FINAL PROJECT REPORT **YEAR** 3 of 3
WTFRC Project Number: CP–09-904

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

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Cooperators: Travis Allan, Allan Bros. Fume Trial Site; Mike Conway, Trident Agricultural Products.

Total Project Request: Year 1: $18,294 **Year 2:** $18,760 **Year 3:** $19,071
Total for Three Years: $56,125

Other funding sources

No other public agency provided grants to this project. Several private companies were involved financially in the testing of proprietary products. Trident deserves special recognition, as they provided substantial effort to the set-up and application of this trial, and in-kind support (fumigation) $4000 value, and a grant of $4000.

Budget
Organization Name: WSU **Contract Administrator:** Jennifer Jansen
Telephone: 509-335-2867 **Email address:** jjansen@wsu.edu

	2009	**2010**	**2011**
Salaries	11,493	11,951	12,429
Benefits	5,401	5,617	5,842
Wages			
Benefits			
Equipment	100		
Supplies	100		
Travel	1,200	1,200	800
Miscellaneous			
Total	$18,294	$18,760	$19,071

Footnotes: Salaries and benefits are in support of 0.34 FTE of a full time technician. Travel is to plot sites.

ORIGINAL OBJECTIVES: ***Fire blight of apple and pear:*** We will continue to test fire blight control products in the orchard, on both apple and pear, to assess efficacy of new or poorly tested substances.

1. To increase confidence in the biological organism that appeared promising in the 2008 trials, we will significantly expand our testing to include a range of alternative treatments.
2. We will further study the relationship of temperatures to fire blight infection risk.

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

1. We will determine apple tree growth and productivity over a range of chloropicrin and 1, 3-DCP rates.
2. We will calculate the extrapolated economic impact of the various treatments.
3. 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.
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.

SUMMARY OF SIGNIFICANT FINDINGS

- Over four years and in seven separate apple and pear fire blight control material trials, a dried yeast product, *Auriobassidium pulullans*, called "Blossom Protect" in Europe, controlled fire blight as well or better than the standard and test antibiotics. Issues that remain to be resolved include potential for causing russet. No russet increase was seen in these trials.
- The antibiotic kasugamycin, usually protected blossoms as well as streptomycin (AgriStrep, Fireman), and both were slightly superior to oxytetracycline (Mycoshield, FireLine.**)** The addition of oxytetracycline to kasugamycin did not improve performance.
- Two proprietary copper compound formulations often provided blossom protection equal to antibiotics. The standard (Kocide 3000) copper compound used as a comparison in the trials did not adequately protect the flowers from infection, a result common in past trial copper treatments. The new copper compounds did not appear to russet apples, D'Anjou or Bartlett pears when applied during primary bloom. This russeting issue continues to be the main obstacle to use, and both must undergo much more fruit safety tests during the critical post bloom infection period.
- This past two season's most effective treatments in both apple and pear trials were applications of acibenzolar–s-methyl (ASM, Actigard) at 50% primary bloom, followed by an antibiotic at time of inoculation. Application of this product to the soil under the test tree reduced blight infection, but not significantly.
- The "CougarBlight" fire blight infection risk model was upgraded in 2010 by conversion of the temperature risk values to relate directly to the hourly growth rate of E. amylovora on apple stigmas. Research by Dr. Larry Pusey, USDA-ARS Wenatchee provided the basic data used for this upgrade. The model was adapted to the WSU DAS for 2011.
- Fruit production started in the 3rd season of growth in the apple replant/fumigation trial. After two seasons of marked differences in vegetative development vs. the untreated replicates, the various fumigation treatments produced profoundly more fruit than the untreated portions of the orchard. A preliminary economic analysis indicated that economic returns, adjusted to account for fumigation, picking and packing costs, were increased by $2,600 to $4,000 per acre. This was a 530% economic return over three years on the cost of the fumigation.

FIRE BLIGHT - RESULTS & DISCUSSION:

2009 & 2010 Results Summary: Standard antibiotics continued to perform very well in the material efficacy trials. The potential new alternative antibiotic, kasugamycin, proved essentially as effective as currently registered antibiotics. Certain copper containing materials performed very well when applied two or three times to blossoms prior to full bloom inoculation. Concerns remain about the potential of copper compounds inducing russet, especially when applied during the critical secondary blossom period during the first 3 weeks after primary bloom. The European yeast biological "Blossom Protect" was applied at various rates and frequency of application, and timings, with or without acid buffers. It became increasingly obvious that frequency of application during the development of flowering leading up to an infection period was a critical aspect affecting performance. Three applications were more consistently effective than two, and one application was inadequate. The search for an alternative acid buffer to replace the recommended bulky "Buffer A" was not successful. Acid buffers used alone had about a 35% suppressive effect on infection.

2011 Results: Three non-antibiotic materials performed very well in the 2011 trials. Two copper compounds, one I'm calling "copper product TS (Trade Secret)" from Gowan, and the other called "Cueva" from Certis, reduced fire blight infection as well as, or sometimes better than, standard and test antibiotics. Copper compounds have rarely performed well in past trials, and have a history of causing fruit skin marking. The "TS" copper was applied to both D'Anjou and Bartlett pears as a russet/phytotoxicity trial. There was no russet on the fruit skin observed at harvest, even on the usually russet-prone D'Anjou pears.

The biological product, to be marketed in the USA spring of 2012 as "Blossom Protect," is a mixture of two strains of *Auriobassidium* *pulullans*, a type of yeast, which is applied in combination with a specific pH 4-5 acidic buffer (Buffer A). This genus and species is commonly found in the Pacific Northwest as a natural colonizer of apple and pear flowers so will probably thrive and spread to newly opened blossoms under PNW conditions. It is not likely that this organism is producing its own antibiotic to achieve antibiotic-like performance in inoculated trials, as this is not typical of yeasts. It is possible that another mechanism, such as successful competition for resources on the stigma surface or within the nectary, serves as a control process. In order for control to occur, it appears that this organism must be in place soon after each flower opens so as to become well-established on the flower before the introduction of *Erwinia amylovora*, the fire blight pathogen.

Actigard (acibenzolar–s-methyl, or ASM) is a substance that has been reported to induce various plants to trigger specific disease resistance mechanisms prior to attack by a certain pathogens. This concept is called specific acquired resistance (SAR). Actigard has been tested by fire blight researchers in various countries over the last decade, and is reported to have some modest effect on the severity of host damage. In this project's 2010 trials, treatment with this product during bloom, followed by an effective antibiotic at the full bloom time of inoculation was the highest rated treatment. This triggered greatly expanded testing in 2011. Seven treatments with different rates, concentrations, timing and application methods were carried out, some with and some without an antibiotic at full Bloom. All of these various treatments involving mid-bloom application of Actigard, followed by treatment with antibiotic at the time of infection performed slightly (numerically) or significantly (statistically) superior to the antibiotic only treatment. This effect is going to be studied further in future trials with other antibiotic and non-antibiotic combinations. The Actigard was also tested for effect as a stand-alone material, sprayed prior to infection and post-infection, and lowered the degree of infection, but not enough to be encouraging.

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

2011 FIRE BLIGHT CONTROL PRODUCT EFFICACY – PEARS

Product	Rate	Timing	% Infection	% Control
Actigard Pre-bloom, Sprayed on. + Strep, 100% bloom + Act. 1 – 2" shoots *	Actigard 2 oz./A Strep. 200 ppm Actigard 2 oz./A	Actigard 50% bloom Strep. 100% Bloom Act. @ 1 - 2" shoot	0.85a	98.5
Actigard Pre-bloom, Sprayed on. + Strep 100% bloom*	Actigard 2 oz./A Strep. 200 ppm	Actigard 50% bloom Strep. 100% Bloom	2.6ab	95.5
Actigard Pre-bloom Soil drench, then Strep + Actigard @ 100% bloom *	Actigard 0.5 lb./A to soil, Strep. 200 ppm + Actigard 6.4 oz./A	Actigard drench @ 50% bloom, Strep. + Actigard @ 100% Bloom	3.4abc	94.1
Actigard Pre-bloom Soil drench and spray, then Strep @ 100% bloom *	Actigard 0.5 lb./A to soil + Actigard 2 oz./A , then Strep 200 ppm	Actigard drench and spray @ 50% bloom, Strep. @ 100% Bloom	4.5bcd	92.2
Actigard Pre-bloom drench, then Strep @ 100% bloom *	Actigard 0.5 lb./A to soil, then Strep 200 ppm	Actigard drench @ 50% bloom, Strep @ full Bloom	6.7de	88.3
Streptomycin 17%*	1 lb/A, 200 ppm	100% bloom	7.1de	87.6
"Blossom Protect" A.p. Yeast (full rate) + Buffer A (full rate)	1.34 lb/100gal/A 9.35 lb. /100/A	20 & 50% 100% bloom	8.2ef	85.7
"Blossom Protect" A.p. Yeast (3/4 rate) + Buffer A (1/2 rate)	1.0 lb/100gal/A 5.0 lb. /100/A	20 & 50% 100% bloom	8.4ef	85.4
TS Copper Product GWN-9979	64 fl.oz./A	50% and 100% bloom	10.6fg	81.5
TS Copper Product GWN-9979	48 fl.oz./A	50% and 100% bloom	10.6fg	81.5
Oxytet. (FireLine)	1 lb/A, 200 ppm	100% bloom	11.1fg	80.7
Cueva (copper soap)	1 gallon/100/A	20 & 50% 100% bloom	11.6gh	79.8

Table 1a. ***Pears***: Summary of data. Values followed by the same letter should not be considered different. **Least Significant Difference in percent infection = 2.96, (95% confidence).**
Streptomycin was effective in this trial because a streptomycin susceptible lab strain of the blight bacteria, Erwinia amylovora, was used to inoculate the flowers.

2011 FIRE BLIGHT CONTROL PRODUCT EFFICACY - PEARS, (CONTINUED)

Product	Rate	Timing	% Infection	% Control
Bacillus subtilis CX-9090 (Certis)	1 lb/100gal./A	50% and 100% bloom	13.0ghi	77.4
TS Copper Product GWN-9979	96 fl.oz./A	50% and 100% bloom	13.4ghi	76.7
Kasumin **8L** (1x)	16 fl.oz./A, 100 ppm	100% bloom	14.7ij	74.4
Bacillus subtilis QRD146 AgraQuest	1.5 lb/100gal./A	30 & 50% 100% bloom	17.2j	70.0
B. subtilis- Serenade MAX, AgraQuest	3.0 lb/100gal./A	30 & 50% 100% bloom	21.2k	63.1
Actigard Pre-bloom, Sprayed 3 times prior to inoculation	Actigard 1 oz./A each spray	20 & 50% 100% bloom	24.8l	56.5
Kasumin **2L** (1x)	64 fl.oz./A, 100 ppm	100% bloom	26.4m	54.0
Actigard, Sprayed twice after 1st symptoms seen	1.34 oz / A	Sprayed twice, three day interval, after 1st symptoms seen	35.7n	37.8
No treatment, inoculated check	**0**	**NA**	**57.4o**	**0**

Table 1b. Pears (continued): Summary of data. Values followed by the same letter should not be considered different**. Least Significant Difference in percent infection = 2.96**

Treatment	Number of Treatments	Highest Percent Control	Lowest Percent Control	Average Percent Control
Strep + ASM*	6	98.4	90.6	95.1
Copper (new forms)	9	98	76.7	85.8
Streptomycin	9	90	75	85.3
BCYP + Buffer A	13	90	72	82.6
Oxytetracycline	15	93	53	78.9
Kasugamycin	8	89	62	77.5
Gentamycin	6	88	51	74.5
Serenade	12	84	38	63.5
Copper (old forms)	7	80	26	49.5
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 2. Summary of author's current and past fire blight control efficacy trial results. Plots all inoculated. *ASM = Actigard, BCYP = Auriobassidium pulullans, "Blossom Protect."

Year	Crop	Product	Rate / A	# Sprays	Buffer A rate / A	% Control
08	Pear	Blossom Protect	1.34 lb	4	9.35 lb/100	90
08	Apple	Blossom Protect	1.34 lb	4	9.35 lb/100	86
11	Pear	Blossom Protect	1.34 lb	3	9.35 lb/100	85.7
11	Pear	Blossom Protect	1.0 lb	3	5.0 lb /100	85.4
10	Pear	Blossom Protect	1.34 lb	3	4.7 lb /100	82.4
10	Pear	Blossom Protect	1.34 lb	3	9.35 lb/100	81.1
09	Apple	Blossom Protect	1.34 lb	4	9.35 lb/100	80.8
10	Apple	Blossom Protect	0.68 lb	3	4.7 lb /100	79.3
10	Pear	Oxytet. 17%	1.0 lb	1	na	77
09	Apple	Blossom Protect	1.34 lb	2	9.35 lb/100	73
08	Pear	Oxytet. 17%	1.0 lb	1	na	72.4
09	Pear	Oxytet. 17%	1.0 lb	1	na	72.4
10	Apple	Blossom Protect	1.34	3	9.35 lb/100	72
08	Apple	Oxytet. 17%	1.0 lb	1	na	70.5
09	Apple	Oxytet. 17%	1.0 lb	1	na	70.1
09	Apple	Blossom Protect	1.34 lb	4	No buffer	69.5
09	Pear	Blossom Protect	1.34 lb	2	9.35 lb /100	67
10	Pear	Blossom Protect	1.34 lb	3	Alternative buffer	62.8
10	Apple	Oxytet. 17%	1.0 lb	1	na	62
10	Apple	Blossom Protect	1.34 lb	3	Alternative buffer	61.8
09	Pear	Blossom Protect	1.34 lb	4	No buffer	59

Table 3. All results of treatments with A. pulullans ("Blossom Protect") since 2008, with oxytetracycline (Mycoshield, FireLine) results as a comparative standard.

Note in table 3: The best performing treatments with "Blossom Protect" were (usually): Applied at full recommended rates, applied with the recommended rate of "Buffer A," and were applied 3 or 4 times prior to inoculation. The treatments that were less effective had lower rates, alternative or no buffers and / or fewer applications. In other words, follow the label directions for best effect.

ORCHARD REPLANT DISEASE PROJECT - RESULTS & DISCUSSION:

2009 & 2010 Results: Tree growth was measured after each of the first two seasons. There were significant differences in vegetative growth of trees growing on fumigated vs. unfumigated replicates. The trunk calipers were larger and the tree height greater in replicates growing on fumigated soils, but the total shoot growth after the second season was the most different (see table 4.)

The trees produced a crop in 2011, one year prior to expectations, so tree vegetative growth was suppressed by fruit competition. In 2011 and in all further evaluation seasons, fruit yields and quality become the main evaluation criteria.

2010 (second season) tree growth data:

Treatment:	*PicPlus (150 lbs./A Chloropicrin) 0 DCP*	*PC60 (144 lbs./A Chloropicrin) 94 lb/A DCP*	*Telone C-35 (25 GPA, 98 lb/A cloropic) 178 lb/A DCP*	*Telone C-17 (30 GPA, 51 lb/A cloropic) 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. 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.

2011 (third season from sleeping eye) fruit data:

Treatment:	*PicPlus (150 lbs./A Chloropicrin) 0 DCP*	*PC60 (144 lbs./A Chloropicrin) 94 lb/A DCP*	*Telone C-35 (25 GPA, 98 lb/A chloropic) 178 lb/A DCP*	*Telone C-17 (30 GPA, 51 lb/A chloropic) 260 lb/A DCP*	*Untreated*
Number of Fruit / tree.	16.7bc	15.5c	19.6a	18.6ab	8.5d
Weight lbs. Fruit / tree	7.5b	7.5b	9.3a	9.1a	3.7c
Weight lbs. per fruit	0.45ab	0.49a	0.48a	0.49a	0.43b
Fruit Grams average	204ab	220a	216a	222a	195b
Fruit box size average	94.1b	86.3a	89.0a	86.3a	98.3c
% size 72 & +	8.8	8.8	9.3	12.9	2.2
80	13.2	16.6	12.5	15.8	8.0
88	25.4	32.2	27.0	27.2	15.0
100	27.8	27.8	28.5	26.2	27.9
113	14.6	8.8	12.1	14.4	23.0
125	8.8	3.9	8.5	3.4	15.5
138 & -	1.4	1.9	2.1	0.1	5.4
%88+	47.4	57.6	48.8	55.9	25.2
%100-	52.6	42.4	51.2	44.1	74.8
Yield per Acre, lbs. (1708 trees)	12,808b	12,826b	15,935a	15,529a	6,286c

Table 5. Fruit production in third season Cripp's Pink apples planted as a "sleeping eye" on M9, planted after fumigation on a replant site.

Treatment A	***PicPlus (175 lbs per ac: 150 lbs./A chloropicrin, 0 1,3-DCP)***

Box size	% in box size	Acre yield	Wt by size group	80% pack wt	Packed boxes	Price*	$ by size group
72+	8.8	12808	1127	902	21	35.41	760
80/88	38.6	12808	4944	3955	94	37.04	3488
100-	52.6	12808	6737	5390	128	27.01	3466
						Total	7714
		**Minus costs, adjustments of:			$2,495	**Adjusted:**	**$5,219**
Treatment B	***PicClor 60 (20 GPA: 144 lbs./A chloropicrin, 94 lb/A 1,3-DCP)***						
Box size	% in box size	Acre yield	Wt by size group	80% pack wt	Packed boxes	Price*	$ by size group
72+	8.8	12826	1129	903	21	35.41	761
80/88	48.8	12826	6259	5007	119	37.04	4415
100-	42.4	12826	5438	4351	104	27.01	2797
						Total	7975
		**Minus costs, adjustments of:			$2,557	**Adjusted:**	**$5,418**
Treatment C	***Telone C-35 (25 GPA: 98 lb/A chloropicrin, 178 lb/A DC)***						
Box size	% in box size	Acre yield	Wt by size group	80% pack wt	Packed boxes	Price*	$ by size group
72+	9.3	15935	1482	1186	28	35.41	1000
80/88	39.5	15935	6294	5035	120	37.04	4441
100-	51.2	15935	8159	6527	155	27.01	4198
						Total	9639
		**Minus costs, adjustments of:			$3,000	**Adjusted:**	**$6,639**
Treatment D	***Telone C-17 (30 GPA, 51 lb/A chloropicrin 260 lb/A DCP)***						
	% in box size	Acre yield	Wt by size group	80% pack wt	Packed boxes	Price*	$ by size group
72+	12.9	15529	2003	1603	38	35.41	1351
80/88	43	15529	6677	5342	127	37.04	4711
100-	44.1	15529	6848	5479	130	27.01	3523
						Total	9585
		**Minus costs, adjustments of:			$2,941	**Adjusted:**	**$6,644**
Treatment E	***Untreated***						
Box size	% in box size	Acre yield	Wt by size group	80% pack wt	Packed boxes	Price*	$ by size group
72+	2.2	6286	138	111	3	35.41	93
80/88	23	6286	1446	1157	28	37.04	1020
100-	74.8	6286	4702	3762	90	27.01	2419
						Total:	3532
		**Minus costs, adjustments of:			$898	**Adjusted**	**$2,634**

Table 6. Rough estimate of fruit gross economic value per acre. *Approximate FOB average on 11/17/2011. ****Costs, adjustments**: picking @ $!7/bin, packing @ $7 / box, and fumigation @ $650-750/Acre. Credit for 5 cents/lb. for cull fruit. Fumigation costs are now covered, and will not play a role in future economic analysis. SLIGHT ERRORS ARE DUE TO ROUNDING OF NUMBERS.

Executive Summary:

EXECUTIVE SUMMARY

Fire Blight:

- Over four years and in seven separate apple and pear fire blight control material trials, a dried yeast product, *Auriobassidium pulullans*, called "Blossom Protect" in Europe, controlled fire blight as well or better than the standard and test antibiotics. Issues that remain to be resolved include potential for causing russet. No russet increase was seen in these trials.
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- This past two season's most effective treatments in both apple and pear trials were applications of acibenzolar–s-methyl (ASM, Actigard) at 50% primary bloom, followed by an antibiotic at time of inoculation. Application of this product to the soil under the test tree reduced blight infection, but not much.
- The "CougarBlight" fire blight infection risk model was upgraded in 2010 by conversion of the temperature risk values to relate directly to the hourly growth rate of E. amylovora on apple stigmas. Research by Dr. Larry Pusey, USDA-ARS Wenatchee provided the basic data used for this upgrade. The model was adapted to the WSU DAS for 2011.

Replant/fumigation:

- Fruit production started in the 3rd season of growth in the apple replant/fumigation trial. After two seasons of marked differences in vegetative development vs. the untreated replicates, the various fumigation treatments produced profoundly more fruit than the untreated portions of the orchard (see table 5.) A preliminary economic analysis indicated that economic returns, adjusted to account for fumigation, picking and packing costs, were increased by $2,600 to $4,000 per acre (table 6.) This was a 530% return over three years on the cost of the fumigation. As would be expected with higher yields; number of fruit per tree and total fruit weight per tree was improved by fumigation, as was average fruit size. Percentage of fruit per box size was documented to aid economic analysis.

Future directions:

Fire Blight: To further investigate synergistic effects following sequential applications of various compatible classes of blight control materials.

Fumigation: We will continue to document the long term production and economic impact of fumigation in a very modern apple orchard. At the conclusion in 2014, or sooner if necessary, this data will be published in both professional and popular form.