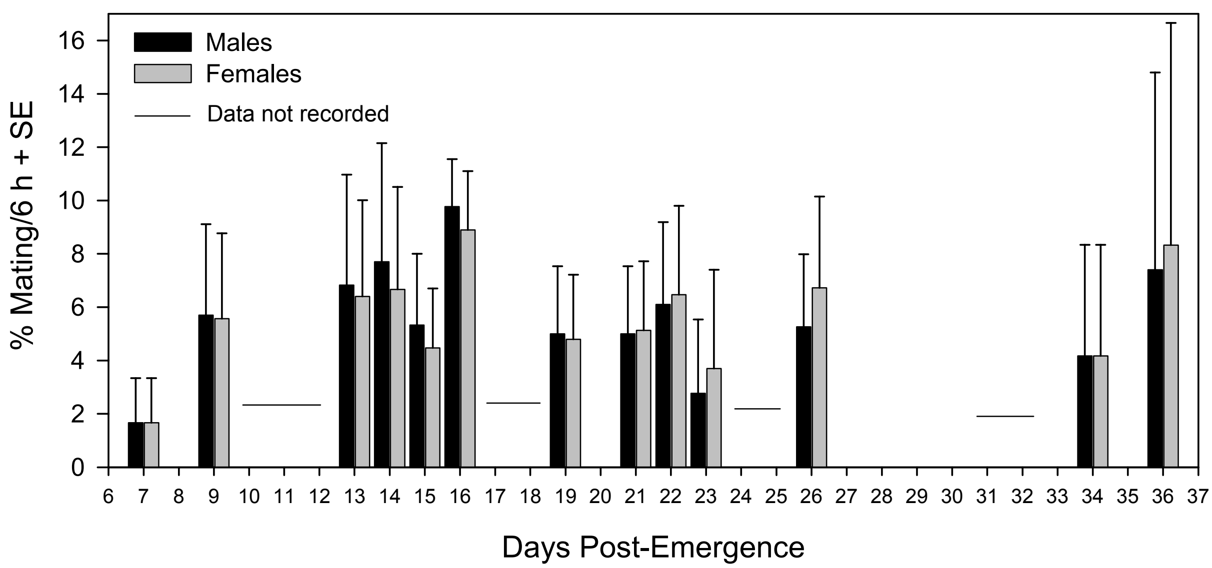


Fig. 3. Mating of cherry fruit flies as a function of age in the laboratory.

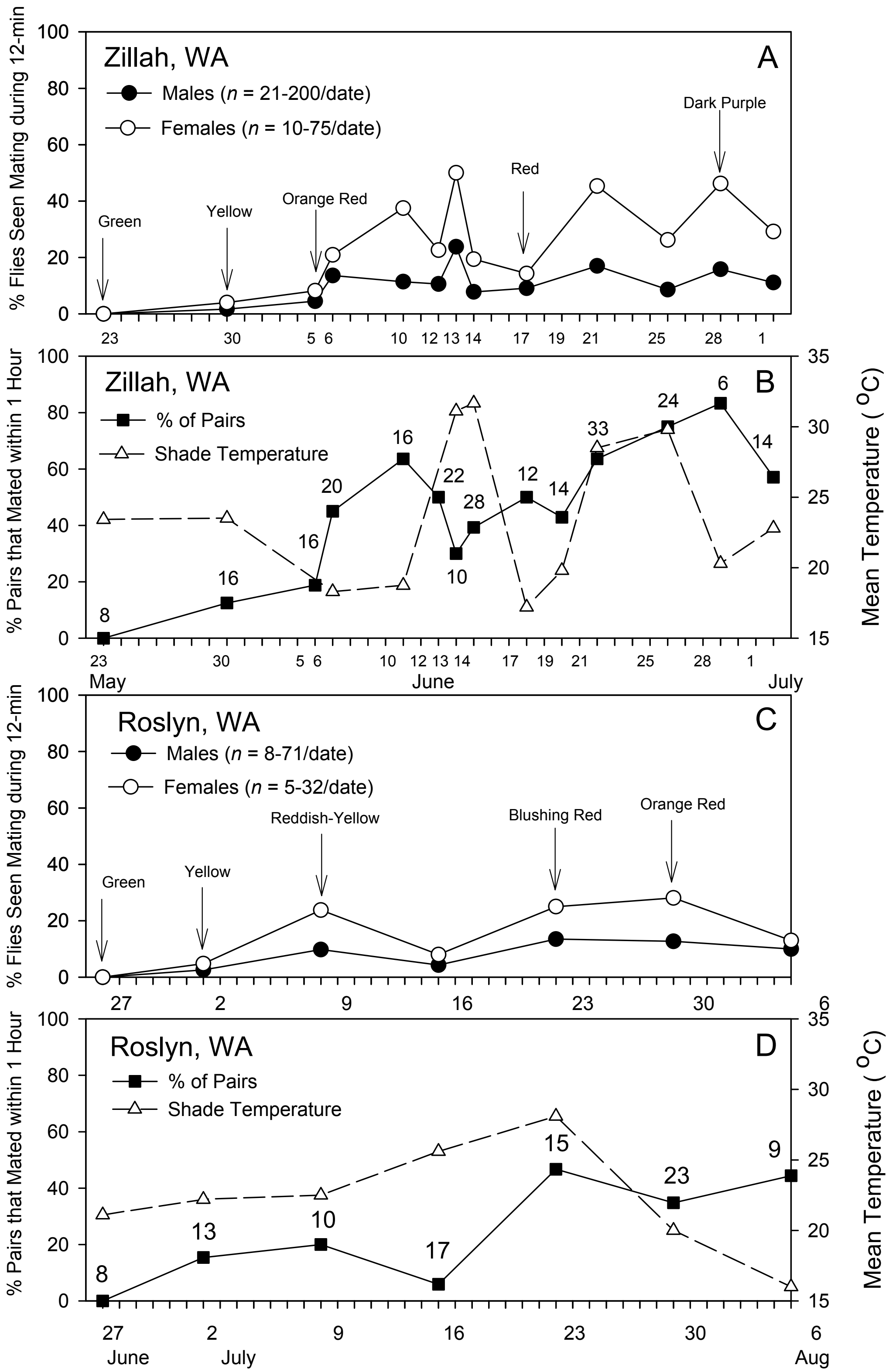


Fig. 4. Percentage of cherry fruit flies seen mating in trees and % that mated inside cups over the season in Zillah and Roslyn, WA, 2002.

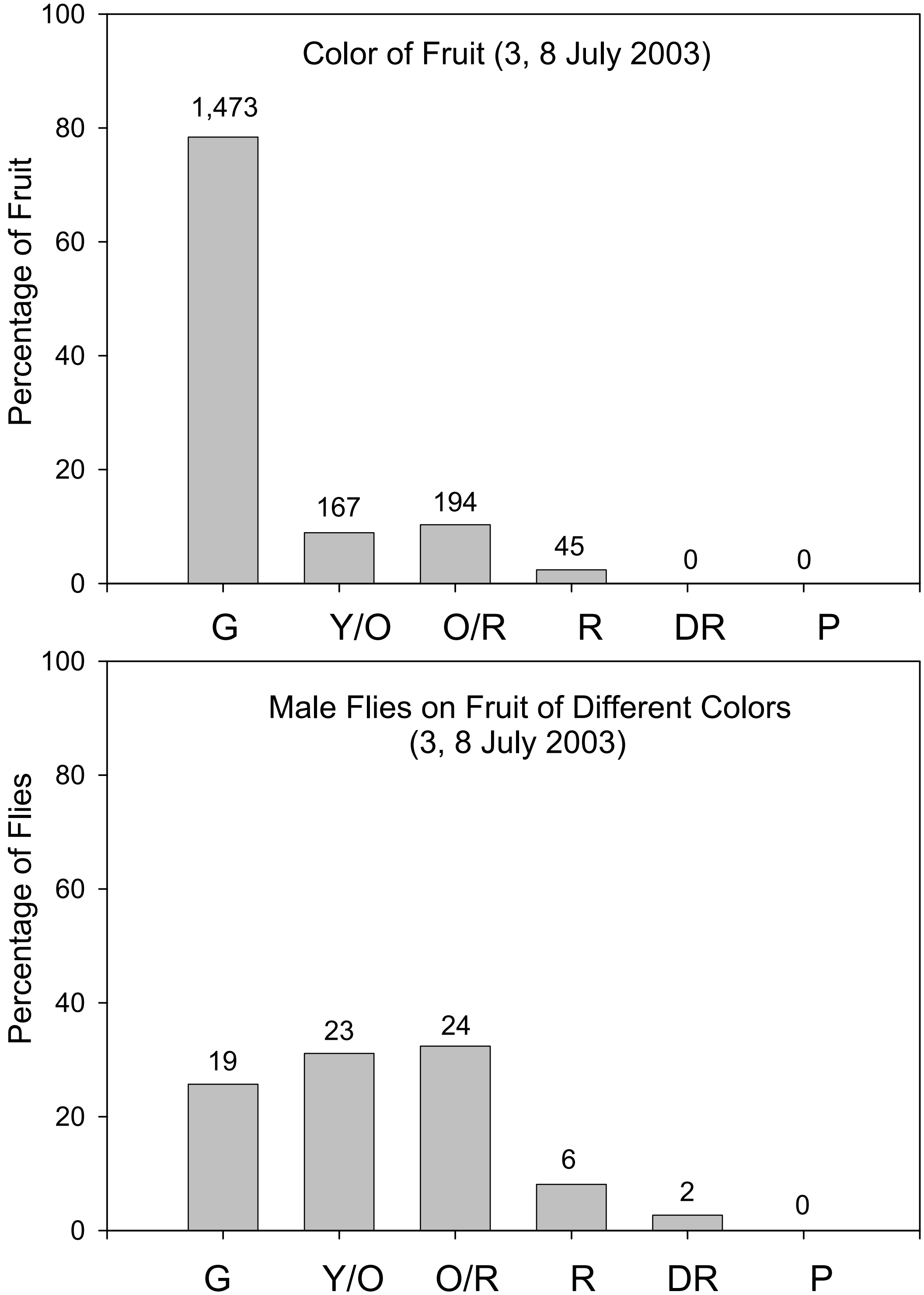


Fig. 5. Color of cherries and numbers of male flies on cherries of different color classes on 4 trees on 3 and 8 July 2003 in Roslyn, WA. G = green; Y/O = yellow/orange; O/R = orange/red; R = red; DR = dark red; P = purple. Numbers above bars are sample sizes

Budget:
Project title: Factors Affecting Mating By Cherry Fruit Flies
PI: Wee Yee
Project duration: 2001-2003
Current year: 2003
Project total (3 years): **$51,745.88**
Current year requested: **$10,745.88**

Year	Year 1 (2001)	Year 2 (2002)	Year 3 (2003)
Total	22,000	19,000	10,745.88

Current year breakdown

Item	Year 1(2001)	Year 2 (2002)	**Year 3 (2003)**
Salaries	15,000	17,500	**7,950.80**[1]
Benefits (%)			**795.08**
Wages			
Benefits (%)			
Equipment	6,000	1,500	**1,500**[2]
Supplies			
Travel	1,000		**500**[3]
Miscellaneous			
Total	22,000	19,000	**10,745.88**

[1]One GS-3 or GS-4 ($9.42 or $10.58/h), full time, 3 months and 1 GS-3, 50% time, 3 months.
[2]Cages, cherries; [3]To field sites.

FINAL REPORT
Project # CH-01-13

Project title: Host and Feeding Preference of Cherry Fruit Fly
PI: Wee Yee
Organization: USDA-ARS, Wapato, WA

Objectives:
2001
- Determine cherry fruit fly activity within days and during the season.
- Relate fly abundance to larval infestation of fruit.
- Determine distances flown by the flies.

2002
- Determine host use patterns by flies in eastern and western Washington.
- Determine the preference of flies for different varieties of sweet and sour cherries and native hosts in the laboratory, and ...
- Developmental rates of flies in these different hosts.

2003
- Continue to monitor fly populations on sour and sweet cherries in eastern and western Washington and identify new hosts.
- Identify food sources of flies on different cherry hosts over the season in eastern and western Washington.
- Evaluate the food sources and preferences in the laboratory, with goal of incorporating foods in baits for control.

Significant findings:
2001
- Males were found mostly on fruit, but females were found equally on fruit and leaves; flies were most during active midday.
- There was a poor relationship between flies detected using unbaited yellow panels and larval infestation of fruit.
- Flies dispersed from host trees, whether they had fruit or not, averaging 50 m after 2 weeks.

2002-2003
- Sour cherries had many more adult flies than sweet cherries in eastern Washington. This pattern may have been caused by a loss of sweet cherries due to birds and not a preference by the flies for fruit. Numbers on the two hosts were similar in western Washington.
- Flies preferred to lay eggs into sour over sweet cherries, but the differences were not large. Host preference may play a role, with one factor being fruit color or visibility.
- New hosts of the cherry fruit fly were English laurel, *Prunus laurocerasus*, a hedgerow plant, and possibly black hawthorn, *Crataegus douglasii* (pending emergence of adults in winter) in western but not in eastern Washington (preference for these hosts not determined).
- Bitter cherry appeared to be preferred over cascara, and choke cherry was not preferred.
- Bitter cherries with high fly populations were seen from July into September in the Nile Valley, a ponderosa pine ecosystem, near the commercial growing areas.
- Cultivated cherries appear to be preferred over bitter cherries and cascara.
- Flies apparently cannot survive on leaves alone, suggesting the amounts of leaves the flies need to obtain enough food is substantial.
- Leaves had sugars on the surface, but the minute amounts were unable to sustain the flies. Fruit (at least when opened) and aphid honeydew thus far appear to be the main or certainly the most concentrated sugar sources for flies.
- Flies seemed to preferred concentrated sugars over diluted sugars, and sugars over protein foods.

- Flies are probably highly attracted to concentrated food baits because foods in nature appear to be in diluted and scattered.

Methods (2003):
1. Fly numbers on 4-6 pairs of sour and sweet cherries in 2003 were determined throughout the season, as in 2002. Fruit samples were collected at bi-weekly basis from trees to determine larval infestations of fruit. Adult and larval numbers on bitter cherry and cascara in western Washington were determined weekly or bi-weekly to document their possible role in contributing to fly populations on cultivated cherries.
2. Choice experiments using whole branches with fruit from sour and sweet cherry trees that had been held inside sleeves were conducted.
3. To determine if substances on leaves and fruit can sustain longevity and fecundity and whether possible nutrients on them change over the season, branches with intact and damaged leaves and fruit were removed from cultivated and native host trees throughout the season and brought into the laboratory, placed in containers with water (to keep them fresh) inside cages, and exposed to flies. Five groups of 10 field-collected male and female flies were exposed to substrates. Observations were made to determine if a preference for fruit or leaves existed.
4. Substances from leaves were washed and the concentrates dried on plastic. Groups of 3-5 females and males were exposed to the fruit and leaf concentrates and also to whole fruit and leaves to determine if a preference in foods and their form exists.

Results and Discussion:
<u>2001</u>

Male and female flies differed in their activity on leaves and fruit. Males spent the majority of their day on fruit, whereas females spent equal time on fruit and leaves. Both were most active midday. This suggests that short-lived insecticides on leaves will be especially effective and immediate against females that feed on leaves.

There was a poor relationship between flies detected using unbaited yellow panel traps and larval infestation of fruit. This indicates the traps used were not attracting large percentages of flies in the population, and that better attractants are needed. However, for detection purposes, traps will detect at least some flies if populations are large.

Flies dispersed readily from host trees, averaging 50 m after 2 weeks. This seems to occur regardless of whether fruit are present or absent in trees. This apparent instinct to disperse is important because flies dispersing from infested backyard trees seem to be the major threat to commercial orchards. Factors that cause large numbers to disperse are especially important and need to be studied.

<u>2002-2003</u>

Sour cherries had more adult flies than sweet cherries in eastern Washington in 2002 and 2003 (Fig. 1). This pattern was apparently caused in part by the loss of sweet cherries due to birds and not a clear preference by the flies for sour cherry fruit (Table 1), or to greater development on sour cherries, as size and survivorship of pupae from the two hosts were similar. This does not preclude an actual preference, as color and visibility of sour cherries may be greater than sweet cherries, especially when both are ripe. When both fruit are on the trees, infestation rates between sour and sweet fruit are similar (Fig. 2). This suggests that the greater adult numbers seen on sour trees are a result of fruit loss. The fact that sour trees retain fruit longer indicates they are greater producers of flies and thus a greater threat to commercial orchards in the Yakima Valley. This is apparently not the case in western Washington, where infestations on the two are nearly equal.

New hosts of the cherry fruit fly were discovered. These were native cascara, *Rhamnus purshiana*, introduced English laurel, *Prunus laurocerasus*, a hedgerow plant, and possibly native black hawthorn, *Crataegus douglasii* (pending emergence of adults in winter). Six English laurels were sampled in 2003. From these, 140 pupae were obtained from 1,672 fruit (0.084 larvae/fruit). These are hosts in western Washington, but apparently not in eastern Washington.

Native trees and cultivated cherries were attacked by cherry fruit flies across the state. Cascara, bitter cherry, and black hawthorn were hosts in some form in the coast forest ecosystem in western Washington (Fig. 3), but cultivated sweet and sour cherries seemed to be more preferred than any of these native hosts (Table 2). Bitter cherries but not chokecherries or black hawthorn were infested with high fly numbers in the ponderosa pine ecosystem of the Nile Valley (Fig. 4). This population is important because it is fairly close to commercial plantings. Similar populations probably exist near the canyons in Wenatchee. Flies from these may be a source of flies in commercial plantings. Cultivated cherries in backyards or urban settings appear to be the only cherry fruit fly host in the sagebrush-bunchgrass ecosystem of the Yakima Valley (Fig. 5). This is important because in this area these trees can be specifically targeted for control of flies. However, flies on native hosts in the other ecosystems need to be monitored as they represent continual threats to the industry.

Flies apparently cannot survive on leaves alone (Table 3), suggesting the amounts of leaves the flies need to obtain enough food is substantial. Gas chromatography analyses indicated leaves had sugars on the surface, but the minute amounts were unable to sustain the flies. Flies placed in beakers with leaf and fruit concentrates died within 3 days, same as controls. Surprisingly, even intact fruit failed to sustain the flies. Fruit and aphid honeydew thus far appear to be the main or certainly the most concentrated sugar sources for flies (especially if ripe fruit are opened by birds). The results suggest food is scarce in the environment or at least is difficult to find in concentrated form. Laboratory results indicated flies fed on large amounts of 20%-60% sucrose, but only on small amounts of 2% sucrose. In addition, flies did not feed on protein sources alone without a sugar stimulant, indicating a preference for sugar over protein foods.

Conclusions

The threat of cherry fruit flies to the commercial cherry industry is continual because of the presence of high fly numbers on cultivated sour and sweet cherry trees in abandoned lots and residential yards and on native hosts. No clear factor as yet explains fly predominance on some seemingly preferred hosts. Flies are clearly able to sustain themselves by feeding on sugars and proteins within trees, but food sources have been difficult to identify. Once fly populations are established on hosts, substantial efforts are needed to remove the populations, as the flies do not require outside vegetation for sustenance. The knowledge gained in this project lays the foundation for future work on how to control the flies on a variety of native hosts and cherries using food-based sprays.

Table 1. Preference of cherry fruit fly for sour and sweet cherry fruit on paired branches, 2003.

	Sour Cherry (Mean ± SE)	Sweet Cherry (Mean ± SE)	t	***P***
Preference Parameter				
Males on Fruit[a]	0.80 ± 0.19	0.18 ± 0.14	2.820	0.0667
Females on Fruit[a]	0.20 ± 0.08	0.12 ± 0.12	0.475	0.6645
Males on Leaves[a]	0.22 ± 0.06	0.60 ± 0.29	-1.367	0.2651
Females on Leaves[a]	0	0	------	------
Eggs per Fruit	0.50 ± 0.18	0.03 ± 0.02	2.687	0.0746
% Fruit with eggs	24.8 ± 7.8	2.2 ± 1.3	3.596	0.0369
Fruit Characteristics				
Diameter (cm)	1.97 ± 0.04	2.60 ± 0.06	7.667	0.0046
Weight (g)	4.23 ± 0.21	9.06 ± 0.48	8.025	0.0040
Hardness (durometers)	34.4 ± 1.7	56.0 ± 4.6	5.896	0.0097
% Sugar	14.2 ± 0.4	27.8 ± 1.0	11.030	0.0016

Five or 6 females and 29 males released per cage
[a]Per 1.5-2 min observations

Table 2. Adult *Rhagoletis indifferens* presence and larval infestation of native trees and cultivated cherries in representative sites within three ecosystems in WA, 2001-2003.

Tree Species	No. Trees Trapped	Pct. with Flies	No. Trees Fruit Picked	% Trees Infested	Total Fruit	Total Pupae[a]	Pupae/fruit/ Tree ± SE
Coast Forest Ecosystem (Vancouver and vicinity)							
2001							
Cascara	3	100.0	3	-------	------	7	-----[b]
Black Hawthorn	14	64.3	-------	-------	------	-----[b]	-----[b]
2002							
Cascara	7	57.1	8	75.0	3,885	94	0.024 ± 0.010
Bitter Cherry	8	75.0	13	92.3	6,059	615	0.125 ± 0.029
Black Hawthorn	20	90.0	6	------[b]	2,095	------[b]	------[b]
Cultivated Cherry	51	31.4	6	83.3	808	26	0.030 ± 0.009
2003							
Cascara	16	37.4	18	33.3	3,922	21	0.004 ± 0.002
Bitter Cherry	27	51.8	29	89.5	8,761	1,021	0.139 ± 0.024
Black Hawthorn	26	55.6	18	-------[b]	4,465+[b]	375+[b]	--------[b]
Cultivated Cherry	42	64.3	39	82.1	1,260	539	0.417 ± 0.061

Table 2, continued

Tree Species	No. Trees Trapped	Pct. with Flies	No. Trees Fruit Picked	% Trees Infested	Total Fruit	Total Pupae[a]	Pupae/fruit/ Tree ± SE
Ponderosa Pine Ecosystem (Nile Valley)							
2003							
Bitter Cherry	30	96.7	26	73.3	9,880	346	0.107 ± 0.022
Choke Cherry	24	8.3	22	0	7,516	0	0
Black Hawthorn	12	8.3	11	0	6,106	0	0

Tree Species	No. Trees Trapped	Pct. with Flies	No. Trees Fruit Picked	% Trees Infested	Total Fruit	Total Pupae[a]	Pupae/fruit/ Tree ± SE
Sagebrush-Bunchgrass Ecosystem (Yakima Valley)							
2001							
Choke Cherry	14	0	-------	------	------	------	------
Cultivated Cherry	40	92.3	40	92.5	20,918	5,561	0.337 ± 0.05
2002							
Choke Cherry	26	15.4	3	0	596	0	0
Cultivated Cherry	32	53.1	32	71.9	6,026	1,694	0.278 ± 0.053
2003							
Choke Cherry	44	2.3	44	0	27,354	0	0
Black Hawthorn	17	0	8	0	3,248	0	0
Cultivated Cherry	37	94.6	28	96.4	4,875	3,650	0.745 ± 0.210

---------, data not collected.
[a]Fly identification confirmed by rearing to the adult stage.
[b]2001, 2002, not reared to determine if *R. indifferens*; 2003, currently being reared to determine if *R. indifferens* or apple maggot, *R. pomonella*.

Table 3. Percent survival ± SE of cherry fruit flies exposed to different substrates in the field and laboratory, 2003. Four replicates each.

Treatment	Field (23 flies/rep)	Laboratory (8-11 flies/rep)
Control	0.0 ± 0.0a	11.1 ± 11.1a
Leaves Only	43.5 ± 20.7bc	2.8 ± 2.8a
Fruit Only	5.4 ± 4.1ab	48.9 ± 3.2b
Leaves + Fruit	54.3 ± 13.8c	43.9 ± 13.9b
Leaves + Fruit + Aphids	71.7 ± 5.8c	65.8 ± 6.1b

Means with the same letters within columns are not significantly different ($P > 0.05$).

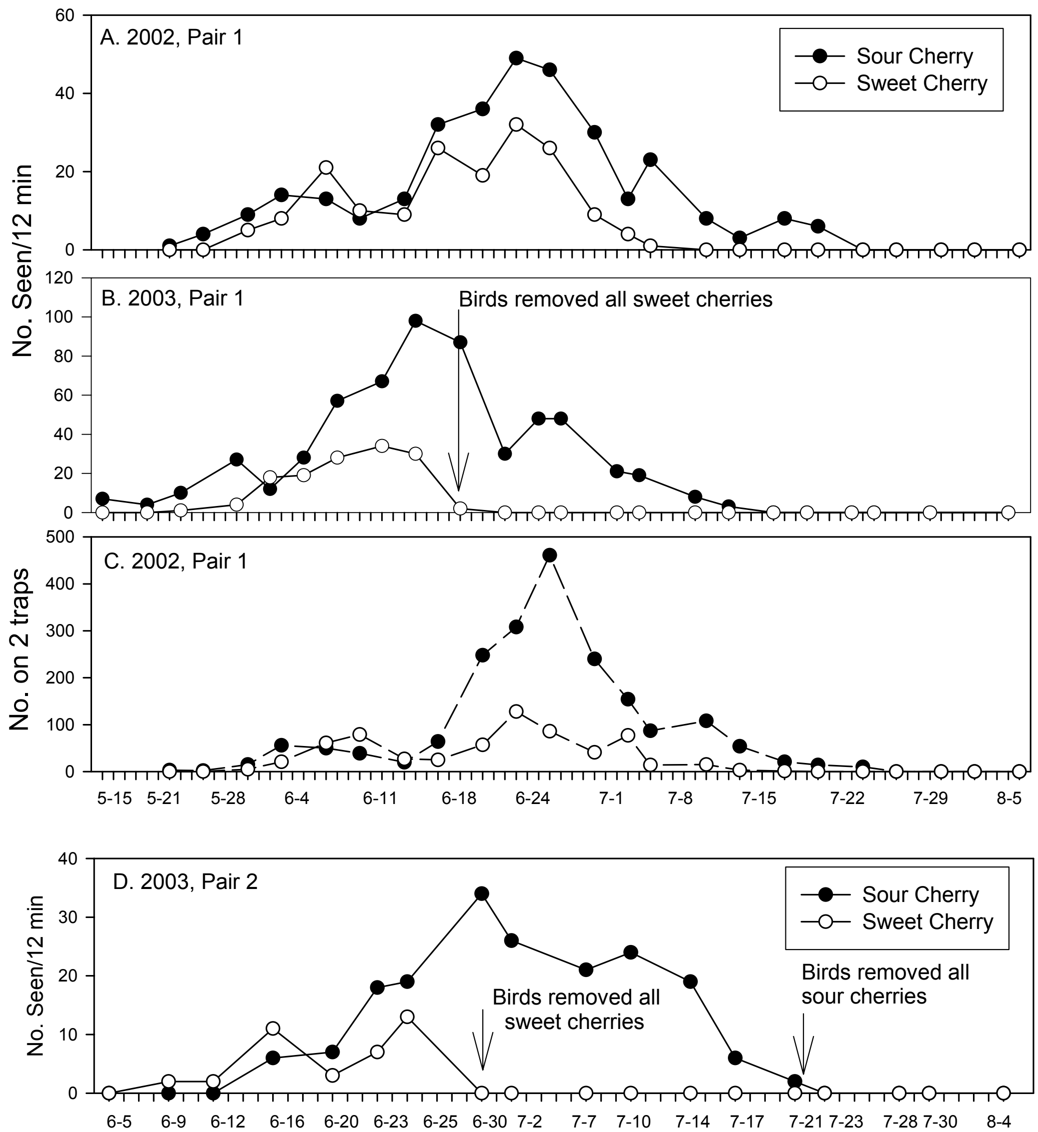


Fig. 1. Cherry fruit fly abundance on representative sour and sweet cherries in the Yakima Valley, 2002-2003.

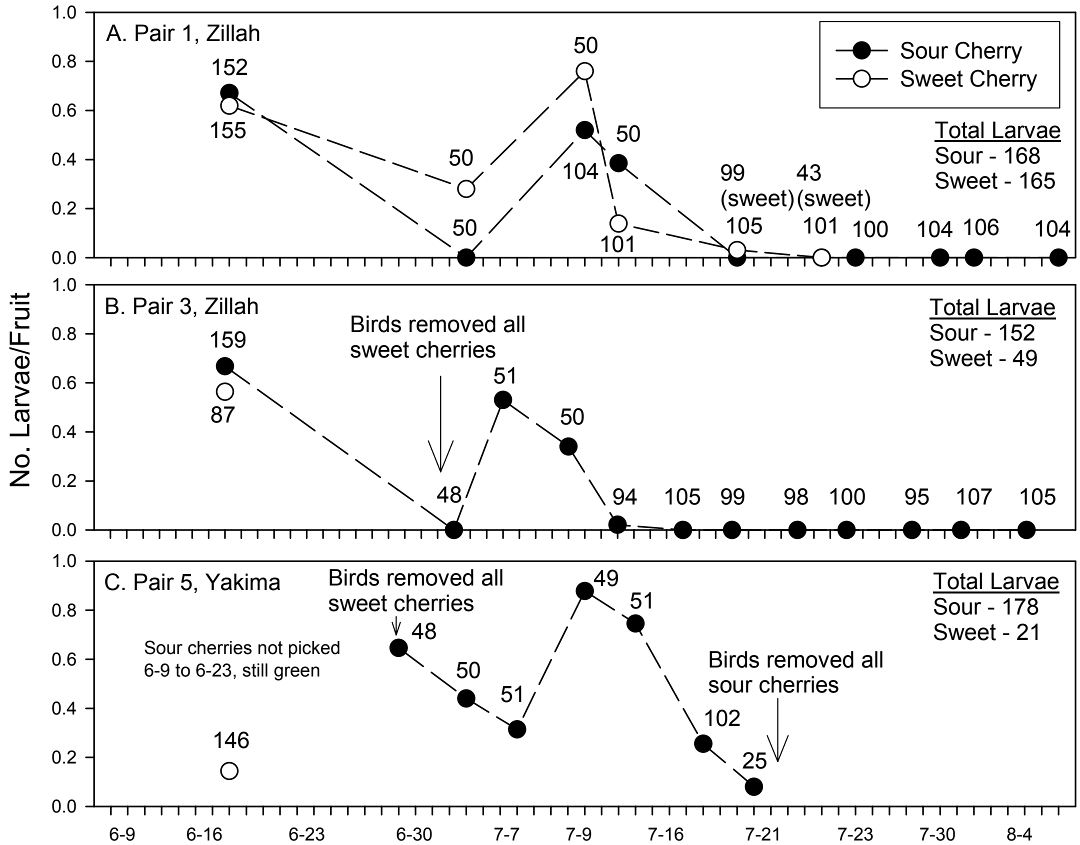


Fig. 2. Infestation of sour and sweet cherry fruit by cherry fruit flies in the Yakima Valley, 2002.

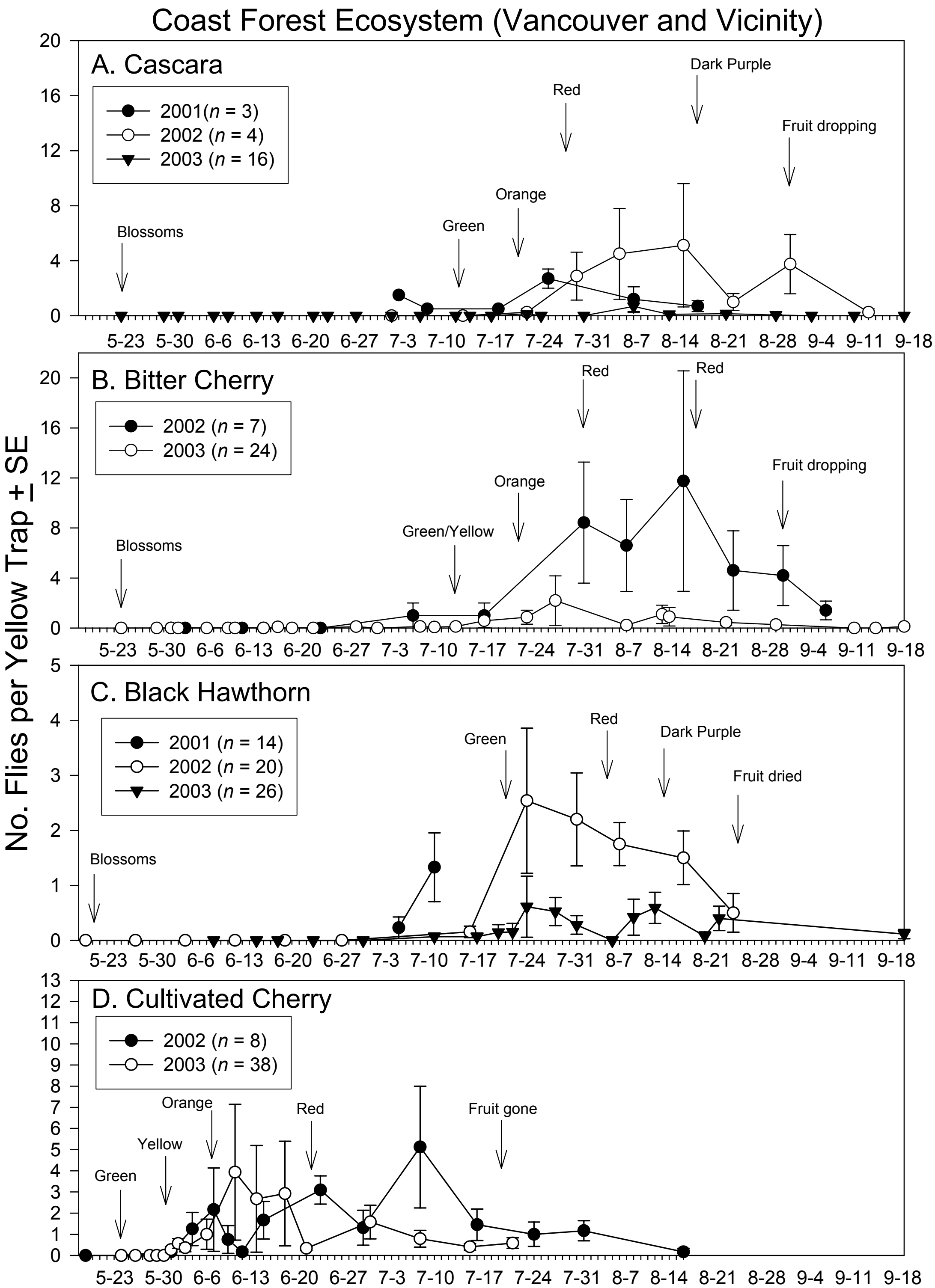


Fig. 3. Use of native trees and cultivated cherries by cherry fruit flies in the coast forest ecosystem.

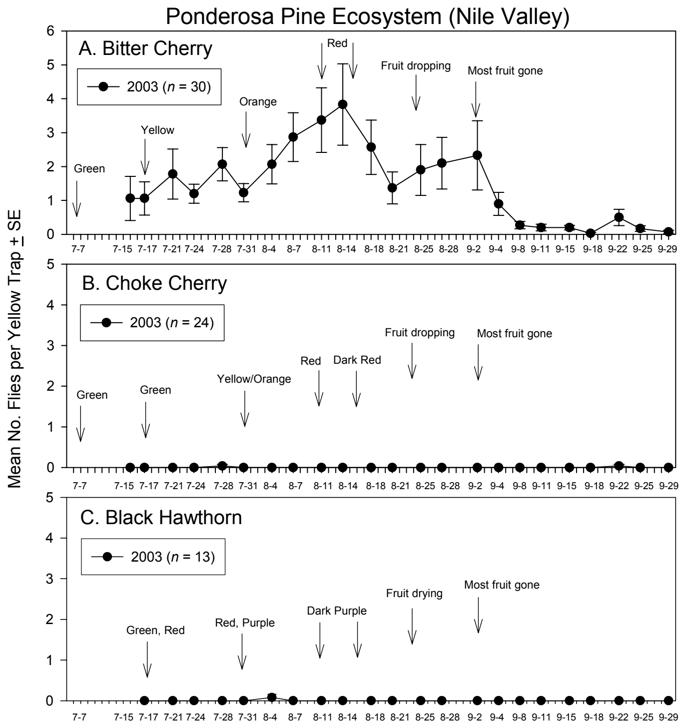


Fig. 4. Use of native trees by cherry fruit flies in the ponderosa pine ecosystem.

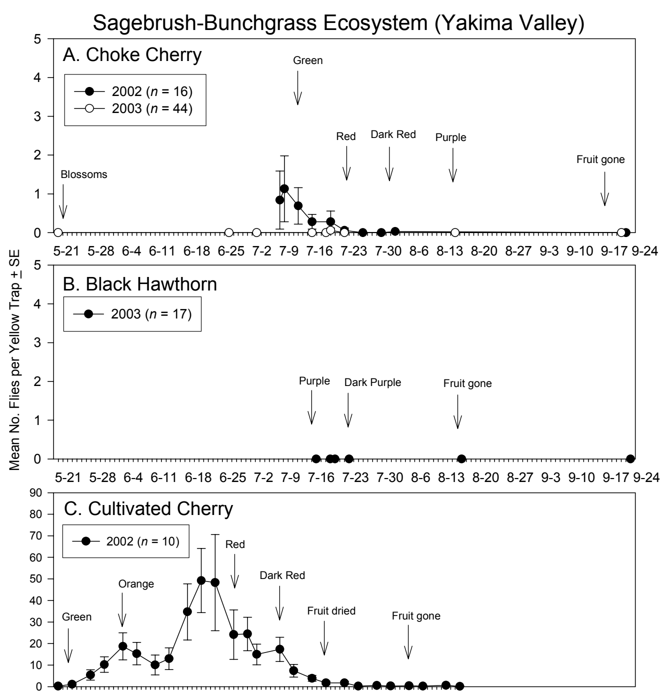


Fig. 5. Use of native trees and cultivated cherries by cherry fruit flies in the sagebrush-bunchgrass ecosystem.

Budget:

Project title: Host and Feeding Preference of Cherry Fruit Fly
PI: Wee Yee
Project duration: 2001-2003
Current year: 2003
Project total (3 years): **$54,477.60**
Current year requested: **$21,977.60**

Year	Year 1 (2001)	Year 2 (2002)	Year 3 (2003)
Total	14,000	18, 500	21,977.60

Current year breakdown

Item	Year 1(2001)	Year 2 (2002)	**Year 3 (2003)**
Salaries	11,000	16,000	**18,616.00**[1]
Benefits (%)			**1,861.60**
Wages			
Benefits (%)			
Equipment	2,500	1,000	
Supplies			
Travel	750	1,500	**1,500**[2]
Miscellaneous			
Total	14,000	18,500	**21,977.60**

[1]GS-6 ($13.19/h), full time, 6 months, and 1 GS-3 ($9.42), full time, 3 months; [2]To field sites.

FINAL REPORT
WTFRC Project # CH-02-200,

Project title: Cherry fruit fly distribution and trapping
PI: Wee Yee
Organization: USDA-ARS, Wapato, WA

Objectives:
2002
- Determine if cherry fruit fly distributions and infestation levels can be predicted using traps and visual counts.
- Determine relationship between infestation rates in previous years (as determined by trap catches and infestation rates) and future infestations.

2003
- Determine effects of tree size on ability of traps to detect flies and predict infestation levels.
- Determine ability of traps to reduce fly infestations.

Significant findings:
2002
- Trap catches did predict infestation levels of fruit, with red spheres and late season catches yielding better relationships and possibly greater predictive power.
- Trap catches determined that 45% of trees were infested, while rearing of larvae from fruit indicated trees were 71% infested, suggesting trap sensitivity needs to be increased.
- Traps placed inside cages recaptured up to 35% of males and 46% of females, with a corresponding reduction in fruit infestation levels.
- All trees surveyed in 2000 and 2001 that were positive for flies on traps were also positive in 2002, but the absolute fly numbers were not predictable.

2003
- Red sphere traps with sustained ammonia release were effective in predicting infestation levels when fly populations were high.
- Red sphere traps detected flies and predicted infestation levels equally well on large and small trees.
- Red sphere traps reduced fly infestations and therefore can possibly be used suppress infestation levels.

Methods:
1. To test the effects of tree size on fly detection, either 1 or 4 red spheres baited with 10 g ammonium carbonate were hung on the south sides of 10-20 randomly selected small-moderate size (8-15 ft) or large trees (> 15 ft) in Tri-Cities and Yakima areas (40-80 total trees). Traps were deployed in late May and early June and left on trees for 2-2.5 weeks. In mid June, 200-500 fruit were collected from around the trees. Fruit were placed on screens and larvae allowed to emerge from the fruit. Larvae were counted each day over 3 weeks. The percentages of trees that were fly positive based on trap catches, visual inspections, and larval infestations were compared as in 2002. The hypothesis tested was that the small-moderate size trees provide more consistent fly detections than the large trees.
2. To determine the effects of traps on larval infestations, 9 or 12 cages were placed over individual 10-12 ft tall trees in the USDA Moxee Farm in May. Either one or 4 red sphere traps baited with 2 g ammonium carbonate (to be consistent with 2002) were hung on each of 3 or 4 trees. A control with no traps was included. Flies were collected from the field, maintained in the lab, and then released inside cages in mid June. The numbers collected on traps and infestation rates in the fruit were determined in early-mid July.

Results and Discussion:

2002

In 2002 in Union Gap and Yakima, fly catches on red spheres and yellow panels indicated that 45-48% of the 31 trees in the study were infested, whereas collection of fruit and rearing of the larvae indicated that 71% were actually infested (Table 1). These data suggest that traps as deployed (probably low ammonia release from 2 g ammonium carbonate) can be used to detect and predict infestations by flies only to a limited degree. Both spheres and yellow panels failed to detect moderately high infestations.

Even though traps failed to detect some infestations, red sphere and yellow panel catches were positively correlated with infestation levels in most cases, although usually not significantly (Fig. 1 and 2). Trap catches on spheres generally were better correlated with larval infestations than were yellow panels. However, because tree sizes and structure varied, some of the differences may have been caused by these factors and not by trap type. Proximity to other cherry trees, such as in an orchard setting, and fly density may influence reliability. In large trees, more traps may be required, or traps must be placed at higher levels, for accurate assessment of fly populations. The location of the trees also needs to be taken into account. Almost all the trees used in this study were isolated in yard or had only a few trees nearby. Thus the trees were probably not infested by immigrating flies. In a few cases, the high numbers of flies and low infestation rates suggest that flies may have been dispersing through some of the yards and not staying on the trees. Tree size, fruit load, and tree location all will influence the behavior and movement of the flies and needs to be studied in relation to trap captures.

Visual inspections were usually positively correlated with trap catches. This suggests that when flies are difficult to see, the traps are also less likely to capture flies. However, in one case 81 and 69 flies were collected on one yellow trap in consecutive weeks but only 2 and 3 flies were seen. Periodic visual examinations on trees thus seem less reliable than longer-term trap catches in determining infestations.

Nine trees spread over Kennewick, Richland, Prosser, Yakima, and Cle Elum that were positive for flies on traps in 2000 and 2001 were positive again in 2002, indicating that infestations persist in trees year after year. Whenever fruit are available, flies will tend to stay on the same trees and will not disperse far from it, as dispersal tendencies by the fly are relatively low. Surprisingly, the actual numbers caught on unbaited yellow traps were not predictable from year to year, except between 2000 and 2002 ($r = 0.624$, $P = 0.073$; 2000 and 2001 and 2001 and 2002, $P > 0.07$), suggesting either these traps are not sensitive enough or that fly populations naturally fluctuate greatly from year to year, depending on fruit load, weather conditions, and other factors. Increased trap sensitivity is important because reliable predictions of infestation levels can lead to better planning for control measures in the following years.

In 2002, traps placed inside caged trees recaptured up to 30% of released flies (Table 2). The actual infestations were not significantly reduced, but trapped trees did tend to have lower infestation rates (Table 2). Because the supercharger lures used in the study may have lost all their ammonia after 1 week, a longer-lasting ammonia source may be needed to continually trap flies throughout the season and reduce infestations.

2003

Relationships between flies caught on ammonia-baited red spheres and infestation of fruit in Kennewick and Yakima, where fly populations were high, were significant (Fig. 3). In Moxee, where populations were lower, relationships were not significant (Fig. 3). As in 2002, the visual inspections yielded weaker relationships (Fig. 4), perhaps because they were conducted once during the season. There was not a strong relationship between tree height and predictability of larval infestations using the red sphere traps, as traps worked equally well on short or tall trees (Fig. 5). Infestation levels of fruit were lower in trees trapped with 4 ammonia-baited red spheres (Table 3). This suggests that when populations are low, these traps can reduce infestation levels. Only 10% of flies were recovered, suggesting that the traps removed males that were needed to inseminate the females, and that the eggs of females not trapped may not have hatched.

Overall Conclusions

The overall results of this study indicate that red sphere traps baited with ammonia can be used to predict the level of infestations. In the infested back yard tree, this ability could determine whether it is necessary to exert control measures or not. By removing flies in trees with low, difficult to detect infestations, the threat of flies immigrating into commercial orchards can be substantially reduced. Additionally, the removal of flies by traps can reduce populations to a level that may allow more effective control using non-insecticide methods. Both of these outcomes will benefit the environment and the cherry industry.

Table 1. Relationship between numbers of trees infested with *Rhagoletis indifferens* and fly-positive trees based on numbers caught on traps and seen on cherry trees in the Yakima Valley, May-June 2002. E, early, 22 May-4 June; L, late, 4-13 June.

			2002 % Trees Positive for Flies Based On:			
		% Trees	Trap Catch		Visual Counts	
Treatment	*N*	Infested[c]	E	L	E	L
1 Red sphere[a]	9[b]	56	33	33	33	33
4 Red spheres[a]	9	67	44	44	22	44
1 Yellow Panel	8	75	50	62	25	38
4 Yellow Panels	5	100	60	60	20	20
Totals – all treatments	31	71%	45%	48%	25%	35%

			2003 % Trees Positive for Flies Based On:	
		% Trees		
Treatment	*N*	Infested[c]	Trap Catch	Visual Counts
1 Red sphere, backyard	28	96.4	85.6	85.6
1 Red sphere, orchard	40	97.5	82.5	20.0

[a]Spheres not baited with ammonium carbonate early sampling, but was for late sampling.
[b]One tree that was trapped only during the late period not included; [c]Based on larvae in fruit.

Table 2. Percentages of *Rhagoletis indifferens* ± SE recaptured by red sphere traps (baited with 2 g ammonium carbonate) and infestation rates inside field cages in Moxee, WA, 19 June to 15 July, 2002 and 2003. Cumulative total flies released inside parentheses. Three cages per treatment. M = males, F = females.

				2002			
	No. Flies Released			Cumulative Percent Recaptured			
Release	Per Cage		Control	1 Red Sphere		4 Red Spheres	
No.[a]	F	M		M	F	M	F
1	13	90	------	16.3 ± 6.4a	28.2 ± 9.3a	28.2 ± 3.1a	46.2 ± 27.7a
2	9 (22)	44 (134)	------	14.0 ± 4.0a	30.3 ± 7.6a	22.0 ± 1.0a	32.7 ± 21.5a
3	7 (29)	19 (153)	------	14.4 ± 4.5 a	33.3 ± 8.1a	22.1 ± 0.9a	35.1 ± 15.8a

	Infestation of Fruit		
	Control	1 Red Sphere	4 Red Spheres
Total No. Larvae/Tree	355.0 ± 93.5a	240.0 ± 87.7a	103.0 ± 35.8a
No. Larvae/Fruit	0.322 ± 0.086a	0.251 ± 0.092a	0.102 ± 0.36a

[a]18 June, 25 June, 5 July. Means followed by the same letter within rows are not significantly different (ANOVA, *P* > 0.05).

Table 3. Effects of trapping trees with ammonia-baited red spheres on infestation of fruit by cherry fruit flies inside field cages, Moxee, WA, 2003.

	2003	
15 females, 50 males released	Control – 4 replicates	4 Red Spheres – 5 replicates
Total No. Larvae/Tree	29.50 ± 2.63a	1.40 ± 0.98b
No. Larvae/Fruit	0.272 ± 0.040a	0.010 ± 0.008b

Means followed by the same letter within rows are not significantly different (ANOVA, *P* > 0.05).

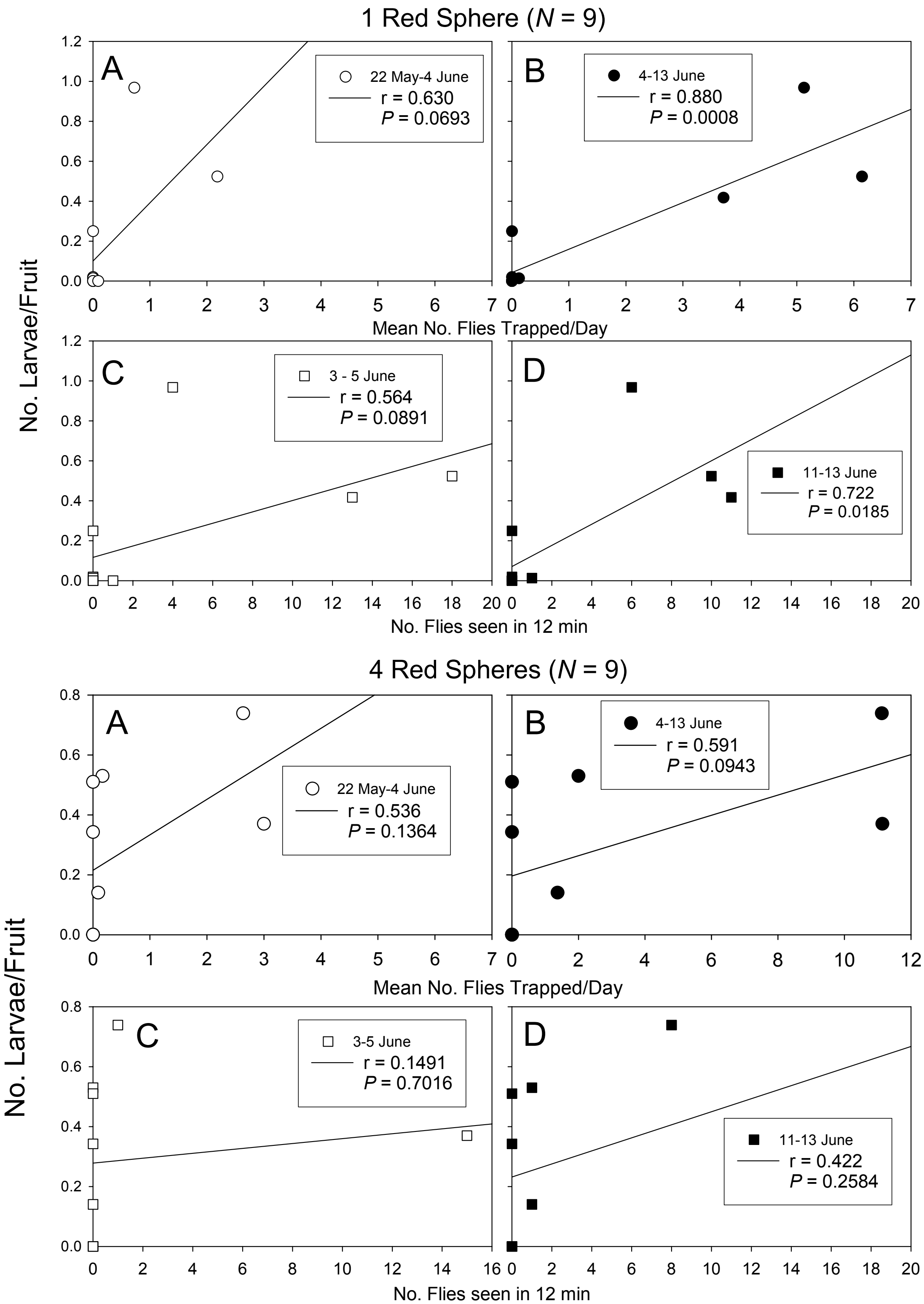


Fig. 1. Relationships between red sphere trap catches, numbers seen, and numbers of larvae inside cherry fruit in Union Gap and Yakima, WA, 2002.

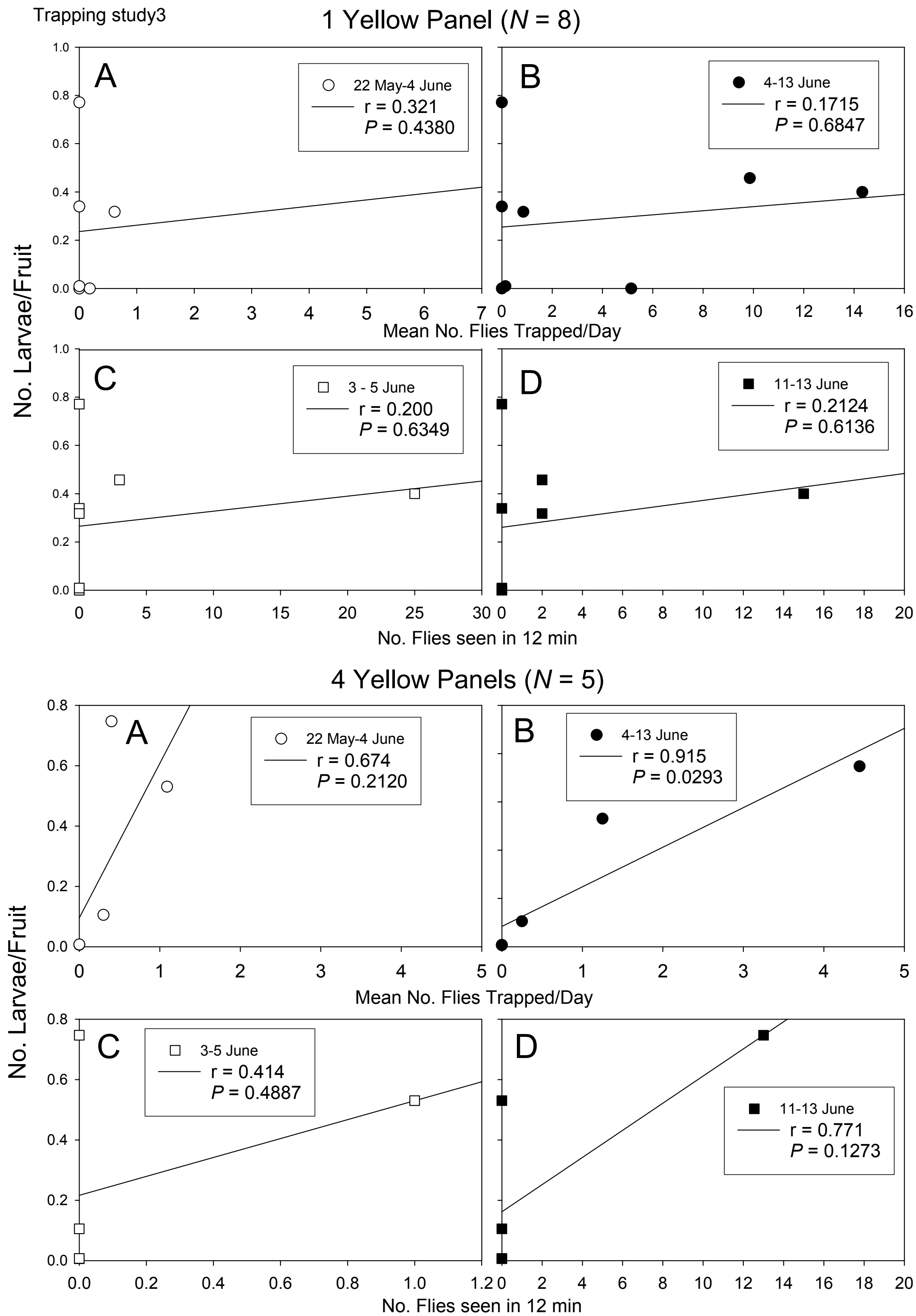


Fig. 2. Relationships between yellow panel trap catches, numbers seen, and numbers of larvae inside cherry fruit in Union Gap and Yakima, WA, 2002.

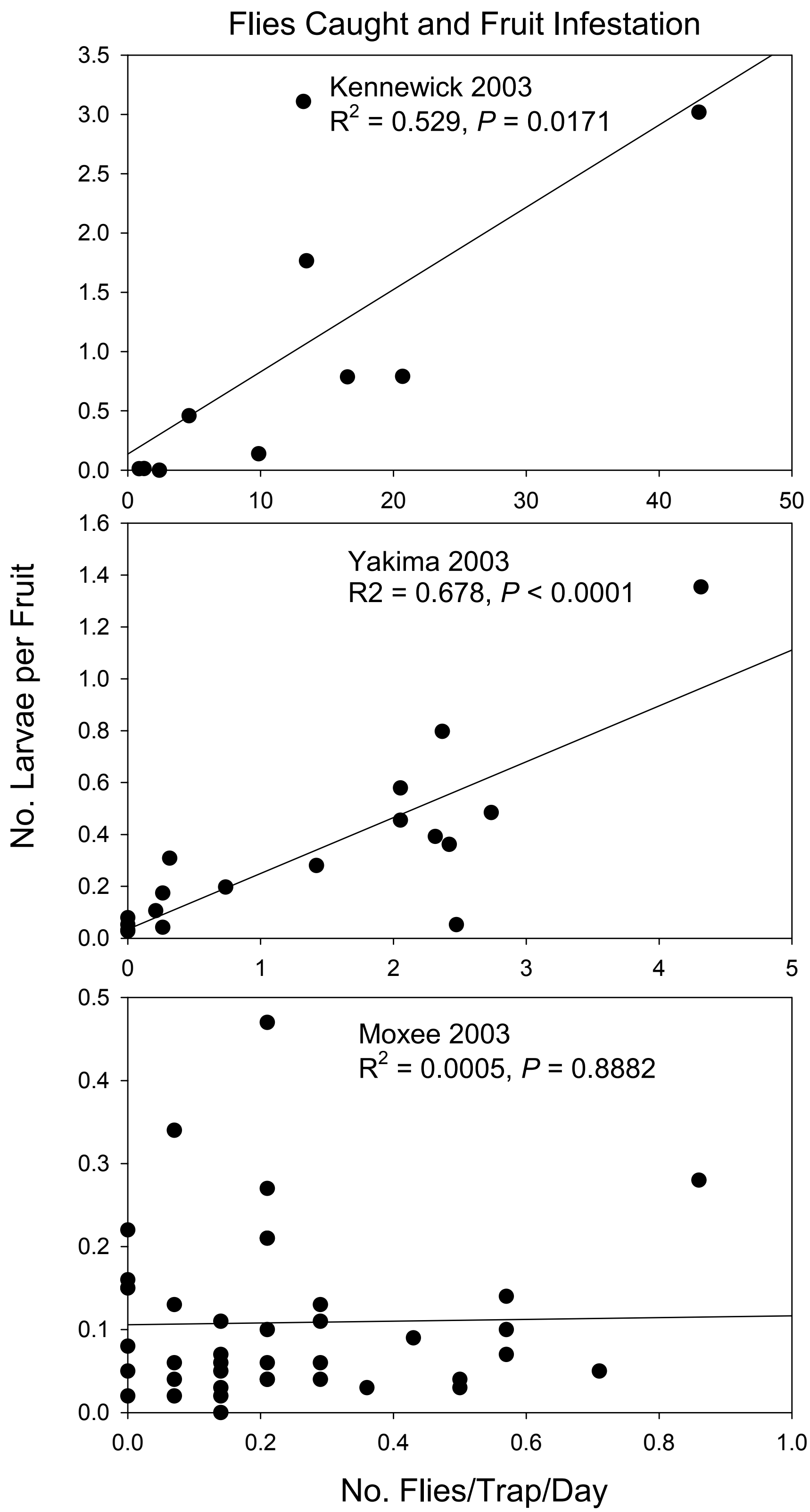


Fig. 3. Relationship between numbers of flies caught on red spheres and infestation of fruit, 2003.

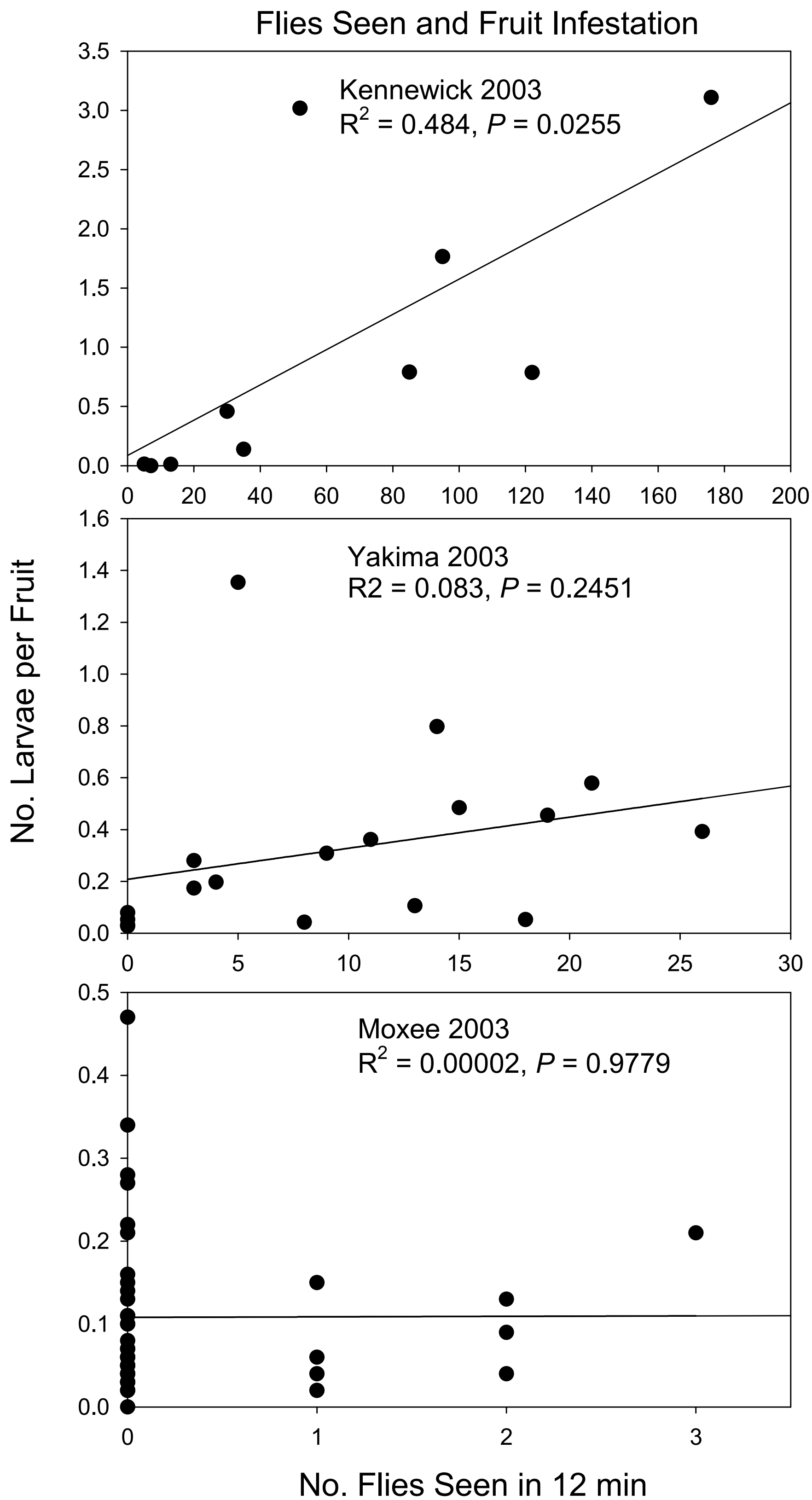


Fig. 4. Relationship between flies seen and infestation of fruit, 2003.

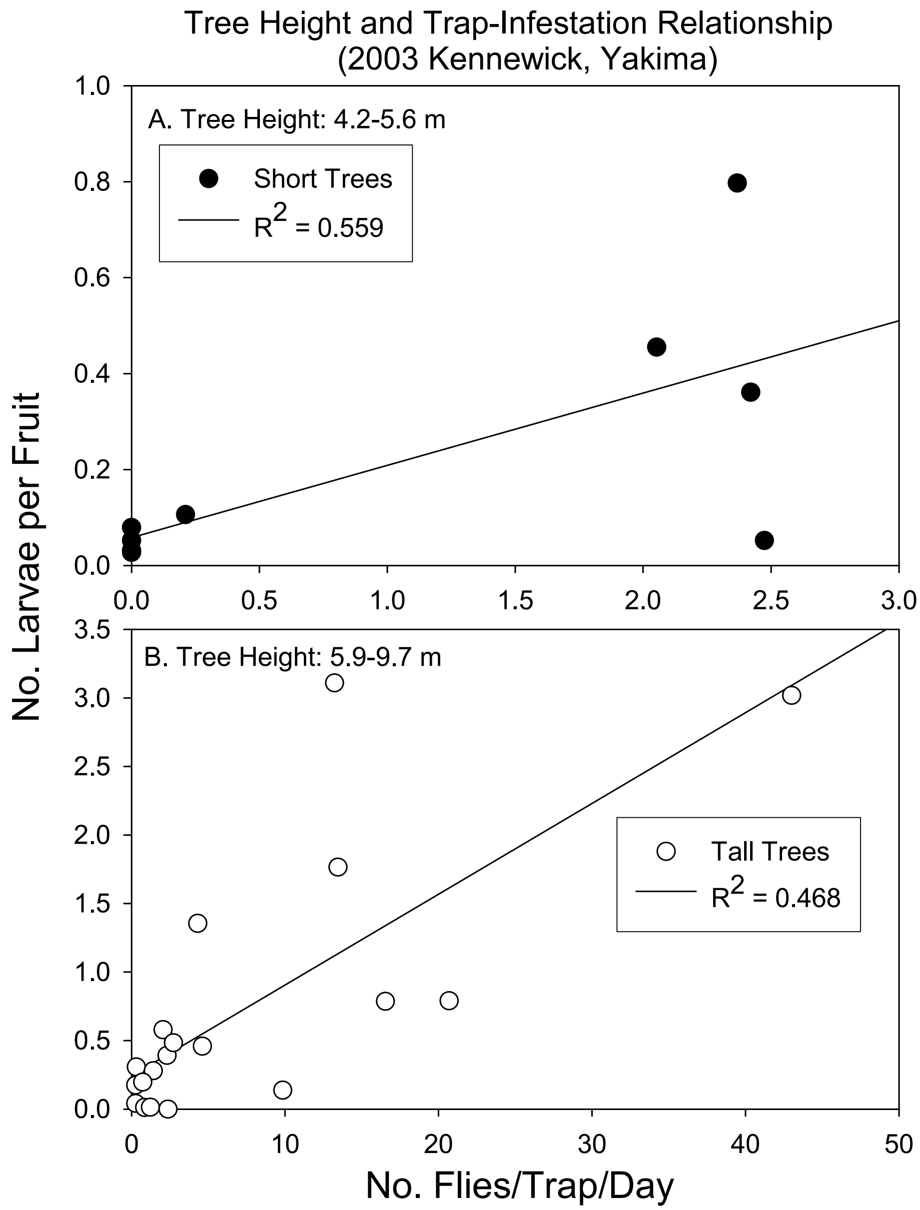


Fig. 5. Relationship between flies caught and infestation of fruit, 2003.

Budget:

Project title:	Cherry fruit fly distribution and trapping
PI:	Wee Yee
Project duration:	2002-2003
Current year:	2003
Project total (2 years):	**$22,660.72**
Current year requested:	**$12,660.72**

Year	Year 1 (2002)	**Year 2 (2003)**
Total	10,000	**12,660.72**

Current year breakdown

Item	Year 1(2001)	**Year 2 (2003)**
Salaries	9,000	**11,055.20**[1]
Benefits (%)		
Wages		**1,105.52**
Benefits (%)		
Equipment		
Supplies	1,000	**500**[2]
Travel		
Miscellaneous		
Total	10,000	**12,660.72**

[1]GS-5 ($11.84/h) and GS-3 ($9.42/h), full time, 3 months; [2]Traps

FINAL REPORT

Project title: Cherry Fruit Fly Control Options

PI: Timothy J. Smith
Organization: WSU Extension, North Central Washington
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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 a numbered product. Actara was identified as a soon-to-be-registered option, but not included due to non-interest by the registrant.

Objective 2: All products, rates and timings (listed below) were tested under pest pressure conditions far in excess of what would be expected in commercial orchards. All products tested proved highly effective, did not damage the fruit or foliage, did not appear to induce excessive mite damage, and some of the products appeared to control other important pests. Bait and Entrust applications proved to be effective, practical options for organic and conventional growers.

Objective 3: There are three or four new, effective products available for management of cherry fruit fly. It is likely that an additional three or four will be labeled in the next few years, some aided by the research funded through this project. These new products are in three different classes of insecticide.

Methods and materials:

Test sites: Two relatively small sweet cherry orchards documented as infested in 2002 were used as sites for replicated trials, with four to six single-tree replicates used for each timing and rate. One of these small orchards was utilized for the seven-day spray intervals with generally lower product rates, the other for ten-day spray intervals and higher product rates. Sixteen "back-yard situations," with a total of 61 infested trees, trapped and heavily infested in 2002, were included as rate and timing efficacy trials. Six of these highly infested sites, selected as most difficult spray application situations, were treated with GF-120NF bait only. Two relatively large commercial organic cherry orchards with a history of CFF infestation were included for demonstrations of newly registered, but untested, organically acceptable materials and application methods. Untreated check trees were left in both of the replicated trials and two of the "Backyard" trials. An isolated single abandoned cherry tree with the lowest documented 2002 trap catch (11) was left unsprayed to document the trap-catch increase potential (to 90+ in 2003) in other test sites. At the end of the test period, unsprayed trees were either stripped of fruit or sprayed with dimethoate to reduce or eliminate infestations.

Materials included in research: Acetamiprid (Assail) 1.7, 2.4 and 3.4 ounces product/A, 7 or 10 day spray intervals, thiacloprid (Calypso) 2, 4 and 6 fl ounces product/A, 7 or 10 day spray intervals, imidacloprid (Provado) 4 fl. oz. product/A, 7 day intervals, spinosad (GF-120NF Bait), 20 fl. ounces 0.02% ai product/A (about 0.13 grams active ingredient spinosad per acre), 7 day intervals, spinosad (Entrust) 1.25 ounces product/A, 7 day intervals, and a confidential numbered product, rate and other details a deep secret.

Application: All materials except bait were applied by a "Solo" backpack air-blast/mist sprayer at about 100 gallons per acre. The GF-120NF bait was applied in 2 – 17 acre test orchards with a 12 volt, electric pump, auxiliary sprayer strapped to the back of a "four-wheel" ATV motorcycle. Two adjustable-angle D3 disc nozzles directed streams of the bait/water mix across the middle of the tree. Calibration was somewhat difficult due to low application volumes, and as 10-12 MPH is not a traditional application speed. Generally, the 20 ounces per acre of bait was applied diluted in 1.75 to 2 gallons of water per acre to one side of every tree (alternate rows). Application time was about 2 minutes per acre. The side of the trees treated was alternated weekly. The six single to fifteen tree bait plots were baited with a 1:5 bait to water mix applied with hand-held "window washer" squirt bottles. One ounce of the mixture was applied to each test tree (1/5 ounce product per tree). Most of the bait test trees were significantly taller than those in a commercial orchard, so bait was applied no higher the lower 1/3 of the tree. No significant rainfall occurred during the bait application trials.

Results and discussion:
Objective 1: Product included in this project that is newly registered but not extensively tested in Washington: Provado. Products included in this project that are newly registered but not tested on cherry fruit fly: Entrust and GF-120NF Bait (organic options). Products included in this trial screening at the request of the registrant: Assail, Calypso, and a numbered product. Products not tested in this trial, soon to be registered, but not extensively tested: Actara.

Objective 2: All products, rates and timings (see tables 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. Trap catch numbers tend to be suppressed on infested trees by residual control products. See table 1 for a contrast between the trap catch numbers and year to year increase on treated and untreated trees.

In the "conventional" product tests, zero larval infestation was found in 9,600 fruit sampled from treated trees on 10 infested sites. Untreated trees had 4 to 9 percent of fruit infested.

Table 1. Conventional Product Results Summary:

Product	Ai/A	Product Rate/A	Spray Interval	# of Trees	# of Sites	# Fruit	Larvae Found	Adults Trapped in 2002	Adults Trapped in 2003
Untreated	0	0	NA	4	3	1100	64	44	102
Assail 70WP	33.7 g	1.7 oz	7	10	2	800	0	39	34
Assail 70WP	67.4 g	3.4 oz.	7	4	1	800	0	21	1
Assail 70WP	47.5 g	2.4 oz.	10	4	2	800	0	61	48
Assail 70WP	67.4 g	3.4 oz.	10	6	1	1200	0	12	3
Calypso 4F	28.3 g	2 fl. oz.	7	4	1	800	0	21	1
Calypso 4F	56.7 g	4 fl. oz.	7	4	1	800	0	21	1
Calypso 4F	85.0 g	6 fl. oz.	7	4	1	800	0	30	3
Calypso 4F	28.3 g	2 fl. oz.	10	3	2	800	0	40	13
Calypso 4F	85.0 g	6 fl. oz.	10	6	1	1200	0	12	3
Provado 1.6	22.7 g	4 fl. oz.	7	4	1	800	0	21	1
Numbered	NA	NA	7	5	1	800	0	30	3

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 damage. Some moderate leaf symptoms induced by mite feeding were observable by late summer on the trees treated with Provado, Assail, and Calypso.

Assail 3.4 oz/A, Calypso 4 and 6 oz./A, and Provado 4 oz./A applied at CFF control timing greatly suppressed well-developed black cherry aphid colonies. The lower rates of Assail and Calypso were less effective. As would be expected, Entrust and GF-120NF had no effect on black cherry aphid.

In organic product trials, no larvae were found in 2,400 fruit treated weekly with Entrust on “high pressure” sites, while untreated checks were 4 to 9 percent infested. GF-120NF bait application proved to be quite practical in both large acreage and single-tree applications. Of the six highly infested “backyard” situations treated weekly with the bait, one larva was found on the most “difficult” treatment site in a 700 fruit sample taken 10 days after the normal harvest date. On the five other bait treatment sites where an average of 50 adults were caught per trap in 2002, no larvae were found in 1,800 fruit following 2003 treatments.

Demonstration of effective commercial-scale organic CFF control was carried out in two orchards. One of the orchards had larvae found in the fruit in both 2001 and 2002, despite alternate day, maximum rate pyrethrum spray applications. Adults were trapped in this orchard each of the three weeks leading up to harvest in 2002. In 2003, the grower switched to weekly applications of 1.25 ounces per acre of Entrust starting four days after regional trap catches and the CFF model (Jones) indicated first adult emergence. Three weekly Entrust sprays were applied. As harvest neared, starting two days after the final Entrust application, 20 fl. oz./A GF-120NF bait mixed in 0.9 GPA water was applied weekly through harvest (three applications). A final “clean-up” Entrust spray was applied immediately post-harvest. No adults were caught on traps in the orchard and no larvae were found in fruit this year. The number of CFF spray applications by the grower dropped from sixteen in 2002 to seven in 2003. Material and application costs for CFF control were reduced from $1788/A in 2002 to $332/A in 2003.

A second organic orchard was involved to demonstrate the practicality of bait application to larger orchards. The bait was applied through the sprayer described above to a relatively steep, seventeen-acre orchard with various tree sizes and row spacings. Application took about 2 to 2.5 minutes per acre, and was completed on the 17 acres in about an hour, including mixing and loading. The applicator reported no problems during the five weekly applications.

The most significant application observations and suggestions resulting from the bait application demonstrations include:

1. The bait must be completely mixed with the water before it is placed into the spray tank.
2. The ATV should have a speedometer to aid evenness of application.
3. The two D3 nozzles at 10-12 mph, on alternate rows apply about 0.8 to 1.0 GPA of spray mix.
4. The spray stream travels as far as 22 feet, and can easily reach any portion of the tree.
5. Moderate wind does not affect application.
6. The sprayer driver should wear a safety helmet for protection against low hanging limbs.
7. This new technology is a great excuse to buy an ATV.

Table 2. Organic Product Results Summary:

Product	Ai/A	Product Rate/A	Spray Inter-val	# of Trees	# Fruit	Larvae Found	Adults Trapped in 2002	Adults Trapped in 2003
Entrust	28.3 g	1.25 oz.	7	4	1000	0	30	0
Entrust	28.3 g	1.25 oz.	7	5	1000	0	40	10
Entrust	28.3 g	1.25 oz.	7	1	400	0	16	4
Entr. Check	0	0	NA	1	400	16	40	10
GF-120NF	.005 oz.	20 fl.oz.	7	1	400	0	15	3
GF-120NF	.005 oz.	20 fl.oz.	7	15	700	1	90	12
GF-120NF	.005 oz.	20 fl.oz.	7	3	200	0	60	3
GF-120NF	.005 oz.	20 fl.oz.	7	1	400	0	14	23
GF-120NF	.005 oz.	20 fl.oz.	7	1	600	0	25	15
GF-120NF	.005 oz.	20 fl.oz.	7	1	200	0	150	13
GF Check	0	0	NA	1	300	28	11	90

Objective 3: Numerous "stone fruit" labels for products that are effective on CFF are recently approved or will be likely 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 two others.

Budget:
Project duration: 2003
Current year: 2003
Project total (1 year): $9,054

Item	Year 1 (2003)
Salaries[1]	**$6,264**
Benefits (34%)	**2,130**
Wages	**0**
Benefits (16%)	**0**
Equipment	**0**
Supplies[2]	**400**
Travel[3]	**260**
Miscellaneous	**0**
Total	**$9,054**

[1] Technician – three months salary – to find and secure test trees, assist application and assess infestation levels.
[2] Supplies include spray materials, traps, lab supplies and sprayer fuel.
[3] Travel – technician use of own vehicle at 250 miles per month reimbursed at .34/mile.

FINAL REPORT

Project title:	*Lygus* Bug and Thrips Ecology in Washington State Stonefruit Orchards Final Report 2001-2003
PI:	D.B.Walsh, Agrichem./Environ. Educ. Spec., WSU- Prosser
Organization:	WSU, Dept. of Entomology, IAREC, Prosser
Co-PI(s):	M. Bush, Coop. Ext. Agent, Yakima, County R. Wight, Field Research Dir., IR4 Project, WSU-Prosser

Objectives: *Lygus*

1. Compare Lygus sampling techniques for *Lygus* on the orchard floor.
2. Establish damage thresholds for *Lygus* on stone fruits in the Yakima Valley and Columbia Basin.
3. Attempt to fine tune the UC Lygus phenology model to fit eastern Washington Lygus populations.
4. Develop riparian habitats that will not serve as a point source for *Lygus* infestations.
5. (New for 2003) Evaluate the role of cover crop and orchard floor management on pest and beneficial abundance.

Objectives: Thrips

1. Screen candidate compounds for their ability to suppress thrips populations that are infesting stone fruit orchards. Candidate compounds include spinosyns, insect growth regulators, synthetic pyrethroids, and neonicotinyls.
2 Evaluate several sampling techniques to determine thrips abundance.
3 Develop a relationship between thrips feeding and fruit injury.
4 (New for 2003) Evaluate orchard floor insecticide/ herbicide treatments on thrips abundance

SIGNIFICANT FINDINGS- *LYGUS*

Orchard Sampling. In 2001, 2002 and 2003 several *Lygus* abundance sampling techniques were investigated. Techniques tested included sweep net samples of the orchard floor, beat sampling of trees, and colored sticky cards. Sweep net sampling of the orchard floor was the only technique tested that caught substantial numbers of *Lygus*. The use of colored sticky cards in measuring abundance of *Lygus* was not efficient at capturing Lygus.

Phenology Model. A phenology model currently used in California proved effective at predicting the first generation hatch of *Lygus* in late-May in Eastern Washington and the subsequent peak hatch event in mid-July. However, the model lost predictive accuracy as the season progressed and would provide little predictive value for when adult migration into orchards might occur in April or May.

Biological Control. A parasite *Peristenus* spp. attacks the nymph stages of Lygus and keeps individuals from reaching sexual maturity by emerging in the late instar nymph or early adult stage. Extensive surveys conducted by Walsh in 2002 and 2003 determined the presence of Lygus parasitism by *Persitenus* spp. in several important fruit production regions in Washington State. However, the results of the survey were disappointing in that levels of parasitism were low or not detected in several important stone fruit growing areas

SIGNIFICANT FINDINGS-THRIPS

Flight monitoring. Thrips flight activities were monitored in stonefruit orchards with yellow and blue sticky card traps in 2001 and 2002. Blue cards are proving to be significantly ($P<0.01$) more effective then yellow cards at catching western flower in stone fruit orchards. We have observed a definite orchard edge effect with the orchard floors bordering riparian buffers having significantly ($p<0.01$) greater populations of thrips then the orchard floor 92 meters inside the orchard. There were also significant ($P<0.05$) differences in abundance of thrips as measured by blue sticky card with the orchard floor having a greater abundance of thrips then cards placed in the canopy on both the orchard edge and 92 meters in.

Cover Crops. Replicated plots of 14 cover crop blends were established on the Roza unit at WSU IAREC in May 2003. We have documented significant differences among cover crop blends in their potential to build populations of western flower thrips.
Orchard floor treatments. Post-harvest orchard floor insecticide and herbicide treatments were inconclusive in their effect on the distribution of thrips population within the tree canopy.

SIGNIFICANT FINDINGS-RIPARIAN BUFFERS. We have developed considerable evidence that riparian areas are confirmed sources of hemipteran and thrips pests. These include both stinkbugs, (Jay Brunner, personal com), *Lygus* bugs and flower thrips (Walsh unpl. data). We have also documented an increase in the populations of several beneficial arthropods in riparian buffers. We have also identified host plant on which Lygus can complete development and feral plants around which the abundance of flower thrips are greater then plants that appear to be non-hosts for flower thrips

Methods: - *Lygus*

1. Lygus sampling. We compared several sampling techniques to assess Lygus populations in the riparian sites and nearby orchard floors in early spring to assess when adults became active and to determine when the first generation egg hatch takes place. Sampling techniques tested included sweepnet, colored sticky cards, whole plant quadrants, and insect vacuums.
2. Lygus damage thresholds. Sleeve cages were sewn in 2001 that covered 1 meter lengths of tree branch. Fruit was thinned so that constant ratios of *Lygus* to fruit can be maintained. Adult *Lygus* were introduced into the sleeve cages on apricot trees on May 21 at ratios of 0.8, 0.4, 0.2, 0.1, 0.067, 0.05 and 0 *Lygus* per fruit. Each cage treatment was replicated 4 times on apricot trees on May 21, 2001 and April 30, June 25, 2002. Cages were left on the trees for 2 weeks and when they were removed the branches
were treated with acephate. A damage assessment was taken just prior to commercial harvest.

Phenology Model. A phenology model currently used in California proved effective at predicting the first generation and subsequent hatch of *Lygus* in late-May in Eastern Washington and the subsequent peak hatch event in mid-July. This model has little predictive value for when adult migration into orchards might occur
in April or May.
Biological Control. A parasite *Peristenus* spp. attacks the nymph stages of Lygus and keeps individuals from reaching sexual maturity by emerging in the late instar nymph or early adult stage. Extensive surveys conducted by Walsh in 2002 and 2003 determined the presence of Lygus parasitism by *Persitenus* spp. in several important fruit production regions in Washington State. However, the results of the survey were disappointing in that levels of parasitism were low or not detected in several important stone fruit growing areas.
Orchard floor cover crops. Replicated plots of 14 cover crop blends were established on the Roza unit at WSU IAREC in May 2003. Irrigation was applied by handline sprinklers and irrigation was applied to mimic recommended orchard management practices. Sweep net surveys were conducted every 2 weeks and the number of Lygus, thrips and spiders captured was quantified and calculated.

Methods- Thrips

1. Insecticide efficacy. An insecticide efficacy trial was established in a nectarine orchard in the lower Yakima Valley to test the post fruit set efficacy of registered and candidate compounds on flower thrips. Registered compounds that will be screened include endosulfan, carzol, and spinosad. Candidate compounds tested include lamda-cyhalothrin, pyriproxifen, thiamethoxam, and novoluron. Insecticides were applied by hand wand at 100 gallons per acre to 6 one tree replicates. Shake samples were taken taken prior to and at timed intervals following insecticide application.

Orchard floor insecticides and herbicides were applied post harvest to determine their effect on the distribution of thrips in the tree canopy.

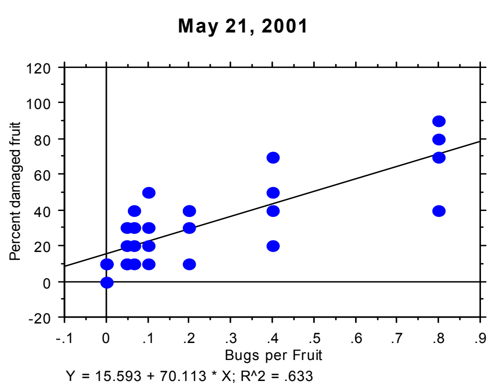
2 Insecticide residual. A primary constraint for efficacy studies on thrips on tree fruits is inconsistency in pest distribution. Following insecticide application we caged 4 individual fruit per tree/replicate in the orchard. Into these cages we placed approximately 10 immature thrips. These individual treated fruit were collected several days prior to commercial harvest. The fruit was evaluated and graded for thrips damage.

3. We have tested several techniques for evaluating thrips population abundance in stone fruits and other crops. Techniques tested have included several colors of sticky card traps, a beating sample, a water shake sample, and an alcohol shake sample. We will adapt these techniques to provide recommendations for sampling thrips abundance in stonefruit orchards.

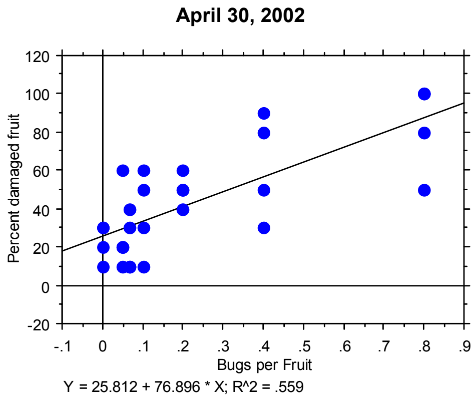
RESULTS/ DISCUSSION LYGUS-2001-2003

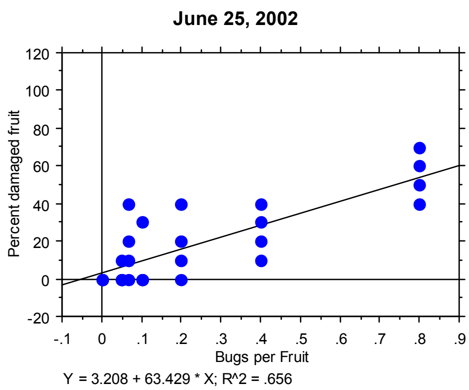
Lygus have an extensive host range of both native and exotic plants. In extensive field surveys conducted during summer of 2001, 2002, and 2003 we have observed a greater abundance of *Lygus* in riparian field sites directly adjacent to orchards with established stands of exotic flowering weedy plants then in sites comprised mainly of bunch grasses or native shrubbery. This research has enabled us to develop a list identifying which introduced and native plants are serving as alternate hosts for *Lygus*.

Lygus feeding has been likened to chemical injury. *Lygus* feeding damage in stonefruit orchards is a significant concern after fruit set Branch cage studies in 2001 and 2002 have helped quantify proportional *Lygus* abundance to fruit damage. Sleeve cages were sewn in 2001 that covered 1 meter lengths of tree branch. Fruit was thinned so that constant ratios of *Lygus* to fruit can be maintained. Adult *Lygus* were introduced into the sleeve cages on apricot trees on May 21 and April 30, June 25, 2002 at ratios of 0.8, 0.4, 0.2, 0.1, 0.067, 0.05 and 0 *Lygus* per fruit. Each cage treatment was replicated 4 times on apricot trees on each date. Cages were left on the trees for 2 weeks and when they were removed the branches were treated with acephate. A damage assessment was taken just prior to commercial harvest. Lygus damage was noted if necrotic feeding spots were present below the fruit surface.



Lygus feeding injury results of regression analysis between the ratio of adult Lygus bugs per fruit to the percent of fruit observed to





<u>Biolgical control</u>. A parasite attacking Lygus spp. was discovered in 1995 in Washington State and subsequent collections in Parma, Idaho in 1996 and 1997 showed that the parasite was present (Mayer unpublished data). The parasite has been described as *Peristenus howardi* Shaw (Hymenoptera: Braconidae), a new species . Previously, *Peristenus pallipes* Curtis was reported from Idaho. However, recent taxonomic work on the genus indicates that these may have been misidentified. *Peristenus* spp. attacks the nymph stages of Lygus and keeps individuals from reaching sexual maturity by emerging in the late instar nymph or early adult stage.

Collections made in 2000 (Mayer, unpublished data) did not document the parasite's presence beyond the Touchet, Washington and Parma, ID regions. Extensive surveys conducted by Walsh (AE News 2003) in 2002 and 2003 determined the presence of Lygus parasitism by Persitenus spp. in several important fruit production regions in Washington State. However, the results of the survey were disappointing in that levels of parasitism were low or not detected in several important fruit growing areas Extensive surveys in 2002 and 2003 determined the presence of Lygus parasitism by *Persitenus* spp. In total over 75 sites were surveyed and over 8,000 Lygus were dissected to determine if *Peristenus* spp were present. Parasitism by of Lygus by *Peristenus* was greatest in areas that were less disturbed by human activity.

Phenology Model. A phenology model Walsh helped develop in 1990 (www.ipm.ucdavis.edu) proved effective at predicting the first generation hatch of *Lygus* in spring in Eastern Washington (Table 1) and the subsequent peak hatch periods for the 2nd and 3rd generations of Lygus in 2001, 2002, and 2003. In running this model degree days are accumulated starting on March 1 with 54° Fahrenheit serving as a horizontal lower-cutoff for development. Eggs laid by adult Lygus in late-winter will require approximately 252 degree days in order to hatch. This corresponded well with when we observed our 1st generation of nymphs in both orchards and in our riparian survey sites

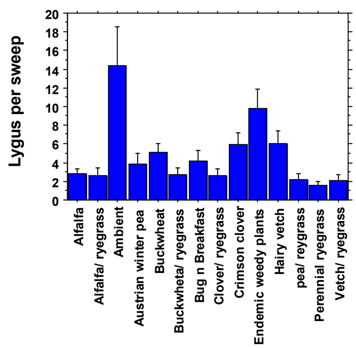
(Table 1) in mid to late May. Although this model proved fairly effective at predicting hatch periods for Lygus during the summer months it has been our observation that the majority of feeding injury on tree fruits is caused by adult Lygus and that this model does little towards predecting when adult Lygus will migrate into tree fruit orchards. Rather rainfall patterns and the subsequent dry-down of the over-wintering hosts of Lygus is a prime cause of spring movement of adult Lygus. During the summer months harvest of field and forage crops (primarily alfalfa) also contributes to movement of adult Lygus.

Table 1. Cumulative degree day accumulations 54°, predicted dates of peak hatch for the 1st, 2nd, and 3rd generations of Lygus and the actual average number of Lygus caught per sweep among all of the samples taken bi-weekly at our riparian survey sites (n=72) for 2001 and 2002.

	2001			**2002**		
Date	Cumulative DD	Model Prediction	Nymphs /sweep	Cumulative DD	Model Prediction	Nymphs / sweep
March 1	0		n/a	9		n/a
April 1	35	(1st adult 4/2)	n/a	27	(1st adult 4/9)	n/a
April 15	39		n/a	69		n/a
May 1	109	1st hatch	0	119	1st hatch	0
May 15	198	(May 23)	0	166	(May 27)	0
June 1	384		**1.6**	307		**0.6**
June 15	484		1.2	473		1.3
July 1	675		0.8	713		1.5
July 15	961	2nd hatch	1.3	991	2nd hatch	**3.2**
August 1	1196	(July 23)	**3.0**	1351	(July 17)	0.3
August 15	1513		1.6	1573		1.2
September 1	1784	3rd hatch	0.7	1870	3rd hatch	**3.4**
September 15	1984	(Sept. 8)	**2.4**	2052	(Sept. 8)	1.3
October 1	2153		1.2	2173		1.3
October 15	2215		0	2235		0
November 1	2237		0	2272		0
		2003				
March 1	0		n/a			
April 1	50	(1st adult 4/2)	n/a			
April 15	84		n/a			
May 1	131	1st hatch	0			
May 15	194	(May 25)	0			
June 1	360		**1.3**			
June 15	555		1.5			
July 1	758		0.6			
July 15	987	2nd hatch	0.9			
August 1	1370	(July 22)	0.8			
August 15	1619	3rd hatch	2.1			
September 1	1900	(Aug 22)	3.2			
September 15	2074		**6.1**			

Orchard floor cover crops. Replicated plots of 14 cover crop blends were established on the Roza unit at WSU IAREC in May 2003. Cover crop blends included perennial rygrass, buckwheat, buckwheat/ryegrass, alfalfa, crimson clover, hairy vetch, alfalfa/ryegrass, clover/ryegrass, vetch/ryegrass, Austrian winter pea, pea/ryegrass, Bug n Breakfast, and naturalized and endemic weeds. Irrigation was applied by handline sprinklers and irrigation was applied to mimic recommended orchard management practices. Sweep net surveys were conducted every 2 weeks and the number of Lygus, thrips and spiders captured was quantified and calculated. In total the cover crop plots were sampled 6 times on 30 June, 14 July, 29 July, 12 August, 9, September and 22 September respectively. Analysis of variance demonstrated that there were no significant differences in Lygus populations among the sample dates so all the dates were pooled.

Lygus bugs per sweep- all sample days pooled



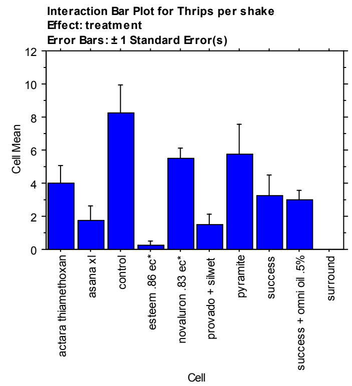
In 2003, the "Ambient" and "Endemic weedy plants consisted primarily of pigweeds and barnyard grass. These plots are essentially the same but have extra plots will prove helpful in the future as we expand these studies. We can conclude that all of the cover crops were superior to no weed control in reducing populations of Lygus bugs as estimated by sweep net samples.

RESULTS/ DISCUSSION- Thrips 2001, 2002, and 2003

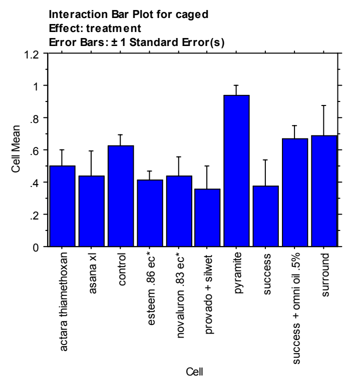
2001. An efficacy trial was established in a nectarine orchard in the Columbia Basin at which 9 insecticides were evaluated for their ability to suppress thrips on nectarines. Insecticides were applied on July 27, 2001 with a handgun sprayer to runoff.

Insecticide efficacy was measured in 3 ways. (1) shake samples of branches were taken 3 days after insecticide application. (2) To measure insecticide residual sleeve cages made of floating row crop cover were placed over 4 individual fruit per replicate tree 3 days following insecticide application. Approximately 10 western flower thrips were then placed into each individual cage. The cages were then left on for 1 week. After which the individual fruit were picked, transported to IAREC and evaluated for thrips feeding damage. (3) An equivalent number of representative non-caged fruit were harvested at the same and transported to IAREC and evaluated for the presence of thrips feeding injury.

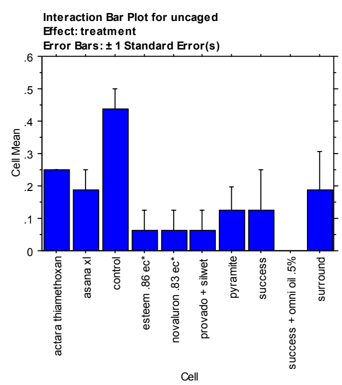
Formulated product	**Active ingredient**	**lb ai/Acre**
Novaluron 0.83 EC	novaluron	0.039
Esteem 0.86 EC	pyriproxyfen	0.11
Success	spinosad	0.156
Success + Omni oil 0.5%	spinosad	0.156
Asana L	esfenvalerate	0.075
Provado + Silwet	imidacloprid	0.10
Surround	kaolin	50 (product)
Actara	thiamethoxam	5.5 oz (product)
Pyrimite	pyribaden	0.3
Untreated control		



Results for thrips shake samples 3 days after insecticide application on July 30, 2001. Actara, Asana, Esteem, Provado, both Success treatments and Surround provided significant control (p<0.01) of thrips compared the untreated control in pairwise *t*-tests.



Results of damage assessment of caged fruit. Approximately 10 thrips were placed w/i individidual fruit cages for 1 week. No insecticide treatment provided effective residual and prevented thrips feeding injury compared to the no treated control in this study



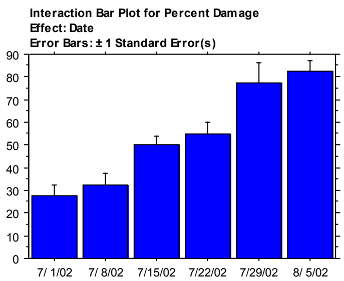
Results of damage assessment of non-caged fruit..All of the insecticides provided significant (*p*<0.01) control of thrips and prevented thrips feeding injury compared to the non treated control in pairwise *t*-tests in this study.

Insecticide Efficacy 2002

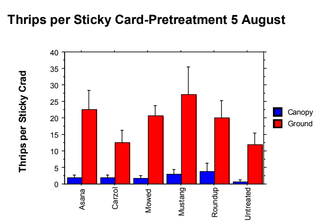
Two insecticide trials were established in 2002. The first was established in early April in the Mesa, WA area. A late frost devastated the orchard about 3 days after we made the applications. A second trial was established in Sunnyside, WA on 4/26/02 and the following insecticides were applied

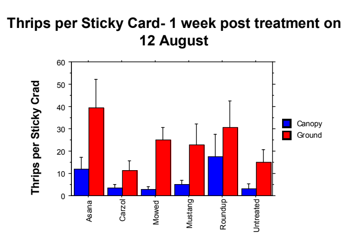
Formulated product	Active ingredient	lb ai/Acre
Success + Omni oil 0.5%	spinosad	0.156
Carzol	Formetanate-hydrochloride	2 # product
Actara	thiamethoxam	5.5 oz (product)
Fujimite	fenpyroximate	0.15
Asana L	esfenvalerate	0.075
Untreated control		

Shake samples of branches were taken 3 days after insecticide application and sticky cards were placed in the tree canopy. No differences in thrips populations were observed within this trial **Temporal Thrips feeding injury.** In 2002 we designed a sequential sample experiment in which we established cages weekly from July 1, 2002 through August 5, 2002. Cages were placed over individual fruit on control trees. Fifteen to 20 thrips were placed into 10 per tree to total 40 cages each week. On August 8, 2002 the fruit were removed from each cage site and rated for thrips feeding injury. Damage from thrips feeding in these no choice tests increased with fruit maturity though the month of July and demonstrates that late-season suppression of thrips is important at high population densities.



Orchard floor treatments. The orchard floor of a late bearing cherry orchard was treated post harvest with some candidate compounds, roundup and mowing to determine if these treatments changed the distribution of thrips within the canopy. The treatments included Carzol, Asana, Mustang-Max, Roundup, and mowing. Pretreatment samples determined that populations were fairly low as measured with yellow sicky cards place at 5 inches above the soil surface and 5 feet in the canopy. Cards were placed out on 2 August, 2003 and were removed on 5 August. Subsequently all of the treatments and mowing were applied on 5 August 2003. A post-treatment 3 day sticky card samples were taken on 12 August.





These treatments were inconclusive and will require repeating.

Thrips Sampling. Thrips flight activities were monitored in a peach orchard in the Yakima Valley near Wapato and at a peach and a nectarine orchards near Mesa. This study was run in conjunction with other projects that we had ongoing on thrips management on several other crops comparing blue or yellow sticky cards as a monitoring tool. At present thrips abundance has been counted on 320 blue cards and 320 yellow cards in or near stonefruit orchards. Blue cards are proving to be significantly (P<0.01) more effective then yellow cards at catching western flower thrips in or near stonefruit orchards.

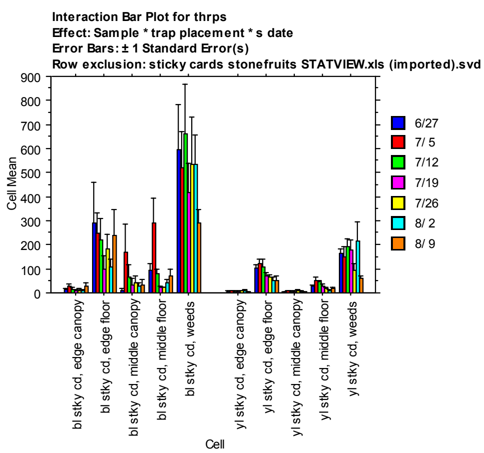
ANOVA Table for thrps

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Sample	1	918090.000	918090.000	44.715	<.0001	44.715	1.000
Residual	638	13099350.000	20531.897				

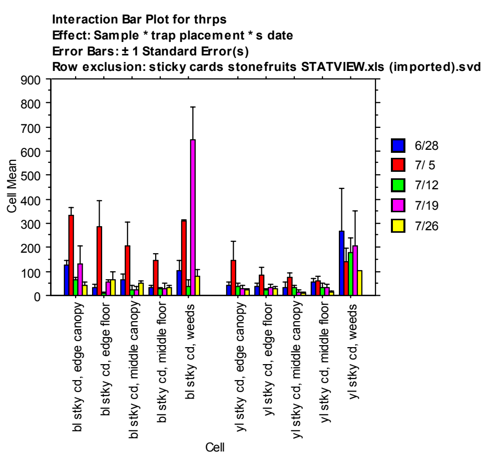
Means Table for thrps
Effect: Sample

	Count	Mean	Std. Dev.	Std. Err.
bl stky cd	320	128.375	189.163	10.575
yl stky cd	320	52.625	72.671	4.062

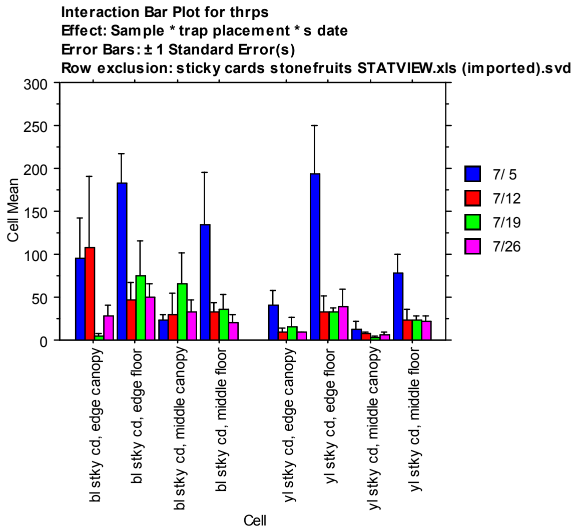
At each orchard site blue and yellow sticky cards were placed weekly in weeds near the orchards edge, on the orchard floor and canopy on edge of the orchard and on the floor and canopy of trees 160 feet in the orchard. At each site the blue cards consistently caught more thrips then the yellow cards and the greatest abundance of thrips was observed in nearby "weeds" followed by cards placed on the edge of the orchard floor.



Results from sticky card traps collected weekly from a peach orchard near Wapato, WA. The counts are the number of thrips captured per 5" by 3" sticky card in the 72 hours prior to the day listed. There is a definite edge effect with utilizing sticky cards to estimate thrips populations in this orchard

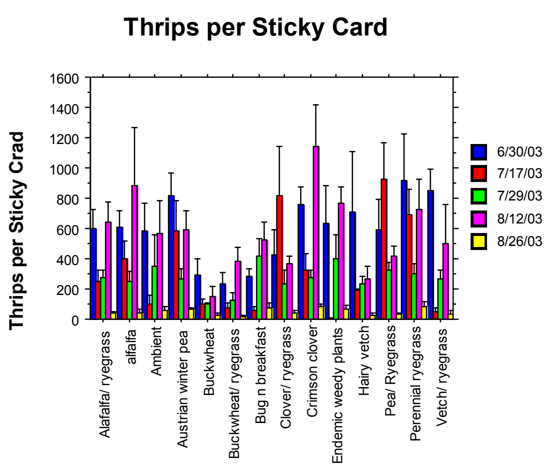


Results from sticky card traps collected weekly from a peach orchard near Mesa, WA. The counts are the number of thrips captured per 5" by 3" sticky card in



Results from sticky card traps collected weekly from a nectarine orchard near Mesa, WA. The counts are the number of thrips captured per 5" by 3" sticky card in the 72 hours prior to the day listed.

Orchard floor cover crops. Replicated plots of 14 cover crop blends were established on the Roza unit at WSU IAREC in May 2003. Cover crop blends included perennial rygrass, buckwheat, buckwheat/ryegrass, alfalfa, crimson clover, hairy vetch, alfalfa/ryegrass, clover/ryegrass, vetch/ryegrass, Austrian winter pea, pea/ryegrass, Bug n Breakfast, and naturalized and endemic weeds. Irrigation was applied by handline sprinklers and irrigation was applied to mimic recommended orchard management practices. Sweep net and yellow sticky card surveys were conducted every 2 weeks and the number of thrips and captured was quantified and calculated. In total the cover crop plots were sampled 5 times on 30 June, 14 July, 29 July, 12 August, and 9, September respectively. Population estimates on sticky cards varied across dates and within plots. However, thrips populations tended to be reduced in buckwheat/ buckwheat combination plot. Since this was the establishment year for these plots we will have to see how things change as the cover crops mature over the next several years.



FINAL REPORT
WTFRC Project #: CH-01-14 **Organization Project #: 13C-3361-5291**

Project Title: Protecting Pacific Northwest cherry orchards from serious virus threats.

Principal Investigator:
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Organization: Washington State University – IAREC, Prosser
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Co-Investigator & Affiliation:
Bill Howell, Manager NRSP-5, WSU-Prosser

Cooperators: Various growers

Project Objectives:
Develop a strategy to control the rapid decline of cherry trees associated with *Cherry leaf roll nepovirus.*

a) Determine transmission mechanisms for *Cherry leaf roll virus* in orchards of the Pacific Northwest and conditions affecting the disease development associated with this virus.
b) Initiate small-scale trial to determine symptoms of *Cherry leaf roll virus* on new and promising cherry cultivars.

Determine the biology of an emerging and very severe virus disease of cherries in the Columbia River Valley.

a) Determine sources of an emerging virus disease in Central Washington and the impact of these diseases on cherry varieties and rootstocks.
b) Develop diagnostic capabilities suitable for monitoring little cherry viruses in orchards of the northwest.

Significant findings:
Project Objective 1:

- A rapid decline of trees of sweet cherry trees is induced by *Cherry leafroll virus* in association with one or more of the *Ilarviruses* that are common in Pacific Northwest cherry orchards (i.e., *Plum American line pattern*, *Prunus necrotic ringspot* and *Prune dwarf ilarviruses*).
- Most trees exhibiting significant *Cherry leaf roll virus*-induced decline are 12 to 25 years old.
- No *Cherry leaf roll virus* is detected in registered mother trees in nurseries participating in the Washington certification program.
- *Cherry leaf roll virus* is pollen-borne. However, the exact mechanism by which this virus is naturally transmitted to cherry trees remains to be determined.
- A voluntary monitoring program was established to keep *Cherry leaf roll virus* out of commercial pollen sources.
- Identification of *Cherry leaf roll virus* in the Pacific Northwest, and recognition of the impact that it can have on sweet cherry production led to an industry-wide survey funded by the Commission.

Project Objective 2:

- *Little cherry virus-4* has been identified in sweet cherry trees of Washington and Pennsylvania. This was the first detection of this virus in the US. This is significant because the means by which *Little cherry virus-4* spreads in the orchard is unknown.
- Western X disease has re-emerged as a major disease of sweet cherry production. This follows a series of unusually mild and dry winters.

- We developed a laboratory test to detect trees infected with a new, rapidly spreading virus in the mid-Columbia Basin. Aggressive tree testing and removal has contained the virus.
- The development of more sensitive testing methods has revealed the presence of *Apple chlorotic leaf spot virus* associated with several instances of declining cherry trees.
- *Tobacco ringspot virus* was identified for the first time in cherry trees in Washington State. Correct identification resulted in tree removal.

Results and discussion:
Cherry production underwent an ambitious revitalization program during the early 1950's. To restore productivity of an ailing industry, trees affected with virus-like diseases were removed throughout the Northwest cherry growing districts. With the advent of certification programs in the early sixties, the incidence of virus diseases abated significantly. However, the emergence of several "new" viruses and the re-establishment of others have resulted in significant reductions in yield and profitability for affected cherry producers.

Objective 1: Our research revealed the presence of a virus that had not been detected in our orchards before. The symptoms of *Cherry leaf roll virus* by itself are not dramatic in the common cherry varieties grown in the Pacific Northwest. Virus infection does reduce tree vigor and yield, and the fruit is small and late ripening, but there are no intense disease symptoms. However, infected trees are weakened, and delayed fruit ripening with poor fruit size complicates orchard management.

There is another group of the viruses (the *Ilarviruses*) that are pollen-borne, and very common in all cherry production areas of the world. These viruses include *Prunus necrotic ringspot virus* and *Prune dwarf virus*. Because of the pollen-borne nature of these viruses, most orchard trees become infected with one or more of these viruses by the time the orchard is 15 years old. Since the trees are already mature and productive, the modest impact on production is largely tolerated. A third pollen-borne *Ilarvirus* is *Plum American line pattern virus*, but this is very rare in our production blocks. Our research has revealed that when one or more of these three viruses are present in a tree that is also infected with *Cherry leaf roll virus*, the mature and otherwise productive sweet cherry trees begin a period of rapid decline that ultimately results in their removal from the orchard.

The walnut isolate of *Cherry leaf roll virus* is known to be widespread in walnut in California where it causes significant financial losses, but our discovery of the cherry isolate of *Cherry leaf roll virus* was the first in this continent. Consequently, it was necessary to very quickly learn critical information so that growers could manage their orchards effectively.

A molecular-based laboratory test was developed that allowed us to confirm the identity of the virus as the cherry isolate of *Cherry leafroll virus* and to begin limited testing. These early results indicated that the isolates from several disparate locations in the Yakima Valley were identical. Antisera from laboratories around the world were acquired and evaluated for their ability to detect local strains of the virus. Antisera from the walnut isolates in California reacted only weakly with our local cherry strain and hence were of no value for routine testing. Test reagents for the elderberry strain reacted reasonably well with the cherry isolate. However, sensitivity and reliability of the serological ELISA was increase substantially when antisera specific for the cherry isolate was located from a European source and imported for our diagnostic purposes. Extensive virus testing was used to determine the distribution of *Cherry leaf roll virus* within infected trees, and to determine the most appropriate sampling methods for virus detection. This included determining the part of the season when virus detection is most reliable, the type of tissue that provides the most reliable results and the number of samples that must be collected from each tree for accurate detection. This critical information was then used as the basis for all subsequent tests, including the current industry-wide survey.

In Washington, 928 trees were sampled representing 48 separate production blocks of sweet cherry. [Note: this does not include the trees tested as part of the WTFRC-funded industry survey initiated in 2003.] Of more that 200 trees that tested positive for *Cherry leaf roll virus,* only five trees had been in the orchard for less than 7 years. Similarly, only a very small number of infected trees were more than 30 years old. Sites of *Cherry leaf roll virus* infections were in blocks throughout the lower Yakima River Valley and the lower Columbia basin ranging from Union Gap to Mesa.

Within the blocks that contained the virus, the incidence of *Cherry leaf roll virus* ranged from less than 1% to 32% of the trees infected. Through discussion with growers and fieldmen, it appears that the symptoms in the most severely affected blocks were first observed about 10 years ago.

It is difficult to develop a clear picture of the rate of spread of *Cherry leaf roll virus* since data is available for such a short period. As part of creating a baseline from which to monitor virus spread, large plots in three blocks were mapped in great detail. Every tree was tested for *Cherry leaf roll virus* plus three common *Ilarviruses*. Every tree in these blocks was re-tested in each of two subsequent years. Now there is clear evidence that *Cherry leaf roll virus* does spread naturally in the orchard. However, continued monitoring will be required to obtain an estimate of the rate of spread.

In addition, registered mother trees in the WSDA Certification program were tested for *Cherry leaf roll virus*, and all were free of this virus.

Cherry leaf roll virus belongs to a group of viruses that are predominantly transmitted by nematodes and/or by pollen. We identified the presence of a potential nematode vector, *Xiphinema rivesi*, in several of the affected orchards. However, three years of screenhouse and orchard trials did not reveal any transmission of the local strains of *Cherry leaf roll virus* by this nematode. In California, the walnut strain of *Cherry leaf roll virus* is pollen transmitted. Because there are significant differences in virus strains and pollen physiology (*i.e.* wind versus insect borne pollen), this assumption cannot be applied automatically to the situation in cherries. Our previous research confirmed that pollen from *Cherry leaf roll virus*-infected trees is ELISA-positive. Moreover, the virus in this form is infectious and is able to initiate infection when virus-laden pollen is mechanically rubbed onto experimental herbaceous hosts or when pollen from infected trees is applied to herbaceous plants in the presence of thrips. We are currently conducting research to resolve whether thrips can mediate the transmission of *Cherry leaf roll virus* from pollen to young cherry trees.

The mechanism by which the disease is spreading requires further study. However, the pattern seen in the distribution of infected trees has been very distinctive. An initial infection develops in an orchard, potentially several miles from any known source of infection or other cherry trees. Once established, disease radiates outward slowly from the initial infection site to adjacent trees. Initially, only one or two shoots of a newly infected tree will express symptoms, but eventually, all of the major scaffold limbs become involved.

Studies of this virus are still in their initial stages. However, from the early results of some grower efforts, it appears that tree removal is a viable strategy for stopping the spread of this virus. However, it has also become evident that such tree removal efforts must be aggressive, and infected trees completely removed at the first indications of symptoms. Of course, it is prudent to confirm the identity of the pathogen before removing the tree.

Objective 2: Through frequent contact with growers and fieldmen, we have become aware of several disease situations in the sweet cherry industry. We actively investigated these instances to determine the nature of the pathogen involved, and to provide information on its control, when available, to the grower.

Foveaviruses: In a Central Washington orchard, a virus disease emerged that induced severe die back of shoot tips and even major scaffold limbs, leaf loss, small fruit that is late ripening and dramatic foliar symptoms. The wood cylinder of the 'Montmorency' interstock was severely pitted.

Within 4 years, this disease spread through a significant portion of an otherwise productive 12-year old sweet cherry orchard and more than 170 mature trees were removed. This aggressive tree removal by the grower significantly slowed the spread of diseased trees, but continued monitoring is essential to determine the potential long-term impact of this virus. We developed a molecular laboratory test that is adequate for a limited number of samples, but more accessible diagnostic methods should be developed.

We partially characterized the genome of this virus and determined that it is part of the rusty mottle group of cherry viruses. That is, this virus is related to *Cherry rusty mottle virus*, *Cherry necrotic rusty mottle virus*, and *Sour cherry green ring mottle virus*. These viruses form a cluster of related but distinct viruses that infect cherry trees.

***Western-X disease**:* In the 1950's, Western X disease was widely prevalent in the sweet cherry industry, to the degree that survival of an economically viable industry was threatened. This situation was one of the factors that precipitated a statewide effort to eliminate virus-infected trees and led to the establishment of the State certification program. This disease is caused by a form of bacteria (phytoplasma) that behaves, in many respects, like a virus. It is transmitted by any one of three species of leafhopper and over-winters in a number of weedy plants. A series of warm dry winters has led to a resurgence of this disease. Infected trees produce small, poorly colored cherries that do not ripen. There may be additional symptoms that are specific to different cherry varieties and rootstocks. It is difficult to control the transient populations of leafhopper that can first introduce Western X disease into an orchard, but their control in the orchard throughout the growing season plus identification and removal of infected trees are essential elements of a program to stop spread of this disease within the orchard.

Little cherry disease: Little cherry disease is causing significant crop losses in some orchards of the Pacific Northwest. The little cherry disease virus that is common here is *Little cherry virus-3.* This virus is spread by the apple mealybug and the spread of the virus can be significantly reduced or stopped by controlling this insect. However, during our studies, we revealed the presence of a very different virus that can be associated with this disease, *Little cherry virus-4.* The disease symptoms caused by these viruses are very similar, but the viruses themselves are different and actually belong to different virus genera. The spread of *Little cherry virus-4* can be very rapid as was seen in northern Germany in the 1990's. However, unlike *Little cherry virus-3,* the means by which this virus is spread is unknown so no specific control measure can be recommended.

We developed laboratory tests that identify and distinguish between the three pathogens that cause little cherry diseases: *Little cherry virus-3*, *Little cherry virus-4* and Western X phytoplasma. Although the tests are time consuming and expensive, they are available on a very limited basis and allowed us to determine that these three pathogens are currently in our industry causing substantial economic loss to individual growers.

Apple chlorotic leafspot virus: This virus occurs frequently in older apple trees where it causes little or no production difficulties in most varieties. Although it is also known to infect *Prunus* species, it was not thought to be very important in sweet cherry production. Our recent efforts have revealed the presence of *Apple chlorotic leafspot virus* in several cherry orchards exhibiting a variety of disease symptoms from severe ring spot and leaf necrosis to tree decline. We are improving our diagnostic capabilities to allow us to better detect and investigate the role of this virus in diseases of sweet cherry. The importance of this virus in sweet cherry production may have been seriously underestimated.

Clearly, viruses are not involved in every case of orchard decline. However, it is important to recognize when viruses induce or contribute to tree decline or reduced orchard income. It is also critical to know which virus(es) are involved in orchard decline in order to take appropriate measures to save the substantial capital investment represented by orchard trees.

Project budget:
The total funding received from the Washington Tree Fruit Research is summarized below:

Item	**3-Year Total (2001-03)**
Salaries	$34,182
Benefits	$11,021
Wages	---
Benefits	---
Equipment	---
Supplies	$21,409
Travel	---
Miscellaneous	---
TOTAL RECEIVED	$66,612

The National Research Support Project 5 made substantial in-kind contributions of virus-free research material, access to tree fruit virus collections, plus labor and expertise required for much of the virus testing and transmission studies. USDA-CSREES provided $31,668 for 1 year to expand the level of testing for *Cherry leaf roll virus* in the 3 western cherry producing States of Washington, Oregon and California. The Nursery License Research Fund administered by the Washington State Department of Agriculture has provided $14,145 for the first 2 years of a *Cherry leaf roll virus* transmission study. Washington State University provided significant levels of infrastructure and technical support through the duration of this project.

CONTINUING PROJECT REPORT YEAR 2/2
WTFRC Project # CH-03-301

Project title: Eliminating Cherry Leafroll Disease from Pacific Northwest Orchards

PI: Michael Bush
Organization: Washington State Univ., Coop. Extension, Yakima County
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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 two 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.

Producers and fieldmen often characterize the symptoms expressed by cherry trees infected with CLRV as generic tree decline. Some of the symptoms that have been 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.

The leading activity during the winter months of 2003 was an educational program to introduce CLRV to cherry producers, agricultural consultants and cherry fieldmen throughout the Pacific Northwest. The goals of this activity 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 understood and thought to be limited. 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 2,500 to 3,000 meeting participants. Speakers made it clear that this virus will negatively impact production and that prompt identification and removal of these infected cherry trees can 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 and Chuck Peters were hired for the role; Denny Jones 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 3,000 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 200 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. Initially 100 notebooks were assembled and distributed by February. An additional 75 notebooks were assembled and distributed between March and cherry harvest.

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. 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.

Our objectives remain the same for year 2004 as in 2003 except we will seek to broaden our focus to other cherry production regions, particularly the Wenatchee Valley. We intend to survey industry fieldmen and consultants to assess the degree of cooperation in tree removal and their impressions as to whether CLRV is a growing or contained threat to the cherry industry in the Pacific Northwest.

Significant findings:

- CLRV was identified in 392 of the 1,068 cherry samples submitted to the WSU ELISA laboratory. This represents roughly 98 CLRV-infected cherry blocks.
- Nearly all cherry trees that tested positive for CLRV were from Yakima, Benton and Franklin Counties. Fourteen orchard blocks were identified from samples submitted by the Franklin County Horticultural Pest & Disease Board in a separate survey project. One positive sample was collected in the Wenatchee Valley.
- Roughly 35% of these samples were from four orchards, three of which were near the Grandview Township.

Methods:

1. An industry liaison will be hired to coordinate CLRV identification and eradication efforts and work with a technical response team consisting of WSU-IAREC scientists, WSU Extension personnel, and Washington Tree Fruit Research Commission staff.
2. Educational and recruitment efforts will continue to target cherry packinghouses, agrochemical field staff and crop consultants. An emphasis will be directed towards expanding our educational efforts toward the regional fruit grower groups from the Wenatchee Valley and cherry packinghouses, agrichemical supply companies and private consultants in this region.
3. The industry liaison and investigators will contact all fieldmen who collected samples that tested positive for CLRV. The location of each positive sample will be marked with GPS technology so that project investigators or cooperators can revisit each location. Infected tree removal will be recommended or confirmed and adjacent trees will be monitored or sampled for CLRV. If grower confidentiality is an issue with any fieldman, we will rely on the fieldman's testimony on approximate tree location and tree removal and encourage fieldmen to scout and sample any adjacent trees for CLRV.
4. Timeline FY 2003/04.

   October to February- One-on-one interview with fieldmen regarding the location and details for each cherry tree diagnosed with CLRV during the 2003 growing season. Follow up visits by the CLRV Technical Response Team to precisely mark and assess the eradication procedure practiced at each site.

   March to April Resume sampling of cherry trees at sites where CLRV-infected trees were detected. Bud and emerging leaf samples will be taken from adjacent trees to determine whether CLRV has spread within each block. The educational efforts will continue and we will continue to recruit fieldmen and consultants to sample any trees with symptoms of cherry decline or CLRV.

   May to August Expand our survey to other regions of Washington particularly the Wenatchee Valley. Visual assessments as well as ELISA screening of tree leaf and fruit samples from new blocks will continue based on situations brought to our attention by consultants and growers.

   August to Sept. Follow-up visits of positive sites to confirm tree removal. Program evaluation based on grower/fieldmen/consultant interviews.

Results and discussion:
Our project screened 392 out of over 1,000 samples as positive for the cherry leafroll virus. In many cases multiple samples originated from a single orchard block and we estimate that the number of orchards with at least one tree infected with CLRV rose from 40 orchards in 2002 to 98 orchards in 2003. All but one of orchard was located in Yakima, Benton or Franklin Counties. The Franklin County Horticultural Pest and Disease Board hired summer interns to walk cherry blocks in the county in search of trees with CLRV symptoms. Nearly 1,500 acres of orchard was covered in five months and nearly 200 samples were sent the WSU ELISA laboratory for testing. Over 60 samples representing 14 orchards tested positive for CLRV in Franklin County. In Yakima County, three orchards, centered near the Grandview Township, accounted for about 150 positive samples. The Grandview Township accounted for roughly 35% of the samples sent to the WSU ELISA Laboratory that tested positive for CLRV. Only one sample taken from the Wenatchee Valley tested positive for CLRV. There were no positive finds for CLRV out of Oregon.

Throughout 2003 we had varying levels of cooperation between packinghouse and agrichemical fieldmen. Based on our sample tracking system, we will be able to note those operations that were not reasonably represented in the 2003 survey and renew our efforts in 2004 with a focus on these operations. We also encountered several growers and fieldmen who desired anonymity regarding the location of positive finds and this was not conducive to our efforts to generate a distribution map. We will pursue this mapping concept, but intend to compromise to a scale of resolution that satisfies our needs and still maintains grower anonymity. We anticipate an increase in the number of samples sent to the WSU ELISA for CLRV screening in 2004 compared to 2003. Most of our educational efforts and materials were distributed by mid-June and this timing did not provide some fieldmen and growers with sufficient time to assess and sample their orchards for CLRV.

One major setback to the success of the project is growers who refuse to remove trees that the project has screened and diagnosed as positive for CLRV. Efforts to convince the grower to remove these trees through adjacent grower peer pressure and Horticultural Pest & Disease Boards is in process. The eventual resolution of these situations will be taken into account in our evaluation of this program.

Our CLRV educational efforts have enhanced grower awareness of other cherry diseases that can negatively impact cherry production including Little cherry disease, Western-X disease, and Rugose mosaic disease. This increased awareness together with a willingness to quickly and properly remove these trees will improve the overall health of the cherry industry.

We determined that over 500 cherry trees have been removed as a result of this project. 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. Four orchards alone accounted for nearly 200 of those trees removed. We attribute the removal of these trees to our educational program directed towards the growers that convinced them that CLRV is a highly virulent disease that will significantly impact tree productivity and spread to adjacent trees if the infected tree is 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: 2003-2004
Current year: 2004
Project total (2 years): **$123,000**
Current year request: **$62,585**

Current year breakdown

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

[1] Industry liaison– this position will be hired through WSU or directly by WTFRC and will be 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).

FINAL REPORT
WTFRC Project #CH-03-302 **WSU Project #14C-4164-2812**

Project title: Postharvest quality of late season cherry varieties grown in Washington State

PI: Eugene Kupferman, Jake Gutzwiler (Associate in Research)
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

Objectives:
1. Refine and standardize the methodology for evaluating the quality of cherries following postharvest handling and storage.
2. Determine the quality characteristics after storage of late harvested newer cherry varieties grown in Washington State.

Significant findings:
Harvest maturity study:
- Skin and flesh color were equally good indicators of fruit maturity at harvest for all varieties tested. A color chart was developed to standardize rating of flesh color.
- At harvest, 'Bing' skin color (CTIFL 4 to 8) did not reflect changes in fruit quality but in 'Skeena,' 'Lapins' and ''Sweetheart' skin color reflected important quality changes.

Storage study:
- 'Bing' quality was best from the second or third harvest (CTIFL 6, 8).
- 'Lapins,' 'Skeena' and 'Sweetheart' quality was the best after the third harvest (CTIFL 8).

Pitting study:
- 'Sweetheart' had less pitting than 'Lapins' or 'Bing' (65%, 48% and 43% undamaged fruit, respectively) regardless of maturity.
- Less mature 'Bing' and 'Lapins' had more pitting than more mature fruit.
- 'Skeena' had the least damaged fruit in this trial, yet commercially packed 'Skeena' were very pitted.

Water study:
- Fruits submerged in 32ºF water were firmer and less susceptible to shrivel after 14 days in storage than those not submerged in water.
- There was no deterioration in the quality of 'Lapins' after submersion for 5 or 10 minutes.

MA bag atmospheres:
- Fruit quality was not influenced by MA bags under controlled conditions at 32ºF.
- Under lab conditions MA bags did not develop enough CO_2 to have an effect. Atmospheres did not change over time in storage.
- In a limited survey of commercial situations MA bags did not achieve optimal O_2 and CO_2 levels.

Methods:

Maturity and storage study:

'Bing,' 'Lapins,' 'Skeena' and 'Sweetheart' cherries were harvested three times from an orchard on Wenatchee Heights. Harvests corresponded to colors represented on a color scale produced by CTIFL (France) at color ratings of 4, 6 and 8. A 25-fruit sample from each of five trees harvested 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.

Pitting study:

A 25-cherry sample was taken from each of five trees for pitting evaluation. Cherries were held at 38ºF for six 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 32ºF plus 24 hours at 70ºF before evaluating damage. Fruit damage assessed is expressed as the percentage of damaged fruit.

Water study:

A sample of second-harvest 'Bing' and 'Lapins' was held for 5 or 10 minutes in 32ºF water and evaluated for fruit condition and firmness after 14 days at 32ºF.

Results and discussion:

Maturity study:

'Bing' skin color (within CTIFL 4 to 8 range) was not strongly associated with SS (Figure 1), acidity (Figure 2), size (Figure 3) or firmness (Figure 4) at harvest. In 'Skeena' and 'Lapins,' SS, acidity and size increased and firmness decreased with successive harvests and were related to skin color at harvest. 'Sweetheart' size and SS increased with successive harvests but acidity and firmness declined; all three attributes were related to skin color at harvest.

Firmness was acceptable in all varieties and at all harvest times; however, 'Bing' was consistently the least firm variety. 'Lapins,' 'Skeena' and 'Sweetheart' cherries were less firm with successive harvests. Firmness was inconsistent among varieties at harvest 1 (CTIFL 4). At harvest 2 (CTIFL 6) 'Bing,' 'Lapins' and 'Sweetheart' were all of similar firmness. At harvest 3 (CTIFL 8) 'Skeena' and 'Sweetheart' were of similar firmness; likewise, 'Bing' and 'Lapins' were of similar but lower firmness.

The lack of correlation between 'Bing' color and quality attributes allows some flexibility in harvest timing. Most notably, 'Bing' cherries produced in different regions may be harvested over a range of color levels (CTIFL 4 to 8) without a change in quality. It is apparent that harvesting fruit with darker skin color yields higher quality fruit in 'Lapins,' 'Skeena' and 'Sweetheart.'

Pitting study:

At the first harvest, 'Bing' and 'Lapins' were more susceptible to pitting than at other harvests (Figure 5). 'Skeena' displayed the least susceptibility to pitting with less than 30% of fruit damaged. 'Sweetheart,' with the exception of the last harvest, also sustained little damage. At the last harvest date, 'Sweetheart' may have been more susceptible to damage due to sustained field heat stress.

Water study:

Cherries submerged in water were less susceptible to postharvest shrivel and were firmer than cherries placed directly into cold storage. After water treatments, there were no negative effects of water immersion on 'Bing' and 'Lapins' quality.

Storage study:
Cherries stored for 7 to 28 days did not lose significant weight, size or SS. Skin and flesh color darkened in storage. Stem color was maintained with more than 90% of all stems retaining green color through 28 days of storage, with the exception of the third harvest of 'Bing' after 28 days.

Lapins had lower acidity at harvest and at all evaluations than the other varieties. All varieties lost acidity in storage but at different rates (Figure 6). 'Bing' retained high acidity for seven days after harvest, then dropped to the level of 'Skeena' and 'Sweetheart.' 'Skeena' acidity declined immediately after storage, and evened off for a week before dropping again. Acidity of 'Sweetheart' and 'Lapins' declined at a lesser rate than the other varieties.

Because acidity is a major component of cherry flavor, decreases in acidity could help determine the shipping/storage limits of each variety. 'Bing' started out with more acidity than the other varieties and held acidity for seven days of storage. However, 'Sweetheart' retained the acidity for longer periods in storage.

Firmness differences after storage were dictated by those at harvest. Following seven days in storage 'Skeena' fruit was the firmest and 'Bing' the softest (Figure 7). Successive harvest samples of 'Bing' and 'Sweetheart' showed less decline in firmness than 'Lapins' and 'Skeena' after seven days of storage. Fruit from the third harvest of 'Lapins' was of marginal firmness.

Summary:
Incorporating the maturity, storage and pitting components of this study takes steps toward defining optimal harvest and storage times for each variety.

'Bing' may be harvested at color levels between 4 and 8 on the CTIFL chart without compromising quality. The storage study indicated that 'Bing' did not lose significant firmness at later harvest dates. Conversely, increased susceptibility to pitting at the first harvest (CTIFL color 4) suggests that 'Bing' quality is best after the second harvest (CTIFL color 6) and it can be stored without serious loss of acidity for at least seven days.

'Lapins' lost firmness with successive harvests; however, fruit was larger and higher in SS and acidity at the third harvest (CTIFL color 8). This variety was more susceptible to pitting at the first harvest (CTIFL color 4) than at later harvests. Acidity loss in storage was also less severe than in other varieties. 'Lapins' should be harvested at CTIFL color 8 in order to achieve high SS and acidity levels and avoid susceptibility to pitting at low maturity. Because there is little acid loss, this variety may be stored/shipped for up to 14 days without losing flavor.

'Skeena' also lost firmness with successive harvests and was larger, higher is SS and acidity at the third harvest (CTIFL color 8). In the lab environment 'Skeena' was less susceptible to pitting than other varieties. Storage firmness did not drop below 300 g/mm after any harvests. There were no significant losses in acidity until after 14 days of storage. This variety should be harvested at CTIFL color 8 in order to achieve large size and higher SS and acidity. Unlike 'Lapins,' there is no apparent danger of severe pitting at low maturity levels. This variety may be stored for up to 14 days without losing acidity.

'Sweetheart' developed more sugar with successive harvests but at the same time lost acidity. Fruit size increased at the third harvest (CTIFL color 8). Fruit does not appear to be susceptible to pitting to the same degree as 'Bing' and 'Lapins' unless under stressful conditions (field heat stress in the third harvest). Acidity loss over extended periods is less severe than in other varieties, and firmness values after storage are retained well at the third harvest. 'Sweetheart' should be harvested at CTIFL color 8, allowing time to increase in SS. They may be stored for at least 14 days with little acid loss.

Budget:
Project duration: 2003 (one-year project)
Current year: 2003
Project total (1 year): $18,390
Current year request: $18,390

Year	Year 1 (2003)
Total	**18,390**

Current year breakdown

Item	Year 1 (2003)
Salaries[1]	**9,700**
Benefits (33%)	**3,201**
Wages	**1,500**
Benefits (16%)	**240**
Equipment	**0**
Supplies[2]	**2,999**
Travel[3]	**750**
Miscellaneous	**0**
Total	**18,390**

1 Jake Gutzwiler, Associate in Research.
2 Supplies include updates and repair for FirmTech firmness device, fruit, modified atmosphere film, cherry packing material, lab supplies.
3 Travel to obtain fruit samples.

Figure 1. Soluble solids content was measured at three cherry maturity levels based on CTIFL colors 4, 6, and 8 on 25-cherry samples of 'Bing,' 'Lapins,' 'Skeena' and 'Sweetheart.'

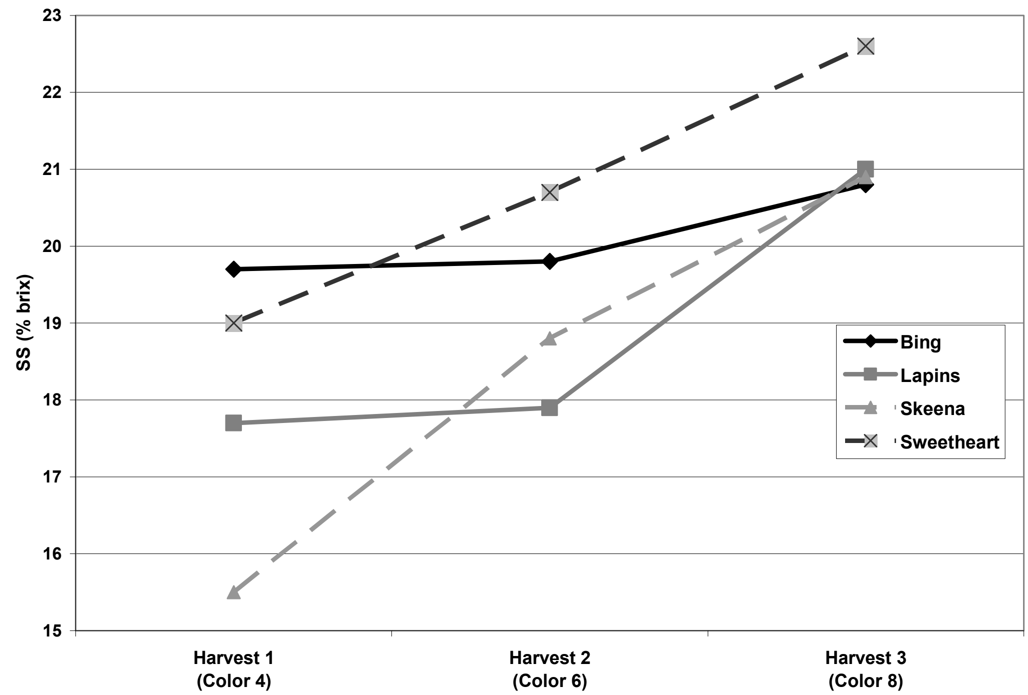


Figure 2. Titratable acidity was measured at three cherry maturity levels based on CTIFL colors 4, 6, and 8 on 25-cherry samples of 'Bing,' 'Lapins,' 'Skeena' and 'Sweetheart.'

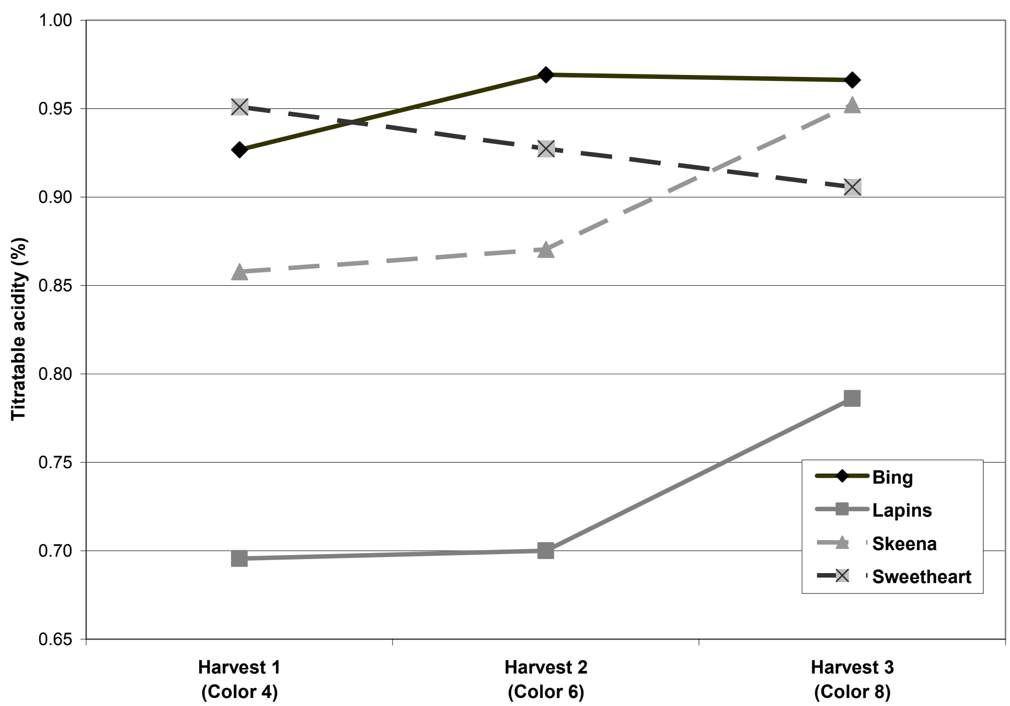


Figure 3. Cherry row size was measured at three cherry maturity levels based on CTIFL colors 4, 6, and 8 on 25-cherry samples of 'Bing,' 'Lapins,' 'Skeena' and 'Sweetheart.'

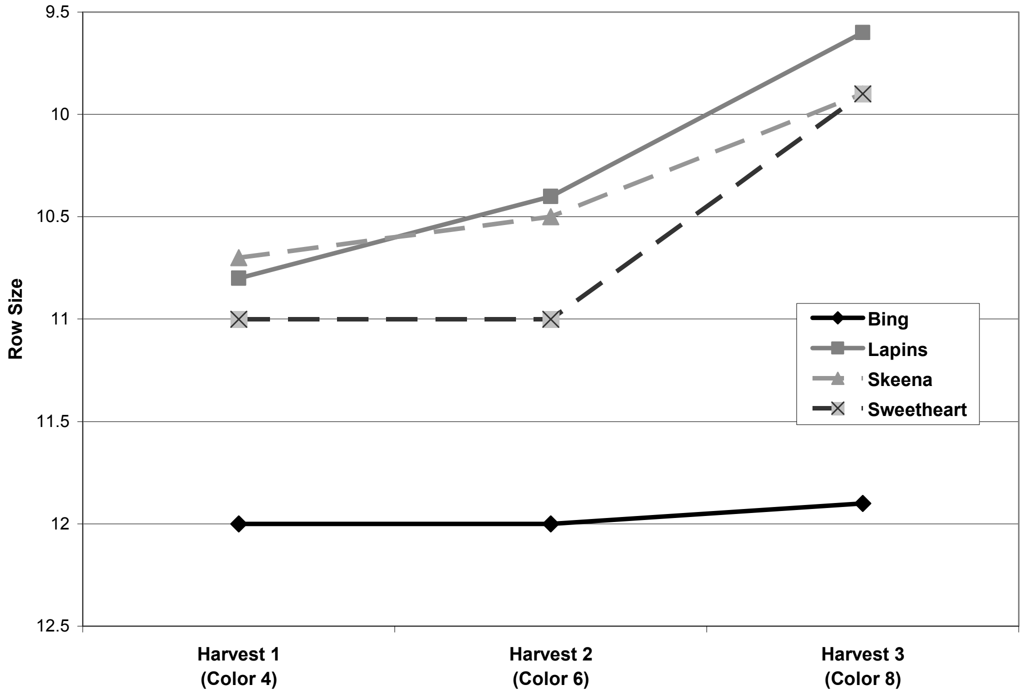


Figure 4. Firmness was measured using the FirmTech I at three cherry maturity levels based on CTIFL colors 4, 6, and 8 on 25-cherry samples of 'Bing,' 'Lapins,' 'Skeena' and 'Sweetheart.'

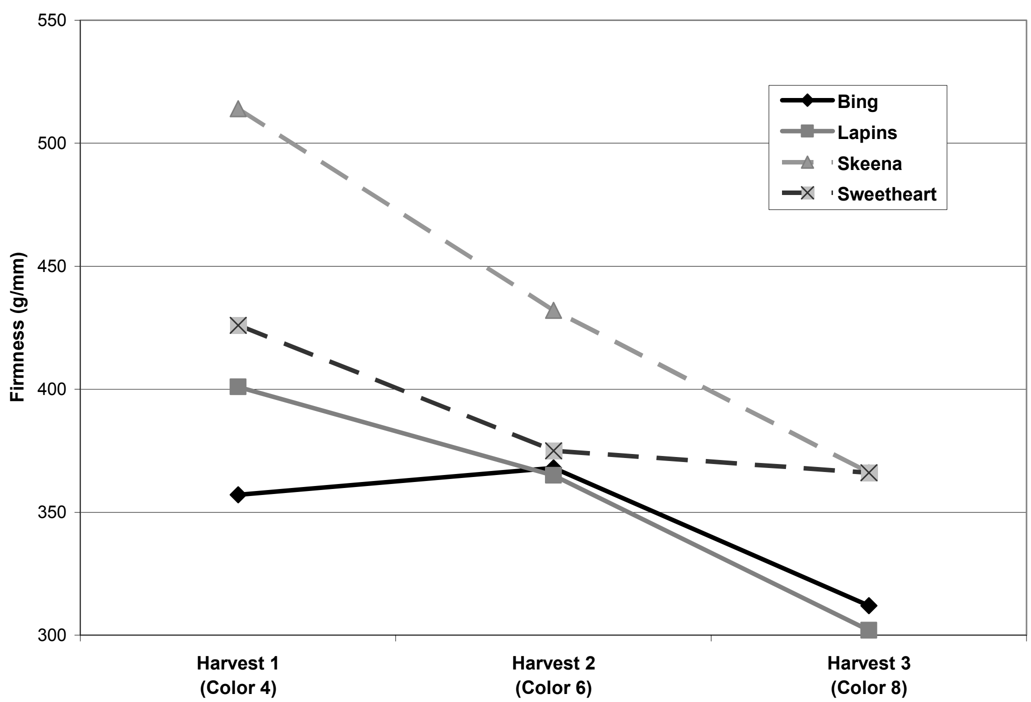


Figure 5. Pitting was induced at three cherry maturity levels based on CTIFL colors 4, 6, and 8 on 25-cherry samples of 'Bing,' 'Lapins,' 'Skeena' and 'Sweetheart,' then evaluated as percentage of fruit damaged after 14 days in storage.

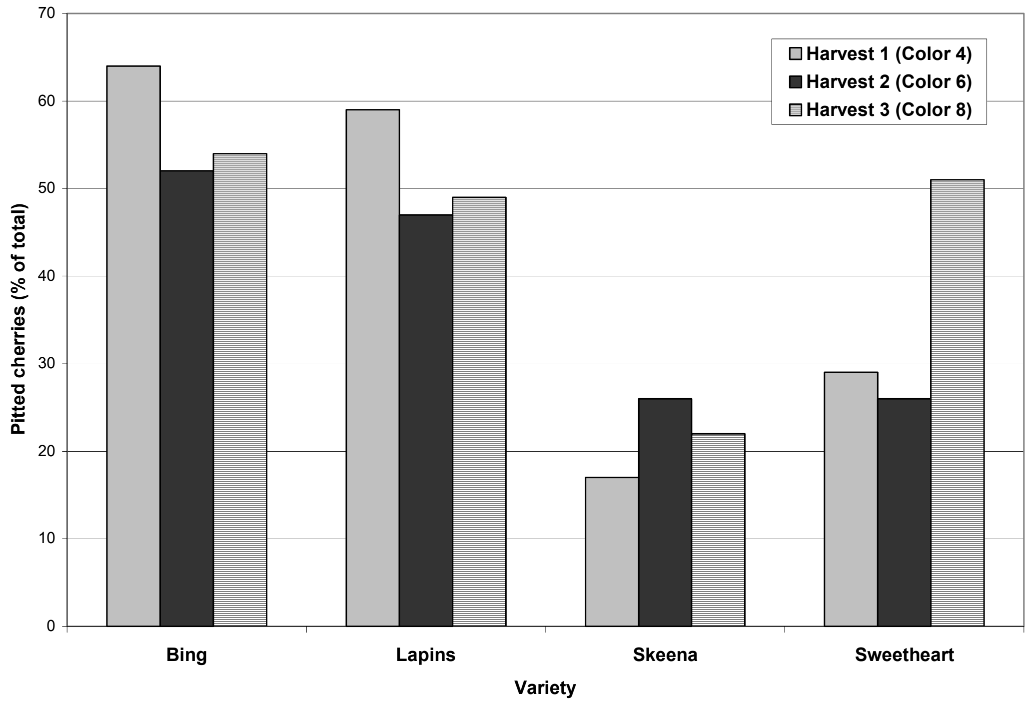


Figure 6. Titratable acidity was measured after storage at 32ºF for 0, 7, 14 and 28 days in storage on 25-cherry samples of 'Bing,' 'Lapins,' 'Skeena' and 'Sweetheart.'

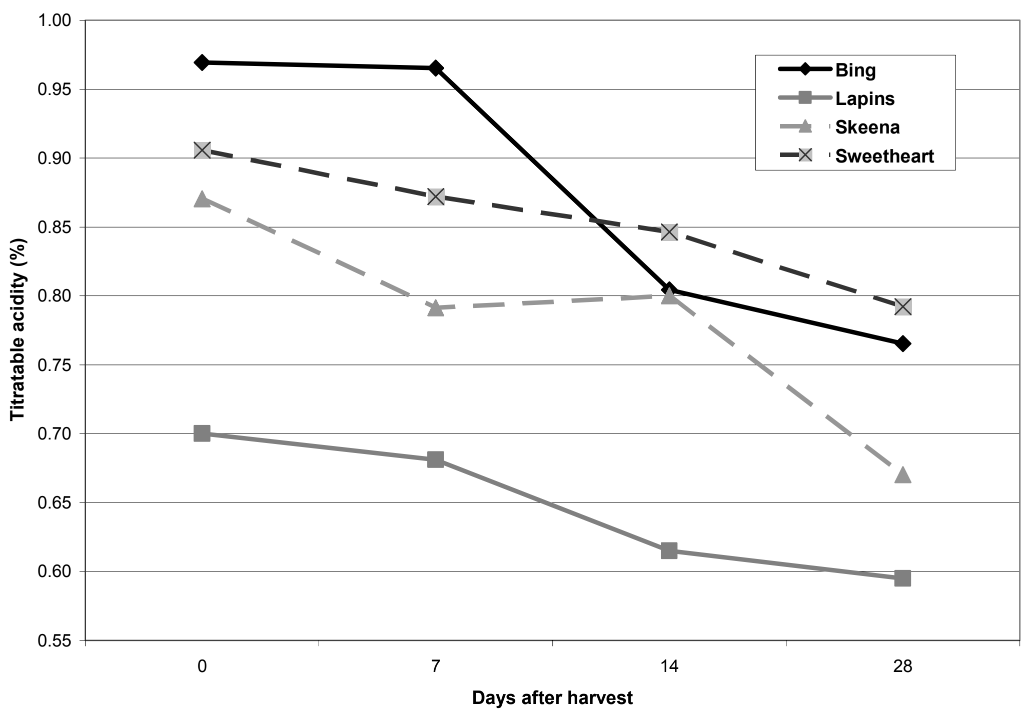
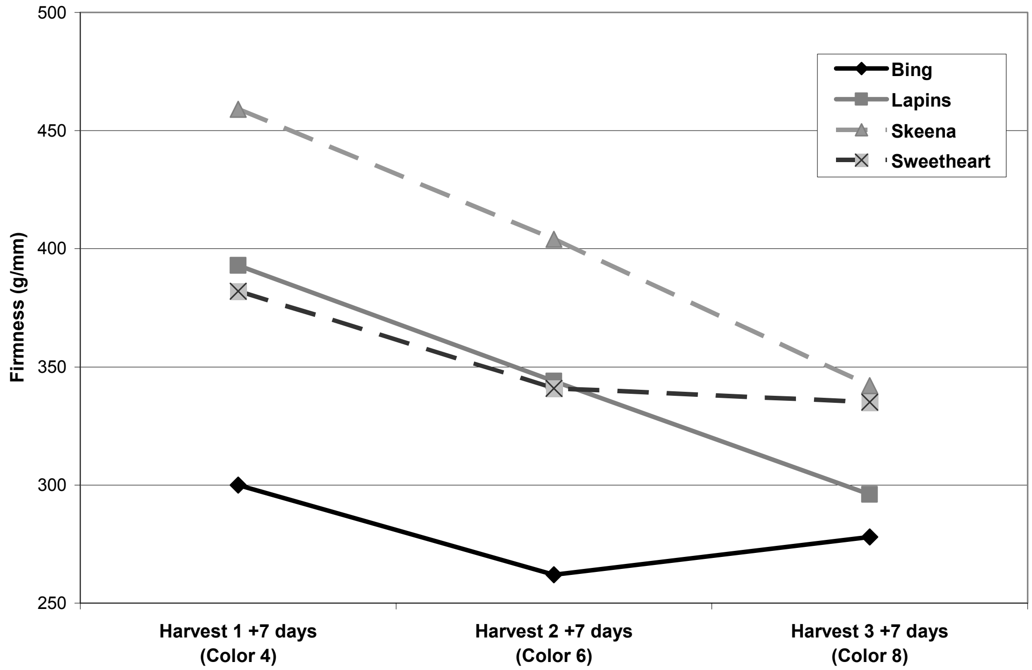


Figure 7. Firmness was measured using the FirmTech I at three cherry maturity levels based on CTIFL colors 4, 6, and 8 on 25-cherry samples of 'Bing,' 'Lapins,' 'Skeena' and 'Sweetheart' after 7 days of storage at 32ºF.



FINAL REPORT
WTFRC Project # CH-01-08

Project Title: Mechanical Harvester for Fresh Market Quality Stemless Sweet Cherries

PI: Donald L. Peterson, Agricultural Engineer USDA/ARS
Appalachian Fruit Research Station
Kearneysville, WV

Cooperators: Matthew Whiting, Bob Harris, Dennis Hayden

Objectives: The principal objective of this research was to develop a mechanical harvesting system for stemless, fresh market quality sweet cherries. Secondary objectives were to: (1) determine compatible tree training and cultural practices, (2) develop an effective fruit removal actuator and positioning system, (3) develop fruit catching/collecting components that minimize damage, and (4) test the system under field conditions to determine feasibility. Objectives for 2003 were: (a) to improve the bin handling system and, (b) continue extensive testing under "commercial" conditions to elucidate harvester performance with various training systems and cultural practices.

Significant findings:

- An improved bin handling system was developed so that both harvester halves could deposit filled bins to the ground. Empty bins were spotted in the orchard and loaded by hand onto the harvester.
- In a commercial orchard, a three-hour test was conducted to test harvester field capacity. Every fourth tree was harvested ('Van' pollenizer), 9 row with 21 harvested trees per row. Yield averaged 33 #/tree. Two operators filled 21 bins: equivalent of 56 bins in an 8-hour day (28 bins/worker/8 hour). Time included changing bins, turning at ends of rows, and some delays due to minor repair of impact rubber pads. Harvest capacity would improve if every tree were harvested.
- In 2003 ethrel was effective in reducing fruit detachment force from over 500 gm to the 190-250 gm range.
- Machine harvested fruit quality in 2003 was not as good as in the previous three years. At the Rosa test site, 17 bins of 'Bing' were machine harvested and graded by a commercial packing shed (Western Sweet Cherry Group). Results were 63.8% fresh pack, 12.2% 13 row, 3% brine, 21.6% culls and 2.1 % shrink. In a test in a commercial 'Bing' orchard, 17 bins were machine harvested and graded in the same commercial packing shed. Results were 54.5% fresh pack, 4.9% 13 row, 1.3% brine, 37.7% culls and 1.6 % shrink. Cherries that had been hand harvested from the same orchard, but a week earlier (and probably less susceptible to damage), graded 70.9% fresh pack, 6.2% 13 row, 7.9% brine, 12.6% culls and 2.4 % shrink. Samples of cherries hand harvested on the same day of machine harvest were misplaced.

Methods: We are satisfied with the equipment development phase of this project. New plantings of sweet cherries are being trained to be compatible with this harvesting concept. When these plantings start producing a commercial crop (2005 or 2006), we propose that the harvesting concept be evaluated extensively at that time. We also are ready to work with commercial manufacturers to transfer this technology.

Results and discussion: The mechanical sweet cherry harvester demonstrated that it could improve harvest labor productivity by 14 times. All the key machine components for commercial adoption have been developed. Fruit quality from machine harvesting was not as good as it was in the previous 3 years of testing. After the harvest season was over, we may have discovered the reason for this reduction in fruit quality. Over the last 2 to 3 years a large number of cherries had worked their way under the inclined catching conveyors and the pits had wedged between the soft foam flights and the cover sheet. These pits presented many hard surfaces to the falling cherries and therefore likely to cause extensive pitting. The conveyors were cleaned before harvesting apples. A method to eliminate the problem was devised.

Budget:
Mechanical harvester for cherries
Donald Peterson
No money requested for 2004.

CONTINUING PROJECT REPORT **YEAR 3/3**

TITLE: Peach rootstock evaluations

Principal Investigators: Matthew Whiting, Assistant Horticult., WSU-IAREC
Washington State University

OBJECTIVE:
- Evaluate effects of rootstock genotype on tree growth habit and vigor, precocity, and fruit quality

SIGNIFICANT FINDINGS:
- 2003 was the first cropping year for the 2001 planting
- all rootstocks from the 2001 planting induced fruiting
- fruit yield was tremendously variable
    - SLAP, Bailey, Julior, and Lovell were the highest yielding rootstocks (>12 kg/tree)
    - Jaspi, P30-135, K146-44, Pumiselect, VVA-1, and K146-43 were the least precocious (< ~8 kg/tree)
- fruit quality varied among rootstocks
    - fruit soluble solids were highest on P30-135 (15.8 ^{o}brix) and mostly similar among the other rootstocks (~11-13 ^{o}brix)
    - fruit weight and fruit diameter were highest from BH-4, SLAP, WA-1, and SC-17
- scion vigor was affected by rootstock genotype:
- SLAP, Lovell, Bailey, and BH-4 were the most vigorous rootstocks (*i.e.*, tcsa >40 cm^2)
- K146-44, P30-135, K146-43, and WA-1 were the most dwarfing rootstocks (*i.e.*, <15 cm^2)
- mortality was generally very low although significant losses occurred on K146-43 (2/4), BH-4 (2/6), and Pumiselect (2/12)

METHODS:
Research orchards were planted in 2001 and 2002 with Cresthaven as the scion variety on a total of 18 different rootstock genotypes. The orchard is a sandy-loam soil and irrigated with under-tree microsprinklers. Standard commercial pest management practices are followed. For each rootstock the following data will be collected annually:
- first and full bloom dates
- tree growth habit (vigor, branch angle)
- fruit yield
- fruit quality (mass, soluble solids, diameter, firmness)
- tree mortality/graft incompatibility

BUDGET:

Project: Peach rootstock evaluation
P.I.: Whiting
Project duration: 2002-2004
Current year: 2004
Project total: $6,200
Current year request: $2,200

Year	2002	2003	2004
Total	$2,200	$1,800	**$ 2,200**
Current year breakdown			
Item			
Salaries			
Benefits (28%)			
Wages	**1,000**	**1,000**	**1,000**
Benefits (16%)	**160**	**160**	**160**
Equipment			
Supplies	1,040	640	1,040
Travel			
Miscellaneous			
Total	$2,200	$1,800	**$ 2,200**

Rootstock	Brix		Weight (g)		Diameter (cm)		Yield (kg)		TCSA (cm^2)		Yield efficiency (kg/cm^2)		Tree mortality
BH-4	12.7	bc	271	a	8.3	a	9.5	bcde	44.2	abc	0.200	cde	2/6
Bailey	11.8	c	245	cd	8.0	c	17.7	ab	44.5	ab	0.418	bc	0/6
Hiawatha	13.0	b	237	d	7.9	c	11.4	bcd	34.7	bcd	0.342	bcd	1/8
Jaspi	11.5	c	251	abc	8.0	abc	1.6	e *	26.8	d	0.047	e	0/6
Julior	13.2	b	233	d	7.8	c	13.0	abc	34.0	cd	0.366	bcd	0/8
K146-43	12.6	bc	178	e	7.2	d	8.1	bcde	7.9	ef	0.799	a	2/4
K146-44	12.9	bc	180	e	7.2	d	2.4	de	3.8	f	0.216	bcde	0/4
Lovell	11.7	c	231	d	7.8	c	12.5	abc	45.8	a	0.280	bcd	0/8
P30-135	15.8	a	168	e	6.8	e	2.1	e	7.2	f	0.282	bcd	1/8
Pumiselect	11.2	c	227	d	7.8	c	4.1	cde	23.7	de	0.129	de	1/4
SC-17	12.6	bc	251	abc	8.0	c	10.8	bcd	35.8	bcd	0.309	bcd	1/8
SLAP	11.7	c	263	ab	8.2	ab	19.0	a	47.4	a	0.405	bc	0/8
VVA-1	13.4	b	256	abc	8.0	bc	8.0	cde	14.9	ef	0.465	bc	0/4

Table 1. Effect of rootstock genotype on fruit yield and quality and death of 3-year-old Cresthaven peach trees (2001 planting). Means followed by the same letter within columns are not significantly different by LSD ($P < 0.05$).

Rootstock	TCSA (cm^2)		Tree mortality
Adesoto101	22.6	bc	0/8
Cadaman	28.4	a	0/8
Lovell	24.0	ab	0/8
MRS2/5	18.5	cd	0/8
Penta	17.8	d	0/8
Pumiselect	20.9	bcd	1/8
VSV-1	9.7	e	0/8
WA-1	6.0	e	0/8

Table 2. Effect of rootstock genotype on vigor and death of 2-year-old Cresthaven peach trees (2002 planting). Means followed by the same letter within columns are not significantly different by LSD ($P < 0.05$).

CONTINUING PROJECT REPORT **YEAR 2/3**

TITLE: Apricot variety evaluations

PI: Matthew Whiting, Assistant Horticult., WSU-IAREC

OBJECTIVES:
- Evaluate germplasm productivity, fruit quality and horticultural traits (*e.g.*, bloom dates, harvest dates, growth habit)

- Engage the apricot industry to optimize the usefulness of this trial

Significant findings:
- Date of first bloom (Table 2):
    - Katy bloomed the earliest (~11 March), about two weeks earlier than in 2002
    - Castlebrite, Goldrich, Patterson, and Perfection also were early blooming selections (12 March)
    - Dunstan, Fantasme, Hargrand, Lehrman, Orangered, and Vulcan were late blooming selections (16 – 17th March)
    - Alex was the latest blooming selection (18 March)

- Harvest date (Table 1):
    - PA 7005-2, Malise, Goldcot, Beliana, and Tomcot were the earliest ripening selections (~3 July)
    - Tilton, Fantasme, Patterson, and Lehrman were late-maturing selections (~22 July – 29 July)
    - Westley was the latest maturing selection (1 August)

- fruit quality varied tremendously among scion varieties (Table 1)

- PA 7512-3, PA 7005-2, Malise, Tilton, and Goldcot were the smallest selections (< 50 mm diameter, ~ 60 g or less)
- Goldbar, Katy, Lehrman, Perfection, and Goldstrike were the largest selections (> 60 mm diameter, > 120 g)
- Lehrman, Goldbar, Perfection, and Hargrand yielded the best quality fruit

Methods:
The research orchard was planted in 1997 at 12 x 18' in north-south rows. Under-tree microsprinklers and propane heaters have been installed. The block is comprised of 33 apricot (*Prunus armeniaca* L.) selections, several of which were developed at WSU-Prosser. For each selection the following data will be collected annually:

- first and full bloom dates
- fruit set rating
- tree growth habit (vigor, branch angle)
- fruit yield rating
- fruit quality (mass, soluble solids, diameter, acidity, firmness)

BUDGET:

Project title: Apricot variety trial
P.I.: Matthew Whiting
Project duration: 2002-2004
Current year: 2004
Project total (3 years): $6,600
Current year request: $2,200

Item	Year 1 (2002)	Year 2 (2003)	**Year 3 (2004)**
Wages	$1,000	$1,000	**$1,000**
Benefits	$ 160	$ 160	**$ 160**
Supplies	$1,040	$1,040	**$1,040**
Total	$2,200	$2,200	**$2,200**

Table 1. Quality of apricot selections included in variety trial at WSU-Roza. Data from multiple picks are included when possible.

Harvest Date	Variety	Diameter (mm)	Weight (g)	Firmness (kg)	Sol. Solids
7/3	Beliana	52.1	70.2	1.7	15.7
7/22	Blenheim	50.3	68.6	1.8	18.5
7/3	Castlebrite	50.6	74.9	1.6	12.3
7/25	Fantasme	52.5	79.9	4.8	12.7
7/29	Fantasme	56.0	93.0	4.1	15.4
7/8	Goldbar	64.4	149.2	>5	10.7
7/15	Goldbar	61.2	130.5	3.5	13.3
7/3	Goldcot	48.5	62.8	2.2	15.3
7/11	Goldensweet	50.6	75.8	3.9	16.3
7/3	Goldrich	53.9	99.3	>5	12.3
7/3	Goldstrike	60.5	120.3	3.0	13.1
7/15	Hargrand	59.5	112.4	4.8	16.5
7/18	Hargrand	53.9	91.7	4.5	17.0
7/3	Katy	62.2	124.2	1.9	12.8
7/18	Lehrman	61.6	133.2	3.4	16.4
7/22	Lehrman	61.2	123.8	6.4	14.7
7/3	Malise	47.8	60.8	3.7	13.5
7/8	Modesto	54.1	84.5	4.8	12.6
7/11	Modesto	57.5	100.5	3.2	
7/15	Modesto	54.7	90.3	3.2	14.6
7/8	OrangeRed	51.8	81.6	3.0	15.7
7/11	PA63-55	47.5	59.2	3.6	13.4
7/11	PA7003-2	51.1	69.8	3.5	15.7
7/3	PA7005-1	54.9	89.1	>5	13.2
7/8	PA7005-1	56.7	98.2	3.4	15.6
7/3	PA7005-2	46.2	58.2	4.0	15.4
7/11	PA7005-9	53.7	88.1	3.3	
7/15	PA7005-9	56.5	103.6	3.5	14.2
7/22	PA7512-3	42.6	46.1	4.3	11.7
7/18	Patterson	50.8	70.6	4.1	15.6
7/22	Patterson	48.6	65.8	2.6	15.3
7/25	Patterson	52.0	77.5	4.3	13.1
7/18	Perfection	61.1	125.6	3.2	12.6
7/3	PugetGold	57.2	105.8	>5	12.1
7/15	PugetGold	54.1	97.8	3.6	15.3
7/15	Riland	55.2	99.0	2.1	14.2
7/8	Rival	56.8	103.4	>5	13.4
7/11	Rival	56.3	99.9	3.7	13.9
7/25	Tilton	49.1	68.0	10.6	11.9
7/29	Tilton	48.3	62.7	4.1	14.1
7/3	Tomcot	51.0	79.7	1.9	15.8
7/22	Westley	46.5	58.0	6.3	12.9
7/25	Westley	49.0	66.0	5.7	12.8
7/29	Westley	54.5	93.2	3.4	14.0
8/1	Westley	53.1	88.0	2.7	14.8

Table 2. Bloom data of selections from apricot variety trial at WSU-Roza. * Initial set rating is on a scale of 1 to 5 with 1 being very light set and 5 being a very dense fruit set. ** Bloom rating is on a scale of 1 to 5 with 1 being very light bloom, and 5 being a very dense bloom.

VARIETY	First bloom (March)	Full bloom (March)	Petal fall (March)	Initial Fruit Set*	Bloom Rating**
Alex	18	24	29	1	4
Beliana	14	16	23	2	3
Blenheim	13	16	22	3	4
Castlebrite	12	17	23	2	4
Chinese	15	18	23	1	3
Dunstan	16	22	27	1	1
Fantasme	16	20	24	2	3
Goldbar	13	17	23	1	4
Goldcot	15	18	23	1	2
GoldenSweet	13	18	25	3	5
Goldrich	12	17	22	1	4
Goldstrike	14	18	23	1	4
Hargrand	16	23	28	2	4
Helena	14	18	23	1	4
Katy	11	16	18	1	4
Lehrman	16	20	25	1	2
Malise	14	18	23	1	4
Modesto	13	17	22	2	4
Moorpark	15	20	25	1	4
Orangered	16	21	24	1	3
PA7003-2	15	20	22	1	4
PA7005-1	14	18	22	1	3
PA7005-2	14	18	24	3	4
PA7005-9	14	18	23	1	4
Patterson	12	17	22	4	5
Perfection	12	18	21	1	3
PugetGold	14	18	22	2	3
Riland	15	19	24	1	2
Rival	13	18	22	1	4
Tilton	15	20	25	3	5
Tomcot	14	17	22	2	3
Vulcan	17	22	26	1	2
Westley	14	20	24	3	4

FINAL REPORT
PROJECT NO.: CH-01-17

TITLE: Clonal Rootstock Performance/Evaluations

Principal Investigators: Matthew Whiting

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D.R. Ophardt, Res. Tech. Supervisor, WSU-Prosser

OBJECTIVES:
Comprehensive rootstock research is necessarily a long-term project. However, various components of the objectives will be completed annually.

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: e.g., 'Bing' on 5-6 different Gisela rootstocks in grower trials representing diverse production locations (planted in 1994-95); 'Chelan', 'Tieton', 'Cashmere', 'Selah', and 'Benton' on Mazzard, Mahaleb, 'Colt', 'Edabriz', and various Gisela and Weiroot rootstocks (planted in 1998).
3. Analyze the physiology of interactive rootstock/scion horticultural traits (e.g., canopy leaf area, yield efficiency, precocity, graft compatibility). On-going as personnel allows.

SIGNIFICANT FINDINGS:
1998 NC-140 Trial Rootstocks Training and growth of the 1998 NC-140 trial trees continued and 2003 represented the second significant cropping season for most trees. There existed tremendous variability in fruit yield, fruit quality, and growth in 2003.

In addition, by vigor category from the 1998 NC-140 rootstock trial in 2003:

- the following are **dwarfing** rootstocks (i.e., exhibit vigor reduction of 40 – 50% compared to Mazzard): W53, W72, W154, Edabriz, Gi209/1, and Gi473/10
  - yield was greatest in Gi209/1, Gi473/10, W72, and Edabriz (24 – 29 kg/tree), and lowest in W154 and W53 (13 - 15 kg/tree)
  - W72 exhibited the best combination of yield and quality - over 24 kgs of fruit were harvested averaging 7.7 g with 50 % 10.5-row and larger
- the following are **semi-dwarfing** (i.e., 70 –80% of Mazzard): Gi195/20, Gi5, Gi7, and W158 yield was greatest in the Gisela series Gi7, Gi5 and Gi195/20 (34 - 40 kg/tree) and lowest for W158 (19 kg/tree)
  - Gisela 5 exhibited the best combination of yield and quality - over 34 kgs of fruit were harvested averaging 7.2 g with 49 % 10.5-row and larger

- the following are **vigorous** (i.e., ≥90% of Mazzard): W13, W10, Gi6, Mahaleb, Gi318/17, and P-50
  - yield was greatest for Gi6 (39 kg/tree) and Gi318/17 (37 kg/tree), intermediate for Mahaleb, W10,W13 (20 – 31 kg/tree)), and lowest for Mazzard and P-50 (5 - 6 kg/tree)
  - Gi 318/17 exhibited the best combination of yield and quality - over 37 kgs of fruit were harvested averaging 7.8g with 58 % 10.5-row and larger

Summarizing data from all rootstocks over the 2003 growing season:

- there is no clear relationship between scion vigor and fruitfulness among these rootstocks
- trunk expansion is negatively related to tree yield efficiency (Fig. 2)
- a slight negative relationship ($r^2 \approx 0.1 – 0.5$) existed between fruit yield and quality (e.g., ^{o}brix, fruit weight)
- a slight positive relationship ($r^2 = 0.4 – 0.55$) existed between tree vigor and quality
- yield efficiency was closely and negatively related to fruit quality ($r^2 = 0.46 – 0.88$, Fig. 3)
- fruit quality was best on Mahaleb (8.3 g/fruit, 24.4 ^{o}brix) and worst on Gisela 7 and 195/20 (6 g/fruit, 17 ^{o}brix)

'Chelan' Rootstock Trial The 1998 'Chelan' rootstock trial continued to exhibit differential reactions between rootstocks in 2002/2003. One complete replication (4 trees) on Mahaleb have been lost to gopher damage during the winter; no trees on other rootstocks were damaged. Although growth was generally excellent on all rootstocks, the trees on Mahaleb died. About 6% of the trees on Mazzard exhibit a health problem and only 2% of the trees on Colt. None of the trees on Edabriz, Gisela 6, GI 209/1, or GI 195/20 have exhibited any unusual symptoms. All of the trees on Gisela 5 exhibit a minor degree of premature leaf coloration and/or premature defoliation. These results with Mahaleb confirm several grower observations of tree mortality on Mahaleb.

WSU Variety Rootstock Trial Varieties included in this trial are: Chelan, Tieton, Benton, Selah, Rainier, and elite selections PC 8011-3, PC 7147-9, and PC 7903-2. 2003 represented the second crop on most rootstocks. Rootstock impacted scion precocity and fruit quality tremendously. In general, fruit quality was excellent, particularly compared to similar aged 'Bing' trees of the NC-140 trial, with a high percentage of fruit being 10.5-row and larger.

Across all scion varieties:

- fruit soluble solids were highest on Edabriz and Gisela 209/1 (~ 22 ^{o}brix) and lowest on Gisela 6 (~ 19 ^{o}brix)
- individual fruit mass was lowest for Edabriz (9.5 g), and highest on Gisela 195/20 and Gisela 6 (> 11 g)
- yields were highest on Gisela 6 and 5 (22 and 19 kg/tree, respectively), 50% less on Edabriz, and 70% less on Gisela 209/1
- fruit row-size distribution was excellent from all rootstocks but best on Gisela 195/20 (97% 10.5-row and larger) and worst on Edabriz (71% 10.5-row and larger)
- fruit firmness was excellent on all rootstocks (>290 g/mm) but highest from Gisela 5-rooted trees

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. Improved estimates of rootstock influence on canopy vegetation (a key measure of potential fruit sizing capability) will be made with a non-destructive, portable, microprocessor-based leaf area meter to be obtained in 2002.

A new plot of 'Chelan' on Mazzard, Mahaleb, 'Colt', 'Edabriz", and various Gisela rootstocks was planted in 1998 to document whether industry concerns of certain graft incompatibilities with this important new variety are warranted. A small plot of 'Lapins' on Mazzard and Mahaleb was also planted to examine graft incompatibility potential. If and when evidence of incompatibilities arise, tissue samples will be taken from respective graft unions for biochemical analysis and investigation of the potential for developing a screening test for other incompatible rootstock/scion combinations.

Two new plots of WSU-Prosser varieties (including Benton, Selah, Glacier, and Tieton) and elite selections (including 8011-3, 8011-7, 8012-9, 8014-1, 7217-2, 7306-1, 8007-2, and 8005-1) on the new PiKu series (selections 1 and 3) of rootstocks, the Gisela series (including 5, 6, and 12), Mazzard, and Mahaleb were planted in 2002. Growth, fruiting, fruit quality, graft compatibility will be monitored in these plots.

RESULTS & DISCUSSION:
Sweet cherry varieties grown on standard seedling rootstocks like Mazzard are slow to bear fruit and particularly vigorous. These are not desirable traits in a rootstock. However, fruit quality from mature Mazzard-rooted trees can be excellent and hence, despite the inefficiencies of production systems based on this rootstock, it continues to be widely planted. Growers have utilized various horticultural (*e.g*., deficit irrigation, limb bending) and chemical (*e.g*., Ethrel, Apogee) strategies to overcome the lack of precocity and excessive vigour of Mazzard-rooted trees, with limited success. A potentially more sustainable and reliable solution to these production problems may lie in the use of genetics to achieve scion size control and/or precocity.

This research project has documented the effects of about 20 rootstocks on scion growth, fruiting, fruit quality, and compatibility. Rootstock genotype affected each of these parameters. In 2003, Mazzard was the least productive and most vigorous. Weiroot 53 was the least vigorous (25% of Mazzard) and several Gisela selections (Gi 7, Gi 6, Gi 318/17, Gi 195/20) were the most productive (35 – 40 kg/tree, 5-7 fold greater than Mazzard). Cumulatively since planting, the Gisela series of rootstocks have been the most productive (Fig. 1) as seven of the eight highest-yielding rootstocks were Giselas. Edabriz and Mahaleb were intermediate and the Weiroot series and Mazzard were even less productive. Precocity was not related to vigor. For example, Gisela 6 was very productive (~ 93 kg/tree) and Mazzard was unproductive (~ 17 kg/tree), both are vigorous rootstocks. In addition, Weiroot 53, the least vigorous rootstock, has been unproductive (~ 39 kg/tree) while other dwarfing rootstocks have been quite productive (*e.g*., Gi 209/1, 69 kg/tree).

However, of greater relevance is the cumulative yield of premium quality fruit (*i.e*., 10.5-row and larger). Such an analysis reveals again, tremendous variability among rootstocks (Fig. 1). Gi 318/17, Gi 6, W10, and Gi5 yielded the greatest amount of premium quality fruit. In the case of Gi 6, this was accomplished through high fruit yields per tree of which only about 42% was 10.5-row and larger. In contrast, W10-rooted trees were much lower yielding (*ca*. 43 kg/tree) but had a higher percent, almost two-thirds, of 10.5-row and larger fruit.

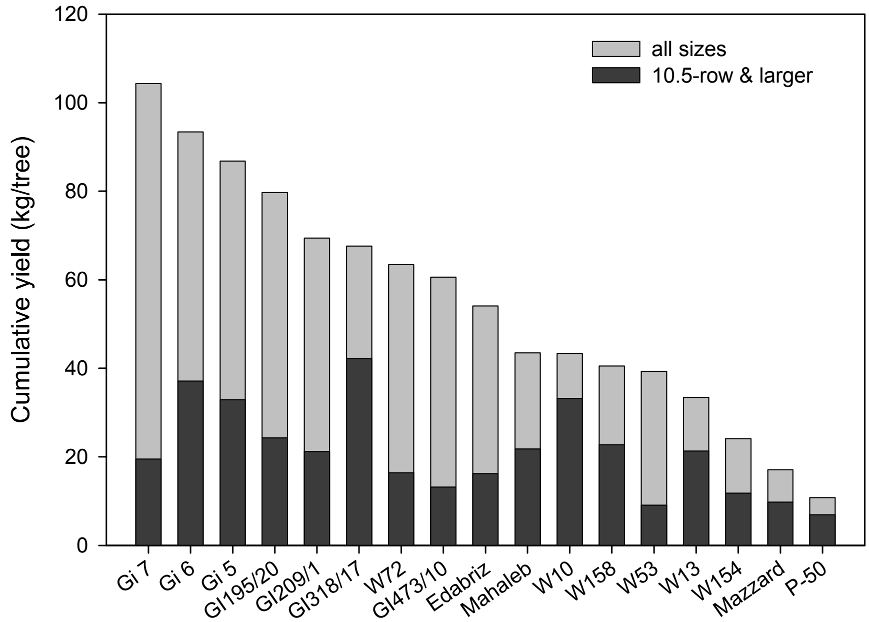


Figure 1.
The effect of rootstock on the cumulative yield of all fruit and 10.5-row and larger 'Bing' fruit (kg/tree) between 1998 and 2003.

Among all rootstocks a close negative relationship existed between tree yield efficiency and annual growth (Fig. 2). This shows that secondary growth of sweet cherry trees is not a strong sink. Moreover, this relationship demonstrates a degree of competition between radial expansion of the trunk and fruit growth because expansion is restricted when trees exhibit high yield efficiency. Therefore, high crop load on trees of limited canopy can inhibit tree growth and canopy development, imparting a dwarfing effect. This effect suggests that the use of yield efficiencies based upon TCSA (*i.e.*, kg fruit/cm^2) for comparative germplasm evaluations may be misleading without reference to this potentially confounding factor. A similar relationship occurs within a scion/rootstock combination (Whiting and Lang, 2003).

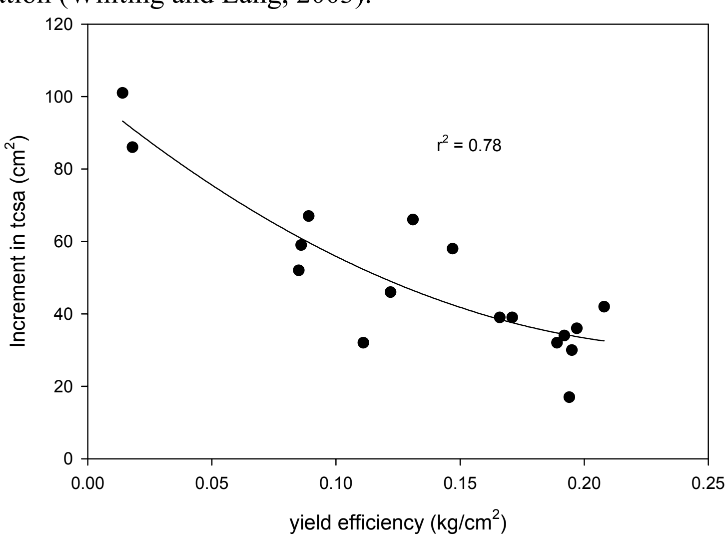


Figure 2.
Relationship between 'Bing' tree yield efficiency (kg fruit per cm^2 trunk cross-sectional area (tcsa)) and the annual increment in tcsa (cm^2).

Not surprisingly, fruit quality, whether measured as soluble solids or weight, is negatively related to tree yield efficiency (Fig. 3). This trend has been more precisely described for 'Bing'/Gisela 5 trees in another project (see report 'Quantifying Limitations to Balanced Cropping). This is the first report of such a relationship across rootstock genotypes however. This result underscores the need to balance crop load with canopy size to produce high quality fruit from size-controlling and precocious rootstocks. Fruit soluble solids are more closely related to tree yield efficiency than fruit weight (r^2 = 0.88 and 0.46, respectively) because sugar accumulation occurs during stage III of fruit development and is therefore dependent upon metabolism during 2003. In contrast, fruit weight is determined, to some degree, during the previous season and therefore less dependent upon tree factors during the season of actual fruit growth and development.

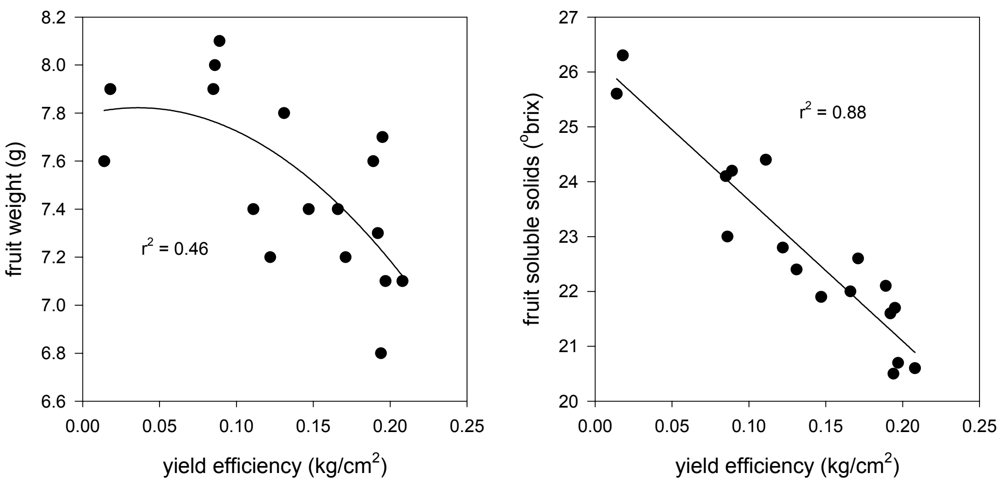


Figure 3. Relationships between ‘Bing’ tree yield efficiency (kg/cm^2 tcsa) and fruit weight (g) and soluble solids (^{o}brix) on 17 different rootstocks.

Fruit yield and quality were evaluated in a plot of WSU selections (Cashmere, Chelan, Tieton, Benton, Selah, Rainier, PC 8011-3, PC 7903-2, and PC 7147-9) planted also in 1998 on Edabriz and several Gisela rootstocks. Tree anchorage was weak for Tieton/Gisela 6 trees and a support structure (likely a single wire trellis) is recommended for that combination. All other combinations exhibited good growth and anchorage. No incompatibilities are apparent at this early stage.

Compared to Bing, fruit quality from this trial was far superior, with the majority of fruit being 10.5-row and larger (Table 1). This is attributable to the improved genetic potential for large fruit in these selections and suggests that, unlike Bing, new varieties on precocious and/or dwarfing rootstocks are less likely to bear heavy crops of poor quality fruit. Gisela 195/20 produced the highest yields and best quality fruit. This is a somewhat size-controlling rootstock that was a particularly good match with Tieton (>40 lbs/tree, 12.2 g, 99% 10.5-row and larger), a variety renowned for bearing light crops.

Rootstock	Yield (lb)	Fruit Weight (g)	Soluble solids	smaller than 12-row (%)	11 and 12-row (%)	10.5-row and larger (%)
Edabriz	25	9.5	22.1	2	27	71
Gi 195/20	44	11.2	21.5	0	3	97
Gi 209/1	20	10.4	22.7	1	18	81
Gi 5	29	10.4	20.6	0	16	84
Gi 6	36	11.1	19.8	1	14	86

Table 1. Effect of rootstock on fruit yield and quality. Data are means across 9 scion varieties (Cashmere, Chelan, Tieton, Benton, Selah, Rainier, PC 8011-3, PC 7903-2, and PC 7147-9).

This project has generated critical clonal rootstock/scion performance information that is providing new strategies for early-producing, high-yielding, efficiently-harvested PNW sweet cherry orchards. The screening for incompatibilities may help prevent economic losses due to unforeseen graft incompatibility of new rootstocks, and screening for adaptability to environmental extremes may help prevent catastrophic economic losses in new or mature orchards. The analysis of rootstock influence on important horticultural characteristics assists in developing management strategies for maintaining productivity in high-density orchards. In addition to annual NC-140 project reports on vigor and yield, 5-year cumulative studies will be compiled after 5 and 10 years in the 1998 trial. Information transfer will occur through research reports at industry meetings (e.g., Cherry Institute, IDFTA), on-site grower evaluations of IAREC and industry cooperator research plots, and publication of results and recommendations in industry (e.g., Good Fruit Grower) and scientific periodicals (e.g., Fruit Varieties Journal, HortScience, etc.).

Literature cited

Whiting, M.D. and G.A. Lang. 2003. Bing Sweet Cherry on the Dwarfing Rootstock Gisela 5: Crop Load Affects Fruit Quality and Vegetative Growth but not Net CO_2 Exchange. J. Amer. Soc. Hort. Sci. In press

Project no.: CH-01-17
Current year request: n/a
Project total: $ 52,706

Year	2001	2002	2003
Total	$15,580	$19,380	$17,746

Current year breakdown

Item			
Salaries[1]	5,897	5,797	6,083
Benefits (28%)	2,123	1,623	1,703
Wages[2]	3,500	6,000	6,000
Benefits (16%)	560	960	960
Equipment		2,000	
Supplies[3]	3,000	2,500	2,500
Travel[4]	500	500	500
Miscellaneous			
Total	$15,580	$19,380	$17,746

[1] 1/6 annual salary for Mr. Efrain Quiroz
[2] Time slip wages for harvest, data collection, and fruit quality and laboratory analyses.
[3] Supplies for fruit evaluations
[4] Travel to plots

NEW PROJECT PROPOSAL **PROPOSED DURATION: 3 YEARS**

TITLE: Clonal Rootstock Performance/Evaluations

Principal Investigators: Matthew Whiting
Organization: Irrigated Agriculture Research and Extension Center, WSU-Prosser
Address: 24106 N. Bunn Road, Prosser, WA 99350
Phone: (509) 786-9260
E-mail: mdwhiting@wsu.edu

Co-Investigators: W.E. Howell, NRSP5/IR2 Manager, WSU-Prosser
D.R. Ophardt, Res. Tech. Supervisor, WSU-Prosser

JUSTIFICATION:
Traditionally, sweet cherry orchards in Washington State have been trained to multiple leader systems on vigorous seedling rootstocks (*e.g*., Mazzard and Mahaleb) at tree densities ranging from 100 to 200 trees per acre. When mature, these systems may be very productive and produce excellent quality fruit, despite not being particularly efficient. The need for a more rapid return on investment, a more labor-efficient system, and the decline in labor availability favor the research and development of novel production systems. In order to compete with cherry-producing countries that have access to an abundant, inexpensive labor force, Washington growers must transition to higher density production systems with improved labor efficiency. This may be accomplished through reductions in canopy volume and vigor so that the tree may be accessed with limited use of ladders. For other tree fruit species this has been accomplished through genetic means (*i.e*., rootstocks that reduce vigor and induce precocity). However, to date very little research has examined the influence of new rootstocks on sweet cherry tree growth, yield, and fruit quality.

OBJECTIVES:

4. 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.

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

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

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

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

LITERATURE REVIEW:

At this stage, a review of pertinent literature on new clonal rootstocks for sweet cherry production is necessarily brief. The fact is, very little research has addressed rootstock effects on scion growth and fruiting. Even less has been published. It is apparent, in other tree fruit species such as apple, that genetic improvement of rootstocks can revolutionize an industry by introducing size control and precocity as well as resistance/tolerance to many common pathogens. Several new series of rootstocks for sweet cherry production have been introduced in the past 10 years but our understanding of their impact on scion vigor and fruitfulness is in its infancy. These include the Gisela, PiKu, and Weiroot series. The most widely planted of these are Gisela 5 and Gisela 6. Both rootstocks induce precocity and Gisela 5 reduces scion vigor in the range of 50 – 60% of that of a standard Mazzard-rooted tree (Whiting and Ophardt, 2004). In an 8-year study of rootstock effect on fruit yield and quality Whiting and Ophardt (2004) found that overall, Gisela 6 was the most productive rootstock yielding between 12 and 25% more fruit than Gisela 5-rooted trees and 50 to 85% more than Mazzard-rooted trees. Both Gisela 5 and 6 were significantly more precocious than Mazzard and induced fruiting two years after planting. Early yields of Gisela series rootstocks were about 4.5 to 6-fold higher compared to Mazzard-rooted trees. This trait is of particular interest to sweet cherry growers because the revenue from early fruit sales allows growers to pay off the high costs of orchard establishment. Preliminary estimates indicate that due to the precocious nature of Gisela 5 and 6 rootstocks, growers may break even 7 years before they would with Mazzard-rooted trees (Seavert, pers. comm.).

Despite the potential advantages of several new rootstocks, their commercial acceptance has been limited. The future utilization of these and the next 'wave' of rootstocks in a commercial scenario will require the development of practical strategies for producing high yields of excellent quality fruit on these rootstocks. Such production systems will be formulated from an understanding of how rootstock affects fundamental canopy characteristics and tree yield potential. This research project proposes to develop this knowledge across a wide range of rootstock and scion genotypes.

Whiting, M.D. and D. Ophardt. 2004. Rootstock and training system affect sweet cherry tree growth, yield potential and fruit quality. In preparation.

Project: Clonal Rootstock Evaluations
P.I.: Whiting
Project duration: 2004-2006
Current year: 2004
Project total: $57,928
Current year request: $19,895

Year	2004	2005	2006
Total	**$19,895**	$18,849	$19,184

Current year breakdown

Item			
Salaries[1]	**6,199**	6,554	6,816
Benefits (28%)	**1,736**	1,835	1,908
Wages[2]	**6,000**	6,000	6,000
Benefits (16%)	**960**	960	960
Equipment[3]	**1,500**		
Supplies[4]	**2,000**	2,000	2,000
Travel[5]	**1,500**	1,500	1,500
Miscellaneous			
Total	**$19,895**	$18,849	$19,184

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

2003 Research Report/2004 Proposal
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 findings in YR 2003:

- 8 additional MSU rootstock selections were planted in the test plot at MSU's Clarksville Horticultural Experiment Station (CHES) with Hedelfingen scion. This represents an additional 48 trees.
- 4 additional MSU rootstock selections were planted in the test plot at WSU-Prosser. This represents an additional 32 trees.
- It is projected from nursery counts that 2004 plantings will result in the evaluation of 84 MSU rootstock selections totaling 386 and 243 trees, respectively, at CHES and Prosser.
- In general, the MSU rootstock selections induce precocity with flowering in the second year after planting.
- Observations for the CHES plot indicate that the rootstocks confer different levels of freeze tolerance with a few selections appearing to confer increased hardiness compared to GI 6. Some rootstock selections are beginning to show symptoms consistent with graft incompatibility.

Methods:

This project consists of four stages:

1. Propagation: Years 1997 –2001 (completed)
2. Virus testing: Years 1998 – 2002 (completed)
3. Planting of grafted trees in test plots: Years 2001 – 2004
4. Rootstock plot evaluation at MSU & WSU: beginning in YR 2001-MSU & YR 2002-WSU.

Years 2002 to 2004, for which a 3 year budget was developed, represent Transition Years in which virus testing, budding and plot establishment will be sequentially completed. Year 2005 will be the first year where the only activity will be plot evaluation. The data to be collected on the trees in the MSU and WSU test plots will be tree survival, trunk cross-sectional area, bloom date, flower number and/or bloom density, crop load and fruit size. Crop load and in special cases actual yield and fruit size data, will only be collected from the most promising selections. This is because it is not necessary to record detailed data from selections that are not performing well and will obviously be discarded.

Results and Discussion:

Plot Establishment

There are currently 49 MSU rootstock selections, totaling 282 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.

There are currently 21 MSU rootstock selections, totaling 117 trees, planted at the test plot in Prosser (Fig. 2). The control rootstock is GI 6 and the scion is Bing with Tieton/GI6 as the pollinator.

The 103 trees for the MSU 2004 planting were produced at Hilltop Nurseries. This represents 35 MSU selections. Sleeping eye buds were put in another 97 additional rootstocks. If these buds take, these trees will be planted in 2005. The 126 trees for the Prosser plot were produced at Meadow Lake Nurseries. This also represents an additional 35 MSU selections. The 2004 planting will be the last planting in the first test trials of the MSU rootstocks.

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

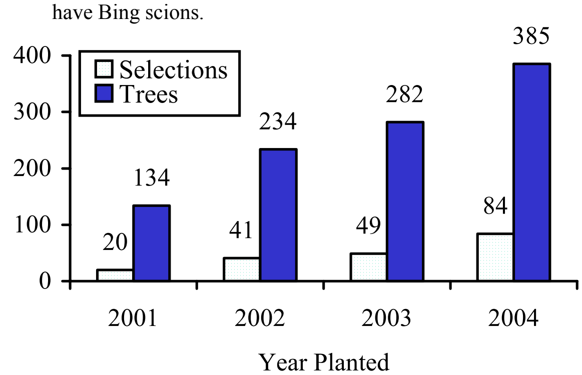
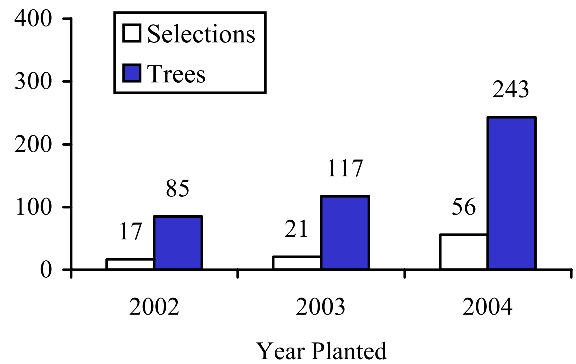


Fig. 2. The cumulative number of MSU rootstock selections and trees currently planted and projected to be planted in Prosser, WA. All of the rootstock selections have Bing scions.



Clarksville – Bloom and trunk growth

Trees planted at CHES in 2002 began to flower with just a few flowers per tree (Fig. 3). Hedelfingen/GI 6 had an average of 2 flowers per tree. Trees that are a year older, planted in 2001, induced larger numbers of flowers (Fig. 4). The highest average flower number category included Hedelfingen/GI 6 with an average of 42 flowers per tree. Unfortunately a spring freeze resulted in a significant flower death. Trunk growth varied for the different rootstocks. In general, Hedelfingen/GI 6 exhibited a high rate of trunk growth compared to the MSU rootstock selections (Figs. 5 & 6).

Fig. 3. Flower counts for Hedelfingen on GI6* and MSU Selections for Clarksville, MI. Trees were planted in 2002.

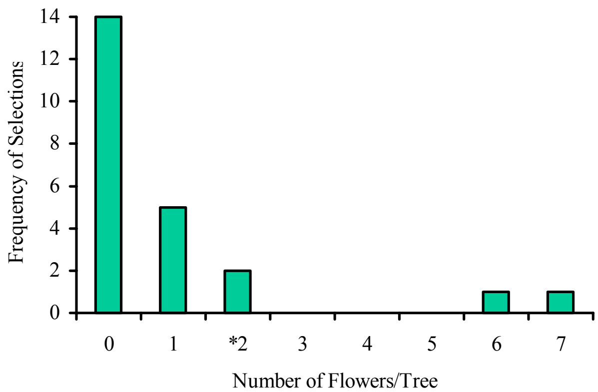


Fig. 4. Flower counts for Hedelfingen on GI6* and MSU Selections for Clarksville, MI. Trees were planted in 2001.

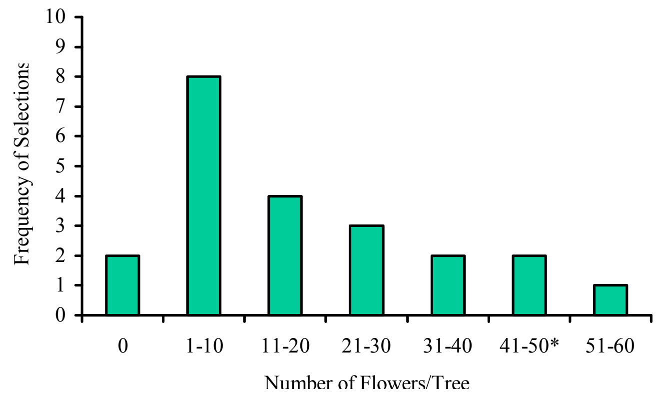


Fig. 5. Trunk growth for trees planted in 2001 at Clarksville, MI. Measurements are in mm and represent the trunk growth between Sept 2002 and Sept 2003. Rootstocks are Hedelfingen and Bing on GI6* and MSU Selections.

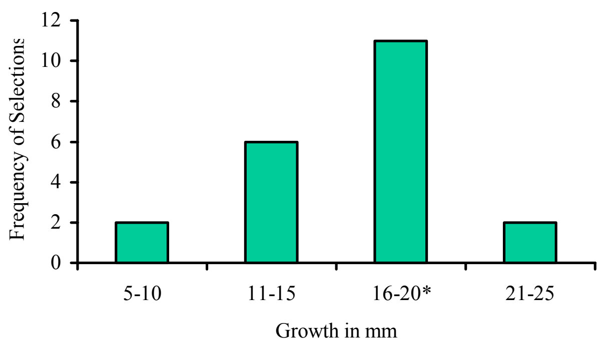
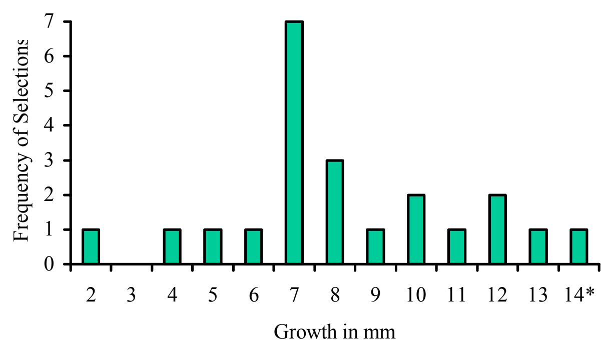


Fig. 6. Trunk growth for trees planted in 2002 at Clarksville, MI. Measurements are in mm and represent the trunk growth between Sept 2002 and Sept 2003. Rootstocks are Hedelfingen on GI6* and MSU Selections.



Prosser – Fruit numbers and trunk growth

The majority of the MSU rootstock selection trees planted at Prosser in 2002 induced flowering and fruiting one year after planting. The fruit number averages ranged from zero to 25 with Bing/GI 6 producing an average of 16 fruit per tree (Fig. 7). Truck growth among the trees also varied.

Fig. 7. Fruit data for Bing on GI6* and MSU Selections for Prosser, Wa. Trees were planted in 2002. ** Represents Tieton GI5, GI6, and GI12.

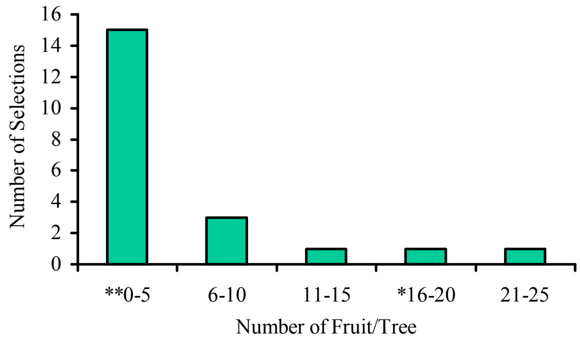


Figure 8

Figure 9

Clarksville – Other observations of rootstock-induced changes

Freeze tolerance: There was severe winter injury on many Bing trees at CHES due to a cold snap in the fall prior to the plants achieving maximum dormancy. The winter injury on GI 6 consisted of one out of 5 trees dead and the remaining 4 trees exhibiting severe wood injury (Fig. 8). By comparison, Bing/III 4 (33) had no winter injury suggesting that this rootstock was able to somehow "prevent" the tree for freeze injury (Fig. 9).

Figure 10

Graft incompatibility: Symptoms consistent with graph incompatibility were apparent on some of the combinations based upon observations made on September 17, 2003 (Fig. 10).

Branch angle: MSU rootstock number III 15 (18) appeared to predispose the scion to wide branch angles relative to the other rootstock candidates.

These observations noted above are being recorded and will be critical in the selection of rootstock candidates that will eventually be propagated for second test trials.

Summary: The MSU cherry rootstock selection project is on target to complete planting of the first grafted trials at MSU and WSU in spring 2004. The abundance of bloom induced by the MSU rootstock selections planted in the MSU and WSU test plots indicate that precocious flowering is easy to achieve. Differences in rootstock induced hardiness and graft incompatibility were apparent in the 2003 growing season and are being recorded as part of the evaluation process.

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), Field Testing will be the only activity beginning in YR 2005.
Current year: 2003
Project total (3 years): $30,489
Current year request: $9,927

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.

Other support: MSU support at CHES for the Iezzoni program is estimated to be ~ $20,000. Funding totaling $3,000 was obtained from the IDFTA for Year 2003 for the project entitled "First grafted trial of MSU's sweet cherry rootstock selections".

Appendix 1: Methods and Objectives for the Transition Year (2004):

YR 2004: Complete the planting phase of the rootstock project at MSU and WSU & continue with data collection.

Table 1: Year 2004 activities to be accomplished by Amy Iezzoni and/or Audrey Sebolt (MSU cherry breeding technician).

	Spring	Summer	Fall
MSU	▪ Plant pollinator trees[1] and trees from the YR 2001 cuttings. ▪ Minimal tree training and pruning. ▪ Take bloom and x-sectional area data[2].	▪ Re-evaluate plot maps and record any dead/sick trees. ▪ Evaluate crop load and fruit data[2].	▪ Data analysis and updating of planting/plot inventory.
WSU	▪ Plant pollinator trees and trees from the YR 2001 cuttings. ▪ Minimal tree training and pruning. ▪ Travel to Prosser to assist in the data collection [bloom and x-sectional area data.][2,3]	▪ Re-evaluate plot maps and record any dead/sick trees. ▪ Evaluate crop load and fruit data[2].	▪ Travel to the West Coast to attend the Cherry Research Review.

[1] The rootstock candidates for MSU and WSU were budded with Hedelfingen and Bing, respectively. Therefore, for each test plot, pollinator trees (MSU-Ulster/GI 6; WSU-Tieton/GI6) need to be purchased so that the Bing/Hedelfingen : pollinator ratio is 8:1.

[2] Data collected: trunk cross-sectional area, bloom date, bloom density, crop load, and fruit size. Crop load and in special cases actual yield data plus fruit size will only be collected from the most promising selections.

[3] Funds are requested to travel to Prosser to assist in tree evaluation.

YR 2005: Evaluate the MSU rootstock candidates planted in field plots at MSU and WSU for their ability to induce dwarfing and precocity. Record tree survival, cross-sectional area, bloom and fruit ripening date, fruit size, and estimates of bloom density and crop load. Crop load and in special cases actual yield data plus fruit size will be only collected from the GI 6 control and the most promising selections. Rationale: There is no need to collect data from selections that are not performing well and will obviously be discarded.

Propagation for advanced trials of promising selections will be initiated if and when any of the MSU rootstock selections look promising.