Project Title: What factors impact mite outbreaks in pear?

Report Type: Final Project Report

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Project Duration: 2 Year

Total Project Request for Year 1 Funding: $33,054
Total Project Request for Year 2 Funding: $33,857

Other related/associated funding sources: None

WTFRC Collaborative Costs: None

Other related/associated funding sources:
<u>Requested</u>

Funding Duration:	June 2024 – May 2027
Amount:	$109,581
Agency Name:	Washington Tree Fruit Research Commission (ACP) & Fresh and Processed Pear Committee Research
Notes:	New funding request to pursue research on whirligig mite releases and conservation. In addition to unrelated work in potatoes, this proposal was brought about by determining that whirligigs were highly abundant in some pear orchards surveyed in this project. This project will determine if whirligig releases have potential; we will seek additional funding from Specialty Crop Block to expand the work if results are promising.

Budget 1
Primary PI: Rebecca Schmidt-Jeffris
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Supervisor: Rodney Cooper
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Item	2022	2023
Salaries[1]	$9,297	$9,529
Benefits[1]	$744	$762
Wages	$0	$0
Benefits	$0	$0
Equipment	$0	$0
Supplies[2]	$9,000	$9,000
Travel[3]	$0	$0
Miscellaneous	$0	$0
Plot Fees	$0	$0
Total	**$19,041**	**$19,291**

Footnotes:
[1]GS-4 technician for 4 months per year, 100% FTE at 8% benefits, Year 2 includes 2.5% COLA increase. Technician would conduct sampling in the Yakima area, process/count samples, and slide mount mites for identification (Schmidt-Jeffris will identify). This technician will also conduct surface sterilization and PCR for gut content analysis for all samples (Yakima, Wenatchee, and Hood River).
[2]Molecular supplies for gut content analysis, sticky cards for field sampling – to be purchased for entire project team.
[3]Fuel to field sites will be provided by USDA base funds and is not requested.

Budget 2

Primary PI: Louis Nottingham/Robert Orpet
Organization Name: WSU
Contract Administrator: Shelli Tompkins
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Station Manager/Supervisor: Chad Kruger **Email Address:** cekruger@wsu.edu

Item	2022	2023
Salaries[1]	$1,827	$1,900
Benefits[2]	$553	$575
Wages[3]	$3,900	$4,056
Benefits[3]	$373	$388
Equipment	$0	$0
Supplies	$0	$0
Travel	$0	$0
Miscellaneous	$0	$0
Plot Fees	$0	$0
Total	**$6,653**	**$6,919**

Footnotes:
[1]Nottingham salary ($7,612.50/mo × 12 mo × 2% FTE = $1,827 Year 1, Year 2 reflects 4% COLA increase) Nottingham to supervise data collection efforts in the Wenatchee area.
[2] Benefits rate for Nottingham is 30.3%.
[3]Summer technician at $15/hr×13 hr/wk ×20 wks, 9.6% benefits rate, salary includes 4% COLA increase in Year 2

Budget 3
Primary PI: Chris Adams
Organization Name: OSU
Contract Administrator: Charlene Wilkinson
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Station Manager/Supervisor: Steve Castagnoli
Email Address: steve.castagnoli@oregonstate.edu

Item	**2022**	**2023**
Salaries[1]	$2,187	$2,252
Benefits[2]	$875	$901
Wages[3]	$3,900	$4,017
Benefits[3]	$390	$402
Equipment	$0	$0
Supplies	$0	$0
Travel	$0	$0
Miscellaneous	$0	$0
Plot Fees	$0	$0
Total	**$7,352**	**$7,572**

Footnotes:
[1]Adams salary ($109,344/yr × 12 mo × 2% FTE = $2,187 Year 1, Year 2 reflects 4% COLA increase). Adams to supervise data collection efforts in pear in the Hood River area.
[2] Benefits rate for Adams is 40%.
[3]Technician at $31,200/yr × 5 mo × 40% FTE. 10% benefits rate. Includes 4% COLA increase in Year 2.

OBJECTIVES

1. Identify management practices that affect pest mite and natural enemy populations.

2. Identify which natural enemies are more frequently consuming pest mites.

3. Determine if there is an association between spider mite and pear psylla abundance.

SIGNIFICANT FINDINGS

- Wenatchee Valley had substantially higher twospotted spider mite populations than Yakima Valley or Hood River. Hood River locations in 2022 had very few spider mites, but were more similar to Yakima numbers in 2023. In 2023, Hood River sites had higher pear psylla populations than Wenatchee, contrary to expectations. Yakima Valley had much higher rust mite populations than the other two regions in both years of the survey.

- While phytoseiids ("typhs") were found in the survey, they were much less common than in apple orchards. This suggests that in pear orchards where pest mites do not flare, other natural enemies may be responsible for biological control. Yakima orchards were dominated by *Typhlodromus caudiglans*, whereas Wenatchee orchards were dominated by *Galendromus occidentalis*. This likely reflects the prey preferences of these two phytoseiids (rust mites and twospotted spider mites, respectively) and the abundance of particular prey items. Relatively few phytoseiids were found in Hood River orchards, even in orchards where spider mites were relatively abundant.

- Weed wash samples effectively detected phytoseiids and spider mites in the ground cover. Orchards with very high TSM populations in the weeds also had outbreaks in the trees, but there was no consistent correlation between ground cover and canopy populations at moderate or low densities. There was also no clear trend on where TSM appeared first (weeds versus canopy). The phytoseiid community in the weeds was more diverse than the canopy.

- The composition of the orchard natural enemy community varied dramatically by region. Very few natural enemies were captured on beat trays in Hood River in 2022, so we focused on 2023 to compare regions. Wenatchee sites had more *Deraocoris*, *Camplyomma*, and *Chrysopa* lacewings; Yakima sites had more *Stethorus,* other ladybeetles, whirligig mites (*Anystis*), phytoseiids, and spiders (anyphaenids, oxyopids, philodromids, salticids); Hood River sites had the fewest natural enemies but did have more *Chrysoperla* lacewings and linyphiid and theridiid spiders than the other two regions. Other predatory hemipterans (besides *Deraeocoris* and *Camplyomma*) were relatively rare, but more abundant in Yakima and Hood River.

- We tested 1,375 natural enemies captured on beat trays for the presence of twospotted spider mite and pear psylla DNA. *Deraeocoris* was the most abundant predator and tested positive at the highest rates for pear psylla and TSM. *Chrysopa* lacewings, *Anystis*, and several spider families also frequently tested positive for pear psylla. *Chrysoperla* lacewings, *Anystis*, and several spider families had high positive rates for TSM. Accounting for predator abundance, the majority of TSM positives were *Deraeocoris*, spiders, *Campylomma*, and *Stethorus*, and the majority of pear psylla positives were *Deraeocoris*, spiders, *Campylomma*, and *Chrysopa*.

METHODS

This two-year (2022-2023) study was conducted in commercial pear orchards in each of three pear-growing regions: Wenatchee, Yakima, and Hood River. Orchards represented a variety of management types (e.g., conventional, organic, soft IPM) and mite outbreak frequency and intensity. Each orchard was sampled every 1-3 weeks, with sampling frequency increasing during late July to mid-August when mite outbreaks are most likely to occur.

At each sampling date, a 50-leaf sample was collected from throughout the orchard block. Leaves were brushed with a mite brushing machine and the resulting sample will be counted using a microscope. We counted eggs and motiles of spider mites (twospotted spider mite, European red mite, brown mite), pear rust mites, pear psylla eggs and nymphs, and predatory mites. Any predatory mites found were removed from the sample and stored in 70% ethanol, then slide-mounted for identification. Five sticky cards were also placed throughout the orchard block. From these, we counted ladybeetles, lacewings, *Deraeocoris*, anthocorids (to genus), *Stethorus*, *Campylomma*, *Geocoris*, and *Nabis*. We conducted beat samples on 5 trees spaced roughly evenly throughout the orchard block. Any small predatory insects (of the appropriate size to eat mites) were directly placed in molecular grade ethanol for later counting and gut content analysis by PCR.

We also assessed herbicide strip weediness. We measured the distance from the edge of the herbicide strip to the trunk for the five sample trees to determine the herbicide strip size. For the same set of trees, we also estimated percent composition of bare ground, grass, and broadleaf weeds in the space adjacent to the tree (0.5×0.5 m quadrat). The presence/absence of dominant weed species was also recorded. Weeds were also collected from within the quadrat, brought to the lab, and then rinsed with ethanol to remove any arthropods. The ethanol "rinsate" was then poured through a vacuum filter with filter paper. Spider mites and phytoseiids captured on the filter paper were counted.

We determined that typical molecular gut content analysis using universal COI primers is not suitable for this study. Neither our pest mites nor pear psylla amplify well with this primer. Instead, we used species-specific primers for each predator collected in the study to determine whether it had recently fed on a pest of interest. An existing twospotted spider mite specific primer was determined to be suitable for our use. A colleague (B. Ohler) recently designed a highly specific pear psylla primer, which will also screen our predators with. We have successfully sequenced pear rust mites and are in the process of designing and optimizing a primer to detect their DNA. All other molecular work has been completed.

We have conducted some preliminary modelling to determine which factors are likely associated with mite outbreaks at the surveyed sites. However, we will continue to refine our analysis to better handle the large quantity of data collected.

RESULTS AND DISCUSSION

In 2022, we monitored a total of 20 locations: nine in Yakima Valley, six in Wenatchee Valley, and five in Hood River. In 2023, we monitored 18 locations: seven in Yakima Valley, six in Wenatchee Valley, and five in Hood River. In 2022, pest mites were nearly absent at all locations in Hood River. We also noted that almost no natural enemies were captured on beat trays in Hood River; therefore, new sites were selected in 2023. Yakima Valley dropped three sites and added one in 2023, whereas all the Wenatchee Valley sites remained the same between both years.

To compare pest and natural enemy populations between the regions, we calculated seasonal averages only using dates with strong overlap in pear psylla degree days (PPDD). There were fewer dates of overlap between regions in 2022 than 2023. The PPDD ranges used were 1150-3050 in 2022 and 2120-4400 in 2023. Wenatchee Valley sites had much higher twospotted spider mite populations than the other two regions, with Yakima Valley intermediate (Fig. 1). Phytoseiids were generally

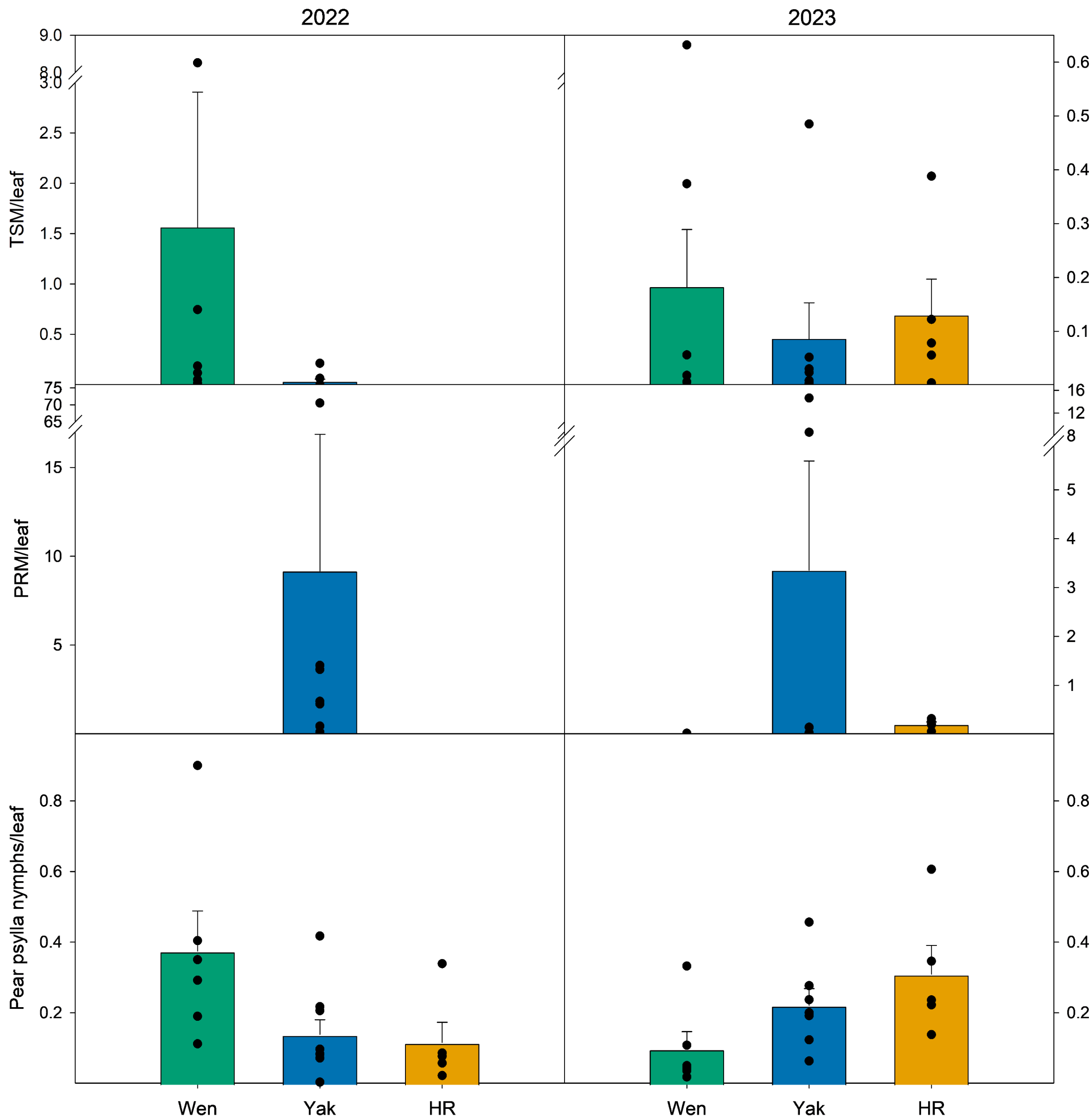

Fig. 1. Mean (±SE) pest counts per leaf in the three growing regions in 2022 and 2023, during the sampling period with the most PPDD overlap between the sites monitored. The black circles are the means for the individual orchards surveyed. Y-axis breaks are used to incorporate outlier data points for mite counts.

uncommon, especially compared to prior work in apple orchards (Schmidt-Jeffris et al. 2015). They were rarest in Hood River (3 total specimens found across all orchards throughout the season). In Yakima, one orchard reached 1.10 phytoseiids/leaf in 2023, but this was extraordinarily high compared to the other orchards. In general, orchards rarely exceeded 0.1 phytoseiids per leaf. In Yakima, *Typhlodromus caudiglans* is the dominant predatory mite, likely due to high populations of its preferred rust mite prey (Fig. 1). In Wenatchee, *G. occidentalis* is the dominant predatory mite, again due abundant preferred prey (spider mites). Only one organic orchard in Yakima had a different dominant canopy species (and in fairly low abundance), which we have yet to identify. Our results indicate that orchards with high populations of rust mites can expect *T. caudiglans* to be their most common phytoseiids, whereas those with twospotted spider mites can expect *G. occidentalis*.

Alcohol weed washes were effective at detecting spider mites and phytoseiids in the ground cover and were a much more efficient method of collecting mites than examining plant material. There was a correlation between TSM abundance in weed washes and in the canopy, although this relationship was not consistent across all orchards (Fig. 2). In general, orchards where TSM were absent from the weeds did not exceed per leaf thresholds, but moderate levels of TSM in the weeds were less indicative of levels in the canopy. Phytoseiid diversity was higher in the weeds than the canopy and *G. occidentalis* in particular was less abundant. The presence of *G. occidentalis* in the weeds was almost always associated with an orchard where TSM exceeded thresholds and were therefore also abundant in the weeds. Corresponding with leaf counts, Wenatchee had the highest number of TSM in weed wash samples both years (Table 1). In 2022, Wenatchee had more phytoseiids in the weed wash samples than the other regions and ~50% were *G. occidentalis*. In 2023, Yakima had over 10× as many phytoseiids in weed washes as the other regions (Table 1); this was driven primarily by one orchard where over 70 *T. caudiglans* females were found during the course of sampling; on 9 Sep 2023 alone, 54 phytoseiids were found in the weed wash sample for this location. This orchard

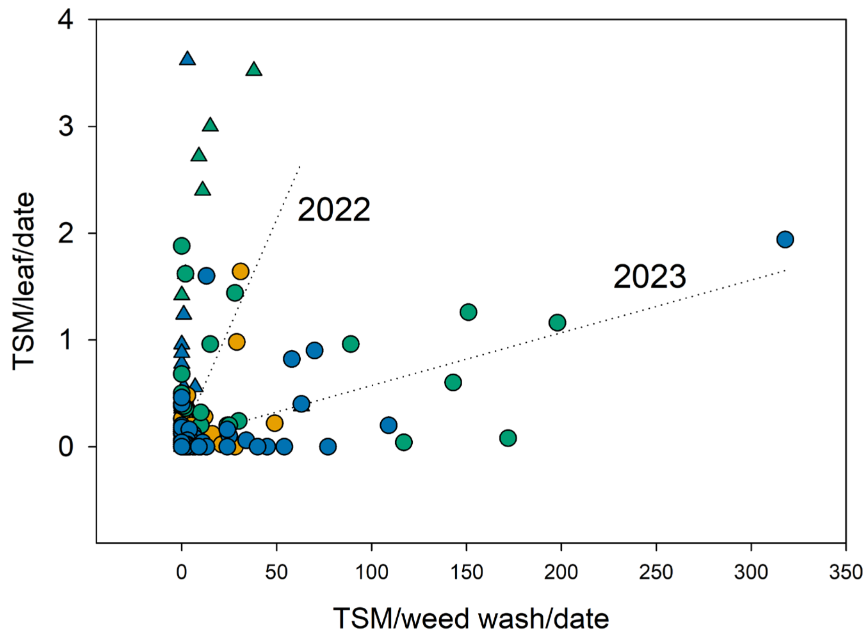

Fig. 2. TSM in weed wash samples versus leaf samples on each date studied in each orchard.

Table 1. Mean (±SE) mites per weed wash sample per date in each region.

	Region	*n*	TSM	Phytoseiids
2022	Wen	6	6.69 ± 3.11	0.31 ± 0.21
	Yak	9	0.34 ± 0.11	0.05 ± 0.03
	HR	5	0.03 ± 0.03	0 ± 0
2023	Wen	6	14.58 ± 13.39	0.21 ± 0.07
	Yak	7	10.21 ± 5.90	2.35 ± 0.80
	HR	5	5.27 ± 1.86	0.10 ± 0.07

Table 2. Mean (±SE) natural enemies per sample (5 beat trays) for each region in 2023. Phytoseiid counts shown are per leaf. In each row, the darkest box corresponds to the region where a natural enemy was most abundant.

	Region	*n*	TSM	Phytoseiids
2022	Wen	6	6.69 ± 3.11	0.31 ± 0.21
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	HR	5	5.27 ± 1.86	0.10 ± 0.07

year	area	_FREQ_	anthocoris	anthocorisSE	anyphaenid	anyphaenidSE	brown	brownSE	campy	campySE	chrysopa
2022	H						0.03333	0.03333			

was dominated by *T. caudiglans* (79%), which was likely feeding on the unusually high rust mite population (>15/leaf).

The most common natural enemies in beat tray samples were *Deraeocoris*, spiders, *Stethorus*, and *Campylomma* (Table 2). Poor beat tray capture in Hood River in 2022 made it difficult to compare natural enemy populations between the regions, so only data from 2023 samples are shown. Wenatchee sites had more *Deraocoris*, *Camplyomma*, and *Chrysopa* lacewings; Yakima sites had more *Stethorus,* other ladybeetles, whirligig mites (*Anystis*), phytoseiids, and spiders (anyphaenids, oxyopids, philodromids, salticids); Hood River sites had the fewest natural enemies but did have more *Chrysoperla* lacewings and linyphiid and theridiid spiders than the other two regions. Other predatory hemipterans (besides *Deraeocoris* and *Camplyomma*) were relatively rare, but more abundant in Yakima and Hood River. The lower abundance of natural enemies in Hood River in 2023 may have contributed to the higher pear psylla populations.

Across both years, Yakima orchards had wider herbicide strips (2.3 ± 0.3 m) than orchards in Hood River (1.2 ± 0.1 m) or Wenatchee (1.1 ± 0.1 m). All orchards in Yakima had clover, dandelion, mallow, and chickweed present and black medic, pigweed, and field bindweed were also common (Table 3-4). In Hood River, clover, dandelion, and mallow were also the three most common weeds (Table 3-4). Wenatchee differed from the other two areas – field bindweed was the most common, followed by dandelion, mallow, and lambs quarter. Some weeds were found in a majority of orchards, but still relatively uncommon within samples (e.g., lambs quarter in Wenatchee and Yakima). Yakima orchards tended to be grassier than Wenatchee and Hood River orchards (Fig. 3), potentially indicating that the herbicide strip was managed less heavily.

We compared orchards where spider mites exceeded the threshold (0.5/leaf) at least once to those that did not. Of the more common weed groups, field bindweed and lambs quarter incidence differed the most between the "exceeded" and "did not exceed" groups; orchards that exceeded thresholds had more than twice as many samples with bindweed present as those that did not (lambs quarter 76% higher in "exceeded" orchards). This indicates that these weeds in particular should be monitored for spider mites and may need to be carefully controlled to reduce outbreak risk. However, bindweed was also more common in Wenatchee (where spider mite outbreaks more commonly occur); more complex modelling procedures may better determine which of these variables is truly associated with TSM outbreaks versus regional differences. There were similar difficulties determining which natural enemies were associated with lower pest populations using more basic modelling procedures.

Table 3. Percent of orchards where a given weed was present, 2022-2023.

	Yakima	Wenatchee	Hood River
Clover	100	50	90
Dandelion	100	67	80
Mallow	100	67	70
Chickweed	100	17	10
Black Medic	90	0	0
Pigweed	80	0	30
Field Bindweed	80	100	10
Lambs Quarter	70	67	0
Shiny Geranium	70	0	0
Broad Leaf Plantain	60	0	30
Prostrate Knotweed	40	0	0
Narrow Leaf Plantain	20	0	0
Purslane	10	0	0
Horsetail	0	50	0
Ribes	0	33	0

The gut content analysis data used two species-specific primers (TSM, pear psylla) and provides insight regarding which natural enemies are consuming key pear pests in the field. However, our analysis only indicates that a predator recently ate one of these pests and not how many or when. Most differences in results between regions were due to the abundance of particular groups of predators and the availability of the two pests, therefore we are showing the combined results of both years for all three regions. A high percentage of *Deraeocoris* tested positive for TSM (40%) and pear psylla (59%) (Table 5), resulting in this species making up the largest total number of positives. Of the groups where >20 individuals were collected, *Deraeocoris*, *Anystis*, and *Chrysoperla* most frequently test positive for TSM and *Deraeocoris*, *Anystis*, and *Chrysopa* most frequently test positive for pear psylla (Table 5). However, when the abundance of the natural enemy groups was considered, *Dereaocoris*, spiders, and *Campylomma* accounted for the majority of positives for both pests (Fig. 4). In 2023, we identified the spiders to family and are able to further breakdown which groups are consuming the two pests. Anyphaenids, oxyopids, philodromids, and salticids were the most abundant. A relatively high proportion of all these groups tested positive for both pests (Table 6). Oxyopids and anyphaeids contributed to a relatively high proportion of both the TSM and pear psylla positives, and salticids to the pear psylla positives (out of all positive natural enemies combined). Earwigs are undersampled on beat trays, leading our gut content work to likely underestimate their importance in pear orchards.

Table 4. Percent of samples (quadrats) where a given weed was present, 2022-2023.

	Yakima	Wenatchee	Hood River
Dandelion	47.0	6.7	16.8
Clover	25.5	1.5	14.3
Mallow	21.4	6.9	11.4
Field Bindweed	18.9	33.8	0.2
Chickweed	18.2	0.1	0.1
Prostrate Knotweed	9.0	0.0	0.0
Lambs Quarter	5.2	3.2	0.0
Pigweed	4.8	0.0	5.2
Broad Leaf Plantain	4.6	0.0	1.8
Black Medic	3.9	0.0	0.0
Shiny Geranium	1.6	0.0	0.0
Purslane	1.2	0.0	0.0
Narrow Leaf Plantain	0.8	0.0	0.0
Ribes	0.0	0.0	0.0
Horsetail	0.0	5.4	0.0

Spiders and whirligig mite (*Anystis*) are likely underappreciated as predators in orchards, although their role may be more important in the Yakima Valley where they appear to be more abundant. Surprisingly, only 22% of *Stethorus* tested positive for TSM; they were abundant in some orchards where TSM populations were low, indicating they may be eating another food source. Additionally, we did not observe *Stethorus* larvae in any of our orchards, indicating that they may be reproducing exclusively in extra-orchard habitat. The two green lacewing genera collected (*Chrysopa* and *Chrysoperla*) appear to substantially differ in prey preferences; few *Chrysoperla* tested positive for pear psylla whereas 52% of *Chrysopa* were positive. If *Chrysoperla* minimally contribute to pear psylla predation, then scouts may need to distinguish between green lacewing genera to estimate the expected level of biological control. Finally, the gut content results provide additional evidence that *Deraeocoris* is a key predator of both TSM and pear psylla in pear psylla orchards. Its role in controlling TSM should be further investigated. We will continue to work with this data set to develop models that highlight factors that contribute to spider mite outbreaks.

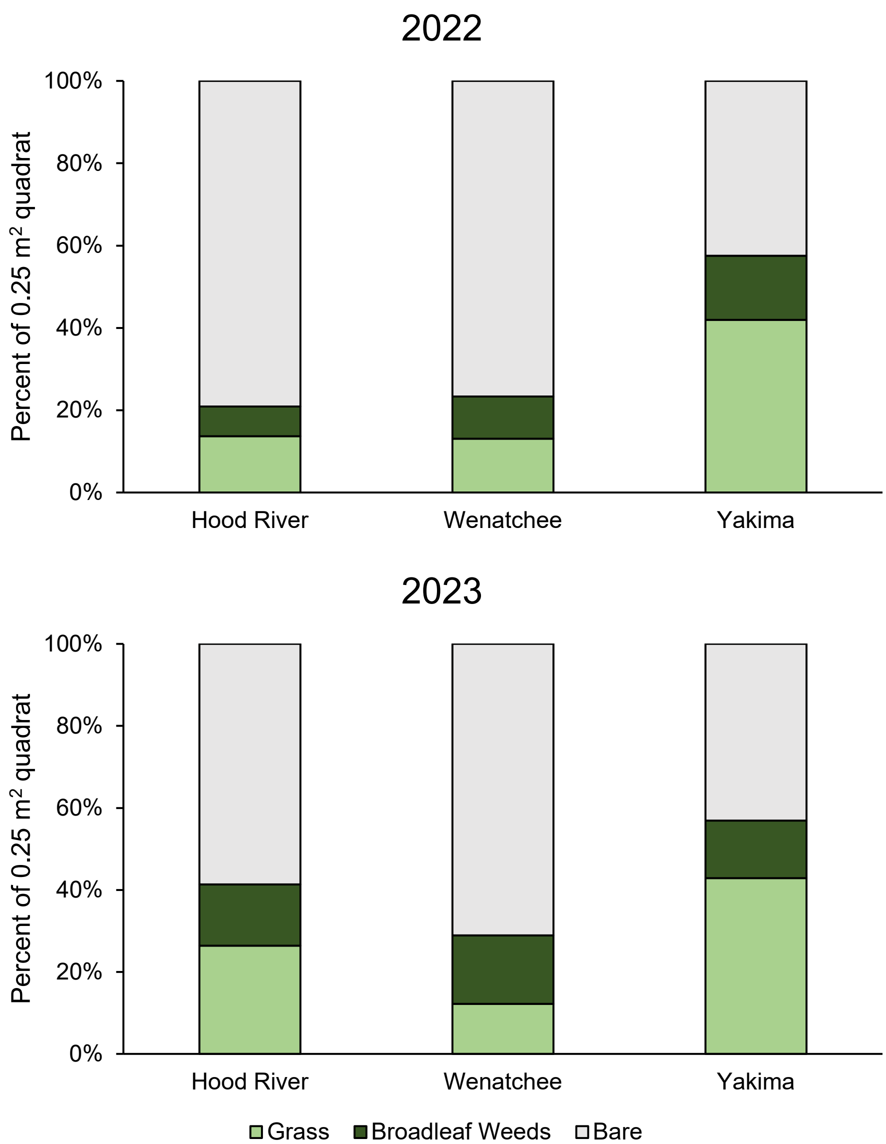

Fig. 3. Ground cover composition 0.5 m into the row from the base of the tree.

Table 5. Percent of samples from each natural enemy group testing positive for TSM and pear psylla (PP) DNA using species-specific primers.

	n	**% TSM+**	**% PP+**
Earwigs	34	3	29
Campylomma	188	23	24
Deraeocoris	505	40	59
Anthocoris	7	14	57
Orius	13	23	15
Geocoris	3	67	33
Nabis	15	33	27
Berytidae	3	0	33
Hemerobiidae	8	0	38
Chrysopa	42	21	52
Chrysoperla	36	31	14
Stethorus	161	22	1
Other ladybeetle	38	16	24
Spider	292	24	30
Opiliones	8	13	0
Anystis	22	32	45

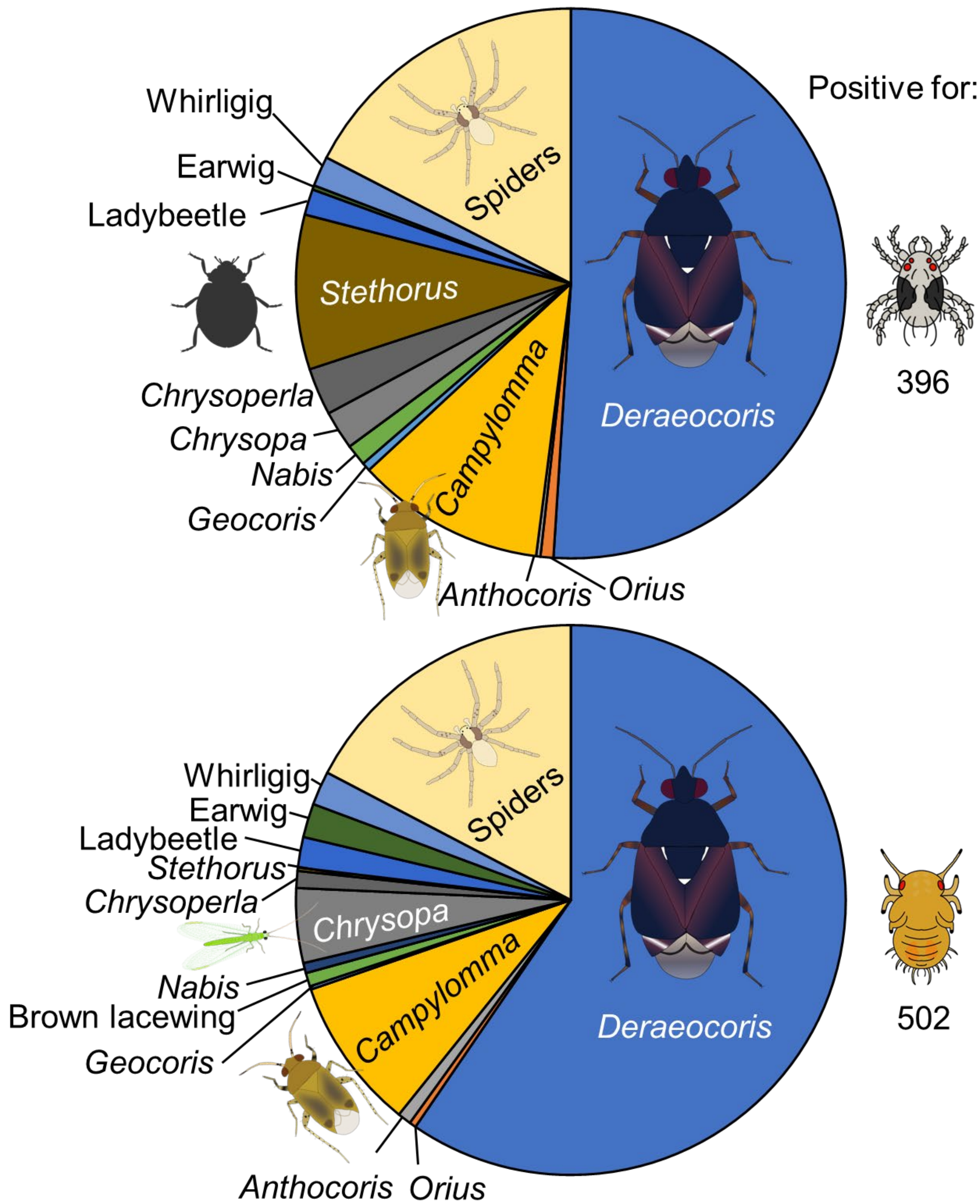

Fig. 4. The relative proportion of each natural enemy group making up samples that tested positive for TSM or pear psylla DNA.

Table 6. Percent of samples from each natural enemy group testing positive for TSM and pear psylla (PP) DNA using species-specific primers in 2023. In 2023, spiders were identified to family.

	n	**% TSM+**	**% PP+**
Earwigs	18	6	28
Campylomma	161	26	25
Deraeocoris	377	45	60
Anthocoris	5	20	80
Orius	4	50	0
Geocoris	1	100	0
Nabis	11	36	27
Berytidae	1	0	0
Hemerobiidae	1	0	0
Chrysopa	24	25	50
Chrysoperla	29	38	7
Stethorus	115	30	1
Other ladybeetle	14	14	7
Opiliones	7	14	0
Anystis	18	39	50
Anyphaenidae	32	38	47
Dyctinidae	1	0	0
Linyphiidae	16	44	31
Oxyopidae	42	38	29
Philodromidae	33	30	6
Salticidae	30	23	53
Theridiidae	10	20	40
Thomisidae	6	17	17

EXECUTIVE SUMMARY

Project title: What factors impact mite outbreaks in pear?

Key words: spider mite, rust mite, *Tetranychus urticae*, *Epitrimerus pyri*, natural enemies

Abstract:

After pear psylla, twospotted spider mite (TSM) and pear rust mite are the key pests of pears in the Pacific Northwest. TSM outbreaks can be sporadic and difficult to predict. We sought to determine which factors, including spray programs, mowing, weed community, orchard dustiness, weed management, and the natural enemy community, best predicted flare ups of either mite pest. We also used molecular gut content analysis as a method for determining which predators likely played the largest role in biological control. We collected data from orchard managers and sampled the weed community and ground cover composition, as well as sampling for arthropods using leaf samples, weed washes in ethanol (for spider mites and phytoseiids), beat trays, and sticky cards. Sampling was conducted in 2022-2023 in orchards in three pear growing regions: Wenatchee, Yakima, and Hood River. Preliminary data analysis suggests that the presence of field bindweed may contribute to TSM outbreaks, but more sophisticated analysis is needed to account for correlation between the variables measured. Field bindweed was present in most orchards in Yakima and Wenatchee, but absent in Hood River; it was particularly abundant in Wenatchee. In general, Yakima orchards had larger pear rust mite populations and Wenatchee orchards had larger TSM populations. This corresponded to these areas having phytoseiid communities dominated by *Typhlodromus caudiglans* and *Galendromus occidentalis*, respectively; this is likely due to the prey preferences of each predator for the most common pest of each region. Both TSM and phytoseiids could be found in weed wash samples; very high abundance of TSM in the orchard canopy corresponded with high abundance in weed wash samples, but moderate levels did not strongly correlate with leaf counts. The relative abundance of natural enemy groups varied by region. Hood River had fewer natural enemies than the other two locations. In Wenatchee, *Deraeocoris* and *Campylomma* were the most abundant and highly dominant. In Yakima, *Deraeocoris* and *Campylomma* were also the most abundant, but spiders and *Stethorus* also made up a large portion of the natural enemy community. We determined that COI-barcoded primers were not suited for our target pests and instead used species-specific primers for TSM and pear psylla; we are working on developing a primer to target pear rust mite and have identified a promising sequence. In addition to being abundant, *Deraeocoris* tested positive for both pest species at high rates, indicating that it may be the most critical predator in pear orchards. Spiders and whirligig mite (*Anystis*) also tested positive at high rates and are likely underappreciated as predators in orchards, although their role may be more important in the Yakima Valley where they appear to be more abundant.