FINAL PROJECT REPORT

Project Title: Evaluation of integrated fire blight control technologies

PI: Ken Johnson
Organization: Oregon State University
Telephone/email: 541-737-5249 johnsonk@science.oregonstate.edu
Address: Dept. Botany and Plant Pathology
Address 2: 2082 Cordley Hall
City: Corvallis
State/Zip OR 97331-2902

Cooperators:
Materials: Arysta Life Sciences, Syngenta

Other funding sources: None

Total Project Funding: $ 90,484

Budget History:

Item	**2009**	**2010**	**2011**
Salaries FRA 6mo	20,000	15,450	10,300
Benefits OPE 63%	12,600	9,734	6,489
Wages			
Benefits			
Equipment			
Supplies	4,000	3,800	2,111
Travel local	1,000	1,000	500
Plot fee	1,500	1,500	500
Miscellaneous			
Total	39,100	31,484*	19,900**

*Budget reduced from original proposal owing to shift of Obj. 4 to WTFRC Apple Crop Protection.
**Budget reduced from original proposal owing to near completion of objectives 1-3.

OBJECTIVES:

1. **Integrate a new material, Kasumin, for blossom blight control programs in conventional orchards.**
2. **Evaluate potential for the fire blight pathogen to become resistant to Kasumin.**
3. **Evaluate integrated biological/chemical control of fire blight with a spontaneous mutant of BlightBan C9-1 resistant to Kasumin.**
4. **Evaluate control of blossom blight with programs acceptable for fruit export to the European organic markets. (Apple crop protection funds)**
5. **Evaluate use of soil drenches of a systemic acquired resistance inducer as a fire blight management tool in diseased pear trees.**

SIGNIFICANT FINDINGS:

- The product Kasumin 2L (kasugamycin) provided outstanding control of fire blight of pear and apple; EPA registration is on track for 2012.
- Resistance management strategies for Kasumin -- i.e., mixtures with oxytetracycline and integration with biological control -- provided excellent fire blight control. These strategies should help to ensure longevity of the product.
- An effective non-antibiotic strategy for fire blight control of pear was developed. This strategy is being implemented for pears exported under the International Organic Program standard.
- Pot drenches and trunk paints of the SAR inducer, ASM (acibenzolar-*S* methyl), significantly slowed expansion of fire blight in inoculated shoots of potted 'Bosc' pear.
- In the field, ASM applied as a drench did not consistently slow the advance of running fire blight cankers, but an ASM paint used in combination with cutting of blight reduced the significantly the severity of 're-ignited' fire blight cankers.

RESULTS AND DISCUSSION

1) Integration of a new material, Kasumin, into blossom blight control programs for conventional orchards.

a) 2011 season. Treatments of Kasumin alone and in combination with other materials where tested in 2011, marking the fifth year of evaluation. Trees used in the 2011 study averaged 587 flower clusters per tree. Fire blight risk as determined by the COUGARBLIGHT model was low during the bloom period but disease intensity on inoculated trees was moderate with water treated trees averaging 78 blighted clusters per tree (14% of flower clusters) (Table 1). Each of the treatments significantly reduced ($P \leq 0.05$) incidence of infection and total number of infected flower clusters per tree compared to the water-treated control. Kasumin 2L and 8L (kasugamycin), Firewall (streptomycin), and Fireline (oxytetracycline) provided excellent disease control. The integrated program of Bloomtime in early bloom followed by Fireline (200 ppm), or a mix of Kasumin (100 ppm) and Fireline (50 ppm) at full bloom also provided excellent control. The pathogen inoculum used in the study was 50% streptomycin-resistant and 50% streptomycin-sensitive *E. amylovora*. Firewall (streptomycin) suppressed disease by 85%, whereas Kasumin 2L provided 93% control.

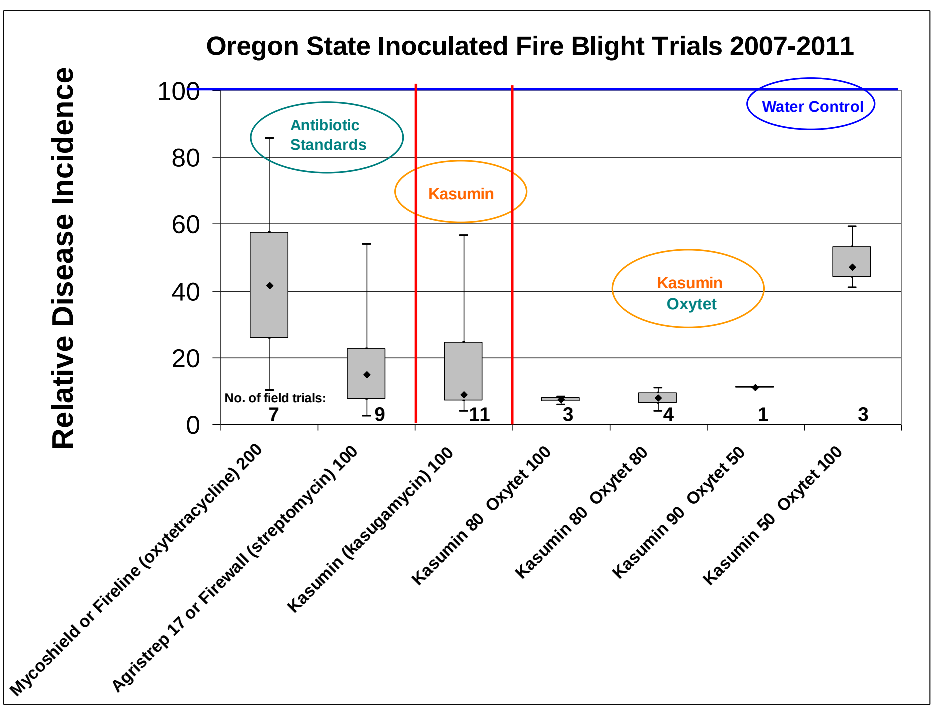
Table 1. Evaluation of Kasumin for suppression of fire blight of Gala apple, 2011

Treatment	Rate per 100 gallons water	Date treatment applied*: 4 May 30% bloom	6 May 70% bloom	10 May Full bloom	Number of blighted clusters per tree**	Percent blighted floral clusters ***
Water control	**------**	**X**[§]	**X**	**X**	**78 a**[#]	**14.1 a**[#]
Agri-mycin 100 ppm	8 oz.	---	---	X	13 b	2.1 b
Bloomtime then	5 oz.	X	X	---	10 bc	1.6 bc
Kasumin 2L 90 ppm	52 fl oz.	---	---	X		
plus Fireline 50 ppm	4 oz.	---	---	X		
Bloomtime then	5 oz.	X	X	---	8 bc	1.4 bc
Fireline 200 ppm	16 oz.	---	---	X		
Kasumin 8L 100 ppm	16 fl. oz.	---	---	X	8 bc	1.4 bc
Kasumin 2L 100 ppm	64 fl. oz.	---	---	X	5 c	1.0 c

* Trees inoculated on 9 May with 5×10^5 CFU/ml of a 50:50 mix of *Erwinia amylovora* strain Ea153N (streptomycin-sensitive) and strain Ea153S (streptomycin-resistant). ** 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 the same letter are not significantly different according to Fischer's protected least significance difference at P = 0.05.

b) Summary Kasumin field trials from 2007 to 2011. Over the period, a total of nine orchard trials in pear and apple were conducted. Data were summarized in box and whiskers plots as 'Relative Disease Incidence', which for each trial is the number of fire strikes in the Kasumin (or comparative)

Fig. 1



treatment divided by the number of fire strikes in the water-treated control (expressed as a percentage) (Fig. 1). The median response for Kasumin was > 90% control, which was equivalent to streptomycin (targeted to streptomycin sensitive strains of *E. amylovora*) and better than the median 58% control obtained with oxytetracycline. [Note: trials in 2007, 2008, and 2009 had two treatments of each antibiotic, and had trials in 2010 and 2011 had one treatment.]

Mixtures of Kasumin and oxytetracycline were evaluated as a resistance management strategy. Use of effective chemicals in mixes has long been advocated as a means to delay the resistance development in plant pathogens, and in fact, the original formulation of streptomycin registered in the 1950s was amended with 10% oxytetracycline for this purpose (van der Zwet & Keil 1979). In the mid-1960s, the oxytetracycline formulated into this premix was dropped (because it didn't contribute control). Resistance in *E. amylovora* to streptomycin was first reported in California in the early 1970s, 13 years after first registration, but only a few years after removal of the oxytetracycline. In considering mixtures to evaluate in this study, we wanted effective amounts of each material with an eye toward the cost of the mixture to the grower and also toward previous observations that Kasumin applied multiple times at higher rates has been phytotoxic to pear (Adaskaveg et al., 2011). Thus, 80 ppm of both Kasumin and oxytetracycline was tested, and although many other mixtures could be evaluated, this particular mixture provided excellent fire blight control. Over the series of trials, however, phytotoxic effects of Kasumin were not observed in any trial at any of the tested rates.

In 2011, we observed that a 90:50 (ppm K:O) mixture also was effective when oversprayed in an integrated program with Bloomtime Biological (*P. agglomerans* E325) whereas in previous trials a 50:100 (ppm K:O) was not (Fig. 1). Although not observed in this research, work by others researchers (T. Smith, *unpublished*; Ngugi et al. 2011) has shown Kasumin is slightly less effective than streptomycin (against sensitive strains) when tested under extreme disease pressure (high inoculum). Moreover, as shown in Fig. 1, the effective mixtures of Kasumin and oxytetracycline showed less variability in control than Kasumin alone. Mixtures containing Kasumin at full label (100 ppm) with a partial rate of oxytetracycline (e.g., 50 ppm) could be advisable in high disease pressure situations as both a resistance management strategy and as a treatment to enhance control.

When registered, Kasumin will enhance and broaden the effective tool box for conventional fire blight management. Kasumin is not used in human medicine, and shows no cross resistance to streptomycin or oxytetracycline. Kasumin is likely not absorbed into pear or apple tissue as readily as streptomycin, which is considered locally systemic. Analogous to oxytetracycline, sprays of Kasumin should be timed at full to late bloom beginning when moderate (as opposed to high) levels of disease risk have been forecasted.

Objective 2) Evaluate potential for the fire blight pathogen to become resistant to Kasumin and 3) Evaluate integrated biological/chemical control of fire blight with a spontaneous mutant of BlightBan C9-1 resistant to Kasumin).

These objectives were addressed by a graduate student, Andrew Hubbard, M.S. His thesis is online at: http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/21845/completed.pdf?sequence=6**.**

By first treating trees with a biological agent (BlightBan C9-1 or Bloomtime Biological) followed by Kasumin, an 'integrated strategy' reduces the likelihood of selection for kasugamycin-resistance in the pathogen. The mechanisms that reduce selection pressure are suppressed pathogen populations via competition with the biological agent and limitation of Kasumin use (e.g., to one application as opposed to the two applications often typical in commercial production). Over the

2007 to 2011 period, the orchard trials showed that there was no statistical difference between integrated control with Kasumin compared to Kasumin alone (Table 1 (above) and Table 2 (below)).

Table 2. **Integrated control with Kasumin and Kasumin-resistant BlightBan C9-1S**

		Fire blight strikes per tree
2009 Bartlett Pear	**Water**	**485 a**
	P.v. **C91S^{kr} then Kasumin**	**38 b**
	P.v. **C91S then Kasumin**	**42 b**
	Kasumin twice	**33 b**
2009 Gala & Golden Delicious Apple	**Water**	**132 a**
	P.v. **C91S^{kr} then Kasumin**	**18 b**
	P.v. **C91S then Kasumin**	**16 b**
	Kasumin twice	**8 b**
2010 Gala Apple	**Water**	**236 a**
	P.v. **C91S^{kr} then Kasumin**	**14 b**
	P.v. **C91S then Kasumin**	**16 b**
	Kasumin once	**20 b**

Means within cultivar and year followed by same letter are not significantly different according to Fischer's protected least significance difference at P = 0.05. Experiments conducted in orchards located near Corvallis, Oregon. ***Pantoea vagans*** **C9-1S^{Kr} is a kasugamycin-resistant selection of** ***Pantoea vagans*** **C9-1S (the organism in BlightBan C9-1 and related to** ***Pantoea agglomerans*** **strain 325 in Bloomtime Biological).**

We also hypothesized that use of Kasumin could have a negative impact on populations of the biological agent on flowers and that this effect could be overcome by use of a kasugamycin-resistant strain of *Pantoea vagans* strain C9-1S, thereby improving the efficacy of the biological component of the integrated strategy. In the field, data collected on disease incidence and on population sizes of the biological agents on flowers failed to support this hypothesis. For example, in the 2009 'Bartlett' pear experiment, during full bloom, incidence of recovery for both the Kasumin-sensitive and -resistance strains of *P. agglomerans* (sensitive = strain C9-1S; resistant = strain C9-1^{Kr}) averaged > 75% of sampled flowers, and the population size of these antagonists on flowers from which it could be recovered ranged from 10^4 to 10^5 CFU per flower (Fig. 1). (Note: this is in contrast to pathogen populations, which are strongly suppressed by the Kasumi overspray [data not shown]). The results indicate that non-target effects of Kasumin on 'sensitive' *Pantoea agglomerans* are relatively small, and thus, use of Kasumin 2-3 days after a biological treatment would be expected to have minimal impacts on populations of bacterial biological control agents. In this regard, the effect of Kasumin on non-target bacteria on flowers was more like that observed with oxytetracycline than observed with streptomycin.

Fig. 2. Strain C9-1S Strain C9-1Kr

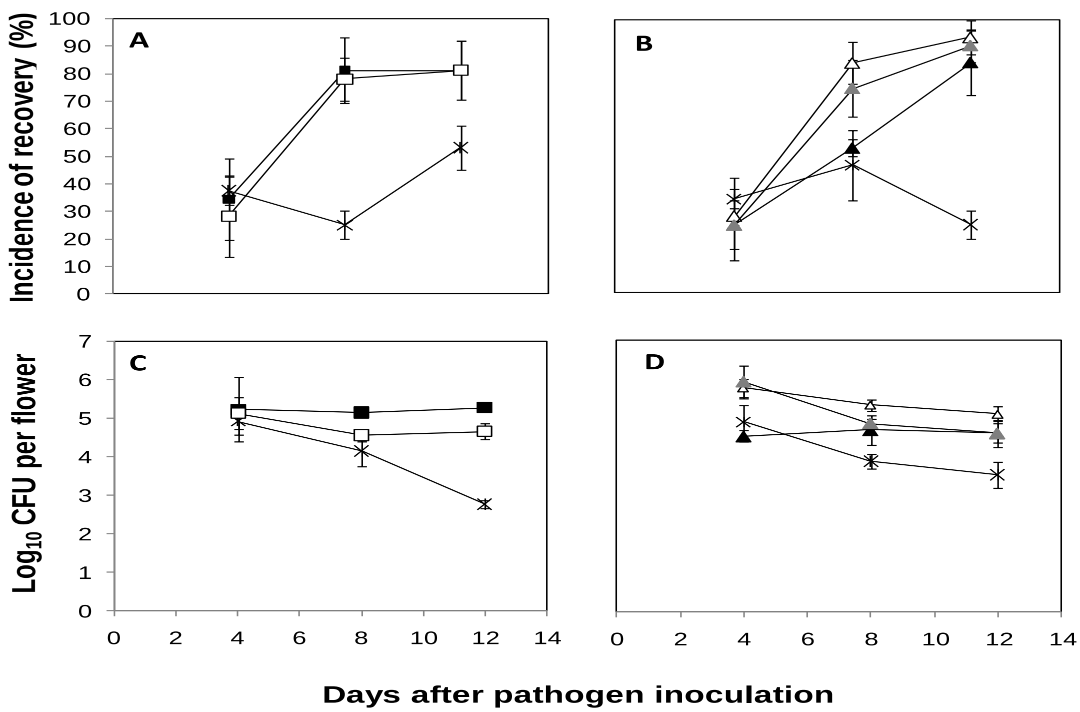


Fig. 2. Incidence of recovery (A, B) and population size (C,D) of *Pantoea vagans* strains C9-1S (A,C) and strain C9-1^{Kr} (B,D) on flowers of Bartlett pear treated with these bacterial antagonist and then oversprayed with antibiotics. The antagonist and antibiotic treatments were made in the context of integrated biological and chemical fire blight control and occurred in 2009 in an experimental orchard located near Corvallis, OR. Specific integrated antagonist strain and antibiotic treatments were: C9-1S with oxytetracycline (200 µg/ml, ■), C9-1S with Kasumin (100 µg/ml, □), C9-1^{Kr} with oxytetracycline (200 µg/ml ▲), C9-1^{Kr} with Kasumin 100 µg/ml (∆) and C9-1^{Kr} with oxytetracycline (80 µg/ml) and Kasumin (80 µg/ml, ▲). (∗) indicates each strain on water control.

In the years of this project, McGhee & Sundin (2011) characterized resistance in the fire blight pathogen to kasugamycin. Analogous to our results with biocontrol agent *Pantoea vagans*, selection of kasugamycin-resistant strains of the fire blight pathogen with the ability to grow at the maximum label rate of Kasumin (100 ppm) was observed to be a two-step mutation process (i.e., the initial selectable mutation (frequency 10^{-9} to 10^{-10} CFU) to resistant occurs at a sub-label rate (~50 ppm), then a second mutation is required for *E. amylovora* (or *P. vagans*) to achieve the ability to grow at 100 ppm (maximum label rate). In contrast, a spontaneous mutation in these bacteria to resistant to the maximum label rate of streptomycin is a one step process, and a spontaneous mutation to resistant to oxytetracycline has not been characterized (even from a laboratory selection process). Thus, because of the 2-step process, the risk of selecting resistance in *E. amylovora* to Kasumin is intermediate to the other registered antibiotics or fire blight control. Also analogous to our results, McGhee & Sundin (2011) found that kasugamycin had only minor effects on the non-target bacterial flora of apple flowers.

4) Evaluate control of blossom blight with programs acceptable for fruit export to the European organic markets.

Effect of frequency of treatment for integrated non-antibiotic control. In orchard trials, for both pear and apple, increasing the frequency of treatment of biological products improved fire blight control. For example, a stigma-colonizing *Pantoea agglomerans* product (Bloomtime Biological or BlightBan C9-1) applied at 30 and 70% bloom followed by two applications of the fermentation product of *Bacillus subtilis* QST 713 (Serenade Max) at full bloom and petal fall reduced the incidence of blighted flower clusters by an average of 71% (four orchard trials) compared to 47% when each component of this product combination was used only once.

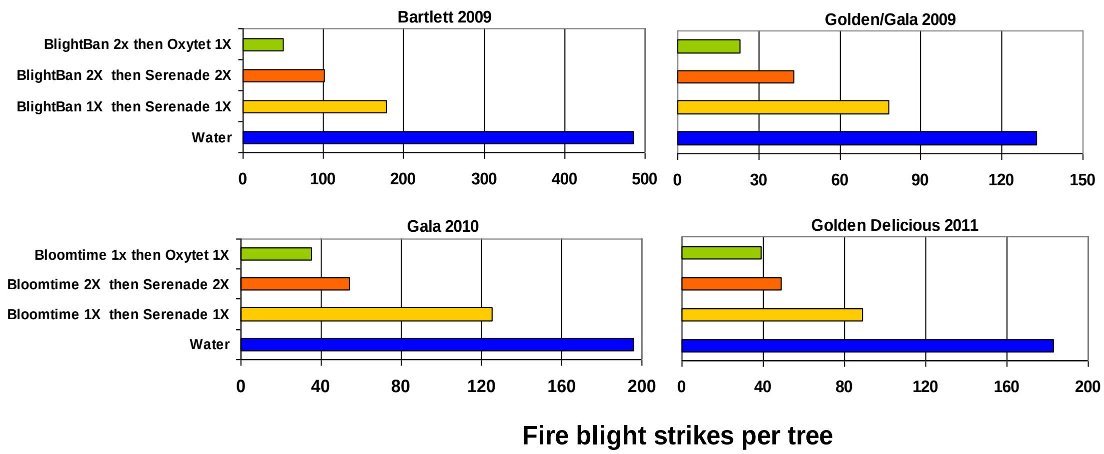


Fig. 3. Incidence of fire blight on pear and apple flower clusters as affected by integrated biological and antibiotic treatments in orchard trials conducted near Corvallis, Oregon from 2009 to 2011.

The integrated approach first demonstrated by Stockwell et al. (2008) and Lindow et al. (1996) utilized a gram negative bacterial antagonist (e.g. *P. agglomerans* and/or *Pseudomonas fluorescens*) to suppress the pre-requisite epiphytic phase of *E. amylovora* on floral stigmas followed by an oxytetracycline treatment later in bloom to prevent infection in the floral cup (nectary). The non-antibiotic program we modeled on this strategy involved substitution of the biological product, Serenade Max, for oxytetracycline. In this role, Serenade Max proved to be inhibitory to the fire blight pathogen, but obtaining levels of fire blight control closer to that achieved with oxytetracycline after a bacterial antagonist required doubling the frequency of application of the biological products (Fig. 2). This result indicates that non-antibiotic programs for fire blight will likely be more expensive than programs utilizing antibiotics because satisfactory disease control will require more treatments in the orchard. Spraying more often also means that orchardists will need to be more preventative in their approach to fire blight control (i.e., sprays required every few days) as opposed to reactive, where a single antibiotic spray could be applied based on an imminent infection event forecasted by a disease warning model (CougarBlight).

Obj. 5) Evaluate use of soil drenches of systemic acquired resistance inducers as a fire blight management tool in diseased pear trees.

a) Greenhouse studies on SAR induction. Greenhouse experiments were conducted in both 2009 and 2011 with Bosc pear. The experimental design was to inoculate the pathogen into the growing tip of the terminal shoot and then measure fire blight canker expansion through the summer. SAR treatments (drench. sprays, and paints of acibenzolar-*S* methyl (ASM)) were applied at inoculation, 1 month prior to inoculation, or one month after inoculation.

Drenches of ASM slowed expansion of running fire blight cankers in potted Bosc pear (Fig. 4 A, B). In non-treated trees, the canker expanded form the shoot tip to an average of halfway down the main trunk. In contrast, with the exception of the 1 mo delayed drench treatment in 2011, cankers on ASM-drenched trees expanded only a short distance into the woody trunk tissue; these trees remained alive and continued to produce new shoot growth. *Sprays* of ASM provided inconsistent responses with the treatments timed 'at inoculation' and 'delayed to one month after inoculation' providing a significant slowing of canker expansion in 2009, but with none of the spray treatments providing a significant reduction in 2011 (Fig. 4 C, D). *Paint* treatments of ASM (in 2011 only) slowed expansion of fire blight regardless of time of treatment; although between September 14 and October 20, running cankers on ASM painted trees tended to catch up with canker expansion on the untreated trees (Fig. 4 E).

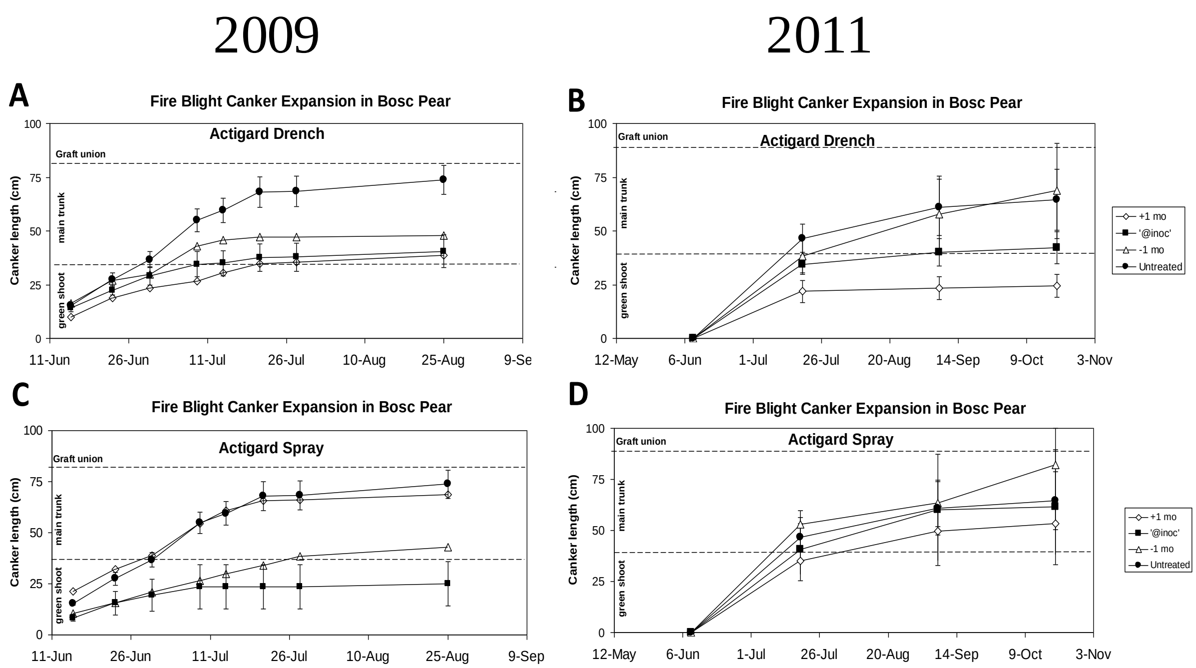
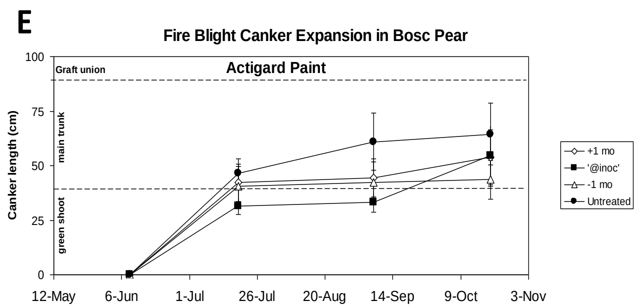


Fig. 4. Effect of a drench (A, B), foliar spray (C, D), or trunk paint (E) of the SAR-inducer, ASM, on expansion of fire blight cankers in greenhouse-grown 'Bosc' pear in 2009 & 2011. All trees were inoculated with the fire blight pathogen in early June. ASM treatments were made one month prior (+1 mo), at (@ inoc), or one month after inoculation (-1 mo). Rates of Actigard (50% ASM) were 50 mg/pot (drench), 500 (2009) or 450 (2011) mg/L to runoff (spray), and 30 g/L in 2% PentraBark (painted onto woody trunk tissue). Each point is the mean of 6 trees except the 'non-treated' points, which represent 10 trees. Lines drawn through each point are +/- one standard error of the mean.



b) Field studies on SAR induction in pear. Similar to the greenhouse experiments**,** the general approach was to inoculate pear trees with the fire blight pathogen (10^9 colony forming units per ml); inoculum was either placed onto flowers (2011 experiments) or onto cut terminal ends of growing shoots (2010). After running cankers were established in the trees, experiments with SAR-inducing treatments (drenches, sprays, paints, combinations, untreated control) were arranged randomly onto the diseased trees. Two types of experiments were performed: a) analogous to the greenhouse, measure the effect of ASM on expansion of running cankers, and b) measuring the severity of re-ignited cankers after removal (pruning) of disease symptoms. The pruning cuts to remove blight were made as *intentional short cuts* to ensure a high probability of canker re-ignition.

i. 2010 season: running cankers on 2-yr-old Bosc pear. Trees were inoculated on 9 June and ASM treatments were applied 23 June. A drench treatment combined with a foliar spray of ASM significantly slowed expansion of fire blight cankers. The final sizes of cankers in the drench/spray treatment were 33% smaller than in the untreated control (Table 3). Cankers on all trees stopped expanding in mid/late-July, which coincided with slowing of new shoot growth.

Table 3. Effect of ASM on length of fire blight cankers on 2-yr-old Bosc pear near Corvallis, OR in 2010.

Method of ASM application	Canker length (cm) Longest			Next longest			Total canker			Reps
Drench	22.4	±	3.5[#]	7.3	±	1.3	27.9	±	4.1	28
Paint	23.0	±	3.3	7.4	±	0.6	29.7	±	3.6	28
Spray + drench	**13.6***	±	**3.2**	**5.7**	±	**0.9**	**19.2***	±	**4.2**	**14**
Spray + paint	19.4	±	4.3	10.2	±	2.4	27.5	±	5.7	14
Untreated	22.6	±	5.1	8.2	±	2.7	28.4	±	6.1	14

[#] Standard error of the mean

* Significantly different ($P < 0.05$) from the untreated control as determined by t-test.

ii. 2011 season: Running cankers on 11-yr-old Bartlett pear. Trees were inoculated on 21 April. ASM treatments were applied on 2 June when canker length was 3- 8"; ASM treatments were repeated on 10 June. Diseased branches were 'harvested' on 17 August; data were recorded as strikes per tree and weight of diseased branches removed by pruning. ASM treatments applied to trees with running cankers did not result in a significant reduction of disease severity (Fig. 5).

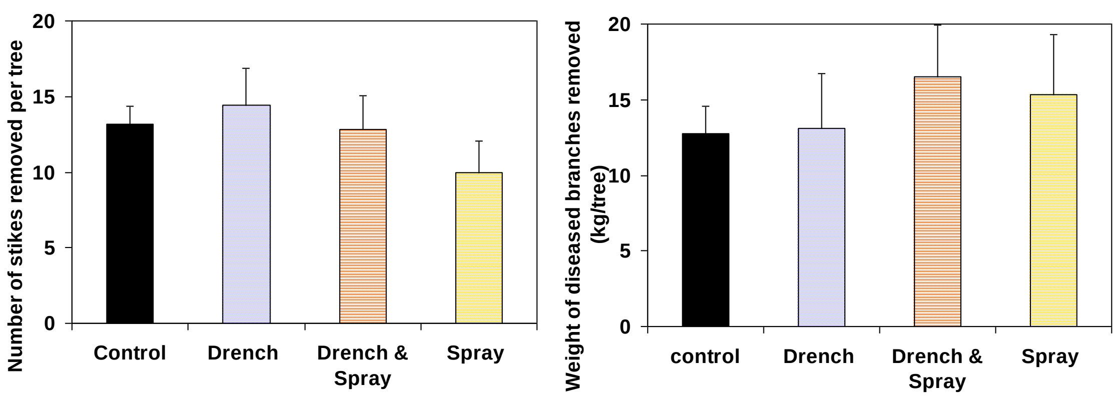


Fig. 5. Effect of drenches and sprays of the SAR-inducer, ASM, on severity of running fire blight cankers in 11-yr-old 'Bartlett' pear. Trees were inoculated with the fire blight pathogen in late April. Canker length was 3-8" on 2 June when they were treated with ASM in a drench (2 g Actigard in one liter poured into shallow collar dug around base of each tree) or sprayed (0.3 g Actigard per L sprayed to runoff (~3 L/tree)). Actigard treatments were repeated 10 June. Each bar is the mean of 5 trees arranged in a randomized complete block design.

iii. 2011 season: Pruned cankers on 11-yr-old Bartlett pear. This experiment was done in the same orchard block described under 'ii' above with a similar date of inoculation (4/22) and dates Actigard spray treatments (6/2 & 6/10). Treatments were 'Cut only' and 'Spray, cut and paint'. Cuts made 6 and 14 June and 8 July at 5 cm (2") below canker margin – ALL CUTS WERE INTENTIONAL SHORT CUTS to ensure a high probability that cankers would re-ignite.

Immediately after cutting, the ASM paint was applied to 25-30 cm (10-12") of symptomless branch below the cut. Compared to cut only, the severity of the re-ignited fire blight cankers was significantly reduced by the spray and paint combination of ASM treatments.

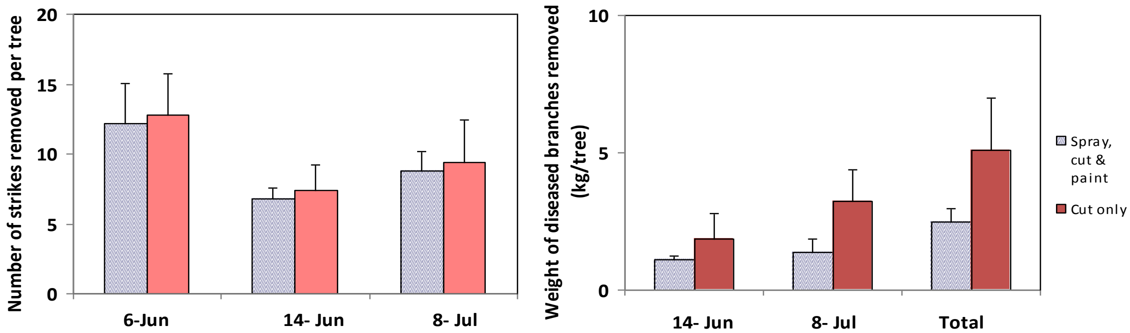


Fig. 4. Effect of branch paints and oversprays of the SAR-inducer, ASM, on re-ignition of fire blight cankers in 'Bartlett' pear. Trees were inoculated with the fire blight pathogen in late April. Canker length was 3-8" on 2 June when they were sprayed with ASM (0.3 g Actigard per L sprayed to runoff (~3 L/tree)); the spray was repeated 10 June. Fire blight cankers were cut 5 cm (2") below canker margin (intentional short cuts) on 6 and 14 June and 8 July. On 6 and 14 June, on sprayed trees, 25-30 cm of symptomless branch below each cut was painted with Actigard (30g/L) in 2% Pentrabark. Each bar is the mean of 5 trees.

iv. 2011 season: Pruned cankers on 2-yr-old Bosc pear. This experiment was planned to be a repeat of the 2010 Bosc pear experiment (described under 'i' above) but after initiating the cutting treatments in the Bartlett pear experiment (described under 'iii'), we decided to cut the fire blight out of the trees and then measure the severity of the re-ignited fire blight cankers. Flowers on trees were inoculated on 1 May. ASM treatments were applied on once June 6, and cankers were cut once on June 8 (an average of 20-25 cm (8-10") below margin of canker. Disease was allowed to re-ignite and severity of disease was assessed on 10 October as '% of the tree dead'.

After cutting once, severe running cankers re-ignited in most trees. The trees that received the ASM paint and the ASM spray/drench combination, however, showed reduced severity compared to the non-treated control, the drench and spray only treated trees.

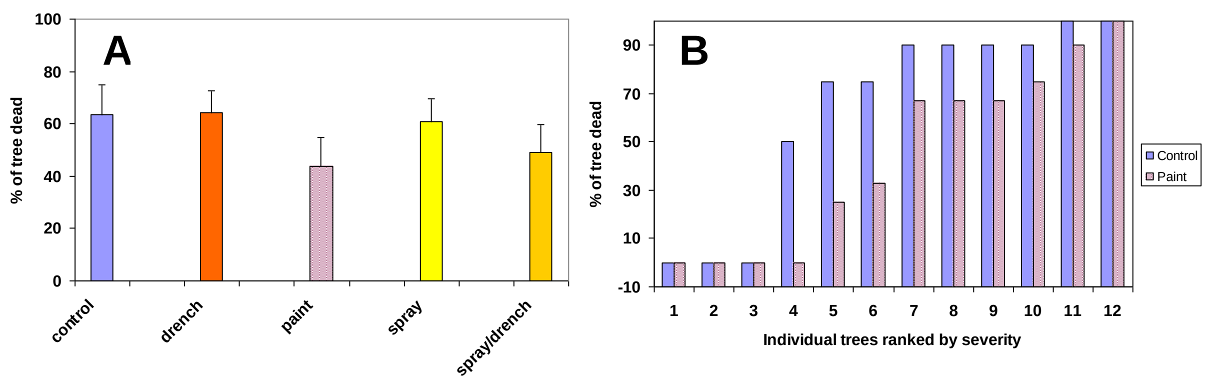


Fig. 4. Effect of a drench, spray, or paint of the SAR-inducer, ASM, on re-ignition of fire blight cankers in 'Bosc' pear. Trees were inoculated with the fire blight pathogen on 1 May. ASM treatments were applied on 6 June. ASM was applied as a drench (1 g Actigard in 500 ml poured into shallow collar dug around base of each tree), spray (0.45 g Actigard per L to runoff), or trunk paint (Actigard 30g/L in 2% Pentrabark). Cankers from the May inoculation were removed on 8 June; average canker length was 55 cm (22") at the time of removal. The percent of tree dead after canker re-ignition was assessed on October 8. A) Each bar is the mean and standard error of 12 trees; B) ranked comparison of the disease severity of individual ASM-painted trees to individual trees in the untreated control.

Discussion of SAR. Like apple, fire blight susceptible pear cultivars can respond to treatments of the SAR inducer, acibenzolar-*S* methyl (ASM), resulting in slowed canker expansion in diseased trees. The effect of ASM on suppression of fire blight was most dramatic when drenches were applied to potted greenhouse-grown trees. In contrast, drenches of ASM did not show a strong effect when applied in the orchard. Perhaps the confined root system in the pot allows for a more efficient uptake of ASM compared to drenches applied to field-grown trees, where the material was placed only at the base of the tree.

In the future, we intend to focus on branch and trunk paints in tree rescue-type treatments because this method of application provided the best responses in the field environment. Moreover, with greenhouse-grown apple (see 2012 apple crop protection report), trunk paints of ASM showed levels of PR-gene induction that were on par with the levels of induction achieved by pot drench. The measurement of PR-gene induction provides a marker on whether or not a SAR inducer is providing consistent induction of host defense genes. In contrast to pot drenches and trunk paints, foliar sprays showed a consistently low level of PR-gene induction.

For the body of data collected from pear and apple (see 2012 apple crop protection report), ASM treatments applied by paint and spray were most suppressive when the pathogen was present but the amount of active disease in the tree was small. For example, in the greenhouse, paint or spray treatments made at the time of inoculation (pathogen present, small amount of disease) were generally more effective that treatments made one month prior (no pathogen) or one month after inoculation (increased amount of disease). In the field, an ASM paint applied to symptomless branch below a cut canker provided a stronger response than trunk paints applied to trees where cankers were left to run.

For the reasons given above, ASM could prove practical as aid to cutting blight in pear, either reducing severity of re-ignited cankers (as demonstrated) or perhaps reducing the incidence of re-ignition. In this research, our rate of canker re-ignition was high because of intentional short cutting, which we deemed necessary to obtain consistent, measurable responses in a small plot experiment. A large commercial block with fire blight could provide a better test of the effect of ASM on canker re-ignition as the trees would be pruned properly and the larger scale of a commercial block would increase the number of cuts that receive the ASM treatment.

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EXECUTIVE SUMMARY

Project Title: Evaluation of Integrated Fire Blight Control Technologies

Investigator: Ken Johnson, Oregon State University

SIGNIFICANT FINDINGS:
Kasumin:

- The product Kasumin 2L (kasugamycin) provided outstanding control of fire blight of pear and apple; EPA registration is on track for 2012.
- Resistance management strategies for Kasumin -- i.e., mixtures with oxytetracycline and integration with biological control -- provided excellent fire blight control. These strategies should help to ensure longevity of the product.

Industry implications: When registered, Kasumin will enhance control and broaden the effective tool box for protection of pear flowers from fire blight in conventionally managed orchards. Kasumin is more effective than oxytetracycline, and we expect it to have a positive impact on fire blight management, particularly in high disease risk situations. The risk of resistance developing in the fire blight pathogen to Kasumin is intermediate to streptomycin (higher) and oxytetracycline (lower).

Organic fire blight control:

- An effective non-antibiotic strategy for fire blight control of pear was developed. This strategy is being implemented for pears exported under the International Organic Program standard.

Industry implications: The information we have been generating has been immediately implemented by growers in the International Organic Program (IOP). Furthermore, the issue of non-antibiotic control of fire blight has increased in importance because the USDA National Organic Program (NOP) has set a 2014 phase out (sunset) on use of streptomycin and oxytetracycline under the NOP standard.

Systemic acquired resistance:

- Pot drenches and trunk paints of the SAR inducer, ASM (acibenzolar-*S* methyl), significantly slowed expansion of fire blight in inoculated shoots of potted 'Bosc' pear.
- In the field, ASM applied as a drench has not consistently slowed the advance of running fire blight cankers, but an ASM paint used in combination with cutting of blight reduced the significantly the severity of 're-ignited' fire blight cankers.

Industry implications: Even with excellent products for prevention of fire blight, the disease still occurs and its clean-up can be difficult, especially in young orchards. Systemic acquired resistance (SAR) is an induced defense response in a tree, which when induced in pear and apple has the potential to slow/stop fire blight progression. Commercial products that induce SAR in pear have potential to be used as aids in cutting of fire blight to prevent re-ignition of advancing cankers and to enhance protective sprays when mixed with antibiotics.