

CONTINUING PROJECT REPORT**YEAR: No-Cost Extension****Project Title: Integrated Fire Blight Management**

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Total Project Request: Year 1: \$78,979

Year 2: \$77,323

Other funding sources**Agency Name:** Applications made to SCRI**Amt. awarded:** \$418,722 to WA state**Budget 1****Organization Name:** WSU**Contract Administrator:** Shelli Tompkins/Kate Roberts**Telephone:** 509.335.2885**Email address:** shelli.tompkins@wsu.edu/arcgrants@wsu.edu

Item	2019	2020	2021
Salaries	\$3,734 ¹	\$11,650 ¹	
Benefits	\$1,421 ²	\$4,433 ²	
Wages			
Benefits			
Equipment			
Supplies	\$14,324 ³	\$1,000 ⁴	
Travel	\$500	\$1000	
Miscellaneous			
Plot Fees	\$2,100	\$2,100	
Total	\$22,079	\$20,183	\$0

Footnotes: ¹Salaries for a scientific assistant one-month year 1 and 3 months year 2 (DuPont).²Benefits at 38% for scientific assistant (DuPont).³Trees, posts, wire etc and contract labor for planting 3 new blocks for a young tree trial (\$6,155), and blossom blight trials (\$8,169). ⁴Trial supplies \$1,000.

Budget 2**Organization Name:** Cornell**Contract Administrator:** Donna Loeb**Telephone:** (315) 787-2325**Email address:** dr2@cornell.edu

Item	2019	2020	2021
Salaries	\$8,000	\$8,320	
Benefits	\$5,200	\$5,408	
Wages			
Benefits			
Equipment			
Supplies	\$2,000	\$2,000	
Travel			
Plot Fees	\$1,700	\$1,700	
Miscellaneous			
Total	\$16,900	\$17,428	\$0

Footnotes: ¹Salaries for a temporary employee 2 months at \$4,000 per month. Funds for temporary summer worker with experience in designing and conducting fire blight field trials in apples.

²Benefits at 65%.

³Materials: materials for conducting planting apples, including trees, flagging tape for treatment labeling. This would include materials for making pruning treatments and cleaning up after application of bactericides, and personal protection to be used during bactericide applications.

³Plot fees \$1700.

Budget 3**Organization Name:** OSU Agric. Res. Foundation**Contract Administrator:** Russ Karow**Telephone:** (541) 737-4066**Email address:** Russell.Karow@oregonstate.edu

Item	2019	2020	2021
Salaries FRA 3.5 mo	\$5,827	\$8,765	
Benefits OPE 61%	\$3,554	\$5,347	
Wages			
Benefits			
Equipment			
Supplies	\$7,154	\$2,500	
Travel	\$1,365	\$1,000	
Plot Fees	\$2,100	\$2,100	
Miscellaneous			
Total	\$20,000	\$19,712	\$0

Footnotes: ¹Salaries for a senior faculty research assistant 1.2 mo in 2019, 1.6 mo in 2020 at \$5000 per month.

²Benefits at 61% for faculty research assistant.

³Trees, posts, wire etc. and contract labor for planting a young tree trial (\$6,155), trial supplies \$1,000. ⁴Trial supplies.

Budget 4

Organization Name: Penn State University **Contract Administrator:** Mary Masterson/Laura Reddington

Telephone: 814-865-9446; 814-867-0058 **Email address:** mmm183@psu.edu / lcr129@psu.edu

Item	2019	2020	2021
Salaries	\$7,358 ¹	\$11,370 ¹	
Benefits	\$2,867 ²	\$4,430 ²	
Wages			
Benefits			
Equipment			
Supplies	\$7,275 ³	\$1,700 ⁴	
Travel	\$1,000	\$1,000	
Plot Fees	\$1,500	\$1,500	
Miscellaneous			
Total	\$20,000	\$20,000	\$0

Footnotes: ¹Salaries for a research technician, 2 months in year 1; 3 months in year 2.

²Benefits at 38.97% for scientific assistant.

³Trees, posts, wire etc and contract labor for planting a young tree trial (\$7,275), trial supplies \$1,000.

⁴Trial supplies.

OBJECTIVES

1. Test materials to prevent bloom infections including biologicals, tank mixes, and mixes with bioregulators.
2. Demonstrate management strategies for young trees including coppers, plant defense elicitors, and Prohexodine Calcium (PhCa).
3. Test strategies to manage blocks once they are infected. Treatments will address how far back to cut, the utility of stub cuts, timeliness of cutting and the use of plant defense elicitors.
4. Provide outreach on fire blight prevention and management.

SIGNIFICANT FINDINGS

- Alternative organic program Blossom Protect+ Buffer Protect (70% bloom), Previsto (100% bloom), Thyme Gard (petal fall) performed as well as standard organic program Blossom Protect+ Buffer Protect (70% bloom), Previsto (100% bloom, petal fall) in one trial.
- Thyme oil (23%) product Thyme Gard treated trees had blossom infections lower but not statistically different than water treated checks in two trials.
- Cinnerate treated trees had significantly lower numbers of blossom infections than water treated checks in one of four trials.
- In young tree trials cluster removal performed best in Pennsylvania and 3 copper applications (Previsto NY, Basic Copper PA) performed best of spray applications to keep numbers of blossom infections low.
- Prohexodine Calcium 12 oz at tight cluster and petal fall reduced the numbers of blossom infections in New York and Pennsylvania young tree trials by 70-87% but provided no significant effect in Oregon.
- In 14th leaf Pink lady apple trees in Washington where fire blight cutting began when fruit were at 4 cm few new strikes (<1 avg) occurred after initial cutting. In 3rd leaf Gala in Oregon all cutting treatments significantly reduced the number of new strikes compared to the no-treatment control where aggressive, BMP and BMP+ Actigard treatments had zero additional strikes.
- In 14th leaf Pink Lady in WA leaving a long stub (approx. 4 in.) significantly reduced the number of cankers to progress through this year's growth onto structural wood compared to BMP and short stub cutting treatments. In 3rd leaf Gala in OR all cutting treatments used significantly reduced the number of cankers progressing to structural wood.
- In 3rd leaf Gala trees in OR 17% of no-treatment control and trees receiving breaking treatments had rootstock blight occur compared to zero in Aggressive, BMP, BMP No-Sanitize, and BMP+Actigard treatments.
- Breaking treatments left significantly more canker in the tree than other cutting treatments in OR leaving a source of infection for the subsequent year.

METHODS

Objective 1: Test materials to prevent bloom infections. This objective took place at research farms in Orondo, Washington (40-yr-old 'Red Delicious' apple); Corvallis, Oregon (60-yr-old 'Bartlett' pear and 5-yr-old 'Gala' apple); Geneva, New York (18-yr-old 'Gala' apple on B.9 rootstock), and Biglerville, Pennsylvania (12-year-old 'Cameo' apple on B.9 rootstocks). Experiments were arranged in a randomized complete block with 4 to 6 replications of single tree plots. Products were applied to the area of the tree to be inoculated according to manufacturer recommendations using a Stihl SR420 or Solo 451 mist blower backpack sprayer with a wetting agent. Products were applied to wet, near dripping previously calibrated to equal 100 gal/A. At 100% bloom (of the king blooms) *Erwinia amylovora* was applied at 1×10^6 CFU ml⁻¹ dilution (1×10^7 PA) to lightly wet each cluster on April 18, 2020 Washington, April 15 or 19, 2020 Oregon (Gala and Golden Delicious apple, respectively), April 22, 2020, Pennsylvania Gala apple, May 21, 2020 New York Gala apple. Whole trees (OR, NY), or the bottom 8 feet (WA, PA) were inoculated. Trees were

visually evaluated for flower cluster infection every week following treatment and infection counts summed across all dates. Fruit was evaluated for russet fruit skin marking before fruit colored over. Statistical analysis was performed using mixed models, analysis of variance ANOVA, and multiple means comparison T test (LSD) SAS v 9.4.

Objective 2: Young Tree Trials. Young tree trials were performed in Orondo, WA (2-yr-old WA38 apple on M9.337 and G.41 rootstock); Geneva, NY (2-yr-old Gala apple on G.935 rootstock); Biglerville, PA (3-yr-old Gala apple on M.9 337 rootstock), and Corvallis, OR (6-yr-old Gala apple on M9.Nic 29 and 2-yr-old Gala apple on M9.337 rootstock). Experiments were arranged in a randomized complete block of four replicates with four trees per treated replicate in WA, NY, PA and 9 single tree replicates in each block in OR. Products were applied to wet, near dripping previously calibrated to equal 100 gal/A with a Stihl SR420 or Solo 451 mist blower backpack sprayer. At 100% bloom (of the king blooms) *Erwinia amylovora* was applied at 1×10^6 CFU ml⁻¹ dilution to lightly wet each cluster on April 23, 2020 Washington; April 15 or 19, 2020 Oregon; May 5, 2020 Pennsylvania; May 21, 2020 New York.

Objective 3: Test strategies to manage blocks once they are infected. Cutting trials were performed in Benton City, WA (14-yr-old cv. Pink Lady, rootstock M9.337); Biglerville, PA (3-yr-old cv. Gala, rootstock M9.337); Geneva, NY (15-yr-old cv. Idared, rootstock B.9) and Corvallis, OR (3-yr-old cv. Gala, rootstock M9.337). The experiment was arranged in a randomized, complete block design with 6-15 replications (15 WA, 10 PA, 6 OR, 6 NY) of 6-7 treatments applied to single tree plots where each tree had 1 to 15 WA (average 2.5), 4 to 23 (average 8.8) OR strikes per tree. No strikes developed in either NY or PA. Infections consisted of natural infection WA; inoculation April 24, 2020 OR (9×10^8 CFU/ml); inoculation June 12, 2020 NY (1×10^6 CFU/ml NY); May 5, 2020 PA (1×10^6). Initial cutting was performed on June 2, 2020 WA, May 22, 2020 OR, July 5, 2020 NY, July 13, 2020 PA. Four and eight weeks after treatment additional cuts were made where new strikes were found. Trees were evaluated for the number of additional strikes, the length of infected area from new strikes, tree death, canker formation on structural wood and remaining canker size.

Treatments included: **Best Management Practice** - Cutting back 12-18" from the end of the infected area into 2-year old wood and sanitizing loppers with a 10% Clorox solution; **No Sanitation** - Cutting back 12-18" from the end of the infected area into 2-year old wood *without* sanitation; **Aggressive** - Cutting back 30" from the end of the infected area; **Long Stub** - Cutting back leaving a 5" stub and sanitizing between cuts; **Short Stub** - Cutting back leaving a 1-2" stub and sanitizing between cuts; **Breaking** - Breaking back to the joint at the end of the first-year growth; **No-treatment control**.

RESULTS

No noticeable fruit marking occurred with any treatments. The effect of materials on blossom infections is outlined in Table 1.

Table 1 Effect of Fire Blight Materials for Prevention of Blossom Blight**

Treatment	Rate per 100 gal	Timing	Washington**	Oregon§	Oregon*	New York#	Pennsylvania†
Streptomycin standard [✓]					strikes per 100 clusters		
(Firewall 17) ^x	28.8 oz ^x						
(Firewall 50) ^v	2.7 oz ^v	100% bloom	2.8 ± 1.2 a	3.8 ± 1.5 a	1.5 ± 0.4 a	12.0 ± 2.2 bc	4.6 ± 7.5 c
Oxytetracycline standard [✓] (Fireline 17)	28.8 oz ^x	50% bloom, 100% bloom, petal fall	8.2 ± 2 b	±	4.1 ± 0.6 b	27.5 ± 9.4 b	10.1 ± 9.4 a-c
Organic Standard Blossom	1.24 lb	50% bloom,					
Protect/Buffer	8.75 lb	80% bloom,					
+ Soluble Copper (Previsto)	3 qt	100% bloom, petal fall	9.5 ± 1.3 bc	1.8 ± 0.4 a	---	7.0 ± 2.3 c	6.8 ± 6.2 a-c
Organic Alternative Blossom	1.24 lb						
Protect/Buffer + Soluble Copper	8.8 lb	80% bloom,					
(Previsto)	3 qt	100% bloom,					
Thymegard	2 qt	petal fall	---	2.1 ± 0.8 a	---	---	---
		80% bloom, 100%					
Thyme Gard (0.5%)	2 qrt	bloom +1 day, petal fall	17 ± 2.3 cd	---	---	---	4.9 ± 5.5 a-c
Alum [✓]	8 lb	100% bloom, petal fall	22 ± 4.2 d		4.2 ± 1.6	28.0 ± 16.3 b	11.5 ± 6.2 ab
		50% bloom, morning					
Cinnerate	1 qt	after inoc, petal fall	19 ± 3.5 d	---	---	24.0 ± 8.7 b	15.4 ± 26.6 a
Cinnerate	1 qt	100% bloom, petal fall	---	---	28 ± 1.7 c	---	---
		100% bloom ^{x,v} , +1 day ^x ,					
Water-treated check	NA	petal fall ^{x,v}	31 ± 7.1 d	24 ± 5 b	31 ± 1.7 c	80.1 ± 6.5 a	7.2 ± 3.4 a-c

[✓] Amended with Regulaid: 30 fl. oz. per 100 gallons.

^xWashington. Washington had additional 50% and petal fall applications. ^vOregon.

* Transformed log($x + 1$) prior to analysis of variance; non-transformed means are shown.

**Values within columns followed by the same letter are not significantly different ($P \leq 0.05$) according to the LSMEANS procedure in SAS 9.4.

‡Washington application dates were: April 14 (20% bloom), April 16 (50% bloom), April 17 (80% bloom) and April 18 (full bloom), April 19 (full bloom plus 1 day), April 22 (petal fall). Inoculation was conducted on the evening of April 18, 2020 at full bloom (of king blooms) using a suspension of 50% freeze-dried cells of *Erwinia amylovora* strain 153N (streptomycin and oxytetracycline sensitive pathogen strain) and 50% live cells, which was prepared at 24×10^6 CFU per ml.

§ Oregon Golden delicious apple, application dates were 17 April and 21 April, 2020 (petal fall). On the evening of 19 April, a motorized 25-gallon tank sprayer equipped with a hand wand was used to fog a suspension (~2 liters per tree) of freeze-dried cells of *Erwinia amylovora* strain 153N (1×10^6 CFU per ml).

* Oregon Gala apple, application dates were 17 April and 21 April, 2020 (petal fall). Inoculation was done on the evening of 15 April.

#New York 2020 application dates were 29 April (tight cluster), 7 May (pink), 16 May (40% bloom), 20 May-(80% bloom), 22 May(100% bloom/petal fall), 29 May (petal fall/early terminal shoot growth).

†Pennsylvania application dates were: 4 April (tight cluster); 13 April (pink); 20 (20% bloom); 22 April (50% bloom; first inoculation); 23 April (+12 h post inoculation); 27 April (100% bloom, second inoculation); 28 April (+12 h post inoculation); 4 May (Petal fall). A frost occurred on 17 April, damaging a significant number of blossoms, thereby affecting results. In addition, the average temperature during the trial period was 49°F and no fire blight infection periods occurred.

Table 3. Effect of Products Applied for Prevention of Blossom and Shoot Blight in Young Trees on Blossom Blight.

Treatment	Rate per 100 gallons	Timing	Strikes per 100 clusters																		
			Washington [‡] 2 nd leaf WA38			Oregon [§] 6-yr-old Gala			Oregon [§] 2-yr-old Gala			New York [#] 2nd leaf Gala			Pennsylvania [†] 3 rd leaf Gala						
Inoculated Check	water	100% bloom, +1 day, petal fall	0	±	0	41	±	6	a	39	±	7	a	77.2	±	4.4	a	71	±	20.1	a
Flower removal	NA	Pink	0	±	0	---				---				---				0	±	0	c
Basic Copper	1.5 lb	3 applications	5	±	0	---				---				27.3	±	3.3	b	8.3	±	12.1	c
Previsto	3 qt	3 applications																			
Or Cueva	4 qt		0	±	0	---				---				5.5	±	2.1	c	17.3	±	17.2	c
PhCa ^{y z}	6 oz	tight cluster, petal fall	0	±	0	---				---				6.5	±	1.7	c	42.4	±	24.0	b
PhCa ^{y z}	6 oz	full pink	---			34	±	3	a	36	±	4	a	29.5	±	9.7	b	---			
PhCa ^{y z}	12 oz	tight cluster, petal fall	0	±	0	---				---				10.5	±	1.0	c	21.8	±	23.5	c
Actigard	2 oz	10% bloom, 80% bloom, petal fall	0	±	0	---				---				17.8	±	2.3	bc	14.4	±	16.1	c
PhCa ^{z y}	6 oz	full pink	---			31	±	5	a	32	±	5	a	20.8	±	3.9	bc	---			
Actigard	2 oz		---			31	±	5	a	32	±	5	a	20.8	±	3.9	bc	---			
Regalia	64 oz	10% bloom (pink), 80% bloom, petal fall	0	±	0	33	±	7	a	37	±	5	a	26.5	±	1.7	b	---			
Employ	2 oz	10% bloom, full bloom, petal fall	0	±	0	---				---				23.5	±	2.9	b	---			
Fireline 17 (standard oxytet)	28 oz	50% bloom, 100% bloom, PF	---			---				---				10.0	±	1.3	c	---			

^y Amended with surfactant (Regulaid) at 16 fl oz per 100 (Oregon) 32 oz per 100 gal (Washington).

^z Kudos amended with 1 lb of ammonium sulfate per 100 gal (Washington), 6 oz. ammonium sulfate (Oregon).

[‡] Washington application dates were: April 15, pink, April 19 (20% bloom), April 21 (50% bloom), April 23 (full bloom), April 24 (full bloom plus 1 day), April 28 (petal fall). Inoculation was conducted on the evening of April 23, 2020 at full bloom (of king blooms) using a suspension of freeze-dried cells of *Erwinia amylovora* strain 153N (streptomycin and oxytetracycline sensitive pathogen strain), which was prepared at 1.3 x 10⁶ CFU per ml. **Only 3 cluster infections occurred in the block.**

[§] Oregon application dates were: 11 April full pink). Inoculation was conducted on the evening of April 23. On the evenings of 15 and 19 April, a motorized 25-gallon tank sprayer equipped with a hand wand was used to lightly fog a suspension of freeze-dried cells of *Erwinia amylovora* strain 153N (streptomycin and oxytetracycline sensitive pathogen strain), which was prepared at 1 x 10⁶ CFU per ml (0.1 to 0.2 liters per tree).

[#] New York application dates were New York application dates were 29 Apr "tight cluster", 7 May "pink", 16 May-40% bloom, 20 May- 80% bloom, 22 May-100% bloom/petal fall, 29 May- petal fall/early terminal shoot growth.

[†] Pennsylvania application dates were: 6 Apr (tight cluster); 20 Apr (pink); 27 Apr (20% bloom); 1 May (50-80% bloom); 8 May (Petal fall). Frost occurred on 17 Apr and a freeze occurred on 9 May. There were no days indicating an infection period for fire blight during our trial. The average temperature was ~50°F during the test period.

**Values within columns followed by the same letter are not significantly different ($P \leq 0.05$) according to analysis of variance ($F > 0.05$).

In 14th leaf Pink lady apple trees in Washington where fire blight cutting occurred when fruit were at 4 cm few new strikes (<1) occurred after initial cutting. In 3rd leaf Gala in Oregon all cutting treatments significantly reduced the number of new strikes compared to the no-treatment control where aggressive, BMP and BMP+ Actigard treatments had zero additional strikes. In 14th leaf Pink Lady in WA leaving a long stub (approx. 4 in.) significantly reduced the number of cankers to progress through this year's growth onto structural wood compared to BMP and short stub cutting treatments. In 3rd leaf Gala in OR all cutting treatments used significantly reduced the number of cankers progressing to structural wood. In 3rd leaf Gala trees in OR 17% of no-treatment control and trees receiving breaking treatments had rootstock blight occur compared to zero in Aggressive, BMP, BMP No-Sanitize, and BMP+Actigard treatments. Breaking treatments left significantly more canker in the tree than other cutting treatments in OR which signifies a source of infection in future years.

In Pennsylvania and New York cutting trials were performed but no infections occurred and thus cutting treatments were not conclusive.

Table 4. Effect of treatment on the number of new strikes after initial cutting of fire blight infections.

	Washington Pink lady 14 th leaf			Oregon Gala 3 rd leaf			New York* Idared 15 th leaf	Pennsylvania Gala 3 rd leaf
BMP	0.7	± 0.30	ab	0	± 0	a	---	---
Aggressive	0	± 0	a	0	± 0	a	---	---
BMP NO-sanitize	0.3	± 0.19	ab	1.2	± 0.5	a	---	---
Short Stub	0.4	± 0.21	ab	---			---	---
Long Stub	0.3	± 0.19	ab	---			---	---
Breaking	0.9	± 0.66	b	1.3	± 0.3	a	---	---
NTC	0.5	± 0.27	ab	11.3	± 1.5	b	---	---
BMP+Actigard	---			0	0	a	---	---

Table 5. Effect of treatment on the average cumulative length of cankers left in trees at the end of the season (cm).

	Washington Pink lady 14 th leaf			Oregon Gala 3 rd leaf			New York Idared 15 th leaf	Pennsylvania Gala 3 rd leaf
BMP	1.1	± 0.12	a	0	± 0	a	---	---
Aggressive	0	± 0.03	a	0	± 0	a	---	---
BMP NO-sanitize	1.1	± 0.14	a	3	± 3	ab	---	---
Short Stub	0.8	± 0.04	a	---			---	---
Long Stub	1.0	± 0.16	a	---			---	---
Breaking	3.2	± 0.21	a	5	± 2	b	---	---
NTC	29.1	± 4.25	b	155	± 31	c	---	---
BMP+Actigard	---			0	± 0	a	---	---

Table 6. Effect of treatment on the percentage of strikes progressing to structural wood.

	Washington Pink lady 14 th leaf			Oregon Gala 3 rd leaf			New York Idared 15 th leaf	Pennsylvania Gala 3 rd leaf
BMP	11.9	± 6.6	ab	0	± 0	a	---	---
Aggressive	0	± 0	a	0	± 0	a	---	---
BMP NO-sanitize	12.4	± 7.0	b	19	± 9	b	---	---
Short Stub	14.4	± 7.3	b	---			---	---
Long Stub	0	± 0	a	---			---	---
Breaking	18.7	± 5.5	b	12	± 3	ab	---	---
NTC	10.5	± 3.8	ab	64	± 6	c	---	---
BMP+Actigard	---			0	± 0	a	---	---

Table 7. Effect of treatment on the number of infected trees which develop rootstock blight (fall observation).

	Washington Pink lady 14 th leaf	Oregon Gala 3 rd leaf	New York Idared 15 th leaf	Pennsylvania Gala 3 rd leaf
BMP	0 ± 0	0 ± 0	---	---
Aggressive	0 ± 0	0 ± 0	---	---
BMP NO-sanitize	0 ± 0	0 ± 0	---	---
Short Stub	0 ± 0	---	---	---
Long Stub	0 ± 0	---	---	---
Breaking	0 ± 0	1 of 6	---	---
NTC	0 ± 0	1 of 6	---	---
BMP+Actigard	---	0 ± 0	---	---