Blossom Application of Novel Silver Compounds for Fire Blight (*Erwinia amylovora*) Management in Apples

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Abstract

Fire blight, a devastating disease of apple and pear worldwide, causes annual losses of millions of dollars (US). Current primary disease management tools are treatment with streptomycin or kasugamycin, or removal of infected trees. In the US and other countries, antibiotic resistant isolates have appeared, making disease management more difficult. If blossom infections can be decreased/eliminated, yield/tree losses can be greatly reduced. Agress® and AgreGuard™-1, unique silver compounds for crop protection, could be effective antibiotic replacements. Flower clusters at full-bloom were spray-treated 24h post-inoculation with *E. amylovora*. The Utah State University fire blight risk model showed "extreme" risk for fire blight infection on the treatment day. Treatments were: a copper soap product at 2 concentrations, AgreGuard™-1, Agress®, and an *Aureobasidium pullulans* product (applied 2-3 days pre-inoculation). Disease levels were compared to untreated controls, and streptomycin and kasugamycin standards in a replicated trial. Agress® outperformed all other products and controls, while AgreGuard™-1 was equivalent to antibiotic standards for disease incidence reduction. There were few systemic infections; none with silver treatment. No phytotoxicity was observed for any treatment. The results indicate that the silver products could be effective antibiotic alternatives in fire blight management even under conditions of very high disease pressure and infection risk.

Introduction

Background – Fire Blight (*E. amylovora*) in Apple and Pear

- Disease management is mostly via antibiotics (e.g. streptomycin, kasugamycin) or removal of infected trees
  - Oxytetracycline is often not as effective as streptomycin
- Growers are most concerned about blossom infections in spring – if infections occurring during this stage can be reduced or eliminated, yield losses and tree losses could be greatly reduced

New Possibilities for Fire Blight Management

- New silver products for crop protection have demonstrated unique effectiveness against both bacterial and fungal infestations in greenhouse and field trials (as foliar and seed treatments)
- Low risk of microbial resistance development
- Cost competitive with low environmental impact
  - Small quantities required for efficacy
  - No significant accumulation/residue in plant tissues at effective non-phytotoxic levels
- **Agress®**: High oxidation state silver (Ag) compound
- **AgreGuard™-1**: Uniquely stable Ag(I) compound

Methods

- All trials conducted at Utah State University's Kaysville Research Farm on 3 apple varieties (Gala, Fuji, Golden)
- All statistical analyses performed using SAS 9.3 Proc glimmix
- Each treatment and variety combination was repeated 4x

2011 Field Season

- Similar to 2012 (below), but trees were treated with 1 spray at full-bloom, and there were 5 Agress® treatments (0.005% w/v, 0.05% w/v, 0.1% w/v, 0.5% w/v. 1% w/v)

2012 Field Season

- Trees were treated with 2 sprays: at king bloom and at full bloom
- First treatment was applied during a Utah fire blight forecasting system "Caution" risk warning (indicates potential for infection within a few meters of an active canker)
- Second treatment was applied during an "Extreme" risk warning ((i.e. when blossoms get wet from rain/irrigation, infection will occur)
- Apples from untreated trees and trees with the lowest and highest Agress® concentrations were sent to Exova for testing of Ag accumulation in the fruit

Treatments

- Untreated control, streptomycin and oxytetracycline standards
- 3 Agress® treatments (0.005% w/v, 0.01% w/v, 0.1% w/v)

Methods, continued

2016 Field Season

- 10 flower clusters per tree per variety were treated once at full-bloom after inoculation with *E. amylovora* 24h earlier
- The day of inoculation had an "Extreme" risk warning
- The day of treatment had an "Exceptional" risk warning (i.e. orchards may get fire blight infections regardless of the orchard's fire blight history if blossoms get wet)

Treatments

- Untreated control, streptomycin and kasugamycin standards
- 3 copper soap treatments (0.5% v/v, 1% v/v, 0.5% v/v at full bloom + 2 additional sprays 2 weeks apart)
- Agress® (0.25% w/v)
- AgreGuard™-1 (0.35% w/v)
- *Aureobasidium pullulans* product (applied 2-3 days pre-inoculation)

Analysis (All Field Seasons)

Trees were evaluated weekly for:

- Disease incidence – # of infected trees (2011, 2012), or % of infected clusters per tree (2016)
- Disease severity – systemic infection present/absent (2016); 0: no disease, 1: 1-2 infected shoots, 2: 3-4 infected shoots; 3: 4+ infected shoots/1 systemic canker, 4: 2+ systemic cankers (2011, 2012)
- Phytotoxicity (fruit) – 0: no phytotoxicity, 1: occasional russeting, 2: occasional deformation or increased russeting, 3: severe russeting, 4: severe deformation
- Phytotoxicity (foliar, % leaf area necrosis) – 0: no phytotoxicity, 1: <10%, 2: 10-25%, 3: 25-50%, 4: 50-100%

Note: Studies in 2011-12 were performed with a previous Agress® formulation and relied on natural *E. amylovora* infection. In 2016, a new Agress® formulation was tested along with AgreGuard™-1.

Figure 1. A fire blight infected shoot.

Results: 2011

Table 1. Disease incidence, yield, and phytotoxicity results.

Treatment	Disease Incidence (# trees)	Avg. yield/tree (kg)**	Phytotox. (leaf)	Phytotox. (fruit)
Untreated	2 a*	8.24 a	0.00 c	0.0 c
Streptomycin	1 ab	6.85 a	0.00 c	0.0 c
Oxytetracycline	1 ab	7.64 a	0.00 c	0.0 c
Agress® 0.005%	**0 b**	**6.65 a**	**0.00 c**	**0.0 c**
Agress® 0.05%	**1 ab**	**7.90 a**	**0.00 c**	**0.0 c**
Agress® 0.1%	**0 b**	**7.27 a**	**0.00 c**	**0.0 c**
Agress® 0.5%	**0 b**	**7.16 a**	**1.75 b**	**2.8 b**
Agress® 1.0%	**0 b**	**8.74 a**	**3.08 a**	**1.3 a**

- Severity was significantly higher in untreated control (with systemic cankers), compared to Agress® treatments & streptomycin (p=0.05)
- Highest Ag concentration found was 0.06 ppm in a Fuji apple from a tree treated with 1.0% Agress®; apples from trees treated with 0.005% Agress® ranged from 0.00-0.03 ppm Ag

*Treatments with the same letter are not significantly different

**Yield in Table 1 is for Gala and Golden varieties only

Results: 2012

Table 2. Disease incidence, severity, and yield results.

Treatment	Disease Incidence (# infections/trees)	Avg. severity	Avg. yield/tree (kg)
Untreated	1.80 a	0.92 a	11.78 a
Streptomycin	0.75 ab	0.50 ab	12.05 a
Oxytetracycline	0.08 b	0.08 b	13.16 a
Agress® 0.005%	**1.00 ab**	**0.58 ab**	**11.47 a**
Agress® 0.01%	**0.75 ab**	**0.50 ab**	**11.74 a**
Agress® 0.1%	**0.67 ab**	**0.50 ab**	**14.90 a**

- All treatments in the Golden variety had significantly lower incidence of fire blight compared to the untreated control; there were no significant differences between treatments for incidence in Fuji &Gala
- By variety, severity results were similar to disease incidence; there was a higher average severity for streptomycin and 0.01% Agress® in the Fuji due to one canker developing on ¼ trees in both groups
- No foliar or fruit phytotoxicity for any treatments
- No silver detected in any apples from trees treated with Agress®

Results: 2016

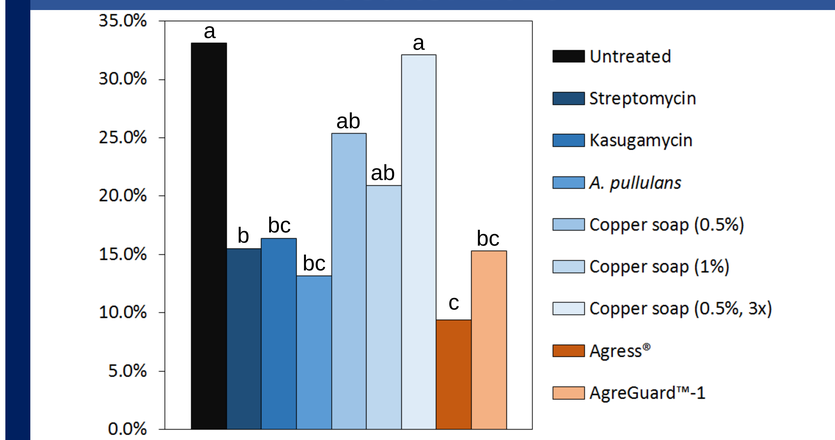

Figure 2. Disease incidence across all varieties – average percent infected blossoms across 3 cultivars & 4 reps (p=0.0036).

- Golden: All treatments showed significantly fewer incidences than untreated and 0.5% 3x copper soap; Agress® was lowest (5%)
- Fuji: Incidences for Agress®, AgreGuard™-1, and 0.5% 3x copper soap were significantly lower than untreated; Agress® and AgreGuard™-1 were lowest (~11%)
- Only a few systemic infections resulted from initial blossom infections; no systemic infections were observed on branches treated with Agress® or AgreGuard™-1
- No phytotoxicity on leaves or apples observed with any product

Conclusions

- Agress® outperformed all other products and controls tested for disease incidence reduction, while AgreGuard™-1 was equivalent to antibiotics standards
- Silver treatments were able to eliminate systemic infections without causing phytotoxicity
- New silver products could be effective antibiotic alternatives in fire blight management, even under conditions of very high disease pressure and risk of infection
- Future testing will look at increasing the dose of AgreGuard™-1 to determine if improved performance can be achieved without phytotoxicity developing

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