2011 California Cherry Research Reports

University of California
Washington State University
California Cherry Advisory Board
University of California Cooperative Extension

CALIFORNIA CHERRY RESEARCH REVIEW

Tuesday, January 24, 2012
Evelyn Costa Assembly Room
San Joaquin County Agricultural Center
2101 E. Earhart Avenue, Stockton, California 95206
Sponsored by the University of California Cooperative Extension
California Cherry Advisory Board, and California Cherry Growers & Industries Foundation

8:30 am **Welcome**
Joe Grant, UC Cooperative Extension, San Joaquin County

8:40 **Diagnosis, epidemiology & control of fungal canker diseases in sweet cherry**
Dr. Doug Gubler, Dept. of Plant Pathology, UC Davis

9:05 **Managing pre- and post-harvest diseases of sweet cherries**
Dr. Jim Adaskaveg, Dept. of Plant Pathology, UC Riverside

9:30 **Biology and control of Spotted Wing Drosophila**
Dr. Bob Van Steenwyk, Department ESPM, UC Berkeley

10:05 **Break**

10:25 **Spotted Wing Drosophila: Insecticide residue degradation and maximum residue levels in sweet cherries**
Stephanie Rill, Entomology Staff Research Associate, UC Cooperative Extension, Kern County

10:50 **Postharvest control of SWD in sweet cherries for export markets**
Dr. Spencer Walse, USDA-ARS, Parlier, CA

11:15 **A systems approach to renovating the sweet cherry industry**
Dr. Matthew Whiting, Washington State University, Prosser, WA

11:45 **Oriental Fruit Fly quarantine update for cherry growers.**
Scott Hudson, Agricultural Commissioner, San Joaquin County

12:15 **ADJOURN**

2.5 hours continuing education credit pending (0.5 hr. Laws & Regulations, 2.0 Other)

CCAB 2011 RESEARCH REPORT
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2011 CCAB RESEARCH PROJECTS Approved Funding (3/31/2011)

ITEM	CCAB PROJECT NUMBER	PROJECT LEADER	PROJECT TITLE	FIRST FUNDED PROJECT YEAR	ORIGINAL ESTIMATED DURATION	CURRENT YEARS REMAINING	TOTAL COST TO DATE	2010 FUNDING	2011 PROPOSED FUNDING	2011 REQUESTED FUNDING
PRE-HARVEST PROPOSALS										
1	10-11-99	Doug Gubler UCCE	Diagnosis, epidemiology and control of canker diseases in sweet cherry.	2010	2 years	N/A	$32,500	$12,500	$37,200	**$20,000**
2	WSU 08-11-90	Ken Eastwell	Reducing Impact Little Cherry Virus Vector Identification	2008	N/A	On-going	$25,000	$10,000	$15,000	**$15,000**
3	MSU 06-11-78	Gregory Lang	Cropping Physiology	2006	N/A	On going	$6,734	$6,734	$0	**$0**
4	WSU 08-11-90	Ken Eastwell	Managing virus diseases detrrimental to cherry production.	2008	2 years	1 year	$4,800	$0	$10,000	**$4,800**
5	WSU 10-11-90	Don Elfving	Branch induction in young sweet cherry trees without injury to bark.	2010	1 year	N/A	$2,400	$1,200	$1,200	**$1,200**
						NW to fund $8,441 for project total of $13,441				
6	08-11-91	Kitren Glozer Lang, Grant	Use cherry growth, yield and fruit quality: Demand-driven optimization of nitrogen availility	2008	3 year	N/A	$28,800	$10,000	$0	**$0**
7	11-11-101	Jim Adaskaveg	Root and Nematode Control	2011	2 years	N/A	N/A	$0	$11,500.00	**$0**
8	11-11-104	David Haviland	Development of Residue Degradation Curves for Insecticides against SWD	2011	1 year	N/A	$30,000	$0	$0	**$30,000**
	POST HARVEST PROPOSALS									
9	ARS 10-11-100	Spencer Walse	The treatment of U.S. cherries with methyl bromide to eliminate the spotted wing drosophila,	2010	1 year	1 year	$11,413	$11,413	$0	**$0**
10	11-11-103	Bob Van Steenwyk	Post-Harvest Treatments, Ground Spray and Monitoring	2011	2 year	1 year	$12,159	$0	$12,159	$12,159
JOINT PROPOSALS										
11	08-11-95	J. Adaskaveg J. Grant	Management & Epidemiology of Pre & Postharvest Foliar and Fruit Diseases of Sweet Cherry	2008	4 years	On going	$100,000	$25,000	$28,000	**$28,000**
								TOTAL	$115,059	**$111,159**

First two digits indicate year project began.
Second two digits indicate current year or year project concluded.
Third two digits indicate unique project number, in numeric order from 1987.

Annual Report - 2011

Prepared for the California Cherry Advisory Board

Project Title:	Management and Epidemiology of Pre- and Postharvest Foliar and Fruit Diseases of Sweet Cherry
Project Leader:	Dr. James E. Adaskaveg, Department of Plant Pathology, University of California, Riverside, CA 92521 (951) 827-7577
Cooperators:	Dr. H. Förster, D. Thompson, and J. Grant (Farm Advisor)

SUMMARY

In 2011, dormant, blossom, preharvest, and postharvest management studies were done on major diseases of sweet cherry in California. In bacterial blast and canker studies, we continued using the antibiotic kasugamycin (Kasumin) and the sanitizer peroxyacetic acid (Perasan) in several field studies with inoculated flowers and branches. Highlights were:

- Perasan was ineffective when applied as a dormant treatment to reduce bacterial canker from lateral stem puncture wounds or in protecting stub cuts from infection.
- The antibiotics Kasumin and Mycoshield were highly effective and significantly reduced bacterial blast of wound-inoculated blossoms; whereas copper was ineffective.
- The biological treatment Actinovate also reduced bacterial blast significantly from the non-treated control.
- In studies evaluating the natural incidence of bacterial blast, Kasumin and Mycoshield were very effective in single applications at either 50% or 90% bloom, whereas copper was less effective to ineffective.
- Copper did not inhibit strains of *Pseudomonas syringae* from different locations until concentrations reached 125 ppm or higher, indicating low sensitivity or resistance.

In our powdery mildew trials, eighteen fungicide treatments were evaluated with a wide range of effectiveness. Highlights were:

- The most effective treatments included Quintec, Luna Sensation, Merivon, Fontelis, Quadris Top, Inspire XT and several numbered compounds (Q8Y78, YT669).
- Development of fungicides with unique modes of action (such as SDHI fungicides and BAS560-metrafenone) needs to be continued to prevent overuse of quinolines (Quintec), DMIs, and QoIs.

In pre- and post-infection studies for control of brown rot and Botrytis blossom blight, highly effective fungicides with excellent pre- and post-infection activity against both blossom diseases were identified. Top materials included:

- FRAC 3/11fungicides (e.g., Adament, Quadris Top)
- FRAC 7/11 fungicides (e.g., Pristine, Luna Sensation, Merivon, and Q8Y780)
- FRAC 3 DMI fungicides (e.g., Quash, Inspire XT)

Evaluation of preharvest treatments for fruit decay control after harvest (without washing) and for postharvest decay control after postharvest washes of fruit. Considering the heavy rainfall at harvest this year, efficacy studies were limited. Treatments that performed well include:

- Treatments (5 days PHI) containing a DMI fungicide (Quash, Inspire XT, Quash mixed with the new compound V-10135, and the Elite-Elevate mixture) had high efficacy against brown rot on non-washed and washed fruit.
- Compounds with intermediate efficacy included V-10135, Quash/S-2200, Adament, and Q8Y78.
- None of the fungicides was very effective against gray mold.

The activity of the fungicides on non-wound inoculated fruit was also evaluated.

- In addition to the compounds that were effective on wound-inoculated fruit, the new fungicide YT669, as well as Ph-D, Quadris Top, Luna Sensation, Pristine, Merivon reduced the incidence of decay to very low levels on non-wound inoculated fruit.

- Ph-D was applied as an organic formulation and its high efficacy indicates that it is a promising treatment for organic fruit production.
- Overall, DMI-containing fungicides were most effective against brown rot. These fungicides penetrate into the fruit, persist after postharvest washes, and subsequently help to protect fruit from infections occurring after harvest.

Efficacy of new and registered postharvest treatments for managing decays. New developments in 2011 were:

- The postharvest fungicide fludioxonil (Scholar) received an MRL and food additive tolerance in Japan.
- Organic formulations of polyoxin-D were evaluated as postharvest treatments.
- A new pre-mixture fungicide, Merivon, was evaluated for postharvest use that represented two new modes of action as compared to currently registered fungicides.
- Orius was evaluated as an alternative to Tebuzol and Elite for maintaining the tebuconazole postharvest registration on sweet cherry. Both alternative fungicides are similar to Elite.
- Postharvest drench studies were also done to evaluate the effect of fungicide drench time, hydro-cooling duration, and fruit washing before and after treatment at selected temperatures to determine optimal conditions for using postharvest fungicides (i.e., those approved in Japan). The high effectiveness of the treatments evaluated under a range of conditions was related to obtaining desired fungicide residues.

INTRODUCTION

Overview. The goals of this project are to evaluate new fungicides, natural products, biologicals, and other treatments for the management of pre- and postharvest diseases of sweet cherry. In the last few years, a plethora of new fungicides have been developed. Most of the newer single-fungicides (picoxystrobin, fenpyrazamine, Fontelis, Vivando, Quash, Ph-D, etc.) have a single-site mode of action. This emphasizes the implementation of resistance management strategies to avoid the development of resistant pathogen populations. One of these strategies is the use of pre-mixtures with at least two ingredients of different mode of action that are both active against the pathogen(s). Following the introduction of Pristine, Adament (tebuconazole + trifloxystrobin), Luna Sensation (fluopyram + trifloxystrobin), Inspire XT (difenoconazole + propiconazole), Quilt Xcel (azoxystrobin + propiconazole), Quadris Top (azoxystrobin + difenoconazole), A16976 (difenoconazole + chlorothalonil), Merivon (fluxapyroxad + pyraclostrobin) and Q8Y78 (picoxystrobin+ penthiopyrad) have been developed. Natural products/biocontrols included Actinovate and Ph-D (polyoxin-D) that were evaluated to possibly provide organic growers with alternative treatments for managing major diseases of sweet cherry including brown rot, Botrytis blossom blight and gray mold, as well as powdery mildew. Major goals are to identify and develop treatments to: 1) Prevent overreliance on any one fungicide and develop treatments that would allow for rotations and high levels of control of brown rot; 2) Develop new treatments for managing blossom and fruit diseases caused by *Botrytis cinerea*; and 3) Identify additional modes of action against powdery mildew. In an additional objective we evaluated new treatments for the management of bacterial canker and blossom blast caused by *Pseudomonas syringae*. The antibiotic kasugamycin (Kasumin) that is currently being registered in the United States was compared to oxytetracycline (Mycoshield), the biological Actinovate, and peroxyacetic acid (Perasan).

For postharvest management, our accomplishments in the last several years include the development of several products with unique modes of action. These are: Elite (Tebuzol, Orius), Scholar, Judge (fenhexamid), Penbotec (pyrimethanil), and Mentor (propiconazole). An organic formulation of Ph-D is also being evaluated and is proving to be a promising treatment. These products could be used alone or in mixtures of products to manage all the major decays of sweet cherry. With the establishment of MRLs in many export countries in the last five years and with the establishment of a food additive tolerance (FAT) for fludioxonil in Japan in 2011, Scholar will represent the first postharvest fungicide that the North American cherry industry can use for domestic and international markets including the Japanese market. Scholar is very stable in the presence of chlorine in re-circulating drench or flooder treatments and in combination with other postharvest fungicides, making it cost-effective. The availability of several fungicides belonging to different chemical classes and of different sanitizers for wash treatments is essential for managing the major diseases occurring on sweet cherry after harvest in California. The development of integrated strategies will also be critical for preserving the

efficacy of these fungicides against postharvest fruit decays and for the successful marketing of sweet cherry in global markets where maximum residue limits (MRLs) will be important factors in the future.

Objectives

1. Evaluate, under field conditions, bloom and preharvest applications of new experimental compounds (e.g., fungicides such as Luna Sensation, Quadris Top, Inspire XT, BAS703, and biological products such as Actinovate, Regalia, and Ph-D) as compared to registered fungicides for control of brown rot blossom blight and pre- and postharvest brown rot fruit decay.
   a. Continue to identify new treatments for gray mold (a weakness of DMI fungicides) and brown rot (to prevent resistance from developing to DMI fungicides in orchard populations of *Monilinia* species with potential overuse of these fungicides).
   b. Evaluate new powdery mildew fungicides (i.e., Vivando) and SDHI compounds (fluopyram, fluxapyroxad) using different rates and timings and develop a powdery mildew fungicide program that integrates newly registered materials with current single-site and multi-site mildew fungicides.
   c. Evaluate biologicals and OMRI approved organic treatments.
   d. Evaluate kasugamycin against bacterial blast in flower inoculation studies and canker in stem inoculation studies. Cooperate with J. Grant/C. Ingels project on copper sensitivity of *P. syringae* in canker orchards.
2. Evaluate new fungicides as postharvest treatments and develop cost-effective application methods:
   a. Evaluate generic tebuconazole formulations (Orius 45WP, Tebuzol 45WP) and compare to Elite. Continue to evaluate Scholar, Penbotec, Mentor, Scholar-Mentor and Orius/Tebuzol-Elevate mixtures.
   b. Continue to develop EC_{50} values, baseline sensitivities, and resistance monitoring in target pathogen populations to newly developed fungicides.
   c. Evaluate biologicals and OMRI approved organic treatments (Ph-D).
3. Evaluate postharvest sanitation treatments (e.g., Perasan, potassium hypochlorite) and filtration systems, as compared to standard sodium hypochlorite treatments.

MATERIALS AND METHODS

Evaluation of new fungicides for control of powdery mildew of sweet cherry. A field trial in San Joaquin Co. was conducted to evaluate fungicides for powdery mildew control. Treatments were initiated at full bloom (protection from primary inoculum or ascospores from overwintering chasmothecia), and were followed by two additional treatments (protection from secondary infection from conidia) with selected fungicides (see Fig. 1) to shift the disease progress curve to later in the growing season. Additionally, two rotation programs were evaluated. On 1 June 2011, the incidence of powdery mildew was evaluated on five shoots from inside the tree and on five shoots from the outer tree perimeter for each of the four single-tree replications. Data were analyzed using analysis of variance and LSD mean separation procedures of SAS 9.1.

Evaluation of new fungicides for control of brown rot and Botrytis blossom blight and fruit decay. Laboratory experiments were conducted to evaluate the pre-and post-infection activity of fungicides against brown rot and gray mold blossom blight. For pre-infection activity (protection), blossoms were collected at white bud, opened in the laboratory, and treated using a hand sprayer. After 12 h, blossoms were inoculated with a spore suspension of *M. fructicola* or *B. cinerea* (15,000 conidia/ml) until water droplets formed on anther filaments. To evaluate the post-infection activity ("kick-back'), blossoms were collected, inoculated, and treated after 24 h with a hand-sprayer. Blossoms were evaluated for stamen infection after 4-5 days of incubation at 20 C, >95% relative humidity. Disease incidence was evaluated as the number of stamens infected divided by the total number of anthers per blossom. Three replications of 8 blossoms were used for each treatment and data were analyzed using analysis of variance and LSD mean separation procedures (SAS 9.1).

To evaluate preharvest fungicide applications for control of fruit decay, orchard sites were established in San Joaquin Co. and at UC Davis. In the San Joaquin trial, fungicides were applied to trees 5 days before harvest using a back-pack sprayer calibrated to deliver 100 gal/A (This short PHI was used because persisting rains).

Fruit were harvested, wounded with a glass rod (1 x 1 x 0.5 mm; 8 fruit from each of four single-tree replications), and inoculated with 20 µl of a conidial suspension of *M. fructicola* or *B. cinerea* (40,000 conidia/ml). In the UC Davis trial, treatments were sprayed to run-off to branches with fruit using a hand sprayer. Fruit (8 fruit from each of three single-tree replications) were harvested after one day and non-wound drop-inoculated with a spore suspension of *M. fructicola* (100,000 spores/ml). All fruit were incubated for 3-7 days at 20 C, >95% RH. Percent incidence of infection was determined as the number of fruit infected of the total number of fruit evaluated. Data were analyzed as described above.).

Evaluation of preharvest treatments for postharvest decay control. To evaluate preharvest fruit treatments for postharvest decay management, treated fruit from the San Joaquin orchard were harvested, washed in a small-scale drencher for 5 min at ambient temperature, and wound-inoculated with *M. fructicola* or *B. cinerea* as described above. Percent incidence of infection for brown rot and gray mold was determined as the number of fruit infected of the total number of fruit evaluated. Data were analyzed as described above.

Evaluation of treatments for control of blossom canker and bacterial blast. The efficacy of Perasan for the management of bacterial canker was evaluated using commercial field applications in the same cv. Coral cherry on Colt rootstock. The bark of 2-year-old twigs was puncture-wounded using a nail (3 wounds per twig) and stub cuts were made on Dec. 2, 2010. Wounds were spray-inoculated with *Pseudomonas syringae* (10^7 cfu/ml). Treatments were applied using a commercial air-blast sprayer at 100 gal/A immediately afterwards. Inoculated twigs were sampled on April 13, 2011 and canker lengths were measured. Data were statistically analyzed using analysis of variance and mean separation procedures.

Trials on bacterial blossom blast were done in an orchard in San Joaquin Co. on cv. Coral cherry on Colt rootstock. Pistils, stamens, and part of the petals were removed using scissors and bactericide applications (Kocide 3000, Kasumin, Mycoshield, and Actinovate) were made using a hand sprayer. After air-drying, blossoms were inoculated with *Pseudomonas syringae* (10^7 cfu/ml) by hand-spraying. Inoculated branches were covered with white bags for two days and the incidence of disease (based on the number of diseased blossoms per total number of blossoms) was evaluated after 1 and 2 weeks. For evaluation of treatments to control the natural incidence of blossom blast, applications with Kocide 3000, Kasumin, and Mycoshield were done at 50% bloom (3-9-11), at 90% bloom (3-16-11), or at both timings using a backpack air-blast sprayer at 100 gal/A. Blossoms on ten spurs of each tree were evaluated for the incidence of blast on 3-30-11.

Efficacy of new and registered postharvest treatments for control of brown rot, gray mold, and Rhizopus rot of sweet cherry. A series of experiments was conducted to evaluate the efficacy of simulated postharvest field treatments that are potentially being done immediately after harvest for the management of postharvest decays. Parameters evaluated in five studies included fungicide rates, hydrocooler treatments for selected durations and at selected times after fungicide treatment, fungicide dip vs. drench treatments, pre-washes, temperature of fungicide and post-treatment ('hydrocooler') washes, as well as the amount of residues in treated cherry fruit. Drench treatments were done using a small-scale drench system. Fruit were wound-inoculated with *M. fructicola, B. cinerea,* or *R. stolonifer* before and/or after treatment.

In comparative laboratory tests, the postharvest efficacy of Scholar, Elite, Orius (tebuconazole), two formulations of polyoxin-D (i.e., Ph-D organic and CX10440), Xemium (fluxapyroxad), and Merivon as compared to Pristine were evaluated in their efficacy against brown rot, gray mold, and Rhizopus rot. Fungicides were applied as aqueous solutions. Fruit were wound-inoculated with 20 µl of a spore suspension of *M. fructicola, B. cinerea,* or *R. stolonifer* (30,000 spores/ml), incubated for 11-14 h, and then treated using an air-nozzle sprayer. Fruit were incubated for 4-7 days at 20 C, >95% RH. Incidence of decay was determined as the number of fruit infected of the total fruit evaluated. Data were analyzed using analysis of variance procedures of SAS 9.1.

Evaluate postharvest sanitation treatments (e.g., Perasan, potassium hypochlorite) and filtration systems, as compared to standard sodium hypochlorite treatments. This objective was postponed due to the delay of a supply of potassium hypochlorite from the registrant. This objective will continue if product is available.

RESULTS AND DISCUSSION

Evaluation of new fungicides for control of powdery mildew of sweet cherry. The efficacy of new fungicides and new pre-mixtures was evaluated in our research plot in San Joaquin Co. Three applications were done over a 6-week period starting at full bloom with blossom blight applications. At evaluation time, leaves on trunk shoots (water sprouts) or the older outside canopy leaves showed symptoms of powdery mildew in the untreated control. The average severity rating was 4.7 to 4.8 (for a maximum rating of 5). The most effective treatments included Quintec, all SDHI-containing pre-mixture fungicides (Luna Sensation, Merivon, and Q8Y780), as well as the SDHI Fontelis, and selected DMI fungicides such as Adament, Inspire XT, and Quadris Top (Fig. 1). The experimental QoI YT669 also performed very well. Other numbered compounds such as S-2200 (rate dependent efficacy), tank mixtures of Xemium+Vivando or S2200+Quash were intermediate in their performance.

Thus, we continued to demonstrate the excellent activity of several new fungicides against powdery mildew and we show that the disease can be reduced to acceptable levels by properly timed applications. Development of fungicides with unique modes of action (such as SDHI fungicides and others) needs to be continued to provide options in rotation programs and to prevent overuse of quinoline (i.e., Quintec), DMI, and QoI fungicides. In bloom and petal fall fungicide programs, materials should be used that are very effective against blossom blight and powdery mildew diseases such as selected pre-mixtures. Luna Sensation, Merivon, and Q8Y780, all containing SDHI fungicides, should be excellent powdery mildew fungicides that could be used in rotation with other fungicides. Similarly, Vivando is potentially an excellent rotation material or mix partner because of its unique mode of action and specificity against powdery mildew fungi (Quintec is also specific to powdery mildew). Rotation of these different mode-of-action fungicides potentially may off-set resistance selection by limiting the use of any single-site mode of action fungicide (i.e., single FRAC number) and thus, this reduces the selection pressure. Limiting any one fungicide product will also reduce the residue and ensure that MRLs are not exceeded with any of the trade partners of the cherry industry.

Efficacy of new fungicides for control of brown rot and Botrytis blossom blight. Fungicide treatments were evaluated on detached opened blossoms in comparative laboratory studies. In pre- and post-infection studies, new and registered fungicides were very effective against brown rot blossom blight (Fig. 2) and Botrytis blossom blight (Fig. 3). Highly effective fungicides with excellent pre- and post-infection activity against both blossom diseases included: FRAC 3/11fungicides (e.g., Adament, Quadris Top); FRAC 7/11 fungicides (e.g., Pristine, Luna Sensation, Merivon, and Q8Y780), as well as FRAC 3 DMI fungicides (e.g., Quash, Inspire XT). S-2200 was the only fungicide that showed post-infection but not pre-infection activity against brown rot. Due to the good pre- and post-infection activity of most fungicides, the practice of a single delayed-bloom spray when environmental conditions are not very conducive for disease development is an excellent strategy for obtaining highly effective disease control with a minimal number of blossom applications on sweet cherry to manage blossom diseases.

Evaluation of preharvest treatments for fruit decay control without postharvest washes and for postharvest decay control after postharvest washes. Two preharvest efficacy trials were conduced in 2011. A heavy rainstorm that occurred between fungicide application and harvest in the first trial caused extensive fruit splitting and subsequent decay. Few non-injured fruit could be harvested for our efficacy studies, and there was only enough to evaluate the efficacy of the treatments on wound-inoculated fruit. Considering this heavy rainfall, some treatments, especially those containing a DMI fungicide, still performed with high efficacy against brown rot on non-washed fruit in these applications that were made five days before harvest. These included Quash (even when used at a low rate of 2.5 oz/100 gal), Inspire XT, Quash mixed with the new compound fenpyrazamine (V-10135), and the Elite-Elevate mixture (Fig. 4). Thus, the DMI fungicides with their locally systemic action are still unrivaled for management of brown rot decay. Compounds with intermediate efficacy included fenpyrazamine by itself, Quash mixed with another new compound (i.e., S-2200), Adament, and Q8Y78 which is a new pre-mixture of picoxystrobin and penthiopyrad. None of the fungicides was very effective against gray mold (Fig. 4). This is probably because fungicides that are active against this decay (e.g., Elevate, Pristine and other SDHI compounds) do not penetrate into the fruit (i.e., non-systemic) and residues on the fruit were removed by the rain.

The activity of the fungicides on non-wound inoculated fruit was evaluated at the UC Davis location where fruit splitting from the rain was less severe. Only a few trees were available for the study, and thus, applications were made to individual fruit-bearing branches by hand-spraying. In this test, all treatments significantly reduced the incidence of brown rot decay from that of the control (Fig. 5). In addition to the compounds that were effective on wound-inoculated fruit in the first study, the new fungicide picoxystrobin (YT669), as well as Ph-D, Quadris Top, Luna Sensation, Pristine, Merivon reduced the incidence of decay to very low levels. Ph-D was applied as an organic formulation and its high efficacy indicates that it is a promising treatment for organic fruit production. In last year's trials this compound also showed very good efficacy against gray mold.

On washed fruit, very similar results for the control of brown rot were obtained for most treatments as compared to non-washed fruit (Fig. 4). This is probably because removable residues were already washed off by the heavy rainfall before harvest. The main exception was Fontelis that was more effective on the washed fruit; and this cannot be easily explained.

Overall, DMI-containing fungicides were most effective against brown rot. These fungicides penetrate into the fruit, persist in postharvest washes, and subsequently help to protect fruit from infections occurring after harvest without additional postharvest fungicide application.

Evaluation of treatments for control of blossom blast and bacterial canker. In the two trials that were conducted for the management of bacterial canker after inoculation of blossoms with *P. syringae*, treatments with Kocide 3000 had little or no effect on the incidence of blossom blast (Figs. 6,7). In contrast, kasugamycin (Kasumin), Mycoshield, and the biocontrol Actinovate significantly reduced the disease. Numerically, treatments with Kasumin showed the lowest amount of disease and Mycoshield was intermediate. Mycoshield was included in the study because it is known to be effective against bacterial diseases, but no new registrations for this antibiotic are planned.

Kasumin and Mycoshield were also very effective in air-blast spray applications to control the natural incidence of blossom blast (Fig. 8). Both antibiotics were similarly effective in applications done at 50% or 90% bloom. Kocide 3000 again was either not effective or less effective than the other two treatments. Significant reductions in the incidence of blast after applications with Kocide 3000 were only obtained using a single application at 90% bloom or two applications at 50 and 90% bloom. Thus, Kasumin is a promising treatment for the management of blossom blast and our studies are an important step in the development of this treatment for use on cherry in California. Critical to its development is the determination of infection periods because the antibiotic is not very persistent in the environment and additionally, should be used only at proper timings to prevent overuse and potential selection for resistant populations.

In our previous studies, treatments for the management of bacterial canker showed only minimal effects. This year, Perasan was evaluated at a higher rate (500 ppm) in commercial air-blast spray applications. Although applications were done immediately after inoculation, the severity of disease (i.e., canker length) was not reduced significantly from that of the control. Thus, although we made considerable progress in the management of bacterial blast, the control of bacterial canker is still a long-term goal. Due to the long infection period for woody tissues, this will likely remain a challenge for a long time. Possibly, the use of a biocontrol agent such as Actinovate should be evaluated in future studies.

Efficacy of new and registered postharvest treatments for control of brown rot, gray mold, and Rhizopus rot of sweet cherry. In postharvest decay management in 2011, several studies were done for the development of a field drench application system where treatments potentially are applied in the field immediately after harvest. Advantages include protection of any wounds on fruit that occur during harvest from fungal infection in the most timely manner. In a series of experiments on the efficacy of simulated postharvest field treatments with mostly using Scholar, parameters evaluated included fungicide rates, hydrocooler treatments for selected durations and at selected times after fungicide treatment, fungicide dip vs. drench treatments, pre-washes, temperature of fungicide and post-treatment ('hydrocooler') washes, as well as the amount of residues in treated cherry fruit. In

additional postharvest studies, the efficacy of new and registered fungicides was evaluated with an emphasis on polyoxin-D that potentially could be registered for organically grown fruit.

Development of a field drench application system. In a rate comparison, treatments with Scholar 230SC at 6 fl oz/100 gal (= 112 ppm) were overall highly effective, but in some cases slightly less effective as compared to the 10-fl oz rate (= 187 ppm) (Figs. 10, 11). This demonstrated again, that in fungicide dip and drench applications a high efficacy can be obtained using lower rates as compared to a spray application. Increasing drench duration from 1, 5, to 10 min increased fungicide residues from 5.9, 9.5, to 10.2 ppm, respectively (Fig. 13). Interestingly, lower amounts of fludioxonil accumulated in fruit when Scholar was mixed with Orius as compared to treatments with Scholar alone (Fig. 14). When 1% fruit coating (D251) was added to the re-circulating fungicide solution, efficacy remained very high (Fig. 12). Pre-washes of fruit slightly decreased fungicide uptake, but did not compromise efficacy (Fig. 13). Hydrocooler treatments for selected durations done 1 to 3.5 h after fungicide application sometimes reduced residues in fruit but mostly did not reduce the efficacy of Scholar as compared to non-hydrocooled fruit (Figs. 11, 12, 13). Penbotec was also highly effective in the drench treatments against brown rot and gray mold but not Rhizopus rot (Fig. 12). Scholar treatments applied at 22-23C or 5-12C were similarly highly effective, but in one study there was a trend for lower residues for treatments at lower temperature (Fig. 13) but not in another study (Fig. 14).

Thus, in these experiments we evaluated several conditions that potentially are encountered in the commercial use of a postharvest fungicide field drench application. The very high effectiveness of these treatments under a range of conditions is notable and this was correlated with fungicide residues. Because cherry fruit production and handling practices after harvest and prior to the fungicide treatment may determine the accumulation or uptake of residues, further studies are needed to find standardized conditions for limiting fungicide residues to the maximum allowed values.

Efficacy of new and registered postharvest treatments. Comparative evaluations were done in laboratory studies where fruit were wound-inoculated and then treated (i.e., Inoculated-Treated) to simulate harvest and handling practices that generally lead to fruit injuries followed by packinghouse fungicide treatments to prevent decay. Several exciting developments occurred in 2011: 1) The postharvest fungicide fludioxonil (Scholar) received a MRL and food additive tolerance (FAT) in Japan; 2) Organic formulations of polyoxin-D were provided by two registrants for evaluation as postharvest treatment; 3) A new pre-mixture fungicide was evaluated for postharvest use that represents two new modes of action as compared to currently registered postharvest fungicides; and 4) Orius (similar to Tebuzol) was evaluated as an alternative to Elite for maintaining the tebuconazole postharvest registration on sweet cherry. As of 2010, the registrant of Elite announced it would no longer support the registration of Elite including both pre- and postharvest labels. Fortunately, UPI the registrant of Tebuzol added postharvest usage onto its label from the Elite Section 24C label. Thus, the Section 24C for postharvest usage of Elite will expire and Tebuzol is positioned to be the replacement.

An important finding in our postharvest studies last year was that an organic formulation of polyoxin-D (Ph-D) showed very good efficacy against brown rot and especially gray mold as a post-harvest treatment. Although not highly effective against Rhizopus rot, polyoxin-D is a very promising treatment that potentially could be approved for organically grown fruit. Thus, a goal was to evaluate organic formulations of polyoxin-D as organic postharvest fungicide treatments as compared to registered postharvest fungicides for the sweet cherry industry. Both polyoxin-D formulations were effective against brown rot and gray mold, significantly reducing the incidence of these decays by 70-80% from that of the untreated control. These fungicides were not effective against Rhizopus rot and in general, Ph-D performed more consistently than CX 10440; additionally, the organic formulation of Ph-D was more consistent than the conventional formulation. Furthermore, higher rates of CX-10440 did not improve the performance, whereas higher rates of Ph-D did significantly reduce the incidence of Rhizopus rot. Scholar and Elite were consistently the most effective fungicides in all of the trials reducing all the decays including Rhizopus rot to zero or near zero levels (Figs. 15 to 18).

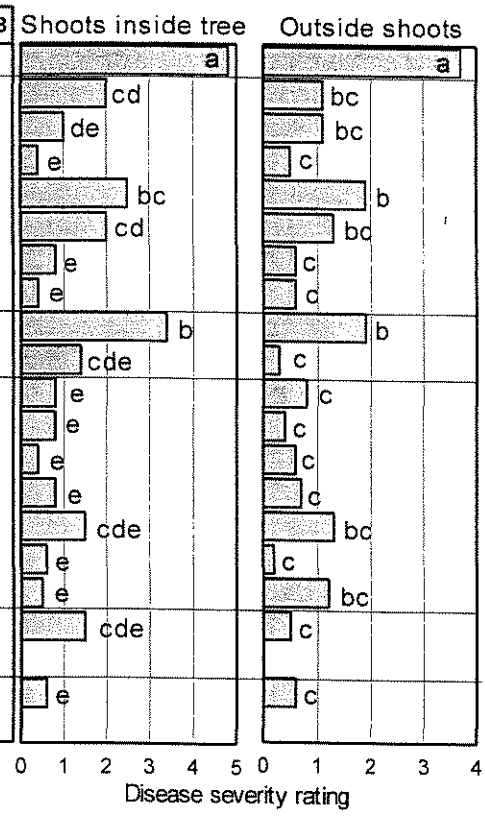
In studies evaluating the potential of Orius as a postharvest alternative for the canceled Elite, Orius was highly effective and similar to Elite in reducing the incidence of all of the decays evaluated: brown rot, gray mold, and Rhizopus rot (Figs. 17,18 and 20,21). Orius also performed well at reduced rates in combination with Scholar in a tank mixture, resulting in excellent decay control (Fig. 21). Overall, Scholar by itself is the most effective broad-spectrum treatment ever developed and is a stand-alone treatment because it is not used in preharvest applications. Still, it can be used in combination with tebuconazole or with Mentor, and these mixtures will provide an excellent anti-resistance management strategy.

A new pre-mixture fungicide, Merivon (containing pyraclostrobin and fluxapyraxad), that is being developed for preharvest use, was also evaluated for postharvest use. Similar to the other postharvest trials described above, Merivon and one of its components, fluxapyroxad (BAS700), was compared to Pristine and one of its components, boscalid (BAS510). Fluxapyraxad and boscalid, both SDHI fungicides, performed poorly as postharvest treatments against brown rot, gray mold, and Rhizopus rot of ripe sweet cherries (Figs. 19,20). Merivon and Pristine were compared at the equivalent amount of pyraclostrobin in each treatment. Both pre-mixture fungicides were highly effective against the three decays (Figs. 19,20).

Evaluate postharvest sanitation treatments (e.g., Perasan, potassium hypochlorite) and filtration systems, as compared to standard sodium hypochlorite treatments. This objective was postponed due to the delay of a supply of potassium hypochlorite from the registrant. This objective will continue if product is available. Potassium hypochlorite possibly may provide packers an alternative to the standard sodium hypochlorite as a sanitizing treatment. Some municipalities limit the amount of sodium disposed by businesses into waste water facilities. In addition to peroxyacetic acid, having multiple oxidative materials for maintaining water used in packinghouses free of microbial contamination is essential in providing produce free of bacteria than may cause human diseases or fungi that cause fruit decay.

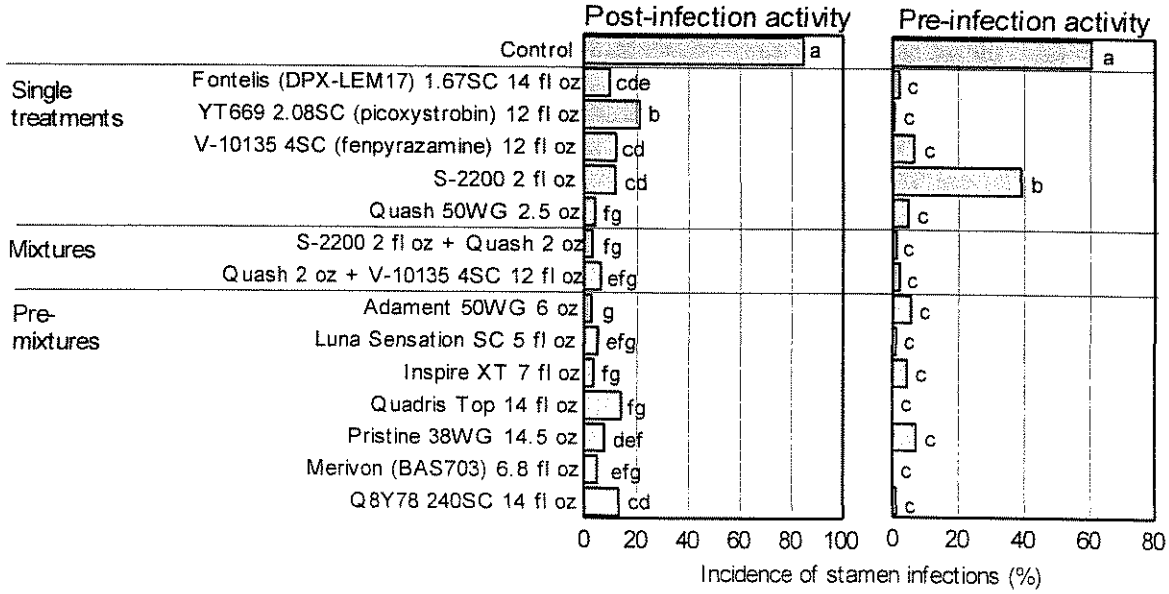
Fig. 1. Efficacy of preharvest fungicide applications for management of powdery mildew of Bing sweet cherries in San Joaquin Co. - 2011

		3-17	4-7	4-28
	Control	---	---	---
Single treatments	S-2200 2 fl oz	@	@	@
	S-2200 3 fl oz	@	@	@
	YT669 2.08SC 12 fl oz + NIS	@	@	@
	V-10135 4SC (fenpyrazamine) 12 fl oz	@	@	@
	Quash 50WG 2.5 oz	@	@	@
	Fontelis (DPX-LEM17) 1.67SC 14 fl oz + NIS	@	@	@
	Fontelis (DPX-LEM17) 1.67SC 20 fl oz + NIS	@	@	@
Mixtures	Quash 50WG 2 oz + V-10135 4SC 12 fl oz	@	@	@
	S-2200 2 fl oz + Quash 50WG 2 oz	@	@	@
Pre-mixtures	Adament 50WG 6 oz	@	@	@
	Luna Sensation 5 fl oz	@	@	@
	Inspire XT 7 fl oz	@	@	@
	Quadris Top 14 fl oz	@	@	@
	Pristine 38WG 14.5 oz	@	@	@
	Merivon (BAS703) 6.8 fl oz	@	@	@
	Q8Y78 240SC 14 fl oz	@	@	@
Rotations	Xemium (BAS700) 3.4 fl oz	@	-	-
	Vivando (BAS560) 10 fl oz	@	@	@
	Iprodione 4F 12 fl oz	@	-	-
	Quintec 2L 7 fl oz	@	@	@



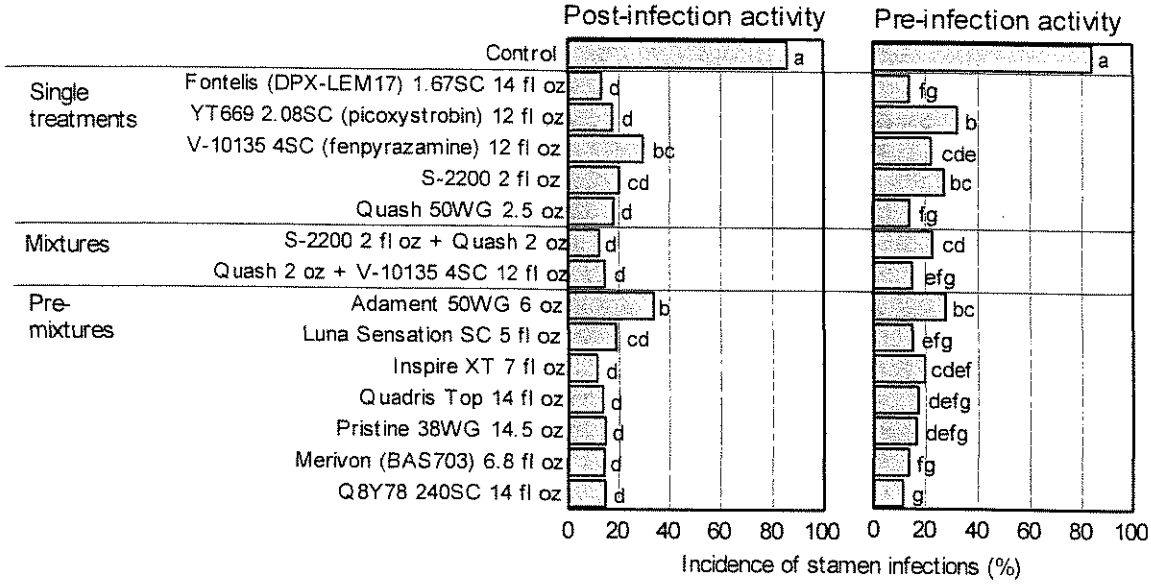
Treatments were applied in the field using an air-blast sprayer (100 gals/A). Evaluation was done on 6-1-11. For this, 10 leaves from 5 shoots from inside or outside of the tree were sampled. Disease was evaluated using the following rating: 0=healthy, 1 = 1-3 lesions, 2 = <25%, 3 = up to 50%, 4 = >50% of leaf area affected. Q8Y78 240SC is a pre-mix of picoxystrobin and penthiopyrad.

Fig. 2. Efficacy of pre- and post-infection treatments with selected fungicides for management of brown rot blossom blight of Bing sweet cherry



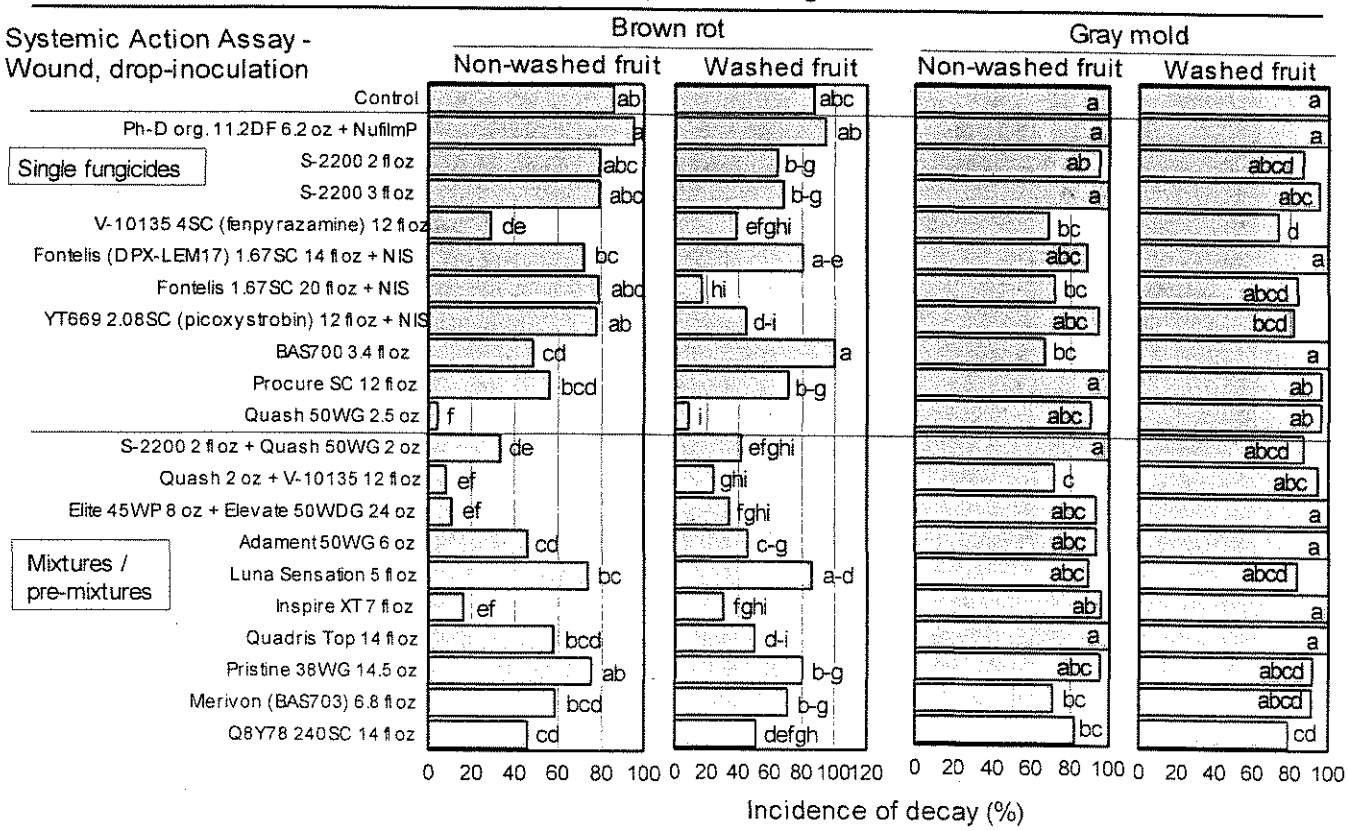
For evaluation of the pre-infection acticity, closed blossoms were collected in the field, allowed to open, and treated in the laboratory using a hand sprayer. After 12 h blossoms were inoculated with a spore suspension of *M. fructicola*(15K/ml). For evaluation of the post-infection activity, blossoms were inoculated were treated with a hand-sprayer after 24 h. Blossoms were evaluated for stamen infections after 4-5 days of incubation at 20 C. Q8Y78 240SC is a pre-mix of picoxystrobin and penthiopyrad.

Fig. 3. Efficacy of pre- and post-infection treatments with selected fungicides for management of gray mold blossom blight of Bing sweet cherry



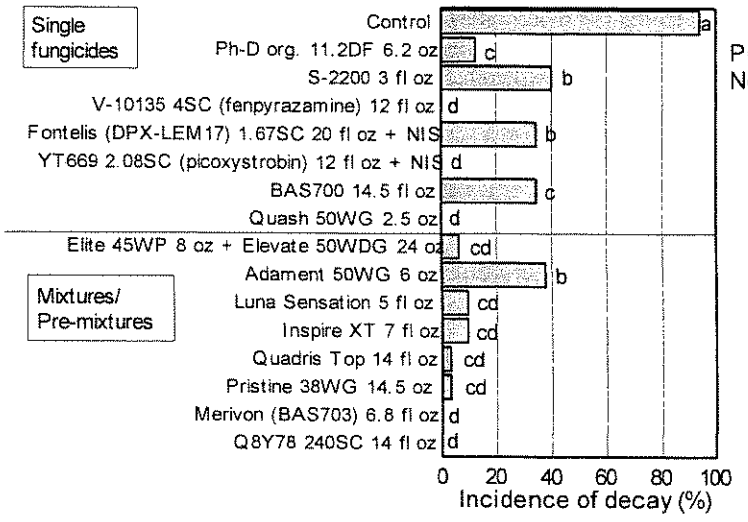
For evaluation of the pre-infection acticity, closed blossoms were collected in the field, allowed to open, and treated in the laboratory using a hand sprayer. After 12 h blossoms were inoculated with a spore suspension of *B. cinerea* (20K/ ml). For evaluation of the post-infection activity, blossoms were inoculated were treated with a hand-sprayer after 24 h. Blossoms were evaluated for stamen infections after 4-5 days of incubation at 20 C. Q8Y78 240SC is a pre-mix of picoxystrobin and penthiopyrad.

Fig. 4. Efficacy of 5-day preharvest fungicide treatments for management of postharvest brown rot and gray mold of Bing cherries - Orchard 1



Treatments were applied on 6-2-11 using an air-blast sprayer at a rate of 100 gal/A. High rainfall occurred between time of application and harvest. Washes of harvested fruit were done in a small-scale drencher. Fruit were wound-inoculated with *M. fructicola* or *B. cinerea* (500,000 spores/ml) and incubated at 20C for 6 days. Q8Y78 240SC is a pre-mix of picoxystrobin and penthiopyrad.

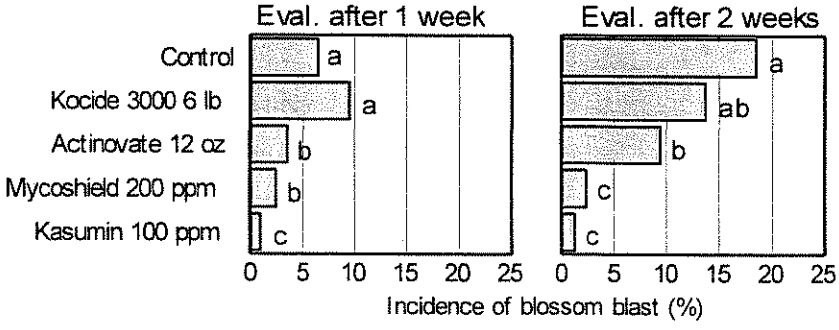
Fig. 5. Efficacy of 1-day preharvest fungicide treatments for management of postharvest brown rot decay of Bing cherries - Orchard 2



Protective Action Assay - Non-wound, drop-inoculation

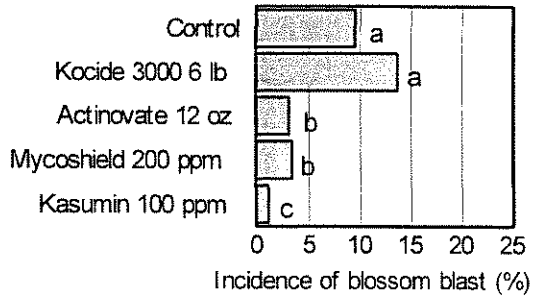
Treatments were applied on 6-16-11 using a hand sprayer. Fruit were non-wound drop-inoculated with *M. fructicola* (100,000 spores/ml). NIS = non-ionic surfactant. Q8Y78 240SC is a pre-mix of picoxystrobin and penthiopyrad.

Fig. 6. Evaluation of antibacterial treatments for protection of inoculated blossoms of cv. Coral cherry on Colt rootstock against bacterial blast in San Joaquin Co. 2011



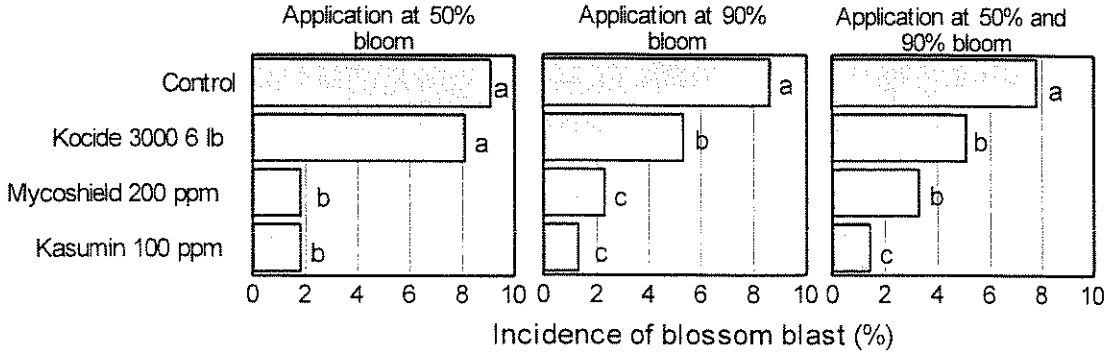
Blossoms were wounded by cutting off pistils, stamens, and part of the petals. Applications were made using a hand sprayer. After 2 h, blossoms were inoculated with *Pseudomonas syringae* (10^7 cfu/ml) by hand-spraying. Inoculated branches were covered with white bags for 2 days and disease was evaluated after 1 and 2 weeks.

Fig. 7. Evaluation of antibacterial treatments for protection of inoculated blossoms of cv. Coral cherry on Colt rootstock against bacterial blast in San Joaquin Co. 2011



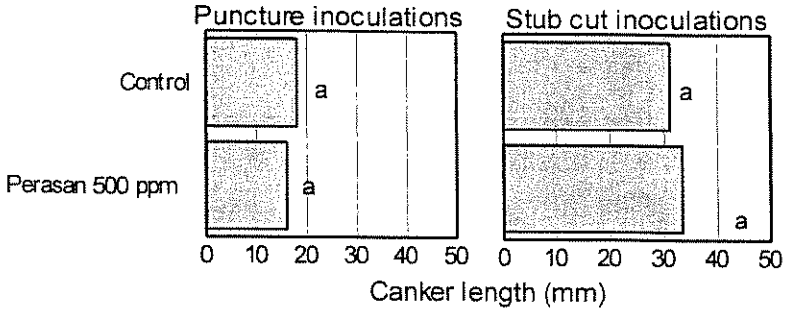
Blossoms were wounded by cutting off pistils, stamens, and part of the petals. Applications were made using a hand sprayer. After 3.5 h, blossoms were inoculated with *Pseudomonas syringae* (10^7 cfu/ml) by hand-spraying. Inoculated branches were covered with white bags for 2 days and disease was evaluated after 2 weeks.

Fig. 8. Evaluation of antibacterial treatments for protection of blossoms of cv. Coral cherry on Colt rootstock from natural infections of bacterial blast in San Joaquin Co. 2011



Applications were made using a backpack airblast sprayer at 100 gal/A on 3-9 and 3-16-11. Blossoms on 10 spurs of each tree were evaluated for disease on 3-30-11.

Fig. 9. Evaluation of commercial applications with Perasan for protection of inoculated twigs of cv. Coral on Colt rootstock cherry trees against bacterial canker in San Joaquin Co. 2011

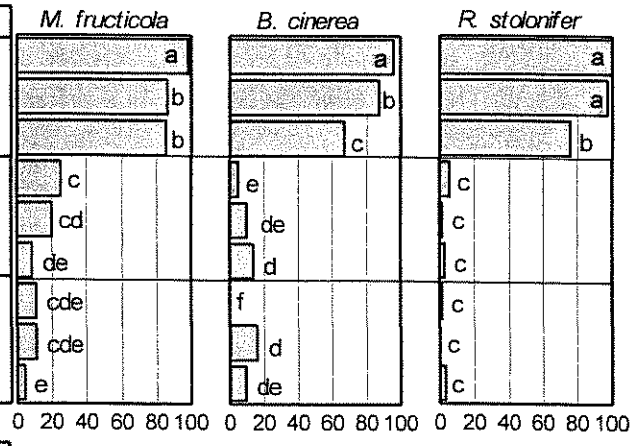


The bark of 2-year-old twigs was puncture-wounded using a nail (3 wounds per twig) and stub cuts were made on Dec. 2, 2010 Wounds were spray-inoculated with *Pseudomonas syringae* (10^7 cfu/ml). Treatments with Perasan at 500 ppm were applied using a commercial airblast sprayer at 100 gal/A immediately afterwards. Inoculated twigs were sampled on April 13, 2011 and canker lengths were measured.

Fig. 10. Evaluation of simulated postharvest field treatments of sweet cherry for management of fruit decays

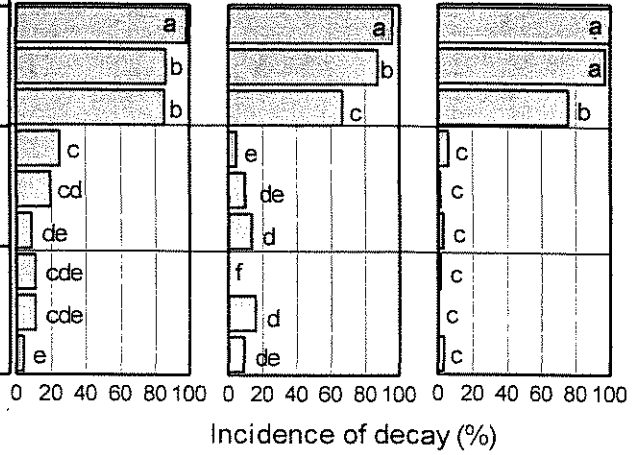
A. Inoculated - Treated

Dip treatment	Hydocooler
Control	-
Control	1 h
Control	3.5 h
Scholar 6 fl oz	-
Scholar 6 fl oz	1 h
Scholar 6 fl oz	3.5 h
Scholar 10 fl oz	-
Scholar 10 fl oz	1 h
Scholar 10 fl oz	3.5 h



B. Treated - Inoculated

Dip treatment	Hydocooler
Control	-
Control	1 h
Control	3.5 h
Scholar 6 fl oz	-
Scholar 6 fl oz	1 h
Scholar 6 fl oz	3.5 h
Scholar 10 fl oz	-
Scholar 10 fl oz	1 h
Scholar 10 fl oz	3.5 h

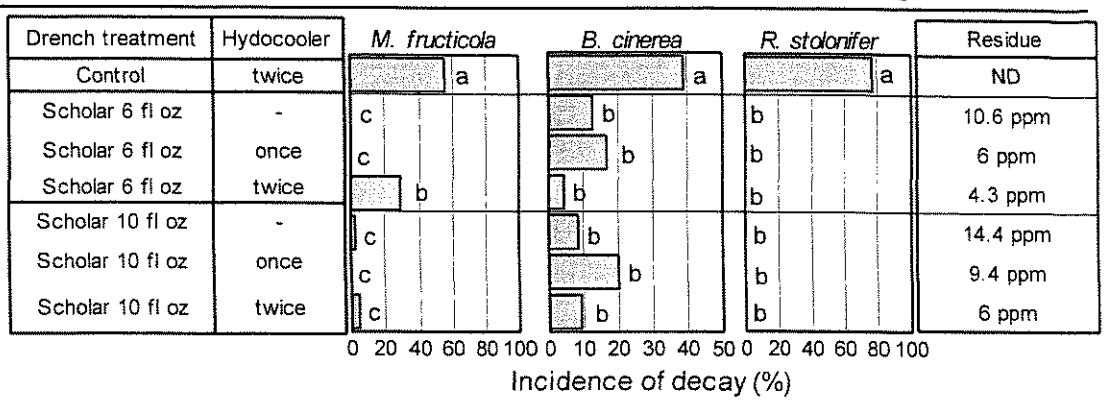


Incidence of decay (%)

For the Inoculated-Treated schedule, fruit were wound-inoculated with *M. fructicola*, *B. cinerea*, or *R. stolonifer* (30,000 spores/ml). After 1 h, fruit were dipped for 8 min in water (controls) or Scholar solutions at ambient temperature. After 1 h or 3.5 h, aliquots of the fruit were floated through a commercial hydrocooler (4.5 min pass time), air-dried, and then incubated at 20C for 5 to 7 days. For the Treated-Inoculated schedule, fruit were first treated as described above and then inoculated.

Fig. 11. Evaluation of simulated postharvest field drench treatments of sweet cherry for management of fruit decays and persistence of residues after hydrocooling

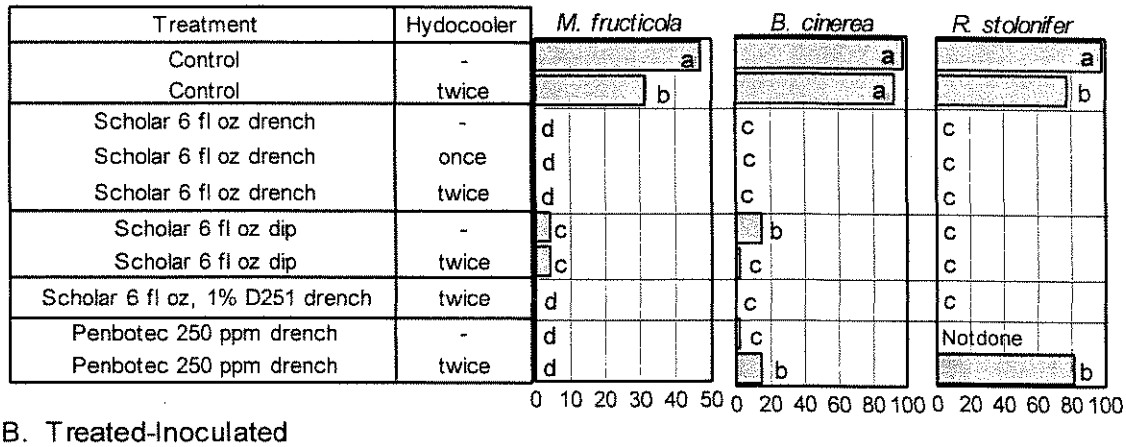
A. Inoculated - Treated



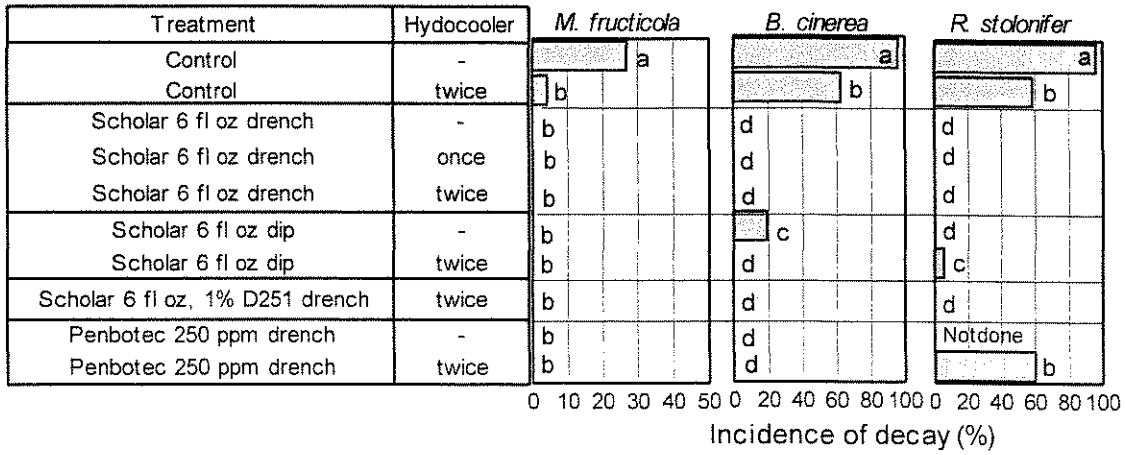
Fruit were wound-inoculated with *M. fructicola*, *B. cinerea*, or *R. stolonifer* (30,000 spores/ml). After 2-3 h, fruit were treated for 5 min in a small-scale re-circulating drencher with fungicide or water (control). After 2.5 h, aliquots of the fruit were floated through a commercial hydrocooler (4.5 min pass time), air-dried, and then incubated at 20C for 5 to 7 days.

Fig. 12. Evaluation of simulated postharvest field drench treatments of sweet cherry for management of fruit decays

A. Inoculated - Treated



B. Treated-Inoculated

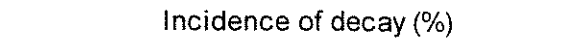


For the Inoculated-Treated schedule, fruit were wound-inoculated with *M. fructicola*, *B. cinerea*, or *R. stolonifer* (30,000 spores/ml). After 1-2 h, fruit were treated for 5 min in a small-scale re-circulating drencher or by dipping with fungicide or water (control). After 2.5 h, aliquots of the fruit were floated once or twice thorugh a commercial hydrocooler (pass time 5 min each). Fruit were then incubated at 20C for 5 to 7 days. For the Treated-Inoculated schedule, fruit were first treated as described above and then inoculated.

Fig. 13. Evaluation of simulated postharvest field drench treatments of sweet cherry with Scholar for management of fruit decays and persistence of residues after hydrocooling

Treated-Inoculated

Pre-wash (simulated hydrocooler)	Scholar drench	Post-wash (simulated hydrocooler)	*M. fructicola*	*B. cinerea*	*R. stolonifer*	Residue
-	-	-	a	b	a	---
5 min at 25C	-	-	a	a	a	0.2 ppm
-	5 min at 22C	-	b	c	c	8.4 ppm
5 min at 25C	1 min at 22C	10 min at 4.4-5.3C	b	c	c	5.9 ppm
5 min at 25C	5 min at 22C	10 min at 4.4-5.3C	b	c	c	9.5 ppm
5 min at 25C	10 min at 22C	10 min at 4.4-5.3C	b	c	c	10.2 pmm
5 min at 25C	5 min at 22C	-	b	c	c	8.7 ppm
4 min at 10-11.6C	5 min at 11.6-12.8C	-	b	c	c	9 ppm
4 min at 10-11.6C	5 min at 11.6-12.8C	5 min at 4.4-5.3C	b	c	b	3.8 ppm
4 min at 10-11.6C	5 min at 11.6-12.8C	10 min at 4.4-5.3C	b	c	b	4.7 ppm



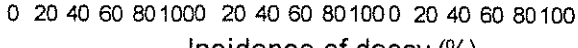
Incidence of decay (%)

Fruit were pre-washed or not washed using a small-scale drench system, treated or not treated with Scholar 230SC (6 fl oz) by drenching, and washed or not washed again using a small-scale drench system. Washes and Scholar treatments were done for selected durations and at selected temperatures. Fruit were then wound-inoculated with *M. fructicola*, *B. cinerea*, or *R. stolonifer* (30,000 spores/ml) and incubated at 20C for 5 to 7 days.

Fig. 14. Evaluation of simulated postharvest field drench treatments of Bing cherry with Scholar and Orius for management of fruit decays

Treated-Inoculated

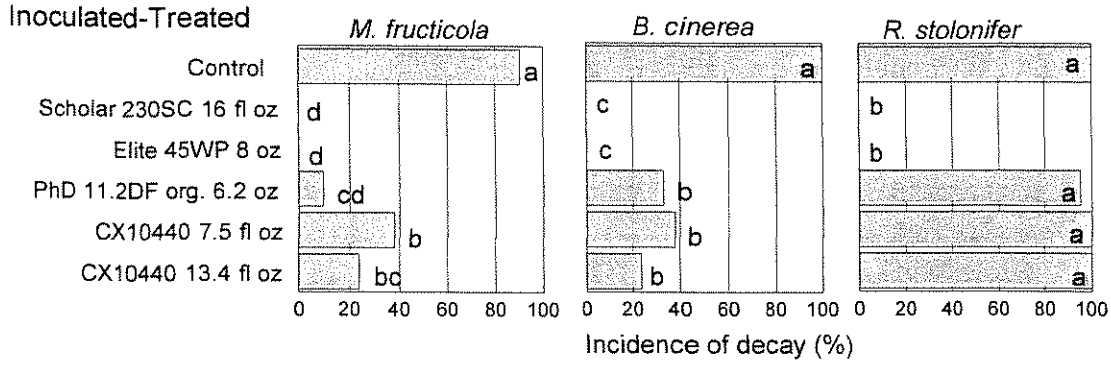
Prewash	Fungicide	Application	*M. fructicola*	*B. cinerea*	*R. stolonifer*	Residue Flud.	Residue Tebuc.
-	-	-	a	a	a	ND	ND
5 min at 23C	-	-	a	a	a	0.1 ppm	---
5 min at 23C	Scholar	Drench 15 sec at 23.5C	c	d	c	1.8 ppm	---
5 min at 23C	Scholar	Drench 30 sec at 23.5C	c	d	c	2.9 ppm	---
5 min at 23C	Scholar	Drench 60 sec at 23.5C	b	c	c	3.8 ppm	---
5 min at 23C	Scholar + Orius	Drench 30 sec at 23.5C	c	d	c	1.1 ppm	2.5 ppm
5 min at 23C	Scholar + Orius	Drench 60 sec at 23.5C	c	d	c	1.3 ppm	3.2 ppm
5 min at 23C	Scholar + Orius*	Drench 60 sec at 23.5C	c	d	c	1.3 ppm	4 ppm
5 min at 23C	Scholar + Orius	T-Jet	b	b	b	1.7 ppm	2.6 ppm
5 min at 23C	Scholar	Drench 60 sec at 5 C	c	d	c	3.1 ppm	---



Incidence of decay (%)

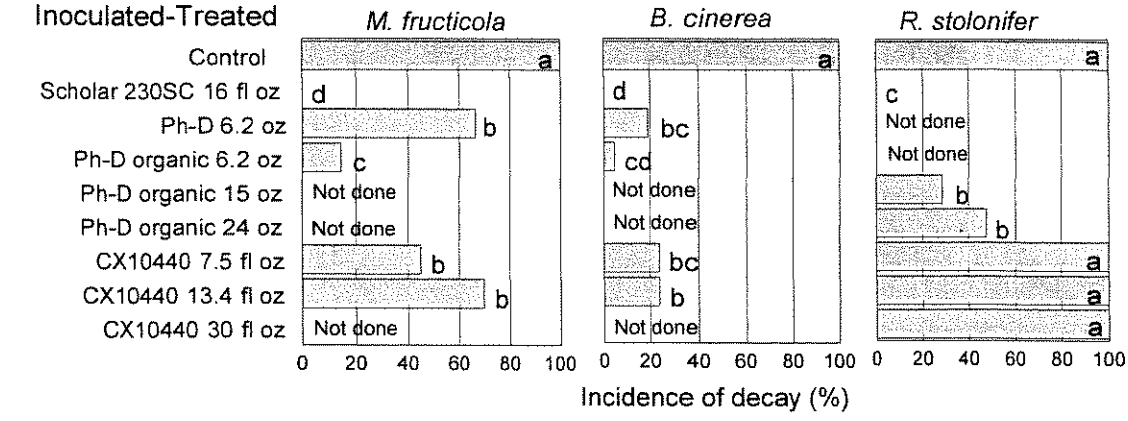
Fruit were pre-washed or not washed using a small-scale drench system and treated or not treated with Scholar 230SC (6 fl oz) or Orius (271 ppm) by drenching (except the Scholar+Orius* treatment that had 4 fl oz of Scholar) or by T-Jet application at selected temperatures and for selected durations. Fruit were then wound-inoculated with *M. fructicola*, *B. cinerea*, or *R. stolonifer* (30,000 spores/ml) and incubated at 20C for 5 to 7 days.

Fig. 15. Postharvest treatments with registered and new fungicides for decay control of sweet cherry fruit in laboratory studies



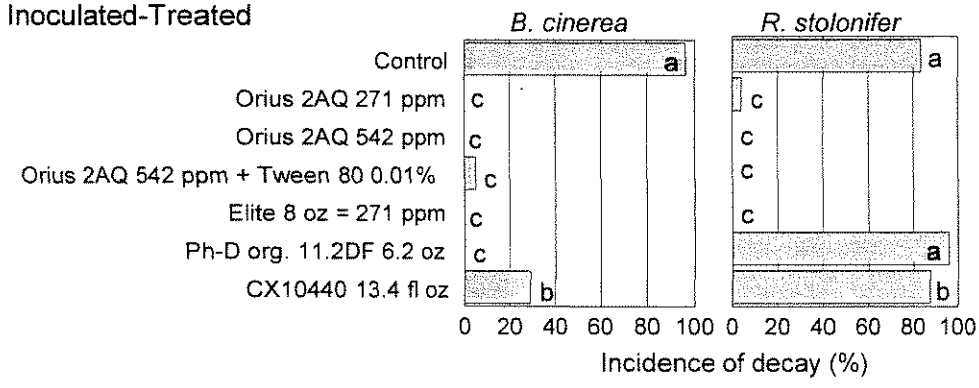
Fruit were wound-inoculated with spores of *M. fructicola*, *B. cinerea*, or *R. stolonifer* (30K spores/ml) and treated after 11 h with aqueous fungicide solutions using an air-nozzle sprayer. Fruit were then incubated at 20C.

Fig. 16. Postharvest treatments with registered and new fungicides for decay control of sweet cherry fruit in laboratory studies



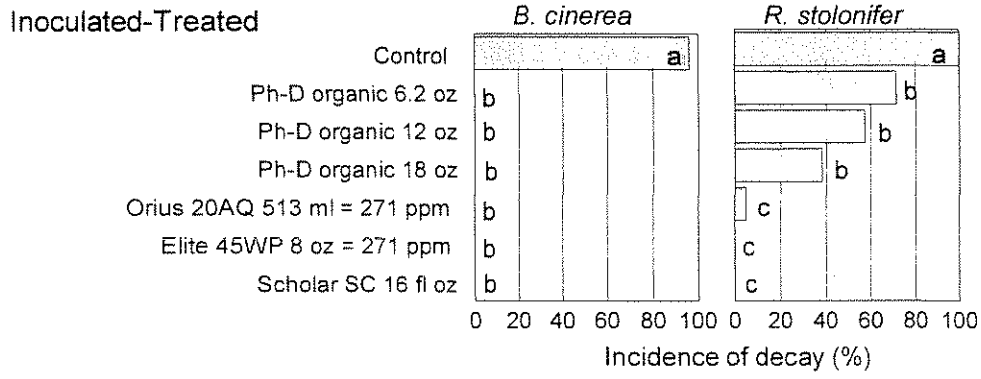
Fruit were wound-inoculated with spores of *M. fructicola*, *B. cinerea*, or *R. stolonifer* (30K spores/ml) and treated after 14 h with aqueous fungicide solutions using an air-nozzle sprayer. Fruit were then incubated at 20C.

Fig. 17. Postharvest treatments with registered and new fungicides for decay control of sweet cherry fruit in laboratory studies



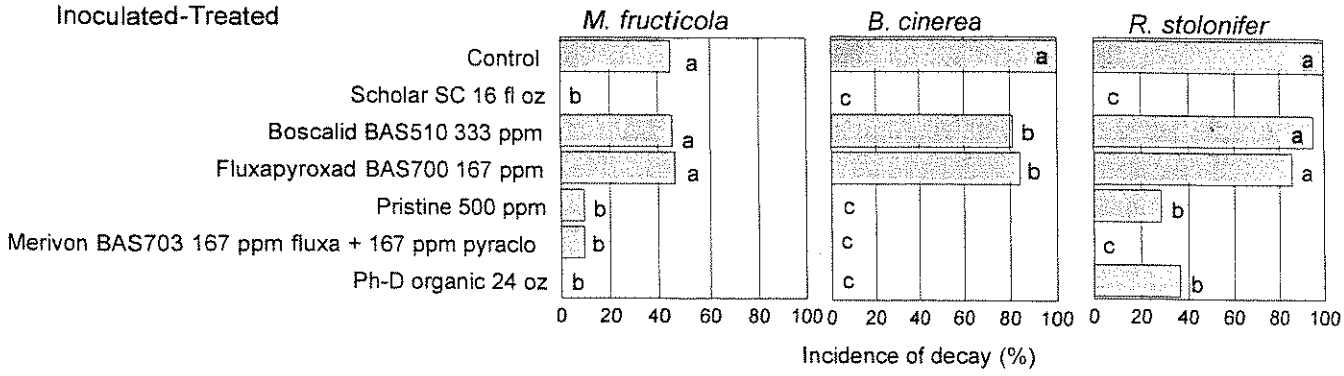
Fruit were wound-inoculated with spores of *B. cinerea* or *R. stolonifer* (30K spores/ml) and treated after 13 h with aqueous fungicide solutions using an air-nozzle sprayer. Fruit were then incubated at 20C.

Fig. 18. Postharvest treatments with registered and new fungicides for decay control of sweet cherry fruit in laboratory studies



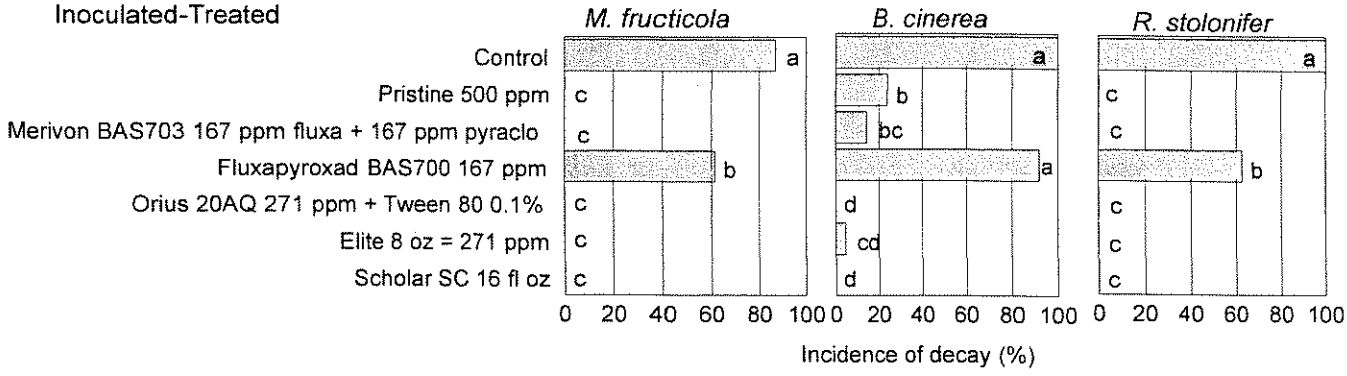
Fruit were wound-inoculated with spores of *B. cinerea* or *R. stolonifer* (30K spores/ml) and treated after 13 h with aqueous fungicide solutions using an air-nozzle sprayer. Fruit were then incubated at 20C.

Fig. 19. Postharvest treatments with registered and new fungicides for decay control of sweet cherry fruit in laboratory studies



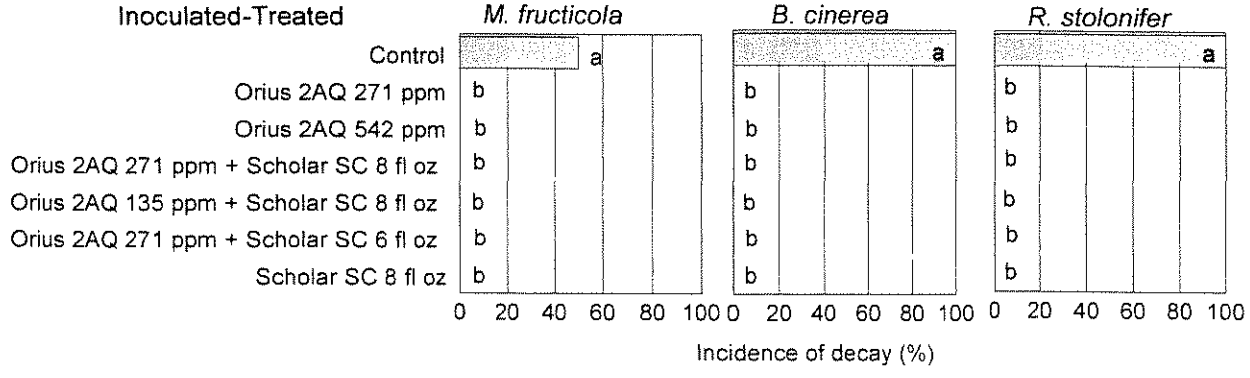
Fruit were wound-inoculated with spores of *M. fructicola, B. cinerea,* or *R. stolonifer* (30K spores/ml) and treated after 14 h with aqueous fungicide solutions using an air-nozzle sprayer. Fruit were then incubated at 20C.

Fig. 20. Postharvest treatments with registered and new fungicides for decay control of sweet cherry fruit in laboratory studies



Fruit were wound-inoculated with spores of *M. fructicola, B. cinerea,* or *R. stolonifer* (30K spores/ml) and treated after 14 h with aqueous fungicide solutions using an air-nozzle sprayer. Fruit were then incubated at 20C.

Fig. 21. Postharvest treatments with registered and new fungicides for decay control of sweet cherry fruit in laboratory studies



Fruit were wound-inoculated with spores of *M. fructicola, B. cinerea,* or *R. stolonifer* (30K spores/ml) and treated after 13 h with aqueous fungicide solutions using an air-nozzle sprayer. Fruit were then incubated at 20C.

BIOLOGY AND CONTROL OF THE SPOTTED WING DROSOPHILA
PHENOLOGY AND TRAP TYPE COMPARISON IN UNSPRAYED CHERRIES

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1. Seasonal Phenology in Unsprayed Cherry Orchards

Background: Monitoring was continued for a second year in unsprayed cherry orchards in both the Northern San Joaquin Valley and the Santa Clara Valley to determine the normal flight pattern and populations of this new pest in the various cherry growing regions. Two of the three original (2010) unsprayed orchards were monitored in the San Joaquin Valley in 2011; the third 2010 orchard was sprayed in 2011. Only one of the original three Santa Clara Valley orchards from 2010 remained unsprayed this year. As damage and awareness of this pest grows, it is getting increasingly difficult to find any unsprayed orchards.

Methods: Seasonal changes in natural SWD populations were monitored with standard deli traps. Four traps were hung in each orchard beginning in mid March 2010 and checked weekly throughout 2010 and 2011. Standard "Deli" traps made from white, 1 quart plastic yogurt containers with lids were used. Traps were baited with 4 ounces of apple cider vinegar and amended with 2 teaspoons per gallon of unscented dish soap to reduce surface tension of the bait solution. Bait was changed weekly. Sixteen 3/16" entry holes were burned or drilled into the side of each container just below the lid. Earlier work had shown this to be a good number and size to maximize SWD capture and minimize the capture of larger insects that may obscure the SWD capture. Traps were hung in the shade on the north or east side of the tree, 3 to 5 feet from the ground and at least 50 feet apart in the orchard. The SWD males were counted in the field and the spent bait and trap capture were put in labeled vials and brought back to the lab for further examination under a dissecting microscope. In the lab, SWD males were counted again to validate field counts. SWD females and non-SWD *Drosophila flies* were also counted, and other "contaminating" insects (that interfered with being able to see the male SWD in the traps in the field) were identified and visually rated for general abundance.

In addition to the untreated phenology sites, single traps were placed in a number of commercial orchards in each region to compare the impact of commercial sprays on the SWD population.

Results: The flight pattern varied by climatic region.

The No. San Joaquin Valley: In both 2010 and 2011, the flight began in late April, peaked about June 1st, slowly declined through June, dropping to very low levels by the end of July. Very low trap catches continued through the summer. In 2010, a small flight resumed in late October, peaked in November and again declined to very low levels through the winter until the following April when flight resumed. It is yet to be seen if this November peak will be repeated in 2011. (Figures 1 & 2). The damage in these unsprayed orchards is reported in an inset in Figures 1 and 2. The damage varied somewhat by variety but generally increased over the approximately 10 day period from the beginning to the end of harvest and was unacceptably high for all varieties even on the earliest possible harvest date.

Figure 3 shows a comparative flight pattern for eight commercially sprayed cherry orchards in Contra Costa Co. SWD sprays generally began in May, two to three weeks before harvest was anticipated, and were successfully in reducing the orchard population and damage to very low levels.

Santa Clara Valley: In 2010, flight began in mid April and continued throughout the spring, summer, and fall. It dropped to very low levels in mid December (Figure 4) and remained low throughout the winter until flight resumed the following spring. Figure 6 shows the resumption of flight at the same time in early April in the two

more typical well irrigated, shady orchards, before their spray programs began in mid May. The one remaining unsprayed orchard in 2011 is shown in Figure 5. This is a hot, dry, open site which is not as conducive to SWD. Population levels were much lower at this site than the other sites although the 2011 flight pattern was similar to the previous season. Figure 6 shows the successful suppression of 2011 flight due to regular commercial sprays. In these orchards the flight resumed in August after spray residuals were gone and built to a huge peak in mid September before declining.

Flights are generally higher in the cooler coastal district than in the hot interior valley. Figures 7 and 8 show the comparative 2011 flights for the two Valleys with the average weekly maximum and minimum air temperatures as well as the active SWD range (50-86F) and the optimum activity range (68-77F) from the Japanese literature. The temperatures for the Santa Clara Valley fall within the maximum and minimum activity range for much of the summer which may explain the continuous summer flight with small depressions after periods of higher temperatures. Flight drops off in the summer in the San Joaquin Valley once the maximum weekly temperatures routinely exceeded 86F.

The SWD gender distribution varied from orchard to orchard and over the season. In general it would appear than orchards with favorable environments – shady canopies, well irrigated, no pesticides – have a fairly equal distribution of males to females throughout the season. Those orchards with a less favorable environment often have greater numbers of females than males, particularly during spring.

2. Trap Design Comparison: Standard side holes/solid top vs. screen top/rain shield

Background: Early spring work in citrus orchards in Newman showed the screen top trap to catch more SWD than the standard trap with holes in the side. The comparison was moved to the two unsprayed phenology orchards in the No. San Joaquin Valley just before the SWD flight was expected to begin in cherries to see if we got the same benefit in cherries.

Methods: Standard traps were 1 quart, white, opaque plastic containers with sixteem 3/16" holes drilled around the side within 1.5 inches from the top; the top was solid to keep out rain and irrigation. The screen traps used the same container with no holes on the side but a 1/8" screen on top with a wing trap top for a rain shield. Four screen traps were paired with the four standard traps in the Contra Costa and the San Joaquin County phenology blocks in mid-late March. All traps were baited with the standard mix of 4 ounces of apple cider vinegar amended with 2 teaspoons of unscented dish soap per gallon which was changed weekly. Traps were checked weekly. The number of SWD males, SWD females and non-SWD *Drosophila* species were recorded. Other "contaminating" insects (that interfered with being able to see the male SWD in the traps) were identified and rated for general abundance according to the following scale:

0 = no other insects besides SWD
1 = Low number of non-targets - easy to see all the SWD
2 = Mod.low number of non-targets - look more carefully but can see all SWD
3 = Mod. number of non-targets - a little hard to see all the SWD
4 = Mod. high number of non targets - difficult to see all the SWD
5 = Very high number non-targets - impossible to see all the SWD

Results: The catch *pattern* was the same for both trap types – beginning, ending and peaking on the same dates. However, as in the citrus "pretest", the screen top traps caught more SWD than the standard hole traps (Figure 9). The screen traps also caught more non target species and had a higher contamination rating than the standard traps (Figure 10). The main contaminants were other drosophila and sap/fruit beetles and to a lesser degree filth flies and otidid flies. The ratio of SWD:other drosophilla species was low and quite similar for both trap types indicating that both traps were catching a lot of contaminants and a similar percentage of SWD to other drosophila. However, since the standard traps had fewer of all types of insects, it was easier to read those traps in locations where contamination was an issue. In locations where contamination is low – as might be the case

in a sprayed orchard – the screen traps may provide a more sensitive indicator of SWD migration or spray efficacy or spray longevity.

Figure 1: 2010 trap catches and damage in 3 unsprayed cherry orchards in the No. San Joaquin Valley.

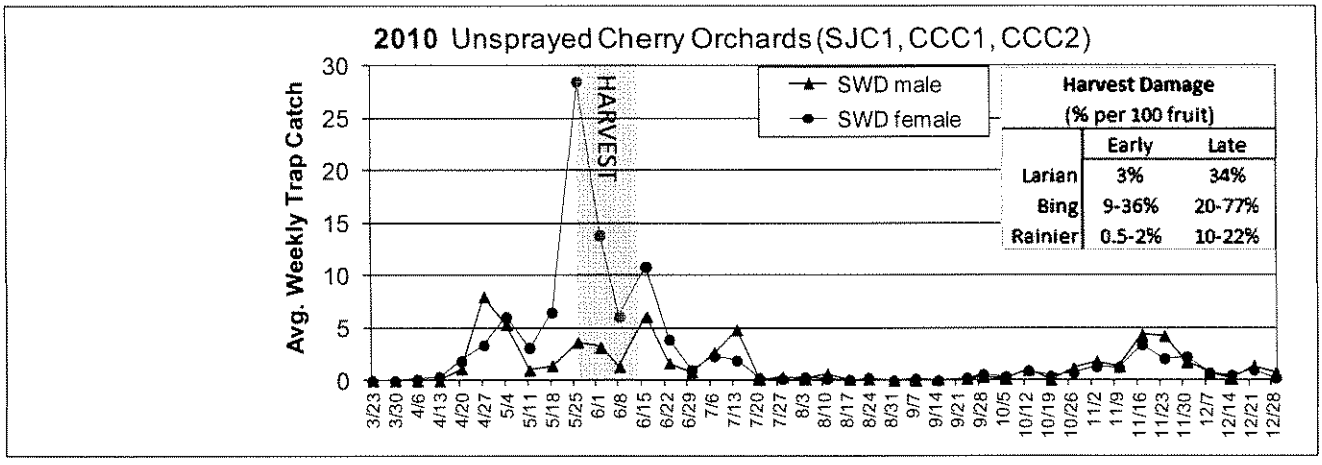


Figure 2: 2011 trap catches and damage in 2 unsprayed cherry orchards in the No. San Joaquin Valley

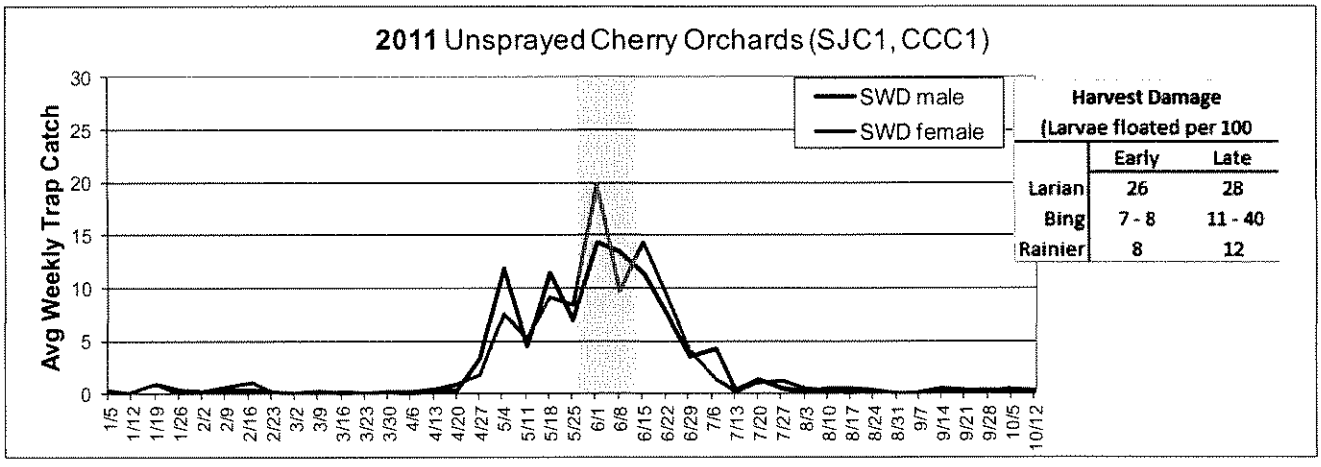


Figure 3: 2011 trap catches in 8 sparyed cherry orchards in Contra Costa County.

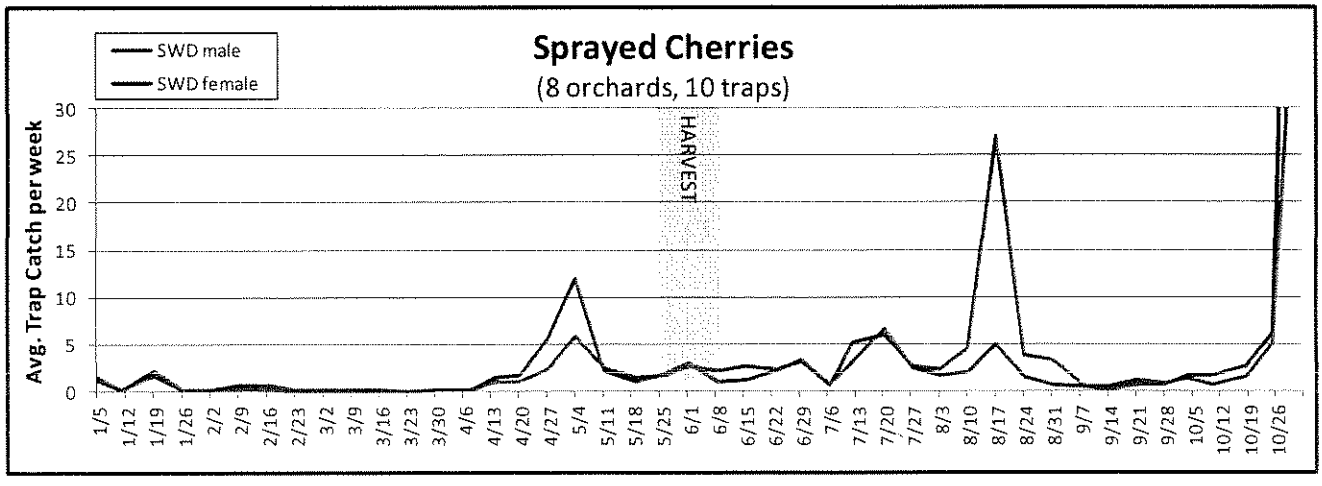


Figure 4: 2010 trap catches in 3 unsprayed cherry orchards in the Santa Clara Valley

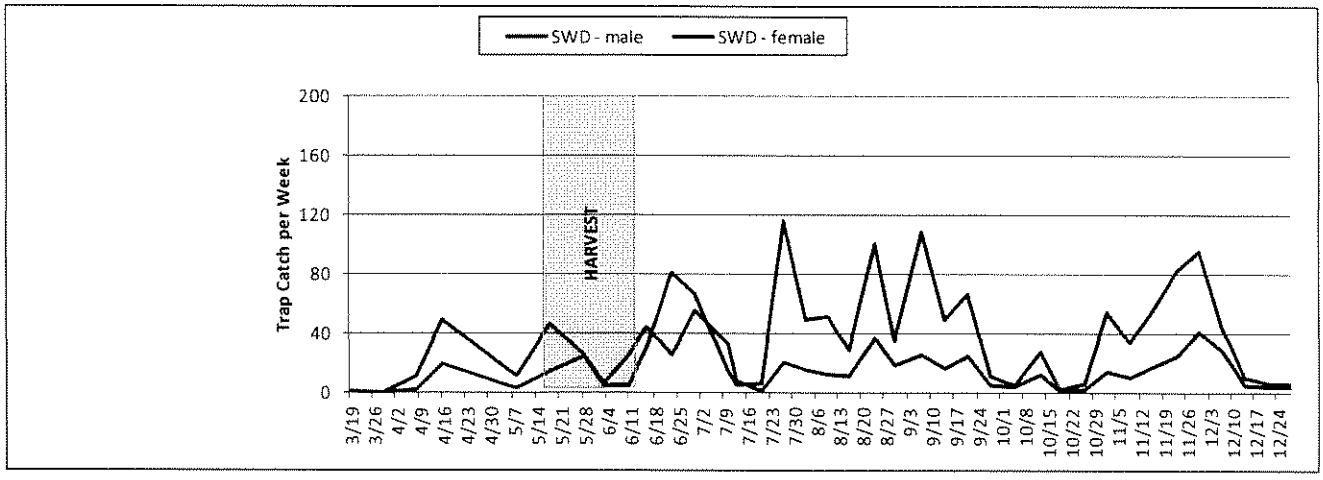


Figure 5: 2011 trap catches in 1 unsprayed cherry orchard in the Santa Clara Valley

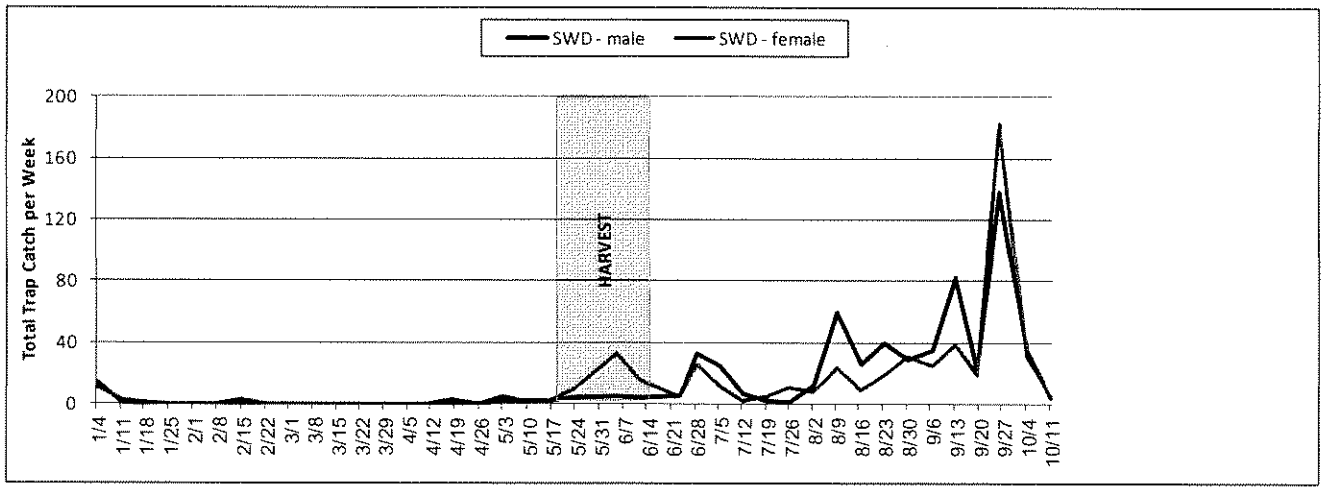


Figure 6: 2011 trap catches in 2 sprayed cherry orchards in the Santa Clara Valley

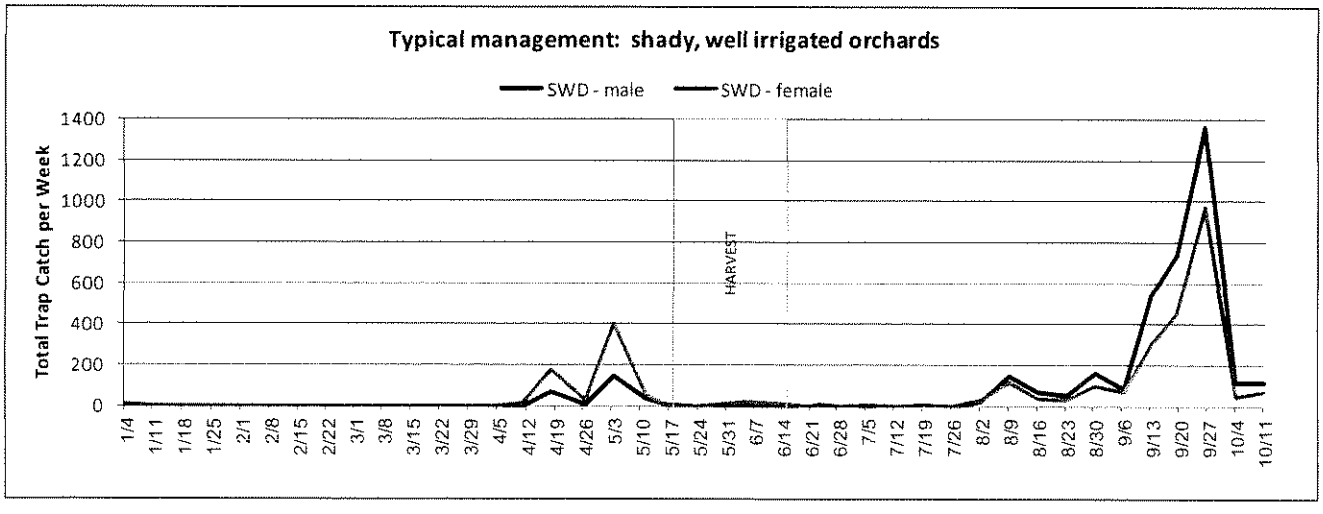


Figure 7: 2011 No. San Joaquin Valley trap catches and weekly maximum and minimum temperatures in relation to known SWD activity ranges.

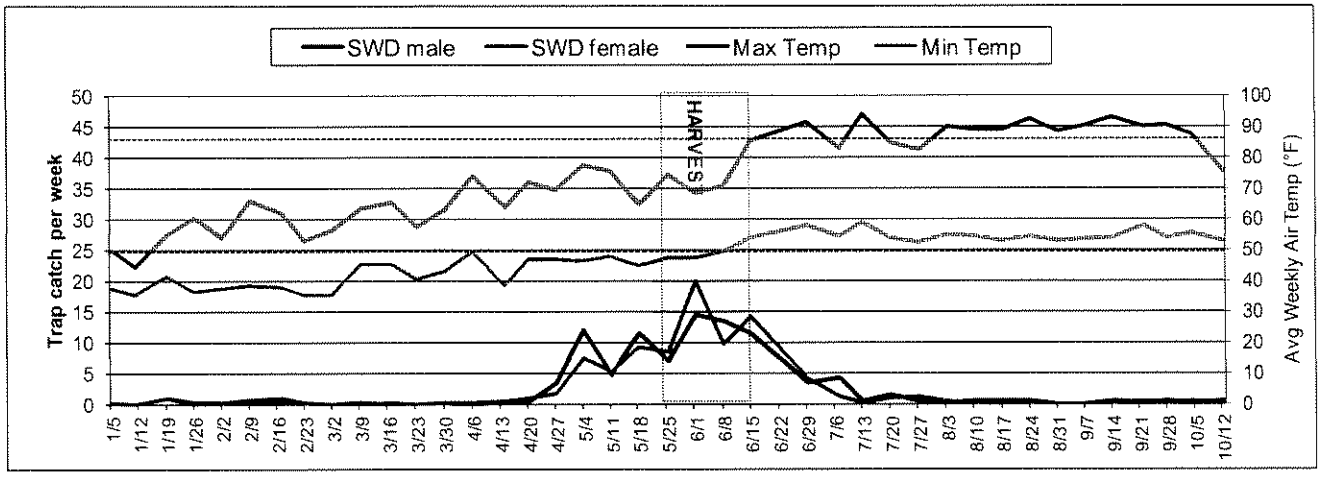


Figure 8: 2011 Santa Clara Valley trap catches and weekly maximum and minimum temperatures in relation to known SWD activity ranges

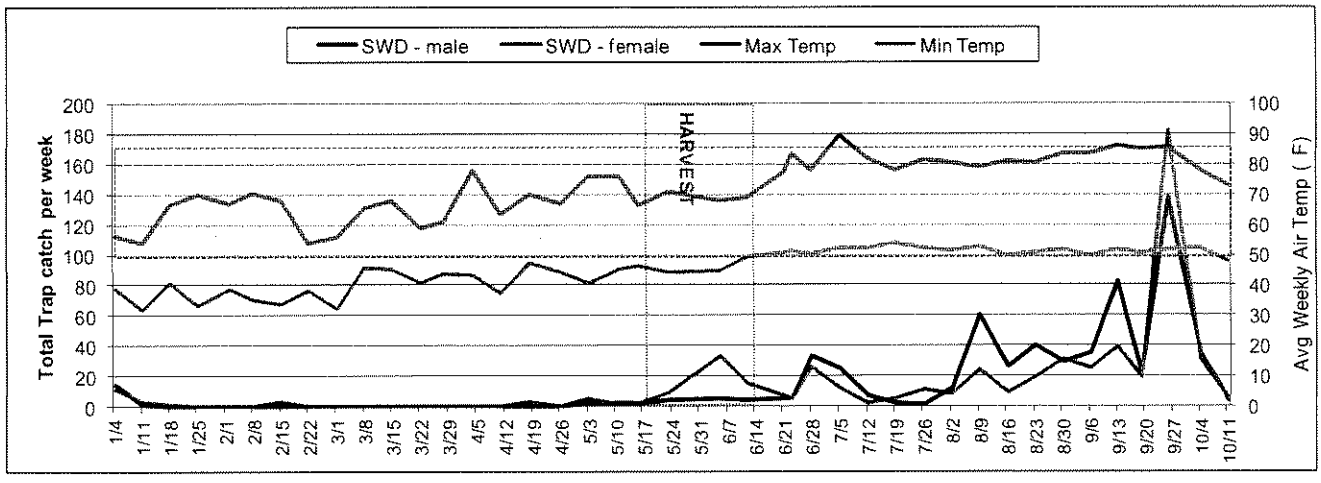


Figure 9: 2011 comparison of standard side hole vs. screen top traps in 2 unsprayed orchards in the No. San Joaquin Valley.

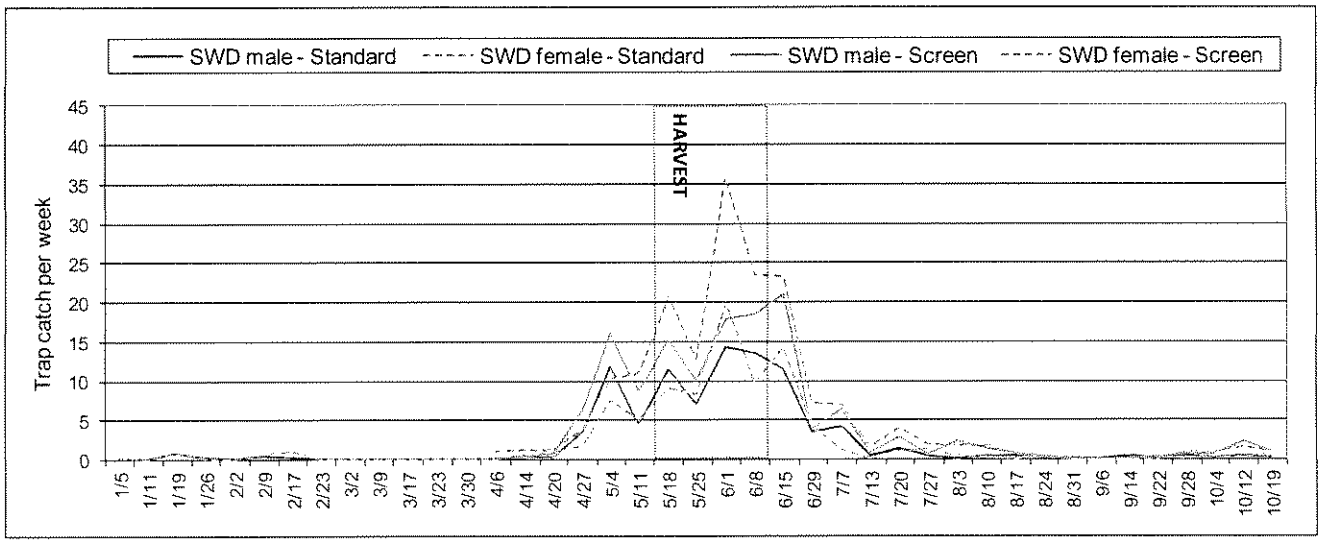
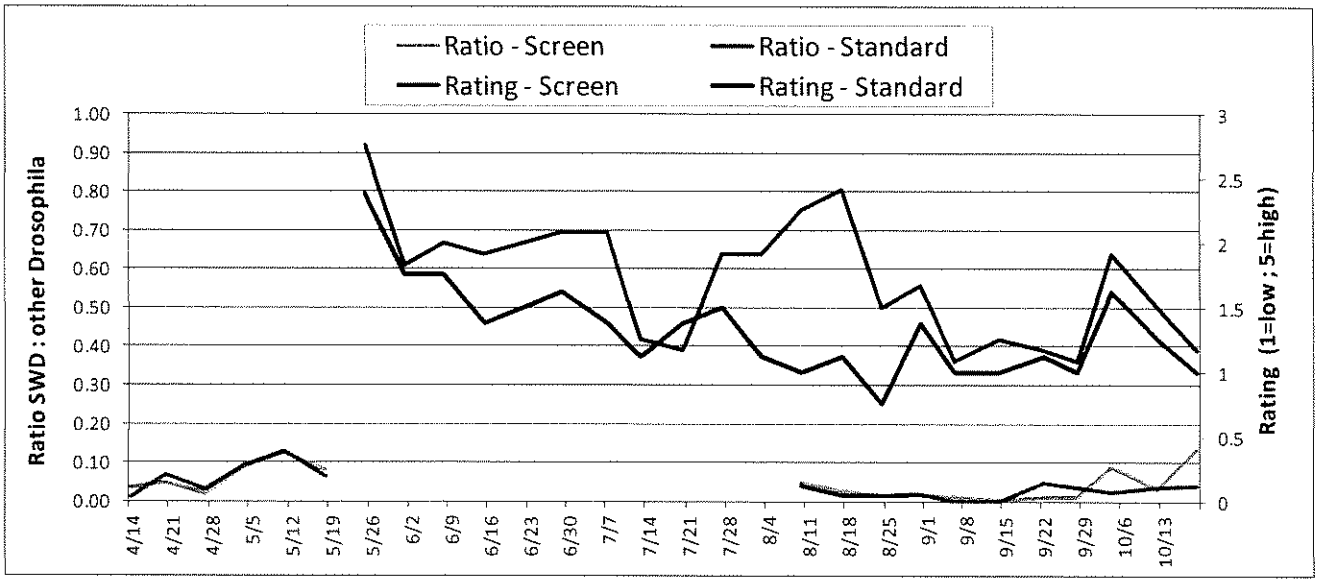


Figure 10: Contamination ratios and ratings of standard side hole vs. screen top traps.



FINAL PROJECT REPORT

Project Title: Development of residue degradation curves for insecticides against SWD

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Cooperators:
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Project Funding
Agency Name: Project was jointly funded by the California Cherry Advisory Board, the Oregon Sweet Cherry Commission, the Washington Tree Fruit Research Commission, and the Okanagan Kootenay Cherry Growers Association, British Colombia.

Total Project Funding: $30,000 (year 1 of 1)

Budget Distribution:

Item	CCAB	WTFRC	OSCC	OKCGA
Salaries	2,089	3,161	1,875	1,498
Benefits	911	1,378	817	644
Equipment	0	0	0	0
Supplies (Residue analysis)	12,000		4,300	
Travel		460		307
Indirect costs				551
Total	15,000	4,999	7,001	3,000

INTRODUCTION AND OBJECTIVES

Maximum Residue Limits (MRLs) are a measurement of the maximum level of pesticide residues that are allowed on a commodity for human consumption. These levels, commonly referred to as tolerances, are dictated by government organizations in their efforts to ensure that food products are safe to eat.

All countries have the right to establish their own MRLs, leading to discrepancies in the amount of residues that are tolerated on food imported from other countries (Table 1, Fig. 1). These differences arise from the use of different datasets and criteria while establishing tolerances, and from different policies about allowable residue levels prior to when an MRL can be established. Thus, a commodity with a legal amount of residue in the country in which it was produced may have an illegal residue in a country to which it is exported. If detected, the shipment will be rejected, and unless an alternative market is found rapidly, may result in a complete economic loss for the exporter.

The recent introduction of spotted wing drosophila (SWD) into cherry-producing areas of the western United States has heightened concerns regarding MRLs for countries that import U.S. cherries. Current management programs for SWD require one or more insecticide treatments within the last few weeks of harvest. The problem is that these treatments, though considered safe according to the U.S. and California Environmental Protection Agencies, have the potential to cause fruit to be rejected when it is shipped to countries where tolerances for residues are not established or are established at levels lower than those in the US.

The purpose of this project is to address this issue through two objectives. The first was to improve our understanding of the in-field degradation rates of six insecticides used for SWD. The second was to evaluate the effects of post-harvest washing on residue levels. The overall goal once these objectives were accomplished was to propose treatment programs that would not only be effective, but that could also still allow for the exportation of fruit.

SIGNIFICANT FINDINGS

During the spring of 2011 we established two experimental orchards and evaluated the use of six insecticides (Table 2) when used approximately 21 days before harvest and four insecticides when used approximately 7 days before harvest. These orchards were used to evaluate degradation curves for each insecticide at each location. Results of the experiments were used in conjunction with current international maximum residue levels to determine the relative risk associated with exporting fruit that has been treated with each insecticide. This information was combined with existing knowledge about the biology of spotted wing drosophila, its relationship with cherries as a host, and information regarding pesticide efficacy to propose an insecticide program that would be effective but still allow for the export of fruit to all major export markets. Based on this information we proposed a three-spray program based on Warrior II approximately 21 days before harvest, followed by an application of Success approximately 7-14 days before harvest, followed by an application of a low rate of Malathion approximately 3-7 days to harvest. In cases where only two applications are needed we proposed the substitution of a single application of Success or Malathion approximately 7 days to harvest in place of using each product individually as in the three-spray program. Following these programs should allow cherry growers to effectively control spotted wing drosophila while still maintaining the ability to export fruit.

RESULTS

Applications of the spinosyns Delegate and Success resulted in relatively low residue levels that degraded quickly (Fig. 2a-b). When applied 21 days before harvest, residue levels for both insecticides ranged from 0.06 to 0.19 ppm during the evaluations at 0 and 3 DAT, and at or below the limit of detection of 0.05 ppm thereafter. The 21 DAT sample was omitted due to the minimal to non-detectable residue levels during the previous two samples. When applications of Delegate and Success were made 7 days before harvest, similar results were found with residue levels ranging from non-detectable to 0.09 ppm through 3 DAT, followed by levels below the minimum detection level for both products at both sites by the preharvest interval of seven days.

Residue levels for pyrethroids (Fig. 2c-e) were more variable among products than for spinosyns and remained higher for a longer period of time. Applications of fenpropathrin produced the highest residue levels and had the slowest degradation. When applied 21 or 7 days before harvest, Danitol residue levels 3 DAT (the US preharvest interval) ranged from 0.89 to 2.93 ppm. These numbers are well within the U.S. and Japanese MRLs for fenpropathrin (5 ppm), but exceed tolerances for Canada, Korea, Taiwan and the EU (0.01 – 0.5 ppm) (Table 1). Residue levels on both cultivars remained above the MRLs for the latter countries even at 21 DAT.

Applications of lambda-cyhalothrin at 21 days before harvest resulted in residue levels ranging from 0.10 to 0.31 ppm from the time of application through 7 DAT (Fig. 2d). At 14 DAT (the U.S. preharvest interval), residue levels ranged from 0.08 to 0.11 ppm. These levels were approximately one-half to one-fifth lower than the MRLs for all major export markets (0.20 to 0.50 ppm) (Table 1).

Applications of zeta-cypermethrin at 21 days before harvest resulted in residue levels ranging from 0.08 to 0.23 ppm at 0 through 7 DAT (Fig. 2e). At the preharvest interval of 14 days residue levels ranged from 0.09 to 0.11 ppm. This is within the U.S., Japan and EU MRLs (1.0 to 2.0 ppm), but is about equivalent to the Canada MRL of 0.1 ppm and above the Australian MRL of 0.01 ppm (Table 1). Korea and Taiwan do not have MRLs established for zeta-cypermethrin, thus any residue would cause fruit to be rejected. By 21 DAT residue levels ranged from 0.02 to 0.05 ppm, which would have qualified fruit for export to Canada, Japan and the EU (0.1 to 2.0 ppm), but would still result in the rejection of fruit in Australia, Korea and Taiwan (0.00 to 0.01 ppm).

Applications of the organophosphate Malathion at 21 and 7 days before harvest at the 1,754 ml/ha (1.5 pt/acre) rate (which is lower than the maximum label rate due to risk of phytotoxicity) resulted in residue levels that ranged from non-detectable to 0.12 ppm through 2 DAT and from non-detectable to 0.06 ppm at the preharvest interval of 3 DAT (Fig. 2f). These levels were below the MRLs for all countries (0.50 to 8.0 ppm) except the EU (0.02 ppm); the extremely low MRL for the EU meant that some of the residues found would be unacceptable (Table 1). By 7 DAT residue levels for Malathion ranged from non-detectable to 0.02 ppm.

Evaluations of the effects of simulated post-harvest processing had variable results on residue levels. Of the six pyrethroid samples tested thirteen days after application, Danitol residues were decreased by an average of 22.0%, Warrior residues were decreased by an average of 15.7% and Mustang levels were increased by an average of 5.6%. Simulated processing two days after application of Danitol resulted in an average reduction of just over half of the residues (51.7%) whereas changes in residue levels for Delegate, Success and Malathion could not be determined due to one or both residue levels being below the minimum detection levels of 0.01 (Malathion) or 0.05 (Delegate and Success). These results suggest that cherry producers can make a general assumption that post-harvest processing is going to likely help reduce pesticide residues, especially when residues are initially high. However, the high variability in the results of this study suggest that making predictions about

residue reductions will be sufficiently complex that growers should rule out post-harvest reductions as a reliable method for ensuring that fruit does not exceed residue tolerances. Growers need to continue ensuring that residue levels are below MRLs for intended markets at the time of picking and prior to processing.

DISCUSSION

Current management programs for SWD are based on three general types of treatments. These are long-residual products with preharvest intervals of ≥14 days, mid-range products with a 7-14 day preharvest interval, and products for use close to harvest (1-3 day preharvest interval). Long-residual products are those that are typically applied at the initiation of the straw stage of development when fruit becomes susceptible to attack by *D. suzukii*. Of the products tested the pyrethroids Danitol, Mustang and Warrior II all had relatively long residuals. Of these, Warrior II has the best overall profile as a long-residual product whose application resulted in residue levels in this study that were below the MRLs of all major export markets for cherries. These data also suggest that growers who export fruit should avoid the use of Danitol; Mustang use should be avoided on fruit that is for export to Canada, Korea and Taiwan.

Of the middle-range products for use 7 to 10 days before harvest, Delegate and Success both produced residue levels below the lower detection limit of 0.05 ppm at the preharvest interval of seven days. This suggests that either insecticide is equally valuable for use. However, between these two products Success has a better MRL profile of 0.05 to 1.00 ppm for major export markets whereas MRLs for Delegate include a default MRL in Canada of 0.01 ppm while for Taiwan no MRLs have been established such that any detection would disqualify fruit.

Malathion and Danitol are the only two insecticides in our study that have preharvest intervals of three days or less. At a use rate of 1.75 liters/ha (1.5 pt/acre) residue levels for Malathion in our studies were low enough to allow for the export of fruit to all major export markets with the exception of the EU, which has an exceptionally low MRL for this product. Growers planning on shipping fruit to the EU should probably avoid Malathion because residue levels in our trials, even at 7 DAT with a below-maximum labeled rate, were still close to the EU MRL of 0.02 ppm. In weighing their options these growers might also consider the use of permethrin or pyrethrin, which are considered to have very short residuals, but were not tested as part of this project.

When all things are considered, data from this project can be used to outline potential spray programs that should be effective for *D. suzukii* and still allow for the export of fruit. For example, areas requiring three insecticide applications could consider using Warrior II at the initiation of straw, followed by an application of Success 7 to 14 days before harvest, and followed by an application of Malathion 3 to 7 days before harvest. This should allow fruit to be shipped to all major export markets with the possible exception of the EU (depending on how quickly Malathion residues degrade). In areas where only two applications are needed, the second and third applications described above could be combined into one application of either Success or Malathion around 7 days before harvest (with the same potential concern for Malathion in the EU). As needed, additional applications of Malathion and or permethrin or pyrethrin (not tested) would be the most likely candidates for treatments between harvests.

Another variation would be the use of spinosad close to harvest. The results of this study were used to support a Special Local Needs SLN label for Entrust (the organic formulation of spinosad) in Washington [and Oregon] which allows a preharvest interval of three days on sweet cherry. In addition, IR-4 studies are underway nationwide which test a preharvest interval of one day for this product on cherries, which would provide even greater flexibility to producers near or during harvest, with minimal risk of violating export MRLs.

When organized in the manner described above growers should be able to successfully treat for *D. suzukii* in a manner that is effective, that utilizes multiple modes of action as part of a resistance management program, and that allows fruit to qualify for export. However, because of the

complexity of treatment programs for *D. suzukii* and the potential for residue-based export restrictions of fruit, growers should develop plans for management well before harvest. Plans should be made only after consulting with representatives of the packing house and should include multiple options for control programs depending on where the fruit will be shipped. They should also be flexible enough to account for one or more treatments based on in-field monitoring programs.

Growers should also be conservative while estimating how data from this project relate to their individual orchards. Residue levels are dependent on many factors such as equipment type, application type, water volume, drive speed, rate used, tree size, canopy density, exposure to sunlight, precipitation, etc. Despite the fact that this project was conducted under typical commercial field conditions, it is important to remember that this project only represents two orchards in Kern County, CA during the 2011 harvest season, and results are expected to vary among locations throughout the western United States.

Table 1. Maximum residue limits (MRLs) of major international importers of cherries for six insecticide active ingredients commonly used for control of *D. suzukii*. MRLs are current as of May 2011[1].

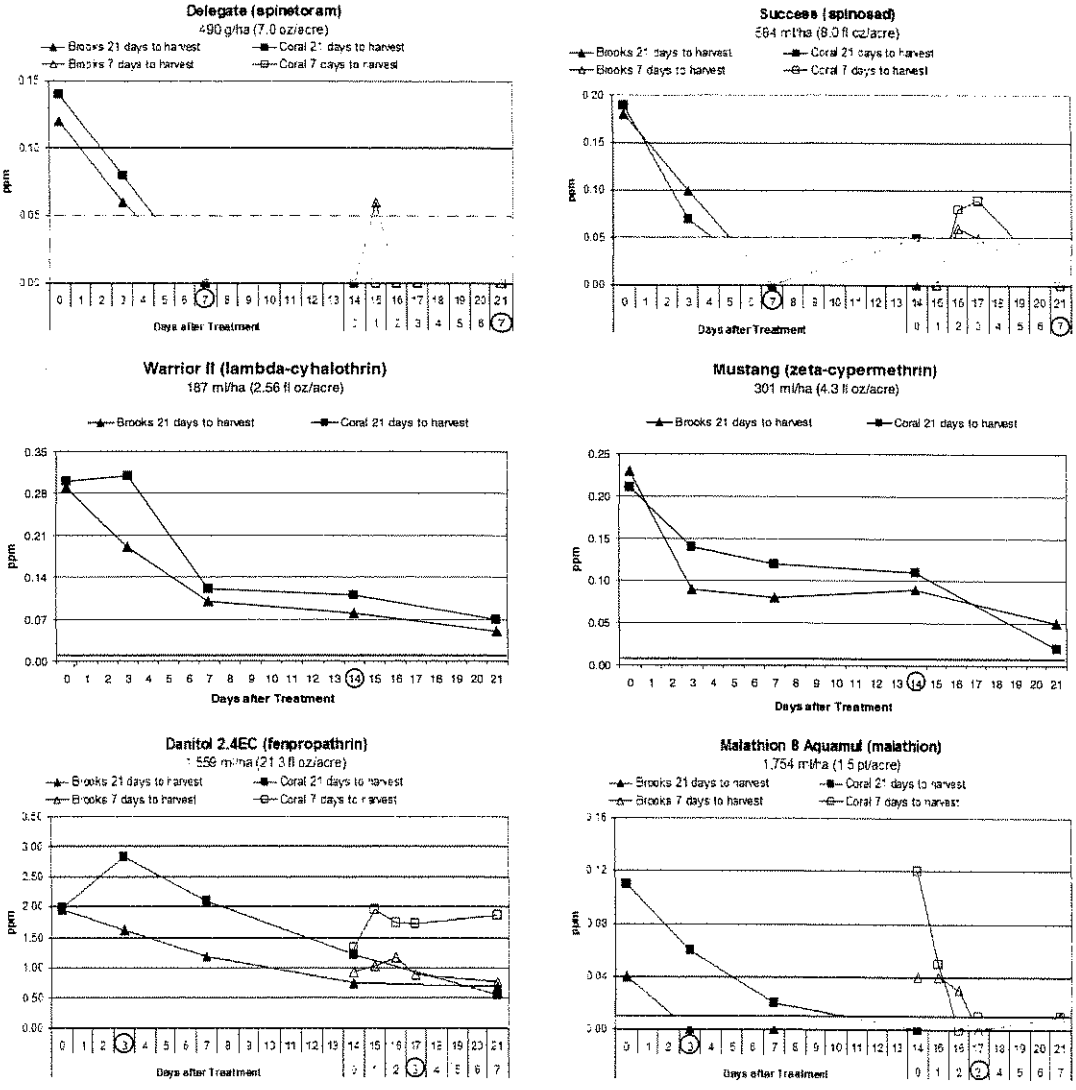
Active Ingredient	Lower Detection Level[2] (ppm)	MRL (ppm)						
		US	Canada	Japan	South	Taiwan	EU	Aust-ralia
Fenpropathrin	0.01	5.00	0.10	5.00	0.50	0.50	0.01	-
Spinetoram	0.05	0.20	0.20	0.01	0.10	-	0.05	0.20
Malathion	0.01	8.00	6.00	6.00	0.50	0.50	0.02	2.00
Zeta-cypermethrin	0.01	1.00	0.10	2.00	-	-	2.00	0.01
Spinosad	0.05	0.20	0.20	0.20	0.05	0.20	1.00	1.00
Lambda cyhalothrin	0.01	0.50	0.20	0.50	0.50	0.40	0.30	0.50

[1]Source: Based on the California Cherry Advisory Board's Online Export Manual, May 2011 (http://www.calcherry.com/industry). Since MRLs change frequently be sure to check for updated and current MRLs prior to shipping fruit to export markets.
[2]Minimum level at which residues can be detected.

Table 2. Names, manufacturers, use rates and preharvest intervals for insecticides that were tested for residues.

Product and formulation	Manu-facturer	Active ingredient	Rate form. product[1]		Preharvest interval[2] (days)
			per ha	per acre	
Danitol® 2.4 EC	Valent	Fenpropathrin	1,559 ml	21.3 fl oz	3
Delegate™ 25 WG	Dow	Spinetoram	490 g	7 oz	7
Malathion 8 Aq	Loveland	Malathion	1,754 ml	1.5 pt	3
Mustang® 1.5 EW	FMC	Zeta-cypermethrin	301 g	4.3 oz	14
Success® 2 SC	Dow	Spinosad	584 ml	8 fl oz	7
Warrior II 2 CS	Syngenta	λ-cyhalothrin	187 ml	2.56 fl oz	14

[1]With the exception of Malathion, application rates were defined as the highest rate allowable per the pesticide label. Due to the risk of phytotoxicity, the Malathion rate was lowered to a level that is generally considered to be effective on *D. suzukii*, but that minimizes the risk of damaging the leaves and fruit.



Figs. 1 (a-f). Residue levels of a) Delegate, b) Success, c) Warrior II, d) Mustang, e) Danitol, and f) Malathion following applications at 21 and or 7 days before harvest. Residue levels of non-detectable are reported as zero residues even though actual residue levels may be anywhere between 0.0 ppm and the minimum detection threshold of 0.05 ppm (for Delegate and Success) or 0.01 ppm (for Warrior II, Mustang, Danitol and Malathion), indicated by the shaded areas. Circled dates indicate the preharvest interval for California in 2011

EXECUTIVE SUMMARY

The recent introduction of spotted wing drosophila (SWD) into cherry-producing orchards of the western United States has resulted in the need for insecticide-based management programs close to harvest. These treatments have become problematic due to inconsistencies among export markets regarding maximum residue levels (MRLs) that are allowed on imported fruit. As a result, fruit that was treated and harvested in a safe manner according to the U.S. Environmental Protection Agency may or may not qualify for export to countries that have lower MRLs, or in some cases no MRLs at all.

This project addressed this issue by evaluating the degradation curves of six insecticides when applied at 21 days to harvest and four insecticides when applied at 7 days to harvest. Results were used to propose three-spray treatment programs based on the use of Warrior II at 21 days before harvest, Success at 7-14 days before harvest, and a low rate of Malathion at 3-7 days before harvest that would be effective, would allow for the export of fruit, and would incorporate the rotation of chemistries as part of a resistance management program. An alternate two-spray program was also proposed for orchards with lower pressure by spotted wing drosophila that combines the latter two treatments in to a single application of either Success or Malathion approximately 7 days before harvest.

Data from this project also documented the effects of simulated post-harvest washing on residue levels on fruit at harvest. Generally speaking, residue levels on fruit that were processed had lower residues than fruit harvested directly off of the tree. However, these reductions were not consistent, predicable or significant enough to recommend that growers rely on washing as part of a residue reduction program.

Optimizing Nitrogen Availability in Cherry Growth to Obtain High Yield and Fruit Quality, Final Report

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ABSTRACT

Research Scope

The study addressed nitrogen (N) cycling, supply and demand in sweet cherry using several combinations of N forms, timings and rates that are typical in California production orchards, using two standard (Mahaleb and Mazzard) and one semi-dwarfing (Gisela 6) rootstocks. Goals included better understanding the source-sink relationships and responses in vegetative and reproductive growth.

Main Findings and Interpretations

- The pattern of rising and falling tissue levels was similar among orchards each year, with peak N levels prior to harvest in both shoot and spur leaves during small fruit development, declining levels postharvest as crop and storage of N removed N from leaves, and lowest levels during the dormant season.
- Fruiting spur leaves and spur buds tended to have higher tissue levels of N than vegetative buds and shoot leaves, thus, spring tissue levels, particularly in those bearing spur leaves that most directly support carbohydrate and nitrogen needs of developing fruits, may be the most critical timing and tissue type to assess for in-season N status.
- Approximately 50-75% of the tissue N present prior to bloom, fruiting and harvest was still present postharvest (September), suggesting that about half the nitrogen available in the fruiting spurs was removed by the crop--at an annual rate of either ~45 or 90# actual N/acre/year. Higher N applications (~150# N/A/yr) did not improve yields or fruit quality.
- At the Mahaleb site, (the heaviest cropping of the three orchards), cumulative yield was highest in treatments that included bloom applications (~1# N/A/year), with total annual applied N of ~45 or 90# N/A/year (statistically equal results). At the Mazzard orchard yield efficiency was improved cumulatively by the 45#N postharvest + 45#N urea pre-leaf fall treatment (September-early October).
- At all sites, CAN17 for dormancy release tended to reduce yields by advancing bloom into freeze-prone timings (Linden orchards), or without freeze damage (Lodi).
- At no time did N appear to be limiting at any site, thus this trial cannot deficient levels. However, a range of adequacy-optimal N for April spur leaves is probably ~2.6-3.0%N.
- Vigor (number of shoot breaks, length of new shoot growth), was least in Bing/Mahaleb with bloom N + 45#N mid-summer, however, significant effects of treatment were not consistent.
- Fruit quality measures:
    - No clear effects
    - Large variation in cropping from tree-to-tree probably affected quality more than N treatments. N not limiting.

Fertilizer Management Recommendations

- N levels should be tested in spring on young (1st or 2nd year of bearing) spur leaves, ~1 month after full bloom for preharvest status.
- Mid-summer spur leaf measurements should be used to track N use by the crop, with yield data, to adjust annual N applied post harvest for optimal cropping without loss of fruit quality.

Good cropping appears to be supported by ~45#N mid-summer; should additional N be indicated, a maximum of 45#N applied in early fall should be used (standard rootstocks). Semi-dwarfing rootstocks should require approximately 50-75% total N required by standard rootstocks.

- Unless a clear need for CAN-induced rest-breaking is demonstrated (less than 70% estimated chill accumulation required) prior to appropriate application timing (see UC recommendations), use of CAN is likely to increase frost-related crop loss and should not be used. If a warming period prior to recommended CAN17 application timing is recorded, such that some 'loss' of dormancy could have occurred, risk increases, and the rate of CAN17 and recommended penetrant should be used at a reduced rate, and only if necessary.
- Specific N forms that appeared to provide benefit included: $CaNO_3$ (mid-summer), urea (fall, pre-leaf fall), and PacificHort Grow Plus N (~1# total N in 2-3 equal applications during bloom). There may be equally beneficial products that can be used as a bloom treatment . Because the product has a proprietary formulation of N derived from specific amino acids, there may be certain formulations that are more likely to be beneficial than others.
- Post-bloom urea was not beneficial in this trial.
- No clear and consistent treatment effects on vegetative growth were found.

PROJECT OBJECTIVES

This project directly addresses the research-based development of cost-effective N fertilization practices to improve N fertilizer use efficiency and minimize environment impacts in sweet cherry production. The FREP program goals aligned with this project include 1) nutrient uptake by tree crops, including determination of tissue nutrient thresholds, and 2) guidelines for orchard fertilization patterns, including foliar nutrient management and effective fertilizer timing. Specifically, for sweet cherry, the objectives include:

- Quantify the seasonal pattern of N partitioning to sweet cherry tissues as influenced by soil and foliar applications, formulations, timing, and rootstock.
- Determine the relationship of fruiting spur N reserves to subsequent spring spur leaf development, fruit set, and fruit growth potential.
- Determine the impact of fall dormancy-inducing and late winter dormancy-breaking treatments on fruiting spur N reserves and early spring growth demand for N.
- Develop recommendations to balance soil and foliar N application methods (timing and rates) to optimize annual fruit yields and quality while minimizing excessive vegetative growth.
- Quantify the seasonal pattern of P, K, Zn, Fe, B, Ca, S, Mg, Mn, and Cu partitioning to sweet cherry tissues as influenced by optimized N fertilization recommendations and rootstock. **This objective was achieved in April, 2010 only in Gisela orchard due to budgetary constraints for DANR Lab analyses.**

Introduction

Sweet cherry bears primarily on fruiting spurs and has a short bloom-to-ripening period for fruit development, which impacts the timeframe for nutrient demand from fruit as well as from the leaf populations that are critical for support of fruit growth. Currently, cherry growers know little about efficiently supplying demand-driven nutrients, of which nitrogen (N) is the most critical. Furthermore, due to relatively high chilling requirements of cherry, dormancy-altering treatments in fall and spring often are applied that further impact nutrient (particularly N) storage in, and demand by, tissues and organs. This project addresses these knowledge gaps and examines the potential to optimize N supply efficiency via soil vs. foliar applications and timings chosen among those already in commercial practice and timed to physiologically important events: dormancy induction and termination, bloom and fruit set, fruit rapid growth, postharvest, and end of growing season. Tissue sampling times were chosen to track flux of nitrogen throughout the seasons.

Average sweet cherry yields in California (~3.2 tons/acre; USDA NASS, 2009) are typically less than those in the Pacific Northwest (~5.5 tons/acre), due partly to insufficient chilling in some years and excessive vigor that promotes vegetative growth at the expense of reproduction. It is not known whether the most commonly used fertilization practice—soil-applied nitrogen (N) just after harvest—supplies N in an optimal, demand-driven timing (i.e., to meet reproductive needs without excessively promoting vegetative growth).

Nutritional status of trees is typically determined by sampling leaves in midsummer (Leece, 1975) when nitrogen content is most stable. For cherry, this is after harvest, so sampling at this time has no impact on the current season cherry production. Foliar sampling earlier in the season may allow growers to diagnose and fix nutritional problems before harvest. Currently, standards available for diagnosing nutritional problems in cherry before midsummer are not available, and standards for midsummer (vegetative shoot leaves) were developed for sweet cherry grown outside of California where growing conditions differ significantly (Righetti and Wilser, 1988; Hanson and Proebsting, 1996; Hansen, 1997). For peach, foliar nutrients at 60 days after bloom were more closely correlated with yield than foliar nutrients later in the season (Sanz et al., 1992). Furthermore, crop load can affect nutrient levels (Sadowski et al., 1995), but nutrient standards do not account for this variability. Sweet cherry growers in California may rely on nutritional recommendations for other California-grown stonefruits or on empirical observations and/or unsupported theories of nutrient benefits for disease prevention or crop load increase. Although, non-fruiting spurs are typically used for foliar analysis, fruiting spurs, in closer association with fruit, may show a stronger relationship to fruit quality. We have sampled buds and leaves from 'young' spurs – those in their first year of production —and from new season extension shoots to have a nitrogen profile of the most vigorous and productive tissues.

Standards are typically based on the appearance of symptoms or on reductions in yield. No deficiency or toxicity symptoms attributable to N have been observed, and yields, while observed in this trial, have been atypical in that they have been more affected by weather conditions (freeze or very optimal conditions in the same year at different sites) than by treatment. Fruit quality has largely been ignored in the development of standards, yet fruit quality, particularly size, color, firmness, Brix, and presence and appearance of attached stems, in the case of sweet cherry, may be affected by nutrient status. Sweet cherries with the best fruit quality have a 9 to 10 'row size' (measure of diameter), soluble solids (Brix) of at least 17%, balanced ratio of soluble solids to titratable acids (%/%) of 0.8 and a uniform color of dark red to mahogany using either the CTIFL color chart (Kappel et al., 1996) or the California Cherry Advisory Board (CCAB) color card. Stems should be fresh and green at harvest and preferably well-attached to the fruit.

Proper nutrition can influence fruit quality, and this has been well documented for apple. Our knowledge of relationships of tree nutrient status and cherry fruit quality is lacking for California growers, although nitrogen uptake from dormancy-breaking treatments was reported in research funded by the CCAB, in 1997, and a nutrient /fruit quality survey of California growers' orchards was funded in 1998. Increasing levels of nitrogen fertilization in cherry have been shown to delay maturity (Hansen, 1997; Stanberry and Clore, 1950; Walker and Fisherr, 1955). Improved calcium and copper nutrition may lead to firmer fruit, and fruit that is less susceptible to rain cracking (Brown et al., 1995). Growers strive to find the right balance of nutrients, but standards based on optimum fruit quality have not been established.

Project/Workplan Description

TASK 1: Seasonal pattern of N partitioning to fruiting spur and shoot storage and growth.

Knowledge of how nitrogen is used, stored and required by the tree throughout the season will enable growers to maximize their nitrogen inputs for the desired balance between vegetative growth and reproduction. Storage of nutrients for subsequent spring bloom, fruit set and first growth is necessary at adequate levels until the tree has developed a full canopy and is able to 'mine' soil nutrients. Furthermore, knowledge of which tissues have the highest demand during growth and the highest concentration of nitrogen at critical growth phases (e.g. fruit-bearing spurs and their leaves for fruit production) may enable growers to structure the tree canopy in a targeted manner, allowing sufficient canopy to support fruit production without sacrificing critical nutrients to excessive vegetative growth. Tissue sampling throughout the growing season in different tissues (vegetative vs reproductive) coincidentally with application of nitrogen at different timings and levels will enable us to develop nitrogen management recommendations for sweet cherry in California.

Subtask 1.1: Assign treatments to develop baseline data – Three experimental orchards were selected by rootstock and location. All were planted in 1998 with 'Bing' as the scion cultivar. Orchard 1 is on *P. mahaleb* seedling rootstock near Lodi on Acampo Sandy Loam soil; trees are planted at 13'x 18' spacing (186 trees per acre). Orchards 2 and 3, located near Linden and contiguous within a single site, were, respectively, on dwarfing clonal rootstock Gisela 6 (*P. cerasus* x *P. canescens*) and Mazzard (*P. avium*) seedling rootstock. Soil at Orchards 2 and 3, which were in adjacent blocks, was Cogna Loam. Orchard 2 was planted at 14' x 17' (183 trees per acre), and Orchard 3 was planted at 12' x 16' (227 trees per acre). Trees at Orchard 1 were trained to a traditional open vase; Orchards 2 and 3 to a 'steep leader' system with three primary scaffold branches. Each trial site was planned as a randomized complete block design with six single-tree replicates separated by one to three "'guard" trees and rows separating treated trees.

Fertilization treatments were initiated during bloom in March 2008. By February 2009, an entire set of treatments had been applied. Inherent differences of training system (tree architecture) and precocity (earliness to bear) are also differences between orchards, based on rootstock. Physiologically-timed nitrogen treatments, (10 nitrogen regimes, **Table 1**) were chosen based on the range of commercial practice. Foliar N treatments were applied by backpack mist-blower sprayer at a carrier volume (based on tree canopy volume) of 150 gallons/acre at Orchards 1 and 3 and 75 gallons/acre at Orchard 2 during 2008 due to smaller tree size, however, all foliar applications were applied at 150 gallons/acre beginning in 2009. Soil-applied nitrogen (postharvest) was applied by spreader. Rates of dormancy-release chemicals (CAN and KNO_3), included in the N treatments in 2009, and CAN included in the 2010 treatments were below those often used commercially due to warm weather in January, with caution due to risk of

phytotoxicity. Thus, by the end of the growing season in 2009, all treatments had been applied twice with the exception of dormancy-release treatments (the project was initiated past the appropriate time for treatment in 2008).

In 2010 certain treatments were eliminated from the treatment list (in 2010, as indicated in Table 1) as it became apparent they were not contributing to the project goals and/or were increasing potential for late frost damage.

Because applications were timed to physiological events, actual dates of application varied annually, but were similarly-timed with respect to bloom date, harvest date and early fall.

Subtask 1.2: Seasonal tissue sampling – Baseline data on N content began in February 2008; seasonal collection of tissues in 2008 included dormant and growing spur and terminal shoot buds, young (fully-expanded, April) and mature (post-harvest in June, and September) spur and shoot leaves, and small fruits collected at 20 days after full bloom, prior to 'pit-hardening' (**Table 2**). We identified the type of buds to be collected as those most representative of high seasonal demand, thus, the spur buds were those entering into the first year of bearing on 2-year-old wood on precocious Mahaleb and Gisela 6 rootstocks and on 3-year-old wood on Mazzard rootstock. Terminal buds from vegetative shoots were selected for tissue analysis. In each case, at least 10 buds were obtained. Shoot and spur leaves were collected from the same types of shoots, at least 10 leaves of each type. Tissue N sampling protocol (bearing spur leaves, extension shoot leaves, small fruits, dormant spur and terminal shoot buds) was adapted in 2009 and in 2010, based on results of tissue analyses for the preceding year to reflect N fluxes (rising and falling tissue levels) as the appropriate periods of nutrient sampling. Nitrogen content on a leaf area basis was tested as an alternative to dry weight basis to compare treatment effects, however, the standard method of nitrogen measurement, as a percentage of the dry weight, was found to better represent nitrogen treatment differences.

Although it has not been possible to quantify the seasonal pattern of P, K, Zn, Fe, B, Ca, S, Mg, Mn, and Cu partitioning to sweet cherry tissues as influenced by optimized N fertilization recommendations and rootstock (Objective 5), we were able to obtain some baseline data in a single orchard (Gisela) after all treatments had been applied. In April, 2010, shoot and bearing spur leaves from the Gisela orchard were sampled for nutrients (**Table 4).** These data allowed us to test for tissue and N level (treatment) differences.

Subtask 1.3: Seasonal growth measurements -- Phenological and productivity data, including full bloom date and duration of bloom, yield per tree, yield efficiency (yield/TCSA), and fruit quality (size, firmness, maturity, Brix and fruit removal force, or 'pull force') were collected during the 2008 season. Trunk cross-sectional area (TCSA) was measured for vegetative growth, calculated from trunk circumferences taken at 6 inches above ground level in March and in October (2008), in December (2009) and July 1 (2010). Vegetative vigor has also been measured by shoot growth and number of new shoot 'breaks' (July 1, 2010). Leaf area was measured in April using digital image analysis (DIA) of leaf photographs (Bakr, 2005; O'Neal, 2002). Leaf size for spurs and vegetative shoots is an indirect measure of photosynthetic capability and carbohydrate production, thus, photosynthate source for growing fruit, and leaf size may be enhanced by appropriate nutrient level.

Harvest for all orchards was a single 'strip pick'. Samples of fruit were obtained at random from pickers' bins and evaluated on the day following harvest for maturity, firmness, size, stem/fruit removal force (FRF) and soluble solids. Maturity was measured by color, as per picking and grading guidelines (CDFA and California Cherry Advisory Board). Only salable mature fruit were evaluated for quality, after a 50-fruit random subsample from bin-collected fruit was evaluated

for spread in maturity (by 6 color grades). Maturity, as measured by color, includes color grades of green, straw, colorbreak (change from straw to pink), light red, dark red, mahogany and dark mahogany color categories with light red (minimum marketable color) through dark mahogany (overripe) standardized by California Cherry Advisory Board color reference cards. A protocol was developed to convert Minolta Color Reader CR-10 readings to the equivalent color grades to eliminate lack of agreement common to visual evaluation. This protocol is similar to industry standards for cling peach (Slaughter and Crisosoto, 2006) and other commodity quality evaluations (Mitcham et al., 1996). Once fruit was graded, a subsample of 25 salable (defect-free, light red to mahogany) fruit were selected and used for fruit firmness, size, fruit removal force (FRF) and soluble solids determinations. Firmness and size (BioWorks FirmTech II) and FRF (Imada digital force gauge) measurements were made on individual fruits; a single soluble solids value was determined using juice extracted from each subsample.

Subtask 1.4: Tissue N analyses. Tissue analyses for nitrogen have shown a consistent pattern across all orchards of nitrogen cycling during the year with peak tissue content during rapid fruit development and reduced levels prior to annual rest (**Figure 1**). Some differences in levels were found between reproductive and vegetative leaves and buds, with reproductive tissues typically higher in N than vegetative tissues.

Subtask 1.5: Data, statistics and reporting -- Statistical analyses of data were performed with SAS (version 9.2; SAS Institute Inc., Cary, NC), for normality, distribution, frequency, and means separation, primarily using General Linear Model (Proc GLM) for 'fixed' effects, Proc Mixed for mixed-effects evaluation of fixed and random effects, Proc Univariate (basic measures, summary statistics, normality (Shapiro-Wilk test) and distribution), Proc Reg or Proc RobustReg for linear regressions, Proc Npar1way non-parametric equivalent of ANOVA (Kruskal-Wallis test) for non-normally distributed data, and where significant differences were found, multiple comparisons (means separation) were performed by Least Squares Means (estimated marginal means), Least Significant Differences, Duncan's or Tukey's tests, correcting treatment means for block effects by the use of Type III Mean Squares and *F*-test, level of significance $P = 5\%$. Outliers were identified using the above tests. In some cases, where no treatment (N regime) differences were found, Proc T-test was used to compare group means with Satterthwaite test for unequal variances applied when *F* tests indicated the need.

TASK 2: Relationship of fruiting spur N reserves to subsequent spring spur leaf development, fruit set, and fruit growth potential

The intent is to create different levels of total N in fruiting spurs with pre-dormant and post-dormant applications of N in different forms and amounts, then to correlate tissue N to subsequent flowering, fruit set, quality, and vegetative growth. This will lead to a recommendation for the most effective strategies to optimize N supply at the most critical times of N demand by fruit and fruiting support tissues.

Subtask 2.1: Assign treatments to develop baseline data and impose varied N – as in Subtask 1.1, 10 nitrogen treatments have been assigned and applied. Total N per acre per year varies from ~46-47 lb to ~153 lb annually, to induce variable N levels in tissues.

Subtask 2.2: Seasonal tissue sampling – as in Subtask I.2; tissue N of reproductive buds was measured prior to end of rest (February, 2008 and January, 2009), budswell (March, 2008), and in early spring at full leaf expansion (mid- to end of April). Small fruits were sampled at the end of Phase I (pit tip-hardening, cellularization of endosperm) for nitrogen as well. Spur leaves

were also sampled in July, 2008, September 2008 and 2009 and spur buds September 2008 and 2009.

Subtask 2.3: Seasonal growth measurements – the outcome of flowering, fruit set, crop load and reproductive growth (in this case fruit diameter), as well as spur leaf area in the same leaves evaluated for N content were measured and analyzed for their relationship to N content. Vegetative growth as number of new shoot breaks and total length of new shoots were measured on each replicate tree (2 limbs per tree) and evaluated for their relationship to cropping and N content.

Subtask 2.4: Tissue N analyses. – As in Subtask 1.4.

Subtask 2.5: Data, statistics and reporting – as in Subtask 1.5.

TASK 3: Determine the impact of fall dormancy-inducing and late winter dormancy-breaking treatments on fruiting spur N reserves and early spring growth demand for N

Subtask 3.1 Assign treatments --The objective of this task was addressed primarily by the following Treatments (Table 1):

(Treatment 2) Soil applied N at 90 lb/acre after harvest plus $ZnSO_4$+urea applied in fall for defoliation plus late-winter KNO_3 for breaking dormancy.

(Treatment 3) Soil applied N at 90 lb/acre after harvest plus fall $ZnSO_4$+urea plus late winter CAN-17 for breaking dormancy.

(Treatment 4) Soil applied N at 45 lb/acre after harvest plus fall $ZnSO_4$+urea plus late winter CAN-17 for breaking dormancy. The rationale is to develop data on tissue N levels and growth from low soil applied N plus dormancy induction/breaking treatments.

Post-harvest applications as soil-applied $CaNO_3$ have been made in both 2008 and 2009. Fall $ZnSO_4$+urea application was be made at timings based on chill portion accumulation (Dynamic Model, Erez et al., 1990.).

Late winter applications were on Jan 20 made at timing consistent with typical commercial practice for CAN-17 (approximately 49-55 chill portion accumulation). Dataloggers were placed in the trial orchards in mid-October to collect chill data for timing of dormancy-inducing and dormancy-breaking treatments, as well as effects of treatments on flowering and fruiting, with respect to amount of chilling received.

The following subtasks are as in the corresponding subtasks in Task 1, with the exception of Subtask 3.3.

Subtask 3.2: Seasonal tissue sampling

Subtask 3.3: Seasonal growth measurements

Subtask 3.4: Tissue N analyses.

Subtask 3.5: Data, statistics and reporting.

RESULTS AND CONCLUSIONS

Detailed results for 2008-2009 are not repeated in this report, other than in the context of cumulative effects over the 3-year trial life. Those results can be found in the Annual Reports for 2008 and 2009.

Tissue Nitrogen, Nitrogen Cycling and Partitioning, Nitrogen Content and Reproductive Potential

Task 1: Seasonal pattern of N partitioning to fruiting spur and shoot storage and growth

The patterns of rising and falling tissue levels is very similar among trials, so that they could be averaged out to fit a 'demand-supply' curve (Figure 1) that illustrates movement of tissue N out of storage tissues and into rapidly growing buds with peak N levels prior to harvest.

N content varied by tissue type (leaf or bud type) and by year, but not among treatments or orchards (Table 3). N content of shoot and spur leaves was consistently higher in April, prior to harvest, than post harvest (July and September), indicating the removal of N by the crop, and probably also cycling of N into storage tissues. Thus, N status for the current season crop is best measured preharvest, from bearing spur leaves, which have higher N content and support fruit growth most directly.

Treatments had effect on N content of spur and shoot leaves in Mahaleb when measured preharvest, but only on shoot leaves in 2010 (Table 4). In both types of leaf in Mahaleb, treatments that included CAN17 and/or urea (PLF, DI) generally had the highest N content in Mahaleb, but not Mazzard. While reasons for this difference between rootstocks is not clear, it could be due either to rootstock capability of uptake or might be due to N being more limiting in Mahaleb, as this orchard was consistently much more heavily cropped than the Mazzard orchard.

N, P, Ca, S, Zn, Mn and Cu were significantly higher in spur leaves than shoot leaves in Gisela, measured in April, 2010 (Table 5). Although these nutrients were not measured at any other time (with the exception of N), it is interesting that this is true for many of the nutrients, not just N. These data are for a single sampling time and rootstock, but the consistent results confirm that preharvest nutrient sampling of bearing spur leaves is more appropriate than postharvest shoot leaves.

Task 2: Relationship of fruiting spur N reserves to subsequent spring spur leaf development, fruit set, and fruit growth potential

Critical values for N established elsewhere were for shoot leaves measured postharvest (Figure 1); the values found for shoot leaves postharvest in this study would indicate that all rootstocks for all years tended to have low N status, yet cropping in Mahaleb was strong every year and vegetative growth, in general, did not appear excessive. There do not appear to be strong trends for cropload (yield; Tables 6 and) as affected by N treatments in this study, thus, either N is not limiting in any case, or sweet cherry may be somewhat insensitive to N levels used in this study. Fruit set does not appear to be affected by treatment; CAN17 applied during late dormancy has, however, shown strong indications of reducing bloom and limiting fruit growth potential by delaying harvest.

Subtask 2.3: Seasonal growth measurements – the outcome of flowering, fruit set, crop load and reproductive growth (in this case fruit size) were measured and analyzed for their relationship to N content. Vegetative growth as number of new shoot breaks and total length of new shoots were measured on each replicate tree (2 limbs per tree) and evaluated for their relationship to cropping and N content.

Task 3: Determine the impact of fall dormancy-inducing and late winter dormancy-breaking treatments on fruiting spur N reserves and early spring growth demand for N

The effect of CAN17 treatments in these trials has been to advance bloom into frost-prone timing (especially in 2009), reducing yields drastically, but also negatively affected yield in Mahaleb without frost (2009). Perhaps application of CAN during late dormancy enhances metabolic activity to promote earlier bloom and leafing out by satisfying early spring demand for N. This has not been an advantage when late freezes occur, nor has there been a 'payoff' in earlier harvest or increased yields.

Yield, Yield Efficiency and Fruit Maturity

Task 1: Seasonal pattern of N partitioning to fruiting spur and shoot storage and growth

Task 2: Relationship of fruiting spur N reserves to subsequent spring spur leaf development, fruit set, and fruit growth potential

Task 3: Determine the impact of fall dormancy-inducing and late winter dormancy-breaking treatments on fruiting spur N reserves and early spring growth demand for N

Yield and yield efficiency (Mahaleb, Table 6; Mazzard, Table 7)

Yields for 2010 in **Mahaleb** (Table 6) were not different among treatments; cumulative yields (2009+2010) were different in that the 45#N postharvest + CAN + dormancy-inducing urea yield was much lower than any other treatment, but not significantly different from the 90#N postharvest or the 45#N postharvest + urea (pre-leaf fall). What is quite interesting, is that the percentage of the crop in the first harvest is significantly reduced y both treatments with CAN--despite the 'popular wisdom' that use of this rest-breaking treatment advances harvest as it typically advances bloom. Yield efficiency was significantly different by treatments, but this was due to TCSA differences as well as yield differences (despite lack of significant treatment effect for yields).

No differences by treatment were significant for **Mazzard** in any yield component, although cumulative yields were much lower (numerically) for both CAN treatments. The yields were significantly lower in 2009 due to crop loss to frost for these treatments, contributing to the numeric differences in cumulative yields.

It is important to note that increasing rates of applied N did not improve yields, and that only about 25% of the preharvest N is removed by the crop.

Fruit maturity as affected by N treatment and yield: Crop loads were not affected by treatment in 2010 and neither was maturity, except in Mahaleb treated with CAN, which showed a delay in maturity, as measured by percentage of the crop harvested on the first date (Table 6).

The harvest at the Mazzard orchard in 2010 was a 'single pick' and no noticeable maturity differences were found.

Fruit Quality (Tables 8 and 9)

Task 1: Seasonal pattern of N partitioning to fruiting spur and shoot storage and growth

Task 2: Relationship of fruiting spur N reserves to subsequent spring spur leaf development, fruit set, and fruit growth potential

Task 3: Determine the impact of fall dormancy-inducing and late winter dormancy-breaking treatments on fruiting spur N reserves and early spring growth demand for N

Fruit quality (firmness, soluble solids, stem removal force, and fruit size) were unaffected by N treatment in the Mahaleb orchard (Table 8), except that firmness at the second harvest was slightly improved by 45#N postharvest + urea pre-leaf fall, and decreased by 90#N postharvest + CAN + dormancy-inducing urea. Firmness and other quality measures were high overall and the differences in firmness are not clearly explained by treatment.

In the Mazzard orchard, soluble solids and rowsize were unaffected by treatment, however, firmness was slightly reduced in the 90#N postharvest, 45#N postharvest + urea pre-leaf fall. Stem attachment force was significantly reduced by 90#N postharvest + CAN + dormancy-inducing urea (Table 9). It is interesting that the highest rate of N cased reduced stem attachment force, although the reason for the treatment effect is not clear.

Vegetative vigor -- Subtask 3.3: Seasonal growth measurements; Tables 10 and 11.

Of the vegetative growth indices measured, only TCSA for 2010 was affected by N treatment (Table 10). The 45#N postharvest + bloom treatment significantly reduced TCSA and numerically reduced the number of shoot breaks and overall shoot growth. No growth measures were affected by treatment in Mazzard (Table 11).

OUTREACH ACTIVITIES

January 27, 2009

California Cherry Advisory Board Annual Research Review

San Joaquin UCCE County Building
Robert J. Cabral Agricultural Center
2101 E. Earhart Avenue, Stockton, California 95206-3949

Optimizing nitrogen availability in cherry growth for high yield and fruit quality
Presented by Dr. G. Lang

Approximately 300 growers and PCAs in attendance

The presentation was well-received and the annual report (2008 FREP annual report) was included in the annual Proceedings

November 18, 2009

Annual FREP Conference

Visalia Convention Center, Visalia

Optimizing nitrogen availability in cherry growth for high yield and fruit quality
Presented by Dr. K. Glozer

Approximately 200 PCAs, researchers and other agribusiness personnel in attendance

The presentation was well-received and the interpretive summary was included in the annual Proceedings; a handout of the PowerPoint presentation was passed out at the meeting

November 17, 2010

Annual FREP Conference

Visalia Convention Center, Visalia

Nitrogen Application Timing and Practices in Sweet Cherry Orchards

Presented by Dr. G. Lang

Approximately 300 growers and PCAs in attendance

The presentation was well-received.

January, 2010

California Cherry Advisory Board Annual Research Review

San Joaquin UCCE County Building
Robert J. Cabral Agricultural Center
2101 E. Earhart Avenue, Stockton, California 95206-3949

Nitrogen Application Timing and Practices in Sweet Cherry Orchards

Presented by Dr. G. Lang

Approximately 250 growers and PCAs in attendance

The presentation was well-received and a written report (by K. Glozer) was included in the annual Proceedings

September, 2011

Optimizing Nitrogen Availability in 'Bing' Cherry Growth for High Yield and Fruit Quality
Presented in poster format at the American Society for Horticultural Science Annual conference.

We appreciate the participation of Dr. Maria Paz Garcia-Suarez, Visiting Scholar, in the 2009 growing season.

RELEVANT LITERATURE

Hansen, P. 1997. Source-sink relations in fruits. X. Effect of nitrogen on fruit growth and composition in sour cherry 'Stevensbaer'. Gartenbauwissenschaft 62 (3) p. 97-101.

Hanson, E.J. and E.L Proebsting. 1996. Cherry nutrient requirements and water relations. In: A.D. Webster and N.E. Looney (eds.) Cherries: Crop Physiology Production and Uses. CAB International, Wallingford, UK.

Kappel, F., B. Fisher-Fleming, and E. Hogue. 1996. Fruit characteristics and sensory attributes of an ideal sweet cherry.

Leece, D. 1975. Diagnostic leaf analysis for stone fruits. 5. Sweet cherry. Austral. J. Exper. Agric. Anim. Husb. 15:118-122.

Righetti, T.L. and K.L. Wilder. 1988. Interpreting cherry leaf analysis. Proc. of the 1988 Cherry Prod. Shortcourse, Washington State University Cooperative Extension.

Sanz, M., Heras, L. and Montanes, L. 1992. Relationships between yield and leaf nutrient status diagnosis. Journal of Plant Nutrition 15:1457-1466.

Saxton, A.M. 1998. A macro for converting mean separation output to letter groupings in Proc Mixed. In Proc. 23rd SAS Users Group Intl., SAS Institute, Cary, NC, pp1243-1246.

Shear, C.B. and M. Faust. 1980. Nutritional ranges in deciduous tree fruits and nuts. Hort. Rev. 2:142-163.

Southwick, S.M. 1999. Cherry Crinkle-Leaf and Deep Suture Disorders. UC ANR Publication 8007. http://anrcatalog.ucdavis.edu/Items/8007.aspx

USDA NASS California Fruit and Nut Review April 15, 2009, vol. 29(4).

Van Steenwyk, R.A. 2009. UC IPM Pest Management Guidelines: Cherry. UC ANR Publication 3440. Diseases: J. E. Adaskaveg, Plant Pathology, UC Riverside, J. L. Caprile, UC Cooperative Extension, Contra Costa County. Acknowledgment for contributions to Diseases: W. D. Gubler, Plant Pathology, UC Davis, B. L. Teviotdale, Kearney Agricultural Center, Parlier. http://anrcatalog.ucdavis.edu/IntegratedPestManag

Table 1. Nitrogen (N) treatments applied to 'Bing' (Prunus avium) sweet cherry at three orchards[x] in 2008-2010, comparing 'standard' postharvest (PH) soil application ($CaNO_3$ 15.5% N) with reduced soil-applied $CaNO_3$ and foliar N. Foliar N treatments include: CAN17 (16.7% v/v, 17% N) or KNO_3 (13.7% N) for dormancy release (DR[y]), PacificHort Grow Plus N (BLOOM; 15% ammoniacal N) applied twice (60 oz/A twice, prior to full bloom+ post-petal fall or 20-30% full bloom + full bloom), low-biuret urea (46% N) applied post-bloom (PBLM), pre leaf-fall (PLF; two applications late Sept-late Oct 7 days apart), or pre leaf-fall with 20 lb/acre $ZnSO_4$ for dormancy induction (DI; applied late October-early November at ~3 chill portions, Dynamic Model).

Treatments and N actual lb/acre (shaded treatments not applied in 2010).

PH July 9	DR	BLOOM	PBLM	PLF	DI	Total actual N (lb/acre/yr)
90 $CaNO_3$						90
90 $CaNO_3$	KNO_3 0.7				9.2	99.9
90 $CaNO_3$	CAN 26.8 or 53.5[y]				9.2	126 or 152.7
45 $CaNO_3$	CAN 26.8 or 53.5				9.2	81 or 98.5
45 $CaNO_3$				25 + 20		90
45 $CaNO_3$		1.12				46.12
45 $CaNO_3$		1.12		25 + 20		91.12
45 CaNO3			2.3			47.3
45 CaNO3			2.3	25 + 20		92.3
45 CaNO3		1.12	2.3	25 + 20		93.42

[x]Orchards vary by rootstock and location [*P. mahaleb* in Lodi, CA; 'Gisela 6' or 'Mazzard' (both *P. avium*) in Linden, CA].

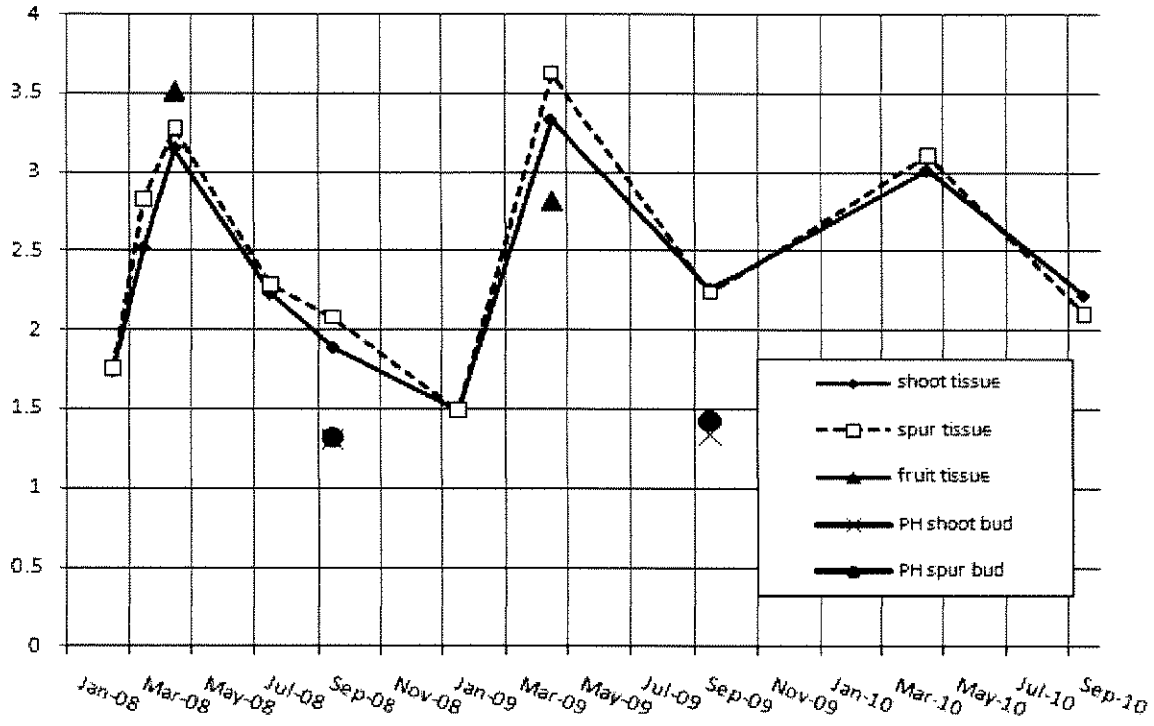
[y]DR treatment applied either 150 gal/acre (2008) or 75 gal/acre (2009-10) for 'Gisela 6' trees (dwarfing rootstock); for CAN17 actual N was either 53.5 or 26.8 lb/acre. Moderate rates of rest-breaking agents were used to reduce the risk of phytotoxicity in unseasonably warm pre-bloom periods. In 2010, applied Jan 9, at 47 chill portions (chill accumulation, Dynamic Model).

Table 2. Sampling of sweet cherry tissues and timing to determine impact of N applications.

2008 Initial year of trial [x]					
Timing	Bud		Leaf		Fruit
	Fruiting spur	Shoot terminal	Fruiting spur	Shoot terminal	
Dormant	X	X			
Early bud swell	X	X			
Fully expanded, spring			X	X	X
Mid-summer			X	X	
Early fall	X	X	X	X	
Late fall	X	X			
2009 Sample schedule changes based on Year 1 (2008) results					
Dormant	X	X			
Fully expanded, spring			X	X	X
Summer, postharvest [y]			X	X	
Early fall	X	X	X	X	
2010 sample schedule changes based on Year 1 and 2 results					
Fully expanded, spring			X	X	
Early fall			X	X	

[x]Samples from Feb-March, 2008 were from all trees/treatments; spring sampling 2008 only included those treatments imposed during and after bloom.
[y] Postharvest samples taken in June, just prior to summer pruning.

Figure 1. 2008-2010 Change in tissue N over time in vegetative and reproductive tissues of 'Bing' sweet cherry averaged from data collected at three orchards. Recommended tissue content (%N) shown below (developed in cherry-growing areas other than California).



Recommended Cherry Leaf %N (summer, vegetative shoot leaf)	Deficient	Low	Optimum	High	Excessive
	< 1.7	1.7 - 2.1	2.2 - 2.6	2.7 - 3.4	> 3.4

Table 3. Nitrogen content (%dry weight), orchards and treatments combined; values across orchards and treatments were not significantly different when all were compared, thus tissue differences only are shown.

		shoot bud	spur bud	shoot leaf	spur leaf	fruit
2008	Feb	1.74	1.76			
	Mar	2.52	2.83	.	.	.
	Apr	.	.	3.15	3.28	3.52
	Jul	.	.	2.23	2.29	.
	Sept	1.32	1.31	1.89	2.08	.
2009	Jan	1.49	1.49	.	.	.
	Apr	.	.	3.33	3.63	2.82
	Sept	1.34	1.43	2.26	2.24	.
2010	Apr	.	.	3.01	3.11	.
	Sept[x]	.	.	2.22	2.10	.

[x] September, 2010 values represent only Mahaleb and Mazzard orchards.

Table 4. 2010 N content of vegetative (first year) shoot leaves and bearing spur leaves (first year spurs) in 'Bing' (*Prunus avium*) sweet cherry at 2 orchards, comparing standard post-harvest soil application ($CaNO_3$ 15.5%N) with reduced soil application supplemented with physiologically-timed foliar applications. Actual pounds N per acre shown; foliar applications of N are low-biuret urea (DI, dormancy-inducing; 46% N) or PacificHort Grow Plus N (bloom, 15% ammoniacal N).

N (lb/A/yr) and treatment		Mahaleb				Mazzard			
		April (5-7 weeks after full bloom)		Sept		April (5-7 weeks after full bloom)		Sept	
		shoot	spur	shoot	spur	shoot	spur	shoot	spur
~50	45PH+bloom	2.58 c[x]	2.85 b	2.46 a	2.30 a	2.66 c	2.73 c	2.22 ab	2.10 a
~90-100	90PH	2.96 ab	3.02 ab	2.40 ab	2.26 a	2.90 b	2.96 b	2.27 a	2.11 a
	45PH+CAN+Urea DI	3.07 ab	3.25 a	2.36 abc	2.24 a	2.88 b	2.88 bc	2.07 ab	1.92 b
	45PH+Urea PLF	3.02 ab	3.10 a	2.33 abc	2.20 a	2.70 c	2.79 c	2.00 b	1.92 b
	45PH+bloom+Urea PLF	2.90 c	3.04 ab	2.24 bc	2.10 a	2.73 c	2.86 bc	2.04 ab	1.94 ab
150	90PH+CAN+Urea DI	3.20 a	3.26 a	2.18 c	2.14 a	3.04 a	3.12 a	2.10 ab	1.94 ab
Significant difference by treatment		***	***	***	NS	***	***	***	***

[x] Mean separation within columns by Least Squares Means, mixed linear model (replicate as random effect, treatment as fixed effect; $P = 5\%$); means with same letter(s) not significantly different. $P = 5\%$, 1%, 0.1%, NS (*, **, ***, non-significant, respectively).

Table 5. Nutrient values for 'Bing' cherry, Gisela orchard in April, **2010**. Nutrient levels did not vary by N treatments, therefore values are shown only by tissue sampled.

Leaf type	% Dry weight					ppm					
	N	P	K	Ca	Mg	S	B	Zn	Mn	Fe	Cu
Shoot	3.26b	0.29b	0.93	0.73b	0.25b	1947b	41.8	23.5b	49.2b	52.8b	13.1b
Bearing spur	3.35a	0.31a	0.96	0.90a	0.26a	1994a	40.2	26.9a	55.9a	54.8a	15.3a
Significance by part	***	***		***	*	***		***	***	*	***

[x]Means in the same column and orchard with different letters differ by Least Squares Means (Tukey) at P = 0.05; ***, **, * or NS = significance at 0.1, 1, 5% level, or non-significant, respectively.

Table 6. **Yield, cumulative yield and yield efficiency, 2010** for 'Bing' (*Prunus avium*) sweet cherry on **Mahaleb** rootstock in response to nitrogen (N) fertilization, comparing only treatments in common. Treatments include postharvest (PH; 45 or 90lb actual N) soil application [$CaNO_3$15.5% N], supplemented with foliar N applications 'timed' to phenological events) in most cases. Foliar N treatments include: **CAN17** (16.7% v/v, 17% N) for dormancy release (DR), **PacificHort Grow Plus N** (bloom; 15% ammoniacal N) applied twice during bloom, **low-biuret urea** (46% N) applied pre leaf-fall (PLF; two applications late Sept-Oct 7 days apart), or pre leaf-fall with 20 lb/acre $ZnSO_4$ for dormancy induction (DI; applied late October-early November at ~3 chill portions, Dynamic Model).

Treatment	N_{actual} (lb/A/yr)	Total yield (kg/tree)	Percentage of crop in first harvest	TCSA (cm^2) 2010	Yield efficiency (kg/tcsa) 2010	Yield 2009-2010
45PH+Bloom	50	40.0 [x]	59.0 a	544.5 b	0.074 ab	108.8 a
90PH	100	38.8	53.8 ab	662.6 ab	0.060 ab	97.4 ab
45PH+CAN+Urea DI	100	46.5	27.8 b	775.1 a	0.062 ab	73.4 b
45PH+Urea PLF	100	47.0	52.0 ab	724.3 a	0.064 ab	97.7 ab
45PH+Bloom+Urea PLF	100	38.7	61.4 a	732.7 a	0.054 b	114.2 a
90PH+CAN+Urea DI	150	59.4	25.2 b	789.9 a	0.075 a	104.3 a
Significance for treatment means differences		NS	***	***	***	***

[x] Analysis by Mixed Model, replicate effects 'random' and treatment effects 'fixed'. Means in the same column and orchard with different letters differ by Least Squares Means (Tukey) at P = 0.05; ***, **, * or NS = significance at 0.1, 1, 5% level, or non-significant, respectively. Percentage data arcsine square root-transformed for analysis; actual means shown.

Table 7. **Yield, cumulative yield and yield efficiency, 2010** for 'Bing' (*Prunus avium*) sweet cherry on **Mazzard** rootstock in response to nitrogen (N) fertilization, comparing only treatments in common. Treatments include postharvest (PH; 45 or 90lb actual N) soil application [$CaNO_3$15.5% N], supplemented with foliar N applications 'timed' to phenological events) in most cases. Foliar N treatments include: **CAN17** (16.7% v/v, 17% N) for dormancy release (DR), **PacificHort Grow Plus N** (bloom; 15% ammoniacal N) applied twice during bloom, **low-biuret urea** (46% N) applied pre leaf-fall (PLF; two applications late Sept-Oct 7 days apart), or pre leaf-fall with 20 lb/acre $ZnSO_4$ for dormancy induction (DI; applied late October-early November at ~3 chill portions, Dynamic Model). Harvest occurred on a single date.

Treatment	N_{actual} (lb/A/yr)	Total yield (kg/tree)	TCSA (cm^2) 2010	Yield efficiency (kg/tcsa) 2010	Yield 2009-2010
45PH+Bloom	50	27.4	560.2	0.050	64.7
90PH	100	28.1	542.4	0.053	59.5
45PH+CAN+Urea DI	100	27.1	561.5	0.049	31.0
45PH+Urea PLF	100	33.6	496.2	0.070	67.8
45PH+Bloom+Urea PLF	100	26.9	522.4	0.052	59.6
90PH+CAN+Urea DI	150	34.0	516.7	0.066	41.8
Significance for treatment means differences		NS	NS	NS	NS

[x] Analysis by Mixed Model, replicate effects 'random' and treatment effects 'fixed'. Means in the same column and orchard with different letters differ by Least Squares Means (Tukey) at P = 0.05; ***, **, * or NS = significance at 0.1, 1, 5% level, or non-significant, respectively shown.

Table 8. Fruit quality, 2010 for 'Bing' (*Prunus avium*) sweet cherry on **Mahaleb** rootstock in response to nitrogen (N) fertilization, comparing only treatments in common. Treatments include postharvest (PH; 45 or 90lb actual N) soil application [$CaNO_3$15.5% N], supplemented with foliar N applications 'timed' to phenological events) in most cases. Foliar N treatments include: **CAN17** (16.7% v/v, 17% N) for dormancy release (DR), **PacificHort Grow Plus N** (bloom; 15% ammoniacal N) applied twice during bloom, **low-biuret urea** (46% N) applied pre leaf-fall (PLF; two applications late Sept-Oct 7 days apart), or pre leaf-fall with 20 lb/acre $ZnSO_4$ for dormancy induction (DI; applied late October-early November at ~3 chill portions, Dynamic Model). Harvest occurred on a single date.

Treatment	N_{actual} (lb/A/yr)	%Soluble solids		Firmness (g/cm^2)		Rowsize		Stem removal force (g/cm^2)	
		June 2	June 10	June 2	June 10	June 2	June 10	June 2	June 10
45PH+Bloom	50	21.5[x]	21.1	264	272	9.8	9.3	792	756ab
90PH	100	21.1	20.7	265	256	10.0	9.4	825	733b
45PH+CAN+Urea DI	100	21.5	21.1	275	272	10.3	9.7	800	772ab
45PH+Urea PLF	100	22.2	21.3	282	271	10.0	9.5	759	802a
45PH+Bloom+Urea PLF	100	21.6	20.5	257	248	10.0	9.4	774	728b
90PH+CAN+Urea DI	150	22.0	20.9	275	257	10.2	9.7	773	604c
Significance for treatment means differences		NS	NS	NS	NS	NS	NS	NS	*

[x] Analysis by Mixed Model, replicate effects 'random' and treatment effects 'fixed'. Means in the same column and orchard with different letters differ by Least Squares Means (Tukey) at P = 0.05; ***, **, * or NS = significance at 0.1, 1, 5% level, or non-significant, respectively.

Table 9. 2010 Fruit quality for 'Bing' (*Prunus avium*) sweet cherry on **Mazzard** rootstock in response to nitrogen (N) fertilization, Treatments include postharvest (PH; 45 or 90lb actual N) soil application [$CaNO_3$15.5% N], supplemented with foliar N applications 'timed' to phenological events) in most cases. Foliar N treatments include: **CAN17** (16.7% v/v, 17% N) for dormancy release (DR), **PacificHort Grow Plus N** (bloom; 15% ammoniacal N) applied twice during bloom, **low-biuret urea** (46% N) applied pre leaf-fall (PLF; two applications late Sept-Oct 7 days apart), or pre leaf-fall with 20 lb/acre $ZnSO_4$ for dormancy induction (DI; applied late October-early November at ~3 chill portions, Dynamic Model). Firmness and rowsize measured by FirmTech II (BioWorks, KS), soluble solids by Atago 3810 PAL-1 digital refractometer and stem removal force by Imada DS2-4 digital force gauge . Rowsize indicates larger fruit with smaller rowsize.

Treatment	N_{actual} (lb/A/yr)	%Soluble solids	Firmness (g/cm^2)	Rowsize	Stem removal force (g/cm^2)
45PH+Bloom	50	16.2	247 a	9.9	555 a
90PH	100	15.6	232 b	10.0	542 a
45PH+CAN+Urea DI	100	15.8	240 ab	10.2	560 a
45PH+Urea PLF	100	15.1	233 b	10.2	542 a
45PH+Bloom+Urea PLF	100	15.4	245 a	13.8	545 a
90PH+CAN+Urea DI	150	15.6	233 b	10.2	452 b
Significance for treatment means differences		NS	***	NS	***

[x] Analysis by Mixed Model, replicate effects 'random' and treatment effects 'fixed'. Means in the same column and orchard with different letters differ by Least Squares Means (Tukey) at P = 0.05; ***, **, * or NS = significance at 0.1, 1, 5% level, or non-significant, respectively.

Table 10. 2010: Nutritional effects on **vegetative growth** in '**Bing**'/'**Mahaleb**', (PH) soil application [$CaNO_3$ 15.5% N] supplemented with foliar N applications 'timed' to phenological events. Treatments include postharvest (PH; 45 or 90lb actual N) soil application [$CaNO_3$15.5% N], supplemented with foliar N applications 'timed' to phenological events) in most cases. Foliar N treatments include: **CAN17** (16.7% v/v, 17% N) for dormancy release (DR), **PacificHort Grow Plus N** (bloom; 15% ammoniacal N) applied twice during bloom, **low-biuret urea** (46% N) applied pre leaf-fall (PLF; two applications late Sept-Oct 7 days apart), or pre leaf-fall with 20 lb/acre $ZnSO_4$ for dormancy induction (DI; applied late October-early November at ~3 chill portions, Dynamic Model).

Treatment	N_{actual} (lb/A/yr)	TCSA (cm^2) 2010	# Shoot breaks	Total shoot growth (cm)	Growth/shoot (cm)
45PH+bloom	50	544.5b	7.2	325.3	45.6
90PH	100	662.6ab	11.8	545.5	50.0
45PH+CAN+Urea DI	100	775.1a	11.3	657.5	59.8
45PH+Urea PLF	100	724.3a	10.5	654.3	60.2
45PH+bloom+Urea PLF	100	732.7a	12.2	611.5	49.9
90PH+CAN+Urea DI	150	789.9a	16.8	607.8	48.0
Significance for treatment means differences		***	NS	NS	NS

[x]Means in the same column and orchard with different letters differ by Least Squares Means (Tukey) at $P = 0.05$; ***, **, * or NS = significance at 0.1, 1, 5% level, or non-significant, respectively.

Table 11. 2010: Nutritional effects on **vegetative growth** in **'Bing'/'Mazzard'**, (PH) soil application [$CaNO_3$ 15.5% N] supplemented with foliar N applications 'timed' to phenological events. Treatments include postharvest (PH; 45 or 90lb actual N) soil application [$CaNO_3$15.5% N], supplemented with foliar N applications 'timed' to phenological events) in most cases. Foliar N treatments include: **CAN17** (16.7% v/v, 17% N) for dormancy release (DR), **PacificHort Grow Plus N** (bloom; 15% ammoniacal N) applied twice during bloom, **low-biuret urea** (46% N) applied pre leaf-fall (PLF; two applications late Sept-Oct 7 days apart), or pre leaf-fall with 20 lb/acre $ZnSO_4$ for dormancy induction (DI; applied late October-early November at ~3 chill portions, Dynamic Model).

Treatment	N_{actual} (lb/A/yr)	TCSA (cm^2) 2010	# Shoot breaks	Total shoot growth (cm)	Growth/shoot (cm)
45PH+bloom	50	560.2	6.2	254.8	41.8
90PH	100	542.4	5.5	270.8	50.7
45PH+CAN+Urea DI	100	561.5	5.7	260.3	45.2
45PH+Urea PLF	100	496.2	6.5	325.7	51.7
45PH+bloom+Urea PLF	100	522.4	5.8	243.8	41.8
90PH+CAN+Urea DI	150	516.7	5.0	218.3	42.8
Significance for treatment means differences		NS	NS	NS	NS

[x]Means in the same column and orchard with different letters differ by Least Squares Means (Tukey) at $P = 0.05$; ***, **, * or NS = significance at 0.1, 1, 5% level, or non-significant, respectively.

FINAL PROJECT REPORT

WTFRC Project Number: CH10106

Project Title: Branch induction in two-year-old wood of sweet cherry

PI: Donald C. Elfving
Organization: Tree Fruit Research & Extension Center
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Cooperators: Dr. M.D. Whiting, WSU Prosser

Other funding sources: NONE

Total Project Funding: $5,875

Budget History:

Item	2010	2011
Salaries[1]	0	0
Benefits[1]	0	0
Wages[2]	1,000	1,500
Benefits[2]	150	225
Equipment	0	0
Supplies[3]	200	300
Travel[4]	1,000	1,500
Miscellaneous	0	0
Total	2,350	3,525

[1] No technical help indicated since Technician position no longer exists. Time-slip help is absolutely essential to collect the volume of data needed to set up trials and evaluate growth responses to the various bioregulator applications involved.

[2] Time-slip help substitutes for unfilled Technician position. Time-slip benefit rate is calculated at 15%.

[3] This category includes miscellaneous supplies, non-capital equipment, consumables, repairs, etc. that are needed to carry out the research project.

[4] Treatment application and data collection at distant sites, all off-station. Includes vehicle lease-to-purchase, operating, repair costs.

Objectives:

1. Test cytokinins without GA to determine efficacy for stimulation of lateral branch development on two-year-old wood using both cuts and high surfactant concentration additives to evaluate efficacy of cytokinins for bud activation and penetrability of older bark.
2. Assess whether supplementation or substitution of cytokinin-based treatment solutions with GA produces any beneficial effect on branching of older wood.
3. Evaluate the characteristics of induced branches on older wood and determine follow-up strategies for modification of branch growth habit if needed.
4. Evaluate effects of treatments to older wood on pedicel development of flowers borne on treated wood sections.

Significant findings 2010:

1. All of the three orchards used for these studies experienced significant cold damage to buds and/or woody tissues from the Oct. 11, 2009 freeze event. The three orchards were located from Stayman Flats near Chelan, WA to the Sunrise orchard near Moses Coulee. In all three locations, the minimum temperature that night reached between 21 and 15°F during the freeze, and in all three locations the rate of temperature decrease overnight equaled or exceeded -1.8°F (-1°C) per hour, a rate sufficient to produce significant damage to unacclimated tissues.
2. In a comparison of Promalin, Maxcel and ProVide (Valent BioSciences) applied to scoring cuts on two-year-old wood of 'Sweetheart' trees, only Maxcel (5,000 ppm) showed some increase in branching over control, but extensive wood damage from cold (low of 21°F on Oct. 11, 2009) significantly compromised the branching potential in this trial.
3. Promalin (5,000 ppm) applied to scoring cuts only modestly increased lateral branching on two-year-old wood of 'Sweetheart' cherry trees compared to untreated control trees. Combining Promalin with Pentra-bark surfactant (Quest Products Corp.) at up to 15% v/v and applying these bioregulator/surfactant mixtures as bands to two-year-old wood of 'Sweetheart' cherry trees was completely ineffective for branch induction. Again, significant wood and bud damage, severe enough to result in the removal of some trees, compromised the results.
4. In a block of 'Early Robin'/Mazzard trees near the Columbia River (Stayman Flats), Promalin (5,000 ppm) applied to scoring cuts only increased branching from two-year-old wood by about two-fold. Bud damage due to cold appeared to limit branching potential. Mixing Promalin with Pentra-bark at up to 15% v/v and applying these mixtures as bands at intervals on two-year-old wood had no effect on branching.
5. Applying either scoring or bioregulator banding to two-year-old wood of 'Early Robin' trees either every 15 or every 30 cm along the two-year-old wood made no difference in branching response.
6. Two trials examined the effects of the surfactants Syl-Tac (Wilbur-Ellis) or Yucca-Aide (Monterey Ag Resources) as supplements for Promalin (2,000 ppm) when applied to scoring cuts or as bands on one-year-old wood of 'Sweetheart' cherry. All the experimental trees were subjected to a low of 15°F on Oct. 11, 2009, resulting in some dieback on terminals of one-year-old wood and an unknown amount of internal tissue damage. The death of the terminal portion of the one-year-old leader acted much as a heading-back cut, producing some stimulation of branching among the remaining live buds. Promalin plus scoring produced about twice the branching of untreated controls, suggesting that cold injury combined with the heading-back effect may have compromised the potential for additional branch induction with bioregulators.
7. In both of these trials, Syl-Tac at 2, 5 or 10% v/v and Yucca-Aide at 0.25, 2 or 15% v/v improved branching as much as did scoring plus Promalin. The other surfactant-concentration

treatments were ineffective. Terminal dieback on one-year-old wood was present in almost every tree in each trial. The uneven branching response to surfactant supplementation may have been due in part to non-visible vascular damage in the treated branch sections.

Significant findings 2011:

1. Four trials, two on one-year-old wood and two on two-year-old wood, were established in a young orchard of 'Bing'/G.6 trees near Wenatchee, WA. Two trials on two-year-old wood of 4th-leaf 'Chelan'/Mazzard trees were established in Pasco. One trial was established on two-year-old wood on 5th-leaf 'Selah'/Mazzard trees in East Wenatchee. The trees turned out to have suffered variable amounts of tissue and bud damage from the late Nov. 2010 freeze event, with the trees near Wenatchee more severely affected. Although the leader shoots on the Wenatchee 'Bing' trees were unpruned, every tree suffered some killing of the upper portion of the new leader shoot that grew in 2010. Thus the trees in spring, 2011 behaved as if they had been headed back in the winter, creating a stimulus for lateral-branch development due to interrupted apical dominance.
2. In a comparison of several different cytokinin/gibberellic acid products applied to scoring cuts at green-tip on two-year wood of 'Chelan' trees that suffered only minor cold damage, scoring alone was no better than no treatment for induction of branching.
3. On both two- and three-year-old 'Chelan' wood, any bioregulator product (Maxcel, Promalin, Pro-Gibb, ProVide, Novagib or GA_7 alone) combined with Syl-Tac surfactant (0.5% v/v) and applied to scoring cuts 15 cm apart resulted in improved branch induction.
4. Surprisingly, on older 'Chelan' wood, any gibberellic acid formulation applied to scoring cuts produced better lateral-branch induction than 6-benzyladenine (Maxcel) alone.
5. In contrast, on two-year-old wood of winter-injured 'Bing'/G.6 trees, any GA + scoring did not induce branching as well as Maxcel (6-BA only) + scoring. Is this a varietal difference or somehow related to the winter damage situation?
6. Increasing the concentration of Promalin combined with Regulaid surfactant applied to scoring cuts on two- and three-year-old wood of 'Selah' trees resulted in a comparable improvement in branching despite some cold injury to buds. Quality of branching at the highest Promalin concentration (20,000 ppm, undiluted product straight from the bottle, no Regulaid) was similar to that from lower concentrations (wide crotch angles, no upright suckers). Branch induction on older wood may be enhanced by higher bioregulator concentrations.
7. In a test of a variety of surfactants combined with Promalin (5,000 mg a.i./liter) and applied as sloppy bands every 15 cm without scoring cuts on 'Bing' trees near Wenatchee, no treatment produced any improvement in lateral branching.
8. Crotch angles of induced branches on two-year-old wood on young 'Bing' trees were unaffected by any treatment. In addition, no induced branches developed into upright suckers. The average crotch angle of induced branches was around 70° - 80°, resulting in desirably flat induced shoots with no evidence for promotion of undesirable sucker growth.
9. Despite post-treatment temperatures in the acceptable range, branching response of two-year-old wood of 5th-leaf 'Chelan'/Mazzard trees was quite limited, due in part to killing of some lateral buds by cold the previous November. Nevertheless, Promalin + scoring produced about a 6 to 10-fold increase in branching compared to untreated controls, scoring + surfactants only, or Promalin + surfactants painted onto unscored bark.
10. In April, 2011, two trials were conducted on one-year-old wood of young 'Bing'/G.6 trees on which a variable amount of that one-year-old wood had been damaged by cold the previous November.
11. Combining various surfactants with Promalin (5,000 mg a.i./liter) and applying those solutions as sloppy bands every 30 cm on the living portion of the one-year-old wood, lateral branching was improved by supplementation of Promalin with either Syl-Tac (5% v/v),

Pentra-bark (5% v/v) or Rocket DL (4% v/v). Lateral branching was similarly stimulated by scoring every 30 cm and painting the scoring cuts with Promalin plus Regulaid (1% v/v). Mixing the surfactants Prolec (0.5% v/v) or Canhance (10% v/v) with a similar concentration of Promalin and applying as sloppy bands did not result in improved branching.

12. Combining the surfactant Canhance (10% v/v) with various bioregulators, each at 5,000 mg a.i./liter and applying each solution to scoring cuts on one-year-old wood of young 'Bing'/G.6 trees, Promalin and Pro-Gibb produced an improvement of over 50% in lateral-branch development from treated wood. The gibberellins ProVide and GA_7 alone were nearly as effective. Canhance alone and Maxcel plus Canhance were completely ineffective for stimulation of branching.
13. Limited observations indicated that the presence of GA in a branch-induction treatment could increase pedicel length on fruit set on spurs on treated wood.

Methods:

Three trials were initiated in 2010 and five in 2011 to examine effects of cytokinins vs. gibberellins along with scoring vs. surfactant treatments on branch induction on two-year-old wood. Two additional trials were initiated in 2010 and two more in 2011 to examine in greater detail the potential for surfactants to substitute for scoring or nicking cuts in one-year-old wood in stimulating lateral branch development. The trials focused on whether surfactants could substitute for cutting the bark on two-year-old wood for encouraging penetration of bioregulators into active tissues, whether GA alone could induce branching on two-year-old wood as has been demonstrated for such treatments on one-year-old wood, whether the distance between scores or banded bioregulator treatments on two-year-old wood had any beneficial effect on branch induction, and whether concentration of Promalin influenced branching success on older wood.

Results and discussion:

One goal of the program was to determine whether gibberellic acid (GA) alone can induce lateral branching in two-year-old wood of sweet cherry. Previous research has clearly shown that GA alone is about as effective as cytokinin for branch induction in one-year-old wood. One advantage this finding confers is that GA products are OMRI-approved, and thus can be used in organic orchards. They are also a bit cheaper than Promalin. Winter injury precluded clear conclusions in 2010. In 2011 the branching results, although diminished to some degree by winter injury sustained in late Nov. 2010, showed that GA products alone were effective for branch induction on two-year-old wood in 'Chelan' cherry, but less strongly in 'Bing'.

In several of the trials, comparisons of surfactant concentrations vs. using scoring cuts to improve bioregulator penetration were undertaken. Despite some cold damage effects in these trials, it was clear that when we applied Promalin to scoring cuts, branching was improved to some extent in every case. These results showed that if there were live buds present on two-year-old wood and that wood had not been killed outright by either the 2009 or 2010 cold events, those living buds could be activated if the Promalin could penetrate into active tissues. Results of the two trials with one-year-old wood confirmed this observation.

In the case of the one-year-old wood, killing the terminal portion of those shoots altered the apical dominance situation by producing the equivalent of a heading-back cut. This physiological change resulted in a certain amount of increased branching, thus limiting the degree to which additional branching could be induced by the bioregulator applications themselves. On one-year-old wood, three surfactant treatments, Promalin plus either Pentra-bark (Quest), Rocket DL (Monterey) or Syl-Tac (Wilbur-Ellis) resulted in sufficient

bioregulator penetration into one-year-old wood to stimulate branching over and above the stimulus produced by cold damage to the upper portion of that wood.

None of the surfactant-supplemented treatments showed significant branching activity on two-year-old wood in the absence of scoring. It appears clear that surfactants alone, even at high concentrations (up to 15% v/v), do not provide a reliable method for assuring bioregulator penetration through the bark and into active tissues on two-year-old or older wood. Our trials indicate that successful branch induction on branch sections older than one year require some form of bark injury to open a path for successful penetration of bioregulators.

Acknowledgements:

The assistance and support of the following people and organizations is gratefully acknowledged: Dr. Greg Clarke, Dan Flick, Kevin Forney, Gary Goodman, Norman Gutzwiler, Ali Hashemi, Jeff Henry, Jim Kelley, Dr. Lawrence Marais, Dr. Peter Petracek, Ed Schaplow, Richard Scranton, Wm. Stringfellow, Kent Waliser, Dr. Matt Whiting, Allview Orchards, Fine Americas, Goodman Orchards, Gutzwiler (Scheble) Orchards, Monterey Ag Resources, Noor Orchards, Quest Products Corp., Sagemoor Farms, Sunrise Orchard (WSU-TFREC), Triple J Orchards, Valent BioSciences, Washington Tree Fruit Research Commission, Wilbur-Ellis Co., Inc. and the WSU Agricultural Research Center.

Reports Published:

Elfving, D.C., D.B. Visser and J.L. Henry. 2011. Gibberellins stimulate lateral branch development in young sweet cherry trees in the orchard. **International Jour. of Fruit Sci. 11:41-54.**

Elfving, D.C. 2010. Plant bioregulators in the deciduous fruit tree nursery. **Acta Horticulturae 884:159-166.**

Elfving, D.C. and T.R. Schmidt. 2010. Bioregulator sprays. p. 133-146. In: M. Bush (coord.), **2010 Crop Protection Guide for Tree Fruits in Washington. EB 0419.**

Executive Summary

1. No surfactant tested, even at high concentration (up to 15 % v/v), was capable of producing sufficient penetration of cytokinin- or gibberellin-based bioregulators through the bark to successfully induce lateral branching on two- or three-year-old wood in young sweet cherry trees. Only when such bioregulators were combined with scoring cuts to permit penetration into living tissues did lateral branching occur on older wood.
2. Gibberellic acid (Pro-Gibb, Novagib, ProVide or GA_7) alone proved effective for induction of lateral branching on two- or three-year-old wood of sweet cherry trees when applied to scoring cuts. This observation suggests that these products may have a role for branch induction in organic sweet cherry orchards.

CONTINUING PROJECT REPORT **YEAR**: 2 of 3
WTFRC Project Number: CH-10-108

Project Title: Reducing the impact of virus diseases on quality cherry production

PI: Ken Eastwell
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Cooperators: Mr. Tim Smith, WSU-Extension, Wenatchee, WA
Dr. Tom Unruh and Dr. Wee Yee, USDA-ARS, Wapato
Various growers

Total Project Request: Year 1: $42,735 Year 2: $44,522 **Year 3: $46,303**

Other funding sources

Agency Name: National Clean Plant Network – Fruit Trees
Amt. requested/awarded: NCPN-FT pays land rental fees and maintenance costs of the virus research block where field experiments are conducted. The estimated cost associated with this project is $42,300 and is a portion of a larger NCPN grant to WSU-Prosser.
Note: WSU is including this information on other funding available for the support of similar research undertaken by the faculty member proposing this research. These resources are listed to identify other support granted for this research and are not included as a commitment of cost-share by the institution.

Budget 1
Organization Name: **Washington State University** **Contract Administrator: Carrie Johnston**
Telephone: **509-335-4564** **Email address: carriej@wsu.edu**

Item	2010	2011	2012
Salaries[1]	$22,537	22,150	23,460[1]
Benefits[2]	8,198	9,711	9,853[2]
Wages		0	0
Benefits		0	0
Equipment		0	0
Supplies[3]	12,000	12,661	12,990[3]
Travel		0	0
Miscellaneous		0	0
Total	$42,735	$44,522	**$46,303**

Footnotes:
1. Salaries: Total of 0.57 FTE Post doctoral researchers for 12 months.
2. Benefits paid at WA State established rates.
3. Supplies: Purchase laboratory reagents and supplies for performing molecular analysis, purchase trees.

OBJECTIVES:

The **overall project objective** is to identify viruses that cause low quality and quantity fruit production, and to develop an understanding of virus biology that will ultimately lead to the **development of effective management strategies for growers.**

Goal 1: Determine the ability of rootstock and inter-stock selections to limit the spread of cherry leaf roll virus and related viruses.

Goal 2: Determine the means of long distance transmission for cherry leaf roll virus.

Goal 3: Document the responses of new cherry cultivars to viruses.

SIGNIFICANT FINDINGS:

- Cherry leaf roll virus is being detected in more orchards throughout the state.
- Even in the absence of mixed infections with other viruses, cherry leaf roll virus causes significant reduction of growth of young 'Bing' trees growing on Mazzard rootstock.
- Of the rootstocks evaluated, 'Colt' rootstock offers the most dramatic response to cherry leaf roll virus preventing the transmission of virus from inoculation sites on the rootstock to the scion, and causing inoculated scions to decline quickly. Such reactions would reduce potential field spread of the virus. After 12 months, stunting and premature leaf senescence is observed on trees of 'Bing' growing on Gisela 12 and Gisela 6 rootstock, and the Citation/Z-stem interstem combination.
- Diseases of the rusty mottle group are caused by closely related members of the Betaflexiviridae family of viruses.

METHODS:

'Bing' scions growing on various rootstocks were established in the orchard; either the rootstock or the scion was then inoculated by chip grafting with buds of a source tree infected with cherry leaf roll virus. The source tree was previously virus tested to insure there were no other viruses in the inoculum. In parallel, a duplicate set of trees was inoculated with an isolate of cherry raspleaf virus.

An experiment initiated earlier to determine the role of pollen transmission to virus-free trees was concluded. A new trial was begun to determine if the presence of a second virus would alter the result. Source trees for cherry leaf roll virus-infected pollen including the cultivars 'Lapin', 'Rainer' and 'Sweetheart' are being grown in the research orchard. Pollen from these trees will be collected and used to pollinate 'Bing' trees that are already established and infected with the common ilarviruses: prune dwarf virus and/or *Prunus* necrotic ringspot virus.

Potential sources of the rusty mottle group of viruses were identified in orchards throughout the western U.S. Buds from these sources were chip budded onto reference trees for preservation and also onto a set of greenhouse woody indicators that are used to categorize the virus-like agents associated with cherry diseases. Tissue from the source trees were also subjected to a full analysis of the virus content to determine the population(s) of viruses associated with the disease symptoms.

RESULTS AND DISCUSSION:

As cherry leaf roll virus is detected in more orchards of the PNW, its impact on sweet cherry production continues to increase. It has been shown that cherry leaf roll virus is transmitted between trees when roots naturally graft. In addition to spreading to adjacent trees, cherry leaf roll virus also infects single trees located long distances from known virus sources. Therefore, an aerial route is suspected. Virus testing and tree removal is an effective solution to stop the spread of disease in orchards when a very few trees are involved. However, in areas where larger numbers of trees are involved, a different strategy may be necessary to effectively maintain production of quality fruit. Selection of rootstocks is being investigated as a means to help facilitate disease management. When

a virus infected root of a susceptible rootstock contacts a hypersensitive rootstock, the virus will solicit cell death in the zone immediately surrounding the point of contact, and thus prevent the virus from moving into the tree with the hypersensitive rootstock. Similarly, if the scion becomes infected through an aerial means, a hypersensitive reaction will develop at the graft union leading to the rapid decline of the infected scion. A hypersensitive rootstock thus acts as a barrier to root transmission and eliminates the shedding of virus-infected pollen from the declining scion. A tree on a hypersensitive rootstock is prevented from serving as a reservoir of infection for the rest of the orchard. Of the rootstocks evaluated, 'Colt' rootstock offers the best "protection". This rootstock resulted in the quick decline of trees within one year of inoculation of the scion, and prevented the virus from moving from inoculated rootstock into the scion. Other rootstocks including 'Gisela 12' and 'Gisela 6', and the 'Citation'/Z-stem interstem combination are showing signs of decline after 12 months, but the rate of decline is not as rapid as that observed with 'Colt'.

Previous observations in commercial orchards indicate that severe symptoms appear when trees are infected with cherry leaf roll virus plus prune dwarf virus and/or *Prunus* necrotic ringspot virus. However, it was observed this year that young trees growing on Mazzard rootstock are dramatically impacted by cherry leaf roll virus alone; growth is significantly impaired.

A parallel study was initiated to identify rootstocks that may offer resistance to the nematode transmitted cherry raspleaf virus. Several known locations of cherry raspleaf virus were surveyed to identify a source of inoculum for this study. However, all trees identified with cherry raspleaf virus were also infected with either prune dwarf virus or *Prunus* necrotic ringspot virus. A source tree containing a mixed infection of cherry raspleaf virus and prune dwarf virus was used to inoculate 'Bing' trees growing on various rootstocks. Twelve months after inoculation, all 'Bing' growing on Krymsk 6 are dead regardless of whether the scion or rootstock was inoculated. Krymsk 6 is sensitive to prune dwarf virus so it is unknown which virus elicited this response. Trees on Gisela 12 rootstock on which the rootstock was inoculated exhibit extreme leaf rolling, an indication of severe stress. Gisela 12 is not sensitive to prune dwarf virus. For future research, the process was started to obtain a source of cherry raspleaf virus that is free of contaminating ilarviruses. To that end, an isolate of cherry raspleaf virus was inoculated onto *Chenopodium amaranticolor*, a host for cherry raspleaf virus but not for prune dwarf virus. The chenopodium plants were allowed to grow for approximately 4 weeks at which time they were approach grafted to each of three virus-free 'Bing' trees. After one month, the 'Bing' trees were tested for cherry raspleaf virus and prune dwarf virus. One tree was not infected with either virus, but two trees were infected with cherry raspleaf virus alone, and not with prune dwarf virus. The two infected trees will provide the inoculum to repeat the cherry raspleaf virus rootstock trial on Krymsk 6 and Gisela 12.

The pollen from trees infected with cherry leaf roll virus is heavily laden with the virus. This rich virus source may provide one source of infection for further spread of virus. Previous studies indicated that although the virus from pollen enters the fruiting structure and the fruit stems, it does not enter the tree bearing the fruit, or if it does, it is very infrequent. Trees remain virus-free even after nearly 10,000 blossoms were pollinated with cherry leaf roll virus-infected pollen. These data suggest that the abscission layered between the cherry stem and the spur may provide an effective barrier to virus transmission. This experiment was conducted with trees and pollen where cherry leaf roll virus is the only virus present. However, in other plant virus systems, it has been demonstrated that the presence of one virus may facilitate infection and movement of another virus by suppressing the plant's innate immune response. To pursue the concept that a second virus is necessary for the pollen transmission of cherry leaf roll virus, a research block was established with trees that are infected with cherry leaf roll virus and whose pollen is compatible with 'Bing' trees. 'Bing' trees infected with prune virus and/or *Prunus* necrotic ringspot virus will be pollinated in 2012 with the compatible pollen and the recipient trees monitored for cherry leaf roll virus infection.

In commercial orchards, cherry leaf roll virus-laden pollen is frequently found in association with gutation emitted by emerging leaf buds. A small experiment was conducted to see if this might be a route by which the virus can enter the tree. Two young trees were forced in the greenhouse and grown under conditions to encourage periodic formation and re-absorption of gutation. Cherry leaf roll virus-infected pollen was dusted liberally onto emerging leaf buds. After growing through the summer, the trees were tested for infection for cherry leaf roll virus but none was detected.

Sweet cherry is affected by a number of virus-like diseases whose etiologies are not known, and several of these diseases are thought to have originated in native vegetation of western North America. These diseases of regional importance are being characterized so that they can be used to evaluate symptom expression of new commercial cultivars; this will assist in disease diagnosis and orchard management.

The rusty mottle disease group is a collective term for several different diseases. Many common cherry cultivars affected by rusty mottle exhibit chlorotic spots while the remaining part of the leaf develops into bright yellow to brown or orange as the season progresses. Many symptomatic leaves are cast early in the summer, leaving a sparse tree canopy. A different group of diseases is represented by cherry twisted leaf characterized by abrupt kinking of the midrib or petiole, thereby causing the leaves of the affected trees to be twisted. Both of these disease groups cause diminished fruit quality. In this study, the viruses associated with rusty mottle and twisted leaf diseases of sweet cherry were characterized. In order to achieve this goal, six isolates of rusty mottle disease and four isolates of twisted leaf disease were graft inoculated onto woody indicator trees (*Prunus avium* cv. Bing and Sam, and *P. serrulata* cv. Kwanzan) and symptoms catalogued. Isolates of cherry necrotic rusty mottle virus and cherry green ring mottle virus were also included. In general, symptoms expressed by the indicators were in agreement with those anticipated based on descriptions in the literature. All isolates of rusty mottle induced mottle symptoms in both *P. avium* cv. Bing and Sam; the twisted leaf isolates caused typical twisted leaf symptoms on *P. avium* cv. Bing and mild mottle symptoms in *P. avium* cv. Sam. On the indicator *P. serrulata* cv. Kwanzan, twisted leaf isolates induced both chlorotic rings and severe epinasty symptoms while the rusty mottle isolates caused symptoms ranging from chlorotic rings, chlorotic mottle to no symptoms at all. As anticipated, cherry necrotic rusty mottle virus induced typical necrotic mottle symptoms on *P. avium* cv. Sam and cherry green mottle virus induced severe epinasty on *P. serrulata* cv. Kwanzan.

The coat protein gene sequences obtained from each diseased tree were determined. Subsequent analysis revealed four distinct clades (virus groups believed to have a common ancestry), each of which is unique and appears to represent four different virus populations. Thus, in addition to cherry green ring mottle virus and cherry necrotic rusty mottle virus, cherry twisted leaf disease and cherry rusty mottle disease are associated with specific well-defined viruses. Full genome sequencing of the viruses associated with six isolates of cherry rusty mottle and four isolates of cherry twisted leaf is nearing completion. When finished, this will allow comparison of the entire genomes of the viruses to support differentiation of the disease causing agents into discrete virus species.

Analysis of these disease isolates lead to the development of a well characterized panel of graft transmissible diseases. Representatives from this collection will be used to inoculate recently released cherry cultivars. Observations will be documented to aid in improved recognition of these diseases in commercial orchards. The abundant sequence information that has been gathered also permits the development of more precise diagnostic methods that can be used to aid growers in the identification of elements that may be affected cherry production.

Acknowledgement: Mr. Dan Villamor performed the genetic analysis of the Betaflexiviridae as part of his doctoral research project.

CONTINUING PROJECT REPORT **YEAR**: 1 of 2
WTFRC Project Number: CH-11-104

Project Title: Developing a management strategy for little cherry disease

PI:	Ken Eastwell	**Co-PI (2):**	Tim Smith
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Cooperators: Elizabeth "Betsy" Beers, Entomologist, WSU-TFREC, Wenatchee, WA
David James, Entomologist, WSU-IAREC, Prosser, WA
Doug Walsh, Entomologist, WSU-IAREC, Prosser, WA
Grower cooperators

Total Project Request: **Year 1:** $28,119 **Year 2: $27,844**

Other funding sources: None

Organization Name:Washington State University Contract Administrator: Carrie Johnston
Telephone: 509-335-4564 Email address: carriej@wsu.edu

Item	2011	2012	
Salaries	13,464	13,056[1]	
Benefits	5,655	5,484[2]	
Wages	- - -	- - -	
Benefits	- - -	- - -	
Equipment	- - -	- - -	
Supplies	9,000	9,344[3]	
Travel	- - -	- - -	
Miscellaneous	- - -	- - -	
Total	$28,119	**$27,884**	

Footnotes:
1. Salary: Post doctoral research fellow (0.32 FTE)
2. Benefits paid at WA State established rates
3. Molecular biology reagents for cloning virus sequences and for virus diagnosis, tissue culture supplies for developing serological reagents.

OBJECTIVES:

The overall objective of this project is to **develop an industry-wide strategy to prevent the continued intrusion of little cherry disease into sweet cherry production regions**. Specific sub-objectives are:

1. An integrated program is required to help slow the spread of little cherry disease. This disease spreads naturally in the orchard, so a coordinated effort is required that includes **identification of potential insect vectors**.
2. **Develop diagnostic capacity to detect viruses associated with little cherry disease**. Current diagnosis can only be accomplished in research facilities. This practice is prohibitively expensive and is not sustainable. Translational research to develop an assay system to be used in a service center environment can provide a critical asset to the future control of this disease.
3. **Develop an educational program to alert growers to existence of little cherry disease in the Washington sweet cherry industry and control measures available to them.**

SIGNIFICANT FINDINGS:

- Little cherry virus 2 was detected in additional orchards, predominantly in the Wenatchee area.
- Preliminary data suggest that grape mealybug is efficient in transmitting Little cherry virus 2 between sweet cherry trees.
- The gene encoding the coat protein of Little cherry virus 1 is highly variable:
  - Comparison of Little cherry virus 1 isolates reveal that the nucleotide sequences encoding the coat protein vary by 30% and the amino acid sequences of the coat proteins vary by 26%.
  - The coat protein of Little cherry virus 1 has been successfully expressed in transgenic mouse cells. This synthesis of the antigen is the critical first step in the production of antibodies for the routine detection of the virus in grower samples.
- The coat protein gene sequences of Little cherry virus 2 are less variable than those of Little cherry virus 1; the prospects of developing diagnostic reagents for Little cherry virus 2 that detect all isolates are good.
  - Nucleotide identity ranges from a minimum of 88% and similarities of the amino acid sequence range from a minimum of 91%.

METHODS:

Research focused on developing reagents suitable for routine testing of orchard samples for the presence of viruses associated with little cherry disease. Existing diagnostic techniques are expensive and cumbersome for routine testing. Two separate strategies were pursued in an effort to circumvent these limitations: 1) partner with a private company to acquire access to new technology for cost effective molecular testing, and 2) develop serological reagents that can be used in a standard ELISA format. Isolates of the two viruses associated with little cherry disease (Little cherry virus 1 and Little cherry virus 2) were identified and the region of the genome that encodes the coat protein was cloned and sequenced. This region of the virus genome was targeted because it serves a dual purpose of being incorporated into molecular assays and utilized for the synthesis of proteins that will be used in the development of serological reagents.

Despite the challenges of detecting little cherry viruses through existing technology, we tested samples either collected from orchards or submitted by growers. The results provide both epidemiological data and also sequence information for developing the assays described above.

Transmission tests were performed in growth chambers to determine if grape mealybug is capable of transmitting Little cherry virus 2 from one sweet cherry tree to another.

RESULTS & DISCUSSION:

Developing an appropriate industry response to the threat of little cherry disease in the western U.S. is a decision making process based on best available information. Key elements of this knowledge base need to be: the ability to correctly identify the underlying cause of small fruit size on a case-by-case basis (i.e. biotic versus abiotic factors), knowledge of the pathogen(s) causing disease, and the way(s) in which the pathogens are moving into and within orchards.

In the 1970s, the apple mealybug (*Phenacoccus aceris* Signoret) was established as the major insect vector of Little cherry virus 2. Since then, the population of apple mealybug in stone fruit orchards has declined dramatically, and has largely been replaced by grape mealybug (*Pseudococcus maritimus* (Ehrhorn)). Therefore, it is critical to determine whether this relatively new pest in stone fruit orchards is also capable of transmitting a virus that causes little cherry disease. A colony of grape mealybug on *Prunus* spp. was identified. This provided a source of insects for transmission experiments. In a growth chamber, crawlers were placed on shoots cut from a field cherry tree known to be infected with a North American isolate of Little cherry virus 2. After an acquisition period of 7 days, approximately 50 crawlers were transferred to each potted virus-free sweet cherry tree. After one week, trees were treated with pesticide to eliminate the mealybugs. This process was repeated on two separate groups of trees to yield a total of 21 young cherry trees that were exposed to potentially viruliferous mealybugs. Two to four months after the inoculation period, leaves were collected from each of the recipient trees and tested by RT-PCR for the presence of the virus. Of the total 21 trees tested, 18 yielded positive results for Little cherry virus 2. It is possible that the positive reaction in the RT-PCR was the result of virus trapped by mealybug debris on the leaf surface but not transmitted. Therefore, the trees will be allowed to continue to grow in the greenhouse so that new growth can be tested at intervals to verify that the positive diagnostic reaction was the result of plant infection and not residual inoculum on the leaf surface. Notwithstanding this concern, the preliminary data strongly suggests that grape mealybug is an efficient vector of little cherry disease. The apparent transmission by grape mealybug of Little cherry virus 2 is very significant. Grape mealybug populations are an increasing concern in the tree fruit industry because they are difficult to control in established orchards. The presence of infected orchards that serve as reservoirs of Little cherry virus 2 along with this abundant insect pest creates a menacing combination. A similar trial to test the mealybug transmission of Little cherry virus 1 is also warranted.

To assist in the future management of this disease, access to efficient diagnostic methods is required. This essential function will allow growers to differentiate trees affected by virus-induced little cherry disease from those that are producing small fruit because of other factors such as winter damage or poor horticultural conditions. The basic strategy to confirm little cherry disease diagnosis is straight forward, but the processes to achieve that goal are technically challenging. In summary, a simple test for little cherry disease viruses would be based upon the ELISA serological technique. For that, animals are needed to produce antibodies to the little cherry virus coat protein. However, it is nearly impossible to purify enough little cherry virus to immunize an animal. Thus, bacteria are used to produce virus protein based upon the genetic code of little cherry viruses. These proteins can then be injected into the animal (usually a mouse) for antibody production. However, antibodies produced in this fashion frequently have limited use in ELISA. To obtain superior antibodies, the virus gene sequences that were inserted into bacteria are being modified and incorporated into the genetic code of animal cells. Once these cells are transplanted into a mouse, the animal will then not only produce proteins of little cherry virus but will also produce the antibodies needed to detect the virus in an ELISA test. Due to protein configurations, the antibodies against proteins produced in the animal should be superior to those produced in reaction to the bacterially produced protein.

To initiate development of reliable testing methods, a database was established with gene sequences encoding the coat proteins of Little cherry virus 1 and Little cherry virus 2. At the nucleotide level, analysis of 25 clones of Little cherry virus 2 coat protein gene sequences (1,080 nucleotides each)

reveals 88% to 100% identity between isolates. When these nucleotide sequences are translated to protein sequences, amino acid similarity ranges from 91 to 100%. When only isolates from Washington State are considered, the degree of similarity is even higher at 94%. This relatively high degree of sequence identity suggests that diagnostic reagents targeting the coat protein region of the Little cherry virus 2 genome will detect a wide range if not all isolates detected in the state. The nucleotide sequence of the Little cherry virus 2 coat protein gene shares only 2% identity with the analogous region of the Little cherry virus 1 genome. As previously reported for other regions of the genome, sequences of Little cherry virus 1 are highly variable. Comparison of the coat protein sequences from 47 clones of Little cherry virus 1 reveals as little as 70% nucleotide identity between clones. Amino acid sequence similarity is slightly higher ranging from 74% to 100%.

Efforts to develop serological assays for Little cherry virus 1 and Little cherry virus 2 are proceeding in parallel. With combined funding from the Washington Tree Fruit Research Commission and the USDA-ARS in 2004, we generated an antibody based on bacterially expressed protein encoded by the genomic sequence of Little cherry virus 1. The resulting antibody was only effective in Western blot analysis for virus proteins and not suitable for routine detection of virus in grower samples. This is a common fate of antibodies produced against bacterially expressed proteins. However, because of this earlier study, current research on Little cherry virus 1 was greatly accelerated. Access to this antibody allowed us to quickly confirm by Western blot analysis that the mouse cell lines are producing Little cherry virus 1 coat protein. In the absence of a similar tool for Little cherry virus 2, validating the expression of the coat protein of this virus in mouse cells is unconfirmed. Synthesis of messenger RNA has been confirmed in at least seven animal cell lines but it is not known if they are efficiently translated into protein. Production of antibodies as the basis of serological assays such as ELISA will continue.

We also partnered with a private firm to access a relatively new technology for nucleic acid analysis. This assay is based on the unique RNA sequence of the virus genome, but unlike the polymerase chain reaction (PCR) assay format, little or no prior processing of the sample is required. It can also be adapted to operate in a field office. It is dependent on knowledge of the sequences that occur in the virus genome. The database of coat protein sequences described above was a valuable asset in new assay development. Based on sequence information obtained by our team, we developed primer and probe sequences that meet basic assay criteria and this information was forwarded to the company for synthesis of diagnostic reagents. They will be available in early November 2011 for preliminary evaluation.

While the enhanced diagnostic methods are being developed, grower blocks continue to be sampled and tested for the presence of Little cherry virus 1 and/or Little cherry virus 2. Test results are pooled based on three general regions of cherry production: Yakima-Benton-Franklin Counties, Grant County and Chelan-Douglas Counties. From this small sample population, it appears that most of the little cherry disease is centered in Chelan-Douglas Counties (Table 1). However, it must be remembered that this was not random sampling but a targeted sampling so the numbers do not reliably reflect the distribution of the disease throughout the state. Nevertheless, a significant presence of little cherry disease was revealed.

To increase the awareness of growers to the issue of little cherry disease, Tim Smith made a presentation entitled "Little Cherry Virus- an old enemy returns as a serious threat to the local cherry industry" at Stone Fruit Day (January 20, 2011) attended by a large and diverse group of growers. Ken Eastwell made a presentation at a field man's breakfast (May 17, 2011). A fact sheet describing current concerns about little cherry disease was prepared and distributed at both events and made available on the Clean Plant Center (NW) web site.

Table 1. Samples were collected and tested for the viruses associated with little cherry disease. Orchards were identified based on communication with growers and field men[1].

Counties	Orchards sampled	Little cherry virus 1			Little cherry virus 2		
		Orchards with LChV1	Samples tested	Samples with LChV1	Orchards with LChV2	Samples tested	Samples with LChV2
2010"							
Yakima-Benton-Franklin	3	0	22	0	1	22	2
Grant	2	1	17	5	0	12	0
Chelan-Douglas	17	4	72	9	12	74	60
2011:							
Yakima-Benton-Franklin	3	0	13	0	0	13	0
Grant	1	1	7	1	0	7	0
Chelan-Douglas	6	2	28	2	6	28	21
2-year total	32	8	159	17	19	156	83
% infected		25%		11%	59%		53%

1. The data presented does not include studies from 2005 that indentified an additional orchard in Chelan-Douglas counties with Little cherry virus 1 and 2 infected trees, and two additional orchards in Yakima-Benton-Franklin counties infected with Little cherry virus 1.

Timing of Spotted Wing Drosophila Control in Cherry 2011

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Test Location: Gilroy, CA

Test Crop: Sweet Cherry *Prunus avium* L. 'Bing' and 'Black Tartarian'

Test Species: Spotted wing drosophila (SWD), *Drosophila suzukii* (Matsumura)

Plot Design: Four treatments were replicated three times in a randomized, complete block design. Each replicate was 1.5 acres or larger in size with the exception of Entrust 80WP followed by Entrust 80WP and untreated check. These were both 0.75 acres per replicate.

Treatments:

Treatment	Rate form/ac	Date of application	Projected Timing[a]
1) Diazinon 50W	4.0 lb	2 May	Green fruit 30 DAFB
Warrior II	5.12 oz	10 May	Straw 41 DAFB
Malathion 8 Aquamul	1.75 pt	21 May	Pink 48 DAFB
Success 2SC	7.00 oz	26 May	Red 55 DAFB (7 DBH)
Entrust 80WP	2.00 oz	1 Jun	Red 59 DAFB (3 DBH)
2) Warrior II	5.12 oz	10 May	Straw 41 DAFB
Malathion 8 Aquamul	1.75 pt	21 May	Pink 48 DAFB
Success 2SC	7.00 oz	26 May	Red 55 DAFB (7 DBH)
Entrust 80WP	2.00 oz	1 Jun	Red 59 DAFB (3 DBH)
3) Malathion 8 Aquamul	1.75 pt	21 May	Pink 48 DAFB
Success 2SC	7.00 oz	26 May	Red 55 DAFB (7 DBH)
Entrust 80WP	2.00 oz	1 Jun	Red 59 DAFB (3 DBH)
4) Success 2SC	7.00 oz	26 May	Red 55 DAFB (7 DBH)
Entrust 80WP	2.00 oz	1 Jun	Red 59 DAFB (3 DBH)
5) Entrust 80WP	2.00 oz	26 May	Red 55 DAFB (7 DBH)
Entrust 80WP	2.00 oz	1 Jun	Red 59 DAFB (3 DBH)
6) Untreated check	--		

[a]DAFB: Days after full bloom and DBH: Days before harvest

Application Equipment: Experimental treatments were applied with an air-blast speed sprayer with a finished spray volume of 250 gallons per acre.

Evaluation Procedures: Treatment efficacy was evaluated by placing a standardized apple cider vinegar (ACV) bait pan trap in the center of each plot. The traps had 1/8 inch screen tops and were baited with 4 oz of ACV that contained 4 ml of color and fragrance-free soap (Palmolive "Pure and Clear") per gallon of ACV with a rain shield. Traps were placed on 19 Apr and monitored weekly until 12 Jul. Trap contents were examined weekly and all SWD were sexed and counted in the laboratory under magnification (20X).

Fruit infestation was determined by sugar floatation method (7 lbs brown sugar per 5 gal of water with a few drops of defoamer). One hundred fruit from each replicate per cultivar (Bing and Black Tartarian) were sampled weekly starting with the first pink Bing fruit. The fruit from each replicate was mashed and immersed in the sugar solution. Larvae that floated to the surface of the solution were counted and removed from the solution and placed in containers with diet. These containers were placed in an environmental cabinet for at least two weeks. After two weeks, the adult flies in the containers were examined under magnification. The SWD were counted and sexed and all other Drosophila species were counted, but not sexed. The Bing cultivar was sampled from 12 May to 6 Jul and the Black Tartarian cultivar was sampled from 12 May to 6 Jun.

Results and Discussion: SWD populations, as measured by ACV traps, increased dramatically from the first trapping date of 26 Apr to the second trapping date of 2 May (Tables 1 to 3). There was no significant difference in female, male or total SWD captured during these two sampling periods. The first application (Diazinon 50W) of the five-application strategy was not made until 2 May. In the 10 May sample, again, there was no significant difference in the female, male or total SWD captured among the application strategies despite the fact that the five-application strategy were sprayed with Diazinon 50W the previous week. The application of Diazinon 50W on 2 May did not have a major impact on the fly population. It appears it takes a week or longer for the Diazinon 50W to take effect. On the 16 May sample, there was significantly fewer female and total SWD in the five-application strategy and two-application strategy compared to the untreated check. The five-application strategy received Diazinon 50W two weeks earlier and Warrior II one week earlier while the four- application strategy had received Warrior II one week earlier. The reason for the low trap count in the two-application strategy is unknown. In the 23 May sample, there were significantly fewer female, male and total SWD in all treatment strategies compared to the untreated check. By 23 May, the five-application strategy had been treated with Diazinon 50W, Warrior II and Malathion 8 Aquamul, the four-application strategy had been treated with Warrior II and Malathion 8 Aquamul and the three application strategy had been treated with Malathion 8 Aquamul. On 26 May each replicate in the untreated check was divided into two equal sections. One section remained untreated and the other section received an application of Entrust 80WP. The other spray strategies received Success 2SC. Then in the 31 May sample there were significantly fewer female and total SWD in the five-application and four-application strategies compared to the untreated check. The three-application and two- application strategies were not significantly different from the untreated check. The final application of Entrust 80WP was applied to all spray programs on 1 Jun. On the 6 Jun sample, there were significantly fewer female and total SWD in the five-application and four-application strategies. There was no significant difference in the female, male or total SWD among the spray strategies in the 12 Jun, 28 Jun, 5 Jul or 12 Jul samples. There was a significantly lower number of females SWD in both two-application strategies and the three-application strategy compared to the untreated check in the 22 Jun sample. The season totals in all control strategies were much lower than the untreated check. However, only females in all control strategies and total SWD in the five-application strategy were significantly lower than the untreated check. Thus the spray strategies were successfully suppressing the adult SWD population.

The number of larvae per 100 Bing fruit was low in the 12 May and 19 May samples with 0.3 larvae per 100 fruit in the untreated check (Table 4). The significance observed in the 19 May sample appears to be an anomaly. There was no significant difference among the treatment strategies in number of larvae per 100 fruit from the 26 May to 6 Jun samples. However, on the 6 Jun sample, the number of larvae per 100 fruit had an unexplained spike in both the five-application and four- application strategies. This high number of larvae per 100 fruit subsided to a lower level in the next week's sample. Also on the 6 Jun sample the untreated check increased substantially but again was not significantly different from the other treatments. In fruit samples from 13 Jun to 30 Jun, the number of larvae per 100 fruit in the untreated check was significantly greater compared to all other treatments and there was no significant difference among the various treatment strategies. The five-application and four-application strategies had fewer larvae per 100 fruit from 13 Jun to 30 Jun than the three-treatment and two-treatment strategies. The harvest was scheduled from 6 Jun to 22 Jun but was postponed until 13 Jun to 30 Jun because of inclement weather. On the 6 Jul sample there was no significant difference between the two-treatment strategy of Entrust 80WP and the untreated check. The larvae found in the fruit were largely SWD until the last sampling date of 6 Jul (Table 5). The fruit was starting to rot on the tree by 6 Jul, which allows other drosophila to enter the fruit. Interestingly, the sex ratio of the larvae appears to favor females, particularly early in the season.

The number of larvae per 100 Black Tartarian fruit in the five-application strategy on the first sampling date of 12 May was significantly lower than in the untreated check but the other treatments did not differ significantly (Table 6). This would indicate that the sprays were initiated at too late to prevent infestation in the pollinator fruit. There was no consistent trend in the number of larvae per 100 fruit among treatments in the 19 May and 26 May samples. In the 31 May sample, there were significantly fewer larvae per 100 fruit in all treatment strategies compared to the untreated check and there was no significant difference among in the different application strategies. Again, In the 6 Jun sample there was no consistent trend in the number of larvae per 100 fruit among treatments, yet there were a significantly greater number of larvae in the four-application strategy compared to the three-application strategy. The larvae found in the fruit were largely SWD (Table 7). The Black Tartarian fruit provides an early season site of infestation for SWD that allows the population to build up before Bing fruit becomes highly susceptible. Thus the treatment strategies should begin not when the Bing fruit is susceptible but when the pollinator fruit becomes susceptible.

Conclusions: The ACV traps appear to be a viable means of monitoring the SWD populations in order to assess the effectiveness of the grower control strategy. Treatments should be initiated at straw or yellow colored fruit in the pollinator fruit or earliest mature cultivar. Control strategies should consist of three or four well-timed applications. These findings agree with research from the previous year. Future research should now proceed to large-scale commercial split plot trials.

Table 1. Mean number of female SWD captured per trap each week in Gilroy, CA – 2011

Treatment	Rate form/ac	Mean[a] female SWD per week												
		26 Apr	2 May	10 May	16 May	23 May	31 May	6 Jun	12 Jun	22 Jun	28 Jun	5 Jul	12 Jul	Total[b]
Diazinon 50WP	4.00 lb	12.7 a	65.7 a	22.3 a	1.3 b	3.7 b	2.0 b	0.0 b	0.7 a	1.0 ab	1.7 a	0.3 a	1.0 a	11.7 b
Warrior II	5.12 oz													
Malathion 8	1.75 pt													
Success 2SC	7.00 oz													
Entrust 80WP	2.00 oz													
Warrior II	5.12 oz	10.7 a	49.7 a	43.7 a	3.7 ab	6.0 b	1.0 b	0.0 b	0.3 a	2.3 ab	0.7 a	1.7 a	1.3 a	17.0 b
Malathion 8	1.75 pt													
Success 2SC	7.00 oz													
Entrust 80WP	2.00 oz													
Malathion 8	1.75 pt	8.0 a	45.7 a	22.0 a	7.7 ab	2.0 b	4.7 b	0.7 b	0.3 a	1.0 b	1.0 a	1.7 a	3.3 a	22.3 b
Success 2SC	7.00 oz													
Entrust 80WP	2.00 oz													
Success 2SC	7.00 oz	6.7 a	27.7 a	20.7 a	2.0 b	4.0 b	6.7 ab	0.0 b	1.3 a	0.7 b	2.3 a	1.3 a	2.3 a	20.7 b
Entrust 80WP	2.00 oz													
Entrust 80WP	2.00 oz						11.7 ab	0.0 b	1.5 a	1.0 b	9.3 a	2.0 a	2.3 a	
Entrust 80WP	2.00 oz													
Untreated check	--	16.0 a	66.0 a	29.3 a	12.0 a	13.3 a	32.7 a	2.0 a	5.0 a	8.3 a	12.7 a	4.0 a	3.0 a	93.0 a

[a]Means followed by the same letter within a column are not significantly different. (Fisher's Protected LSD, $P \leq 0.05$).

[b]Mean total from 16 May to 12 Jul.

Table 2. Mean number of male SWD captured per trap each week, Gilroy, CA – 2011

Treatment	Rate form/ac	Mean[a] male SWD per week												
		26 Apr	2 May	10 May	16 May	23 May	31 May	6 Jun	12 Jun	22 Jun	28 Jun	5 Jul	12 Jul	Total[b]
Diazinon 50WP	4.00 lb	5.7 a	23.3 a	9.0 a	0.7 a	3.0 b	0.3 a	0.0 a	4.7 a	0.5 a	5.0 a	0.3 a	2.0 a	16.3 a
Warrior II	5.12 oz													
Malathion 8	1.75 pt													
Success 2SC	7.00 oz													
Entrust 80WP	2.00 oz													
Warrior II	5.12 oz	9.3 a	29.7 a	13.7 a	0.7 a	2.0 b	0.7 a	0.0 a	5.3 a	1.3 a	3.3 a	7.0 a	5.0 a	25.3 a
Malathion 8	1.75 pt													
Success 2SC	7.00 oz													
Entrust 80WP	2.00 oz													
Malathion 8	1.75 pt	3.7 a	16.0 a	4.3 a	1.3 a	1.3 b	2.7 a	0.7 a	2.0 a	1.3 a	4.0 a	3.7 a	7.7 a	24.7 a
Success 2SC	7.00 oz													
Entrust 80WP	2.00 oz													
Success 2SC	7.00 oz	1.3 a	14.3 a	2.7 a	1.3 a	1.3 b	3.0 a	0.0 a	1.7 a	1.3 a	3.0 a	4.3 a	5.0 a	21.0 a
Entrust 80WP	2.00 oz													
Entrust 80WP	2.00 oz						7.0 a	3.3 a	2.0 a	4.7 a	24.0 a	9.7 a	11.7 a	
Entrust 80WP	2.00 oz													
Untreated check	--	6.0 a	31.7 a	10.0 a	4.7 a	8.0 a	12.3 a	2.5 a	4.3 a	8.7 a	21.0 a	9.3 a	4.7 a	74.7 a

[a]Means followed by the same letter within a column are not significantly different. (Fisher's Protected LSD, $P \leq 0.05$).

[b]Mean total from 16 May to 12 Jul.

Table 3. Mean number of total SWD captured per trap each week in Gilroy, CA – 2011

Treatment	Rate form/ac	Mean[a] total SWD per week												
		26 Apr	2 May	10 May	16 May	23 May	31 May	6 Jun	12 Jun	22 Jun	28 Jun	5 Jul	12 Jul	Total[b]
Diazinon 50WP	4.00 lb	18.3 a	89.0 a	31.3 a	2.0 b	6.7 b	2.3 b	0.0 a	5.3 a	1.0 b	6.7 a	0.7 a	3.0 a	28.2 b
Warrior II	5.12 oz													
Malathion 8	1.75 pt													
Success 2SC	7.00 oz													
Entrust 80WP	2.00 oz													
Warrior II	5.12 oz	20.0 a	79.3 a	57.3 a	4.3 ab	8.0 b	1.7 b	0.0 a	5.7 a	3.7 b	4.0 a	8.7 a	6.3 a	42.3 ab
Malathion 8	1.75 pt													
Success 2SC	7.00 oz													
Entrust 80WP	2.00 oz													
Malathion 8	1.75 pt	11.7 a	61.7 a	26.3 a	9.0 ab	3.3 b	7.3 ab	1.3 a	2.3 a	2.3 b	5.0 a	5.3 a	11.0 a	47.0 ab
Success 2SC	7.00 oz													
Entrust 80WP	2.00 oz													
Success 2SC	7.00 oz	8.0 a	42.0 a	23.3 a	3.3 b	5.3 b	9.7 ab	0.0 a	3.0 a	2.0 b	5.3 a	5.7 a	7.3 a	41.7 ab
Entrust 80WP	2.00 oz													
Entrust 80WP	2.00 oz						18.7 ab	3.3 a	2.3 a	5.7 ab	33.3 a	11.7 a	14.0 a	
Entrust 80WP	2.00 oz													
Untreated check	--	22.0 a	97.7 a	39.3 a	16.7 a	21.3 a	45.0 a	3.0 a	9.3 a	17.0 a	33.7 a	13.3 a	7.7 a	168.5 a

[a]Means followed by the same letter within a column are not significantly different. (Fisher's Protected LSD, $P \leq 0.05$).

[b]Mean total from 16 May to 12 Jul.

Table 4. Mean number of larvae per 100 Bing fruit in Gilroy, CA-2011

Treatment	Rate form/ac	Mean[a] larvae per 100 Bing fruit								
		12 May	19 May	26 May	31 May	6 Jun	13 Jun	22 Jun	30 Jun	6 Jul
Diazinon 50WP	4.00 lb	0.0 a	0.0 b	0.3 a	0.0 a	5.7 a	0.3 b	0.0 b	0.3 b	4.3 b
Warrior II	5.12 oz									
Malathion 8	1.75 pt									
Success 2SC	7.00 oz									
Entrust 80WP	2.00 oz									
Warrior II	5.12 oz	0.3 a	1.0 a	0.0 a	0.0 a	5.3 a	0.0 b	0.0 b	0.3 b	2.7 b
Malathion 8	1.75 pt									
Success 2SC	7.00 oz									
Entrust 80WP	2.00 oz									
Malathion 8	1.75 pt	0.0 a	0.0 b	0.0 a	1.0 a	1.0 a	0.0 b	2.3 b	2.7 b	7.0 b
Success 2SC	7.00 oz									
Entrust 80WP	2.00 oz									
Success 2SC	7.00 oz	0.0 a	0.3 ab	2.3 a	2.0 a	1.0 a	1.3 b	3.0 b	1.3 b	3.3 b
Entrust 80WP	2.00 oz									
Entrust 80WP	2.00 oz			2.7 a	1.0 a	3.3 a	2.3 b	2.7 b	12.7 b	28.3 ab
Entrust 80WP	2.00 oz									
Untreated	--	0.3 a	0.3 ab	0.7 a	2.0 a	7.7 a	12.0 a	29.3 a	55.0 a	119.0 a

[a]Means followed by the same lowercase letter within a column are not significantly different (Fisher's protected LSD, $P \leq 0.1$).

Table 5. Species composition of larvae derived from brown sugar floatation from Bing fruit in Gilroy, CA – 2011.

Emerged adults	Percentage of emerged population								
	12 May	19 May	26 May	31 May	6 Jun	13 Jun	23 Jun	30 Jun	6 Jul
Female SWD	33.3	0.0	60.0	66.7	52.4	45.5	58.7	52.5	0.0
Male SWD	66.7	0.0	40.0	33.3	47.6	50.0	37.0	47.5	0.0
Other drosophila	0.0	0.0	0.0	0.0	0.0	4.5	4.3	0.0	100.0

Table 6. Mean number of larvae per 100 Black Tartarian fruit in Gilroy CA – 2011

Treatment	Rate form/ac	Mean[a] larvae per 100 Black Tartarian fruit				
		12 May	19 May	26 May	31 May	6 Jun
Diazinon 50WP	4.00 lb	0.0 b	0.3 a	0.7 b	0.3 b	1.0 ab
Warrior II	5.12 oz					
Malathion 8	1.75 pt					
Success 2SC	7.00 oz					
Entrust	2.00 oz					
Warrior II	5.12 oz	1.3 ab	4.0 a	0.7 b	0.7 b	0.7 ab
Malathion 8	1.75 pt					
Success 2SC	7.00 oz					
Entrust	2.00 oz					
Malathion 8	1.75 pt	1.0 ab	3.7 a	3.0 ab	1.0 b	0.0 b
Success 2SC	7.00 oz					
Entrust	2.00 oz					
Success 2SC	7.00 oz	0.7 ab	4.7 a	5.7 a	2.3 b	2.3 a
Entrust	2.00 oz					
Entrust	2.00 oz			1.7 b	1.7 b	0.7 ab
Entrust	2.00 oz					
Untreated	--	2.7 a	7.3 a	0.3 b	11.7 a	2.0 ab

[a]Means followed by the same lowercase letter within a column are not significantly different (Fisher's protected LSD, $P \leq 0.1$).

Table 7. Species composition of larvae derived from brown sugar floatation from Black Tartarian fruit in, Gilroy, CA –2011.

Emerged adults	Percentage of emerged population				
	12 May	19 May	26 May	31 May	6 Jun
Female SWD	75.0	52.2	58.6	37.5	25.0
Male SWD	25.0	43.5	41.4	45.8	75.0
Other drosophila	0.0	4.3	0.0	16.7	0.0