

Annual Report - 2023

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

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ABSTRACT

1. Antibiotic resistance

- a. **Surveys** of *Erwinia amylovora* in California pear orchards were continued with 82 strains obtained from 11 orchards in Lake, Sacramento, and Yolo Co. The incidence of resistance to streptomycin was moderate in 2023. Among 76 strains from Sacramento Co., there were 2 with high and 38 with moderate resistance. Three strains from Yolo Co. were moderately resistant, whereas the 3 from Lake Co. were sensitive to the bactericide. All strains were sensitive to kasugamycin and oxytetracycline.

2. Efficacy studies with new bactericides for management of fire blight.

- a. In **in vitro studies**, a mixture of EPL and cinnamaldehyde (Seican) was found to be synergistic: EPL at 500 ppm was not inhibitory, but when mixed with cinnamaldehyde at 100 ppm, growth of *E. amylovora* was completely inhibited.
 - b. In **laboratory studies with ornamental pear flowers**, non-formulated EPL significantly reduced the incidence of fire blight from the untreated control but JAX-1 (cinnamaldehyde + EPL) at 16, 32, or 48 fl oz significantly improved the efficacy from that of EPL alone, and the high rates were similar in efficacy to Kasumin. Mixtures of EPL, KFD 623, and JAX-1 with Syllit were also statistically similar to Kasumin.
 - c. In **laboratory studies to evaluate a new method for preparing bactericide solutions**, water was supplemented with tiny air bubbles creating a nanobubble formulation. This method, however, did not improve the performance of EPL or FireWall in reducing blossom blight of ornamental pear flowers.
- ##### 3. Field trials on the management of fire blight
- were conducted under low natural disease pressure at a commercial Bartlett pear site or under high disease pressure in field inoculation studies with Comice pear and apple pear at UC Davis.
- a. In the Bartlett study, all treatments were effective in reducing blight from the control. The most effective ones included mixtures of Kasumin with Syllit, the experimental bacterial metabolites RAA-A and RAA-B, JAX-1, QAM + Dart, Cinnerate, and KFD 622 or KFD 623 mixed with Syllit and ManniPlex Zn, as well as the NUP17010

formulation of oxytetracycline. Kasumin use is now 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.

- b. After inoculation of Shinko apple-pear, Serenade and Alum were statistically similar to the untreated control with high levels of disease. The most effective treatments were Thyme Guard, Blossom Protect, Firewall 50WP, Oxidate 5.0 and JAX-1. On Comice pear, mixtures of FireLine 45, JAX-1, and Kasumin with Syllit significantly reduced the natural incidence of blight from the control.

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. Fire blight is very difficult to manage, and few effective treatments are available. Integrated programs with sanitation practices and applications with chemical and biological controls are the best approaches. If the disease occurs at low incidence, it may be eliminated by pruning. Thus, 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 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 applications generally fail to control fire blight at satisfactory levels. Therefore, copper is ranked as '+/++' in our UCIPM ratings indicating inconsistent performance depending on environmental conditions. In addition, we reported reduced copper sensitivity in strains of *E. amylovora* from pear that can also explain the moderate and inconsistent performance of copper. Lack of systemic action and low registered rates are other factors contributing to low efficacy.

Treatments with the antibiotics streptomycin (STR) and oxytetracycline (OXY) have been employed for many years to manage fire blight. Continued use for many seasons and lack of alternative control materials resulted in resistance to develop against 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 from very low to very high levels, 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 found to be similarly virulent and competitive as wildtype strains. The highly OXY-resistant 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 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. A manuscript describing this is in press in *Phytopathology*.

Surveys on antibiotic resistance monitoring were continued in 2023 in collaboration with farm advisors, PCAs, and the CA Pear Board. Samples were obtained from Lake, Sacramento, and Yolo Co. Isolates resistant to STR were mostly found in Sacramento Co. with 2 HR and 38 MR isolates. Resistance to OXY (Mycoshield, FireLine) and kasugamycin (Kasumin) was not found in our 2023 survey. Although OXY resistance has been found in Sacramento Co. orchards since 2018, resistance to kasugamycin has never been detected in our surveys. Kasumin became available for use in 2018 in California. 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.

Table 1. Bactericides and additives evaluated in studies on fire blight 2023

| Category | FRAC Code | Active ingredient | Trade name/Code |
|----------------------|-----------|---|--------------------------------------|
| Antibiotics | 24 | kasugamycin | Kasumin 2L |
| | 41 | oxytetracycline | FireLine 45, Mycoshield NUP-17010 |
| | 25 | streptomycin | FireWall |
| Natural products | BM 01 | <i>Acacia</i> sp. bark extract | QAM |
| | BM 01 | bacterial metabolite | RAA-A |
| | BM 01 | bacterial metabolite | RAA-B |
| | BM 01 | capric/caprylic acids | Dart |
| | BM 01 | cinnamaldehyde | Seican |
| | BM 01 | cinnamaldehyde + EPL | JAX-1 |
| | BM 01 | cinnamon oil | Cinnerate |
| | BM 01 | potassium aluminum sulfate | Alum |
| | BM 01 | thyme oil | Thyme Guard |
| Biocontrols | BM 02 | <i>Aureobasidium pullulans</i> | Blossom Protect |
| | BM 02 | <i>Bacillus subtilis</i> QST 713 | Serenade ASO |
| Food preservatives | --- | nisin | food additive |
| | --- | KFD-622-NSN (formulated nisin) | food additive |
| | --- | ϵ -poly-L-lysine | food additive |
| | --- | KFD-623-EPL (formul. ϵ -poly-L-lysine) | food additive |
| Other antimicrobials | U12 | dodine | Syllit |
| | --- | water-soluble zinc | Manniplex Zn |
| | --- | peroxyacetic acid | Oxidate |

With the current emphasis on identifying alternative bactericides, we continued our evaluations of exempt-from-tolerance and potential organic compounds in 2023 including the food preservatives ϵ -poly-L-lysine (EPL) and nisin as non-formulated technical compounds and agricultural formulations. Other products evaluated in 2023 field trials include the biocontrols Blossom Protect and Serenade, the natural products Thyme Guard, Cinnerate, and Dart; the experimental QAM, the fungicide Syllit, and Alum (Table 1). The essential oil product cinnamaldehyde (Seican) alone or in combination with EPL (JAX-1) was evaluated in in vitro, laboratory, and field studies.

OBJECTIVES

1. Continue resistance surveys for streptomycin, oxytetracycline, and kasugamycin in *E. amylovora* populations from pear orchards in California.
 - a) Determine the antibiotic sensitivity of strains of *E. amylovora* provided by farm advisors, PCAs, and growers
 - b) Characterize antibiotic resistance on a molecular basis.
2. Evaluate and optimize the performance of antibiotics, new formulations of copper, as well as new natural products, GRAS food additives, biocontrols, and additives in laboratory and field studies. Treatments identified as effective in small-scale studies will be included in field studies.
 - a) Kasumin in combination with exempt-from-tolerance antimicrobials including copper sulfate.
 - b) Oxytetracycline – new formulations of Mycoshield and FireLine with selected adjuvants or additives to increase overall efficacy.
 - c) Low-copper concentration products such as copper sulfate pentahydrate (MasterCop) and copper octanoate (Cueva) alone and in mixtures.
 - d) New formulations of ϵ -poly-L-lysine and nisin in combination with capric/caprylic acids (Dart), essential oils (Cinnerate), or cinnamaldehyde (Seican).
 - e) The new FDA GRAS bactericide TDA-NC-1, aluminum potassium sulfate (Alum), cinnamaldehyde (Seican), and new essential oils (Cinnerate). The latter two are OMRI-certified.
 - f) New biocontrols have been promised but not disclosed to us for evaluation in the 2023 season.
 - g) Novel methods to prepare bactericide spray solutions will be evaluated in collaboration with a commercial company (Moleaer, Inc.).

MATERIALS AND METHODS

Isolation of *E. amylovora* and bacterial culturing. Samples with fire blight symptoms were obtained in the spring and early summer of 2023 from 7 pear orchards in Sacramento Co., 3 orchards in Lake Co., and 1 orchard in Yolo Co. Infected plant materials (fruit, peduncles, 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-CaCO₃ agar, and single colonies of *E. amylovora* were transferred. A total of 82 strains were obtained and evaluated for their sensitivity to antibiotics.

Laboratory studies on the toxicity of bactericides against *E. amylovora*. STR, OXY, and kasugamycin were evaluated for their in vitro toxicity using the spiral gradient endpoint method. For this, a radial bactericidal concentration gradient was established in nutrient agar in Petri dishes by spirally plating a stock concentration of each antimicrobial using a spiral plater. After radially streaking out suspensions of the test bacteria (10 µl of 10⁸ cfu/ml as determined by measurement of optical density at 600 nm) along the concentration gradient, plates were incubated for 2 days at 25°C. 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.

Several of the new bactericides including cinnamaldehyde, and mixtures of cinnamaldehyde with EPL or nisin were also evaluated for their in vitro toxicity against *E. amylovora* in amended agar studies where the pathogen was in continuous contact with the test substance. A suspension of *E. amylovora* was streaked on the agar surface, and growth was rated after 2 days of incubation at 25°C as '+++ = growth similar as on non-amended agar, '++ = some growth inhibition, '+' = growth inhibited by >80%, and '-' = growth completely inhibited.

Molecular analysis of high STR-OXY resistant strains of *E. amylovora*. High molecular-weight genomic DNA was submitted to long- and short-read whole-genome sequencing. Genomes were assembled and annotated, and sequences were compared with known plasmids.

Studies on the evaluation of new bactericide treatments. Preliminary early-season studies focusing on EPL, EPL + cinnamaldehyde (JAX-1), and nisin 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, and were spray-inoculated with *E. amylovora* (5x10⁶ cfu/ml). The incidence of fire blight was determined after 5 days based on the number of blackened flowers of the total number of flowers. Nanobubble formulations of EPL and FireWall were prepared in collaboration with a commercial company.

In a field trial in a commercial cv. Bartlett orchard in Live Oak, treatments (see Fig. 2) were done using an air-blast sprayer at 100 gal/A on 3-30 (white tip, 5% bloom), 4-11, and 4-18-23. There were four single-tree replications per treatment. The natural incidence of fire blight was evaluated on 5-5-23. New bactericide alternatives were evaluated on Comice pear and Shinko apple pear at UC Davis. On Comice pear, treatments (see Fig. 3) were applied using an air-blast sprayer on 4-12 and 4-18-23. Blight incidence on 5-8-23 was based on the number of flower/fruit clusters with disease of the total number of clusters evaluated. In the trial on Shinko apple pears, treatments (see Fig. 4) were applied using an air-blast sprayer on 3-23 (20-50% bloom) and 3-28-23. Trees were inoculated on 3-25-23 with *E. amylovora* (10⁶ cfu/ml and 2x10⁶ cfu/ml, respectively) after the first application. Blight incidence on 4-18-23 was based on the number of flower clusters with at least one infection of the total number of clusters evaluated. All data were analyzed using analysis of variance and LSD mean separation procedures of SAS 9.4.

Table 2. Sensitivity of *E. amylovora* strains from pear orchards in California to streptomycin, oxytetracycline, and kasugamycin in 2023

| County | Orchard No. | No. isolates | In vitro sensitivity (MIC) | | |
|------------|-------------|--------------|----------------------------|-----------------|-------------|
| | | | Streptomycin | Oxytetracycline | Kasugamycin |
| Sacramento | 1 | 10 | 8 MR 2 HR | S | S |
| | 2 | 8 | 6 S 2 MR | S | S |
| | 3 | 12 | 10 S 2 MR | S | S |
| | 4 | 14 | MR | S | S |
| | 5 | 14 | 4 S 10 MR | S | S |
| | 6 | 15 | 1 S 14 MR | S | S |
| | 7 | 3 | MR | S | S |
| Lake | 1 | 1 | S | S | S |
| | 2 | 1 | S | S | S |
| | 3 | 1 | S | S | S |
| Yolo | 1 | 3 | MR | S | S |
| Totals | 11 | 82 | 2 HR, 39MR, 24S | | |

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

| MIC rating |
|-------------------|
| S = 0.6 - 1.4 ppm |
| MR = 20 - 35 ppm |
| MIC > 100 ppm |

RESULTS AND DISCUSSION

Survey of antibiotic sensitivity in *E. amylovora* strains from pear in California in 2023. Fire blight samples from 11 locations in Sacramento, Lake, and Yolo Co. were made available in 2023 for our annual resistance monitoring, and 82 strains of *E. amylovora* were obtained. All were sensitive to OXY and kasugamycin (Table 2). The 3 strains from 3 orchards in Lake Co. (one isolate per orchard) were also sensitive to STR, similar to previous years' samplings. Among the 76 strains from 7 orchards in Sacramento Co. (multiple isolates from each location), 24 were sensitive to STR. Resistance to STR was detected in each of the orchards, and from three orchards, only resistant strains were recovered. In total, three isolates from one Yolo Co. orchard and 39 isolates from the seven Sacramento Co. locations were moderately resistant to STR (MIC = 20-35 ppm), and two strains from this latter county were highly resistant (MIC >100 ppm). The incidence of STR resistance in Sacramento Co. has been variable over the years, but often was high, and this has been related to the extent of STR usage. Spray records that were made available to us indicate that rotations of copper, STR, OXY, and KAS were used at some locations.

In 2018 to 2020, we detected high levels of OXY+STR resistance (MICs >100 ppm) at several locations in Sacramento Co. that was never reported on previously. Different orchards were apparently sampled in 2023, and no high resistance to this antibiotic was identified. Although we demonstrated in flower inoculation studies that these resistant strains were pathogenic, virulent, and competitive in the presence of sensitive isolates, it is not known if these strains actually persisted at those locations. In 2022, strains with moderate resistance to OXY (MIC 3.1 ppm as compared to 0.2 to 1 ppm for sensitive isolates) were identified. This moderate resistance to OXY in *E. amylovora* also was a new finding.

Molecular analysis of high STR-OXY resistant strains of *E. amylovora*. We concluded the molecular characterization of high OXY resistance in California strains of *E. amylovora*. Long- and short-read whole-genome sequencing showed that *tet*, *strA*, and *strB* genes were acquired by the novel conjugative IncX plasmid pX11-7. These findings demonstrate the enormous adaptability of bacterial plant pathogens to external selection pressures (i.e., bactericidal treatments). A manuscript describing this is in press in *Phytopathology*. The molecular mechanism of moderate resistant to OXY remains to be investigated.

Our detections of STR and OXY resistance and the need to protect the efficacy of kasugamycin stress the high importance of resistance management. Antibiotics should only be used in mixtures or rotations, the number of applications of each per season should be limited to two if possible, new alternatives (e.g., early-season copper, biologicals) should be used, and new options should be developed.

In vitro toxicity of new bactericides. In amended agar studies, the tea tree (i.e., Timorex ACT) and yeast/yeast extract (i.e., CWP) products did not inhibit growth of *E. amylovora* at 1000 ppm (Table 3). Cinnamon oil (i.e., Cinnerate), cinnamaldehyde (i.e., Seican), and EPL completely inhibited growth at 500, 250 ppm, and 1000 ppm respectively. EPL at 500 ppm was not inhibitory, but when mixed with cinnamaldehyde at 100 ppm, no growth occurred. Thus, this EPL-cinnamaldehyde mixture is synergistic and was in field studies in 2023. Both components potentially could be approved for organic production and a commercial formulation was provided by Summit Agro for evaluation in 2023.

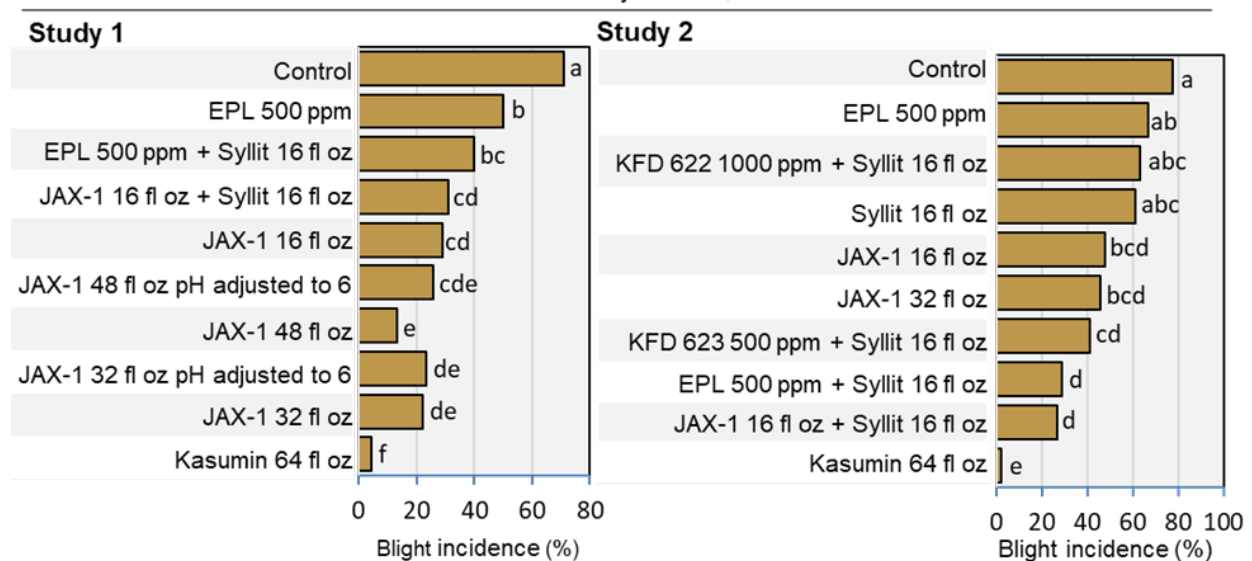
Table 3. In vitro toxicity of new bactericides against *E. amylovora* in laboratory amended agar tests

| Treatment | Concentration (ppm) | Growth rating |
|-----------------------------|---------------------|---------------|
| Control | --- | +++ |
| Timorex ACT - tea tree oil | 1000 | +++ |
| CWP - yeast + yeast extract | 1000 | +++ |
| Cinnerate - cinnamon oil | 100 | +++ |
| | 250 | + |
| | 500 | - |
| Seican - cinnamaldehyde | 50 | +++ |
| | 100 | + |
| | 250 | - |
| EPL | 500 | +++ |
| | 1000 | - |
| Nisin | 1000 | +++ |
| EPL + cinnamaldehyde | 500 + 100 | - |
| Nisin + cinnamaldehyde | 500 + 100 | + |

Nutrient agar was amended with selected concentrations of bactericides and a suspension of *E. amylovora* was streaked out. Growth was evaluated after 2 days at 25C. '+++' indicates that growth was similar as on non-amended agar, '+' indicates that growth was inhibited by >80%, and '-' indicates that growth was completely inhibited.

Laboratory studies with ornamental pear flowers to evaluate new bactericide treatments. In two early-season laboratory studies with ornamental pears flowers, non-formulated EPL, EPL + Syllit, JAX-1, and KFD 623 and KFD 622 formulations significantly reduced the incidence of fire blight, sometimes similar to Kasumin (Fig. 1). EPL + Syllit, JAX-1 + Syllit, and Kasumin had the highest efficacy. Adjusting the pH of JAX-1 from 5 to 6 resulted in reduced phytotoxicity to the flower petals and did not affect efficacy (Fig. 1, Study 1). The food preservatives EPL and nisin previously were not very effective in field studies. They possibly do not persist and degrade quickly in the environment, emphasizing the importance of designing agricultural formulations. KFD 623 + Syllit was effective, but the nisin formulation KFD 622 + Syllit was not effective (Fig. 1, Study 2). In general, the addition of low rates of Syllit to the bactericides improved their efficacy (Fig. 1, Study 2), and this mixture may help reduce resistance development. These results were used to design the treatment lists for our field trials.

Fig. 1. Efficacy of bactericides for management of fire blight of ornamental pear flowers in laboratory studies, 2023

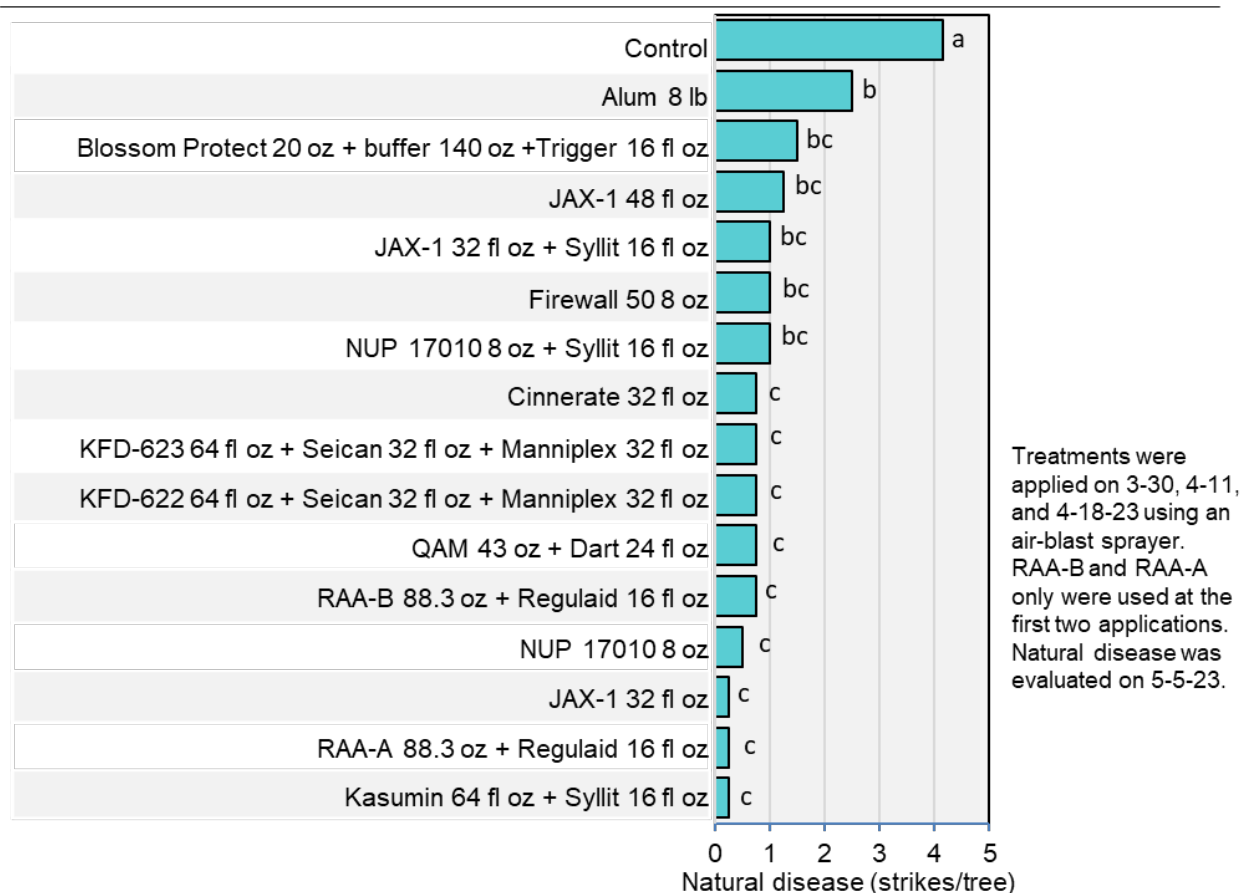


Flowering twigs of ornamental pear (*Pyrus calleryana*) were placed into 100-ml Erlenmeyer flasks containing water with 20 ppm gibberellic acid. Flowers were treated using a hand sprayer and were spray-inoculated with a strep^S/oxy^S isolate of *E. amylovora*. Twigs were covered with plastic bags, and the incidence of fire blight was determined after 5 days based on the number of blackened flowers of the total number of flowers evaluated. Non-adjusted JAX-1 solutions have a pH of 5.

In a trial in a commercial Bartlett orchard, an average of 4.1% of flower clusters were affected by fire blight at evaluation in early May. This low incidence of disease was likely due to the cool spring temperatures in 2023. The most effective treatments included mixtures of Kasumin and Syllit, JAX-1, the bacterial metabolite RAA-A, the NUP17010 formulation of OXY, QAM + Dart, RAA-B, KFD-622 and 623 mixed with Seican, and Cinnerate (Fig. 2). FireWall, JAX-1 or NUP17010 + Syllit, and Blossom Protect were intermediate in their performance followed by Alum as compared to the untreated control. The natural products Cinnerate, QAM, RAA-A, RAA-B, and JAX-1 were identified as effective treatments that reduced the disease to low levels of less than 1% (Fig. 2).

In the UC Davis inoculation study on Shinko apple pear, 26.7% of flower/fruitlet clusters developed disease. Thyme Guard, Blossom Protect, FireWall, Oxidate, JAX-1, and Cinnerate significantly reduced fire blight compared to the untreated control; whereas Alum, and Serenade ASO were not significantly different from the control (Fig. 3). Because Oxidate is not persistent, the sterilant was evaluated as a treatment after inoculation and thus, has the potential to reduce inoculum in an orchard when applied as an early-season treatment.

Fig. 3. Efficacy of bactericides for management of fire blight of cv. Bartlett pears, Live Oak, 2023



In the Comice study, where trees were not inoculated but where disease occurred at high incidence in 2022 after inoculation, 14% of flower/fruitlet clusters developed disease in the control. Only FireLine, JAX-1, and Kasumin, all mixed with Syllit, significantly reduced the incidence of blight from the control (Fig. 4).

In laboratory studies with ornamental pear flowers, water with different sizes (1.4, 1.5 nm or 2.1, 2.4, and 2.5 nm) and concentrations (120 M or 170M) of nanobubbles and mixed with EPL at 500 ppm or FireWall at 100 ppm was prepared by a commercial company and evaluated by us. None of the nanobubble formulations improved the effectiveness of the bactericides (Fig. 5, Studies 1 and 2) after inoculation with *E. amylovora*.

Fig. 3. Efficacy of bactericides for management of fire blight of cv. Shinko apple pears after inoculation, UC Davis 2023

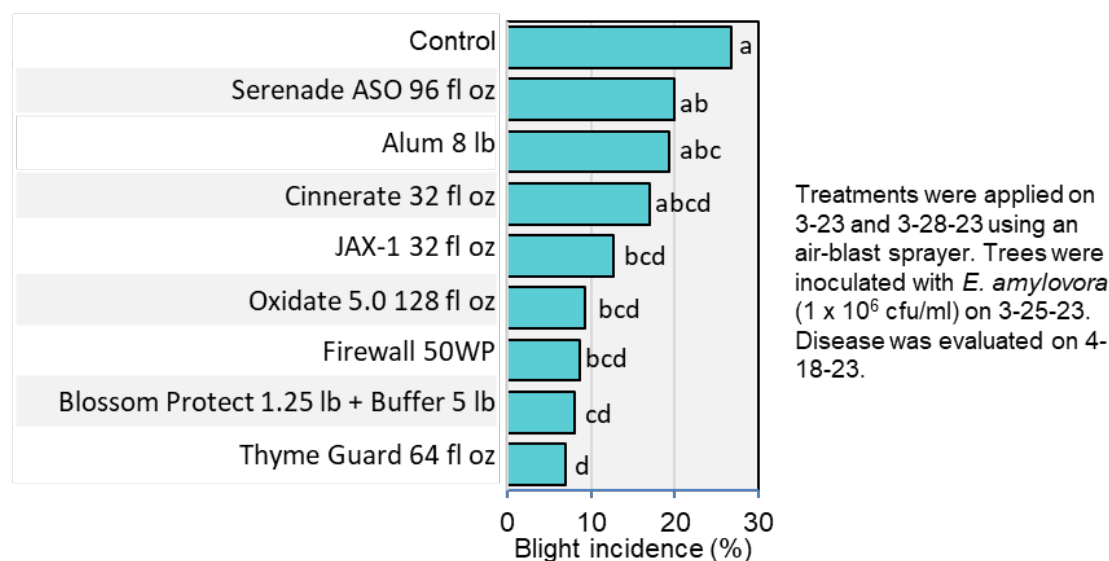
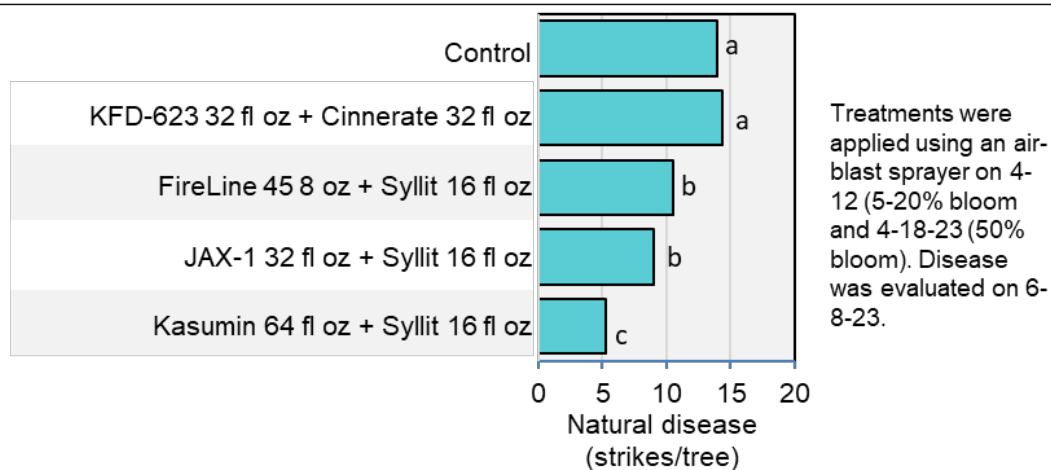
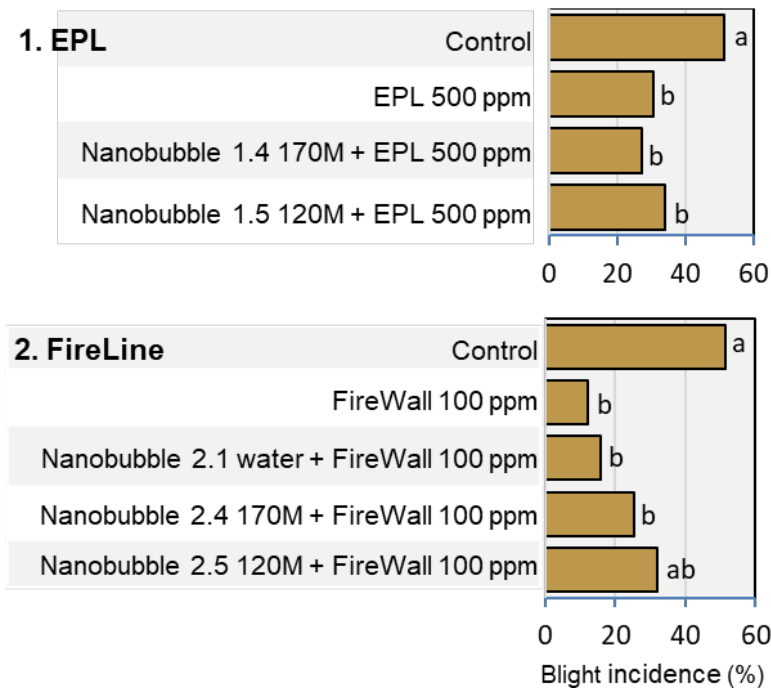


Fig. 4. Efficacy of new bactericides for management of fire blight of cv. Comice pear in a field study at UC Davis 2023



In summary, the efficacy of Kasumin + Syllit was again demonstrated in our 2023 studies. The restricted use of Kasumin (no more than four applications per season) and recommended use in mixture with another bactericide will help to minimize the risk for resistance development. New formulations of oxytetracycline such as FireLine 45 and NUP-17010 are also providing a high level of efficacy. Some of the new experimental natural products consistently reduced the incidence of fire blight and were sometimes as effective as the registered antibiotics. Cinnerate, RAA-A and -B, and JAX-1 were the most promising materials evaluated. KFD 623 (UPL's commercial formulation of EPL) used in combination with Seican and Manniplex Zn were also effective and therefore, should be continued to be evaluated. Moreover, a mixture of EPL and cinnamaldehyde (JAX-1 – Summit Agro) has the potential to be highly effective in the field.

Fig. 5. Evaluation of nanobubble formulations of EPL and FireLine in an attempt to improve efficacy against fire blight in laboratory ornamental pear flowers studies, 2023



Flowering twigs of ornamental pear (*Pyrus calleryana*) were placed into 100-ml Erlenmeyer flasks containing water with 20 ppm gibberellic acid.

EPL and FireLine were prepared in distilled water or selected nanobubble formulations of water. Flowers were treated using a hand sprayer and were spray-inoculated with a strep^S/oxy^S isolate of *E. amylovora*. Twigs were covered with plastic bags, and the incidence of fire blight was determined after 5 days based on the number of blackened flowers of the total number of flowers evaluated.

A new formulation of the natural product QAM (Summit Agro) was more effective in our 2023 studies than the formulation evaluated in 2022 and thus, our studies should continue to include the new QAM formulation. In 2022 and 2023, Alum was inconsistent on pear, but others have shown more consistent results on apple. The biocontrol Blossom Protect continues to show moderate to high efficacy in our studies conducted over numerous years. The biocontrol represents one of the best treatments in organically managed orchards and can be used in rotation with other effective organic treatments once these are made available. We will continue to evaluate new experimental bactericides and biocontrols in future studies to potentially identify additional effective options for fire blight management and to provide rotation alternatives for effective anti-resistance programs in conventionally and organically managed orchards.