Annual Report - 2025

EVALUATION OF NEW BACTERICIDES FOR CONTROL OF FIRE BLIGHT OF PEARS CAUSED BY *ERWINIA AMYLOVORA*

J. E. Adaskaveg, Department of Microbiology and Plant Pathology, University of California, Riverside CA 92521

Collaborators: H. Förster, L. Solari (UC Riverside) and C. Gonçalves, UCCE Lake & Mendocino Co.

ABSTRACT

1. **Antibiotic resistance**
   a. **Surveys** of *Erwinia amylovora* in California pear orchards were continued with 44 strains from 14 orchards in Sacramento, Lake, Mendocino, and Yolo Co. All strains were sensitive to kasugamycin and oxytetracycline. All 12 strains from one orchard in Sacramento Co. were moderately resistant to streptomycin, and 2 strains from a location in Mendocino Co. were highly resistant.
2. **Efficacy studies with new bactericides for management of fire blight.**
   a. In **laboratory studies with ornamental pear flowers**, Kasumin was numerically the most effective treatment, and low and intermediate rates of the new JAX formulation (EPL + cinnamaldehyde) performed statistically similarly.
   b. **Field trials** were conducted under high natural disease pressure on cv. Comice and using inoculation on cv. Shinko apple pear at UC Davis.

      The 8L formulation of Kasumin by itself or mixed with Vacciplant numerically resulted in the lowest incidence of blight in both studies. The NUP oxytetracycline formulation also reduced blight incidence to low levels in the cv. Shinko trial. Treatments with intermediate efficacy on cv. Comice included Curezin, Cinnerate, and the new JAX formulation, whereas on cv. Shinko, these included Curezin, Instill+ProBlad Verde, and JAX, as well as Blossom Protect. Therefore, under high disease pressure, alternative treatments to antibiotics with intermediate efficacy were identified.

      Efforts are underway to register the 8L Kasumin formulation as an organic treatment in cooperation with UPL. The JAX formulation needs to be further improved, and efforts are underway in collaboration with the potential registrant Summit Agro.

INTRODUCTION

Fire blight caused by the bacterium *Erwinia amylovora* is the most destructive disease of pome fruit trees worldwide, especially pears. In California, prolonged rat-tail bloom contributes to a long infection period and the difficulty of management. Few effective treatments are available. An integrated program with sanitation practices and applications of chemical and biological controls is the best approach. If the disease occurs at low

incidence, it may be eliminated by pruning. Regular aggressive pruning out of diseased tissue is essential for keeping inoculum levels low.

Current chemical control programs for fire blight are mostly based on protective treatments with antibiotics or copper. On Bartlett pears, copper treatments traditionally have been used only during the dormant and bloom periods because they can cause fruit russeting. Some newer formulations of copper, however, are labeled at lower metallic copper equivalent (MCE) and can be used after bloom without causing russeting. At low disease pressure, copper compounds can provide satisfactory disease control, and they can be an effective rotational or mix partner. At high disease pressure, however, copper generally fails to control fire blight at satisfactory levels. Therefore, copper is ranked as '+/++' in our UCIPM ratings indicating inconsistent performance depending on environmental conditions and disease pressure. In addition, we reported reduced copper sensitivity in strains of *E. amylovora* from pear that can also explain the moderate and inconsistent performance. Lack of systemic uptake and low registered rates are other factors contributing to low efficacy. However, copper in the new product Instill (soluble chelated copper sulfate pentahydrate) is thought to have some systemic properties.

Treatments with the antibiotics streptomycin (STR) and oxytetracycline (OXY) have been employed for many years to manage fire blight. This continued use and lack of effective alternative control materials resulted in resistance development to STR at many locations in California, mostly in Sacramento Co. Strains with moderate plasmid-based resistance and strains with chromosome-based high resistance have been identified. The incidence of STR resistance has been fluctuating widely among years, and this has been attributed to disease pressure and the intensity of STR use. Strains of *E. amylovora* with reduced sensitivity to OXY were found several times during our surveys. Starting in 2018, however, we detected strains with high resistance to this antibiotic for the first time at several locations in Sacramento Co. These strains were also highly resistant to STR, they were similarly virulent as sensitive strains, and they competed well in co-inoculation studies with sensitive strains. This is a serious concern, but it is not known if these resistant strains will persist in the field in the absence of selection pressure. We have not been able to re-sample the locations where we detected these resistant isolates but this should be done in 2026. We molecularly characterized this new resistance phenotype and demonstrated that tet, strA, and strB resistance genes were acquired by the novel conjugative IncX plasmid pX11-7. These results were published (Phytopathology 113:2165-2173). Resistance to kasugamycin that became available in California in 2018, however, has never been detected in our annual surveys.

Surveys on antibiotic resistance were continued in 2025, and samples were obtained from 14 orchards in Sacramento, Lake, Mendocino, or Yolo Co. Concerns have been expressed by regulatory agencies regarding the use of antibiotics in agriculture, but kasugamycin is not used in human or animal medicine and has a different mode of action from STR or OXY (no cross-resistance). In 2020, after 7 years of environmental resistance monitoring with no detected shifts in sensitivity among non-target bacteria, the EPA has suspended this requirement for the kasugamycin registration.

With the current emphasis on identifying alternative bactericides, we continued our evaluations of exempt-from-tolerance and potential organic compounds in 2025 (Table 1). These included the food preservative ε-poly-L-lysine (EPL) that was formulated as a mixture with cinnamaldehyde (JAX) by chemists of Summit Agro, a potential registrant. Other compounds evaluated were an extract from *Lupinus alba* (ProBlad Verde), cinnamon oil (Cinnerate), laminarin (Vacciplant that was mixed with kasugamycin), the copper compound Instill, and the biocontrol Blossom Protect. The biocontrol YSY was not evaluated again due to lack of efficacy in 2024 trials. The bacterial metabolite RAA had shown good efficacy in previous trials. The registrant indicated that enough data were acquired to obtain a registration on pome fruits and instead, wanted us to do studies on other bacterial tree diseases. Kasugamycin was evaluated as the new 8L formulation that contains organically approved ingredients. All these potentially could qualify as biopesticides with the EPA and ultimately as organic compounds that could be OMRI certified. Treatments evaluated in 2025 are shown Table 1. Therefore, we continue to try to improve their efficacy by using selected additives. Our goal is to develop effective rotational programs for organic farming practices with the use of copper, biologicals, and innovative strategies such as registering food preservatives and OMRI-approved natural products. We also will work on conventional programs with the use of antibiotics alone or in mixtures with copper, dodine, biologicals, or natural products during bloom or as cover sprays during early fruit development.

Table 1. Bactericides evaluated in studies on fire blight 2025

Category	FRAC Code	Active ingredient	Trade name/Code
Antibiotics	24	kasugamycin	Kasumin 2L, 8L
	41	oxytetracycline	NUP-17010
Natural products	BM 01	cinnamaldehyde	Seican
	BM 01	cinnamaldehyde + EPL	JAX
	BM 01	cinnamon oil	Cinnerate
	BM 01	*Lupinus alba* extract	ProBlad Verde
	BM 01	laminarin	Vacciplant
Biocontrols	BM 02	*Aureobasidium pullulans*	Blossom Protect
Food preservative	---	ε-poly-L-lysine, EPL	food additive
Other antimicrobials	M01	Soluble chelated copper sulfate pentahydrate	Instill
	U12	dodine	Syllit
	P07/33 + M01	phosphite + copper + zinc	Curezin
Adjuvants	---	---	Triggr
	---	---	Cogent

OBJECTIVES

1. Continue resistance surveys for streptomycin, oxytetracycline, and kasugamycin in *E. amylovora* populations from pear orchards in California.

a) Collaborate with farm advisors, PCAs, and growers to provide us fire blight samples.

2. Evaluate and optimize the performance of antibiotics, new formulations of copper, natural products, biocontrols, and GRAS food additives in combination with adjuvants. Treatments identified as effective in small-scale laboratory studies will be included in field studies.
    a) Kasumin, Kasumin-organic, and new formulations of oxytetracycline (NUP) in combination with dodine (Syllit), Vacciplant (laminarin), or copper sulfate.
    b) Low-copper concentration products such as copper sulfate pentahydrate (Instill, MasterCop) and copper octanoate (Cueva) in mixtures with antibiotics, as well as Curezin (Cu+Zn+Phosphite) and Selectrocide (old name =Virus Shield (ClO_2).
    c) New formulations of ε-poly-L-lysine (EPL) in combination with essential oils (Cinnerate), or cinnamaldehyde (e.g., JAX A+B, JAX-D).
    d) FDA GRAS plant extracts from *Lupinus albus* (ProBlad Verde), cinnamaldehyde (Seican), cinnamon oil (Cinnerate), thyme oil (ThymeGuard), a soap bark tree extract (BTS), and an *Acacia* sp. extract (QAM). Some of these are already OMRI-certified.
    e) New biocontrols derived from yeasts (YSY) or bacteria and bacterial fermentation products (such as the metabolite RAA).

MATERIALS AND METHODS

Isolation and culturing of *E. amylovora*. Samples with fire blight symptoms were obtained in early summer of 2025 from four pear orchards in Sacramento Co.,
eight orchards in Lake Co., and one orchard each in Mendocino and Yolo Co. Infected fruit, peduncles, and twigs were cut into small sections and incubated in 1 ml of sterile water for 15 to 30 min to allow bacteria to diffuse out of the tissue. Suspensions were streaked onto yeast extract-dextrose-$CaCO_3$ agar, and single colonies of *E. amylovora* were transferred. A total of 44 strains were obtained and evaluated for their sensitivity to antibiotics.

Laboratory studies on the toxicity of bactericides against *E. amylovora*. Using the spiral gradient endpoint method, radial concentration gradients of STR, OXY, or kasugamycin were established in nutrient agar by spirally plating stock concentrations of each antimicrobial using a spiral plater. After radially streaking out suspensions of the test bacteria (10 µl of 10^8 cfu/ml as determined by measuring optical density at 600 nm) along the concentration gradient, plates were incubated for 2 days at 25ºC. Measurements were taken visually for the minimal concentration that inhibited growth by >95% (MIC). The actual antibiotic concentrations were obtained by entering the radial distances of inhibition (measured from the center of the plate) into the Spiral Gradient Endpoint computer program.

Evaluation of new bactericide treatments. Preliminary early-season studies focusing on mixtures containing EPL including a newly formulated product (JAX) were conducted in the laboratory on flowering ornamental pear (*Pyrus calleryana*). Twigs were placed into 100-ml Erlenmeyer flasks containing water with 20 ppm gibberellic acid (to delay senescence), treated using an air-nozzle hand sprayer, allowed to air-dry for 12 h, and were spray-

inoculated with *E. amylovora* ($5x10^6$ cfu/ml). The incidence of fire blight was determined after 4 days based on the number of blackened flowers of the total number of flowers.

Comparative field studies on the efficacy of protective treatments were conducted on cvs. Shinko apple-pear and Comice pear at UC Davis. Two or three applications were done with timings based on temperature, rainfall, and host development. Treatments included the new JAX formulation and other natural products (e.g., Cinnerate, ProBlad Verde, Vacciplant), a new formulation of copper (Instill) and copper/zinc/phosphite (Curezin), and a biocontrol (Blossom Protect). These treatments were used by themselves or in mixtures to develop integrated programs for resistance management and were compared to the new 8L formulation of Kasumin that contains organically approved ingredients or to the NUP formulation of oxytetracycline. Incidence of fire blight was based on the number of flower or fruitlet clusters with disease of the total number of clusters evaluated. Potential phytotoxic effects of the treatments (e.g., fruit russeting) were also evaluated. Treatments were replicated on four trees. Data were analyzed using analysis of variance and LSD mean separation procedures of SAS 9.4.

RESULTS AND DISCUSSION

Survey of antibiotic sensitivity in *E. amylovora* strains from pear in California in 2025. A total of 44 19 strains of *E. amylovora* were obtained from 14 locations in Sacramento, Lake, Mendocino, and Yolo Co. All were sensitive to OXY and kasugamycin (Table 2). All 12 strains from one of the four locations in Sacramento Co. were all moderately resistant to STR, the two strains from an orchard in Mendocino Co. were highly resistant, whereas all other strains were sensitive to STR. Thus, this limited survey with mostly three or fewer strains obtained from each location indicates that STR resistance persists in pear growing regions in California. OXY resistance was not detected, and together with all our previous annual surveys, *E. amylovora* populations

Table 2. Sensitivity of *E. amylovora* strains from pear orchards in California to streptomycin, oxytetracycline, and kasugamycin in 2025

County	Orchard No.	No. isolates	In vitro sensitivity (MIC)		
			Streptomycin	Oxytetracycline	Kasugamycin
Sacramento	1	13	S	S	S
	2	1	S	S	S
	3	1	S	S	S
	4	12	MR	S	S
Lake	1	2	S	S	S
	2	1	S	S	S
	3	1	S	S	S
	4	2	S	S	S
	5	1	S	S	S
	6	3	S	S	S
	7	3	S	S	S
	8	1	S	S	S
Mendocino	1	2	HR	S	S
Yolo	1	1	S	S	S
total	14	44			

Sensitivity to the three antibiotics was determined using the spiral gradient endpoint method.

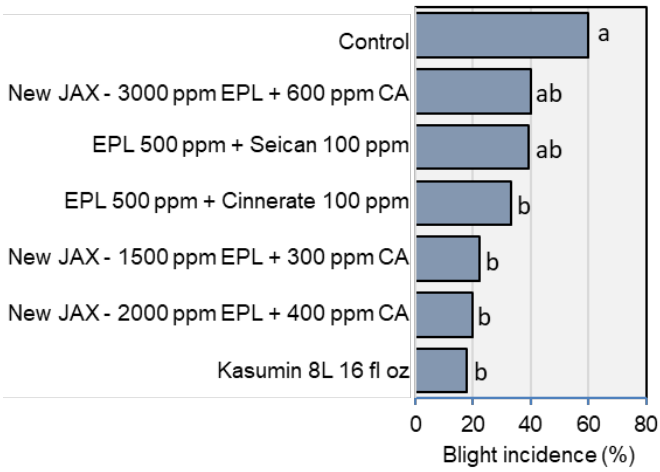
MIC rating:

S: MIC = 0.6 - 1.4 ppm
MR: MIC = 20-30 ppm
HR: MIC = >100 ppm

are all sensitive to kasugamycin. Using resistance management practices with rotational and mixture treatment programs with different bactericides and limiting the number of applications of each bactericide to two per season if possible will help to prevent the spread of resistance and the development of new resistance genotypes. New alternatives (e.g., early-season copper, biologicals) should be used, and new treatment options should be continued to be developed.

Laboratory studies with ornamental pear flowers to evaluate new bactericide treatments. In an early-season laboratory study with ornamental pear flowers, the new JAX formulation of EPL+cinnamaldehyde was compared to our own EPL-cinnamaldehyde or -cinnamon oil mixtures and to the 8L formulation of Kasumin. After 4 days, 60% of untreated flowers showed symptoms of blight (Fig. 1). Kasumin was numerically the most effective treatment with 17.8% incidence, but the low and intermediate rates of JAX were statistically similarly effective (22.2% and 20.0% incidence, respectively). These promising results were used to design the treatment lists for our field trials later in the spring.

Fig. 1. Efficacy of bactericides for management of fire blight of ornamental pear flowers in laboratory studies, 2025

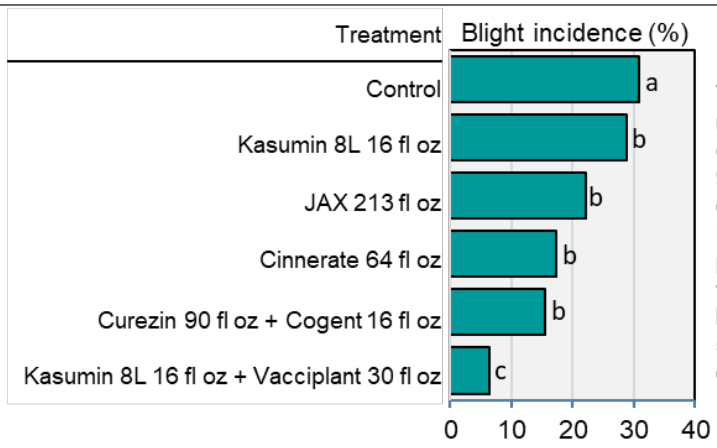


Flowering twigs of ornamental pear (*Pyrus calleryana*) were placed into 100-ml Erlenmeyer flasks containing water with 20 ppm gibberellic acid. Flowers were treated using a hand sprayer and were spray-inoculated with *E. amylovora* after 12 h. Twigs were covered with plastic bags, and the incidence of fire blight was determined after 4 days based on the number of blackened flowers of the total number of flowers evaluated. CA = cinnamaldehyde.

Field studies to evaluate new bactericide treatments. A trial could not be conducted in the commercial Bartlett orchard that we used in numerous previous seasons. Therefore, limited information could be obtained in field studies in 2025. Another commercial pear orchard, however, was identified for our studies in 2026.

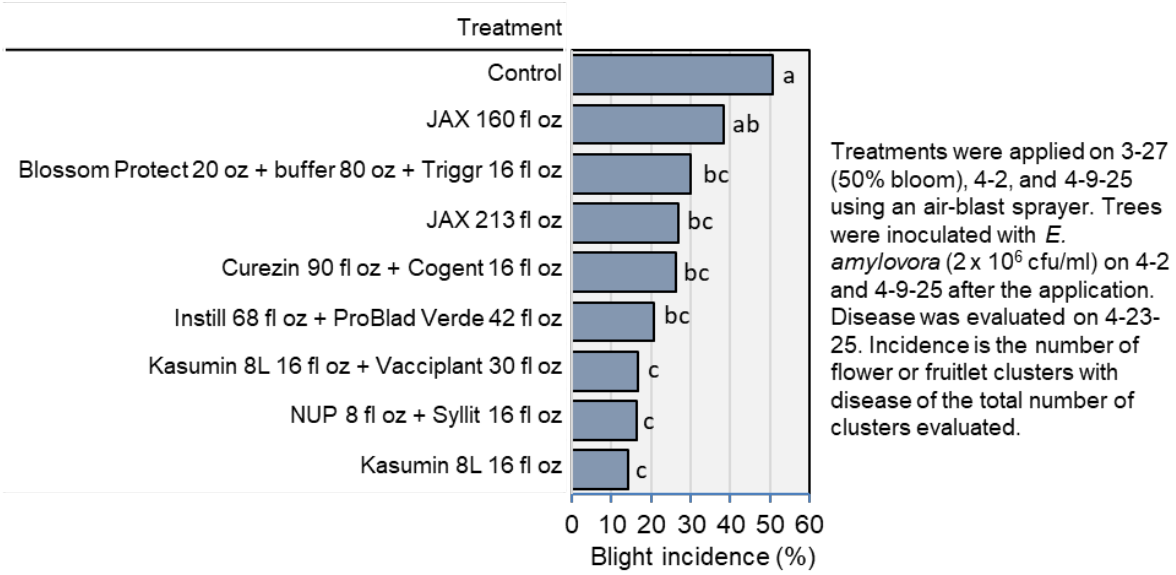
In both studies at UC Davis on cv. Comice (natural disease incidence) and cv. Shinko apple pear (trees were inoculated), average blight incidence on control trees was 30.8% and 50.6%, respectively (Figs. 2,3). Treatments with the 8L formulation of Kasumin by itself or mixed with Vacciplant numerically resulted in the lowest incidence of blight in both studies. Kasumin-Vacciplant (laminarin) was significantly more effective than Kasumin by itself on cv. Comice (Fig. 2), but both treatments performed similar on cv. Shinko (Fig. 3). The NUP oxytetracycline formulation also reduced blight incidence to low levels in the cv. Shinko trial. Treatments with intermediate efficacy in the cv. Comice trial included Curezin, Cinnerate,

Fig. 2. Efficacy of new bactericides for management of fire blight of cv. Comice pear in a field study at UC Davis 2025



Treatments were applied using an air-blast sprayer on 4-3 (50% bloom) and 4-9-25. Disease was evaluated on 4-15-25. Incidence is the percentage of diseased flower clusters with at least one infection of 25-50 clusters evaluated on each tree.

Fig. 3. Efficacy of bactericides for management of fire blight of cv. Shinko apple pears after inoculation, UC Davis, 2025



Treatments were applied on 3-27 (50% bloom), 4-2, and 4-9-25 using an air-blast sprayer. Trees were inoculated with *E. amylovora* (2 x 10^6 cfu/ml) on 4-2 and 4-9-25 after the application. Disease was evaluated on 4-23-25. Incidence is the number of flower or fruitlet clusters with disease of the total number of clusters evaluated.

and the new JAX formulation, whereas in the cv. Shinko study, these included Curezin, Instill+ProBlad Verde, and JAX, as well as Blossom Protect. Curezin and Instill+ProBlad Verde also resulted in intermediate efficacy in our commercial field trial on cv. Bartlett in 2024. Therefore, under high disease pressure, alternative treatments to antibiotics with intermediate efficacy were identified. More frequent applications of these bactericides, especially under lower disease pressure, would probably be more effective.

Conclusions. JAX, Curezin, and Instill+Problad Verde were identified as new alternative treatments to antibiotics with commercially acceptable efficacy in reducing fire blight in our 2025 trials. Similar results were also obtained in our studies on fire blight of apple, supporting our results on pear. Blossom Protect+Buffer continued to perform with intermediate efficacy. Overall, Kasumin 8L, as well as the 45% NUP oxytetracycline formulation, however, were

the most consistently effective new treatments. Efforts are underway to register the 8L Kasumin formulation as an organic treatment in cooperation with UPL. This would be a big benefit for organic pear production. Kasumin use (currently the 2L formulation) is restricted to a maximum of four applications per season (no more than two consecutive applications) and is recommended in mixture with another bactericide to help minimize the risk for resistance development.

The JAX formulation needs to be further improved, and efforts are underway in collaboration with the potential registrant. In 2024, we also identified an odorless formulation of chlorine dioxide (Selectrocide; old name VirusShield) as a potential effective alternative that is organically approved. This product can again be evaluated in 2026 with a new registrant, SMT. New alternative treatments need to be continued to be evaluated for their efficacy and consistency as compared to conventional antibiotics under different environmental conditions with ultimate registrations in the United States as organically approved bactericides.