95th Annual
Orchard Pest & Disease Management Conference

January 13-15, 2021

Keynote Speaker: Covid-19

Cancelled

About the cover: Artist unknown.

95th Annual Orchard Pest and Disease Management Conference

Orchard Pest and Disease Management Conference
2021 Agenda

The Annual OPDMC was cancelled in 2021 due to COVID-19. As the nation and the rest of the world struggled with this pandemic the executive committee decided to post our content online rather than hold a multiday video conference. This year the OPDMC is much smaller. We are very grateful to the presenters who responded with reports for the Program and excited that the majority also submitted a video presentation with audio narration. Kudos to all of these participants for keeping the spirit of OPDMC alive! We hope that you enjoy the reports and videos contained herein. There is plenty of valuable information for everyone.

For reports with associated videos, click the report title to launch the video in your internet browser.

We look forward to seeing everyone at the Hilton Portland next year in person.

Save the date OPDMC 2022

January 12,13,14, 2022.

Orchard Pest and Disease Management Conference
Officers for the 2021 Conference

Chair (2021&2022)
Allison Walston
Valent U.S.A.
PO Box 1976
Hood River, OR 97031

Phone: 503-867-1749

Email: Allison.Walston@valent.com

Chair-Elect (2021&2022)
Chris Adams
Oregon State University

Hood River, OR 97031

Phone: (248) 850-0648

Email: chris.adams@oregonstate.edu

Executive Director
Peter McGhee
OPDMC Executive Director
4815 NW Bruno PL
Corvallis, OR 97330

Phone: 517-331-1816
Email: executivedirector@opdmc.org

Program Chair
Louis Nottingham
WSU Tree Fruit Research & Ext. Center
1100 N. Western Avenue
Wenatchee, WA 98801

Phone: (540) 798-2044
Email: louis.nottingham@wsu.edu

Secretary
Alix Whitener
Technical Services Manager
FMC
Malaga, WA 98828

Phone: 509-669-1656
Email: alix.whitener@fmc.com

Treasurer
Nik Wiman
North Willamette Research & Extension Center
15210 NE Miley Rd
Aurora, OR 97002

Phone: 503-678-1264
Email: nik.wiman@oregonstate.edu

Web Site and Proceedings
Peter McGhee
OPDMC Executive Director
4815 NW Bruno PL
Corvallis, OR 97330

Phone: 517-331-1816
Email: executivedirector@opdmc.org

Past Chair (2020-2021)
Rodney Cooper
USDA-ARS
Yakima Ag. Research Laboratory
5230 Konnowac Pass Rd
Wapato, WA 98951
Phone: 509-454-4463
Fax: 509-454-5646
Email: rodney.cooper@ars.usda.gov

For more information, see: http://opdmc.org/

Order of Presentations

FROM THE 95th ANNUAL

ORCHARD PEST AND DISEASE MANAGEMENT CONFERENCE

January 13-15, 2021

Keynote Presentation: Cancelled

Presentation **Page**

Implementation— Moderator: 1

Effect of Flailing on Overwintering Filbertworm Larvae and Aphid Parasitoids (Andrews). 3

Thresholds & Monitoring— Moderator: 7

Biological Control— Moderator: 10

Integrated Mite Management: nontarget effects of miticides on a potential biological control agent, *Amblydromella caudiglans* (Bergeron)..... 12

Redistribution and establishment of the samurai wasp, *Trissolcus japonicus*, a biological control agent of the invasive brown marmorated stink bug, *Halyomorpha halys*, in Oregon... (Donahoo)..... 16

Effectiveness of Yellow and Blue Sticky Cards for Monitoring Parasitoid Wasps of the Invasive *Halyomorpha halys* (Hemiptera: Pentatomidae) (Holthouse) 17

Deploying mealybug destroyers for pest control in apples (Schmidt-Jeffris)..... 20

Impacts of herbicides on orchard natural enemies (Schmidt-Jeffris)..... 23

Pathology/Diseases— Moderator: 27

Fire Blight Management Options in Utah (Murray)..... 29

Invasive Species— Moderator: 33

The Penalty Box: Developmental Costs for Brown Marmorated Stink Bug on Eastern Washington's Native Plants (Beers)..... 35

Impact of Brown Marmorated Stink Bug Feeding on the Development, Yield, and Quality of Tart Cherry in Utah (Schumm)..... 38

Chemical Control/New Products— Moderator:..... 39

Recent Progress in Preventing *Xylosandrus germanus* Ambrosia Beetle Infestations in NY Apple Orchards (Agnello) 41

Integrating BMSB management into the hazelnut IPM system (Andrews) 44

Biology/Phenology— Moderator: 49

Mating Disruption/SIR— Moderator: 52

It's Raining Moths: Drone Technology for Sterile Codling Moth Release (Athey)..... 54

Development of Sterile Insect Technique for Navel Orangeworm in California Orchards (Wilson) 57

Minutes of the 94th Annual Meeting 63

The Rubber Chicken Award 73

Travel Scholarships for Students 75

Implementation—

Moderator:

Effect of Flailing on Overwintering Filbertworm Larvae and Aphid Parasitoids

Betsey Miller[1], Rachel Blood[1], Ryan Chave[1], Vaughn Walton[1]
[1]Oregon State University, Department of Horticulture, Corvallis, OR

Keywords: filbertworm, *Cydia latiferreana, Trioxys pallidus,* hazelnuts, cultural control, conservation biological control

Abstract: Field trials were conducted from 2018 to 2020 to determine the effect of spring and winter flailing on overwintering populations of *Cydia latiferreana* (filbertworm), a pest of hazelnuts, and *Trioxys pallidus*, a natural enemy of a secondary pest of hazelnuts, the filbert ahpid. Spring flailing had a significant effect on overwintering larval survival and pupation in filbertworm. Across all years, mean larval survival and mean pupation in the 'no flailing' treatment were 1.5 times greater than that in the 'spring flail' treatment. Both spring and winter flailing had a significant effect on emergence of *Trioxys pallidus* from overwintering mummies. Mean emergence in the 'no-flail' treatment was 2.1 times greater than that in the 'spring flail' treatment and 7 times greater than that in the 'winter flail' treatment.

In Oregon hazelnut orchards, flail mowing is a common practice for orchard floor management. Orchards are typically flailed throughout the season to manage weeds, prepare the ground for harvest in late summer and manage leaf litter in winter or spring. A key pest of hazelnuts, *Cydia latiferreana* (filbertworm), overwinters on the orchard floor as a 5th instar larva protected within a hibernaculum of silk and debris. Hibernacula are present on the orchard floor from October through May. Field observations have suggested that flailing is an important management technique for FBW populations. In addition, growers have expressed concern over the effect of flailing on another important insect, *Trioxys pallidus*. This hymenopteran parasitoid is the primary natural enemy the filbert aphid, a secondary pest in hazelnut orchards. It overwinters as an aphid 'mummy' on leaf litter on the orchard floor. To investigate the effects of flailing on these two important insects, we began a field trial in 2018. The trial is on-going through 2021. Here we discuss some final and preliminary results from this field trial.

Methods and Materials

Effect of flailing on FBW. Trials were conducted in a commercial orchard in Amity, OR. Insects were collected in October of all years as hibernacula from hazelnut processing stations and stored at 4°C and total darkness until trials began. In 2018 and 2019, trials were laid out in March of each year; the 2020 trial was laid out in November of the previous year. We placed hibernacula (20 per rep) into organza bags and staked them to the soil surface in the orchard. We covered the bags in whatever leaf litter was present on the orchard floor. In the first two years of the trial, each bag was assigned one of two treatments: 'no flail' or 'spring flail'. In the third year, a third treatment, 'winter flail' was added. The flail treatment consisted of two passes with a flail mower, applied by the grower. The spring flail treatment was applied on 15 March 2018, 12 April 2019 and 16 March 2020. The winter flail treatment was applied 2 January 2020. Bags of hibernacula were collected in May and the number of surviving larvae were recorded. The bags were then transferred to large plastic trays and stored outdoors in a tree-shaded area (similar to the canopy cover in the orchard) in Corvallis, where they could be regularly observed. Larval survival, pupation and adult emergence were recorded weekly.

Effect of flailing on Trioxys pallidus. These trials are being conducted in the hazelnut accessions at the USDA National Clonal Germplasm Repository in Corvallis, OR. Only the first year is being reported here.

Insects were obtained from aphid infested leaves collected from an orchard in Springfield, OR in November 2019. Leaves containing aphid mummies were placed into organza bags and stored at 4°C until trials began. In December 2019, organza bags (10 mummies per rep) were staked to the orchard floor. Each bag was subject to one of three treatments (5 reps per treatment): 'winter flail' (applied on 22 December 2019), 'spring flail' (applied on 11 March 2020) or 'no flail.' Flailing was simulated with a hand-held, gas-powered shredder vac; the shredded contents of each bag were collected into another identical organza bag which was placed back on the orchard floor. In May 2020, organza bags were collected and stored at 24°C and 16L:8D to await emergence of adult *T. pallidus.* A second season of this trial was initiated in November 2020 and is currently underway.

Results and Discussion

FBW. In a factorial analysis of the effect of flailing between years on FBW larval survival, pupation and adult emergence, the interaction of year and treatment was not significant ($p = 0.055$), and data from all three years were pooled. Spring flailing had a significant effect on survival of overwintering larvae ($F_{1,47} = 19.97$, $p < 0.001$) and pupation ($F_{1,47} = 4.66$, $p = 0.04$). Across all years, mean larval survival and pupation with no flailing were 1.5 times greater than with a spring flail. There was, however, no significant difference in adult emergence between treatments ($p = 0.78$), with 23.6 and 21.7 percent emergence in the 'no flail' and 'spring flail' treatments, respectively. In 2020, winter flailing had no significant effect on spring survival ($F_{3,34} = 1.78$, $p = 0.17$), pupation ($F_{3,34} = 1.96$, $p = 0.14$), or adult emergence ($F_{3,34} = 0.97$, $p = 0.42$). Individual means for all years can be seen in Table 1.

These results indicate that flailing in spring could be an important practice for reducing FBW populations. Timing of this spring flail may interact with temperature to increase or decrease the effect of flailing on survival of larvae in the process of breaking diapause. A March flail treatment in 2018 resulted in lower larval survival than an April flail treatment in 2019. These two years experienced relatively high maximum temperatures in the spring months (Fig. 1). It is possible that hibernacula exposed to the elements for a longer period of time were subject to a greater level of desiccation. In 2020, with a relatively milder spring, this effect seems to have been reduced. Our results also indicate that other mortality factors come into play after pupation which lower emergence of adults in both flailed and un-flailed treatments. Winter flailing did not appear to have a significant effect on overwintering FBW. However, with only one season of field data, these results are not conclusive. Mechanical damage to larvae is an important aspect of flailing that was not a factor in this trial design. A separate trial using a vacuum shredder is being conducted to determine the effect of mechanical damage on overwintering FBW is currently underway.

Trioxys pallidus. In the first year of this trial, flailing treatments had a significant effect on emergence of *T. pallidus* ($F_{2,12} = 14.11$, $p < 0.001$). Mean percent parasitoid emergence in the un-flailed treatment was 42%. This was significantly greater than that in both the spring flail treatment (21%) and winter flail treatment (6%) (Tukey's HSD, $p > 0.05$). If data from the second season confirm this effect, these results would help growers to make informed decisions about the timing of their flailing practices to improve both conservation of natural enemies and pest control.

Table 1. Mean ± SE proportion of larvae that survived and pupated after three flail treatments in 2018 (N=5), 2019 (N=10) and 2020 (N=10). Spring treatments were applied 15 March, 12 April and 16 March, respectively. Winter treatments were applied 22 December 2020. Survival was recorded 3 May, 14 May, 10 May, respectively. Pupation was recorded until 4 September, 5 September, and 26 August, respectively. Means within a year (single column) followed by the same letter are not significantly different (Tukey's HSD, $p > 0.05$).

Treatment	Proportion of larvae survived			Proportion of larvae pupated		
	2018	2019	2020	2018	2019	2020
No flail	0.77±0.05*a*	0.71±0.04*a*	0.73±0.07*a*	0.43±0.10*a*	0.30±0.04*a*	0.54±0.07*a*
Spring flail	0.26±0.09*b*	0.52±0.06*b*	0.55±0.06*a*	0.20±0.09*a*	0.17±0.05*a*	0.44±0.06*a*
Winter flail	n/a	n/a	0.73±0.06*a*	n/a	n/a	0.60±0.06*a*

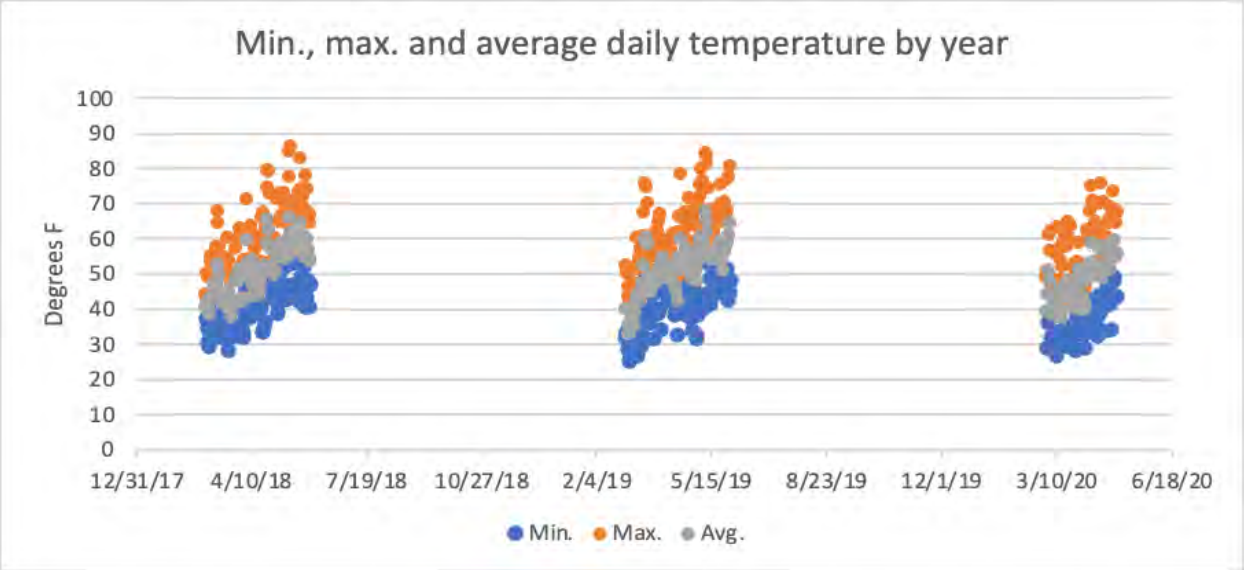


Figure 1. Minimum, maximum and daily average temperatures in the Willamette Valley, OR during spring 2018, 2019 and 2020. Data were collected by the Agrimet weather station in Corvallis, OR.

Thresholds & Monitoring—

Moderator:

Biological Control—

Moderator:

Integrated Mite Management: nontarget effects of miticides on a potential biological control agent, *Amblydromella caudiglans*

Paul E. Bergeron[1, 2], Rebecca A. Schmidt-Jeffris[1]
[1]USDA-ARS Temperate Tree Fruit and Vegetable Research Station, Wapato, WA
[2]Washington State University, Department of Entomology, Pullman, WA

Keywords: *Amblydromella caudiglans*, nontarget effects, miticide, biological control, apple

Abstract: Integrated mite management has been key for the control of spider mite pests in Washington tree fruit for over 50 years, and has relied on the conservation of *Galendromus occidentalis*. Recently, we have seen a shift in grower spray programs away from broad-spectrum pesticide use towards more selective pesticide use. Change in pesticide use is coinciding with a change in predatory mite community composition introducing a second predatory, *Amblydromella caudiglans*, as a potential biological control agent in Washington apple orchards. Here, we examine the nontarget effects of miticides on *Amblydromella caudiglans* using a bioassay and field trial. From bioassays, we see that abamectin and fenpyroximate are the most harmful products to *A. caudiglans*, and bifenazate, cyflumetofen, and hexythiazox are the safest. In a field trial, bifenazate, abamectin, and fenpyroximate where the most harmful products on *A. caudiglans* 7 days after treatment, and all products tested caused a significant reduction in *Zetzellia mali* populations.

Objectives: Examine acute and sublethal effects of miticides on *Amblydromella caudiglans* under laboratory conditions.
Examine miticide effects on predatory mite communities under field conditions.

Results: Bioassay data (figure 1) suggests that acute effects at 48 h after treatment are low to moderate for all products tested. No products caused a significant reduction in fecundity, but treatment with abamectin caused a significant increase in mortality compared to the control. Our results show a significant reduction in percent egg hatch after treatment with fenpyroximate, etoxazole, and clofentizine. No significant differences were found for live larvae production, but abamectin, cyflumetofn, fenpyroximate, etoxazole, and clofentezine reduced live larvae to 0.

Active Ingredient	% mortality	fecundity	% egg hatch	live larvae
Acramite	29	-44	-25	-59
Agri-mek	67	-54	-48	-90
Nealta	0	-43	-44	-90
Onager	9	-51	-38	-70
Fujimite	43	-72	-98	-90
Zeal	24	-58	-98	-90
Vendex	4	11	-57	-63
Envidor	17	-72	-50	-87
Apollo	7	-4	-90	-90

Figure 1. Summary of lethal and sublethal effects based on corrected values, showing percent reduction (mortality) or percent decrease (all other) in comparison to the control. Values are categorized as low (x <25%, light green), moderate (25%≥ x <75%, yellow), and high (x ≥75%, dark red). Positive numbers for mortality or negative numbers for other variables indicate lower or higher values than the control, respectively.

Field trial
Pre counts showed that none of our plots significantly differed in predator abundance. (table 1)
At 3 days after treatment, bifenazate, abamectin, hexythiazox, fenpyroximate, and fenbutatin-oxide all cause a significant reduction in phytoseiid population abundance. There are no significant effects on *Zetzellia mali.*

Table 1. Abundance (mean ± SEM) of *A. caudiglans* before miticide application (0 DAT). Means within columns not followed by the same letter are significantly different. Zet. = *Zetzellia mali*, Phyto = phytoseiid.

Active Ingredient	Zet. Egg	Zet. Motile	Phyto. Egg	Phyto. Motile
Acramite	0.8 ± 0.8	0.8 ± 0.2	4 ± 2.2	38 ± 11.93
Agri-mek	2.6 ± 1.2	2.4 ± 0.4	12.4 ± 7.2	60.2 ± 20.14
Nealta	1.4 ± 0.4	0.6 ± 0.2	6.8 ± 4.8	51.6 ± 32.59
Onager	1.2 ± 1	1.4 ± 0.2	6.2 ± 5	38.4 ± 9.35
Fujimite	0.8 ± 0.4	1.6 ± 0.9	4.4 ± 1.8	29.8 ± 9.16
Zeal	0 ± 0	0.8 ± 0.4	1.8 ± 0.9	41.6 ± 10.91
Vendex	1.8 ± 0.9	2 ± 1.3	3.4 ± 2.2	49.6 ± 17.25
Envidor	0 ± 0	0.2 ± 0.2	3.2 ± 1.5	39.8 ± 21.43
Apollo	0.4 ± 0.2	1.4 ± 0.2	7 ± 3.4	39.4 ± 14.07
Check	1 ± 0.5	1.6 ± 1.2	5 ± 3.1	48.8 ± 13.8

At 7 days after treatment, all products caused a significant reduction in motile *Z. mali* abundance. Additionally, we see significant reductions in phytoseiid egg abundance for bifenazate, abamectin, fenpyroximate, and spirodiclofen. Motile phyotseiid predators saw significant reductions after treatment with bifenazate, abamectin, and fenpyroximate. (table 2). Forty two days after treatment, there are still significant effects on motile *Z. mali* abundance for all treatments except bifenazate and cyflumetofen. Similarly, we see significant effects on abundance of motile phytoseiid predators for all treatments except abamectin, cyflumetofen, and clofentezine. Overall, this suggests that miticide applications have long term effects on predatory mite populations.

Table 2. Abundance (mean ± SEM) of *A. caudiglans* 7 DAT. Means within columns not followed by the same letter are significantly different. Zet. = *Zetzellia mali*, Phyto = phytoseiid.

Active Ingredient	Zet. Egg	Zet. Motile	Phyto. Egg	Phyto. Motile
Acramite	0.4 ± 0.24	1.4 ± 0.75b	1 ± 0.55b	5.2 ± 1.46bc
Agri-mek	0 ± 0	0 ± 0b	0.8 ± 0.2b	7.8 ± 2.69b
Nealta	0 ± 0	1 ± 0.63b	7.2 ± 5.49a	33 ± 20.53a
Onager	0 ± 0	0.8 ± 0.58b	6 ± 1.52a	20.8 ± 6.95a
Fujimite	0.2 ± 0.2	0.4 ± 0.24b	0.8 ± 0.49b	3 ± 1.52c
Zeal	0.2 ± 0.2	1.6 ± 0.4b	7.2 ± 1.77a	16.8 ± 3.6a
Vendex	0 ± 0	0 ± 0b	6 ± 2.19a	20.8 ± 7.06a
Envidor	0 ± 0	0.8 ± 0.37b	0 ± 0b	25 ± 4.91a
Apollo	0 ± 0	1 ± 0.55b	6 ± 1.48a	28.6 ± 8.54a
Check	2.6 ± 1.69	8 ± 5.07a	19.4 ± 17.41a	22.75 ± 7.99a

If time permits, I have more data I would like to discuss. I have data for 14, 21, and 28 days after treatment for the predators, as well as data for brown mite abundance at all of these dates.

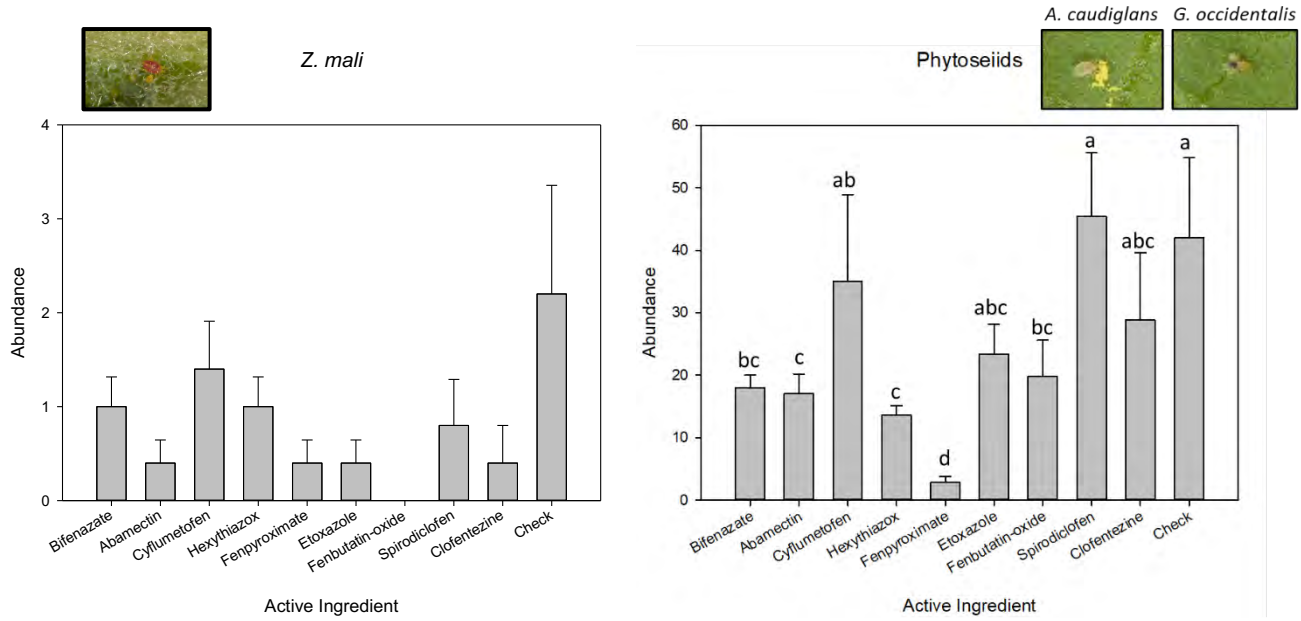
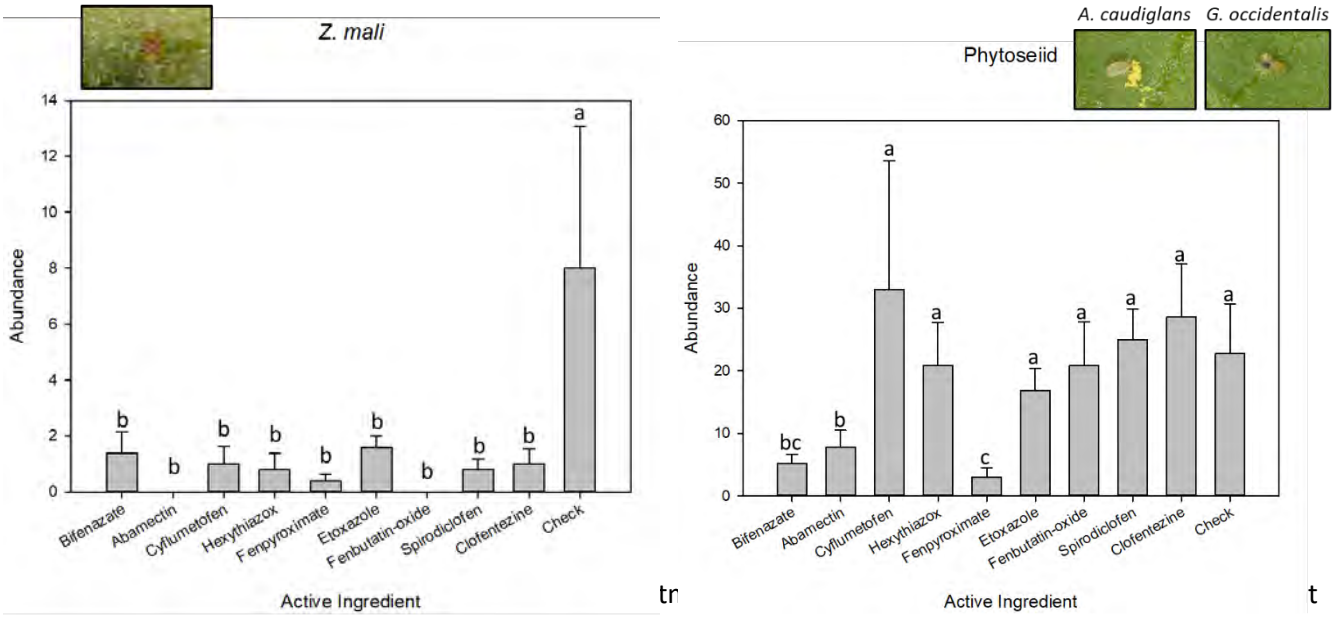


Figure 2. *Z. mali* and phytoseiid abundance 3 DAT. Treatments with different letters above indicate a significant difference between treatments.



tr t

difference between treatments.

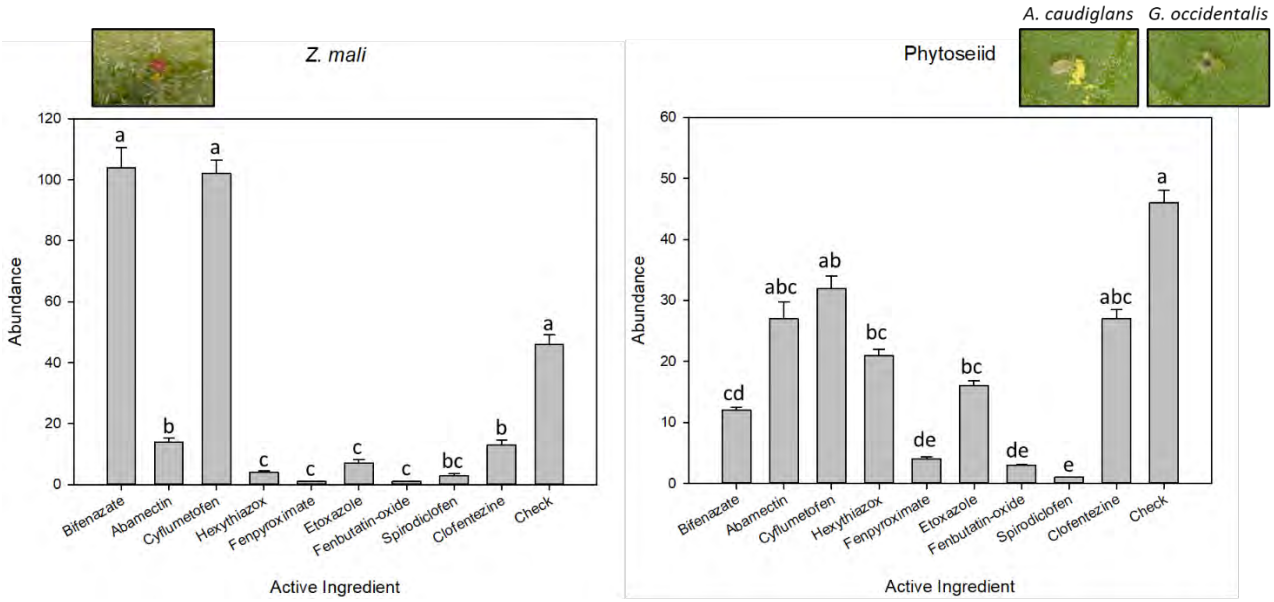


Figure 4. *Z. mali* and phytoseiid abundance 42 DAT. Treatments with different letters above indicate a significant difference between treatments.

Redistribution and establishment of the samurai wasp, *Trissolcus japonicus*, a biological control agent of the invasive brown marmorated stink bug, *Halyomorpha halys*, in Oregon

Claire Donahoo[1], David Lowenstein[2], Richard Hilton[3], Heather Andrews[4], and Nik Wiman[4]
[1]Oregon State University, Corvallis, OR;
[2]Michigan State University, Macomb County Extension Office, Clinton Twp, MI;
[3]Oregon State University, Southern Oregon Research and Extension Center, Central Point, OR;
[4]OregonState University, North Willamette Research and Extension Center, Aurora, OR

Keywords: brown marmorated stink bug, *Halyomorpha halys*, samurai wasp, *Trissolcus japonicus,* egg parasitoid

Abstract: The brown marmorated stink bug, *Halyomorpha halys*, is a rapidly-spreading, polyphagous and invasive pest that has caused millions of dollars of economic damage in US specialty crops and is an increasing problem to the specialty crop industry in the Pacific Northwest. In the home range of *H. halys*, the samurai wasp (*Trissolcus japonicus*) is known to be an efficient parasitoid of the pest, with very high parasitism rates of *H. halys* eggs (>90%). As of 2020, Oregon State University has redistributed the adventive agent at sites across four ecoregions in Oregon with more releases in progress. In 2018 and 2019, we placed sentinel egg masses of *H. halys* and yellow sticky cards at release sites to assess establishment of *T. japonicus* populations in urban, agricultural, and riparian habitats in various locations around the state of Oregon and repeated the experiment with just the sticky cards in 2020. We collected the egg masses 5-7 days after release, while sticky cards were gathered 7-14 days after placement. We also collected wild egg masses of *H. halys* and assessed them for parasitism by *T. japonicus*. Here, we present the parasitism rates of both the sentinel and wild egg masses, as well as the locations in Oregon where *T. japonicus* were captured by the yellow sticky cards.

Effectiveness of Yellow and Blue Sticky Cards for Monitoring Parasitoid Wasps of the Invasive *Halyomorpha halys* (Hemiptera: Pentatomidae)

Mark Cody Holthouse[1*], Lori R. Spears[1], Diane G. Alston[1]
[1]Utah State University, Biology Department, Logan, UT 84322
*Corresponding author: (e-mail: cody.holthouse@usu.edu)

Keywords: *Anastatus*, biological control, brown marmorated stink bug, bycatch, *Telenomus*, *Trissolcus*

Abstract: The brown marmorated stink bug, *Halyomorpha halys* (Stål), is a significant agricultural and urban nuisance pest in many regions of North America. Management efforts have emphasized classical and conservation biological control of *H. halys* by parasitoid wasps in the families Scelionidae and Eupelmidae. An effective technique for monitoring native and exotic parasitoids [e.g., *Trissolcus japonicus* (Ashmead)] is the deployment of yellow sticky cards. Unfortunately, yellow sticky cards also attract high levels of bycatch that reduce sticky card screening efficiency and accuracy. In a search for reduced bycatch, the number of target parasitoid wasps (i.e., *Anastatus spp., Telenomus spp.,* and *Trissolcus spp.),* and non-target arthropods captured on yellow sticky cards was compared to blue sticky cards (known to be attractive to some Hymenoptera). We assessed if blue cards captured a similar target wasp complex to yellow cards while also capturing less bycatch. Yellow and blue sticky cards were deployed in eight urban landscapes, vegetable fields, and fruit orchards from late May through September in 2019 and 2020. Using an ANOVA model, we found yellow sticky cards captured significantly more target parasitoid wasps over blue sticky cards in both years (Fig. 1), across all landscape types (Fig. 2). Target parasitoid wasps were most abundant on yellow cards in urban and orchard sites with *Trissolcus euschisti* (Ashmead) being the most common species across all landscape types. *Trissolcus japonicus* detections were relatively low and occurred on both card colors in 2019 (yellow: *n*= 37, blue: *n*= 8) and 2020 (yellow: *n*= 70, blue: *n*=7). For both yellow and blue sticky cards, peak numbers of target parasitoid wasps were detected in July.

Yellow sticky cards captured almost two times more bycatch than blue, both colors primarily capturing insects from the orders Diptera, Thysanoptera, and Hymenoptera (excluding the target parasitoid wasp genera that parasitize *H. halys* eggs) (Fig. 3). Though attraction of target wasps to blue cards was significantly lower compared to yellow cards, target wasp capture was positively correlated between the two colors in both years (Fig. 4). Our results support that blue sticky cards may detect a similar target parasitoid species complex as compared to yellow sticky cards, just in fewer numbers. With detection (one or more) being of priority in many parasitoid monitoring programs, use of blue sticky cards may provide sufficient wasp capture while reducing the card processing time due to significantly reduced bycatch.

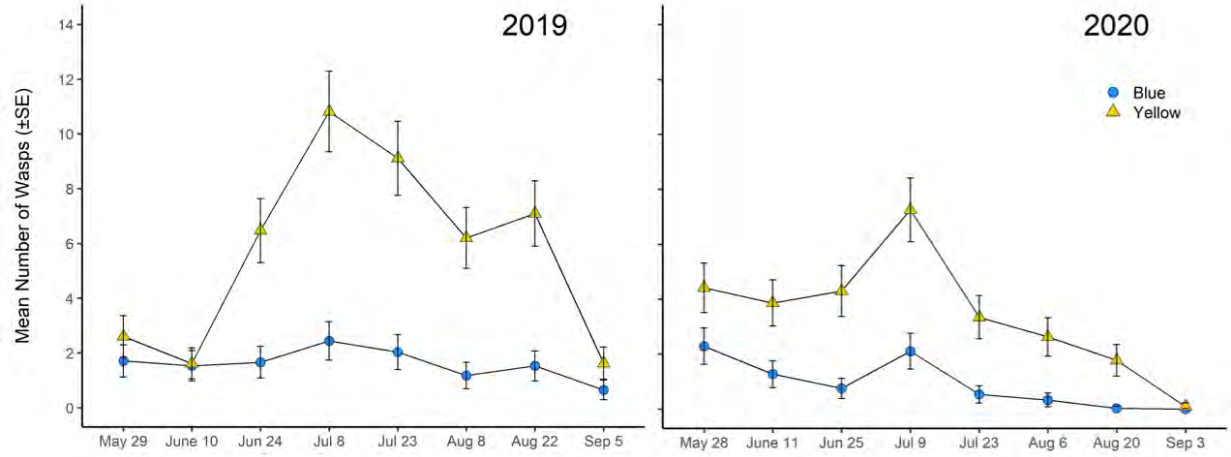


Figure 1. Mean number of target parasitoid wasps (± SE) captured on yellow and blue sticky cards from May to September 2019 and 2020.

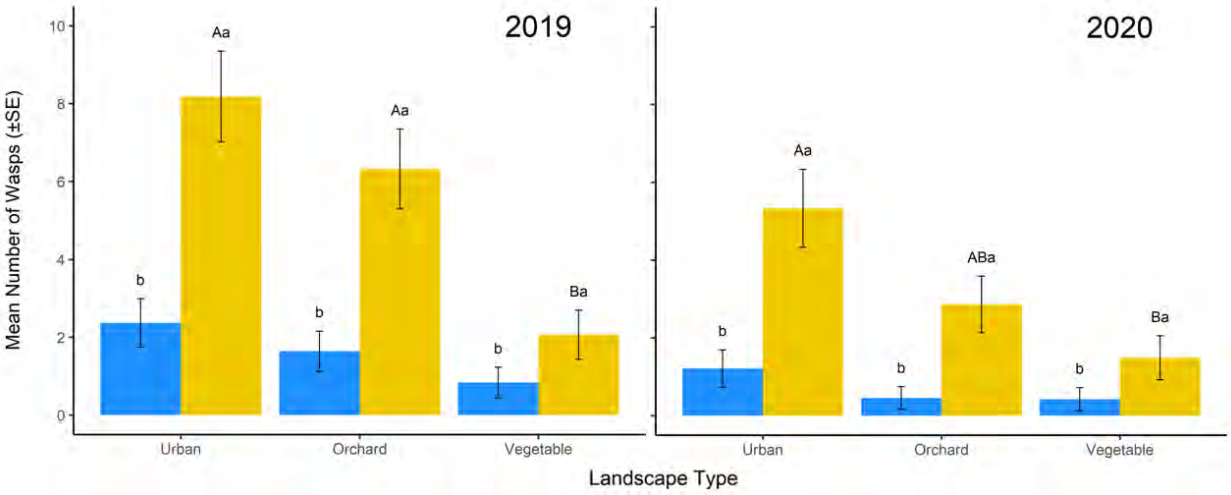


Figure 2. Mean number of target parasitoid wasps (± SE) captured on yellow and blue sticky cards from May to September 2019 and 2020 by landscape type. Lowercase letters represent significant differences between yellow and blue sticky card mean wasp capture within a landscape type. Uppercase letters represent significant differences among landscapes for mean wasp capture on yellow sticky cards (Tukey HSD; $P<0.05$). No significant differences in mean wasp capture among landscape types was detected for blue sticky cards.

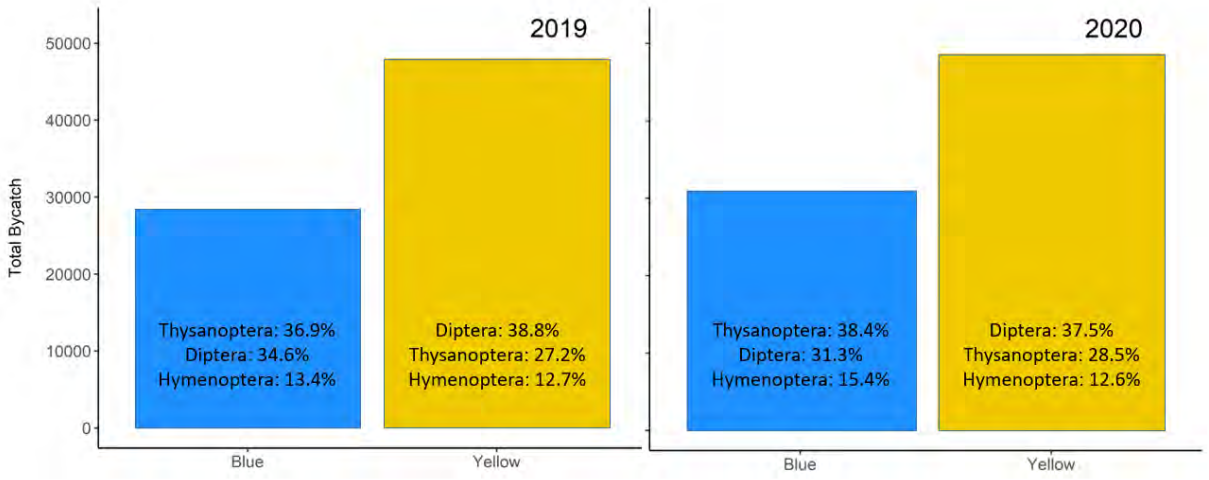


Figure 3. Total number of bycatch captured on blue and yellow sticky cards May through September in 2019 and 2020. The three most commonly occurring insect orders are listed in order of abundance within each bar, the percent is respective of the given color and year.

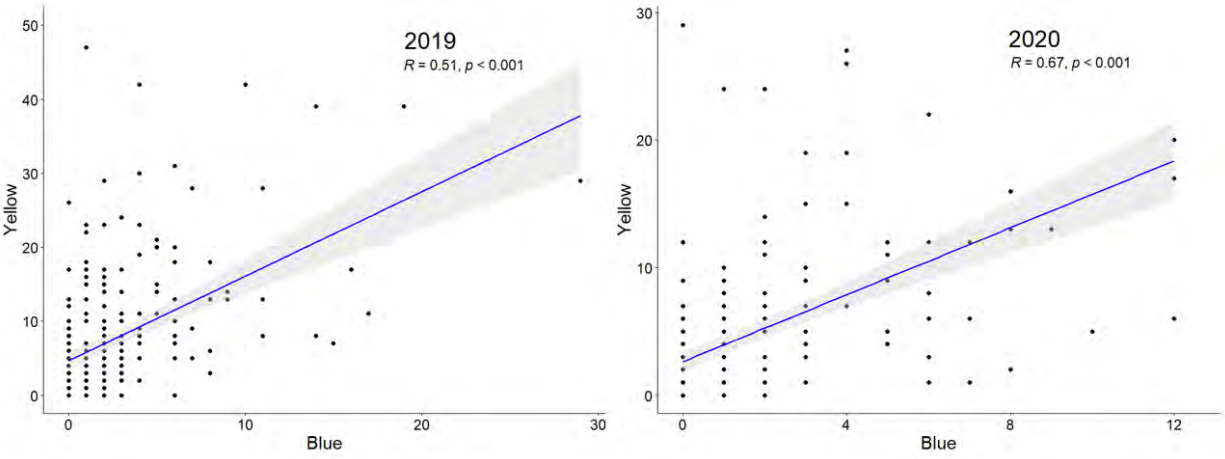


Figure 4. The number of captured target parasitoid wasps on blue compared to yellow sticky cards in 2019 and 2020. The grey shading around the best fit line represents a 95% CI. Correlation was conducted using Spearman's method.

Deploying mealybug destroyers for pest control in apples

Rebecca Schmidt-Jeffris
USDA-ARS, Temperate Tree Fruit and Vegetable Unit, Wapato, WA

Keywords: apple, mealybug, mealybug destroyer, *Cryptolaemus montrouzieri*, augmentation biological control, drone

Abstract: Apple growers are examining non-chemical methods for controlling their pests. Many orchardists have experimented with releasing natural enemies, but are uncertain of which natural enemies, timings, release rates, or techniques should be used. This can leave biocontrol practitioners trying multiple strategies and hoping something works, which is an inefficient use of their time and resources.

Mealybugs are difficult to chemically control in orchards, due to their tendency to hide in bark crevices and other inaccessible spaces. A mealybug natural enemy, the mealybug destroyer (*Cryptolaemus montrouzieri*) is commercially available, but recommendations for its use are based on non-orchard crops and areas with warmer winter temperatures than Washington state's apple growing region. The goal of our project was to determine optimal timing and release rate for mealybug destroyers and examine whether releases by drone are as effective as ground releases.

Fig. 1. Deploying mealybug destroyers by drone

Methods: We compared four mealybug destroyer release treatments to a no-release control in an organic apple orchard (Gebbers Farms, Pateros, WA). The release treatments were 1) early release at high rate (5,000/acre), 2) later release at high rate, 3) later release at low rate (2,000/acre), and later release at high rate via drone (Fig. 1) (the other three treatments were delivered by hand). "Early" releases targeted daytime temperatures >70°F, which is considered the minimum for successful releases of the insect, as per recommendations from the insectary (Biobee). "Late" releases targeted first generation mealybug ovisacs, on which mealybug destroyers prefer to oviposit. The low rate is what the insectary recommends as a "whole orchard" rate, whereas the high rate is the "spot treatment" rate. Plots were 0.11 acres, spaced at least 200 feet apart, and each treatment was replicated five times.

Prior to releases, mealybugs were counted by sampling 15 shoots and 15 spurs per plot and treatments were randomized by pre-count mealybug levels. After each release, mealybugs were sampled once weekly for five weeks (ten weeks total). Following samples were taken every two weeks and then a final sample was conducted shortly before harvest. Mealybugs were counted by sampling 15 shoots and spurs per plot and via burlap strip traps, which were replaced once weekly (Grasswitz and Burts 1995). We initially used 5 burlap strip traps per plot (one per center plot tree, attached to main limb), but increased this to 15 per plot towards the end of the season; we found these traps to be the most efficient and effective sampling method. Mealybug destroyer adults were counted by conducting beat tray samples on the 5 center trees of each plot. We also occasionally found mealybug destroyer larvae in the burlap strip traps. Initially, we attempted to sample mealybug destroyers using sticky cards, but did not find any individuals on the cards for two weeks following the first release.

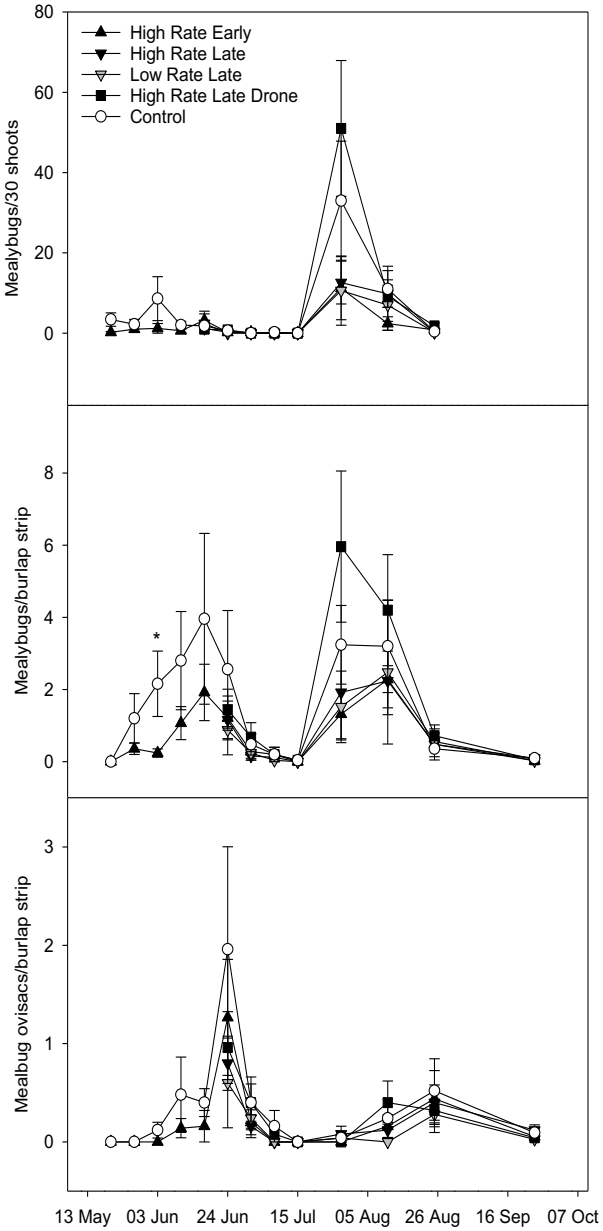


Fig. 2. Mealybug abundance following predator releases on 14 May 2020 (High Rate Early) and 17 Jun 2020 (all other release treatments).

Results and Discussion: There was a general trend for there to be lower mealybug populations in all three release rates delivered by hand, but not by drone (Fig. 2). Variance between replicates was too high for differences to be statistically detected. Due to the preliminary nature of this study, plot sizes were small (0.1 acres), resulting in rapid dispersal of the mealybug destroyers out of the plots (Fig. 3), potentially reducing the apparent efficacy of the treatments.

Burlap strip samples were the most efficient mealybug sampling method, but were not able to detect mealybugs early in the season. Spur samples (not shown) were not able to track mealybug phenology and will be discontinued in 2021. Based on our results, a combination of shoot and burlap samples should be used early in the season, switching to burlap samples only by June to maximize sampling efficiency and effectiveness.

Future work should use larger plot sizes, especially to obtain "fair" comparisons between drone and ground releases. More effective ways of sampling mealybug destroyers should be explored, including use of lure-based traps.

Acknowledgements: We appreciate the technical support of E. Moretti, L. Rehfield-Ray, and C. Jones. This work was supported by donations of mealybug destroyers by BioBee and Gebbers Farms. Chuck Weaver (Parabug) piloted the drone. The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the United States Department of Agriculture or the Agricultural Research Service of any product or service to the exclusion of others that may be suitable.

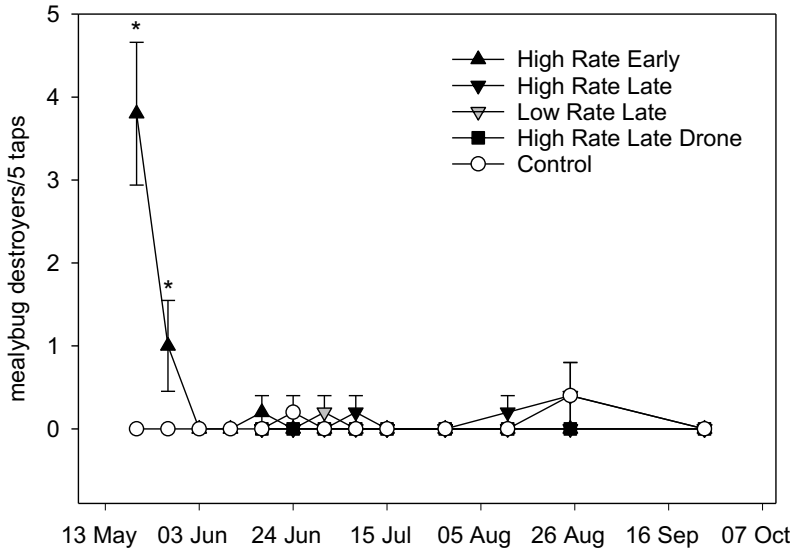


Fig. 3. Mealybug destroyers per plot following releases on 14 May 2020 (High Rate Early) and 17 Jun 2020 (all other release treatments).

Impacts of herbicides on orchard natural enemies

Rebecca Schmidt-Jeffris[1], Paul Bergeron[1,2], and Erica Moretti[1]
[1]USDA-ARS, Temperate Tree Fruit and Vegetable Unit, Wapato, WA; Washington State University,
[2]Department of Entomology, Pullman, WA

Keywords: herbicide, adjuvant, synergy, lacewing, minute pirate bug, convergent lady beetle, predatory mite, *Galendromus occidentalis*, *Amblydromella caudiglans*, *Orius insidiosus*, *Hippodamia convergens*, *Chrysoperla rufilabris*, glufosinate, glyphosate, rimsulfuron, oxyfluorfen, 2,4-D, halosulfuron, paraquat

Abstract: Despite the potential of herbicides to harm natural enemies, almost no research has been done to determine non-target effects of these chemicals on key natural enemies in Pacific Northwest tree fruit. A recent review found that many herbicides were harmful to predatory mites (Schmidt-Jeffris and Cutulle 2019). Recent work on spiders also suggests that herbicides that are harmless when applied alone can reduce predator efficacy when applied with adjuvants (Niedobová et al. 2019). The purpose of this project was to determine which herbicides and adjuvants are the most compatible with biological control by key natural enemies. We also sought to determine if there were synergistic or additive effects of some herbicide+adjuvant combinations.

Methods: We examined the effects of 7 herbicides and 5 adjuvants on 5 different natural enemies. We also tested herbicide/adjuvant combinations of products where specific adjuvants were recommended on the herbicide label. The herbicides tested were Cheetah (glufosinate-ammonium), Matrix SG (rimsulfuron), Sandea (halosulfuron), Goal 2XL (oxyfluorfen), Glyphosate 4DS, Weedar 64 (2,4-D), and Gramoxone (paraquat). The adjuvants tested were a non-ionic surfactant (NIS, Nu-film), methylated seed oil (MSO), crop oil concentrate (COC), ammonium sulfate (AMS), and OS (organosilicone, Kinetic). We tested three insect predators: green lacewing larvae (*Chrysoperla rufilabris*), minute pirate bug adults (*Orius insidiosus*), and ladybeetle adults (*Hippodamia convergens*) and two predatory mite species adults (*G. occidentalis* and *A. caudiglans*). Lacewings and minute pirate bugs were obtained from Beneficial Insectary, the ladybeetles were from IPM Labs, the *G. occidentalis* from Biotactics, and the *A. caudiglans* were from a laboratory colony.

All natural enemies were exposed to pesticide by placing them in arenas with residues that were allowed to air dry for >16 h. The maximum labelled field rate for each product was tested. For lacewings, one individual was placed in a 1.5 mL microcentrifuge tube, which was treated by pipetting 1.5 mL of pesticide solution into the tube, pouring out the pesticide, and letting the tube air dry. Arenas for the *O. insidiosus* and *H. convergens* assays were glass Petri dishes with both sides treated by a Potter spray tower. Arenas for the predatory mites were 1.5 cm diam leaf disks on moistened cotton within a plastic cup, treated with the spray tower. For the insects, we recorded 24 and 48 h mortality. For the predatory mites, we recorded 48 h mortality, number of eggs laid, egg hatch, and number of live larvae produced from treated females.

Results and Discussion: *G. occidentalis* was more sensitive to the herbicides than *A. caudiglans* (Fig. 1). However, the *A. caudiglans* colony was from a field-collected population and may have had more prior herbicide exposure than *G. occidentalis*. For both mites, glufosinate and paraquat caused the greatest mortality. Oxyfluorofen was also very harmful, but due to large reductions in fecundity and egg hatch, as opposed to mortality. Rimsulfuron was the least harmful herbicide. NIS was the most harmful adjuvant for both mites (Fig. 2). Data collection on herbicide+adjuvant combinations for the predatory mites is still in progress.

	Adult mortality		Fecundity		Egg Hatch		Live larvae	
Herbicide	*G. o*	*A. c*	*G. o*	*A. c*	*G. o*	*A. c*	*G. o*	*A. c*
glufosinate	100	100	-	-	-100	-	-100	-100
rimsulfuron	0	7	-1	0	-9	-1	-16	0
halosulfuron	10	0	-30	0	-7	-1	-39	-3
oxyfluorofen	3	14	-70	-61	-79	-90	-96	-97
glyphosate	11	7	-30	0	0	-2	-39	-14
2,4-D	18	10	-41	-19	0	-17	-55	-44
paraquat	56	100	-93	-	-48	-	-99	-100

Fig. 1. Percent increase (adult mortality) or percent reduction (all other) compared to the water control for the predatory mites *G. occidentalis* (G. o) or *A. caudiglans* (A.c) when placed on herbicide residues.

O. insidiosus was more sensitive than the other two insect species (Fig. 3). The most toxic herbicides were paraquat, oxyfluorfen, and glufosinate. The adjuvants did not cause significant mortality in *C. rufilabris* or *H. convergens* (Fig. 3). MSO, AMS, and the OS caused significant mortality in *O. insidiosus*. For all insects, the NIS caused the lowest mortality. Although non-toxic to the insects, adding NIS increased the toxicity of 1) oxyfluorfen and rimsulfuron to *O. insidiosus* and 2) oxyfluorofen to *C. rufilabris* (data not shown). The effects of other adjuvants on insect mortality appeared to be more additive than synergistic (data not shown).

In general, glufosinate, oxyfluorfen, and paraquat were the most toxic products to the five natural enemies tested. The toxicity of glufosinate is particularly concerning; if glyphosate use becomes more restricted, it will likely be replaced with more glufosinate applications. Adjuvant impacts on natural enemies and their synergy with pesticides should be further explored.

	Adult Mortality		Fecundity		Egg Hatch		Live Larvae	
Adjuvant	*G. o*	*A. c*	*G. o*	*A. c*	*G. o*	*A. c*	*G. o*	*A. c*
NIS	26	3	-44	-31	-19	-27	-65	-49
MSO	23	0	-15	-10	-4	0	-39	-14
COC	19	3	0	-20	0	-8	0	-30
AMS	4	7	0	-45	-6	-2	0	-49
OS	7	7	0	4	-1	-18	0	-22

Fig. 2. Percent increase (adult mortality) or percent reduction (all other) compared to the water control for the predatory mites *G. occidentalis* (G. o) or *A. caudiglans* (A.c) when placed on adjuvant residues.

Acknowledgements: We appreciate the technical support of E. Moretti, L. Rehfield-Ray, and C. Jones. This work was funded by the Washington State Commission on Pesticide Registration. The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the United States Department of Agriculture or the Agricultural Research Service of any product or service to the exclusion of others that may be suitable.

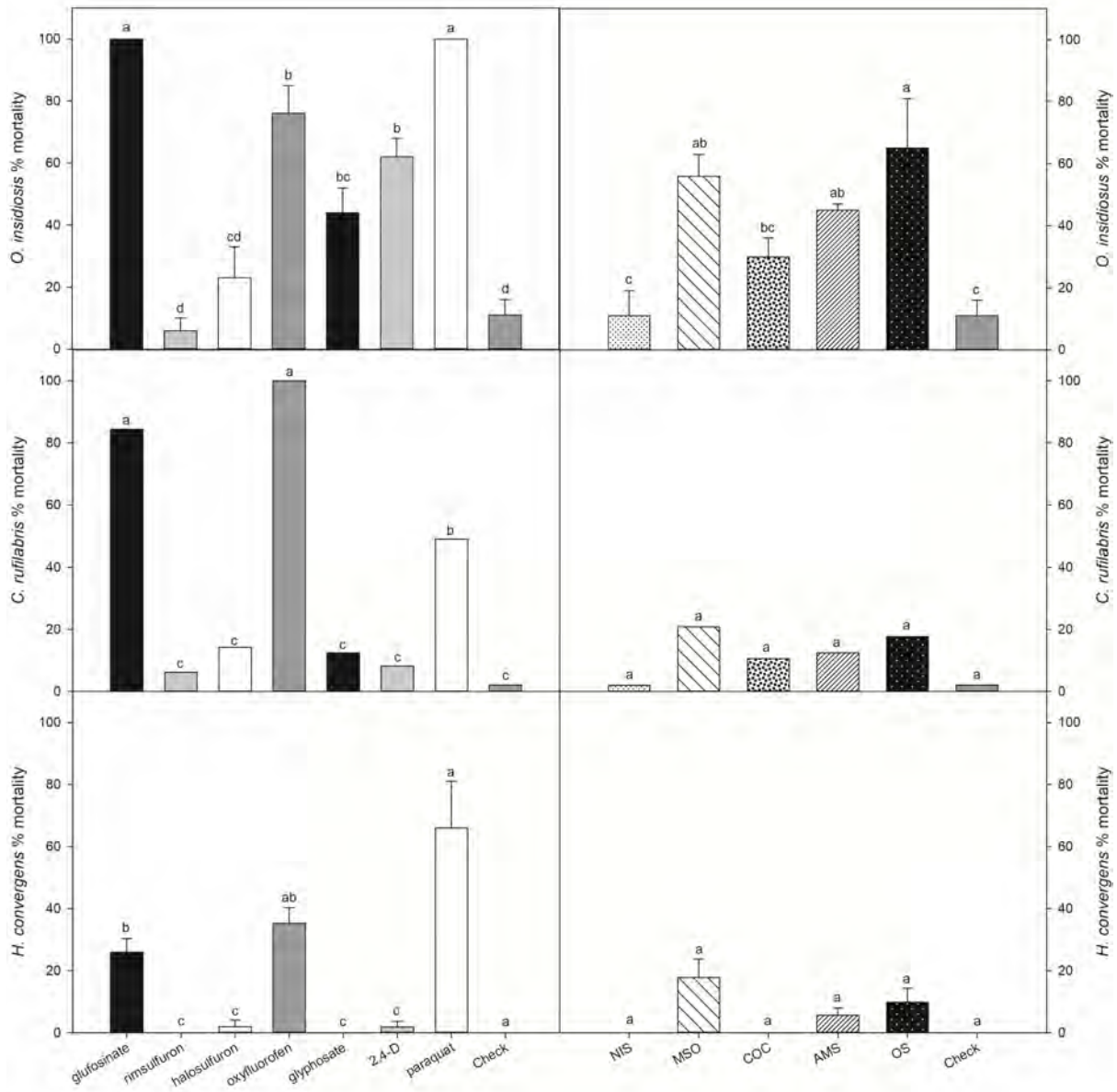


Fig. 3. Percent mortality for three beneficial insects after 48 h exposure to herbicide (left column) or adjuvant (right column) residues.

Pathology/Diseases—

Moderator:

Fire Blight Management Options in Utah

Marion Murray[1] and Claudia Nischwitz[1]
[1]Utah State University, Logan, UT

Keywords: apple, pear, fire blight, *Erwinia amylovora*, streptomycin, kasugamycin, Blossom Protect, Serenade, AgriPhage, Previsto

Abstract: Apple and pear growers report to the Utah Integrated Pest Management (IPM) Program that the primary disease they deal with is fire blight, causing tree losses of up to 10% annually. Fire blight is caused by Erwinia amylovora, a bacterium that is spread during bloom by wind/rain, splashing water, and pollinators to cause infections in flowers. It is unpredictable and difficult to manage due to variable environmental conditions during spring, cultivar and rootstock selection, and density of flower production.

In spring 2020, the Utah IPM Program conducted two trials—one for conventional and organic products to protect flowers from new infections in spring and one for a conventional product to prevent fire blight reignition from pruning cuts in summer.

The trials took place on a 2-acre orchard on the Utah State University Agricultural Experimental Station Research Farm in Kaysville, UT. The 10-yr old, traditionally-planted orchard is comprised of Gala, Fuji, and Golden Delicious varieties, and has a history of fire blight. For the spring bloom trial, the products tested are shown in Table 1.

In a randomized block design, one branch from each of 12 trees (four trees representing the three varieties) was inoculated with the fire blight bacteria during full bloom, on April 29, and this process was repeated in three additional blocks. The treatments listed above (except Garden Phos) were applied to the same inoculated branches at the appropriate timing and rate, according to the product label, and a water-only treatment was included as a control.

In spring 2020, the weather conditions were ideal for infection (warm and intermittent rain), and the inoculation lead to a good amount of infection, where the water-treated control averaged 62% infection across all varieties.

Data was collected at 2 weeks, 3 weeks, and 4 weeks post-inoculation. We determined infection rate of the branches as a percent of total infected flower clusters out of total flower clusters. For fire blight infection in general, the Gala variety has the most infections (54%), and Golden Delicious, the least (30%), shown in Figure 1.

Infection results by treatment are shown in Figure 2. The conventional antibiotic, Agri-Mycin, provided the best control (23% infection), followed by the organic options, Blossom Protect (35% infection), Serenade (40% infection), and AgriPhage (44% infection). We plan to repeat this trial, using combinations of biologicals, and biologicals plus antibiotics, to test for improved control.

On June 2, the above experiment ended, and that day, all trees were pruned to remove visible fire blight-infected branches, using the recommended 14-inches from infection. For each tree, the total number of small, medium, and large cuts were tallied.

Research has shown that the conventional product, Actigard 50 WG, applied after pruning using label directions, can help prevent re-growth (reignition) of the bacteria (Johnson and Temple 2016). Using a hand-sprayer, the product was directed to the pruning cuts, along the branch bark to the trunk, and along the trunk bark for about two feet in either direction. Actigard was applied to the trunks and pruning cuts of 42 trees, and water was applied to the trunks and pruning cuts of 42 trees as a control.

Data was collected one month, two months, and three months later, where we inspected trees for reignition of the fire blight bacteria. Where infected branches were found near pruning cuts, we measured the length of expansion, and whether it was near a small, medium, or large cut.

To determine a difference in fire blight infections before and after Actigard application, we developed a point system for each tree based on the size and total number of cuts, and compared that to a point system based on length of new fire blight growth from a certain-sized cut. The point system allowed us to determine the percent of the cuts that reignited on each tree.

On trees treated with Actigard, 4% of the cut branches started growing fire blight again. On trees treated with water, 9% of branches started growing fire blight again, and on three of those trees, the infection spread into large branches or into the main stem. Based on these findings, Actigard is a good option for post-pruning application to a young, valuable apple or pear orchard that experienced high fire blight infection that spring.

Table 1. Products tested to protect flowers against fire blight infection, and date of application. Flowers were inoculated April 29, 2020.

Brand Name	Description	Date of Application
Agri-Mycin 50	A commonly-used antibiotic (streptomycin) that is highly effective. Inoculation isolates were tested to be susceptible to streptomycin.	April 30
Kasumin 2L	An antibiotic (kasugamycin) that is almost as effective as streptomycin.	April 30
Serenade Opti	An organic product made from the soil-dwelling bacterium, *Bacillus subtilis*. It works by directly targeting the fire blight bacteria and also by competition for space on flowers.	April 26, 28, and 30
Blossom Protect+Buffer Protect	An organic product made from a yeast called *Aureobasidium pullulans*. It works by competing for space on flowers.	April 26, 28, and 30
Previsto	An organic copper soap product that can be applied to open flowers.	April 30
AgriPhage-Fire Blight	A newly-registered organic product made from a mix of bacteriophages that infect and replicate within bacteria. It must be applied before and after infection	April 29 and 30
Monterey Garden Phos	A conventional product made from phosphorus acid that is applied to the trunk and works by inducing a resistance response within the plant.	April 9 (half-inch green stage)
Water	Untreated control	April 30

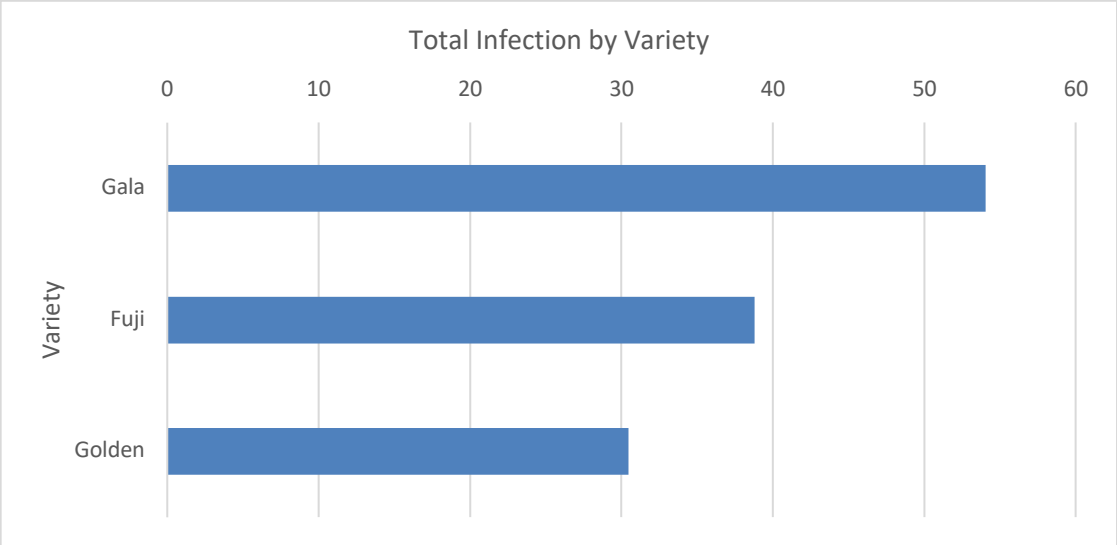


Figure 1. Fire blight infection by variety.

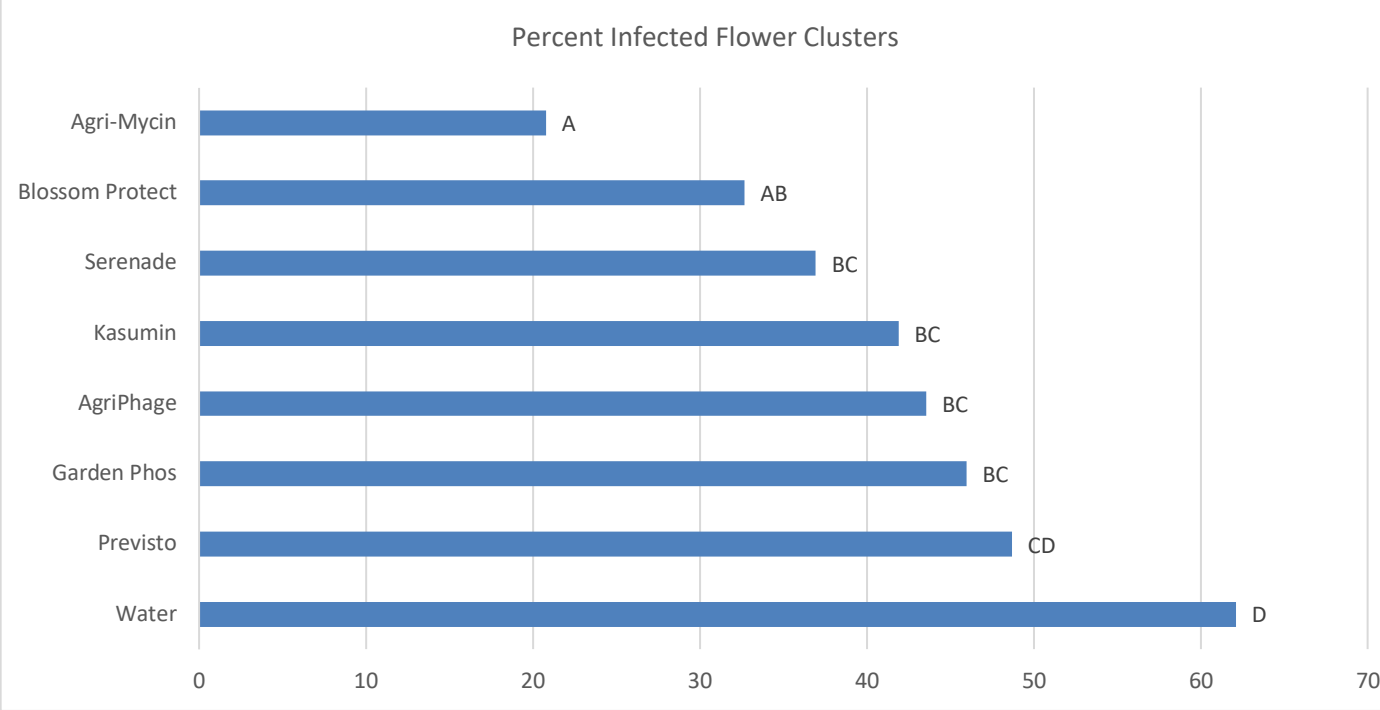


Figure 2. Fire blight treatments on apple, and percent of flower clusters infection by 4 weeks post-inoculation.

Johnson, Kenneth B. and Todd N. Temple. (2016) Comparison of Methods of Acibenzolar-S-Methyl Application for Post-Infection Fire Blight Suppression in Pear and Apple. Plant Disease 2016 100:6, 1125-1131

Invasive Species—

Moderator:

The Penalty Box: Developmental Costs for Brown Marmorated Stink Bug on Eastern Washington's Native Plants

Elizabeth H. Beers[1], James R. Hepler, and Peter Smytheman
Washington State University, Tree Fruit Research and Extension Center Wenatchee, WA
[1]ebeers@wsu.edu

Keywords: brown marmorated stink bug, *Halyomorpha halys*, landscape ecology

Abstract: Brown marmorated stink bug (BMSB) is encountering a novel landscape in the arid shrub-steppe of eastern Washington as its invasion of our area continues. Landscape ecology and risks are currently being modeled, but such models can be informed by specific information on dietary needs and penalties for development on suboptimal hosts. We studied the development of BMSB from egg to adult for two seasons, examining developmental time, survivorship, adult weight, and sex ratio. In all studies, performance of BMSB was poorer on native (western) plants than on either colony diet, or on hosts plants found in the mid-Atlantic region (eastern plants), where BMSB is known to thrive. Survivorship from egg to adult was the most negatively affected; in all three studies, survivorship to the adult stage of nymphs fed on western plants was roughly half that of nymphs fed on a colony diet or eastern plants. Adults of both sexes produced on the western diet were smaller and slower to develop in two of the three studies. A follow-up study was done on the adults reared on eastern vs. western plants to examine fecundity and longevity; both parameters were significantly reduced in the western-diet group. Our results indicate that if BMSB only have access to native arid-land plants, their population growth should be much slower than regions with more rainfall.

Introduction*:* BMSB successfully invaded the eastern and midwestern United States following its first detection in Pennsylvania in the mid-1990s. The outbreak of BMSB in 2010 in the mid-Atlantic fruit-growing region (Leskey et al 2012) was a wake-up call concerning the damage potential of this pest, and efforts redoubled to better understand it biology, ecology, and management. Detections have progressed steadily in most of the western states, although at this writing, only Oregon ranks this pest as a 'Severe agricultural and nuisance [homeowner] problem' (https://www.stopbmsb.org/where-is-bmsb/state-by-state/). Despite large acreages of vulnerable crops, Washington, California and Utah have noted only "agricultural and nuisance problems", but not at the levels experienced the mid-Atlantic states. It has been over a decade since the first detections in the western states (Zack et al 2012), so we might reasonably speculate whether BMSB will reach the same outbreak levels in west.

Much of the large-scale agriculture in the west is in the semi-arid interior valleys, with hot, dry, low-rainfall growing seasons. Irrigation allows temperate crops to be grown here, but the native plant assemblages are sagebrush-bunchgrass. In eastern Washington (which lies in the rain shadow of the Cascade range), the landscape is punctuated by temporary or permanent water courses which can support a wider range of flora at their margins. These areas support fruiting plants such as Oregon grape, golden currant, chokecherry, bitterbrush, elderberry, maple and wild rose. These plants serve as hosts for native stink bugs; and given the highly polyphagous nature of BMSB, they might reasonably be supposed to serve as host plants for this invasive species also. The ability of BMSB to develop on native shrub-steppe plants could mimic the build-up and reservoir of BMSB in woodlots in the mid-Atlantic, which is thought to be a major source of influx of bugs during the growing season. We tested whether BMSB could develop solely on shrub-steppe plants, enabling us to evaluate risk of invasion from unmanaged habitats.

Materials and Methods: Two developmental studies were conducted in 2019, one during the early season (June-July) and one during the late season (August-September). Both studies compared egg to adult development on an assemblage of native eastern Washington plants in comparison to our colony diet. A similar study was conducted in 2020, but comparing native plants of semi-arid Washington to native plants of the mid-Atlantic region (Table 1). Using egg masses from our BMSB lab colony, we reared nymphs from egg eclosion to the adult stage on the various diets. The studies were carried out in replicated BugDorm cages (6 replicates/treatment), with cuttings of plants provided in cups of water, which were replaced when they deteriorated (1-2x weekly). The 2019 plant native cuttings were taken from the Manson area, while the 2020 cuttings were taken from higher elevations in the Wenatchee area, where the same species were present. The colony diet was purchased from local sources (or in the case of peach cuttings, from a local orchard), and the eastern diet plant were taken from residential plantings in the Wenatchee area.

BMSB nymph on chokecherry

Table 1. Plant assemblages used for the 2019-2020 developmental studies

Western plants (2019, 2020)	**Colony diet (2019, early/late)**	**Eastern diet (2020)**
Bitterbrush (*Purshia* sp.)	Peach cuttings (*Prunus persica*)	Catalpa (*Catalpa* sp.)
Elderberry (*Sambucus* sp.)	Carrots (*Daucus carota*)	Maple (*Acer* sp.)
Wax currant (*Ribes* sp.)	Sunflower Seeds (*Helianthus* sp.)	Tree of Heaven (*Ailanthus altissima*)
Chokecherry (*Prunus virginiana*)	Pumpkin seeds (*Cucurbita pepo*)	Virginia creeper (*Parthenocissus quinquefolia)*
Snowberry (*Symphoricarpos* sp.)	Spanish peanuts (*Arachis hypogaea*)	
Serviceberry (*Amelanchier* sp.)		

About a month after the eggs hatched, the cages were checked daily for adult emergence, and the date, weight, and sex of the individuals were recorded. Survivorship was calculated as the number of adults produced per initial 1st instar nymph in each cage.

While adult weight is generally considered a predictor of future reproductive success, we tested this in a follow-up study in 2020. We selected 10 male-female pairs from each plant diet group and placed them in small cages (20 total experimental units), continuing the same dietary regime they received as nymphs. The numbers of egg masses, eggs, and mortality were counted weekly for 15 weeks, providing a measurement of fecundity and longevity.

Results & Discussion: Development time (egg hatch to adult) did not differ between treatments in the 2019 early season study, but both males and females fed a diet of western plants developed more slowly (3-4 days) in the late season study. Survivorship was drastically reduced for the western-plant fed bugs, about half that of the bugs fed the colony diet. The survivorship was lower overall in the late season study (Fig. 1). Adult weight of both males and females was significantly lower in the western diet group (early study), but not different in the late season study; the latter adults were smaller overall than those in the early season study (Fig. 2). Similar trends were seen in the 2020 study comparing eastern vs western plant

diets. Survivorship of nymphs was 18% in the western diet, and 34% in the eastern diet. Adult weight was 15.7% (females) and 12.8% (males) lower on the western diet, and developmental time was 5.9 (females) and 8.3 (males) days longer for the bugs reared on western plants.

The follow-up study of fecundity and longevity confirmed the penalty imposed by the poorer western diet. The number of eggs and egg masses was significantly lower for the bugs fed western plants (Fig. 3), although clutch size (20.8 and 22.5 eggs/mass) was not significantly different. Male longevity was shorter than that of the females (35.7 to 36.1 days), but not significantly different between treatments. Female longevity, however, was highly impacted by diet, ranging from 37.3 days (western) to 58.6 days (eastern), a 36% reduction.

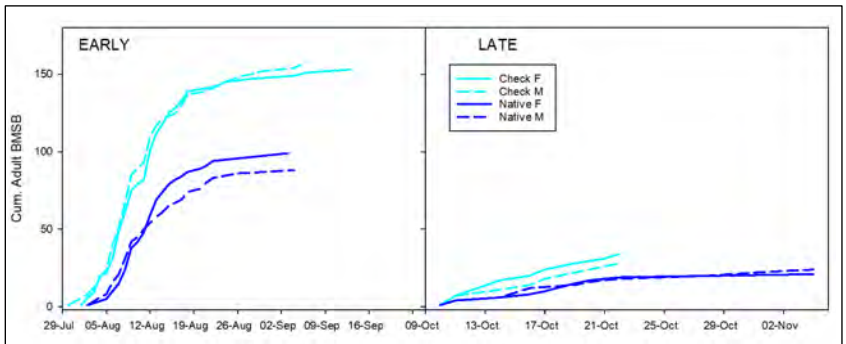


Fig. 1. Adult emergence curves for the early and late season 2019 developmental studies.

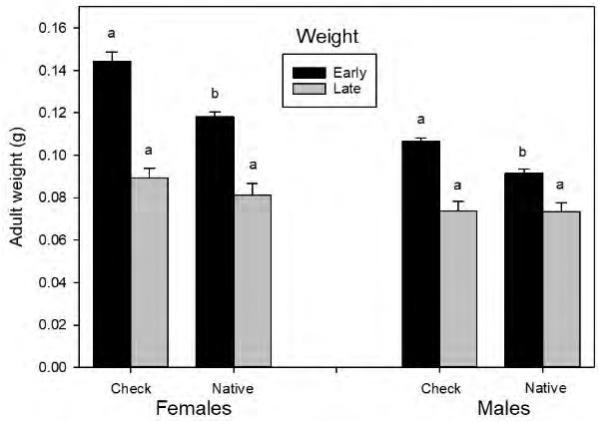


Fig. 2. Adult weight, early and late season 2019 studies.

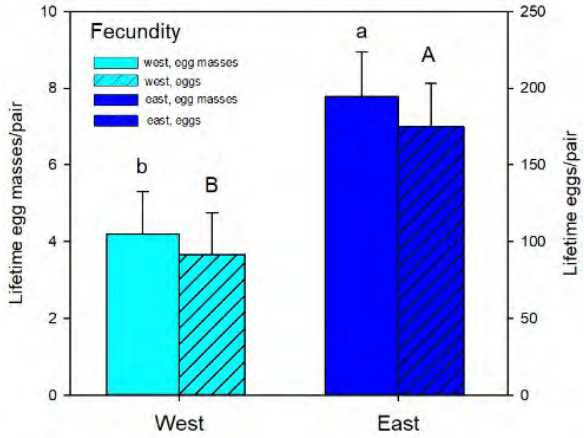


Fig. 3. Adult fecundity on eastern and western food plants, 2020

These results demonstrate unequivocally that the native plants found in the arid interior of eastern Washington are substantially poorer hosts for BMSB. These parameters speak directly to calculations of intrinsic rate of increase and net reproductive rate, indicating population buildup should be much slower in our region. This is especially critical for the second generation, when nymphs failing to reach the adult stage due to slower development will likely not survive the winter. Similarly, nymphal stages are variably sensitive to temperature and humidity (Fisher et al. 2020), and suboptimal environmental conditions and biological control (Abram et al. 2020) may further slow population growth. However, it is uncertain the extent to which BMSB will be confined to native habitats, given the large, contiguous tracts of suitable host plants (tree fruits and berries) available to this highly mobile and polyphagous pest.

Impact of Brown Marmorated Stink Bug Feeding on the Development, Yield, and Quality of Tart Cherry in Utah

Zachary Schumm[1], Diane Alston[1], and Lori Spears[1]
[1]Department of Biology, Utah State University, Logan, UT
Presenting Author: Zachary Schumm; zach.schumm@usu.edu

Keywords: Brown Marmorated Stink Bug, *Halyomorpha halys*, tart cherry, quality, yield

Abstract: Brown marmorated stink bug (*Halyomorpha halys* [Stål]) (BMSB), a destructive and polyphagous agricultural and nuisance pest native to eastern Asia, was first detected in Utah in 2012; agricultural damage was first reported in 2017. Tart cherry (*Prunus cerasus* Linnaeus), a > $14 million annual agricultural commodity in Utah, has not been studied for BMSB susceptibility. Our objective was to determine the impact of BMSB feeding on tart cherry development, yield, and quality. In a randomized complete block design, cages of six BMSB nymphs or adults, plus control cages, were placed weekly on subsequent stages of tart cherry beginning at bud (2018) or petal fall (2019). The bugs were removed after one week along with half of the fruits, which were stained with acid fuchsin to count feeding sites. Cages were resealed after bug removal until the remaining fruits matured, at which time they were harvested and assessed for marketability using a Tomra® laser, and assessed for quality by hand, including mass, diameter, and sugar content. Feeding sites were significantly more abundant in feeding cages than in control cages at most fruit stages ($p < 0.05$). The development of forty to one hundred percent of fed-on fruits between petal fall and pit hardening was terminated (leaving only pits attached to stems), resulting in feeding cages having significantly less marketable fruits than control cages between these stages ($p < 0.05$). In remaining developed fruits, few quality differences between feeding and control cages were significant, suggesting that management should be focused between petal fall and pit hardening to prevent yield loss due to fruit development termination.

Chemical Control/New Products—

Moderator:

Recent Progress in Preventing *Xylosandrus germanus* Ambrosia Beetle Infestations in NY Apple Orchards

Arthur Agnello
Department of Entomology, Cornell AgriTech at NYSAES, Geneva, NY, 14456

Keywords: black stem borer, *Xylosandrus germanus*, apples, trunk sprays, methyl salicylate, verbenone

Abstract: The ambrosia beetle *Xylosandrus germanus* has been documented as causing tree death and decline in NY apple orchards since 2013, mostly in young dwarf apple plantings. Preventive trunk sprays using chlorpyrifos or pyrethroids have not provided acceptable levels of control, nor have topical applications of the repellent verbenone, a component of an anti-aggregation pheromone produced by bark beetles that has been found to repel this and related species from traps and attractive host trees. In 2019, we tested trunk applications of different repellents for *X. germanus* control in potted apple trees, waterlogged to stress them to produce ethanol, and placed inside wooded areas directly adjacent to orchard sites. The preventive treatments, applied on 15 May, included different topical formulations of methyl salicylate (a host defense and signalling compound), alone and combined with verbenone. The methyl salicylate+verbenone combination product was applied at one of two timings, either 15 May (start of the 1st flight) or 12 June (start of the 2nd flight), to assess its usefulness later in the season. Additional treatments were the Systemic Acquired Resistance (SAR) activator products Actigard, Regalia, and a formulation of Salicylic Acid; the insecticide Lorsban (chlorpyrifos) was used as a grower standard comparison. Tree damage was assessed in early July and at the start of September, to determine the effect these repellents had in preventing attacks by this beetle. Of all the treatments, the early verbenone+methyl salicylate application showed the most uniform trend of the lowest infestation characteristics on both evaluation dates (**Table 1**).

In 2020, a "Bullseye Range Test" trial was conducted with a verbenone + methyl salicylate repellent, to assess its ability to prevent traps from catching adults of *Xylosandrus germanus* (black stem borer, BSB), when placed at increasing distances from a treated target. The trial took place at a single orchard site, in which a 2 cm x 30 cm apple bolt (soaked in 30% ethanol for 48 hrs), representing a "target tree", was treated using a caulking gun with a 10-g SPLAT application of verbenone + methyl salicylate (Beetle Guard, Isca Tech) and hung at a 1-m height from a garden hook in a tree row within the orchard, near an edge adjacent to BSB-infested woods. An ethanol-baited bottle trap was placed at a distance of 5, 10, 15, or 20 m from the bolt in each of the four cardinal directions (N, S, E, W) to determine whether the repellent had a "halo effect" on preventing captures of BSB adults at increasing distances from the treated bolt. Traps at each distance from the target bolt were rotated among the four positions every 2 days to eliminate directional site variability, so that traps placed at each distance completed a circuit of the compass in 8 days. We included a Positive Control, consisting of the same setup but without the repellent on the bolt, and a Negative Control, consisting of an apple bolt that had not been soaked in ethanol or treated with the repellent, for a total of 3 treatments. All treatments were set up sequentially in the same tree row, adjacent to each other and at a spacing of 40 m. Target bolts were rotated among the three treatment locations every 2 days, at the same times the bottle traps were rotated. The trial was initiated on 20 May, at the start of the first adult flight, and replicated sequentially over time for three consecutive 8-day periods, ending on 14 June, three days before the end of the flight. At the end of each replicate period, all three target bolts were replaced with fresh bolts and examined in the lab for infestation sites.

There was no significant difference in the average number of black stem borer adults caught in bottle traps at any of the four distances from the target apple bolts in any of the treatments (**Table 2**). Captures in the traps placed nearest (5 m) to the repellent treated bolt were numerically lower than those in the Positive or Negative Controls, but not at a statistical level. These results indicate that the verbenone + methyl salicylate combination did not induce a "halo effect" of protection from the beetles at the distances we tested. However, the repellent was effective in preventing nearly all attacks of the apple bolts by the beetles, as the number of holes in the Repellent treatment was significantly less than in the Positive Control, and statistically equivalent to the Negative Control. This result is consistent with our previous field trials in which a topical application of the verbenone + methyl salicylate formulation effectively protected potted apple trees from attacks by BSB.

[**Table 1** - next page]

Table 2. Mean damage from and 8-day total captures of black stem borer adults in bottle traps placed increasing distances from a centrally located ethanol-soaked apple bolt treated with a verbenone + methyl salicylate repellent. 2020.

	Adults captured[a]/ trap distance from target bolt				**# attack sites[a]**
Bolt Treatment	**5 m**	**10 m**	**15 m**	**20 m**	**in bolt**
Repellent (10 g SPLAT formulation)	15.0 a	15.0 a	12.0 a	28.3 a	3.3 b
Positive Control (ethanol-soaked, no repellent)	17.3 a	12.7 a	11.0 a	16.3 a	30.3 a
Negative Control (no ethanol or repellent)	19.7 a	10.7 a	15.7 a	15.3 a	0.0 b

a - within a column, values followed by the same letter not significantly different (p = 0.05, Student's t-test).

Table 1. Ambrosia beetle infestations in two-year old potted flooded apple trees treated with preventive trunk applications of different materials. Data pooled across three replicated orchard sites, Wayne Co. 2019

			Mean # Infestation Sites		Mean # sites with Empty Galleries		Adults		Brood	
Treatment[a]	Rate	Application Date	9 Jul	3 Sep	9 Jul	3 Sep	9 Jul	3 Sep	9 Jul	3 Sep
Lorsban	1.5 qt/100 gal	5/15	1.3 b	9.7 a	0.8 b	6.1 a	0.2 b	2.9 ab	0.2 b	0.7 a
Verbenone	10 g/tree	5/15	1.6 b	2.2 c	1.1 ab	1.1 bc	0.4 ab	0.9 abc	0.0 b	0.4 a
MeSa	10 g/tree	5/15	1.2 b	3.2 bc	0.4 b	2.4 abc	0.4 ab	0.8 bc	0.1 b	0.2 a
Verb+MeSa (early)	10 g/tree	5/15	0.2 b	0.8 c	0.1 b	0.1 c	0.1 b	0.6 c	0.1 b	0.1 a
Verb+MeSa (late)	10 g/tree	7/9	0.0 b	4.3 abc	0.0 b	3.9 abc	0.0 b	0.4 c	0.0 b	0.0 a
Actigard 50WG	2 oz/100 gal	5/15, 6/12, 7/9	2.2 b	5.9 abc	2.0 ab	3.6 abc	0.2 b	2.1 abc	0.0 b	0.3 a
Regalia	30 ml/gal	5/15, 6/12, 7/9	0.6 b	8.3 ab	0.3 b	4.9 ab	0.2 b	3.0 a	0.1 b	0.4 a
SAR Salicylic acid	8 fl oz/100 gal	5/15, 6/12, 7/9	6.7 a	3.0 bc	4.3 a	1.7 bc	1.2 a	1.2 abc	1.8 a	0.2 a
Untreated Check	—	—	2.2 b	2.7 bc	1.9 ab	1.9 bc	0.0 b	0.7 c	0.0 b	0.1 a

Values in a column followed by the same letter not significantly different ($P < 0.05$, Student's t-test.)

[a] MeSa, methyl salicylate; Verb, verbenone

Integrating BMSB management into the hazelnut IPM system

Heather Andrews, Anthony Mugica, Tatum Keyes, Nate Edmonds, Erica Rudolph, Nik Wiman
OSU North Willamette Research and Extension Center, Aurora, OR

Keywords: *Cydia latiferreana, Halyomorpha halis, Trissolcus japonicus, Corylobium avellanae, Myzocallis coryli*, filbertworm, brown marmorated stink bug, hazelnut aphid, filbert aphid, hazelnut, integrated pest management

Abstract: Filbertworm *Cydia latiferreana* (Walsingham) (Lepidoptera: Tortricidae) is native to the Pacific Northwest and is the key insect pest of Oregon grown hazelnuts, causing direct damage when larvae feed on developing nuts. Conventional growers normally apply 1-2 pyrethroid sprays per season while organic growers rely heavily on spinosad to keep damage below 1%. While a phenology model can help determine timing of the first spray, it does not guide the second spray. Some growers will use degree days and trap catch thresholds to determine spray timing, while others spray based on the calendar. Female moths lay eggs on leaves or nut clusters, and larvae then locate and penetrate the micropyle (thinnest part of the shell). The recent emergence of brown marmorated stink bug *Halyomorpha halis* (Stål) (Hemiptera: Pentatomidae) as an important hazelnut pest has meant that hazelnut growers have another insect pest to contend with that causes direct damage to nut kernels.

The cheapest and most effective products that control both of these pests greatly disrupt integrated pest management programs, and increasing the number of pyrethroid applications to control two pests raises the potential for secondary pest outbreaks. There are a number of biological control agents that help keep *H. halys* in check, including the highly effective Asian egg parasitoid *Trissolcus japonicus,* which has been widely redistributed around hazelnut orchards by our program. *Trioxys pallidus* (Haliday) is another introduced parasitoid that has helped control the native filbert aphid, *Myzocallis coryli* (Goeze) and nonnative hazelnut aphid, *Corylobium avellanae* (Schrank) after becoming established in the 1980's. There are also numerous general predators in orchards which help keep pest populations under control. Ideally, we would hope to integrate management for these two direct pests without increasing insecticide use or increasing secondary pest issues.

Table 1. Treatments applied at Site 1 and Site 2.

Treatment	Component	Active Ingredient	Rate	Adjuvant
1	Water (UTC)	NA	NA	4 oz NuFilm
2	Cyd-X	*Cydia pomonella* granulovirus	6 oz	4 oz NuFilm
2	Surround	kaolin	50 lb	
3	Intrepid Edge	Methoxyfenozide and spinetoram	12 oz	4 oz NuFilm
3	Transform	sulfoxaflor	1.5 oz	
4	Intrepid 2F	methoxyfenozide	16 oz	4 oz NuFilm
4	Transform	sulfoxaflor	1.5 oz	
5	Asana	esfenvalerate	16 oz	4 oz NuFilm
5	Admire Pro	imidacloprid	1.5 oz	

Materials and methods: In July of 2020 we applied several product combinations that were meant to target *H. halys* and *C. latiferreana* at two different sites. Site 1 was an 8th leaf 'Jefferson' orchard located near Salem, OR, and Site 2 located in Aurora, OR contained 4th leaf 'McDonald'. We used a spray gun fitted with a solid cone diffuser and D8 nozzle pressurized to 100psi with an air compressor (Ridgid 4.5gal air compressor) powered by a gas generator (Honda EU3000i) to achieve adequate coverage. All treatments were applied at the rates listed in Table 1. Applications were made 07/08, and 07/09 at sites 1 and 2, respectively and Treatment 2 was reapplied at all sites 07/20. Applications were made close to egg hatch (955 degree-days) and were meant to target neonate larvae. The larger single density planted trees (18ft x 18ft) at Site 1 received approximately 1gal of spray while smaller Site 2 trees in double density planting (9ft x 18ft) received 0.5gal.

Nuts were collected soon after drop, and 100 nuts per tree were inspected for external and internal *C. latiferreana* damage, and nut meats were also quartered and inspected for *H. halys* corking damage. Blank and shriveled nuts were recorded, which can occur naturally, but have also been associated with early *H. halys* feeding.

Statistical models and graphics were produced using the open-source statistical environment R. To test for significant treatment effects, generalized linear mixed models with binomial error distribution and logit link were used. To determine significance of models, analysis of deviance was performed on generalized models, and Tukey multiple comparisons was used to determine differences between treatments.

Results and discussion: At both sites *C. latiferreana* trap captures began near the end of June (Fig. 1). A distinct initial flight was observed prior to treatment at Site 1, while captures remained low and on a gradual incline at Site 2. Peak flight occurred at Site 2 in early August, and early September at Site 1, indicating greater *C. latiferreana* pressure, and potential for late damage at Site 1.

There was a significant treatment effect on the proportion of nuts damaged by *C. latiferreana* at Site 1 (Fig. 2; χ^2 = 19.34, df = 4, $P < 0.001$). Treatment 3 (Intrepid Edge + Transform) significantly reduced *C. latiferreana* damage to 3% compared with Treatment 1, untreated control (UTC), which had 8% damage ($P>0.05$). Treatment 2 (Cyd-X + Surround) reduced damage to 6%, which did not qualify as a significant reduction in damage. *C. latiferreana* pressure was persistent throughout the season, and materials providing long-lasting residual activity appear to have performed better. Surround persisted in the field for the remainder of the season, and while numerical differences were observed compared with UTC, efficacy may have been improved by a third application late in the season when trap catches rose again, particularly since the addition of Cyd-X would further target the second flush of larvae. Treatments 4 and 5 did not significantly improve *C. latiferreana* control compared with UTC. The spinetoram content of Treatment 3 (Intrepid Edge + Transform) appears to have improved efficacy over Treatment 4 (Intrepid 2F + Transform). Spinetoram quickly knocks down pests, while methoxyfenozide provides long lasting residual activity. Spinetoram also lasts longer in the field compared with naturally derived spinosad, and the combination of a product providing quick knockdown with extended field activity performed best in this location with prolonged pressure. Asana is often used against *C. latiferreana*, and residual activity is short lived. This may be the main reason Treatment 5 (Asana + Admire Pro) was not effective against *C. latiferreana*- residual activity did not last long enough to protect against the later pressure at Site 1.

There were no significant treatment effects on *C. latiferreana* damage at Site 2 (Figure 2; χ^2 = 7.008, df = 4, P = 0.1355) where infestation of UTC was only 2%. There were numerical similarities between

treatments at both sites, with treatments 2 and 3 controlling *C. latiferreana* better than Treatment 4. Treatment 5 did appear to perform better at this site where there was less late pressure compared with Site 1. Additional nut samples from Site 2 are currently being evaluated, and hopefully a greater number of samples will lead to significant results.

Halyomorpha halys trap catches were extremely low at Site 1 where we deployed a trap. A total of four BMSB were captured during the entire season. This low pressure was also reflected in damage, which was not prevalent enough for treatment effects to be observed at either site (Site 1: χ^2 = 0.220, df = 4, *P* = 0.994; Site 2: χ^2 = 1.431, df = 4, *P* = 0.8387). A mere 0.39% damage was found at Site 1, and 0.30% damage at Site 2.

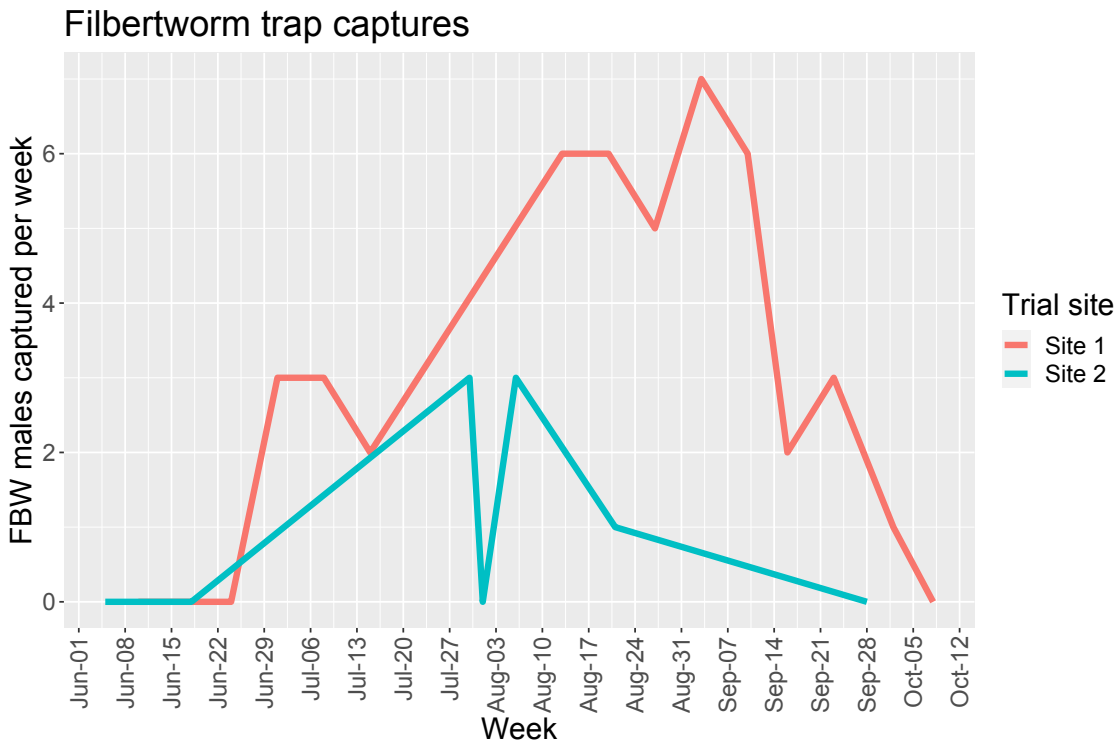


Figure 1. Pheromone trap captures of *C. latiferreana* at the two trial sites.

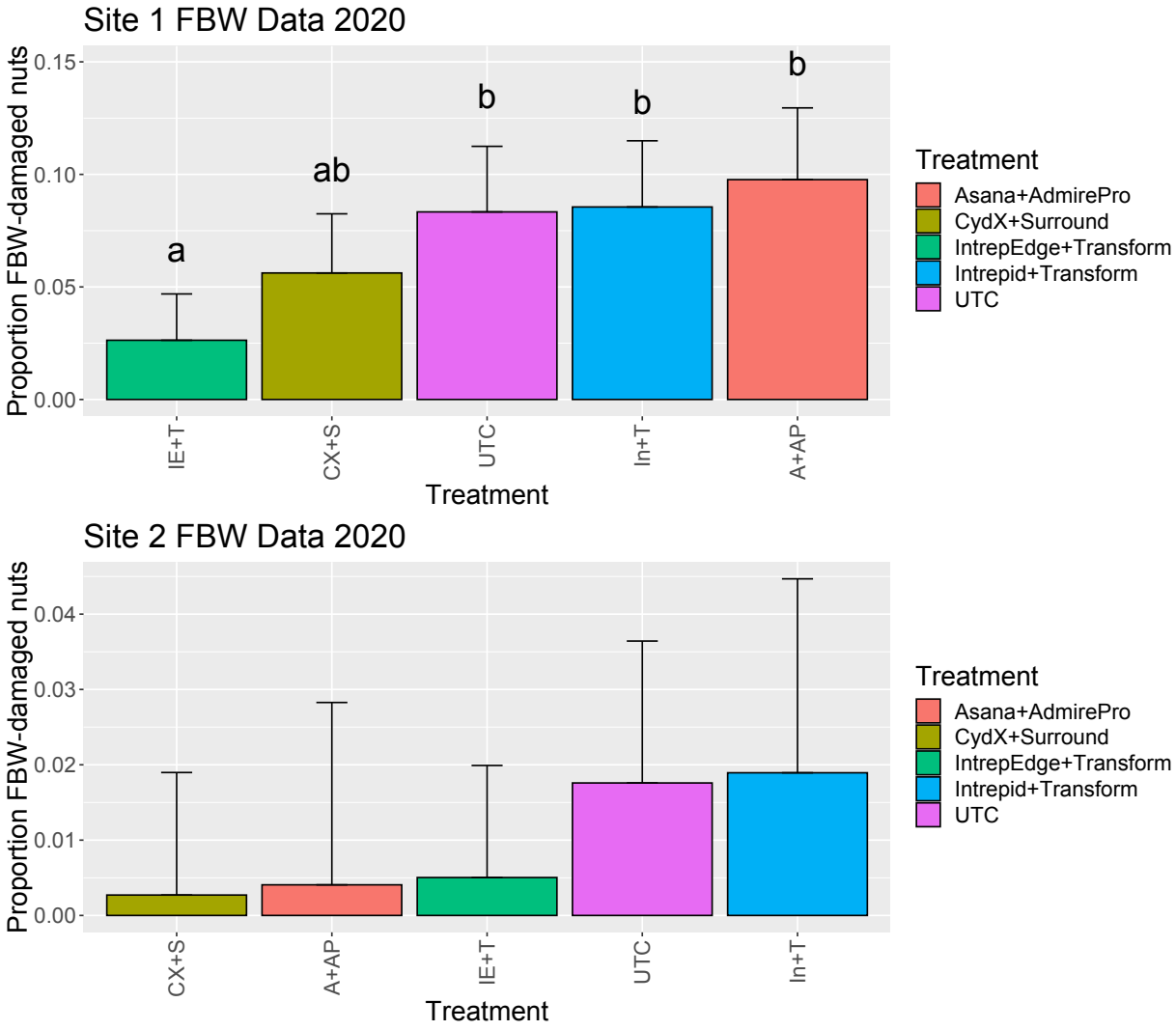


Figure 2. Mean (± SEM) proportion filbertworm-damaged nuts from treated trees at Sites 1 and 2.

Biology/Phenology—

Moderator:

Mating Disruption/SIR—

Moderator:

It's Raining Moths: Drone Technology for Sterile Codling Moth Release

Kacie J. Athey[1], E. H. Beers[2], D. Crowder[3], and T. Northfield[2]
[1]University of Illinois Urbana-Champaign, Dept. of Crop Sciences, Urbana, IL, [2]Washington State University, Tree Fruit Research and Extension Center, Wenatchee, WA, [3]Washington State University, Dept. of Entomology, Pullman, WA

Keywords: codling moth*, Cydia pomonella*, sterile insect release, SIR, organic apple

Abstract: Codling moth has been the key pest of Washington apples since the early 1900s and remains so today. The development of pheromone mating disruption (MD) in the late 1980s helped stabilize pest management programs under constant threat of pesticide resistance and became the foundation of codling moth management for ca. 85 to 90% of the state's apple acreage.

At about the same time as MD was registered in Washington, Canada initiated an area-wide project in the Okanagan Valley of British Columbia using sterile codling moths. This project has been in operation since the early 1990s with good success in suppression of codling moth. What is less known is whether this technique could be part of an integrated pest management (IPM) scheme utilized by individual growers on smaller acreages. Recently, organic fruit growers in Washington state began experiencing higher than expected fruit damage from codling moth and sought a solution to supplement existing programs without causing secondary pest outbreaks. The availability of sterile moths from the (existing) Canadian program makes this new approach possible. Unsurprisingly, very little of the foundational research addressed this type of use; thus exploration of the integrated pest management (IPM) approach was needed. Additionally, there was interest in using new release technologies, such as drones, that could be readily scaled to various block sizes.

In 2018, a pilot study of sterile codling moth release was begun in Okanogan County, WA with sterile moths supplied by the Canadian rearing and sterilization facility in Osoyoos, BC. We applied two rates of sterile moths (800 and 3,200 moths/acre/week) for 22 weeks from late April through mid-September. The SIR treated plots were compared to a non-SIR check. All plots were certified organic apple orchards, and the grower applied a standard organic program of mating disruption, codling moth virus, and horticultural oil. The same blocks and rates were used in 2019-2020, except where block removal forced a change. All sterile moths were applied to the plots by M3 Consulting using a hexacopter drone and a calibrated release device. We monitored the plots throughout the season with pheromone traps, recording numbers of moths by sex (male/female) and origin (wild/sterile). To assess efficacy of the treatments, we and measured fruit damage before harvest by visual observation of both sides of every row in the plot, and counting the numbers of codling moth stings and entries.

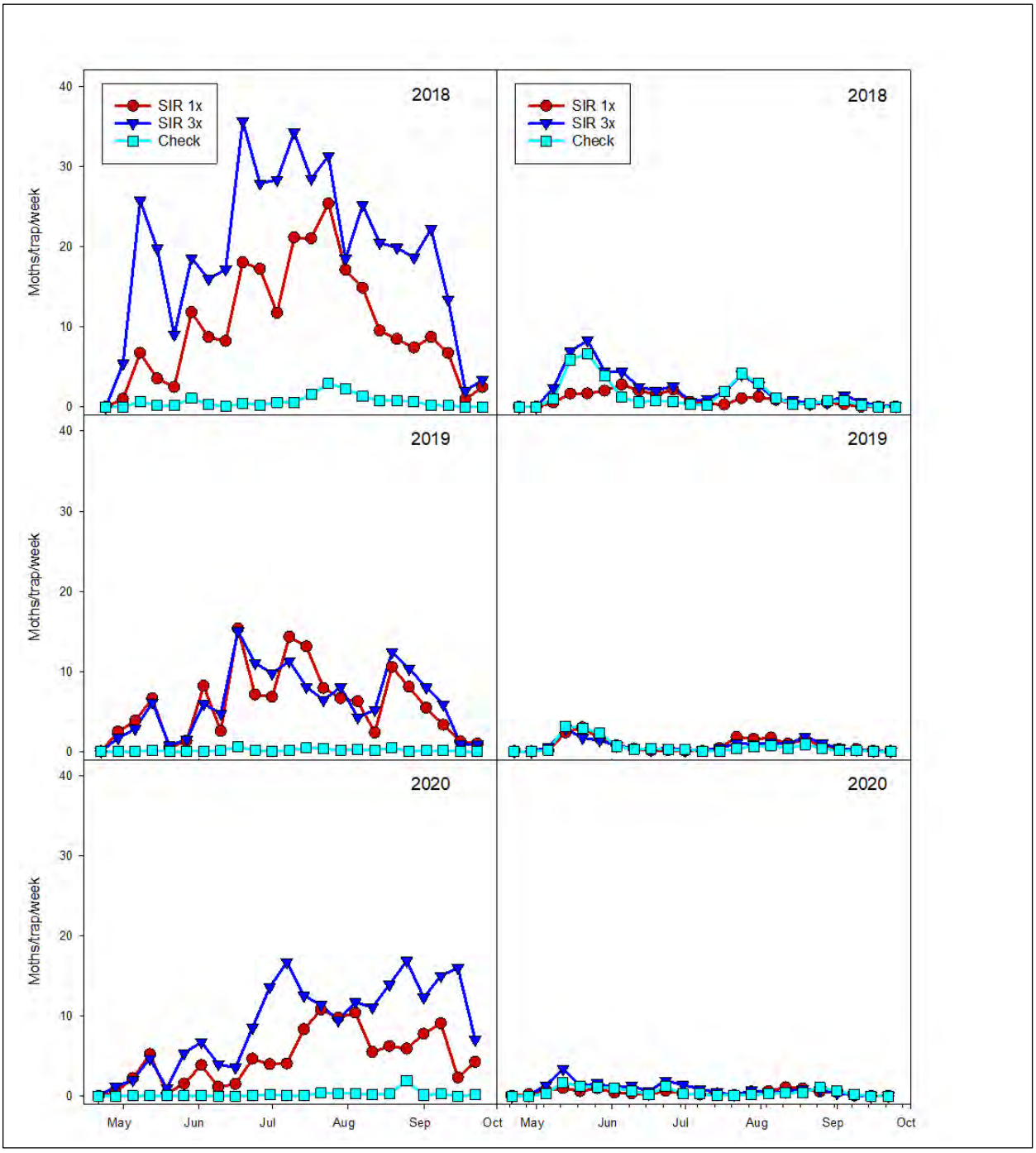


Fig. 1. Trap captures of sterile and wild moths in two SIR treatments and a check, 2018-2020.

The recapture rate of sterile moths fluctuated throughout the season (Fig. 1); in 2018 the recapture rate reflected the differing application rates, but there were few differences in 2019 and 2020. However, the true test of efficacy of any IPM technique is fruit damage. In the first year, the use of SIR moths significantly reduced damaged when compared to the check (Fig. 2). No differences among treatments were found in succeeding years, although damage had declined overall by the third year, irrespective of treatment. Our experience in this pilot project indicates that the underlying insect pressure and

management intensity greatly affects the outcome for a given block, suggesting that each block is in effect a case study. The transition from a single-tactic approach to a multi-tactic approach thus is dependent on the efficacy of deployment of available tactics, and their integration into a comprehensive program.

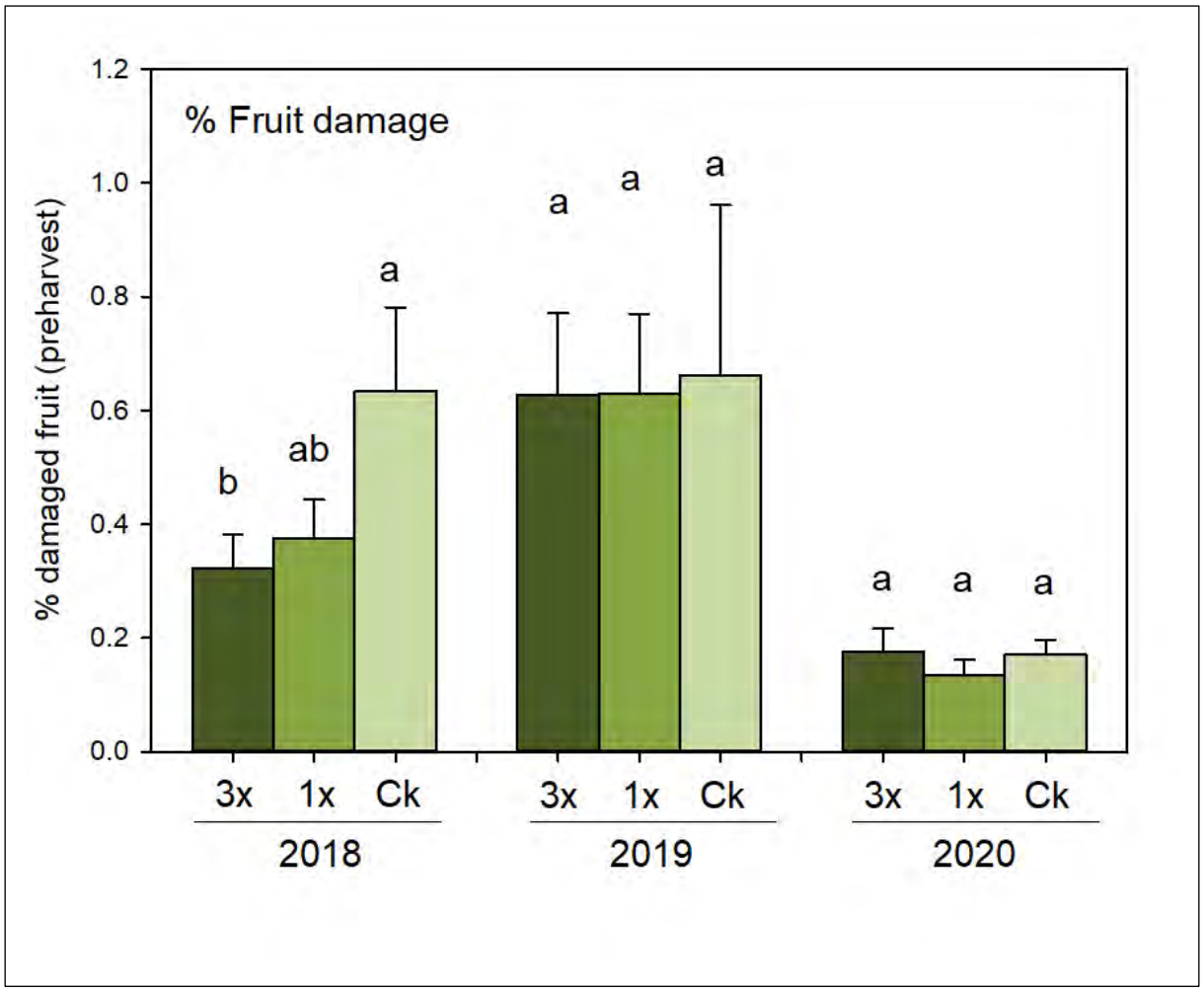


Fig. 2. Percentage codling moth fruit damage, 2018-2020. Replicate 1B was dropped from the analysis in 2020 due to atypical orchard management

Development of Sterile Insect Technique for Navel Orangeworm in California Orchards

Houston Wilson[1], Charles Burks[2], Joshua Reger[1]
[1]Kearney Agricultural Research and Extension Center, Dept. Entomology, University of California, Riverside; [2]USDA Agricultural Research Service, San Joaquin Valley Agricultural Sciences Center, Parlier, CA
Presenting Author: Houston Wilson, houston.wilson@ucr.edu

Keywords: navel orangeworm, *Amyelois transitella*, sterile insect technique, almonds, pistachios

Abstract: The California pistachio and almond industry recently made a large investment in the development of sterile insect technique (SIT) for navel orangeworm (Pyralidae: *Amyelois transitella*) (NOW). Over the past 3 years field and laboratory assays have been utilized to determine the quality and performance of mass-reared and irradiated NOW. Our findings to date indicate that production, handling and release methods all appear to impart some influence on performance of the sterile NOW. Here, we report on Year 3 research efforts from the 2020 growing season. Key findings highlight the importance of transport and release methods on sterile moth recapture, the first recovery of sterile males in mating tables, and an apparent relationship between background wild NOW populations and recovery of sterile NOW in flight traps. A lot of additional work is still necessary to know exactly (or even approximately) the quantity and timing of sterile NOW needed to lower crop damage, much less how their ability to do so might be influenced by covariables such as orchard size, proximity to other tree nuts, and background NOW populations. Additional research is being pursued in these areas over the coming years. The answers to these questions will determine the feasibility of SIT and our ability to integrate it with competing technologies such as mating disruption and insecticide sprays.

Introduction: Navel orangeworm (*Amyelois transitella*) (NOW) is the primary pest of California tree nuts (i.e. almonds, pistachios and walnuts). Adults oviposit onto the nuts and larvae feed on the nutmeats, which reduces crop yield and quality, as well as increase processing costs. NOW infestation is also correlated with incidence of aflatoxin, a known human carcinogen that is heavily regulated in almond markets. As such, growers have a low tolerance for NOW (goal <2% infestation). Management of NOW consists of winter sanitation, mating disruption, well-timed insecticide sprays and timely harvest.
Recently, the California pistachio and almond industries made a significant investment in the development of sterile insect technique (SIT) for NOW that leverages the availability of a preexisting mass-rearing and irradiation facility operated by USDA APHIS in Phoenix, AZ. This facility was originally developed for a sterile pink bollworm (*Pectinophora gossypiella*) (PBW) program and is now being retrofit for production of sterile NOW. The goal is to develop the use of SIT as a complementary strategy to augment the existing IPM toolkit for NOW.

Over the past 3 years, we have led scientific efforts to evaluate the quality and performance of sterile NOW produced by this Phoenix facility. Findings to date have yielded new information on ways to improve the production, handling, transport and release of sterile NOW, as well as verify the field competitiveness of sterile moths with wild moths in orchards. These studies have documented that, when handled and released properly, sterile male and female NOW disperse throughout the orchard and are able to mate with wild NOW – this includes both sterile females attracting/mating with wild males and sterile males locating/mating with sentinel wild-type females. While irradiation can influence NOW performance, the mass-rearing process itself seems to have the strongest negative impacts on moth quality, and findings to

date have implicated the chilling and storage process currently being used in the Phoenix facility (they are kept too cold for too long).

Methods: While field experiments in 2018 and 2020 did include large blocks (640 acre), most recapture data of sterile NOW have been collected in small orchard blocks (<7 acres). Initially low recapture rates in 2018 were potentially attributed to a lack of pheromone response by sterile males. This was subsequently disproven through wind-tunnel assays and instead changes to the release method in 2019 led to significantly increased recovery of sterile NOW.

In 2020, recovery of sterile NOW was compared in 3 small blocks (2 almond, 1 pistachio, 2-5 ac.) and 1 large block (pistachio, 640 ac.). Each block contained a grid of trapping points with paired flight traps, one baited with pheromone lure (captures males) and the other with an ovipositional bait (captures females). The trap grid was 4 x 4 (16 trapping points total) in the small block and 8 x 8 in the large block (64 trapping points total). Sterile moths were released every 2-weeks between May – October using a variety of transportation and release methods. In the small blocks, a grid of 12 mating tables were set out for the first 3 nights following each sterile moth release. Each mating table contained a tethered virgin female NOW that was replaced daily. These sentinel female NOW were collected and dissected the following morning to determine mating success. When a male moth was present, it was also dissected to determine if it was sterile or wild.

Results: – Recovery of Sterile NOW in Flight Traps and Mating Tables
Overall, in 2020 sterile NOW were consistently recovered under field conditions in both the flight traps and mating table assays, but the overall proportion of moths recaptured from a given release event varied significantly (average 2% recapture, range 0.001 - 14%). Data analyses indicate that this variability in recapture rate was influenced by both transportation and release methods (Fig. 1), but surprisingly the strongest predictor of sterile NOW recapture was background wild NOW population (Fig. 2). Upon closer inspection, it appears that recovery rate of sterile NOW was positively correlated with trap catch of wild NOW, indicating that increased activity of wild NOW may somehow lead to increased activity of sterile NOW (or vice versa). This is a unique new dimension to sterile moth performance that will be more closely evaluated in 2021/2022. The total number of sterile moths in a given release event (mean = 5736 ±168 moths) did not have any influence on recovery rate.

As seen in 2019, release method does have an impact on moth performance in field plots. In 2020, the paper bag method that was developed in 2019 continued to produce consistent recovery, which was enhanced further through the addition of tightly packed cardboard tubes into the paper bags (Fig. 3). Moths were also consistently recovered when released by unmanned aerial vehicles (UAVs, i.e. drones) as well as from piloted fixed-wing aircraft (Fig. 1). While the paper bag system works well for experimental purposes, it is critical to continue evaluating different aerial and ground release systems that could potentially work at scale.

Finally, while efforts in 2018 demonstrated that sterile female NOW were able to effectively call and mate with wild males, mating table assays from 2020 are the first to demonstrate that sterile male NOW are able to locate and successfully mate with wild-type sentinel females (Fig. 4). This is a major achievement, and when paired with recovery data indicate that indeed the sterile NOW from the Phoenix facility can successfully disperse in an orchard and both sexes can locate and mate with wild moths.

Conclusions and Future Directions: While preliminary findings are promising and many key limiting factors have been identified (and overcome) over the past three years, there are still many challenges ahead to the development of SIT for NOW. For instance, NOW dispersal and mate-finding in a small block setting is likely quite different from how NOW would distribute themselves across a much larger area. Trapping density and release rates also certainly have an impact on overall recovery rate. On the production side, more information is currently needed about the impacts of chilling and cold storage for NOW aggregation, irradiation and transport, as well as how vibrations and motion impact the quality of NOW while in transit. Furthermore, the potential to combine SIT with mating disruption holds some promise, and additional information is needed on sterile NOW performance in mating disruption blocks. Finally, x-rays offer a safer and potentially more cost-effective opportunity to produce sterile NOW using a non-nuclear irradiation source.

In response, we have started to develop a separate project to model various ecological and economic scenarios for the use of SIT in California, as well as explore an alternative approach to SIT based on the use of x-ray sterilization, and to that end have acquired an x-ray irradiator at the Kearney Ag. Center. As such, research on SIT for NOW is entering a new phase in California. Over the next two years our goal is to evaluate the potential of x-ray sterilization of NOW, improve the chilling and cold storage process, refine our understanding of sterile NOW dispersal in large orchards (both x-ray and Phoenix facility moths) and explore the use of SIT in a mating disruption environment.

Findings from these efforts will not only contribute to the development of SIT for NOW as a complimentary IPM strategy, but also more generally improve our understanding of NOW biology, behavior and movement in orchards, which benefits many other areas of NOW management. Were a large-scale SIT program to prove economically unfeasible, knowledge about how to sterilize NOW in a way that minimizes negative impacts on their field performance would provide an incredibly useful research tool. For instance, sterile NOW could be used for mark-release-recapture studies that would allow us to better understand different aspects of NOW ecology, such as dispersal between orchards or movement within orchards under mating disruption. In this way, this NOW SIT research program not only represents an opportunity to develop a new IPM strategy, but also provides a new research tool to improve our current management strategies.

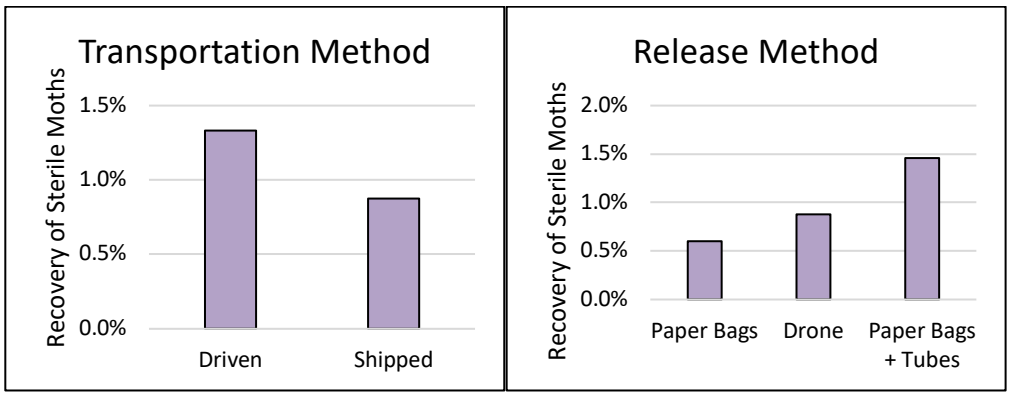


Figure 1. *Recovery of sterile NOW increased when moths were driven in a controlled climate (left) and when released using the paper bag with cardboard tubes or a UAV/drone (right).*

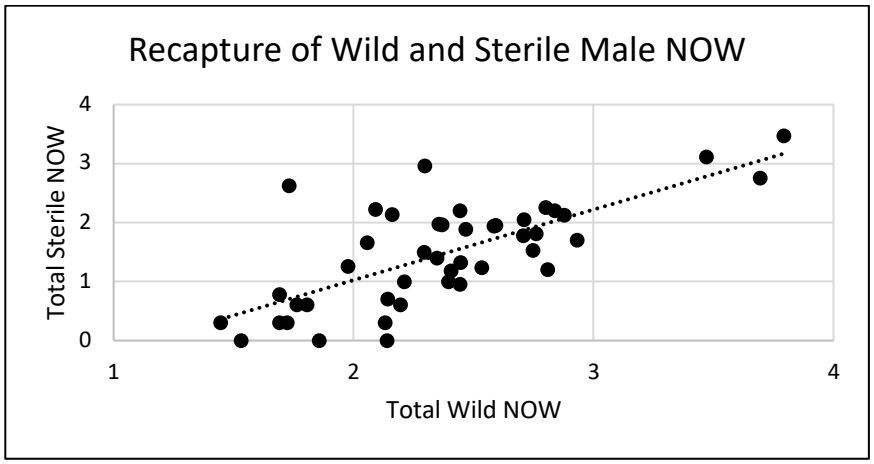


Figure 2. *Recapture of sterile NOW was positively correlated (R^2 = 0.51) with capture of wild NOW. Data are summed across the 2-week period following each release event and log(x+1) transformed for scale.*

Figure 3. *Recovery of sterile NOW was consistent when using paper grocery bags (left), but further improved by releasing from a UAV (center) or adding cardboard tubes to the paper bags (right).*

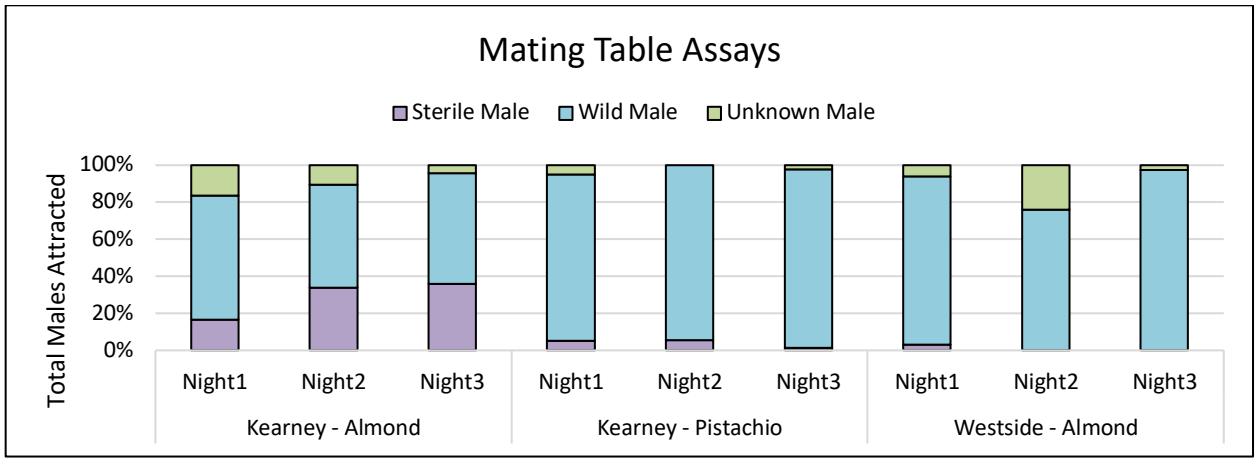


Figure 4. *Mating table assays demonstrated that sterile NOW could indeed locate and successfully mate with wild-type sentinel females.*

Minutes of the 94th Annual Meeting

I. Call to Order

The opening business meeting of the 94th Annual OPDMC Meeting was called to order by Chair Rodney Cooper at 8:56 am (PST) on January 8, 2020. Chair Cooper welcomed approx. 156 attendees to the joint entomology-plant pathology session. The program included 54 papers with 2 cancellations, and no poster session due to low interest. Attendees represented 16 states (AZ, CA, CO, HI, IA, ID, MD, MI, NC, NY, OH, OK, OR, PA, WA) and 4 countries (Japan, Canada, USA, Germany). Chair Cooper pointed out safety exits, the registration desk, where pesticide credit forms were located, and introduced the session moderators. He then asked for each attendee to make a brief self-introduction.

The sessions and moderators:

Mating Disruption/SIR	Chris Adams
Implementation	Karol Krey
Thresholds/Monitoring	Lynn Wunderlich
Biological Control	Kacie Athey (or Rebecca Schmidt-Jeffris in her absence)
Pathology/Diseases	Tobin Northfield
Invasive Species	Greg Krawczyk
Chemical Control/New Products	Louie Nottingham
Biology/Phenology	Houston Wilson

II. Old Business

A. Treasurer's Report: Treasurer Nik Wiman presented the 2019 Treasurer's Report (see Treasurer's Report posted at the end of the minutes). Treasurer Wiman reported $8201 in the account going into the 2020 meeting, an improvement from last year. Approval of the Treasurer Report to follow in the closing business meeting.

B. Approval of the 2019 Minutes: Secretary Alix Whitener announced that the 2019 minutes were posted on the OPDMC website and printed in the back of the abstract booklet. She asked for amendments. There were none. A motion to close the minutes was made by Executive Director Peter McGhee, seconded by attendees Epstein and Van Steenwyk, and were approved by the attendees.

C. Chair Cooper announced the industry donors and student winners of the Student OPDMC Scholarship. Industry donations included Corteva, Certis, Pacific Biocontrol, FMC and OK-SIR, who all donated at the 'GOLD' level this year.
    a. 2020 student scholarship recipients:
        i. Claire Donahoo, Danielle Evans, Adrian Marshall, Lauri Lutes, and James Hepler. Student scholarships were awarded to qualified students with complete applications, awards totaling $3075, and award amounts varied by financial need.

III. New Business

A. Chair Cooper called for the names of any members that had passed away during the last year.
    a. Peter Landolt
    b. Steve Garczynski
    c. Stan Hoyt

d. Everett Burts

A moment of silence was given in their recognition.

B. Chair Cooper announced the Keynote Speaker as Gary Judd whose talk was scheduled for 4:00 pm immediately followed by a mixer in the lobby from 5:00 - 7:00 pm
C. Chair Cooper provided speaker instructions and called for any other new business.
    a. Executive Director Peter McGhee had several announcements:
        i. OPDMC was negotiated for the next two years at the Hilton Downtown in Portland for 2021 $139 and 2022 $144. The membership said around the $140 mark they would like to consider alternative hotels due to cost.
        ii. The change in room setup allows for use of two screens due to an event following the OPDMC Meeting. If attendees had any concerns they were to find Peter and let him know.
    b. Chair Cooper brought up the Rubber Chicken Award for our all-in-good-fun blunder award, as well as the Golden Apple Award for the best presenter and asked the attendees to keep in mind who they would like to nominate at the close-of-business meeting
D. Chair Cooper called for Committee Assignments:
E. Nominations: Rick Hilton (Chair), Alan Knight and Vaugn Walton
F. Audit: Bob Van Steenwyk (Chair), Dave Epstein and Broc Zoller
G. Resolutions: Rebecca Schmidt-Jeffris (Chair), Chris Strohm and Amanda Koppel

Chair Cooper called for a motion to close the opening business meeting. It was moved, seconded, and voted to close the opening business meeting at 9:30 am. Chair Cooper introduced the first session moderator, Karol Krey, and the presentations commenced.

IV. Closing Business Meeting

Chair Rodney Cooper called the closing business meeting to order on January 10, 2020, at 10:37 am.

A. Old Business
    a. Chair Cooper gave a summary report of discussions and decisions from the 2020 Board of Directors' meeting held on January 8 at noon:
        i. Chair Cooper recognized Peter McGhee for organizing our meeting, as well as the registration desk check in volunteers, the Board, and the Scholarship Committee
        ii. 184 registered members in 2020
    b. Treasurer Wiman presented the final treasurer's report
        i. Audit Committee found an error in our opening numbers
            1. 12/31 2019 $8201
            2. Closing 1/10 balance $28112
            3. Total income $21667
            4. Expenses estimated at $25000
            5. Considering increasing our stipend for the executive director

Chair Rodney Cooper called for any other new business.

B. Committee Reports:
    a. Nominations: Rick Hilton, Chair, gave the report. Chris Adams was nominated as Chair-Elect for 2020, Alix Whitener as Secretary, Nik Wiman as Treasurer, Peter McGhee as Executive Director, and Louis Nottingham as Program Chair. Student to serve on the

Scholarship Committee – Claire Donahoo volunteered as the new student representative to the Scholarship Committee. Motion made by Scott O'Keef and vote to approve the nominations; all officers were voted in. Second by Don Thomson and accepted by vote of the membership.

b. Audit: David Epstein, Chair, gave the report. The Audit Committee reviewed and accepted the financial report, and report that the OPDMC financial records are in good order. There was a motion, second and vote to approve the Audit Report. Don Thomson moved and was seconded by Tim Ksander and the membership voted to approve.
c. Resolutions: Rebecca Schmidt-Jeffris, Chair, gave the report. Claire Donahoo, Joannie Lorimore, Tina Phelps, and Heather Andrews were thanked for their service in covering the registration desk. Peter McGhee was acknowledged for all of his meeting support (proceedings, maintaining OPDMC website, and arranging for pesticide credits). Jim Hepler and Adrian Marshall were acknowledged for their support in transporting computer equipment and setting up meeting displays. Karol Krey, Lynn Wunderlich, Kacie Athey, Greg Krawczyk, Louis Nottingham, Houston Wilson, and Chris Adams were thanked for overseeing the entomology sessions, and Tobin Northfield was thanked for overseeing the Pathology/Disease session of the 2020 meeting. There was a motion to accept by Peter McGhee, second by Ron Britt and accepted by a vote of the membership.
d. Chair Cooper summarized the Board Meeting's business
    i. Item: Update the bylaws to include a program chair as a voting member, as well as a vice program chair to serve as a voting member – the bylaws update would be posted to the website for voting.
        1. Discussion: Program chair and other board member terms to a multi-year term to help prevent rapid turnover and help those responsibilities be transferred to the new board members. 3 or 4 year terms, or the program chair/co-chair to serve 2 years each to rollover
        2. Motion to amend the bylaws made by Melissa Tessche and Rick Hilton
        3. Second by Don Thomson
        4. Vote passed
    ii. Item: Create a Code of Conduct to align with modern 501c3 non-profits
        1. Discussion: Highly in favor and suggested to consult ESA for the code of conduct
        2. Motion: Chuck Burks
        3. Second: Rebecca Schmidt-Jeffris and Dave Epstein
        4. Vote passed
    iii. Item: Program changes to keep/divide with Pathology, use a poster session to act as talk overflow when talks fill up, or potentially have a speaker panel at the end of each talk session. Panel discussion would remove one talk but possibly
        1. Discussion: International meeting with the discussion panel after each session was fruitful and tied in all the topics in each section together well. Possibly removing questions after each talk to create more time for the panel, or limit questions to one or two before the panel. Strongly recommend to not remove questions after talks in case clarification is necessary after certain talks. Previous experience shared from some highly effective panels but some are not so effective. Another idea was to open the poster session back up and the program chair could decide

which submissions are posters and which are talks – could possibly solicit industry support to include mixer drink tickets to encourage people to participate in the poster session. Mixer attendance has declined so this could improve the mixer. Hot topic panels and roundtable discussions can also encourage networking and future collaborations.

2. Motion: Motion to allow the board to take these ideas and resolve the program to be – Dave Epstein
3. Second: Wiseman
4. Vote: Passed

C. Chair Cooper called for nominations for the Golden Apple Award.
   a. Nominations: Chris Adams Michigan State/OSU, Karol Krey USDA ARS Wapato
   b. Vote: Karol Krey is our Golden Apple Award winner
D. Chair Cooper for nominations for the Rubber Chicken Award.
   a. Nominations: Bob Vansteenwyk for totally not following the directions slide even though he was the first speaker and had a recent explanation of said directions. Rebecca Schmidt-Jeffris for showing a gel in her presentations AND using rubber chickens to point out her results. Current Rubber Chicken Holder Rick Hilton nominated Greg Krawczyk for showing upside-down videos, the modern version of upside-down slide carousels, and Jay Pscheidt for presenting on a silver bullet solution.
   b. Vote: Greg is our Rubber Chicken Award winner
E. Chair Cooper thanked all of the session leaders, registration desk volunteers, and all of the executive committee members for making the conference run smoothly.
F. Chair Cooper announced next year's meeting dates: January 12-15, 2021 at the Downtown Hilton, Portland.
G. Incoming Chair Allison Walston pounded the gavel at 11:08 am to close the final business meeting

Respectfully submitted,
Alix Whitener, Secretary
Orchard Pest and Disease Management Conference, January 8-10, 2020

Treasurers' Report 2020

Opening Business Meeting:

Total Cash and Paypal Balance (as of 31 December 2018):	*$4401.00*
Total Income from 2019:	*$19,980.00*
Total Expenses of 2019:	*$23,890.00*
Total Cash and Paypal Balance (as of 31 December 2019):	*$8,201.71*

Closing Business Meeting:

Total Cash and Paypal Balance (as of 31 December 2019):	*$8,201.71*
Total number of Registrations (as of 10 January 2020):	*184*
Total Income from 2020:	*$21,667*
Total Cash and Paypal Balance (as of 10 January 2020):	*$28,112.00*
Expenses Estimate for 2020:	*$25,000.00*

Orchard Pest and Disease Management Conference
Resolutions – 2020

1. Be it resolved that this conference extend written appreciation to the management and staff of the **Hilton Hotel** for the courteous service and fine accommodations provided.

2. Be it resolved that the members of this conference express their appreciation to the Executive Director **Peter McGhee**, Past Chairperson **Art Agnello**, Chairperson **Rodney Cooper**, Chair-Elect **Allison Walston**, Secretary **Alix Whitener**, Treasurer **Nik Wiman**, ~~and Program Chair~~ **Betsy Beers** for their leadership and dedication in organizing the 2020 meeting.

3. Be it resolved that the members of this conference extend their appreciation to the Peter McGhee for preparing the abstracts and proceedings, updating and maintaining the OPDMC website, and arranging for pesticide credits; and Adrian & Jim Hepler Marshall for transporting ~~projection~~ Computer equipment and setting up tripods, displays, and covering the registration desk along with Tina Mathis, Jasmine Lawrence.

4. Be it resolved that the members of this conference extend their appreciation to the session leaders: _____ for ably overseeing the entomology sessions, and Tobin Northfield for overseeing the Pathology/Disease session of the 2020 conference. Karel Kray, Lynn Wunderlich, Kacie Athey, Greg Krawczyk, Louis Nottingham, Houston Wilson, Chris Adams

5. Be it resolved that that the Secretary write letters of condolences to family of members who passed away during the past year.
   Names of recently deceased members: _____
   _____

Claire Dunthorne Heather Andrews

Names (print), signatures, and date signed of the 2020 Resolutions Committee Members:

	Name (Print)	Signature	Date
Chair:	Rebecca Schmidt		1/10/20
Member:	AMANDA KOPPEL		1/9/2020
Member:	Christopher		1/18/20

Updated 01/04/2019

Orchard Pest and Disease Management Conference

Nominations – 2020

1. Be it resolved that this conference nominate ~~[illegible]~~ Chris Adams to the position of **Chair Elect** for the 2021 meeting.

2. Be it resolved that this conference nominate Alix Whitenar to the position of **Secretary** for the 2021 meeting.

3. Be it resolved that this conference nominate N.L Wiman to the position of **Treasurer** for the 2021 meeting.

4. Be it resolved that this conference nominate Peter McGhee to the position of **Executive Director** for the 2021 meeting.

5. Be it resolved that this conference nominate Louis Nottingham ~~Betsy Jones~~ to the position of **Program Chair** for the 2021 meeting.

Names (print), signatures, and date signed of the 2020 Nominations Committee Members:

	Name (Print)	Signature	Date
Chair:	Rick Hilton	[signature]	1/9/20
Member:	Vaughn Walton	[signature]	1/9/2020
Member:	Ian Knight	[signature]	1-9-20

Updated 12/23/2019

Orchard Pest and Disease Management Conference

Audit Committee Report – 2020

1. We as members of the Audit Committee have examined the Report of the Treasurer and we accept that the financial records of the Orchard Pest and Disease Management Conference are in good order. Be it resolved that this conference accept the Report of the Treasurer.

Names (print), signatures, and date signed of the 2020 Audit Committee Members:

	Name (Print)	Signature	Date
Chair:	David Epstein		1/10/20
Member:	Doc Zoller	Doc Zoller	1/10/2020
Member:	Robert Van Steenwyk	R.A. Van Steenwyk	1/10/2020

Updated 12/23/2019

Minutes of the 94th Annual Meeting
Orchard Pest and Disease Management Conference
Hilton Hotel, Portland, Oregon
January 8th – 10th, 2020

Board Member Signatures

Peter McGhee, Executive Director	1-10-2020 Date
Rodney Cooper, Chairperson	1-11-2020 Date
Arthur Agnello, Past Chairperson	unable to attend Date
Allison Walston, Chairperson Elect	Jan 10, 2020 Date
Elizabeth Beers, Program Chair	unable to attend Date
Nik Wiman, Treasurer	01-10-2020 Date
Alix Whitener, Secretary	10 January 2020 Date

The Rubber Chicken Award

An enduring tradition of informality is the nomination, voting, and awarding of the Rubber Chicken to one of the presenter during the closing business meeting. The Rubber Chicken may be awarded for a variety of reasons, but egregious behavior in some aspect of presenting a scientific talk is the underlying theme: too long, too short, poor organization, illegible slides, and over-spinning research results are frequently cited.

Notables who have received the award include:

- **Clancy Davis**, Berkeley, California for his quiet, sober, professional demeanor on all occasions.
- **Stan Hoyt**, Wenatchee, Washington for failing to enliven methods of presentation of papers.
- **Don Berry**, Medford, Oregon for never having made a single comment over 20 years.
- **Pete Westigard**, Medford, Oregon for returning from a sabbatical with 400 color slides (all failures) and a new child (a success).

'**Winners' in the Modern Era** (following about a 15-year hiatus, the award was revived during the 75th anniversary meeting):

- **Stephen Welter (2004)**, University of California, Berkeley, for inappropriate behavior by leaving the meeting prior to giving his presentation.
- **Bob Van Steenwyk (2005)**, University of California, Berkeley; Bob suffered at the hands of technology and he could have been forgiven for these technical glitches; however, the membership was in a surly mood after the prolonged business meeting. Bob graciously accepted the award.
- **Alan Knight (2006)**, USDA-ARS, Wapato, Washington, for not submitting a talk.
- **Andy Kahn (2007)**, Wenatchee, Washington, for giving a much too long presentation and refusing to yield the podium - Andy subsequently decapitated our alopeciate friend.
- **Jim Miller (2008)**, Michigan State University, for attempting to coerce the entire membership into his cult of the pheromone, and for admitting to having intimate relations with codling moths; Jim was responsible for the demise of yet another unfeathered friend.
- **Peter Shearer (2009)**, Oregon State University, Hood River, for forgetting, like Dorothy, that he was not in Rutgers anymore (For those of you not present, he gave his talk as the new director of the Hood River Station MACAREC, using the Rutgers template).

- **Harvey Reissig (2010)**, Cornell University, Geneva, for his presentation that introduced a new web based IPM decision support system for NY apple growers that was actually a chemical spray calendar disguised as an IPM program (well played, Harvey, well played…).
- **John Dunley (2011)**, Wilbur-Ellis, Cashmere, Washington, for not being present each morning to turn on the lights, the projector, and the laptop computer before the meeting began. He also assumed that at least one of the many well-educated members of the Conference (ahem, Broc Zoller), most of whom were lugging their own laptops, would be able to find the correct button to turn on the conference laptop, and that labels on the two (!) cords would make the connections between the laptop and projector clear. He was proven to be incorrect.
- **Larry Gut (2012)**, Michigan State University, for now conducting research on pheromone puffers (and finding them effective) after 'pooh-poohing' them for many years.
- **Don Thomson (2013)**, DJS Consulting Services, for delivering the keynote speaker's address in his introduction of Camille before she had a chance to deliver her own presentation. Also, Don temporarily lost the rubber chicken in the foyer, but he did later recover it.
- **Doug Light (2014)**, USDA ARS, Albany, California, for blatantly promoting his own product during his presentation.
- **Brad Higbee (2015)**, Paramount Farms, CA, for delivering an extended talk under false pretenses, breaking the new OPDMC computer, and bragging about his 40-acre research plots.
- **Betsy Beers (2016)**, Washington State University, Wenatchee, for the incompatibility of the slideshows presented by herself and her students despite the fact that she keeps the meeting computer.
- **Lisa Neven (2017)**, USDA-ARS, Wapato, Washington, for submitting her talk late, two times, and including incorrect information on Okanagan Co. in her presentation.
- **Lucia Varela (2018)**, University of California Cooperative Extension, Santa Rosa and Napa, for claiming that she had not seen the slides prior to the presentation; however, she was second author on the presentation; for making personal statements without supporting data; for claiming to have visited every backyard in Chile to see that all had grapevines; and she requested to the audience – "shoot me".
- **Rick Hilton (2019),** was nominated for false advertising because he signed up for BMSB talk in the Invasive Species section of the conference, but then proceeded to spend half of his presentation talking about codling moth.
- **Greg Krawczyk (2020)**, was nominated for showing upside-down videos similar to the old upside-down 35mm slides.

Travel Scholarships for Students

INDUSTRY SPONSORS

For many years, industry participants in OPDMC have been asking for a way to lend financial support the event. Now there is a way to support both OPDMC and the next generation of IPM specialists!

Industry contributions will be accepted in any amount, and sponsors will be recognized in the following categories: Bronze (up to $249), Silver ($250-$499), and Gold ($500+). Contributing organizations will be recognized in the conference program, as well as in the opening and closing business meetings.

INTERESTED STUDENTS

To qualify for the scholarship, students must:

- Submit a complete application
- Attend OPDMC and present a talk
- Be available to help with either conference set up or take down.

The selection committee will review applications and select award recipients from qualified applicants. The number and value of scholarships awarded will depend on the total amount of donations received.

FOR MORE INFORMATION

Visit https://opdmc.org/home/scholarships/

No Thank You Covid-19!

2021 Student Scholarship Sponsors

GOLD LEVEL

Interested in Donating? See https://opdmc.org/home/scholarships/