EVALUATION OF POTENTIAL COMPONENTS OF A FIRE BLIGHT IPM PROGRAM

Rachel Elkins, U.C. Cooperative Extension, Lake and Mendocino Counties
Ken Johnson and Todd Temple, Department of Botany and Plant Pathology, Oregon State University, Corvallis
Steven Lindow, Department of Microbial Biology, University of California, Berkeley

ABSTRACT

The antibiotics oxytetracycline and streptomycin were removed from the National Organic Program (NOP) List of Allowed and Prohibited Substances in October 2014. 5,526 tons of organic pears were produced on 368 acres by 48 growers in California as of 2011 (NASS/CDFA 2012), with more acreage being transitioned in Lake and Sacramento Counties from 2012-2014. Federally-funded research was initiated in California (CA), Oregon and Washington in 2011 to develop and implement non-antibiotic programs for fire blight control based on combinations of NOP-approved materials. Goals are to 1) refine non-antibiotic control programs to maximize fruit finish quality; 2) continue to evaluate non-antibiotic materials with potential for adoption; 3) adapt non-antibiotic control recommendations to disease risk models; 4) monitor commercial organic orchards for establishment of biocontrol agents and presence and severity of fire blight; and 5) teach and extend information on non-antibiotic control to both the organic and conventional growers and pest management professionals. In 2014, CA focused on both organic and conventional strategies: systemic acquired resistance using Actigard®, integrating early season (mid-bloom) applications of the yeast *Aureobasidium pullulans* combined with a citric acid-based buffer (Blossom Protect®/Buffer Protect®) with later season (full bloom and petal fall) applications of anti-microbial lipoproteins, e.g. Serenade Optimum® (SOpt) and Double Nickel 55® and soluble coppers, e.g. Cueva®, and testing various copper formulations for their effects on efficacy and fruit finish. Overall 2014 results from multiple single tree and large scale grower-applied trials suggest that 2015 research should focus on continuing to 1) test Actigard under conditions controlled for fire blight presence and sampling method; 2) Blossom Protect efficacy and ways to mitigate fruit russet risk by applying once at 70% bloom to provide sufficient fire blight control while reducing russet potential under humid conditions, and eliminating or reducing the amount of Buffer Protect, which can interact with copper and increase russet potential, and 3) copper formulations that may differ somewhat in efficacy and russet-inducing potential, although high rates of even low metallic equivalent coppers can russet fruit.

INTRODUCTION

Fire blight is one of, if not the most, serious diseases of pear (van der Zwet and Beer 1999). Through September 2014, antibiotics were the standard materials used to control this bacterial disease in both conventional and organic orchards (Elkins, Gubler, Adaskaveg 2012). In 2014, the antibiotics oxytetracycline and streptomycin were removed from the National Organic Program (NOP) List of Allowed and Prohibited Substances, leaving the increasing number of commercial organic pome fruit growers to “fashion” effective alternative programs to control fire blight, or face certain considerable losses of both crop and trees. While organic production currently comprises a small proportion of sales, demand for all forms of organic pears and pear products has greatly increased, as reflected by increasing prices. California is the second major organic pear producing state behind Washington, and organic pears offer a means for growers (and shippers) to diversify and stabilize their business, **provided** pests can be effectively managed. 5,526 tons of organic pears were produced on 368 acres by 48 growers in California as of 2011 (NASS/CDFA 2012), with more acreage being transitioned in Lake and Sacramento Counties from 2012-2014.

The acknowledged imperative need to control fire blight in organic production was the basis for two successful multistate (CA, OR, WA) USDA-NIFA Organic Research and Extension Initiative (OREI) grants (2011-2013 with a one-year, no-cost extension in 2014 and 2015-2017), *“Implementation of non-antibiotic programs for fire blight control in organic apple and pear in the Western United States”* (K. Johnson, Project Director; R. Elkins, T. Smith and D. Granatstein, Co-Project Directors). From 2011-2014, the team (minus Granatstein who joined in 2015 to evaluate and document project impact) initiated research and subsequently developed non-antibiotic programs for fire blight control based on combinations of NOP-approved materials. California work was key in developing one key component of alternative IPM programs for both conventional and organic pears, that of verifying the ability of pre-bloom fixed copper sprays to reduce fire blight inoculum. This work was completed in 2013 and focus in 2014 was on in-season and post-infection control, including the effect of in-season regimes on fruit russeting. For the second phase from 2015-2017, the project’s goal is to build on previous efforts by moving non-antibiotic fire blight control from development to implementation. Specific goals are to 1) refine non-antibiotic control programs to maximize fruit finish quality; 2) continue to evaluate non-antibiotic materials with potential for adoption; 3) adapt non-antibiotic control recommendations to disease risk models; 4) monitor commercial organic orchards for establishment of biocontrol agents and presence and severity of fire blight; and 5) teach and extend information on non-antibiotic control to both the organic and conventional tree fruit community, as conventional growers will also benefit from this information. Data and knowledge gained thus far has been disseminated regionally and nationally via digital (e.g. webinars, websites) and traditional methods, and these methods will be utilized in the future.

2014 OBJECTIVES

1) Expand on the opportunity afforded by the Experimental Use Permit (EUP) received for the systemic acquired resistance (SAR) agent acibenzolar-S-methyl (Actigard®, Syngenta Crop Protection, Inc., Greensboro, NC) in 2013.

2) Continue to develop an integrated fire blight control program for organic orchards utilizing (primarily) biological alternatives to antibiotics. While the main focus was organic orchards, tactics are also useful for conventional growers facing antibiotic resistance and possible further restrictions on antibiotic use. Focus in 2014 was on integrating early season (mid-bloom) applications of the yeast *Aureobasidium pullulans* combined with a citric acid-based buffer (Blossom Protect®/Buffer Protect®, Westbridge, Vista, CA) with later season (full bloom and petal fall) applications of anti-microbial lipoproteins, e.g. Serenade Optimum® (SOpt) (Bayer CropScience, Davis, CA) and Double Nickel 55® (Certis USA, Columbia, MD), and soluble coppers, e.g. Cueva® (Certis USA, Columbia, MD). Blossom Protect/Buffer Protect was also tested in large plots with grower and pest control advisor (PCA) cooperators.

3) Continue to test various copper formulations for their effects on efficacy and fruit finish as compared to a standard antibiotic program in a conventional orchard.

PROCEDURES

Objective 1) (Figures 1-2) 8-acre sections of five conventionally-farmed orchards in Lake County (3 Bartlett, 1 Forelle, 1 Starkrimson) with a history of fire blight were randomly divided into two 4-acre sections and either treated with 2 oz. per acre (8 oz. total) Actigard® at petal fall and two weeks later (March 24 (Forelle only) – May 2) or left untreated. Standard antibiotic treatments were otherwise applied. Treatments were applied by cooperating growers at 125 gpa using commercial air blast sprayers. Fire blight strikes were counted from May 13 to June 20.

Objective 2a) (Figures 1-2,Table 2) - A randomized complete block single tree trial (5 replicates) was established in a certified organic orchard to test multiple combinations of treatments designed to reduce fire blight incidence while minimizing russeting to ensure commercially acceptable fruit finish. On the date of treatment, suspensions of each product in water were prepared at the appropriate rate and applied to near run-off (2-3 L per tree) with a backpack sprayer at sunrise under calm wind conditions.

Measurement of yeast population – Blossom samples were collected on April 14 (full bloom) and April 21 (petal fall) and evaluated for presence of both fire blight and the yeast organism. Five flower clusters (~25 flowers) were bulk sampled from each replicate tree. Sampled flower clusters were shipped overnight to the Johnson lab in Corvallis. On April 16 and April 23, each flower cluster sample was immersed in 25 ml of sterile phosphate buffer and sonicated for 3 minutes. After sonication, a 10 µl sample of the flower wash and a 1:10 dilution was spread on potato dextrose agar amended with kanamycin (150 µg/ml) (PDA) to enumerate *A. pullulans* populations (April 26).

Disease assessment – Beginning ~2-3 weeks after petal fall, the incidence of fire blight was determined weekly by counting (and removing) blighted flower clusters from each tree.

Fruit russet and frost damage evaluation – Just prior to harvest, 30 fruit were sampled from each replicate tree and delivered to the Lindow lab at UC Berkeley for russet and frost evaluation. Russeting was graded on each fruit using the Horsfall-Barratt rating system. The percentage of fruit having > 7% of the fruit surface covered with russet was used to compare treatments (7% surface russet is an estimate of the threshold for commercial downgrading).

Objective 2b) (Figures 1-2) - 8-10 acre sections of eight orchards (5 Bartlett, 3 Bosc) were divided into two equal sections and one randomly-selected section treated with Blossom Protect/Buffer Protect at 70-80% bloom and full bloom. Treatments were applied by the cooperating growers using a commercial air blast sprayer. All other fire blight treatments were applied as decided upon by the cooperating grower and pest control adviser (PCA). 300 flower clusters per treated section were collected after each treatment and handled in the same manner as previously described. Fire blight strikes were counted in 5 of the 8 orchards by either the cooperating grower or the UC Cooperative Extension field staff. 80-100 fruit per section were collected prior to commercial harvest and evaluated for russet severity in the manner described above.

Objective 3) (Table 9, Figures 1-2) - A randomized complete block design single tree (4 replicates) trial was established to test the effects of two (one yet-to-be-registered and one registered) copper materials on 1) fruit russet and frost damage and 2) fire blight control. Materials tested were GWN-10073 (Previsto® 3.3% metallic copper, Gowan Company LLC, Yuma, AZ) and Copper-Count-N® 8.8% metallic copper (Mineral Research & Development, Charlotte, NC). There were a total of seven treatments applied at varying bloom stage or weekly, either alone or alternated with antibiotics. Untreated and antibiotic standards were also applied.

RESULTS

Objective 1) (Table 1) – There was no significant difference between the Actigard® and control treatment, either including or omitting holdover-related strikes.

Objective 2a) (Tables 3-5)

Measurement of yeast population – There were no significant differences among treatments in yeast presence (log cfu/ml, p=0.32). Yeast presence was numerically higher in the three Blossom Protect treatments without follow-up Cueva soluble copper than in other treatments.

Disease assessment – No fire blight strikes appeared at this trial location, however, results from a similar, but inoculated, trial in Corvallis showed that only one application of Blossom Protect/Buffer Protect at 80% bloom significantly reduced the number and percent of blighted flower clusters versus both the untreated (water only) control and two applications of Serenade Optimum. There was a trend toward less control when the yeast was combined with either either Serenade Optimum or Cueva copper soap.

Fruit russet and frost damage evaluation – Fruit was very clean and there were no significant differences among treatments, only among blocks.

Objective 2b (Tables 6-8, Figure 3)

Measurement of yeast population – There was no treatment difference among the sites, however, location differences in incidence (number of yeast colonies) among trial sites were highly significant ($p<0.0001$). Within each of the eight sites, only two had significant differences in yeast populations between the treated and untreated sections.

Disease assessment – There was no significant difference in disease incidence between the Blossom Protect-treated and untreated blocks for either Bartlett or Bosc.

Fruit russet and frost damage – There was a trend toward increased russeting with Blossom Protect, as indicated by average incidence (Bartlett p=.07, Bosc p=0.19) and greater number of treated fruit with $\leq$7% russet (Bartlett) or "moderate" russet (Bosc).

Objective 3 (Table 10)

Disease assessment – There were no significant differences in the number of fire blight strikes among treatments, although all copper treatments except 32 oz. C-C-N, had numerically fewer strikes than the untreated control and the 64 oz. rate of both GWN-10073 and C-C-N applied 2-3 times appeared to perform as well as the antibiotic standard.

Fruit russet and frost damage – Differences were highly significant. The untreated control and antibiotic-treated fruit were least russeted and fruit treated three times with the highest rate of GWN-10073 the most russeted. Any treatment including 64 oz. GWN-10073 at petal fall exhibited significantly more russet than other treatments; 64 oz. CCN at petal fall, however, was comparatively nearly as clean as untreated or antibiotic-treated fruit. There was little frost damage and no differences among treatments.

DISCUSSION

Systemic Acquired Resistance using Actigard® – It is difficult to assess the benefit of including Actigard in a fire blight management program using a limited number of large-scale commercial blocks due to the great variability among orchard locations, both in fire blight incidence and sampling success. The number of paired treatment blocks would have to be greatly increased to gain valid treatment difference information, and the fire blight sampling protocol greatly standardized and enforced. Any future testing of SAR should be carried out under controlled small plot conditions.

Biological control (Table 9, Figure 4) – Population analysis continues to confirm the ability of Blossom Protect (yeast) to colonize flowers under a wide range of weather and site conditions, as well as its ability to control fire blight (Corvallis trial). This was reinforced by the presence of yeast colonies on control and antibiotic-alone trees in the single tree trial, as well as colonization of flowers in the untreated areas of the large-scale sites. Reduced (though not significantly) mean log cfu/ml of yeast in the treatments that included soluble copper after yeast suggests that copper can suppress the yeast to some extent, as theorized in the 2014 proposal (Figure 4). Russet caused by the yeast continues to be a concern for fresh market fruit, especially under more humid, cool microclimates. Growing areas with higher (recorded) number of hours of leaf wetness correlated with greater russet potential, even though air temperature and total precipitation relevant to fire blight were similar. Areas less prone to russeting had lower relative humidity, and fewer leaf wetness hours, especially in May when fruit was most vulnerable to russeting. These microclimate differences likely explain why incidence of russeting was low in both the Kelseyville single-tree trial and grower-treated trials. In contrast, there was significantly more russet in the Upper Lake and Potter Valley grower-applied Blossom Protect-treated plots. Table 9 shows higher recorded RH and leaf wetness for Upper Lake, which has conditions intermediate between Kelseyville and Potter Valley.

Timing of copper in relation to yeast may be an important consideration under russet-prone conditions. The most severe recorded surface effects occurred when Blossom Protect/Buffer Protect was applied to Bosc pears three days (72 hours) after fixed copper (28% metallic copper equivalent) was applied in mid-April. Signs of surface damage included splitting, enhanced epidermal "roughness" and net-like russet, and reduced final fruit size. Based on symptom pattern, it was surmised that the citric acid-based Buffer Protect catalyzed copper ion solution on the fruit surface, resulting in greater copper russeting and related damage, including fruit growth (perhaps related to lessened cell wall elasticity). While russeting was also increased in the humid Upper Lake site, no copper had been applied prior to the yeast application and neither excessive splitting nor reduced fruit size was observed. Based on the above observed effects on Bosc fruit from one orchard, further testing of Blossom Protect, with and without Buffer Protect, and at various timings in relation to copper applications, is proposed.

Copper rates and timings – Though block variability precluded achieving significant treatment differences, all but one copper treatment (32 oz. C-C-N alone starting at full bloom) reduced the number of fire blight strikes versus the untreated control. 5-7 applications of 64 oz. appeared to provide similar control as 7 applications of antibiotics, however reducing either the rate or number of applications appeared to reduce control.

GWN-10073 enhanced russeting at the 64 oz. rate, regardless of timing, while C-C-N-treated fruit was as clean as antibiotic-treated at the low and high rate. This was surprising but could be related to being applied two fewer times, or indirectly due to a suppressive effect on russet-inducing bacteria. The 3-4 applications of 32 oz. GWN-

10073 induced half the russet effect of the 64 oz. rate, while appearing to provide a similar level of control. Further testing is needed to confirm this observation.

Summary of key conclusions to guide 2015 plans:

- Actigard should be tested on single trees to verify efficacy;
- Blossom Protect continues to provide control, i.e. in Oregon and Washington trials in 2014, however, russet potential remains an issue under humid conditions. One application at 70% bloom may be all that is needed for fire blight control and may minimize russeting provided it is not preceded by copper. Efficacy without Buffer Protect should be tested;
- Copper formulations may differ somewhat in efficacy, however, multiple applications of high rates appears to exacerbate russet;
- Russet potential appears to increase under high relative humidity.

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Table 1. Effect of systemic acquired resistance (SAR) (Actigard®) applied at 20% bloom and petal fall on average number of fire blight strikes in pear orchards treated by cooperating growers in Lake County, California, 2014.

	Average Fire Blight Strikes (per tree)	
Treatment	with holdovers	without holdovers
Control	13.6	5.6
Actigard	26.0	26.0
P-value[1]	NS (0.57)	NS (0.34)

[1] Means analyzed using T-test, *P*-value $\leq$0.05
NS indicates not significant
n=5. Fire blight strikes counted 5/13 – 6/20

Table 2. Organically-approved materials versus antibiotics for fire blight control, Bartlett pear trees, Kelseyville, Lake County, California, 2014.

No.	Treatment	Rate (oz/100 gal)	Bloom Stage	Application Date(s)
1	Water (control)	~	70%, Full bloom, Petal fall	4/8, 4/10, 4/17
2	Agrimycin (100) Mycoshield (200)	8.0 plus 16.0	70% Full bloom, Petal fall	4/8, 4/10, 4/17
3	Oxytetracycline (200)	16.0	70%, Full bloom, Petal fall	4/8, 4/10, 4/17
4	Serenade Optimum (S0pt)	20.0	Full bloom, Petal fall	4/10, 4/17
5	Blossom Protect/Buffer Protect	21.4, 149.6	70%	4/8
6	Blossom Protect/Buffer Protect	21.4, 149.6	70%, Full bloom	4/8, 4/10
7	Blossom Protect/Buffer Protect	21.4, 149.6	70%	4/8
	plus Serenade Optimum	20.0	Full bloom, Petal fall	4/10, 4/17
8	Blossom Protect/Buffer Protect	21.4, 149.6	70%	4/8
	plus Serenade Optimum	20.0	Full bloom, Petal fall	4/10, 4/17
	plus Cueva (1.5 qt.)	48.0	Full bloom, Petal fall	4/10, 4/17
9	Blossom Protect/Buffer Protect	21.4, 149.6	70%	4/8
	plus Serenade Optimum	20.0	Full bloom, Petal fall	4/10, 4/17
	plus Cueva (2.0 qt.)	64.0	Full bloom, Petal fall	4/10, 4/17
10	Blossom Protect/Buffer Protect	21.4, 149.6	70%	4/8
	plus Cueva (3.0 qt.)	96.0	Full bloom, Petal fall	4/10, 4/17

Table 3. Average cfu counts in blossom samples collected from Bartlett pear trees treated with various combinations of biological control agents and soluble copper, Kelseyville, Lake County, California, 2014.

			Log cfu/ml		
			Sample #1[4]	Sample #2[5]	Combined Samples
	Treatment[1]	Bloom Stage[4]	4/14	4/21	
1	Water (control)	FB, PF	0.2 c	1.1	0.6 b
2	Streptomycin (100)	70%, FB, PF	~	~	~
3	Oxytetracycline (200)	FB, PF	~	~	~
4	Serenade Optimum	FB, PF	2.4 ab	0.6	1.5 ab
5	Blossom Protect/Buffer Protect	70%	1.5 bc	2.1	1.8 ab
6	Blossom Protect/Buffer Protect	70%, FB	3.3 a	1.8	2.5 a
7	Blossom Protect/Buffer Protect then Serenade	70% then FB, PF	2.7 ab	2.0	2.4 a
8	Blossom Protect/Buffer Protect then Serenade & Cueva® 1.5 qt.	70% then FB, PF	1.0 bc	0.8	0.9 ab
9	Blossom Protect/Buffer Protect then Serenade & Cueva® 2 qt.	70% then FB, PF	3.8 a	1.2	2.5 a
10	Blossom Protect then Cueva® 3 qt.	70% then FB, PF	1.3 bc	0.6	1.0 ab
	ANOVA (P-value)[2]				
	Treatment		***(≤0.001)	NS (0.25)	*** (0.001)
	Interval		~	~	** (0.01)
	Block		NS (0.15)	NS (0.12)	NS (0.94)

[1] Within columns, treatment means significantly different (Tukey HSD test, $P \leq 0.05$).
[2] **, *** Indicate significance at $P \leq$ 0.01 and 0.001 respectively. NS indicates not significant.
[3] FB=Full Bloom; PF=Petal fall
[4] Samples plated 4/16, observed 4/21.
[5] Samples plated 4/23, observed 4/26.

Table 4. Effect of organically acceptable materials versus antibiotics on number of fire blight strikes, fruit russeting, percent fruit russet severity, and percent fruit frost damage on Bartlett pear trees, Kelseyville, Lake County, California, 2014.

No.	Treatment[1]	Bloom Stage[4]	Fire blight Strikes (avg. per tree)	Average Russeting[4] (no. incidence)	Incidence of fruit[4] with ≤ 3% russet	Incidence of fruit[4] with ≥ 7% russet	Frost Damage[4] (%)
1	Water (control)	FB, PF	0.0	1.36	91.8	2.7	0.0
2	Streptomycin (100)	70%, FB, PF	0.0	2.22	80.5	8.2	0.0
3	Oxytetracycline (200)	FB, PF	0.0	1.50	90.7	4.0	0.0
4	Serenade Optimum	FB, PF	0.0	1.72	85.1	6.7	0.0
5	Blossom Protect/Buffer Protect	70%	0.0	1.30	92.4	3.4	0.0
6	Blossom Protect/Buffer Protect	70%, FB	0.0	2.51	80.6	9.4	0.0
7	Blossom Protect/Buffer Protect then Serenade	70% then FB, PF	0.0	1.99	86.3	7.5	0.0
8	Blossom Protect/Buffer Protect then Serenade & Cueva® 1.5 qt.	70% then FB, PF	0.0	1.91	84.5	9.4	0.0
9	Blossom Protect/Buffer Protect then Serenade & Cueva® 2 qt.	70% then FB, PF	0.0	1.94	86.4	6.8	0.0
10	Blossom Protect then Cueva® 3 qt.	70% then FB, PF	0.0	2.34	85.9	8.1	0.0
	ANOVA (P-value)[2]						
	Treatment		~	NS(0.41)	NS(0.65)	NS(0.75)	~
	Block		~	*(0.02)	*(0.04)	*(0.03)	~

[1] Within columns, treatment means significantly different (Tukey HSD test, $P \leq 0.05$).
[2] * Indicates significance at $P \leq 0.05$. NS indicates not significant.
[3] FB = Full bloom; PF = Petal fall
[4] Samples rated August 2014.

Table 5. Non-antibiotic strategies for fire blight control in pear, Corvallis, Oregon 2014, K. B. Johnson & T. N. Temple, Oregon State University

Treatment	Rate per 100 gallons water	Date treatment applied*: 7 Apr 80% bloom	10 Apr Full bloom	14 Apr Petal Fall	Number of blighted clusters per tree**		Percent blighted floral clusters***	
Water		---[§]	X	X	11.8	a[#]	1.7	a[#]
FireWall 100 ppm	8 oz.	---	X	---	1.3	cd	0.2	cd
FireLine 200 ppm	16 oz.	---	X	X	1.0	cd	0.2	cd
Serenade Optimum	20 oz.	---	X	X	6.0	ab	1.0	ab
Blossom Protect	21.4 oz.	X	---	---	0.3	d	0.1	d
plus Buffer Protect	150 oz.	X	---	---				
Blossom Protect	21.4 oz.	X	---	---	1.8	cd	0.3	cd
plus citric acid	150 oz.	X	---	---				
Blossom Protect	21.4 oz.	X	---	---	1.0	cd	0.1	cd
plus Buffer Protect	150 oz.	X	---	---				
then Serenade Optimum	20 oz.	---	X	X				
Blossom Protect	21.4 oz.	X	---	---	2.5	bc	0.4	bc
plus Buffer Protect	150 oz.	X	---	---				
then Serenade Optimum	20 oz.	---	X	X				
plus Cueva (one pint)	16 fl. oz.	---	X	X				
Blossom Protect	21.4 oz.	X	---	---	1.8	cd	0.3	cd
plus Buffer Protect	150 oz.	X	---	---				
then Serenade Optimum	20 oz.	---	X	X				
plus Cueva (one quart)	32 fl. oz.	---	X	X				
Blossom Protect	21.4 oz.	X	---	---	1.8	cd	0.3	cd
plus Buffer Protect	150 oz.	X	---	---				
then Serenade Optimum	20 oz.	---	X	X				
plus Cueva (1.5 quarts)	48 fl. oz.	---	X	X				
Blossom Protect	21.4 oz.	X	---	---	1.5	cd	0.2	cd
plus Buffer Protect	150 oz.	X	---	---				
then Serenade Optimum	20 oz.	---	X	X				
plus Cueva (two quarts)	64 fl. oz.	---	X	X				
Blossom Protect	21.4 oz.	X	---	---	2.8	bc	0.4	bc
plus Buffer Protect	150 oz.	X	---	---				
then Cueva (3 quarts)	96 fl. oz.	---	X	X				
Blossom Protect	21.4 oz.	X	---	---	1.0	cd	0.2	cd
plus Buffer Protect	150 oz.	X	---	---				
then Serenade Optimum	20 oz.	---	X	X				
plus Actigard	2 oz.	---	X	X				
Luna Sensation	4 oz.	---	X	X	10.8	a	1.7	a

* Trees inoculated on 7 April with 1 x 10^6 CFU/ml *Erwinia amylovora* strain Ea153N (streptomycin- and oxytetracycline-sensitive fire blight pathogen strain).
** Transformed log(x + 1) prior to analysis of variance; non-transformed means are shown.
*** Transformed arcsine($\sqrt{x}$) prior to analysis of variance; non-transformed means are shown.
[§] X indicates material was sprayed on that specific date; --- indicates material was not applied on that specific date.
[#] Means within a column followed by same letter do not differ significantly (P = 0.05) based on Fischer's protected least significance difference.

Table 6. Mean yeast (log cfu/ml) and incidence (% blossoms) in samples collected from Bartlett (5 orchards) or Bosc (3 orchards) pear trees, Lake and Mendocino Counties, California, April 2014.

Orchard	Colony forming units (Log cfu/ml)[2]	Yeast incidence (%)
Bartlett		
Blossom Protect	2.5	77.9
Control	1.7	68.1
P-Value	0.33	0.65
Bosc		
Blossom Protect	1.5	53.5
Control	1.1	41.4
P-Value	0.75	0.76
Bartlett and Bosc Combined		
Blossom Protect	2.1	68.8
Control	1.5	58.4
P-Value	0.33	0.57

[1] Means analyzed by T-test, $P \leq 0.05$).

[2] Samples collected 4/15, plated 4/18, observed 4/23.

Bartlett: n=5, Bosc: n=3, Combined: n=8

Table 7. Average fire blight strikes, fruit russeting, percent russet severity, and percent frost damage on Bartlett pear trees treated by cooperating growers with Blossom Protect/Buffer Protect in Lake County, California, 2014.

Treatment[1]	Average Fire blight Strikes (without holdovers) (per tree)	Average Fire blight Strikes (with holdovers) (per tree)	Average Russeting[3] (no. incidence)	Incidence of fruit[3] with		Frost Damage[3] (%)
				≤3% russet	≥7 % russet	
Blossom Protect	45.0	208.0	1.8	84.2	5.8	0.0
Control	15.0	48.5	0.6	97.5	0.8	0.0
P-Values[2]	NS (0.59)	NS (0.53)	NS (0.07)	NS (0.06)	NS (0.20)	~

[1] Means analyzed using T-test, $P \leq 0.05$, n=2.

[2] NS indicates not significant.

3 Samples rated August, 2014.

Table 8. Average fire blight strikes, skin effects, percent effect severity, and percent frost damage on Bosc pear trees treated by cooperating growers with Blossom Protect/Buffer Protect in Lake County, California, 2014.

Treatment[1]	Average Fire blight Strikes (per tree)	Average Skin Effects[3] (no. incidence)	Incidence of fruit[3] with skin effects				Frost Damage[3] (%)
			% no effects	% minor	% moderate	% severe	
Blossom Protect	0.3	0.8	41.8	19.2	27.7	0.0	0.0
Control	1.0	0.3	61.3	37.4	2.3	0.0	0.0
P-Values[2]	NS (0.49)	NS (0.19)	NS (0.49)	NS (0.41)	NS (0.21)	~	~

[1] Means analyzed by T-test, $P \leq 0.05$, n=3.

[2] NS indicates not significant.

[3] Samples rated August, 2014.

Table 9. Copper fire blight/russet trial treatment and application information, Bartlett pear trees, Scotts Valley (Lakeport), Lake County, California, 2014.

				Copper Application	No. Applications	
No.	Treatment[1,2,3]	Rate/Acre	Bloom Stage	Date(s)	Copper	Antibiotics
1	Untreated Control	~	~	~	~	
2	Agristrep and Mycoshield (antibioticgrower control)	4.8 oz./136 g, 16 oz./454 g	50%, Full bloom, Petal fall	4/16, 4/23, 4/29, 5/7, 5/13, 5/20, 5/28	-	7
3	GWN-10073 alternated w/antibiotics	32 oz./0.95L	50%, Full bloom, Petal fall	4/16, 4/29, 5/13, 5/28	4	3
4	GWN-10073 alternated w/antibiotics	64 oz./1.9 L	50%, Full bloom, Petal fall	4/16, 4/29, 5/13, 5/28	4	3
5	GWN-10073 alternated w/antibiotics	30 oz./1.9 L	Petal fall	5/7, 5/13, 5/28	3	1
6	GWN-10073 alternated w/antibiotics	64 oz./0.95L	Petal fall	5/7, 5/13, 5/28	3	1
7	GWN-10073 alone	64 oz./1.9 L	50%, Full bloom, Petal fall	4/16, 4/23, 4/29, 5/7, 5/13, 5/20, 5/28	7	-
8	Copper-Count-N alone	32 oz./0.95L	Full bloom, Petal fall	4/29, 5/7, 5/13, 5/20, 5/28	5	-
9	Copper-Count-N alone	64 oz./1.9 L	Full bloom, petal fall	4/29, 5/7, 5/13, 5/20, 5/28	5	-

[1] Treatments applied in 100 gallons water (378.5 L.) per acre, or 0.66 gallons per tree (2.5 L. or 12.5 L/5 trees)
[2] Treatments 3,4,5,6,7 applied with 0.5% silicone (BreakThru®) (12.5 ml/tree)
[3] All treatments applied weekly from initial bloom stage.
NOTE Treatments 3 and 4 alternated with Agristrep + Mycoshield on 4/23, 5/7, 5/20
Treatments 5 and 6 alternated with Agristrep + Mycoshield on 5/20

Table 10. Effect of copper products versus antibiotics on average fire blight strikes, average fruit russeting, percent russet severity, and percent frost damage, Bartlett pears trees, Scotts Valley (Lakeport), California, 2014.

No.	Treatment[1]	Bloom Stage[3]	Average Fire blight Strikes[4] (per tree)	Average Russeting[5] (no. incidence)	Incidence of fruit[5] with ≤3 % russet	Incidence of fruit[5] with ≥7 % russet	Frost Damage[5] (%)
1	Control	~	22.7	0.73 d	94.2 a	2.5 d	0.0
2	Grower standard (antibiotics)	50%, FB, PF	11.7	1.02 d	90.3 a	6.4 cd	0.0
3	GWN-10073@ 32 oz/ac. alternated	50%, FB, PF	18.7	3.80 bcd	61.8 ab	17.5 bcd	1.5
4	GWN-10073@ 64 oz/ac. alternated	50%, FB, PF	17.7	6.72 abc	33.4 bc	46.8 abc	2.2
5	GWN-10073@ 32 oz/ac. alternated	PF	16.2	3.53 bcd	69.1 ab	20.0 bcd	0.0
6	GWN-10073@ 64 oz/ac. alternated	PF	17.0	7.70 ab	30.3 bc	56.8 ab	2.3
7	GWN-10073@ 64 oz/ac. alone	50%, FB, PF	14.0	10.84 a	5.8 c	84.8 a	0.8
8	C-C-N 32oz/ac. alone	FB, PF	26.7	1.96 cd	84.3 a	9.9 cd	0.0
9	C-C-N 64oz/ac. alone	FB, PF	13.2	1.81 cd	84.8 a	7.2 cd	1.6
	ANOVA (P-value)[2]						
	Treatment		NS (0.38)	***(≤0.001)	***(≤0.001)	***(≤0.001)	NS (0.73)
	Block		NS (0.08)	NS(0.42)	NS(0.29)	NS(0.28)	NS (0.31)

[1] Within columns, treatment means significantly different (Tukey HSD test, $P<0.05$, strikes: Duncan MRT, $P<0.1$).
[2] *** Indicates significance at $P<0.001$. NS indicates not significant.
[3] FB – Full bloom; PF = Petal fall
[4] Fire blight strikes counted 7/21/2014.
[5] Samples rated August, 2014.

Table 11. Weather conditions relevant to fire blight infection and russet formation during early fruit development, Lake and Mendocino Counties, California, April and May 2014.

Location	Air Temperature						Moisture							
	Minimum (°F)		No. days ≤ 32°F		No. Hours 70-85°F		Precipitation (Total inches)		Average Relative Humidity (%)		Maximum Relative Humidity (%)		Leaf Wetness (Total hours)	
	April	May	April	May	April	May	April	May	April	May	April	May	April	May
Kelseyville[1]	39.2	41.6	0	1	120.6	132.0	1.01	0.00	61	52	86	67	100.4	4.4
Scotts Valley[2]	35.9	38.5	7	3	120.2	147.2	0.96	0.02	72	64	98	82	231.2	96.3
Upper Lake[3]	39.6	42.5	0	0	115.1	148.5	1.36	0.01	72	63	98	80	204.0	59.6
Ukiah[4]	41.3	43.3	0	0	97.8	107.6	0.25	0.01	63	54	87	73	169.4	53.7

[1] Location of single tree shared protocol trial, three grower-applied Blossom Protect and four grower-applied Actigard trials
[2] Location of single-tree GWN-10073 (Previsto®) and Copper Count-N trial and one grower-applied Actigard trial
[3] Location of (one each) grower-applied Blossom Protect and Actigard trials
[4] No formal trial at this location; informational purposes only

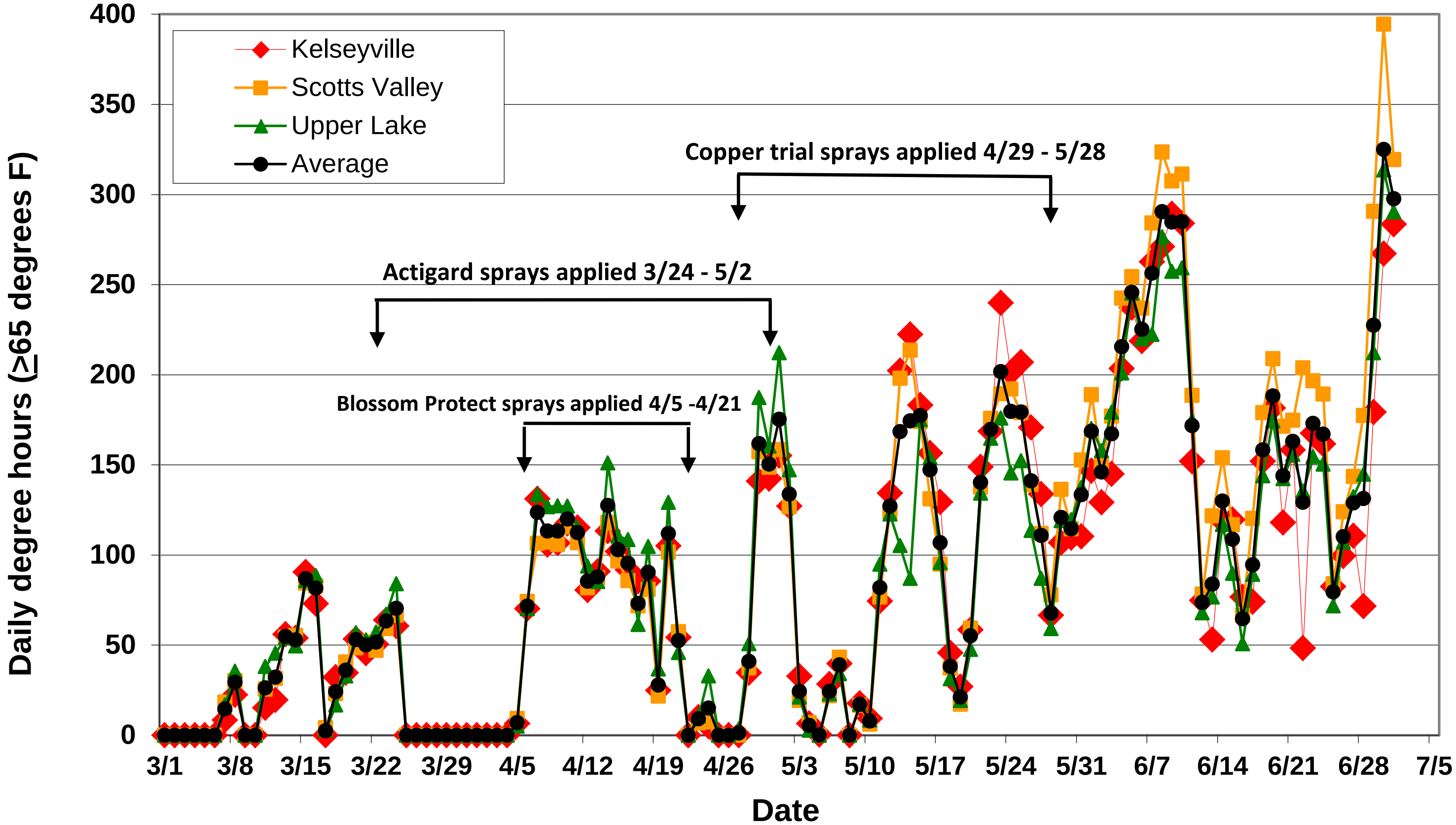

Figure 1: Daily degree hours (base ≥65°F) for Kelseyville, Scotts Valley (Lakeport) and Upper Lake, Lake County, California, March 1 - July 1, 2014 (Source: UCIPM).

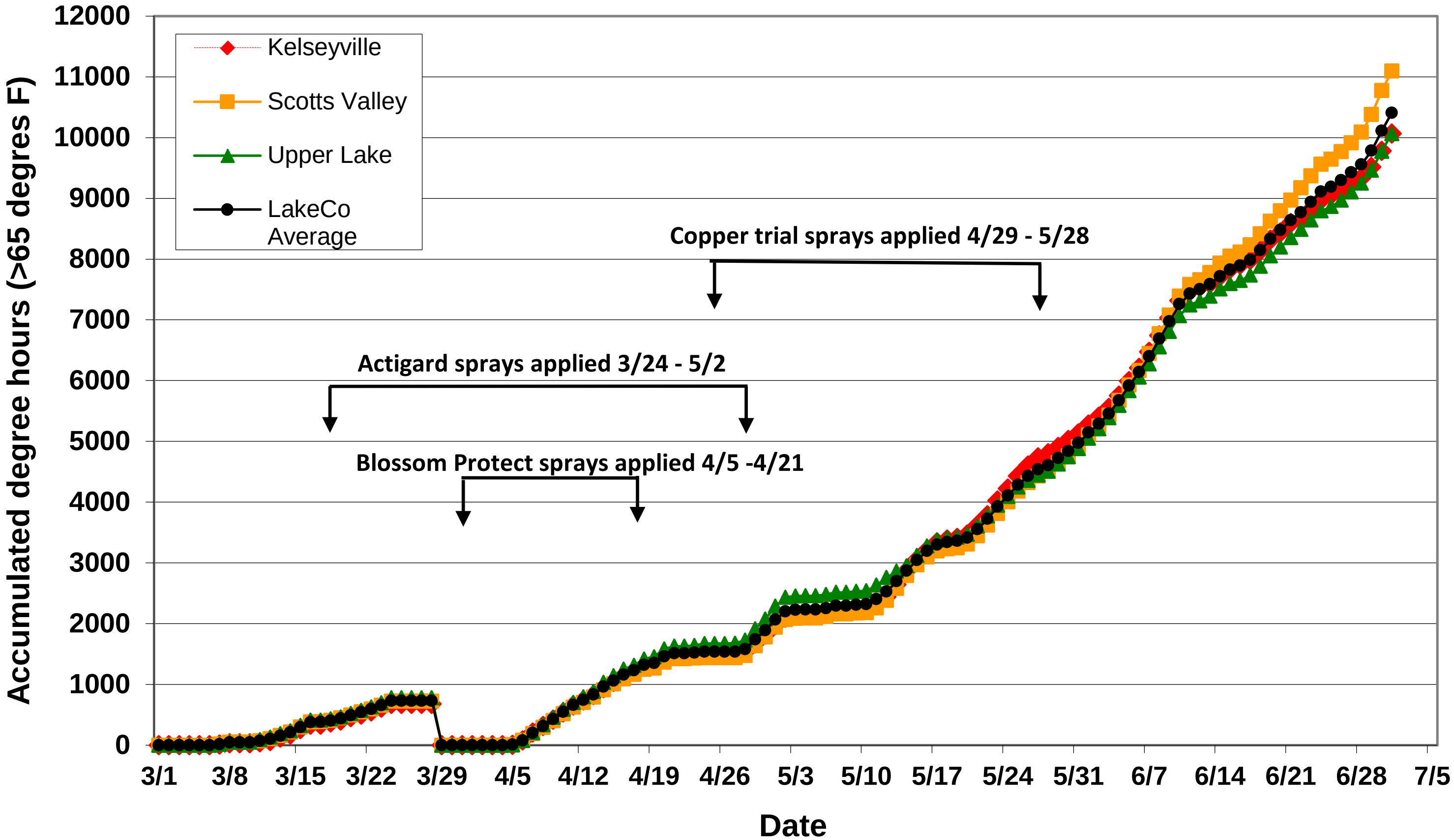

Figure 2: Accumulated degree hours (base ≥65°F with 4-day crash) for Kelseyville, Scotts Valley (Lakeport) and Upper Lake, Lake County, California, March 1 to July 1, 2014. Degree-hours calculated using data from Kelseyville-0.1P (Kel), Scotts_Valley-0.2 P (SVL), and Upper_Lake-0.1 P (UPL) (Source: UCIPM).

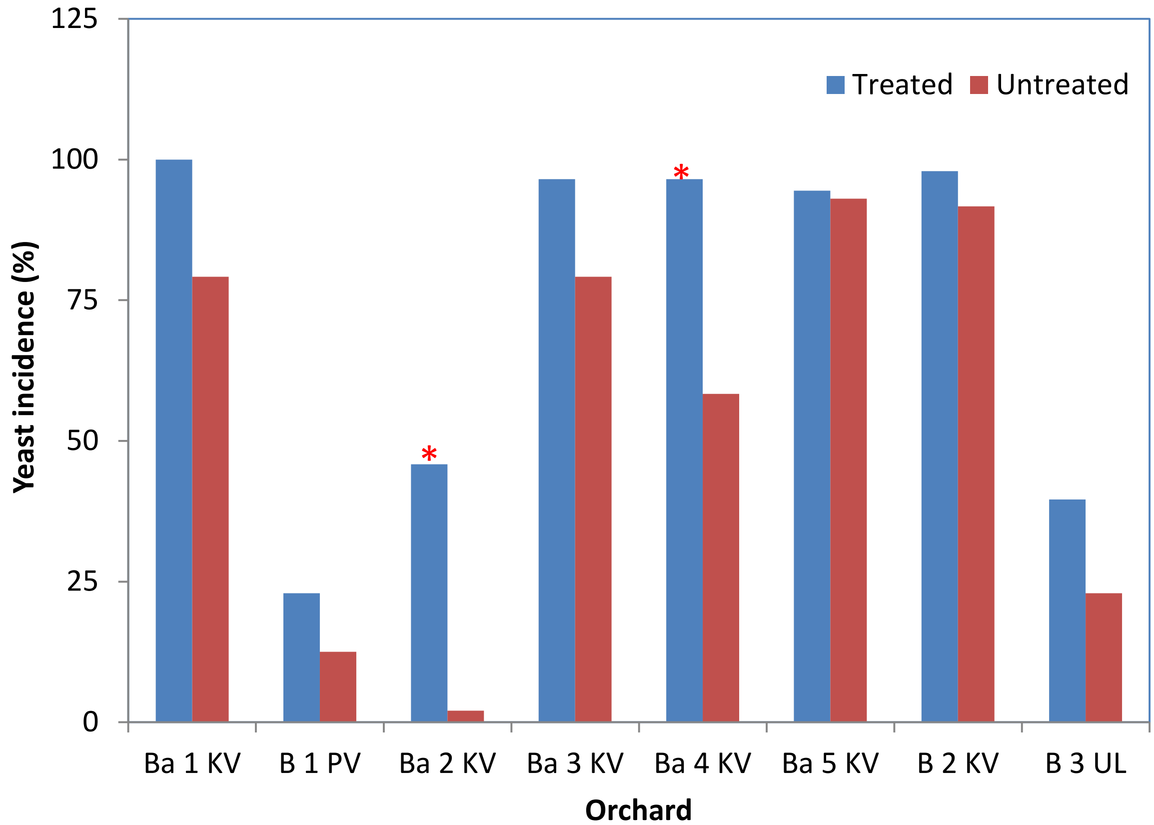

Figure 3. Incidence (% blossoms with colonies present) of *Aureobasidium pullulans* per 300 blossom clusters collected from Bartlett (5 orchards) or Bosc (3 orchards) pear trees, Lake and Mendocino Counties, California, April 2014.

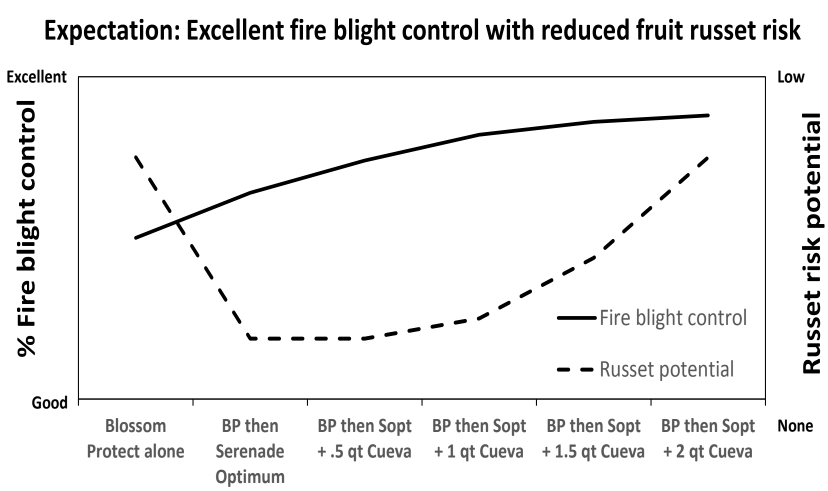

Figure 4. Concept of National Organic Program-approved biological control program for organic pears that provides excellent control of fire blight while minimizing russet risk. (USDA REEIS 2014).