Project Title: Developing a phenology-based management program for pear psylla

Project # PR-20-100

Report Type: Final Project Report

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Total Project Request for Year 2 Funding: $33,794
Total Project Request for Year 3 Funding: $101,308

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Budget 1:
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Item	2020	2021	2022
Salaries[1, 2]	$53,592	$1,900	$57,965
Benefits	$18,641	$569	$20,162
Wages[3]	$9,600$	$9,984	$10,383
Benefits	$901	$937	$974
Equipment[4,5]	$6,000	$8,280	
Supplies[6]	$1,250	$11,400	$11,100
Travel		$724	$724
Miscellaneous			
Plot Fees			
Total	$89,984	$33,794	$101,308

Footnotes:
[1]Research Assistant Professor (Nottingham) = 2% FTE, $7,612.50/month for 12 months x 1.04/year + 29.9% benefits [2]Postdoctoral Research Associate = 100% FTE, $4,313.75/month for 12 months x 1.04/year + 35% benefits [3]Summer Time Slip = $15.00/hr x 40 hr/week x 16 weeks x 1.04/year + 9.4% benefits [4]Toward vehicle purchase [5]Meter Group weather sensors and data loggers for field plots [6]Sampling supplies, pesticides and labor for commercial plot experiments (spraying, pruning, washing) [7]Gas for travel to orchard sites = $3.25/gallon at 20 mpg for 2,000 miles/year + $100 maintenance (years 2 and 3)

OBJECTIVES:

Obj. 1. **Build a pesticide effects database**. Compile information on psylla life-stage susceptibility and non-target effects data from previous studies and perform new experiments to fill knowledge gaps. Use this database in conjunction with the pear psylla phenology model to design the phenology-based management program in Obj. 3.

Obj. 2. **Enhancing the management program with cultural techniques**. Perform field trials to determine optimal timings for kaolin applications, tree washing, and summer pruning at strategic timings.

Obj. 3. **Design and validate the pear psylla phenology-based management tool**. Use the current phenology model and findings from Obj. 1 and 2 to design an optimal spray program for pear psylla. Test this program against standard conventional programs on 2-4 acre plots in commercial orchards and compare costs, pests, natural enemies, and pest injury.

SIGNIFICANT FINDINGS AND ACCOMPLISHMENTS:

(In order of importance)

- **Phenology-based IPM Program Development**: An phenology-based IPM program for pear psylla was developed and made publicly available on the WSU Tree Fruit Extension website (http://treefruit.wsu.edu/crop-protection/psylla-phenology-model/) and DAS (https://decisionaid.systems/). The program includes a degree day model and appropriate timings for insecticide sprays, kaolin sprays, honeydew washing, and summer pruning.
- **Testing the Program**. The phenology IPM program was tested in large commercial plots in 2021 and 2022. The phenology program provided equal control of honeydew fruit injury as conventional orchards. The IPM phenology program resulted in 95% reductions in psylla overwintering adult populations in October compared with conventional orchards. 2022 Seasonal results are publicly available at the WSU Tree Fruit Extension site: http://treefruit.wsu.edu/crop-protection/pear-ipm/2022-pear-pest-scouting/
- **Economics:** The IPM phenology program developed in this project cost $280/acre less than conventional programs, on average. If implemented throughout the 20,000 acres of pears WA, it would save the WA industry $5.6 million per year.
- **Providing Extension:** All information from the project is available online, including the model, recommendations, and real time scouting data. Additionally, we broadcasted summaries of results and reminders of our online resources via 3 Fruit Matters Newsletter articles in 2021 and 4 in 2022. We also hosted two major Extension events including a pear IPM field day at one of our IPM orchards in Peshastin (Sept 2022) and a day-long pear IPM Fruit School in Wenatchee (Dec 2022, organized by T. DuPont).
- **Insecticide Efficacy:** Insecticides shown to be effective on pear psylla and pose low risk to natural enemies include Surround (kaolin), Celite (diatomaceous earth), Esteem (pyriproxyfen), Ultor (spirotetramat), Centaur (buprofezin), Cinnerate (cinnamon oil), Aza-Direct (azadirachtin), and 440 IAP oil. Additional products that are effective on pear psylla, but should be limited due to high risk to natural enemies include Bexar (tolfenpyrad), Assail (acetamiprid), and Actara (thiamethoxam). Malathion, while effective in the lab, has shown low efficacy in the field.
- **Surround timings:** Delayed dormant was the most effective Surround timing. A second spray significantly improved suppression of eggs and nymphs, particularly if applied at budburst. Late fall (early November) Surround sprays helped orchards that cannot be sprayed in the early spring due to wet terrain, but should not replace the early spring spray as they are less effective.

METHODS AND RESULTS:

Obj. 1. Build a pesticide effects database.

Methods. A literature review was conducted to determine all known results from pesticide tests on pear psylla and spider mites in pears. New bioassays were conducted in the summers of 2020, 2021, and 2022 to determine the psylla life stages most susceptible to various selective insecticides. Sprays targeting adults, eggs, and early nymphs were compared for each product. All bioassays followed similar methods with some minor alterations between experiments. Bioassays were conducted using potted d'Anjou pear trees grafted on OHFD rootstocks, 3-5 years old. Adult pear psylla were collected from an untreated pear psylla orchard at the TFREC, gently anesthetized with CO_2, and separated into groups of 6 females and 4 males. Adults were place in 23 x 17cm mesh bags and secured over first-year shoots with at least 4 leaves. Each bag of adults was assigned an insecticide treatment (product and rate) and timing (adult, egg, or nymph). Sprays were made through mesh bags using a 0.5 L aluminum misting bottle. Applications applied to adults were made the same day adults were collected and bagged on shoots. Four to seven days after bagging, all bags were removed, adults were brushed off plants, eggs were counted, and bags were replaced over shoots. The group selected for egg treatments were sprayed in the same manner, then re-bagged. After 7 to 10 days, nymphs were counted and nymphs sprays were made. Further counts occurred every 5 to 7 days until all late instars had become adults, which were counted.

Results: Results from literature review and past years insecticide bioassays have been incorporated into the Crop Protection Guide for Tree Fruit https://cpg.treefruit.wsu.edu/. This includes efficacy rating for effective and non-effective products. In collaboration with Tianna DuPont, we incorporated recommendation information for most effective materials in to an updated Pear IPM fact sheet that has been peer-reviewed by the Extension-review board and published on the WSU Tree Fruit Extension website: http://treefruit.wsu.edu/crop-protection/opm/pear-psylla/. Table 1 shows generalized results from efficacy tests conducted in the past three years. These products were selected based on efficacy demonstrated in past work. Not all products tested are displayed; those displayed had repeated efficacy when sprayed on a given life stage (i.e., eggs) in at least two trials. Life stage sprayed does not necessarily mean life stage killed. Selective materials often prevent development, so mortality occurs at future life-stages. However, it is more important for growers to know when to spray instead of what stage is affects, hence our designation "life stage sprayed."

Table 1. Insecticide demonstrating efficacy for selected products relevant to the phenology model. A **+** indicates that the product caused significant mortality, relative to the check, in at least two trials.

	Life stage sprayed*			
Product	**Adult**	**Egg**	**Instars 1-3 (young nymphs)**	**Instars 4-5 (hardshells)**
Surround (kaolin)	+	+	+	
Celite (diatomaceous earth)	+	+	+	
Oil 440	+	+	+	
Esteem (pyriproxyfen)	+	+		
Ultor (spirotetramat)	+	+		
Cinnerate (Cinnamon oil) 60 fl oz/100 gal [1]	+	+		
Aza-Direct (azadirachtin)				
Bexar (tolfenpyrad)[2]	+	+	+	+
Assail (acetamiprid) [2]	+	+	+	+
Actara (thiamethoxam)	+		+	

*Not necessarily the life stage killed.

[1] Lower rates of 30 and 40 fl oz/100 gal were not effective.

[2] Should not be used more than once per season due to high disruption of natural enemies

Obj. 2 Enhancing the management program with cultural techniques.

2a. Surround Timings

Methods. To determine optimal timings for kaolin applications, Surround WP (kaolin) was applied at 50 lb/acre (200 gpa for large trees, 100 gpa for small trees) to small, replicated plots at various timings in the fall of 2020 and spring of 2021, and again the following year. Each timing was considered a treatment, and received 5 replicate 4-tree plots at both the Wenatchee (TFREC, large trees) and Rock Island (Sunrise, small trees) orchard (10 replicates, 40 trees per treatment timing, total). In year 1, each set of trees was treated at one of the following phenological timings: fall (10 Nov), delayed dormant (4 Mar), budburst (30 Mar), 60% petal fall (21 Apr). Due to the clear advantage observed from the delayed dormant timing in year 1, and considering that this is the most common spray performed commercially, in year 2, we examined which spray timing was optimal in addition to the delayed dormant spray. Therefore, in year 2, all trees (including checks) were sprayed at delayed dormant (3 Mar) in additional to another treatment at either: fall (3 Nov), bud burst (25 Mar), bloom (26 Apr), or petal fall (11 May).

Results. In year 1 (2020-2021), the delayed dormant spray resulted in the greatest decrease in psylla compared to check plots for adults, eggs and nymphs in both large and small trees (Fig. 1, data only displayed for eggs and nymphs in large tree plots). The fall and budburst sprays also significantly suppressed eggs and nymphs compared with the checks, but to a lesser degree than delayed dormant. The 60% petal fall spray did not provide suppression of eggs or nymphs compared with the check.

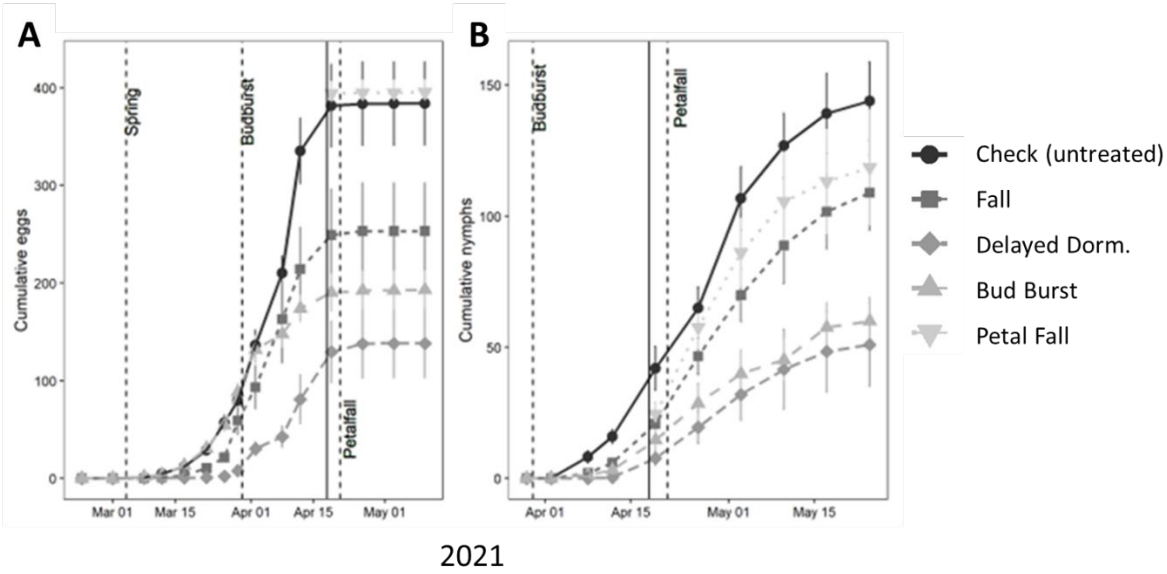

Fig 1. 2021 cumulative psylla densities (new count averages added to previous date) for eggs (A) and nymphs (B) resulting from Surround sprayed at various application timings.

In year 2 (2021-2022), we tested to see which spray timing would be optimal in addition to a ubiquitous delayed dormant spray (Fig. 2). Both budburst and fall sprays provided significant and similar egg suppression to the check, while budburst and petal fall provided significant and similar nymph suppression to the check. Interestingly, the petal fall spray had the least egg suppression compared with the check. The fall spray provided intermediate suppression of eggs, but no additional control of nymphs.

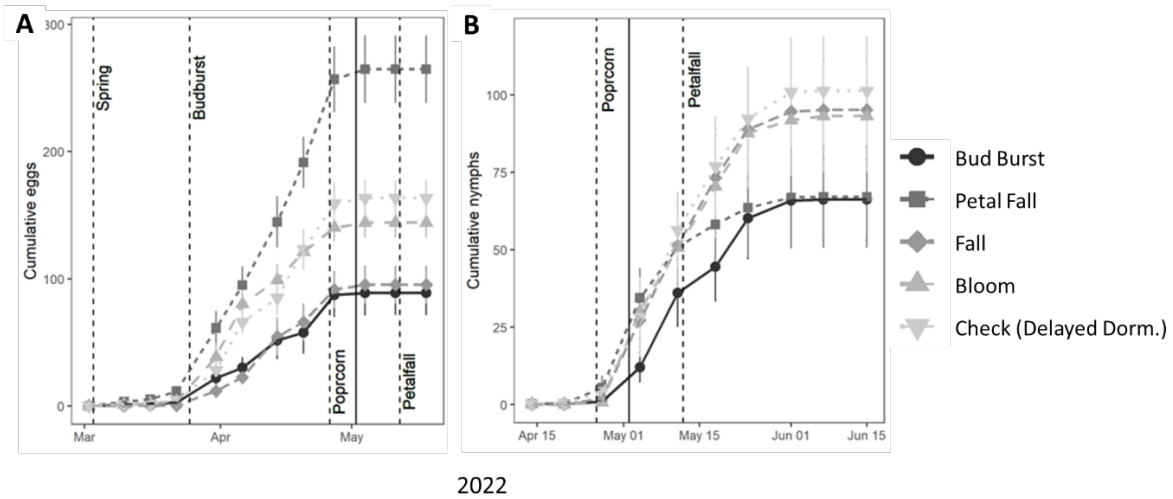

Fig 2. 2022 cumulative psylla densities (new count averages added to previous date) for eggs (A) and nymphs (B) resulting from Surround sprayed at various application timings. All trees were treated once at delayed dormant.

Conclusions: If Surround is only applied once, delayed dormant is the optimal timing to suppress psylla; nevertheless, other prebloom spray timings will also improve suppression. A single spray at petal fall does not appear to improve suppression

In addition to the optimal delayed dormant spray, a second Surround spray will likely improve suppression further, particularly the at the budburst timing. Adding a petal fall spray may worked well to suppress nymphs, but lack of egg suppression is concerning. Adding a fall spray suppressed eggs, but not nymphs, suggesting that this may not be a good addition to a delayed dormant spray. Fall Surround sprays are probably best for situations when a delayed dormant spray cannot be made.

2b. Honeydew Washing Timing:

Methods: An experiment was conducted to establish honeydew washing thresholds based on visual leaf inspections for honeydew droplets. The number of leaves with honeydew droplets was counted on trees each week in 10 commercial orchards (3 conventional, 3 organic, and 4 IPM). Ten trees in each orchard were used, on which 10 leaves and 20 fruit were sampled for presence or absence of honeydew. The number of leaves with honeydew per 100 leaves and number of fruit with honeydew per 200 fruit were determined in each orchard every week. Five percent of fruit affected by honeydew was considered the tolerance threshold.

A second experiment was conducted to determine how many leaves need to be sampled per orchard to accurately estimate the percentage of honeydew affected leaves. One shoot with at least 10 leaves was collected for each of 100 trees at 6 orchards (100 shoots per orchard). The percentage of honeydew affected leaves was calculated for each shoot, and averages for increments of 5 shoots leading up to 100. The monitoring level was established as the number of shoots at which the average honeydew level did not differ from the full 100 shoot sample (i.e., sampling 7 or more shoots provided the same percentage honeydew affected leaves and error as sampling 100 shoots).

Results. The IPM and organic orchards stayed below 5% of honeydew affected fruit throughout the summer. Percentage of honeydew affected fruit increased in conventional orchards in week 8, hitting 20% followed by over 30% in week 9 (Fig. 3). For affected leaves, IPM orchards and conventional orchards both hit 20% in week 6, but only conventional orchards continued to rise. Prior

to week 8, honeydew on leaves hit 35%, suggesting that the visual threshold is between 25 and 35%. Therefore, our honeydew washing threshold is 30% of leaves with visible honeydew droplets.

Between 5 and 10 shoots per orchard area provided the same results as sampling 100 shoots, therefore, 7 was established as the minimum number of shoots to be sampled per orchard area to measure leaf honeydew levels for threshold monitoring. In orchards with known differences in pressure, the 7 shoot rule should be used per "pressure zone".

Conclusions: About 7 shoots with 10 leaves each (70 leaves total) should be monitored for honeydew in each orchard zone. If 30% of the total (21 out of 70 leaves) have visible honeydew droplets, washing should be performed.

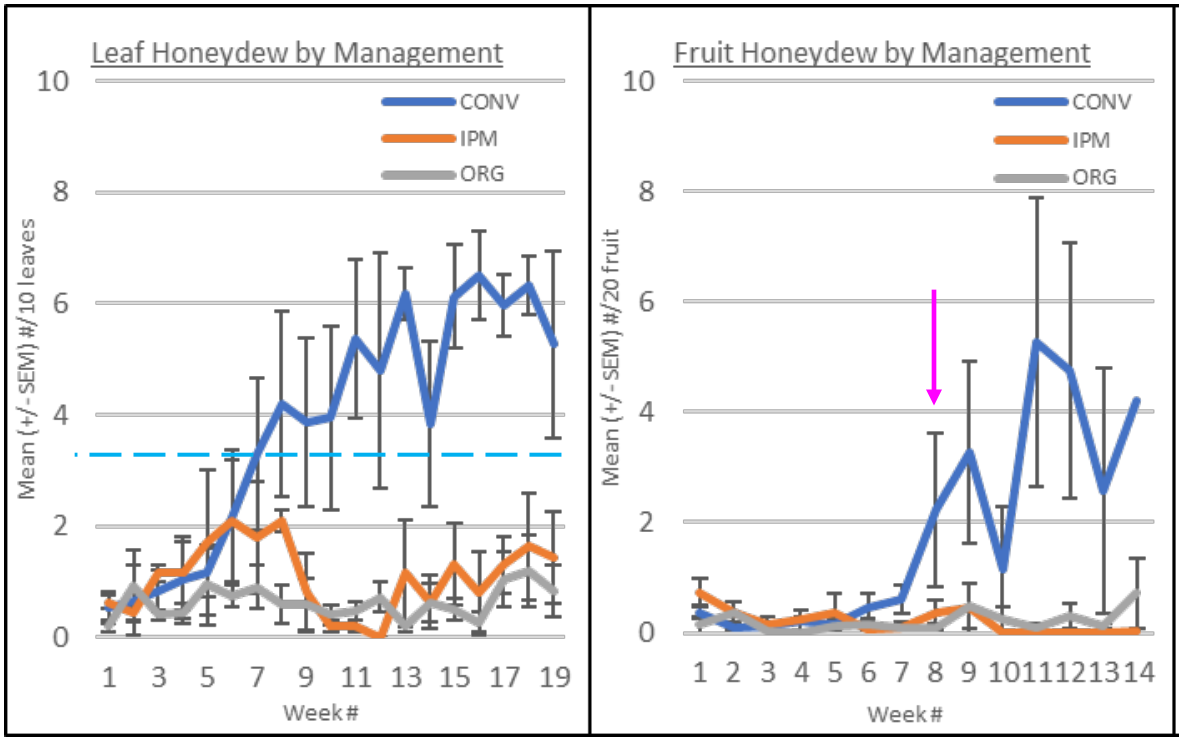

Fig. 3. Left: Mean (+/- SEM) no. of leaves with visible honeydew bubbles per 10 leaves from 10 trees per orchard per week. Right: Mean (+/- SEM) no. fruit with visible honeydew per 20 fruit from 10 trees per orchard perweek. Pink arrows show where fruit injury signficantly increased (week 8). Blue dashed line shows the level of honeydew on leaves (measured in no. of leaves with visible honeydew droplets) preceding fruit injury where signficant differences in honeydew are estimated to occur, indicating leaf honeydew thresholds preceding fruit injury.

Obj. 3 .Design and validate the pear psylla phenology-based management tool

3a. Model Recommendations Development:

Methods: An optimized spray program was developed using Surround (kaolin), Esteem (pyriproxyfen), Ultor (spirotetramat), Aza-Direct (azadirachtin), Cinnerate (cinnamon oil) and horticultural oil at strategic timings. Selective materials and timings for mites, mealybugs, and codling moth were also included. The program was developed using a holistic approach that not only aligned materials with their best psylla life stage target, but also considered elements like cost savings, potential non-target effects, vulnerable tree stages, convenience (i.e., grouping materials into single sprays when possible), logical constraints (i.e., avoiding bloom, particle film residues on fruit, etc.) and label restrictions (spray and pre-harvest interval minimums). Degree day timings for tree washing and pruning were incorporated based on pear psylla phenology (presence of nymphs) and

practical orchard management considerations (i.e., avoiding washing near bloom to avoid fire blight and pruning after shoots are fully developed).

Results: The pear psylla degree day model and corresponding recommendations timings have been made publicly available on in the Decision Aid System (https://www.decisionaid.systems/) and within the WSU Tree Fruit Extension Pear IPM website (http://treefruit.wsu.edu/crop-protection/psylla-phenology-model/). A shortened, two page handout has also been created for printing, and is available at http://s3.us-west-2.amazonaws.com/treefruit.wsu.edu/wp-content/uploads/2022/02/24171655/PDD-2022-Recs-and-Timings.pdf. The two-page handout is copied below in Fig 4 and Table 2.

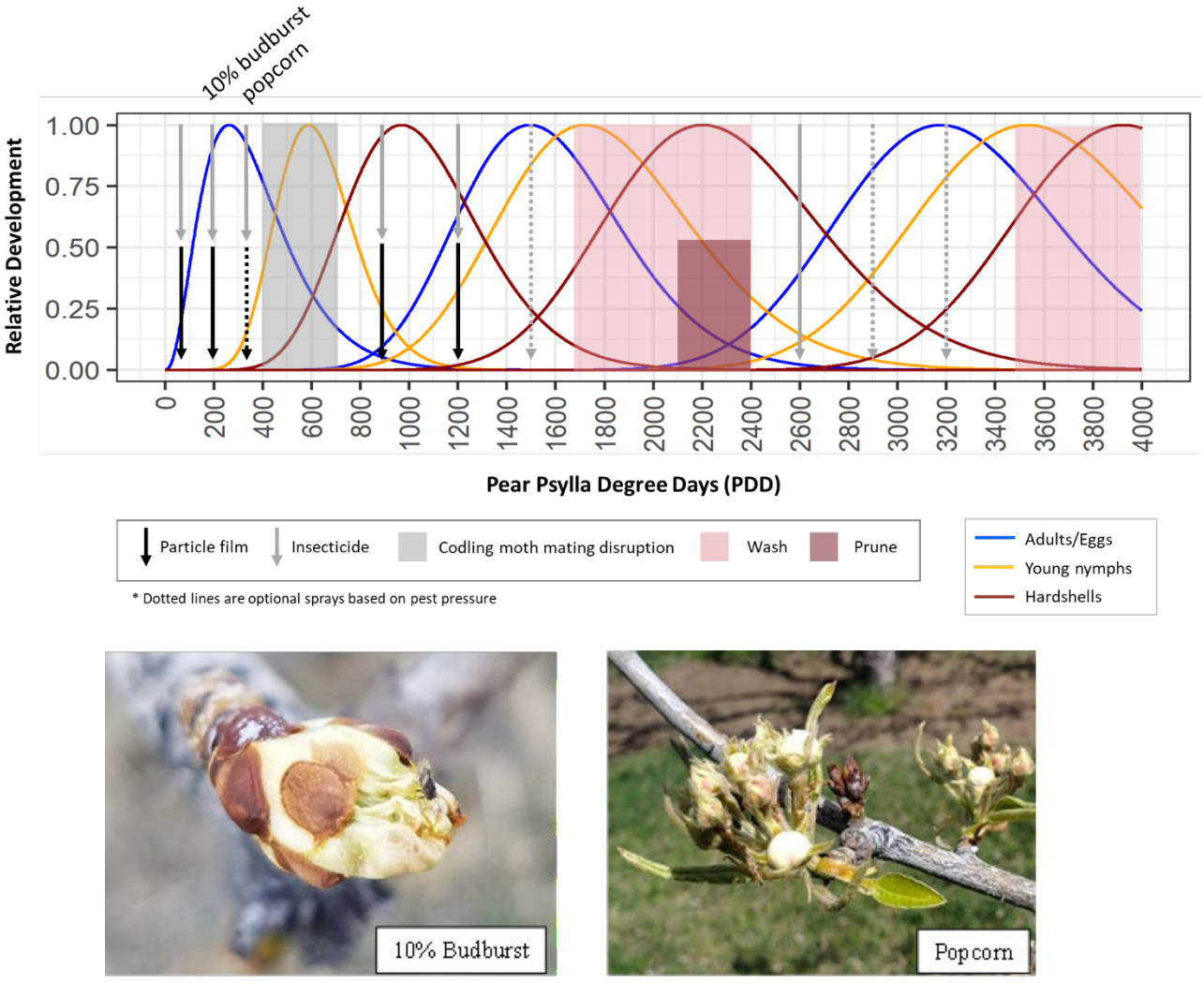

Fig. 4. Pear psylla degree day (PDD) model with overlayed management recommendations. Two timings are based on bud phenology instead of PDD (10% budburst and popcorn, pictures displayed under graph). Solid line arrows indicate "mandatory" sprays (recommended timings regardless of psylla pressure), dotted lines are for high pressure areas and/or years, and blocks are timeframes for cultural techniques. *Growers must follow labels above all else. While these suggestions fall in line with label recommendations, misinterpretations could lead to label breaches. For example, Esteem has three possible timings, but only two applications are allowed per season; therefore, only two of the possible timing can be used for Esteem.

Table 2. Recommendations and timings (either PDD or bud development) for management of pear psylla and other pests.

PDD or bud stage timing	Conditions	Conventional recommendations	Organic recommendations
75 PDD	winterform adults colonizing orchards	**Pear Psylla**: Surround CF or Celite @ 50lb/ac. Add Spreader sticker for added residual efficacy, but mix carefully. **Mites**: Lime Sulfur	**Pear Psylla**: Surround CF or Celite @ 50lb/ac. Add Spreader sticker for added residual efficacy, but mix carefully. **Mites**: Lime Sulfur
10% Budburst	10 % of buds opening from the tip.	**Pear Psylla:** Surround CF or Celite @ 50lb/ac. Add Spreader sticker for added residual efficacy, but mix carefully. **Pear Psylla/Scale**: Esteem	**Pear Psylla:** Surround CF or Celite @ 50lb/ac. Add Spreader sticker for added residual efficacy, but mix carefully. **Pear Psylla/Mealybug/Scale**: Cinnerate and/or Azadirachtin.
Popcorn	Before bloom. All buds have closed white petals.	**Pear Psylla/Scale**: Esteem **Mealybug/Psylla:** Centaur **Pear Psylla**: Surround or Celite @ 50lb/a if only one previous was made. A third Surround or Celite spray at 25 or 50 lb/ac can be made if psylla pressure is high (3 or more adult per tray)	**Pear Psylla/Mealybug/Scale**: Cinnerate and/or azadirachtin. **Pear Psylla**: Surround or Celite @ 50lb/a if only one previous was made. A third Surround or Celite spray at 25 or 50 lb/ac can be made if psylla pressure is high (3 or more adult per tray)
50% Bloom	egg lay and hatching nymphs	**Codling Moth:** Mating Disruption	**Codling Moth:** Mating Disruption
900 PDD	1-5% summerform adults/eggs	**Pear Psylla:** Surround WP or Celite @ 50lb/ac. Add Spreader sticker for added residual efficacy, but mix carefully. **Pear Psylla:** Ultor/Movento + Non-ionic surfactant **Codling Moth**: 1% Oil (375 CM DD)	**Pear Psylla:** Surround WP or Celite @ 50lb/ac. Add Spreader sticker for added residual efficacy, but mix carefully. **Pear Psylla:** azadirachtin and/or Cinnerate **Codling Moth**: 1% Oil (375DD)
1200 PDD	25% summerform adults/eggs	**Pear Psylla:** Surround WP or Celite @ 50lb/ac. Add Spreader sticker for added residual efficacy, but mix carefully. **Pear Psylla:** Ultor/Movento + Non-ionic surfactant **Codling Moth**: 1% oil + Altacor (525 CM DD)	**Pear Psylla:** Surround WP or Celite @ 50lb/ac. Add Spreader sticker for added residual efficacy, but mix carefully. **Pear Psylla:** azadirachtin and/or Cinnerate **Codling Moth**: 1% oil + Virus (525DD)
1500 PDD	50% summerform adults/eggs	**Pear Psylla**: Oil if low to moderate pressure (1-2 adults per tray. If high pressure (3 or more), use oil + Dimilin or Esteem **Codling moth:** 1% oil + Esteem or Dimilin based on moth capture	**Pear Psylla**: 1% oil if low to moderate pressure (1-2 adults per tray. If high pressure (3 or more), use oil + Dimilin or Esteem **Codling moth:** 1% oil + Virus based on moth capture
1700 - 2400 PDD	hardshells increasing	**Pear Psylla**: Honeydew washing if 30% of leaves have visible honeydew bubbles. If using overhead sprinklers, wash for no more than 12 hours at a time. If using an airblast sprayer, use volume of 800 gpa or greater.	**Pear Psylla**: Honeydew washing if 30% of leaves have visible honeydew bubbles. If using overhead sprinklers, wash for no more than 12 hours at a time. If using an airblast sprayer, use volume of 800 gpa or greater.
2200 PDD		Particle films are should not be used for the rest of the season because they can disrupt natural enemies and flare mites.	Particle films are should not be used for the rest of the season because they can disrupt natural enemies and flare mites.
2100 – 2500	hardshell peak, adults low	**Pear Psylla:** Summer prune to remove hardshell nymphs. Target shoots with visible honeydew for removal.	**Pear Psylla:** Summer prune to remove hardshell nymphs. Target shoots with visible honeydew for removal.
2600 PDD	15% summerform adults (2nd gen)	**Pear Psylla/Codling moth:** Dimilin or Esteem	**Pear Psylla:** 1% Oil, azadirachtin and/or Cinnerate. Be care with sensitive varieties. Do not use azadirachtin products on Comice.
2900 PDD	35% summerform adults (2nd gen)	**Pear Psylla/Codling moth:** oil 1%. **Pear Psylla:** If 2 or more psylla adults per tray, include Dimilin or Esteem.	**Pear Psylla:** 1% Oil. **Pear Psylla:** If 2 or more adults per tray, include azadirachtin and/or Cinnerate. Be care with sensitive varieties. Do not use azadirachtin products on Comice.
3200 PDD	50% summerform adults (2nd gen)	**Pear Psylla/Codling moth:** oil 1%. **Pear Psylla:** If 2 or more psylla adults per tray, include Dimilin, Esteem, or an organic material such as azadirachtin or Cinnerate. Be care with sensitive varieties. Do not use azadirachtin products on Comice.	**Pear Psylla/Codling moth:** oil 1%. **Pear Psylla:** If 2 or more psylla adults per tray, include azadirachtin or Cinnerate. Be care with sensitive varieties. Do not use azadirachtin products on Comice.
3500 PDD – Harvest	hardshells increasing to peak	**Pear Psylla**: Honeydew washing if 30% of leaves have visible honeydew bubbles. If using overhead sprinklers, wash for no more than 12 hours at a time. If using an airblast sprayer, use volume of 800 gpa or greater.	**Pear Psylla**: Honeydew washing if 30% of leaves have visible honeydew bubbles. If using overhead sprinklers, wash for no more than 12 hours at a time. If using an airblast sprayer, use volume of 800 gpa or greater.

3b. Testing the Pear Psylla IPM Phenology Model:

Methods: A pilot study to test outcomes of the phenology-based IPM program was conducted in 2021 in commercial orchard blocks being used for another pear-IPM focused project led by Nottingham and DuPont (USDA-NIFA grant award #2019-70006-30443). Plots for this project were either managed as conventional, bIPM (biological-IPM), or organic. In previous years, bIPM plots simply avoided use of broad-spectrum materials (primarily using kaolin, Aza-Direct, Cinnerate, Esteem, Ultor; full list found in DuPont et al. 2021). However, in 2021, bIPM plots followed the phenology program established in this project (Obj. 3a). For each treatment (conventional, bIPM, and organic) there were 4 orchards plots at least 4 acres in size (16 plots total). Plots were sampled weekly throughout the season for all pear psylla life stages, mites, and natural enemies using standard methods of beat trays, bud inspections, leaf brushing, and sticky cards.

In 2022, the same treatments were examined ("bIPM" now called "phenology") in 19 orchards (8 conventional, 8 phenology, and 3 organic). The only change was that 4 phenology orchards were allowed one Bexar (tolfenpyrad) spray at delayed dormant, when risk of harming natural enemies is lowest. Each phenology plot had a corresponding conventional plot within approximately 200 m. All phenology plots used for 2022 were not previously used in 2021, and had not previously been IPM or organic. All orchard groups, except one in Rock Island, were in high pear psylla pressure areas of the Wenatchee Valley (Fig. 5) and involved large old trees. Two of the organic plots had been organic for many years, and one was in its first year of transition. The same sampling methods were used in 2022 as 2021.

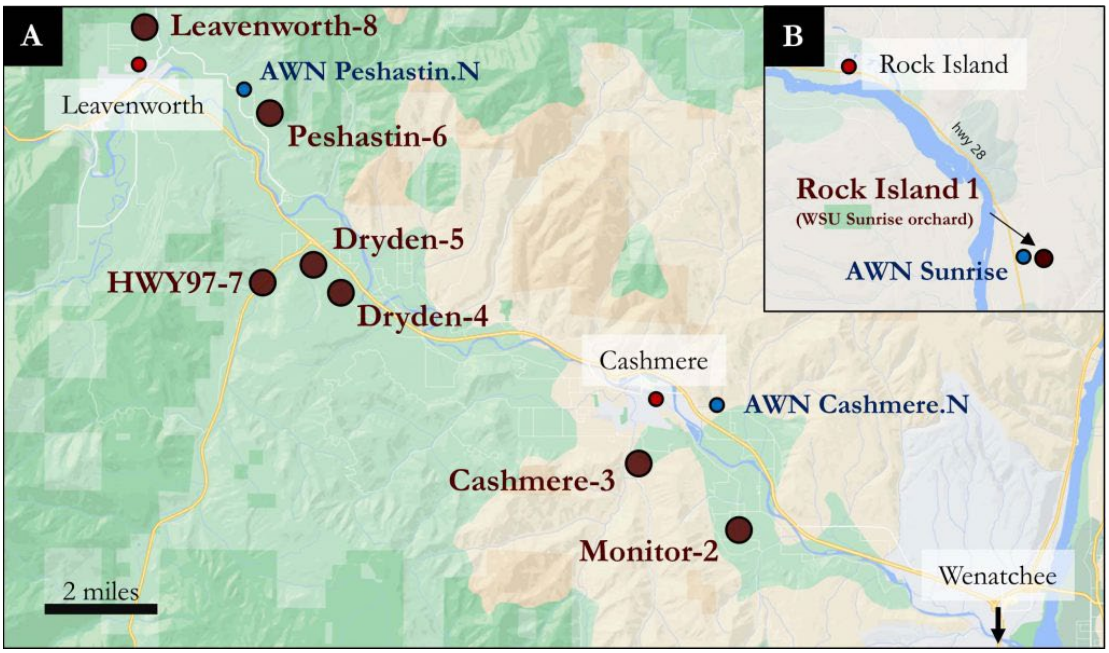

Fig. 5. 2022 sites for insect monitoring in paired commercial pear orchards (phenology and conventional combined as 1 dot, organic not shown). AgWeatherNet (AWN) temperature sensor locations are indicated with blue points.

Results: In 2021, the phenology model program (bIPM) resulted in consistent control of pear psylla nymphs, keeping populations below the treatment threshold of 0.3 nymphs/leaf throughout the season (Fig. 6). Natural enemies in the phenology model program were conserved similar to organic plots, and were significantly greater than conventional plots throughout the season. Data from the 2021 individual plots can be accessed online at http://treefruit.wsu.edu/crop-protection/pear-ipm/2021-pear-ipm-scouting/.

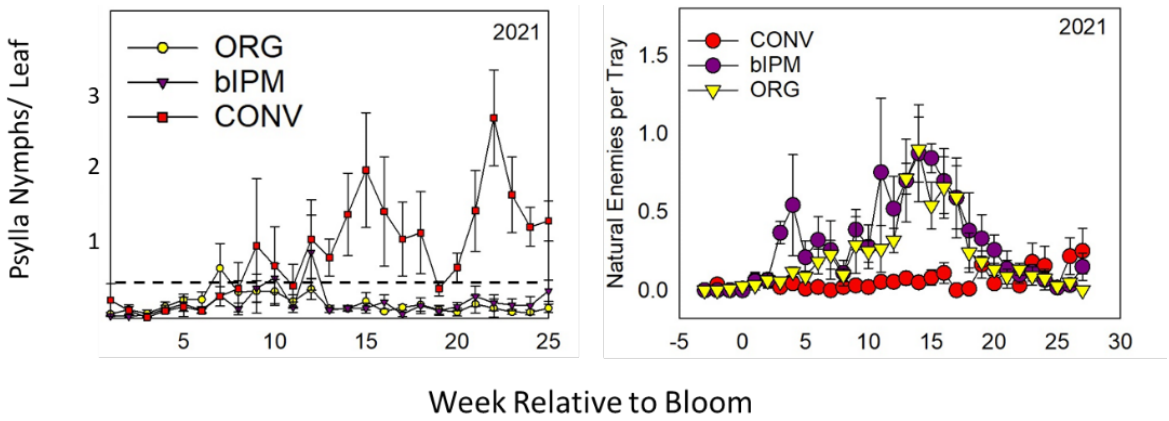

Fig. 6. Pear psylla and combined natural enemy densities in commercial orchard blocks following either the phenology model-based program ("bIPM"), conventional, or organic management, 2021. The dotted line is the treatment threshold of 0.3 psylla nymphs per leaf.

In 2022, phenology (IPM) and organic programs had fewer first generation pear psylla eggs and nymphs than conventional programs; adults were not different (Fig. 7 [left]). For the first summer generation of pear psylla, organic orchards had the most nymphs, phenology was intermediate, and conventional had the fewest (Fig. 7 [right]). For the second summer generation, psylla life-stages were similar among treatments at first (early-Aug); but as harvest approached, psylla nymphs increased in conventional plots relative to phenology and organic (Fig. 7 [right]). The final generation of psylla adults, which would go into overwintering (September and October), were around 10-fold greater in convention plots relative to phenology and organic (Fig. 7 [right]). Natural enemies increased in phenology and organic orchards in early August and remained through the fall, but never established in conventional plots (Fig .7 [right]). While not displayed in this report, we saw no difference in any other pest densities among treatments including codling moth, spider mites, and mealybug.

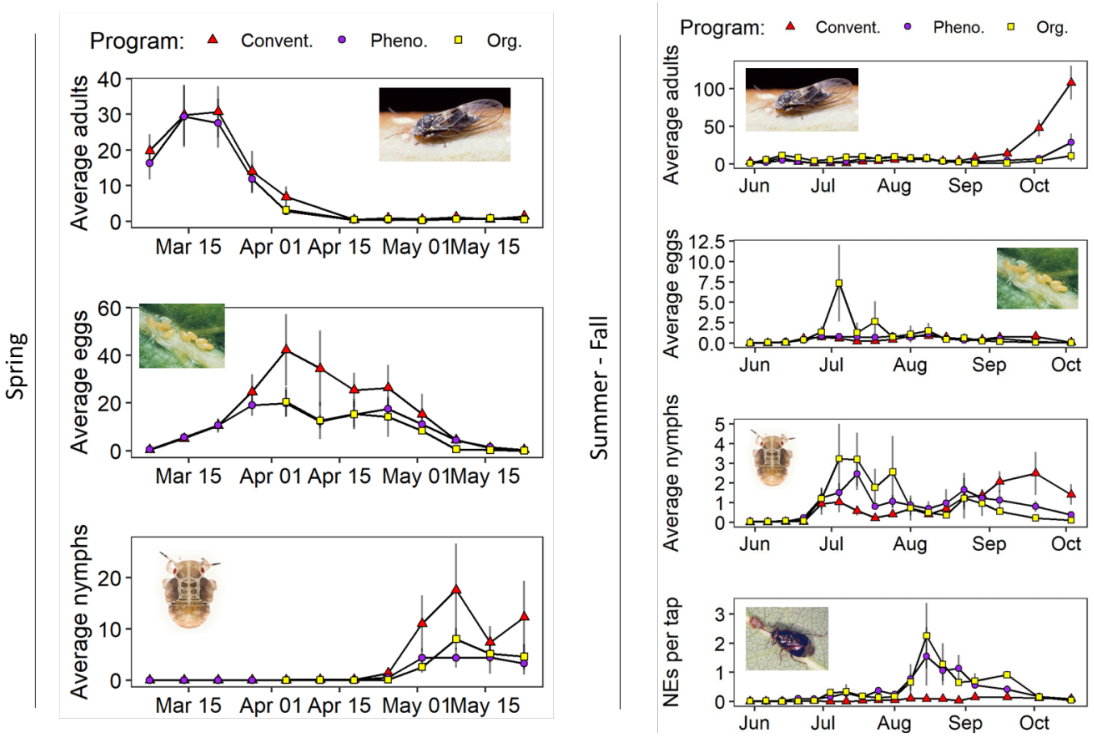

Fig. 7. 2022 weekly averages of psylla adults, eggs, and nymphs in conventional, phenology, and organic orchard treatments.

Season-long phenology spray programs cost $280/acre less than conventional programs, on average (Fig. 8 [left]). The average percentage of fruit rated as US-1 (highest quality, less than 1% honeydew injury) was not different among phenology and conventional treatments for Bartlett (not shown) or d'Anjou (Fig. 8 [right]). It is important to note that some phenology plots experienced greater injury than growers considered "desirable", however, so did conventional.

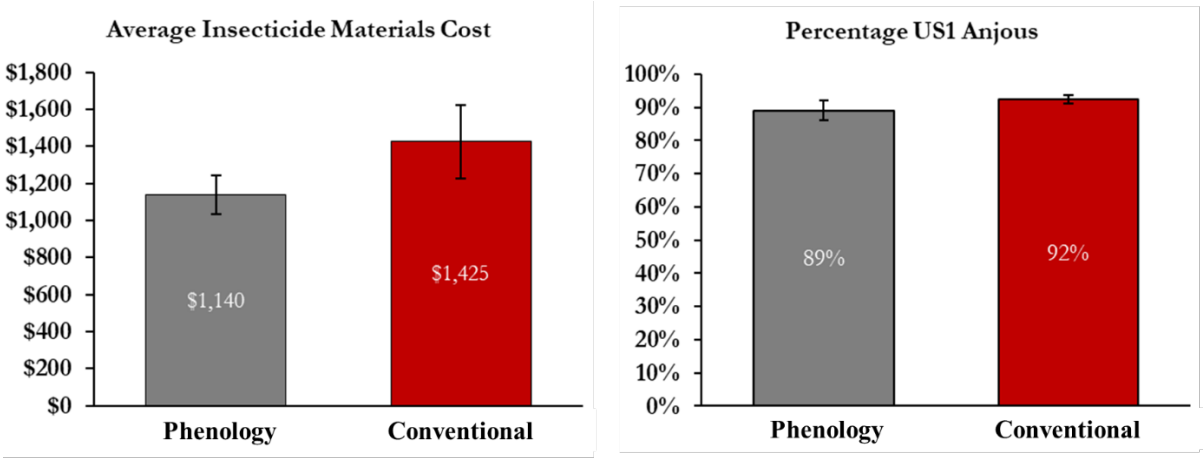

Fig 8. (Left) Average full season cost for all insecticide and miticide spray materials per acre for phenology ($1,140) and conventional ($1,425) programs. (Right) Average percentage of d'Anjou pears (100 sampled per plot) rated as US-1 quality (less than 1% injury) for phenology and conventional programs.

Conclusions: In 2021, the phenology based IPM program provided clearly superior suppression of pear psylla; however, we do not yet have economic data for these plots because they were associated with a different project and it was not originally planned to conduct field trials in this season.

In 2022, the phenology program provided similar control of pear psylla to the conventional program, as demonstrated by the equal percentage of pears rated US-1 across treatments. While some phenology plots experienced more injury than desirable, so did some conventional plots. This shows that the phenology program is not perfect at controlling psylla, as some plots faired better than others; but again, this was also true for conventional plots. The phenology program consistently was less expensive thank conventional, by $280 per acre on average, and used either no broad-spectrum materials or only one (four phenology orchards used one Bexar spray at delayed dormant) per season. This demonstrates that the phenology-based IPM program can effectively manage pear psylla with selective materials and at a lower cost, which was the primary goal of this project. If implemented throughout the 20,000 acres of pears WA, it would save the WA industry $5.6 million per year.

Psylla densities among treatments were more dynamic in 2022 than 2021. The phenology program provided improved psylla suppression to conventional programs early in the season, demonstrating that two Surround sprays early (without added broad-spectrum tank mix sprays) is as or more effective than one Surround spray coupled with multiple tank mixes of broad-spectrum materials like Malathion, Rimon, Assail, and Bexar (also demonstrated in Nottingham et al. 2022).

The first summer generation presented a issue that will be a challenge to gaining adoption of this phenology program. Nymphs were higher in the phenology program than conventional programs for about three weeks in July, which caused significant stress to growers—surprisingly, no one dropped out of our program. Many of cooperators expected that the high psylla pressure in phenology blocks would continue to increase and result in greater injury than conventional. To the contrary, psylla pressure neutralized among treatments around August, and then increased in conventional plots near harvest. Phenology plots ended with similar injury to conventional plots. Similar injury

outcomes were likely the result of the late season psylla serge in conventional and/or the effective use of honeydew washing via overhead sprinklers or airblast sprayers (used in both conventional and phenology).

Just prior to the last generation of psylla, natural enemies (mainly Trechnites, Campylomma, and Deraeocoris) increased in phenology and organic plots, but never developed in conventional. The differences in natural enemies almost certainly explains the steep increase in psylla nymphs and concomitant winterform adult in conventional plots at the end of the season. This trend suggests that areawide adoption of programs that conserve natural enemies (IPM or conventional) will lead to regional reductions in pear psylla for future years, due to massive decreases in adults going into overwintering and increased establishment of natural enemies. It is critical that growers and crop advisors understand these trends, as it will make management easier, less expensive, and more sustainable in future years.

In this project, we have not only developed an IPM program that is effective, strategic, and economical, we have debunked the idea that adopting IPM is "risky", particularly in the first year. Again, our phenology orchards experienced no differences in injury from psylla or any other pest injury. Meanwhile, they cost $280/acre less and produced 10-fold fewer winterform adults, so if anything, there is more risk in remaining conventional. As an industry there is certainly greater risk in not using IPM. It should also be noted that there was nothing special about the orchards in which we tested phenology programs. They were all in their first year of IPM, they were located in high pressure areas of the Wenatchee River Valley (not isolated), and they had large, old d'Anjou and Bartlett trees. The phenology program will remain publicly available within the Tree Fruit Extension website (http://treefruit.wsu.edu/crop-protection/psylla-phenology-model/) and via subscription in the Decision Aid System. We hope growers and crop advisors will not only use it appropriately, but share their results so adoption spreads.

3c. Extension and Outreach: All information from the project is online, including the model, recommendations, and real time scouting data. Additionally, we broadcasted summaries of results and reminders of our online resources via 3 Fruit Matters Newsletter articles in 2021 and 4 in 2022. We hosted two major Extension events including a pear IPM field day at one of our IPM orchards in Peshastin (Sept 2022) and a day-long pear IPM Fruit School in Wenatchee (Dec 2022, organized by T. DuPont).

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Executive Summary

Title: Developing a phenology-based management program for pear psylla

Keywords: Pear Psylla, *Cacopsylla pyricola*, IPM, Phenology, Degree Days

Abstract: Pear psylla has been the most costly pest of pear orchards in Washington since it arrived in the 1940's, particularly in the Wenatchee River Valley, the state's largest pear production region. Coventional pear growers here make 10-15 sprays per season to control psylla, costing about $1,500 per acre on average. Most sprays involve tank mixes of multiple broad-spectrum insecticides that dessimate natural enemy populations. This is not only expensive, but it has led to extremely high areawide populations of pear psylla in Wenatchee due to lack of biological control from natural enemies. Growers in other pear-growing regions, like Hood River, OR, use around three selective sprays for pear psylla per season, then allow natural enemies to do the rest.

The purpose of this project was to develop an effective and economical IPM program for pear psylla, by strategically timing selective techniques (such as IGRs, kaolin, and honeydew washing) with pear psylla degree days and tree phenology. We performed a literature review followed by experiments to determine optimal timings of selective techniques, then incorperated them into a pear psylla phenology model. The final phenology-based IPM program is availble in the WSU Tree Fruit Extension website (http://treefruit.wsu.edu/crop-protection/psylla-phenology-model/) and in the Decision Aid System (https://decisionaid.systems/). The phenology program was tested against standard conventional programs in replicated 2-4 acre commercial orchards throughout the Wenatchee River Valley (four reps in 2021, eight in 2022). In both years, the phenology program controlled psylla densities similar to or better than standard conventional orchards, and led to major increases in natural enemies. The phenology orchards also produced 10-fold fewer psylla adults going into overwintering than conventional orchards. Fruit downgraded by honeydew (only measured in 2022) was not different between phenology and convnetional programs (Fig 1. Right). No differences among programs were seen for other pests including codling moth, mites, and mealybug. The phenology programs cost $280 per acre less than the conventional programs, on average (Fig 1. Left). Across the 20,000 acres of pears WA, this program could save the WA industry $5.6 million per year.

Our results demonstrate that this phenology-based IPM program is effective, economical, and extremely low-risk, even in the first year of adoption. Moreover, areawide adoption results in a regional suppression of overwintering pear psylla, due to conservation of later season natural enemies. This will greatly reduce the areawide populations of pear psylla, making management in future years easier and cheaper for all growers.

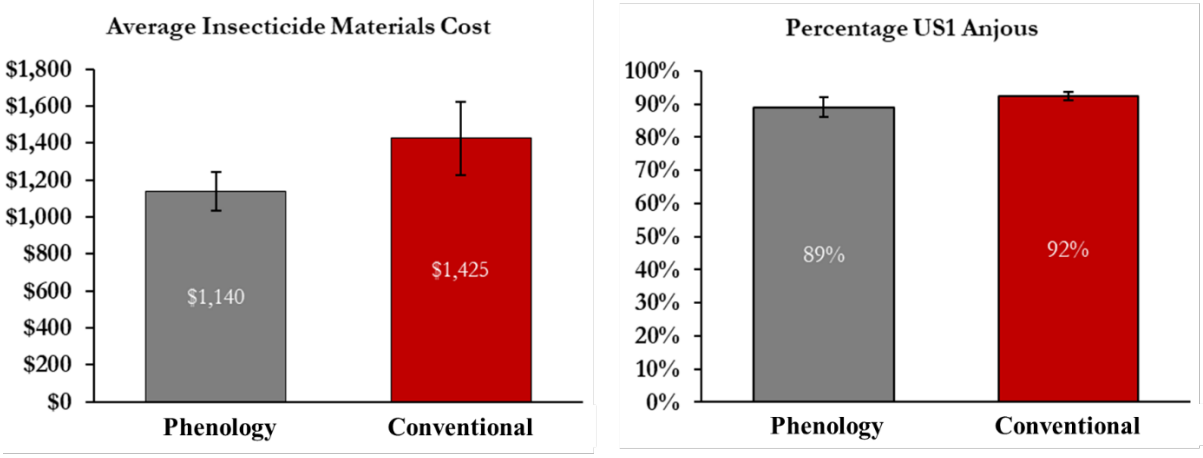

Fig 1. Left graph: 2022 average full season cost for all insecticide and miticide spray materials, per acre, for phenology ($1,140) and conventional ($1,425) programs. Right graph: 2022 average percentage of d'Anjou pears (100 sampled per plot) rated as US-1 quality (less than 1% injury) for phenology (89%) and conventional (92%) programs.