FINAL PROJECT REPORT

Project Title: Integrated fruit production for pears

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Cooperators: None

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Total Project Funding: $352,709

Item	2016	2017	2018	2019
WTFRC expenses	0	0	0	0
Salaries[1]	63,597	75,054	78,056	0
Benefits[2]	21,932	26,250	27,300	0
Wages[3]	6,240	6,490	6,749	0
Benefits[4]	626	651	677	0
Equipment	0	0	0	0
Supplies[5]	4,000	4,000	4,000	0
Travel[6]	3,529	3,529	3,529	0
Miscellaneous	0	0	0	0
Plot Fees[7]	5,500	5,500	5,500	0
Total	105,424	121,474	125,811	0

Footnotes: [1]Research Intern, 7 months (year 1), 12 months (years 2 and 3) 0.40 FTE. Post-Doc, 3 years [2]Benefits for Research Intern 38.6%, Post-Doc 33.5%. [3]Wages for time-slip help, 1.0 FTE, summer. [4]Benefits for time-slip 10%. [5]Supplies – office and lab supplies, electronics, statistical consulting. [6]Travel to plots – motor pool rental. [7]5.5 acres total: 2.7 acres (TF8,9), 2.8 acres (WSU Sunrise)/yr x $1,000/acre, 3 years.

Objectives:

1. *Evaluate selective pesticides and non-insecticidal tactics for supplementing broad-spectrum insecticides for pear pests.*
2. *Determine the potential for the use of insect growth regulators (IGRs) as pre-bloom and post-harvest sprays for reducing overwintering psylla populations.*
3. *Evaluate tree washing techniques for control of pear psylla and mites.*
4. *Evaluate non-target effects on the predatory mite Galendromus occidentalis.*
5. *Evaluate pesticide efficacy for specific pesticide and pest issues.*
6. *Communicate project results as they become available.*

Significant Findings:

- Two applications of Surround CF applied at 50lb/acre, one at delayed dormant and one at popcorn stage, controlled psylla colonization equally or slightly better than a conventional program (Surround + Malathion at delayed dormant and a broad-spectrum tank mix without Surround at popcorn stage).
- Reflective plastic mulch laid in weed strips showed impressive control of psylla pre-bloom, equal or better than conventional programs. This is the first account of this method for control of pear psylla.
- Surround WP suppressed psylla adults and eggs more than other particle films and olfactory repellents.
- Surround WP applied at 100 lb/acre in fall provided acceptable control of psylla the following spring, similar to a March spray at the conventional rate of 50 lb/acre. Fall application worked best when applied after leaf drop (late October or early November).
- A transitional soft program using only particle films, organic materials, and selective IGRs provided acceptable suppression of psylla, but psylla densities and were higher than in conventional blocks that used broad spectrum insecticides. Tree-washing via overhead sprinklers used in the second year of this test reduced psylla injury dramatically. Soft blocks had 50–60% greater nymph densities than conventional blocks, but there was similar (low) fruit russet with just three washes during the summer: late-July, mid- and late August; 6 hours/wash; and 70 gallons/minute/acre.
- FujiMite and Agri-Mek were acutely toxic to larvae and adult females of the predatory mite *Galendromus occidentalis*. FujiMite also completely prevented egg hatch, while Agri-Mek did not affect egg hatch. Acramite was not harmful to any life stage.
- Delegate, Bexar, and Assail were the most toxic materials to psylla overall, resulting in greater than 80% mortality to all life-stage in most bioassays. Softer products such as Cinnerate, Aza-Direct, Neemix, Esteem, Ultor, Centaur, and Dimilin suppressed psylla in the field without harming natural enemies.
- Experiments including bioassays and field trials are available to the public on WSU Tree Fruit website under the Pear IPM section http://treefruit.wsu.edu/crop-protection/pear-ipm/. Updates are also reported in the Fruit Matters Newsletter and via the Pear IPM email listserv (40 members).

Obj. 1. Evaluate selective pesticides and non-insecticidal tactics for supplementing broad-spectrum insecticides for pear pests.

1A. IPM Demonstration Blocks. Methods. In 2016 and 2017, an unreplicated demonstration experiment was conducted to examine soft conventional (herein called ‘soft’) vs. grower standard programs (herein called ‘conventional’) at Sunrise Orchard in Rock Island, WA. A 4-acre plot of 12-year-old trees (Bartlett and Anjou) was divided half, and each side followed a program written by a group of crop advisors. One side received a standard conventional program without restrictions while the other was restricted to selective materials including oil, Surround, neem products, synthetic insect growth regulators (IGRs) (excluding Rimon), lime sulfur, Vendex, Envidor, Cyd-X, Intrepid, and Altacor. In 2017, an overhead honeydew washing system (separate from the under-tree irrigation system) was installed and used to dissolve and remove psylla honeydew only in the soft plot (explained more in Obj. 3). All insects and mites were counted weekly for both years using various techniques: tray taps, bud collections, leaf collection, earwig traps, and sticky traps with plant volatile lures. Fruit were rated at the end of the season for various injuries, although psylla-induced russet was the primary measurement.

Results and Discussion. In 2016, psylla adults remained more abundant in soft plots than conventional plots for most of the season, then evened by mid-August. Psylla nymph counts were similar for most of the season, but a large spike occurred in July in the soft plot, and fruit injury was greater in the soft plot than the conventional plot. Approximately 50% of fruit in the soft plot had minor honeydew marking (1-10% of surface marked, potentially resulting in a downgrade) and ca. 10% had significant marking (10-50%of surface marked, likely resulting in a downgrade or cull), whereas in the conventional plot 20% of fruit had minor marking and 5% had significant marking. Most natural enemies were less abundant in the conventional plot with the exception of lacewings and syrphids, which were similarly abundant between plots. In 2017, similar trends were observed for densities of each psylla life stage and of natural enemies (i.e., higher in the soft plot), however honeydew marking was similar between plots year. In both plots, less than 5% of fruit had any honeydew marking. In addition to both spray programs being better attended, the honeydew washes in the soft plot likely helped even out the injury levels between soft and conventional blocks. Soft plots were washed three times: late-July, early August, and late August.

Fig. 1. Reflective mulch plot, Sunrise Orchard

In summary, soft programs require diligence to keep psylla populations low. Additionally, it can take multiple years to build up natural enemies to levels that will provide effective biological control. This can make growers wary of IPM approaches or less likely to continue them after a difficult transition year. The addition of tree washing allows growers to tolerate higher psylla densities while biological control is rebuilding and could therefore be a very effective strategy to help ease this transition to softer programs.

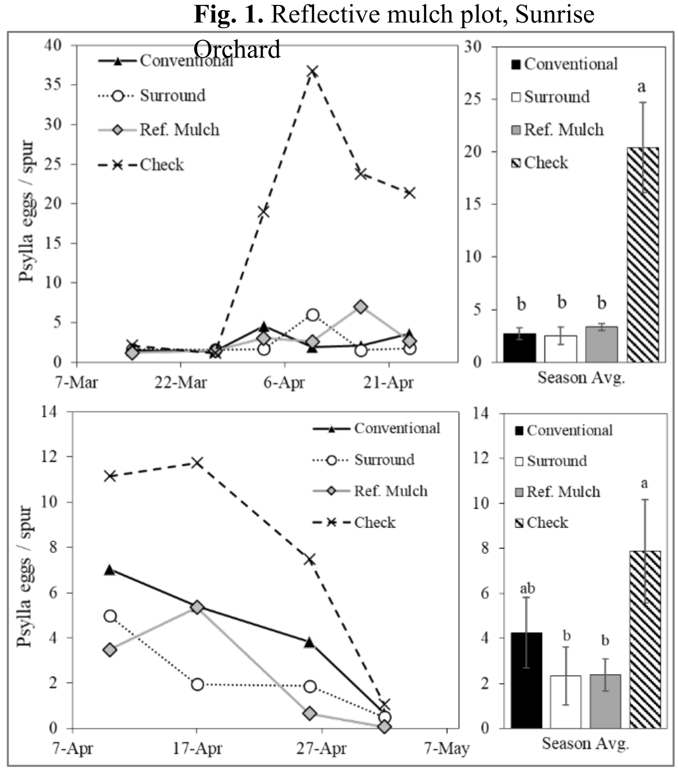

Fig. 2. Psylla egg counts prior to bloom in conventional, reflective mulch, Surround only, and check plots. Counts from six to ten spurs per plot were averaged weekly (left) and cumulative averages calculated (right) in 2018 (top) and 2019 (bottom).

1B. *Pre-bloom Surround and Reflective Mulch*. Methods. Four psylla management programs were compared in 2018 and 2019: two soft programs, one conventional program, and one untreated check (Table 1). Each program was executed on four replicate plots (16 plots total). Each treatment plot consisted of 40 trees across four rows (two Anjou and two Bartlett) (Fig. 1);. The conventional program was developed with local fieldmen. The two soft programs only differed from each other in pre-bloom management (one used Surround, the other reflective mulch), and were followed with regular sprays of IGRs and/or organic insecticides (Table 1). Measurements were taken weekly in these blocks on psylla life stages, spider mites, natural enemies, fruit-set, honeydew residues on leaves, and fruit injury.

Results and Discussion. Psylla pressure in the orchard was high in both 2018 and 2019, as shown by high egg counts in the check plots (Fig. 2). The Surround and reflective mulch early season programs provided equal control of the first generation of psylla eggs and nymphs as the conventional program in both years (Fig. 2). Following these early season management strategies with soft spray programs through the summer resulted in similar suppression of psylla eggs and nymphs throughout the summer. Injury levels were significantly lower in both soft treatments than in the conventional treatment in 2018, but were similar in 2019 (data not shown). Natural enemies were present at moderate densities for all treatments including the check. Lack of differences in natural enemies may be due to smaller plot sizes and untreated boarders, allowing natural enemies to redistribute quickly.

Table 1. Products, rates and timings for pear psylla management programs (mite and codling moth management was the same among all treatments and is not shown) implemented at Sunrise Orchard in 2018 and 2019.

	Conventional (2018/2019)*	**Surround (2018/2019)**	**Reflective Mulch (2018/2019)**	**Check**
Delayed Dormant	Malathion[1, 2] Surround CF 50lb 440 IAP oil 4%	Surround CF 50 lb 440 IAP oil 4%	(reflective mulch installed)	–
Popcorn	Assail / Bexar Rimon / Rimon – / Ultor	Surround CF 50 lb	(reflective mulch)	–
Petal fall	Actara / Assail Rimon / Rimon – / Ultor	– / Surround CF – / Cinnerate 50 fl oz	(mulch removed) – / Surround CF – / Cinnerate 50 fl oz	–
Petal fall + 14	Ultor 1.25L / Delegate Rimon / FujiMite Exirel / Microna	Surround WP / Celite – / Cinnerate – / Neemix	Surround WP / Celite – / Cinnerate – / Neemix	–
Early June	Delegate / Assail	Surround WP / Celite Aza–Direct / Cinnerate Esteem / Neemix	Surround WP / Celite Aza–Direct / Cinnerate Esteem / Neemix	–
Mid June	–	Aza–Direct / – Centaur / –	Aza–Direct / – Centaur / –	–
Late June	Actara	Aza–Direct / – Centaur / –	Aza–Direct / – Centaur / –	–
Mid July	Delegate / Delegate	Aza–Direct / –	Aza–Direct / –	–

*Slashes (/) indicate that a treatment changed from year to year. If there is no slash, no change occurred. Dashes (–) mean that no spray happened. For example: "– / Ultor" means Ultor was sprayed at that timing in 2019 only.

[1] If rate is not listed, the product was sprayed at the highest labeled rate for that pest and crop.

[2] All sprays included 0.5% IAP 440 oil unless otherwise listed (i.e. oil 4%)

In summary, these experiments suggest that two Surround sprays pre-bloom or the use of reflective mulch can provide equal control of pear psylla as standard conventional programs in Central Washington, which use only one Surround spray and many broad spectrum materials. This experiment demonstrated an alternative approach to pre-bloom psylla management that has been used in the past: going soft early. The results show that suppressive techniques involving repellents can sufficiently manage the first generation of psylla and provide a foundation for a soft summer program. This can save growers money in pesticide costs and lower risk of biological control disruption (although we did not see major differences in natural enemies in our experiments). This also provides an alternative approach for the future, since broad-spectrum materials will likely continue to be slowly phased out of use. Finally, reflective ground covers have been shown to increase flowering and yield in the lower canopy of pear trees (and in the tree overall), adding a potentially significant bonus to using this method, considering declining pear yields seen over the last decade.

1C. ***Repellent Sprays-Greenhouse***. Methods. In late winter of 2017, various materials were evaluated for their ability to repel pear psylla adults when sprayed on pear trees. The experiment used potted Anjou trees on OHxF rootstocks in a greenhouse cage. Materials were applied to individual trees, ca. 2.5 ft tall about 2 weeks prior to bud break. Trees were sprayed with hand-held spray bottles until completely wet, ca. 50 ml (1.7 fl oz) per tree. After treatments dried, trees were placed in a 4×4×16 ft mesh cage in a greenhouse. Adult psylla were collected from pear trees at the TFREC in Wenatchee, and 1,200 were released into the cage. Six days after release, the trees were visually inspected for adults and eggs.

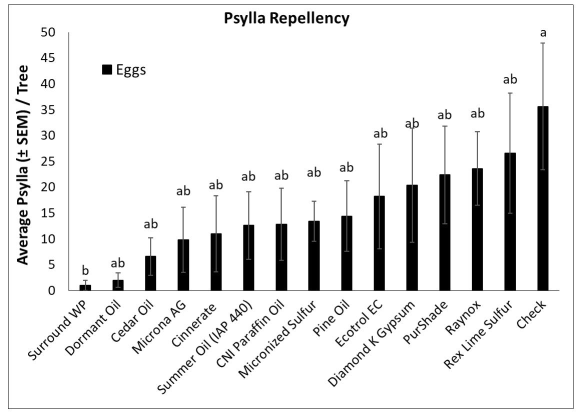

Fig. 3. Average psylla eggs on potted trees treated with various repellents in a greenhouse cage choice test.

Results and Discussion. Due to high variability, there were few statistically significant differences between treatments. The Surround WP treatment had the clearest effect, resulting in the lowest number of eggs (Fig. 3) and adults (not shown). Dormant oil, Microna and cedar oil caused notable but not statistically significant reductions in both eggs and adults.

1D. ***Fall Surround sprays***. Methods**.** Experiments were conducted in the field and near-field to examine the potential for Surround WP applied to pear trees in the fall to control psylla the following spring. This experiment was conducted to address the common issue that higher elevation pear orchards on slopes are difficult to access by tractor sprayer due to snow or wet ground in the early spring, when the first sprays for psylla are necessary. Because Surround WP is formulated with a spreader sticker and is known to be very rainfast, we hypothesized that Surround applied in fall could last through the winter and provide repellency of pear psylla. In the fall of 2017, two-acre blocks on three orchards in Cashmere and Peshastin WA were sprayed with 100 lb of Surround in late October. In 2018, six orchards were studied and another treatment was added: Surround applied before leaf drop in late September. The following spring, a separate block was sprayed with Surround CF at 50b lb/a (standard commercial rate) in March, and another block was left unsprayed (check). Psylla adults were counted via tap counts in the February, March and April of 2018 and 2019, and eggs were counted on spurs in April of 2019 only. At all sampled dates, and immediately before and after sprays, branches were collected from trees to quantify Surround residue decline over the season. Branches were photographed (Fig. 4) and processed in ImageJ software to quantify surface "whiteness" according to mean grey values.

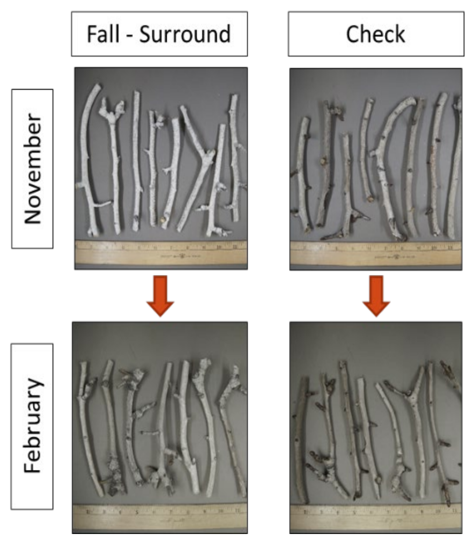

Fig. 4. Photos of cut branches from commercial plots in the November and February; analyzed for Surround residues using Image J.

A corresponding near-field experiment on potted Anjou trees was conducted both years. The trees received the same Surround treatments and timings and were left outside for the winter. In March, additional trees were treated, then all were brought into the greenhouse for a pear psylla choice experiment. One tree from each treatment was placed into a cage (6 cages, 6 replicates). Fifty pear psylla adults were then introduced into each cage. Adults and eggs were counted on each tree about 10 days after introduction.

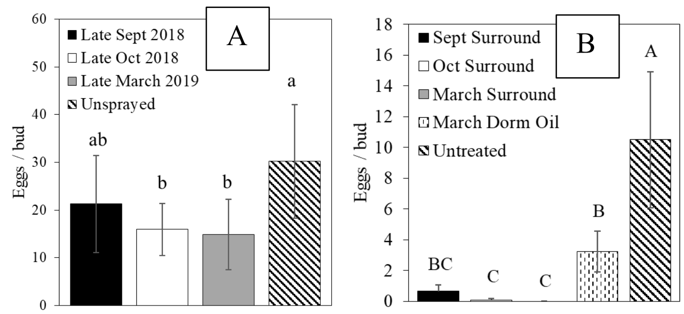

Fig. 5. Average eggs per bud among trees with Surround applied in the fall or spring, and check plots in commercial orchards (A) and a potted tree choice test (B)

Results and Discussion. In both years, adult densities were lower in orchard blocks treated with Surround in October than in check blocks. Adult densities were lowest, numerically, in treatments where Surround was applied in March, however the difference was not significant. Surround applied after leaf drop (late October) provided significant reductions in eggs the following spring compared to the check, and similar reductions compared to Surround applied in March (Fig. 5A). Image J analysis of residue decline showed that coverage was better for late fall sprays (October) than early fall sprays (September), and residues in spring from late fall sprays were whiter than those from early fall sprays. The corresponding potted plant bioassay mostly confirmed these findings, except that early fall sprays achieved better control compared with the check (Fig 5B), likely because we were still able to gain good coverage on these small trees despite leaves being present. Surprisingly, the late fall Surround sprays resulted in better control than dormant oil applied just 24 hours prior to adult introduction in the spring. In summary, applying Surround in the fall is a good option for problematic orchard blocks that are hard to access in the spring. The following approaches seem to improve this method: apply after leaf drop, use higher rates of Surround (100 lb/a), use Surround WP because it has a spreader-sticker in the formulation, consider adding an additional spreader-sticker such as NuFilm.

Obj. 2. Determine the potential for the use of insect growth regulators (IGRs) as pre-bloom and post-harvest sprays for reducing overwintering psylla populations.

Methods. An experiment to examine the effects of the IGR Esteem (pyriproxyfen) applied after harvest was initiated in fall of 2016. The experiment was planned to involve spraying orchard pear trees under field cages, followed by measurement of mortality and/or fecundity of adult psylla the following spring. Unfortunately, a windstorm broke many of the cages, terminating the experiment. Additional attempts to measure the potential for postharvest IGR sprays were not pursued, and instead data on this topic was collected with literature reviews and discussions with researchers (D. Horton, USDA) who studied this concept in the past. Based on this, we concluded that this method is unlikely to provide meaningful control. A primary indicator is that the product, fenoxycarb, which has a similar mode of action to Esteem and was the basis of this work due to its and ability to break adults psylla's reproductive diapause, did

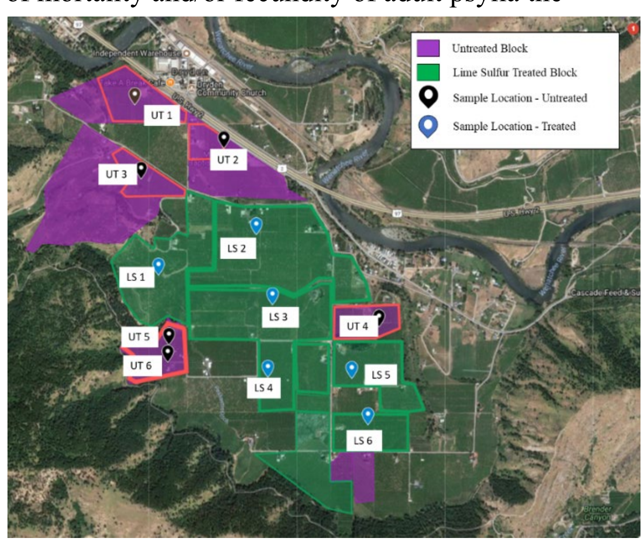

Fig. 6. Pine Flats, WA area-wide lime sulfur map.

not provide control when applied to adults post-harvest despite disrupting the psyllids' reproductive diapause (Krysan 1990).

An attempt at areawide post-harvest sprays was attempted in the fall of 2016 using lime sulfur. About 60% of the orchard acres in the Pine Flats region of Dryden, WA (area south of Hwy. 2, Fig. 6.) received lime sulfur applications following harvest. Adults were sampled in both sprayed and unsprayed locations the following spring. Six treated and untreated sites (12 total) for were sampled via tray taps (10/site) in March 2017.

Results and Discussion. No differences were seen among treated and untreated plots in the Pine Flats sites the following spring (2017). Plots had high psylla adult densities throughout, approximately 35–60 per tray in both treatments. While this does not mean postharvest sprays cannot be made effective, it does suggest that area-wide control requires true area-wide coverage. Because psylla undergo their largest redistribution event in the late mid to late fall, post-harvest sprays must cover enough acreage to reduce the area-wide populations.

Obj. 3 Evaluate tree washing techniques for control of pear psylla and mites.

Methods. In 2017, An overhead sprinkler tree washing system was established in half of the 4-acre pear block at Sunrise Orchard. This system is separate from the under-tree micro-sprinkler irrigation system, and it was not used for irrigation at any point. The system delivers 70 gallons of water per minute per acre using 50 Rain Bird sprinkler heads (R2000) on PVC risers per acre. The system was used in Obj. 1's 2017 demonstration block experiment. The system was run for six hours during the day three times during the season (27 July, 9 August and 29 August). For each wash, a non-ionic surfactant, Regulaid, was injected into the system mid-way through the cycle at 1 pint per acre. The NIS passes through the system in about 5 minutes.

Results and Discussion. In 2016 and 2017, the soft spray programs resulted in higher psylla densities than the conventional program. In 2016, injury resulting from psylla was also greater in soft plots, commensurate with psylla densities. In 2017, following the integration of tree washing, injury was not different among the programs (Fig. 6), suggesting that tree washing removed injurious honeydew. These results also demonstrate how tree-washing systems could be the missing link to help growers adopt soft or organic programs. Transitioning to softer programs has been historically difficult for pear growers due to slow recolonization of natural enemies, often leaving growers with little help from biological control in initial years. Because tree washing increases the tolerance threshold for psylla, higher psylla densities that occur in transition years can be mitigated by simply removing their honeydew. While the ability for honeydew washing to reduce injury has been shown by past research using handgun methods (Brunner and Burts 1981), this is to our knowledge the first demonstration of successful washing via overhead sprinklers.

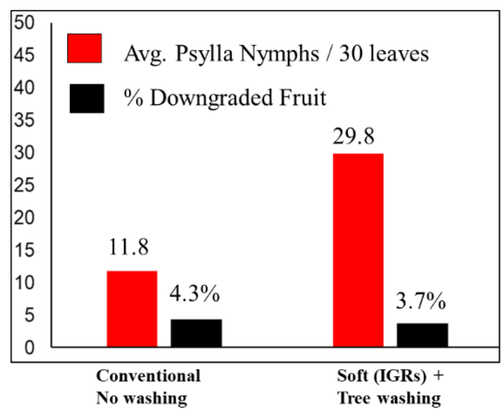

Fig. 7. Psylla nymphs and injury in a demonstration conventional plot without tree washing vs. soft plot with washing.

Obj. 4. Evaluate non-target effects on the predatory mite *Galendromus occidentalis* for commonly used pear miticides.

Methods. A laboratory bioassay was conducted on adult female *G. occidentalis* from a colony collected from a pear orchard in the spring of 2016. We tested three adulticidal acaricides and compared them to an untreated check. In the first part of the bioassay, we measured mortality and fecundity, and in the second part, egg viability and short-term larval survival. The production of live larvae from the treated females is regarded as good summary measure of both lethal and sublethal effects. A single adult female was transferred from the colony to a bean leaf disk 3.5 cm diameter with ample prey in the form of twospotted spider mite eggs and larvae. Fifty arenas per acaricide treatment were tested. The arenas with *G. occidentalis* and prey were sprayed with the field rate of three acaricides (FujiMite, Agri-Mek, and Acramite), plus a check sprayed with distilled water. Mortality and the number of eggs laid were evaluated after three days, at which time the females were removed from the disk, retaining prey. The *G. occidentalis* eggs were allowed to hatch, at which time the viability (% hatch) of the eggs and the number of live larvae were counted.

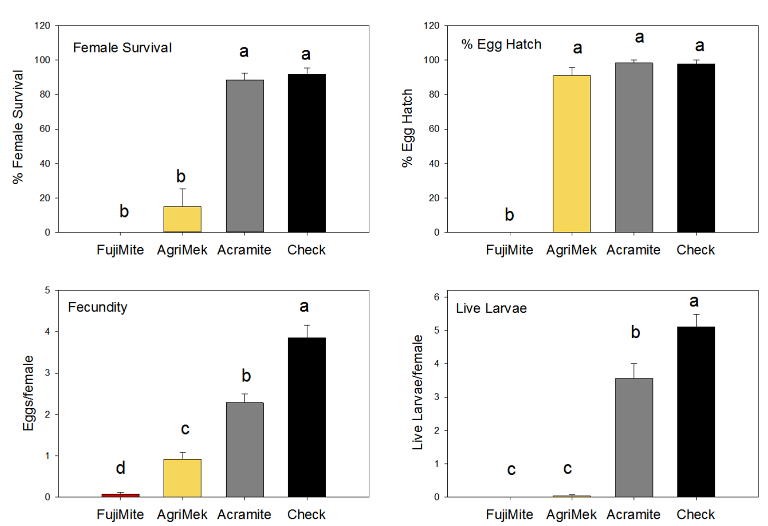

Fig. 8. Various Nontarget effects from miticide/insecticides on the predatory mite *G. occidentalis.*

Results and Discussion. There were no surviving females in the FujiMite treatment after 3 days, and there was poor survival (15%) in the Agri-Mek treatment (Fig. 8). Net fecundity and production of live larvae were greatly reduced in these two treatments. Survival was only slightly impacted in the Acramite treatment (88.6%), with corresponding reductions in fecundity and live larvae. Overall, Acramite is the most selective of the miticides tested to date. Ovicidal miticides (Zeal, Envidor, Onager) will be tested in a separate test in the future.

Obj. 5. Evaluate pesticide efficacy for specific pesticide and pest issues.

Methods. Many field spray trials and laboratory bioassays for chemical control of pear psylla and mites were completed over the course of this project. Slide dip and Potter spray tower methods were used to measure acute mortality and potted plants or excised shoots were used for longer-term studies. Spray trials were conducted in small, replicated field plots (3–4 trees/plot; four replicates) with either single sprays or multiple, program integrated, sprays. All bioassays with reliable outcomes (low check mortality and, if included, high positive control mortality) have been made available to the public on the WSU Tree Fruit Pear IPM webpage: http://treefruit.wsu.edu/crop-protection/pear-ipm/.

Results and Discussion. Seven field trials examining efficacy of specific insecticides and particle films were completed. For conventional products targeting psylla adults, such as Bexar and Malathion, our primary finding was that adulticide sprays should be applied at or before delayed dormant. Adulticides sprayed from tight cluster to petal fall were usually past the adult peak, so adults were naturally declining, and many eggs were already laid. For post-blooms sprays, our trials suggest that insecticides with high psylla toxicity, such as Bexar, Assail, Minecto Pro, and Delegate, can be sprayed less frequently if timed with appropriate life stages. However, these materials do have measurable impacts on natural enemies, which can lead to increased populations of psylla in following generations. Softer materials such as Cinnerate, neem (Aza-Direct and Neemix), IGRs, and particle films, require more frequent applications, especially from petal fall into June; but this allows for development of natural enemies which eventually take over, usually by early July. For small plot experiments, it can be difficult to obtain clear results due to migration potential of psylla; however, some of the most clear reductions in psylla we observed came from short interval sprays of soft materials, and these reductions occurred without commensurate reductions in natural enemies (Fig. 9). Fig. 9 shows two trials testing soft materials, and all treatments resulted in significant suppression of pear psylla nymphs (left graphs). The only treatment in both trials that resulted in a significant natural enemy reduction was the conventional standard positive control in spray trial A (red arrow in right graph, Fig. 9A).

Lab bioassay results are shown in Table 2. Due to limited space, only the product names are shown and rates are only displayed if multiple rates were used within the assay, otherwise, either the high field rate or recommended field rate was used. Differences in percentage mortality were determined using either Tukey HSD or Fisher's LSD tests. Treatments not sharing a letter represent significant differences in percentage mortality.

***Objective 6**. Communicate project results as they become available.*

Experiments, including bioassays and field trials, were posted to the WSU Tree Fruit website under the Pear IPM section http://treefruit.wsu.edu/crop-protection/pear-ipm/, usually within one month of completion. Updates were also reported in the Fruit Matters Newsletter and via the Pear IPM email listserv (40 members). Over the course of the project the postdoc, Louis Nottingham, delivered 49 extension presentations, attended numerous grower meetings, field days, research and reviews in addition to other forms of industry engagement.

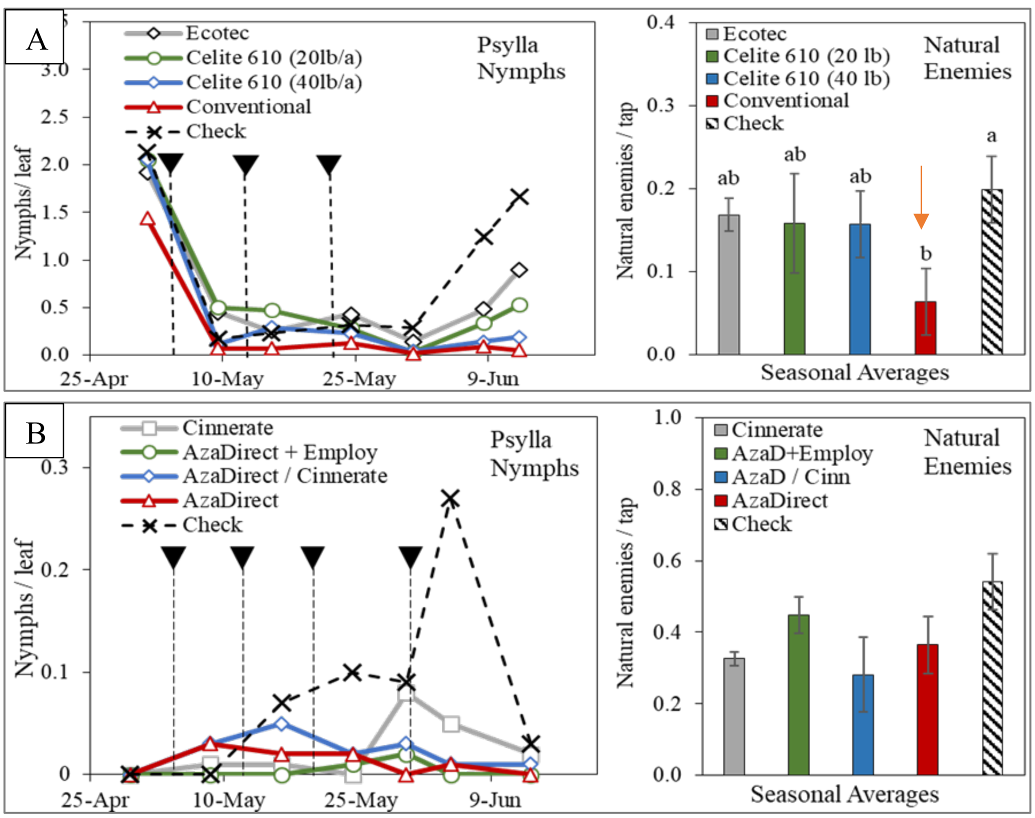

Fig. 9. Two spray trials (A and B) examining soft material programs. Left graphs show resulting psylla nymphs by date and sprays (vertical lines). Right graphs display seasonal natural enemy averages.

Table 2. Percentage mortality for pear psylla life stages (A–C) and pear rust mite (D) from lab bioassays.

A. Nymphs, Pear Psylla					
Instars 1-3, Leaf Dip, 2017		**Instars 3-5,** Leaf Dip, 2017		**Instars 1- 3,** Leaf Dip, 2018	
Pesticide	**% Mortality**	**Pesticide**	**% Mortality**	**Pesticide**	**% Mortality**
Delegate 25WG	100.0 a	Bexar 1.31SC	93.3 a	Bexar 1.31SC	86.67 a
Assail 70WP	100.0 a	Assail 70WP	90.0 a	Nexter 75WP	66.93 ab
Admire Pro 4.6	100.0 a	Agri-Mek 0.7SC	90.0 a	Actara 25WG	59.79 ab
Nexter 75WSP	94.0 ab	Delegate 25WG	86.2 a	FujiMite 0.4SC	28.33 bc
Actara 25WDG	92.0 ab	Actara 25WDG	85.0 a	Vendex 50WP	13.33 c
Bexar 1.31SC	86.3 ab	Exirel 0.83SE	69.3 abs	Nealta 1.67L	0.00 c
Exirel 0.83SE	77.0 abc	Nexter 75WSP	67.6 ab	Check	0.00 c
FujiMite SC	75.3 abc	Admire Pro 4.6	56.0 abcd		
Agri-Mek 0.7SC	62.8 bcd	Altacor 35WDG	17.5 bcd		
Altacor 35WDG	41.8 cd	FujiMite SC	14.0 d		
Check	16.5 d	Check	15.0 cd		

B. Adults, Pear Psylla					
Potter Spray Tower, 2017		**Slide Dip, 2017**		**Potter Spray Tower, 2018**	
Pesticide	**% Mortality**	**Pesticide**	**% Mortality**	**Pesticide**	**% Mortality**
Bexar 1.31SC	100.0 a	Bexar 1.31SC	100.0 a	IAP 440 Oil 4%	100.0
Delegate 25WG	99.0 a	Delegate 25WG	99.0 a	Malathion 5EC	100.0 a
Malathion 5EC	97.0 ab	Malathion 5EC	97.0 ab	Dimethoate 4EC	100.0 a
Lorsban 4EC	94.1 abc	Lorsban 4EC	94.1 abc	Assail 70WP	92.0 ab
Cobalt Adv + PBO	84.0 bcd	Cobalt Adv + PBO	84.0 bcd	Lime Sulfur	78.0 b
Dimilin 2L	79.2 dc	Dimilin 2L	79.2 dc	Wet. Sulfur 15lb	20.0 c
Danitol 2.4EC+ PBO	65.0 d	Danitol 2.4EC+ PBO	65.0 d	Check	8.0 c
Warrior II + PBO	34.0 e	Warrior II + PBO	34.0 e		
Exirel 0.83SE	32.0 e	Exirel 0.83SE	32.0 e		
Check	30.0 e	Check	30.0 e		

C. Eggs, Pear Psylla			
Leaf Dip, 2017		**Potted tree spray, 2017**	
Pesticide	**% Mort.**	**Pesticide**	**% Mort.**
Assail 30SG	87.0 a	Bexar 1.31SC	89.6 b
Bexar 1.31SC	55.6 ab	Assail 70WP	89.9 b
Agri-Mek 0.7SC	18.5 bc	Envidor 2SC	25.1 a
Microna AG	16.7 bc	Ultor 1.25L	25.4 a
Rimon .83EC	15.3 bc	Exirel 0.83SE	23.2 a
FujiMite 0.42SC	14.2 bc	Neemix 4.5	0.9 a
Exirel SE	10.3 c	Centaur 70WDG	11.3 a
Celite 610	9.3 c	Esteem 35WP	32.8 a
Centaur 70WDG	9.2 c	Rimon 0.83EC	0.0 a
Dimilin 2L	7.9 c	Dimilin 2L	9.1 a
Manzate 75DF	4.5 c	Intrepid 2F	38.2 a
Esteem 35WP	3.5 c	Check	13.8 a

D. Pear Rust Mite	
Excised shoots, 2017	
Pesticide	**% Mort.**
Nexter 75WP	98.67 a
Cinnerate 60 floz	95.56 a
Cinnerate 25 fl oz	85.26 ab
Neemix 4.5	67.26 abc
Entrust SC	32.51 cd
Pyganic	53.68 bcd
Azera	51.38 bcd
TetraCURB	88.89 ab
SucraShield	67.84 abc
Summer Oil	84.93 ab
Check	12.33 d

Cinnerate	2.9 c
Ultor 1.25L	2.2 c
Envidor 2SC	1.7 c
Check	4.8 c

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Executive summary

Title: Integrated fruit production for pears

Keywords: Pear Psylla, *Cacopsylla pyricola*, cultural control, biological control, chemical control, reflective mulch, particle films, insect growth regulators

Abstract. The goal of this project was to test multiple strategies and contributing factors to improve IPM programs for pear pests, mainly pear psylla. This project examined cultural controls such as reflective mulches and particle films, chemical insecticide efficacy, non-target effects of insecticides on natural enemies and full season programs. Additionally, a key element of this project was to provide research findings to industry stakeholders in real-time. This was accomplished through the development and updating of the WSU Tree Fruit Pear IPM website, writing newsletter articles in the WSU Extension newsletter Fruit Matters, and by delivering presentations at over 45 stakeholder events.

Summary. Pear psylla is a secondary pest, meaning it can be controlled by natural enemies when undisrupted. However, psylla emerge and colonize orchards in late winter, long before natural enemies. Therefore, it is important to strike a balance between active management and conservation to prevent early season injury without causing late season outbreaks. This is the fundamental principal behind IPM, or 'soft' management. In this project, we developed IPM techniques, and eventually programs, that integrate cultural controls, selective IGRs and organic materials to provide similar control of pear psylla as conventional programs, with fewer side effects. Although soft programs are likely to have elevated psylla populations in initial years due to the time it takes for natural enemies to recolonize, we worked to develop economical strategies to ease this transition, such as using repellents pre-bloom followed by shorter interval sprays of soft materials. Additionally, high water volume tree washing techniques resulted in major improvements to transitioning soft programs by simply washing away excess honeydew.

The use of reflective plastic mulch to repel colonizing psylla was a key novel finding of this project. Early season psylla management has historically been done with multiple broad spectrum sprays which contribute to the lack of natural enemies in conventional orchards. Reflective mulch alone provided equal control to broad spectrum sprays, and past research has shown that it significantly increases pear yields. More work is necessary to optimize this strategy for commercial use and examine if it is economically practical.

Kaolin clay (Surround) has been a common dormant or delayed dormant spray for pear psylla for nearly twenty years. Our examinations of this product provide practical use strategies which have helped to reestablish its importance in commercial programs. A key finding of this project was the importance of multiple pre-bloom kaolin applications. In doing so, we eliminated the need for any additional insecticides prior to bloom. This finding has had a major impact on the industry, taking kaolin from a program additive to a mainstay.

Going forward, a logical direction is to develop management programs that time sprays and cultural strategies to psylla life-stages. Degree-day models have made incredible improvements to management of other tree fruit pests and diseases, and the same is possible for pear psylla. Currently, psylla sprays occur on a 12-18 day schedule, which leads to high costs and wasted sprays. With the gained knowledge from this project about control

techniques and the recently developed psylla degree-day model, it is now possible to put these pieces together.