FINAL PROJECT REPORT

Project Title: Improving the management of two critical pome fruit diseases

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Total Project Request: **Year 1:** $15,155 **Year 2:** $15,737 **Year 3:** $16,343
Three year total: $47,235

Other funding sources

Trident: provided in kind support (fumigation) $9000. Other necessary financial support was received from companies supplying products tested for effect on fire blight or orchard replant during this project. I was Co-PI on the project "Development of Non-Antibiotic Programs for Fire Blight Control in Apple and Pear," from the USDA Organic Agriculture Research and Extension Initiative (OREI). My three year sub-award was a total of $89,661 2012-13-14. The TFRC project funding helped to justify and aquire the OREI grant.

Budget

Organization Name: **WSU** **Contract Administrator:** Jennifer Jansen
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Item	**2012**	**2013**	**2014**
Salaries	$10,125	$10,660	$11,086
Benefits	4,759	4,477	4,656
Wages			
Benefits			
Equipment			450
Supplies			
Travel	600	600	600
Plot Fees			
Miscellaneous			
Total	$15,484	15,737	$16,792
Three Year Total			**$48,013**

Footnotes: Salaries and benefits are in support of 0.28 FTE of a full time technician. Travel is to plot sites. Equipment is for a backpack mist sprayer.

Original OBJECTIVES- *Fire blight of apple and pear:*

1. We will continue to test fire blight control materials in the orchard, on both apple and pear, to assess efficacy and aid registration of effective fire blight control alternatives.
2. We will further study the relationship of temperatures to fire blight infection risk.

Significant Findings- Fire Blight:

Objective 1. We tested a wide range of fire blight control materials, rates and timings in the orchard.

- In 2014, twenty-five products were tested in 42 different timings and/or sequences.
- In 2013, thirteen products were tested in 36 different combinations, series and timings.
- In 2012, ten products were tested with 24 different timings and/or sequences.
- The treatments included the antibiotics streptomycin, oxytetracycline, and the newly registered kasugamycin, also "Blossom Protect" (*Aureobasidium pullulans*, a yeast-like biocontrol), many formulations and compounds of copper bactericides, *Bacillus subtilis* compounds (such as Serenade, Double Nickle and Companion), dihydrogen peroxide (Oxidate) and Actigard or other SAR treatments. See Table for 2014 results summary.
- Of the total102 treatments tested over the past three seasons, 39 usually protected the flowers at 80% or higher level, compared to the inoculated check. This level of control in an inoculated plot indicates potential for excellent control under orchard use conditions. These products did not induce russet in a large scale russet trial that was carried out in 2013 at the WSU Sunrise Research Orchard, but significant concerns remain about potential for russet induction with some of these products. Most forms of copper fungicides and "Blossom Protect" have a potential to mark or russet fruit if applied during or for several weeks after bloom, especially during wet, rainy or high humidity weather. Application during good drying conditions is critical.
- The sequence of application copper fungicides and other non-fire blight related sprays and the pH of the water in the spray tank must be considered carefully. Oils and acid buffers are commonly applied in early season fruit thinning and pest control sprays. Application of oils or products with low (acid) pH within a few days after application of copper products may increase the rate of active copper ion release. This increase could mimic the application of a much higher rate of the copper fungicide, leading to russeting and other fruit damage. Most "Buffers" commonly used in Washington orchard spray mixtures are intended to buffer alkaline water to acidic levels of 4.0 to 5.0. The potential for any product causing fruit finish problems is reported to be relatively higher east of the Rocky Mountains and is experienced much less frequently in low spring rainfall regions of the Pacific Northwestern states, USA.

Product and Timing (* = Organic use)	Average Control %	Highest %	Lowest %	Number of trials used (x) in average and Comments
Blossom Protect* 1,25 to 1.34 lbs. / 100/ A + Buffer Protect* @ 9.35 lbs. / 100 2 or more applications pre-bloom	83.1	95.2	73	(23) Most effective if applied starting at least 3-4 days before infection period begins. Potential for fruit russet when applied during cool, wet conditions.
Cueva* or Provisto 3 or 4 quarts / 100 / A Applied day before infection + ASAP after	Provisto 82.1 Cueva 80.7	98 83.6	62 77.6	(5) Cueva is a copper soap. (14) Provisto is a liquid copper material not yet registered for apples or pears.
Oxytetracycline (FireLine, or Mycoshield) 1 lb. / 100 gal. / Acre Applied day of infection.	79.4	96	62	(17) The standard effective product used in Washington since 1975.
Kasugamycin (Kasumin) Applied day of infection.	79	89	62	(8) An effective product. Use in rotation with others. Newly registered.
Serenade* (recent versions) Double Nickle* Higher label rates.	60.9	81	47	(17) Products have varied in strength, formulation and rate.
Copper Bactericides / Fungicides of Various Chemistries. Check for organic status.	58	70	30	(23) All copper products tested are effective, but less so than other available choices. Useful as part of a control program when applied to dormant trees.

Table 1. Most Consistent Effective Products in Multiple Trials. Summary of average percent control of blight infection (compared to an inoculated untreated check) in similar trials conducted on pears and apples, highest and lowest percent control and comments. Use of trade names does not imply endorsement by author.

Objective 2. Completed the first year, and the fire blight risk model "CougarBlight" is available through WSU DAS, and has been provided to an increasing number of states and other countries.

Significant Findings- Fire Blight Management Products:

1. ***Objective 1***.

Results and Discussion – Fire Blight: 2014 Products, Rate, Timing and Sequence Efficacy Trial.

Note: Some of the products reported below are not yet registered for use in orchards. They are listed only to report research results. Check the label for the crop details prior to any use.

Products	Rate/100 gal./Acre, Timing	% Infection	% Control
Blossom Protect + BP buffer, then Serenade Optimum	BP+BP (1.25 lb & 9.35 lb) 50 & 100% bloom, then 20 oz / 100 Serenade Opt. @ Petal Fall	0.98	97.8
GWN 10373 (Provisto version)	4 qt. / 100 + 64 oz wetter, day before & day after 100% bloom inoculation.	1.75	96.0
Blossom Protect + BP Buff. +Actigard	BP+BP (1.25 lb & 9.35 lb) + Act. 2 oz./ A, twice, 50 & 100% bloom	2.47	94.4
Blossom Protect + BP Buffer standard	BP+BP (1.25 lb & 9.35 lb), twice, 50 & 100% bloom	2.78	93.7
GWN 10074 (Provisto version)	4 qt. / 100 + 64 oz wetter, day before & day after 100% bloom inoculation.	3.0	93.2
GWN 10073 (Provisto)	3 qt. / 100 + 64 oz wetter, day before & day after 100% bloom inoculation.	4.23	90.4
Cueva (Copper soap)	4 qt. / 100, day before & day after 100% bloom inoculation.	4.25	90.4
Cueva	3 qt. / 100, day before & day after 100% bloom inoculation.	5.8	86.8
Blossom Protect + BP Buffer, Cueva	BP+BP (1.25 lb & 9.35 lb), twice, 50 & 100% bloom, then Cueva at petal fall	6.8	84.6
Streptomycin – half rate	0.5 lb./100 gal (100 ppm) applied @ 100% Bloom before inoculation	7.5	83.0
Oxidate	2 gal. /100 gal. / A on day of inoculation, 1 gal. next day, and 1 gallon @ PF	11.7	73.5
Champ Ion	0.5 lb. / 100 / Acre applied at 50 & 100% bloom	11.9	73.0
Phyton27	40 fl. oz. / 100, day before & day after 100% bloom inoculation.	12.1	72.6
Actigard, then oxytet.	Actigard at 50% bloom, oxytet. at 100% bloom	14.5	67.1
Kocide 3000	0.5 lb. / 100 / Acre applied at 50 & 100% bloom	14.7	66.7
Actigard then Oxytet PF, then Act. 6-8 " shoots	Actigard 2 oz. / 100 / A @ 50 & 100% bloom, oxytet. @ PF, then Actigard 2 oz. when shoots 6 – 8 inch	15.2	65.5
Tech Flow NutriCop 20 then CopoCal	Tech Flow NutriCop 20, 2 qt. at Del. Dormant, then CopoCal 3 qt., day before & day after 100% bloom inoculation, again at petal fall.	19.1	56.7
OxiPhos, Oxidate, then oxytet.	OxyPhos 1 gal. on Day of Inoc, 1 gal. OxiDate the day after, then 1 lb./100 oxytet.(Mycoshield) at Petal Fall	19.6	55.6
Italipollina Copper EXL-880	21 fl. oz. / 100 / A, day before & day after 100% bloom inoculation.	20.1	54.4
CopoCal	3 qt/ 100 / A, day before & day after 100% bloom inoculation.	21.6	51.0

Serenade Optimum	32 fl.oz. / 100 / A, at 50%, 100% bloom and at petal fall	22.8	48.3
Badge SC	20 fl.oz. / 100 / A, the day before & 1 day after 100% bloom inoculation.	23.8	46.0
Taegro, then Oxytet., then Taegro	Taegro 5.2 oz. / 100 / A @ Pink, Oxytet. 1 lb/ 100 / A @ 50% bloom, then Taegro 5.2 oz. at 100% bloom.	24.8	43.8
Bacteriophage mixture B	The day before and the day of inoculation.	26.2	40.2
Serenade Optimum then Oxytet, then Serenade Optimum	Serenade Optimum 24 oz. @ pink, then Oxytet. 1 lb/100 / A @ 50% bloom, then Seren. Opt. 24 oz. 100%	26.90	39.0
CopoCal (with 2nd bloom timing)	3 qt./100/A the day before and day after 100% bloom inoculation, again at Petal Fall and PF+10 days	26.92	39.0
BioAtlantis Resistance Blend	35 fl.oz./100/A at 50% bloom open and the day before full bloom and again at Petal Fall	27.4	38.9
Bacteriophage mixture A	The day before and the day of inoculation.	39.5	10.4
Untreated check, inoculated	No treatment, inoculated at 100% bloom open.	44.1	0

Table 2. 2014 Fire Blight Control Product Efficacy trial on Apples.

Treatment	**Number of Treatments**	**Highest Percent Control**	**Lowest Percent Control**	**Average Percent Control**
Strep + ASM*	6	100	90.6	95.1
Copper (new forms)	24	98	76.7	86.9
Streptomycin	12	90	75	85.9
BP + Buffer Protect	19	97.8	72	92.6
Oxytetracycline	18	93	53	79.0
Kasugamycin	8	89	62	77.5
Gentamycin	6	88	51	74.5
Serenade	18	84	38	60.1
Copper (old forms)	17	80	26	54.0
Fungicides	6	57	33	48.6
Acid Buffers	4	39	19	30.5
SAR (Claims)	10	46	0	30.2
Nutrient minerals	3	36	5	18.8

Table 3. Summary of author's current and past fire blight control efficacy trial results. Plots all inoculated. *ASM = Actigard, BP = *Aureobasidium pullulans*, "Blossom Protect." Average of 46.8 percent blight infection in inoculated untreated checks.

Orchard Replant Treatment Trial

Original OBJECTIVES – *Orchard Replant Disease:*
We will demonstrate the effect on soil fumigation on the productivity and quality of apples grown under a very modern production system.

1. We will document apple productivity over a range of chloropicrin and 1, 3-DCP rates.
2. We will provide this information to the fruit growers of Washington in the effort to increase the practice of pre-plant soil fumigation from its current 60% of replanted acres.
3. We will calculate the extrapolated economic impact of the various treatments.
4. We will provide this information to the Northwest Hort. Council, the US EPA, the fumigant registrants, or anyone else involved in the 2013-15 re-registration of soil fumigants.

Significant Findings- Orchard Replant Treatment

Objective 1. Tree growth and size were measured after the first and second year. Growth of all fumigated trees was similar, and much greater than in the unfumigated checks (Table 4). Production and fruit size were documented in 3rd through 5th leaf (2011-2014), (Tables 5 and 6.) The yields in all fumigated treatments greatly exceeded those in the untreated checks. Fruit size was not significantly different after the first year of production (Table 7). It became apparent that the 1, 3-DCP (Telone) part of the standard fumigant mixture (DCP + chloropicrin) plays an important role in the efficacy of the fumigants most commonly applied on old orchard sites. While chloropicrin (the “C” in C-17 and C-35, also applied in “PicPlus” and “Pic 60” in this trial) is necessary to the treatment of replant disease, the treatment of high relative levels of chloropicrin with no 1, 3-D (Treatment A), while much better than the untreated areas, it was the least productive of the fumigation treatments. The moderate 1, 3 DCP + moderate chloropicrin rate treatment was superior. This lower rate of chloropicrin will require much reduced “buffer zone” distances.

Objective 2. The gross economic differences continue to increase (Table 6). Since the orchard was planted as a “sleeping eye in” in spring 2009, the most productive treatment has grossed about $32,000 more per acre than the untreated check, after taking into account the cost of fumigating, picking and packing. This has returned over $50 for each $1spent on the cost of fumigation.

Objective 3. These results have been presented to growers and advisors at numerous times in many venues. The data and results will be published in both popular and scientific texts. Unlike the situation in apples, there are no pear or cherry fruit rootstocks that have been proven resistant to orchard replant disease. In the past, pears and cherries have responded to soil fumigation in a manner similar to the response in apples.

Objective 4. The data from this project was submitted to the US EPA on November 14, 2013 in support of the continued registration and availability of 1, 3-dichloropropine, one of the two active ingredients in pre-planting soil treatments for orchard sites (products such as Telone C-17 and C-35.) Re. Docket ID No. EPA-HQ_OPP_2013-0154.

Treatment:	*A: PicPlus (150 lbs./A Chloropicrin) 0 DCP*	*B: PC60 (144 lbs./A Chloropicrin) 94 lb/A DCP*	*C: Telone C-35 (25 GPA, 98 lb/A chloropicrin) 178 lb/A DCP*	*D: Telone C-17 (30 GPA, 51 lb/A chloropicrin) 260 lb/A DCP*	*Untreated*
Tree Height (inches)	86a	85a	86a	88a	74b
Trunk X-sec. mm^2	249a	249a	236a	253a	139b
Total Shoots (inches)	155a	120a	139a	185a	29b

Table 4. 2010 (second season) tree growth data: Average inches height, cross section area of trunk 4 inches above the graft union and total current season shoot growth of second season Cripp's Pink apples planted as a "sleeping eye" on M9, planted after fumigation on a replant site.

Year	Treatment A PicPlus	B PicClor 60	C Telone C-35	D Telone C-17	Untreated
2010	0	0	0	0	0
2011	12,808	12,826	15,935	15,529	6,286
2012	28,333	32,500	32,437	38,920	17,585
2013	25,556	32,862	30,734	36,591	16,792
2014	26,480	24,422	22,458	29,182	19,003
Total	**93,177**	**102,610**	**101,564**	**120,222**	**59,666**

Table 5. Gross yield per acre in pounds during first six years of growth. See Table 4 for treatment details.

Treatment A	*PicPlus (175 lbs. per ac: 150 lbs./A chloropicrin, NO 1,3-DCP)*						
	average box size 2014	Tree yield (lb.)	Gross wt. lbs./ Acre	90% pack wt.	Packed boxes	$ Value*	$ / Acre by Treatment
	91.81	15.50	26480	23832	567	20	11,389
		**Minus 2014 costs, adjustments of: $4,479				**Adjust 2014: $6,910**	
Total Adjusted Gross / A in 2011 +12 + 13 + 14 crops $41,764							
Treatment B	*PicClor 60 (20 GPA: 144 lbs./A chloropicrin, 94 lb/A 1,3-DCP)*						
	average box size 2014	Tree yield (lb.)	Gross wt. lbs./ Acre	90% pack wt.	Packed boxes	$ Value*	$ / Acre by Treatment
	93.0	14.3	24,442	21,998	524	20	10,475
		**Minus 2014 costs, adjustments of: $4,188				**Adjust 2014: $6,287**	
Total Adjusted Gross / A in 2011 + 12 + 13 + 14 crops: $46,883							
Treatment C	*Telone C-35 (25 GPA: 98 lb/A chloropicrin, 178 lb/A DC)*						
	average box size 2014	Tree yield (lb.)	Gross wt. lbs./ Acre	90% pack wt.	Packed boxes	$ Value*	$ / Acre by Treatment
	91.7	13.15	22,458	20,212	481	20	9,625
		**Minus 2014 costs, adjustments of: $3,841				**Adjust 2014: $5,784**	
Total Adjusted Gross per acre in 2011 through 2014 crops: $46,966							

Treatment D	***Telone C-17 (30 GPA, 51 lb/A chloropicrin 260 lb/A DCP)***						
	average box size 2014	Tree yield (lb.)	Gross wt. lbs./ Acre	90% pack wt.	Packed boxes	$ Value*	$ / Acre by Treatment
	91.3	17.1	29,182	26,264	625	20	12,507
		**Minus 2014 costs, adjustments of: $4,996				**Adjust 2014: $7,512**	
Total Adjusted Gross per acre, 2011 through 2014 crops: $58,823							
Treatment E	***Untreated***						
	average box size 2014	Tree yield (lb.)	Gross wt. lbs./ Acre	90% pack wt.	Packed boxes	$ Price*	$ / Acre by Treatment
	93.1	11.13	19,003	17,103	407	20	8,144
		**Minus 2014 costs, adjustments of: $3,470				**Adjust 2014: $4,674**	
Total Adjusted Gross per acre 2011 through 2014 crops: $25,969							

Table 6. **Yield per acre, box size grouping and rough estimate of fruit gross economic value per acre.** *Approximate FOB average on 11/17/2012. ****Costs, adjustments**: picking @ $20/bin, and packing @ $7 / box. Fumigation @ $650-750/acre accounted for in 2011 cost adjustments. Credit applied for 12 cents/lb. for cull fruit, except 2 cents in 2014.

Year	Treatment A PicPlus	B PicClor 60	C Telone C-35	D Telone C-17	Untreated
2010	0	0	0	0	0
2011	204 (94.1)	220 (86.3)	216 (89.0)	222 (86.3)	195 (98.3)
2012	207.1 (92.1)	198.6 (96)	200.7 (95)	200.5 (95.1)	196 (97.3)
2013	186.5 (102)	195.5 (97.5)	190.3 (100)	191.7 (99.5)	183.9 (103.7)
2014	208.9 (91.8)	205.4 (93)	207.9 (91.7)	208.8 (91.3)	204.8 (93.1)
Average	201.6	204.9	203.7	205.8	194.9

Table 7. Average size of fruit in grams (average number in 42 lb. box in parenthesis).

Executive Summary - Improving the Management of Two Critical Pome Fruit Diseases.

This project was actually two separate efforts, with entirely different sets of goals and expected outcomes.

The replant treatment portion of the project was designed:

- To provide scientifically valid research into the efficacy and necessary rates of chloropicrin as a component of soil fumigants used as a treatment of orchard replant disease. Data was not available on this subject, and the EPA wanted data for re-registration.
- To determine the effect of 1, 3 dichloropropene (1, 3 DCP – "Telone") at various rates when added to chloropicrin.
- To provide information about the lowest effective rate per acre of both products. This information was critical, as the "buffer zones" distances in the new label regulations were determined by rate per acre and acres treated. If these rates were set too low, growers would lose production efficiency and experience seriously reduced returns.
- To provide this data from a trial carried out in high-value cultivar growing under intensive modern system and management.

Results: After six seasons of intensive data collection and analysis, we could support the following conclusions:

- The most effective treatment was a blend of the lowest rate of chloropicrin in the trial (51 lbs. /A) blended with a moderately high rate of 1, 3 DCP (260 lbs./A), a mixture that is identical to the current industry standard of 30 gallons per acre of Telone C-17.
- Chloropicrin, when used at highest rates as the sole soil fumigant, was not as effective as when used at low standard rates blended with 1, 3 DCP.
- Under conditions of this trial (high-value cultivar and intensive management) the standard fumigation treatment increased economic returns by about $32,850 per acre, a return of about $50 for every $1 spent on the cost of fumigation.

Information from this trial is used in reregistration process for both chloropicrin and 1, 3 DCP.

The fire blight treatment portion of the project was designed:

- To research the efficacy, application timing and necessary rates of products used for fire blight blossom infection management.
- To find alternative products acceptable for organic production.

  Results: at the inception of this trial, one effective product, oxytetracycline (Mycoshield), was used for fire blight control in the state of Washington. The results of these trials, supported by others, were instrumental or part of the registration of and use of at least three new products (Blossom Protect, Kasumin and Provisto) that are at least as effective as oxytetracycline. The use and efficacy of other products that may play an important role is now better understood, and more registrations of useful control products are impending.