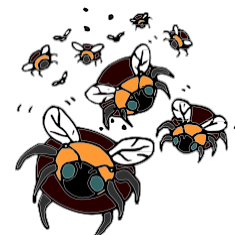
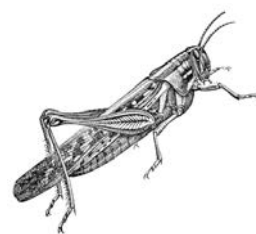
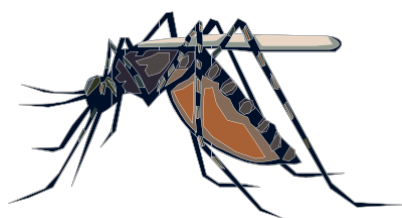


RESEARCH REPORTS

75th ANNUAL PACIFIC NORTHWEST INSECT MANAGEMENT CONFERENCE

HILTON HOTEL
PORTLAND, OREGON
JANUARY 11 AND 12, 2016



****These are research reports only, NOT management recommendations.**

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January 11 and 12, 2016

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AGENDA

75th ANNUAL PACIFIC NORTHWEST INSECT MANAGEMENT CONFERENCE

Hilton Hotel, Portland, Oregon
January 11 and 12, 2016

(Each presentation about 15 minutes long)

MONDAY, JANUARY 11th

Registration	9:00AM
Call to Order Business Meeting	10:00AM
Section I (5-6 reports)	10:15AM
Lunch (on your own)	11:45AM
Section I (2-3 reports)	
Section II (4 reports)	1:00PM
Section IV (2 reports)	
Break	3:00PM
Sections IV (1 report)	
Section V (3 reports)	3:30PM
Adjourn	4:30PM

TUESDAY, JANUARY 12th

Registration	8:00AM
Call to Order	8:30AM
Student Presentations (4 reports)	8:35AM
Break	10:00AM
Student Presentations (4 reports)	10:30AM
Section VI (1 report)	
Lunch (on your own)	11:45AM
Section VI (3 reports)	1:00PM
Section VIII (1 report)	
Final Business Meeting	2:15PM
Adjourn	2:45PM

SECTION I

Invasive Pests, Emerging Pests, and Hot Topics of Interest

SPOTTED WING DROSOPHILA SELECTION OF FRUIT EXPOSED TO BROWN MARMORATED STINK BUG

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The invasive spotted wing drosophila (SWD) (*Drosophila suzukii*) and Brown Marmorated Stink Bug (BMSB) (*Haylomorpha halys*) are both threatening horticultural crops in the US. The prevalence of both species co-utilizing the same host is not well known, but is likely occurring in the fields. Given that BMSB and SWD can feed on small fruits, the question arises whether prior feeding by one species affects subsequent host selection by the second species. Given that BMSB is known to leave behind a distinctive scent, it might be expected that this scent may affect SWD's ability to locate the food source, or deter SWD from utilizing the food source for oviposition. In this way, co-infestations of SWD and BMSB may synergistically increase crop damage, whereby SWD avoid fruits fed on by BMSB and spread out to oviposit in other undamaged fruits. The total sum of damaged fruits is greater with selective avoidance than random feeding events.

Objective: Determine if SWD oviposit differently among fruits with/out prior BMSB feeding.
Raspberry

- No-choice trials
- Choice trials

Blueberry

- No-choice trials
- Choice trials (also done with 'delay' fruit in case BMSB feeding induces changes in fruit after a few days)
- Test relationship between number of SWD eggs laid, BMSB flanges, and °Brix on berry

Methods: SWD were from a laboratory colony started from infested fruits collected in Oregon. The colony and experiments were maintained at 22°C, 16L: 8D, and ~60% RH.

Fruit source. In Aug-Sept 2014, raspberries were collected from a mixed cultivar primocane fruiting raspberry seedling field at Lewis Brown farm. Green raspberries were enclosed in organza bags to prevent naturally-occurring infestation from SWD or feeding by BMSB. At fruit ripening, the stem above each fruit was cut with scissors to leave the fruit intact. Ripe fruit was randomly selected from different plants in the field, and mixed gently prior to use in the trials. Store-bought organic blueberries were during Feb-Mar 2015.

Set-up. To create BMSB-fed and unfed raspberry or blueberry fruit, half of the fruits were placed inside 28 x 28 x 28 cm cages (BugDorm, BioQuip) containing wild-collected BMSB for 24 h. BMSB were observed walking on and feeding on the fruit during this time. After 24 h, the BMSB-fed fruits were mixed to account for potential differences in BMSB activity between

cages. To create unfed fruit, the other half of the fruits were placed in identical cages without BMSB for 24 h. Then fruit were transferred to arenas with SWD for testing. Each arena contained 4 ~2-wk-old mated female SWD in a 23 x 23 x 25 cm plastic cage. Water was provided from a soaked sponge placed through a hole cut in the lid of a 60 ml plastic deli cup. After 24 h of exposure to SWD, the fruit were handled as described below for the different trials. The number of fruit exposed, trial dates, and replicates are described in the Table below.

Assay	Fruit in arena	Trial dates	No. replicates/treatment
Raspberry no-choice	5 fed or unfed	21, 26 Aug, 17 Sept 2014	15, 5 per date
Choice	5 fed + 5 unfed	27 Aug, 3, 9 Sept 2014	14, 4-5 per date
Blueberry no-choice	10 fed or unfed	24, 25 Feb, 3 Mar	15, 5 per date
Choice	5 fed + 5 unfed	17, 18, 19 Feb	30, 10 per date
Choice 'delay'	5 fed + 5 unfed	23, 26 Feb, 3 Mar 2015	28, 8-10 per date

Raspberry - No-choice trial. After 24 h of exposure to SWD, the raspberries from each arena were placed into 120 mL plastic cups (Solo Cup Operating Corporation, Lake Forest, IL). Cups were covered with no-see-um netting (Skeeta, Bradenton, FL) secured by a fitted lid with a 4 cm diameter hole cut into the middle to allow ventilation while preventing further infestation. Cups were held on lab benches for 7 d, after which raspberries were dissected and the number of SWD larvae and pupae were counted. Larval and pupal counts were used as a measure of oviposition because counting eggs on raspberries is difficult. Previous trials that compared the number of eggs counted and the final number of developing SWD after 7 d on the same raspberry revealed that there was a tendency to undercount SWD eggs.

Raspberry – Choice trial. After 24 h of exposure to SWD, the raspberries were held for 7 d as described in the no-choice trial, except that BMSB-fed and unfed raspberries from the same arena were kept in separate cups.

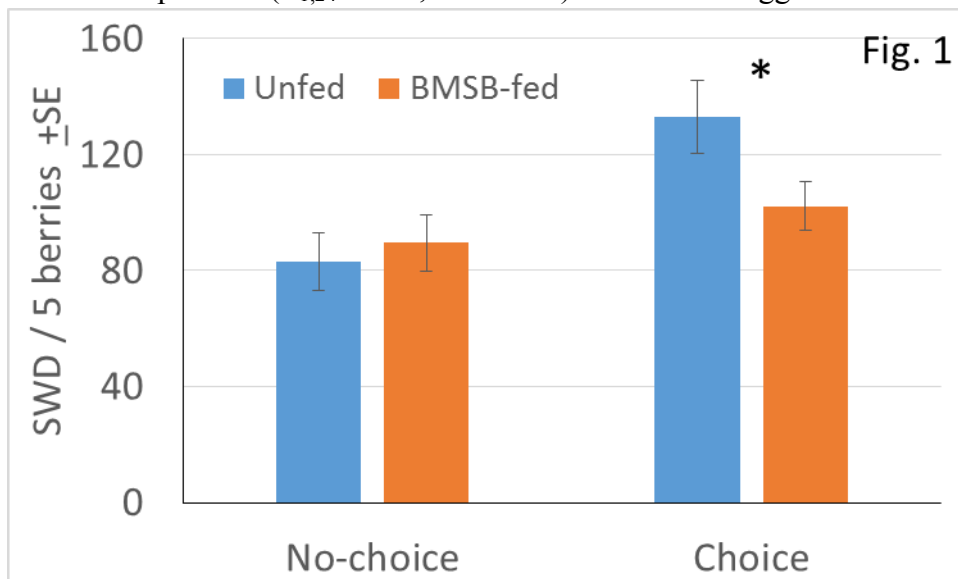
Blueberry – No-choice trial. After 24 h of exposure to SWD, the blueberries were stored individually into bead boxes such that recordings were taken on each berry for the number of eggs laid by SWD, intensity of BMSB feeding (no. of flanges) and °Brix (sugar content). SWD eggs were identified under magnification by the protruding respiratory filaments. To enable the identification of BMSB style sheaths, berries were then soaked for 15 minute in a mixture of 1 g acid fuchsin, 1 ml glacial acetic acid, and 100 ml dH₂O. Berries were then rinsed in dH₂O. This dyed the stylet sheaths bright pink, making them easier to count under magnification. Lastly, each blueberry was macerated individually to obtain juice for brix readings.

Blueberry – Choice trials. In the usual trials, BMSB-exposed fruit were then immediately exposed to SWD for 24 h in arenas. In ‘delay’ trials, blueberries were held in 120 mL plastic cups, covered by no-see-um netting for 72 h before being exposed to SWD in arenas. This “delay” trial was conducted in case BMSB feeding affected fruit quality after a few days which could subsequently affect SWD ovipositional choices. Choice trials included the usual protocol and using “delay” blueberry fruit as described above. After 24 h of exposure to SWD, individual blueberry fruit were recorded for number of SWD eggs laid, BMSB flanges, and °Brix.

Statistical analysis. Data from no-choice, choice and choice ‘delay’ trials were analyzed separately in JMP 11.0.0. For raspberry trials, the total number of SWD larvae and pupae developing from BMSB-fed and unfed fruit were compared with treatment (BMSB-fed, unfed) as a fixed effect and trial date as a random effect. For blueberry trials, the number of SWD eggs laid was compared with treatment as a fixed effect and trial date as a random effect. For blueberry choice and choice ‘delay’ trials, berries were tracked by cages, and paired t-tests also compared the number of eggs laid in BMSB-fed and unfed blueberries. Within each cage, the eggs laid per berry were summed for the 5 BMSB-fed berries and also for the 5 non-fed berries, resulting in one fed and one non-fed value per cage. Data were checked for homogeneity of variances, and no transformations were necessary.

RESULTS

Raspberry. In no-choice trials, there were no differences in the total number of SWD larvae and pupae in BMSB-fed and unfed raspberries ($F_{1,24} = 0.33$, $P = 0.57$) (left graph below). In choice trials, there were marginally fewer SWD larvae and pupae developing in BMSB-fed than in unfed raspberries ($F_{1,24} = 4.05$, $P = 0.056$). This could suggest differential oviposition or

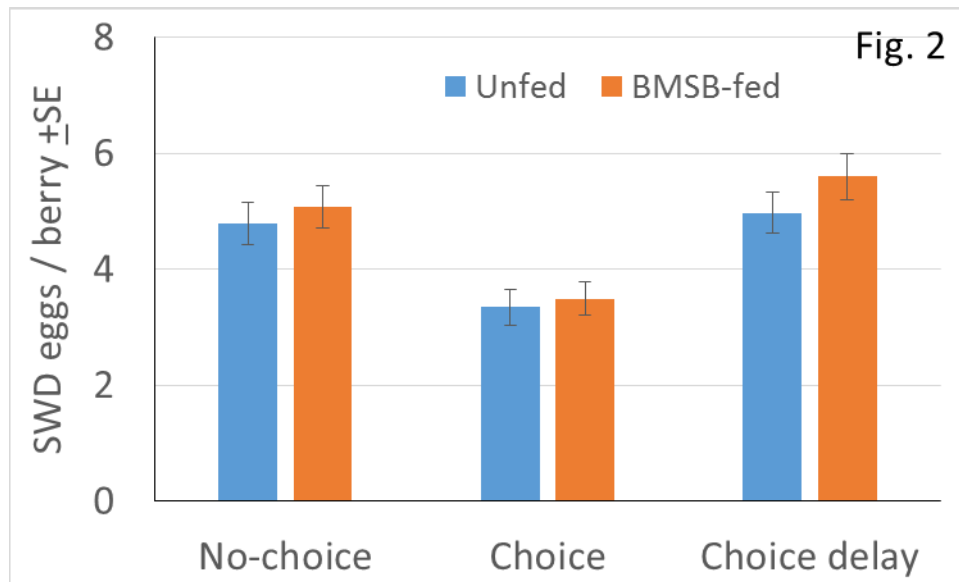


differential development of SWD larvae and pupae on exposed versus unexposed raspberries. Unfortunately, the number of eggs could not be reliably counted on raspberry fruit due to its texture to determine if oviposition rates differed.

Blueberry. No BMSB flanges were found on any of the unfed berries. The mean number of flanges found on BMSB-fed blueberries from the no-choice, choice, choice ‘delay’ trials were 5.92 ± 0.54 , 5.79 ± 0.49 , and 4.76 ± 0.35 , respectively. The number of eggs laid in BMSB-fed and unfed blueberries did not differ in the no-choice ($F_{1,26} = 0.28$, $P = 0.60$), choice ($F_{1,56} = 0.02$, P

=0.90; $t = 0.12$, $df = 29$, $P = 0.90$), and choice ‘delay’ trials ($F_{1,52} = 0.74$, $P = 0.39$; $t = 0.72$, $df = 27$, $P = 0.47$) (Fig. 2).

Regression analyses showed no strong relationships between the number of eggs laid on a berry with respect to its °Brix level or to the number of BMSB flanges as a measure of intensity of BMSB feeding, for any of the trials. In other studies, egg laying often increased as °Brix level of fruit increased with fruit of varying ripeness levels. No substantial trend was observed in these trials probably because the blueberry were ripe and range of °Brix values was limited. The lower and upper 95% °Brix values were 9.68-10.46 in no-choice trials, 9.68-10.46 in choice trials, and 9.79-10.8 in choice ‘delay’ trials.



NUTRIENT PROFILES OF BROWN MARMORATED STINK BUGS

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The brown marmorated stink bug (BMSB), *Halyomorpha halys*, has become a major established pest across the US since it arrived in 1996. Understanding the nutrient profile of BMSB in the wild can potentially pinpoint vulnerable periods for targeted management, and may help predict how plant resources such as crops are utilized. Some information on nutrient status of BMSB pre- and post-overwintering is available from Japan, and more recently from lab feeding studies in Virginia. To date, there is no information on nutrient profiles of naturally-occurring adult BMSB in North America.

The objective of the project was to understand the general nutrient dynamics (sugars, lipids, and glycogen) of wild BMSB adults in the Willamette Valley of Oregon throughout the summer and emerging from overwintering. Summer BMSB were collected from holly at five sites throughout the valley. Overwintering BMSB were collected as they emerged from overwintering structures. All samples were weighed, measured, and ran for nutrient. Females were also dissected.

The general trends are overwintering BMSB had lower nutrient levels compared to summer adults. The nutrient steady decreased as they emerge later. Summer BMSB nutrient level seems to dip mid-summer with peak egg loads in early summer.

Another field season is planned to continue looking at the nutrient levels at the time of emergence and through the summer field season in the Willamette Valley of Oregon.



THE STATE OF PEST MANAGEMENT IN LEGAL CANNABIS PRODUCTION IN WASHINGTON

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Cannabis production is no different from other agricultural crops in that it can become infested with a variety insect, mites and disease. Cannabis production is different from all other agriculture because it is illegal to federally register a pesticide for control of insects and disease. The Washington State Department of Agriculture has developed a list of products that are considered not illegal to use on cannabis in Washington. Many of these products have no practical pest management value. Many other of these products have limited efficacy, short residual or other attributes that limit their usefulness to cannabis growers. Due to the expectation of superior quality and the extremely high value of their crop, cannabis growers are under heavy pressure to control insects, mites and diseases. Due to the combination of these factors growers are using a wide array of pest management products and practices, some of which may be illegal and may pose a risk to pesticide applicators, cannabis workers and cannabis consumers. This situation is exacerbated by a federal probation on Washington State University and USDA conducting pest management research, development of alternatives to pesticides, pesticide applicator training or training on worker protection from pesticides.

The lack of appropriate mechanisms for pesticide applicator and worker protection standards training, the lack of adequate crop protection tools and the absence of traditional research and extension outreach programs has created a “Wild West” mentality where any kind of pest management tactics can occur. The void of traditional pest management research, extension and appropriate tools has created serious and potentially dangerous conditions in cannabis production. This is not a new occurrence. Following a pesticide label has historically not been among the most important considerations in the illegal production of cannabis. What is difference is the cannabis is legally available for medical purposes for the large majority of the U.S population and is completely legal in several states. The widespread legalization of cannabis is bringing historical cannabis pest management practices into public view.

Recent state investigations in Colorado, Oregon and Washington has indicated that illegal pesticide use is not uncommon in the cannabis industry. Below are pesticide residues from flower and concentrate cannabis products in Oregon medical cannabis as reported by an Oregon based cannabis testing facility.

Table 2 is a list of individual samples with the highest levels of pesticides observed so far. These results clearly demonstrate that many products, especially concentrates, have levels of pesticides that greatly exceed EPA tolerances for these compounds on any commodities. It can also be

clearly seen that the highest levels of pesticides observed in concentrates greatly exceeds the highest levels found on Cannabis flowers.

<u>Flowers</u>			<u>Concentrates</u>		
<u>Matrix</u>	<u>Pesticide</u>	<u>Conc (ppb)</u>	<u>Matrix</u>	<u>Pesticide</u>	<u>Conc (ppb)</u>
Flower	Imidacloprid	64,000	Concentrate	Carbaryl	415,000
Flower	Azadirachtin	36,000	Concentrate	PBO	407,000
Flower	PBO	2,700			
			Concentrate	Myclobutanil	392,000
Flower	Azadirachtin	16,700	Concentrate	PBO	220,000
Flower	Imidacloprid	15,300	Concentrate	PBO	180,000
Flower	Azadirachtin	14,274	Concentrate	Myclobutanil	160,000
Flower	PBO	13,500	Concentrate	PBO	137,000
Flower	Azadirachtin	13,200	Concentrate	Azadirachtin	123,000
Flower	Azadirachtin	11,450	Concentrate	Myclobutanil	110,000
Flower	Azadirachtin	11,300	Concentrate	PBO	106,700
Flower	PBO	9,040	Concentrate	Chlorfenapyr	100,000
Flower	Dichlorvos	8,058	Concentrate	Myclobutanil	64,310
Flower	Myclobutanil	8,039	Concentrate	PBO	52,000
Flower	Azadirachtin	7,200	Concentrate	PBO	48,160
Flower	Bifenthrin	5,621	Concentrate	PBO	46,440
Flower	Bifenthrin	4,925	Concentrate	PBO	44,500
Flower	PBO	4,450	Concentrate	Myclobutanil	43,600

This table is from Pesticide Use on Cannabis. Prepared by the Cannabis Safety Institute, June 2015. Authors and Contributors Rodger Voelker, PhD, Mowgli Holmes, PhD.

PESTICIDE USE ON MARIJUANA IN WASHINGTON

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WSDA has developed criteria for pesticides that are allowed for use on marijuana in Washington. Most of the allowed pesticides are biopesticides, organic pesticides, or minimum risk pesticides. In addition, WSDA has developed guidance on submitting applications for Section 24c special local need (SLN) registrations to allow the use of pesticides on marijuana. I will discuss examples of pesticides that can, and that cannot be used on marijuana. I will explain why certain pesticides cannot be used on marijuana.

WSDA has worked with several organizations on providing outreach to the marijuana industry on pesticide use, including the Coalition for Cannabis Standards & Ethics (CCSE), CannaCon, and the Interagency Resource for Achieving Cooperation (IRAC). WSDA has developed guidance documents for the marijuana industry, and has participated in three Cannabis Pest Management workshops.

I will discuss some ideas for agricultural universities, the marijuana industry, and state agricultural agencies to help address the concerns with pesticide use on marijuana.

Web Sites / Publications:

- CannaCon <http://cannacon.org/>
- Coalition for Cannabis Standards & Ethics (CCSE) <http://www.ccsewa.org/>
- Interagency Resource for Achieving Cooperation (IRAC) - Publications
<http://apps.lhwmp.org/IRAC/Publications.aspx>
- WSDA - Pesticide and Fertilizer Use on Marijuana
<http://agr.wa.gov/pestfert/pesticides/pesticideuseonmarijuana.aspx>

BIOCONTROL OF ARTHROPOD PESTS: CURRENT PROJECTS BY THE OREGON DEPARTMENT OF AGRICULTURE

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Ash Whitefly Biological Control: High populations of ash whitefly, *Siphoninus phillyreae* (Hemiptera: Aleyrodidae; AWF) were reported from the Portland metro area to Oregon Department of Agriculture (ODA) and Oregon State University during late summer of 2015. Ash whitefly was first identified in OR from specimens collected in Oak Grove by ODA during October 2014. This insect poses a threat to Oregon's nursery industry as it has an extensive host range including many ornamental plants, and would affect export of nursery plants out of the state. It is considered a pest of citrus in many areas of the U.S. In 2015, Ash whitefly reached nuisance levels in Portland, OR and surrounding areas.

Two biological control agents imported from Israel were released in southern California in 1990 to combat infestations of AWF: *Encarsia inaron* (Hymenoptera: Aphelinidae) and *Clitostethus arcuatus* (Coleoptera: Coccinellidae). Following releases in multiple counties, both agents became established and AWF populations were reduced to nearly undetectable levels in just a couple of years. Both *E. inaron* and *C. arcuatus* were recovered and identified by ODA in September 2015 in Milwaukie, OR in AWF populations on ornamental *Pyrus* trees. Since then, the parasitoid has been recovered from multiple areas around Portland with high levels of parasitism reported (>90% in some areas). However, AWF populations discovered in Grande Ronde, Scappoose, and Corvallis, OR had very little to no parasitism. Populations of AWF in Oregon were observed overwintering on evergreen hosts in December 2015.

A colony of AWF and the parasitoid are being maintained over the winter of 2015-2016 at the ODA Hawthorne facility for inundative releases of the parasitoid in 2016.



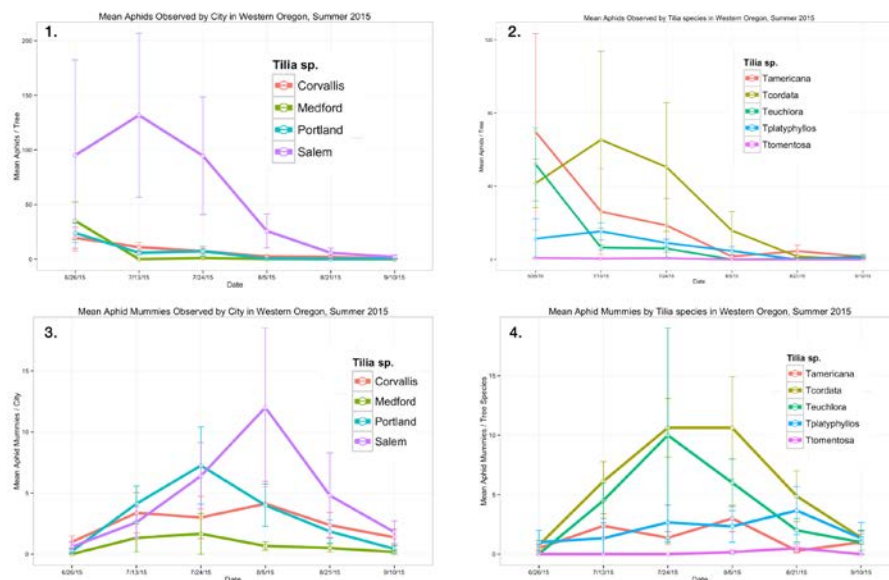
Figure 1: *Clitostethus arcuatus* (Coleoptera: Coccinellidae) and *Encarsia inaron* (Hymenoptera: Aphelinidae). Images by Thomas Shahan, ODA.

Linden Aphid Biological Control: In 2013, a pesticide spray to manage aphids on linden trees in Wilsonville resulted in the death of hundreds of bumblebees in a shopping center parking lot. This event

created a lot of public attention to the non-target effects of pesticides on pollinators and the importance of following proper protocol when applying chemicals to control insect pest. As linden trees (*Tilia sp.*) are popular urban forest trees throughout western Oregon, ODA is investigating the use of biological control to manage *Eucallipterus tiliae* (Hemiptera: Aphididae), a primary pest of lindens as an alternative to pesticide applications. These aphids are considered a nuisance pest because they produce copious amounts of honeydew, which falls on sidewalks, vehicles and furniture beneath the trees and increases amount of black sooty mildew on the trees. In some extreme cases aphids can damage or kill trees.

We conducted a preliminary survey during the summer of 2015 in order to determine the pest and natural enemy complex on linden street trees in Western Oregon. Surveys were conducted in Portland, Salem, Corvallis and Medford. Colin Park, Jodie Lombardi and Mark Hitchcox, USDA-APHIS conducted the samples in Portland. Three common species of linden trees were considered for the survey: *Tilia tomentosa* ('Silver-leaf' linden), *T. cordata* ('Little-leaf' linden) and *T. americana* ('Basswood'). Other species surveyed were *T. platyphyllos* in Corvallis and *T. euchlora* in Portland. Trees were sampled bi-weekly for aphid species, numbers of aphids, numbers of parasitized aphids, and the occurrence of other natural enemies. Parasitized aphids were collected and monitored for parasitoid emergence. Each city had two sites for each species being sampled. Thirty-two *Tilia* trees in total were sampled.

The only species of aphid recovered from our samples was *Eucallipterus tiliae*. Aphid populations were highest at the beginning of the survey in late June, but steadily declined in all cities samples (Figs. 1 and 2). Problematic honeydew accumulation only occurred on trees with the highest populations. Mean aphid mummies observed were much lower than the number of aphids observed, suggesting that parasitoids are not contributing to the decline in aphid populations (Figs. 3 and 4). Aphid mummy counts were higher later in the season than peak aphid populations. Parasitoids were recovered from aphid mummies in all four cities, but identifications are still ongoing. Other natural enemies observed included coccinellids, spiders, lacewings, and *Heterotoma planicornis*, a predacious bug (Hemiptera: Miridae).



Figures 1-4: Mean numbers of aphids and aphid mummies observed compared by *Tilia* species and area sampled during summer 2015. Error bars indicate SE.

***NEZARA VIRIDULA* – SETTLER OR SIGHTSEER?**

Chris Looney, Washington State Department of Agriculture, Olympia WA
Todd Murray, Washington State University Extension, Pullman WA

Nezara viridula (L.) is a polyphagous stink bug pest of gardens and production agriculture, with a particular predilection for peas and other legumes. First described from India in 1758, this species is believed to originate in Ethiopia and is now cosmopolitan in tropical and subtropical regions. In the United States, *N. viridula* occurs from Virginia to Florida, north to at least Kansas in the Midwest, and in California (Panizzi et al. 2000).

In 2014, the Washington State Department of Agriculture received queries from Seattle area gardeners about large populations of an unrecognized stink bug. Photographs were also received that summer by WSU Extension as part of the effort to track *Halys halyomorpha*. While the new stink bugs were clearly *N. viridula*, a species not known from Washington, there was a general expectation that winter temperatures would eliminate what was likely an introduction on vegetable starts from out of state. The 2014 winter was notably mild, and more sightings were reported of *N. viridula* in several other Seattle area locations in 2015. Reports of damage have been erratic, with some gardeners reporting no noticeable impacts despite large populations, and others ascribing leaf blotching on beans and cat-facing on cherries to *N. viridula*. It remains to be seen whether this species will establish permanent populations in western Washington. Cold temperatures normally limit overwintering success, but recent establishment of *N. viridula* populations in the United Kingdom, central Europe, and northern Japan are evidence that milder winter temperatures are contributing to this insect's expanding range (Salisbury et al. 2009, Musolin 2012).

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THERMAL TOLERANCE OF SPOTTED WING DROSOPHILA

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In an effort to better control spotted wing Drosophila (SWD), *Drosophila suzukii*, understanding larval thermal survival limits may lead to effective population control. Such control may be implemented with canopy manipulation and/or black weed mat installation. Research reported here includes bioassays conducted in the laboratory on larvae aged 1-4 days. These larvae were subjected to temperatures from 28-48°C for 60 minutes. Four day old larvae were additionally subjected to heat therapy of 35°C for 30, 60, and 90 mins and then subjected to the same range of temperatures. Survival and emergence of larvae was monitored after 11 days. In-field bioassays were conducted to determine survival in several canopy positions. The impact of black weed mat, no cover (bare soil), white mat, and sawdust installed under blueberry bushes on larval survival was also determined.

Results showed decreased survival rates with increasing temperature. Heat therapy treatments resulted in increased survival rates for larvae that received 30 and 60 minutes of heat therapy. No larval survival increase was found when larvae receive heat therapy for 90 minutes. Survival declined to levels lower than those of control larvae when heat therapy lasted 90 mins. Results from field trials support those found in the laboratory trials. Black weed mat resulted in significant reductions of adult SWD. Bare soil, sawdust, and white mat resulted in similar levels of SWD emergence. The base of blueberry plants was found to have the highest temperatures while western exposed had the hottest temperatures compared to the other locations in the blueberry canopy.

LILY LEAF BEETLE (*LILIOCERIS LILII*) IN WASHINGTON STATE

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Lily leaf beetle (LLB), *Lilioceris lilii* (Scopoli) (Coleoptera: Chrysomelidae), indigenous to Eurasia, is a pest of lilies (*Lilium* spp.), fritillaries (*Fritillaria* spp.) and giant lilies (*Cardiocrinum* spp.) (Salisbury 2008). Though largely a horticultural pest, LLB also feeds and reproduces on native lilies (Cappuccino et al. 2013). In Eurasia LLB ranges from North Africa to Siberia, and from the United Kingdom to China (Bouchard et al. 2007). Likely introduced to North America with imported Asiatic lilies, LLB was first discovered in North America in the 1940s in Montreal, Canada, and was detected in Cambridge, Massachusetts in 1992 (Bouchard et al. 2007). Populations are now established throughout central and eastern Canada and seven northeastern states (Cappuccino et al. 2013). There are no *Lilioceris* native to North America (White, 1993). *Lilioceris cheni*, introduced to control air potato (*Dioscorea bulbifera*) in Florida is the only congener in the United States (White 1993, Center et al. 2012). The first reported occurrence of LLB on the west coast was detected by an alert gardener in Bellevue, Washington, in 2012.



Adult lily leaf beetles in Bellevue, Washington. (E. LaGasa, WSDA)

LLB is active from April-August. Overwintering adults emerge in the spring, feed for several weeks, mate, then begin to lay eggs. Females lay 200–300 eggs throughout the season (Ernst 2005). Newly hatched larvae feed on the undersides of leaves, covering themselves with a layer of excrement. This “fecal shield” is likely a form of protection or disguise from generalist predators (Bouchard et al. 2007). The larvae feed for several weeks, then pupate in the soil for 3–4 weeks. Newly hatched adults feed until the fall and then overwinter in the soil (Cappuccino et al. 2013).

LLB is known to feed on 87 species of *Lilium*, 5 species of *Fritillaria* and one species of *Cardiocrinum* (Salisbury, 2008). It has also been observed feeding on Twistedstalk (*Streptopus lanceolatus*) in natural settings (Cappuccino 2015, Salisbury 2008) and Solomon’s Seal (*Polygonatum*) in the lab (Cappuccino et al. 2013). Adults and larvae are voracious feeders that can cause complete defoliation of plants and damage to buds and flowers (Cappuccino et al. 2013). LLB have been observed feeding on the native lilies *L. candense* in Canada and *L. superbum* in Rhode Island (Cappuccino et al. 2013). As the beetles’ range continues to expand in North America, more native lilies (half of which are

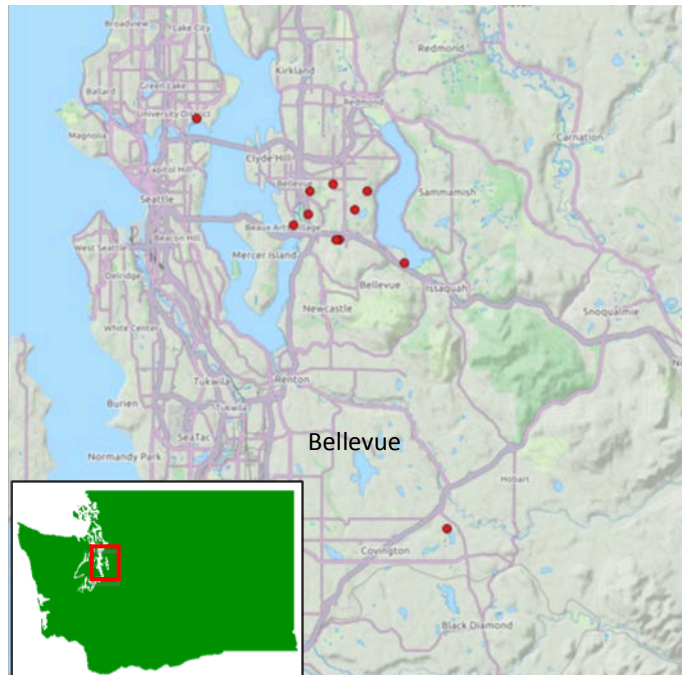


LLB larvae feeding on underside of lily leaf. (E. LaGasa, WSDA)

already threatened or endangered) may be at risk (Cappuccino et al. 2013). LLB can cause home and community gardeners to stop growing lilies and fritillaries. The beetle poses an economic threat to lily and fritillary producers, the cut flower industry, and native plant nurseries in terms of production costs and how the pest affects the consumer market.

Hand removal can effectively control the beetle, although this is time consuming and the feces covered larvae can be repulsive to gardeners. Effective organic and conventional pesticides must be reapplied throughout the season, with potential risk to natural enemies and pollinators (Cappuccino et al. 2013). In Eurasia a wide array of parasitoids target *L. lili*, with parasitism rates reaching

78% in some wild populations (Cappuccino et al. 2013). Three parasitoid wasps (*Tetrastichus setifer* Thomson, *Diaparsis jucunda* Holmgren and *Lemophagus errabundus*) have been screened and released on the East Coast and in Canada. The most effective of these is *T. setifer*, with field parasitism rates of up to 100% (Cappuccino et al. 2013).



Lilioceris lili detections in Washington

As of 2015 there are 11 known populations of the beetle within about a 60 square mile vicinity of central Bellevue. LLB is already causing major plant destruction at home and community gardens in the Bellevue area. Some gardeners in the area have reported “giving up” on trying to grow lilies, and one botanical garden states “We don’t plant lilies anymore (A Wright in litt., November 2015). At least one regional nursery will not buy or trade lilies from King County.

Washington State Department of Agriculture and Washington State University are preparing a grant proposal seeking funds to develop a regional biological control program targeting this pest. If funded, the biological control agent *Tetrastichus setifer* will be released in affected areas to help control beetle populations. Successful establishment would provide permanent control of LLB, protecting lilies and fritillaries in home gardens, natural ecosystems, and commercial operations.

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Section I: Invasive and Emerging Pests

“WINTER CUTWORM” HITS WILLAMETTE VALLEY

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Noctua pronuba is a Noctuid moth, widely distributed throughout Eurasia. Common names for this species include “large yellow underwing” and “winter cutworm”, in reference to the adult and larval stages, respectively. This non-native insect was first introduced to North America near Halifax, Nova Scotia, in 1979. Within a decade, adult moths were detected throughout the east coast, continued advancing west to Idaho, Washington, California, and Oregon by 2001, and are now considered abundant in most of the US. However, accounts of crop damage have been rare, and are evidenced by just a few reports from Michigan (2007), North Dakota (2008), and Idaho (2009). *N. pronuba* has a wide host range and will feed on field crops, vegetables, turf grass, small fruits, ornamentals, and weeds. Recent observations of larval activity are causing concern for PNW growers and homeowners alike.

As an adult, the large yellow underwing displays over 10 morphotypes, but all are recognizable by the distinctive pattern and coloring of the hindwing. Therefore, amateur collectors and naturalists are quick to ID the species, and in fact, have provided much of the detail of what we currently know about *N. pronuba*. Moths are attracted to light traps, and in some instances have been noted aggregating on walls and at street lights. They are strong fliers, and migration is a main mode of invasion. Egg masses are laid on vegetative or abiotic structures including host plants, sticks, fences, vehicles, walls and eaves of houses. After 2-3 weeks eggs hatch, and larvae begin feeding immediately. Development continues through six larval instars, and feeding activity increases on warmer days. This species is commonly called the winter cutworm because larvae can tolerate temperatures of 40°F (4°C) or less. In Michigan, larvae were seen actively foraging on snow banks, thus coining the term ‘winter cutworm’. Larvae persist throughout the fall and winter, and may mature at various times. Details of the lifecycle is disputed.

Due to the unusual activity period of *N. pronuba*, the potential risk for crop damage extends from September through May. *N. pronuba* larvae are especially damaging because they display characteristics of both subterranean and climbing-type cutworms. They also hatch in larval masses, which then become mobile, typical of armyworms. Damage varies widely depending on crop, and can range from leaf-cutting and bloom defoliation to root and crown chewing and stem-girdling. Small grains can be particularly damaged, and regrowth is not guaranteed. Consequences of residential infestation include personal injury due to slippery surfaces, and pet illness if the caterpillars are ingested. Concerns of herbivory in native ecosystems also increases during this type of outbreak epidemic.

Factors that might influence an intensive larval feeding outbreak in agronomic areas include: reduced tillage, perennial cropping systems (especially fall-seeded crops), and areas with volunteer cereals or persistent, low-growing winter weeds. However, because *N. pronuba* is not an economic pest in its native range, there is limited information regarding effective control tactics. General recommendations include crop rotation, weed and volunteer management, and insecticides that are labeled for armyworm and cutworm control.

Positive identification of the winter cutworm can likely be achieved by field scouts and homeowners alike, and an Extension publication will be released (est. Jan 2016 publication date) to aid identification and scouting efforts. Characteristics of mid- to late-stage larvae include:

- tan head capsule with adfrontal pattern (opened “X”) on the eyes

- dark, discontinuous, sub-dorsal markings that are bordered ventrally by a thin, continuous cream colored band. The resulting dashed-line is most apparent on posterior segments, and fades or is not present near the head
- lateral, diagonal white markings accented by black
- examination of the hypopharyngeal complex and mandibular structures is necessary to separate *N. pronuba* from the closely related *N. comes*

Table 1. Investigations to date by OSU project team have revealed *N. pronuba* larvae in many locations and crop/site scenarios.

location	crop	date investigated	inquiry made via (how you were contacted)	investigated by	
Shedd, OR	volunteer ryegrass	8-NOV	phone call to Benton Cty. Extension	Clare Sullivan, OSU Ext.	A. Dreves
Banks, OR	residential turf	10-NOV	email	B. Mc Donald	
Dayton, OR	vineyard	10-NOV	phone call from sales rep	B. Mc Donald	Kurt Wright, Simplot
Vancouver, WA	apartment complex turf	12-NOV	N/A (independent scouting)	Dan Dearing, Simplot	
Yamhill Cty., OR	seedling clover	13-NOV	phone call to Yamhill Cty. Extension	Nicole Anderson, OSU Ext.	A. Dreves
Amity, OR	canola	18-NOV	N/A (independent scouting)	J. Green	
Springfield, OR	residential	20-NOV	email	B. Mc Donald	
Centralia, Chehalis, and Puyallup, WA	turf	8-DEC	was contacted post-presentation	B. McDonald	
Burlington, WA	turf	11-DEC	email	B. McDonald	Steve Link
Willamette Valley, OR	home lawn	13-DEC	N/A (independent scouting)	Tom Cook	

Figure 1. Mid-to-late stage winter cutworms have somewhat distinct patterning and are present throughout the fall and winter. The adult moth is widespread throughout this region but this is the first report of crop damage in Oregon.

Section I: Invasive and Emerging Pests

RECENT DETECTIONS OF THE ASIAN GYSPY MOTH

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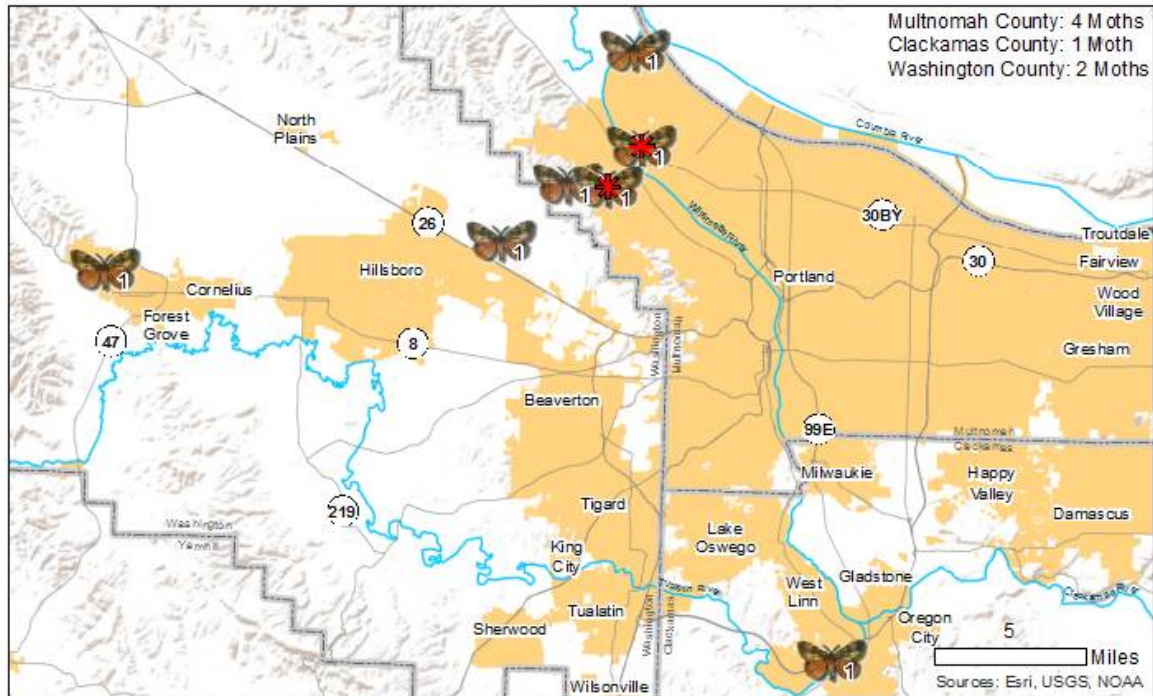
Each year, port inspections and trapping surveys are conducted by agencies as part of a safeguarding effort to prevent the establishment of gypsy moth (GM) in the Pacific Northwest. In 2015, over 15,000 GM delta traps were deployed in Oregon by Oregon Dept. of Agriculture, APHIS-PPQ, Oregon Dept. of Forestry and USFS-FHP. A total of 14 gypsy moths were detected in the state in 2015 from four counties in Oregon. Seven moths were collected in traps from Grants Pass (Josephine County) as part of a third year of delimitation trapping. Positive results were also reported from Forest Grove, Portland and West Linn.

Molecular characterization was performed by on all adult moths collected (USDA-CPHST, Otis Laboratory, Buzzards Bay, MA). Analysis of CO1 coding sequence and nuclear DNA (FS1 site) indicated that while most moths were from a North American origin, two of the moths were of Asian origin. These two moths, and an additional Asian gypsy moth from Vancouver, WA were collected from an area in north Portland near marine port pathways.

The detection of three AGM in the Portland/Vancouver region represents an unprecedented threat. In response, a multiagency multistate effort is currently underway, in consultation with the science technical working group, to eradicate any infestations of AGM in the states of Oregon and Washington.

2015 Oregon Gypsy Moth Detections

Total Moths Caught: 14 (as of 8-27-2015)



Positive Gypsy Moth Trap



Confirmed Asian Gypsy Moth



Gypsy Moth Detection Map
8/28/2015
Oregon Department of Agriculture
Data Source: Esri, Oregon Department of Agriculture
Data Date: 8/28/2015
This map is for informational purposes only and should not be used for legal engineering or surveying purposes. Users of this information should consult the primary data and information sources to determine the usability of the information.

CULTIVAR RESISTANCE TO THE AZALEA LACE BUG

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The azalea lace bug, *Stephanitis pyrioides*, is a recent invasive to the Pacific Northwest and is a growing concern for *Rhododendron* growers. In this study, we conducted cultivar resistance/susceptibility trials in a controlled laboratory environment. In total, five cultivars were tested, one control and four indumentum bearing cultivars. Cuttings of cultivars with indumentum were shown to be highly resistant to feeding damage by the lace bug. Lace bugs placed with cultivar cuttings with indumentum had a mortality rate >95% whereas the control only had a mortality rate of ≈ 10%. The results highlight the importance of cultivar resistance to help in the control of the azalea lace bug.

SECTION II

Bees and Pollinators

POLLEN COLLECTED BY HONEY BEES FORAGING IN BLUEBERRY FIELDS: DISTRIBUTION ON BODY PARTS

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Honey bees are effective pollinators of diverse crops but are considered to be inefficient pollinators of blueberries due to their inability to ‘buzz’ the flowers for release of the pollen from the anthers. This belief has been supported by observations of honey bees ‘robbing’ nectar from the base without entering the flower. Further, in a study conducted at Oregon State University, little blueberry pollen was observed to be present in pollen loads in the pollen basket (corbicula) of honey bees returning to hives placed in blueberry fields. Honey bees remove pollen from their face and body and pack it into a tight ball in the pollen basket for transfer to the hive. This has led researchers to believe that the composition of pollen in pollen loads reflects plants that are pollinated by the corresponding bee. Based on this, the lack of blueberry pollen in honey bee pollen loads provides further evidence that honey bees are not effective pollinators of blueberry crops.

Oregon is a lead producer of blueberries. During the years 2012-2014, the state reported the third highest blueberry yield per acre (USDA NASS, 2015). Despite the belief that honey bees are not effective in blueberries, Oregon blueberry growers typically stock their fields with 2-4 honey bee hives per acre during bloom. In a study focused on determining which bee species contribute to blueberry pollination, surprisingly, there were 45 times more ‘non-robbing’ visits by honey bees than native bees in commercial blueberry fields. Honey bee foragers were observed pushing their heads into blueberry flowers to access nectar. In the process, they can inadvertently pick up pollen via hairy parts of their body, and if some of the pollen escapes transfer to the pollen basket, they can contribute to blueberry pollination without buzzing the flowers. The impact may vary by cultivar as, while traits like bloom time and fruit quality are tightly controlled during variety development, flower size and pollen production may be unintentionally altered and result in variation among varieties, which could affect pollination (Courcelles et al., 2013). In Oregon, the cultivar Bluecrop produces significantly more pollen and is self-pollinated at a higher rate than Draper but impacts of this difference on pollen collection by bees are not known. Hence the objectives of this preliminary research were to: 1) Determine the presence and quantity of blueberry pollen on honey bee body parts other than in pollen loads; 2) Compare pollen abundance on body parts of honey bees foraging in fields of Bluecrop and Draper cultivars.

Methods

In this preliminary study, honey bees were collected from eleven blueberry (six Bluecrop, five Draper) fields in April 2015, and frozen. Each bee was dissected into four sections – head, thorax and abdomen, upper parts of legs (excluding tarsi) and tarsi (Figure 1). Wings were removed prior to dissection, and pollen loads on corbiculae were removed and excluded from the study.

Each body part was suspended in hexane or 100% ethanol, vortexed (two 30-second intervals), sonicated (30 minutes), and centrifuged (5,000 rpm for two 1-minute intervals). A subset of the pollen was quantified using a hemocytometer for estimation of total pollen on the corresponding body part. Pollen was identified as blueberry or 'other'. Subsequently, samples were processed using acetolysis, and pollen identities were confirmed by comparison with reference samples.

Preliminary Results

The study indicated that pollen was carried on the body hair of all the four body sections, namely the head, abdomen and thorax, upper parts of legs, and tarsi. There was significant variation in pollen distribution across the body parts with the legs, specifically the 5-segmented tarsi, carrying significantly more pollen than the head and body (Figure 2, $p < 0.01$). Mean blueberry pollen did not vary between bees foraging in Bluecrop ($4,615 \pm 1146$) and Draper ($4,085 \pm 471$).

Conclusions

The results of this preliminary study indicate that honey bees foraging in blueberry fields accumulate blueberry pollen on diverse body parts besides the corbiculae. Interestingly, the greatest amount of pollen was observed on the tarsi. Honey bees have been observed to push their heads into blueberry flowers for accessing nectar at the base. However, only the upper part of the body enters the flower, and hence the presence of pollen on the tarsi is intriguing. It is possible that the pollen is inadvertently collected from adjacent flowers. If this is the case, then pollen on honey bee tarsi may well contribute to pollination. Based on a study by Dogterom et al. (2000), for maximum fruit set in blueberries, around 125 pollen tetrads are needed. In the current study, thousands of tetrads were observed on the tarsi, and thus more than adequate pollen is present on this body part for successful pollination of several fruits. Further research is needed to determine if tarsi enter neighboring blueberry flowers during nectar foraging, and whether adequate numbers of pollen tetrads from the tarsi are deposited on the stigma for production of a mature berry.

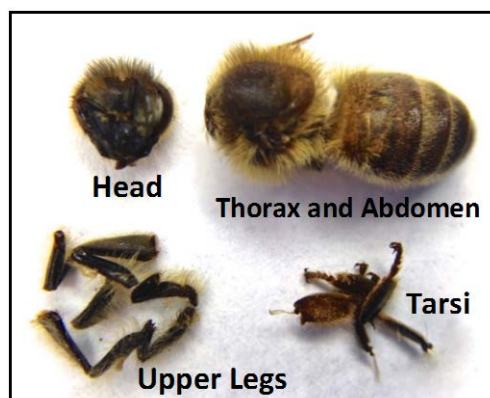


Figure 1. Dissection of a honey bee for quantification of pollen on the different body parts.

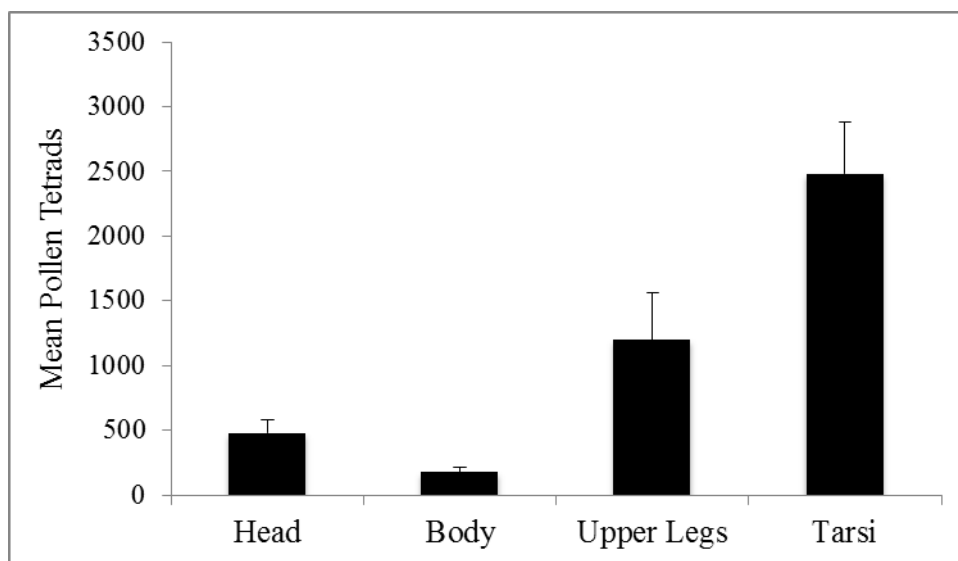


Figure 2. Mean (+SE) blueberry pollen tetrads on body parts of honey bees collected from blueberry fields (n=40).

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Section II: Bees and Pollinators

INTEGRATION OF NATIVE BEE POLLINATOR CONSERVATION WITH PASTURE ENRICHMENT

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Native bees provide valuable pollination services for agricultural crops and for native plants in natural habitats. In recent years, native bee populations have been reported to have declined due to loss of habitat, pathogens, and exposure to toxic pesticides. Bee conservation efforts have been directed towards establishment of ‘bee habitat’, such as flowering hedgerows near agricultural fields, for providing bees with food resources. However, these are often restricted in size due to availability of land, and thus the impacts are limited. In contrast, pastures provide a unique opportunity for bee conservation on a large scale. By adding a diversity of flowering plants that bloom at different periods, native bee populations can be enhanced on grass-dominated pastures. Also, by inclusion of clovers, the soil can be enriched with the nitrogen fixed in the plants, while the increase in protein content can benefit grazing animals. The objective of this study was to evaluate the impact, on native bee pollinators, of adding flowering plants to pastures.

Methods: This study was conducted at four ranches in the Willamette Valley in western Oregon. In fall 2014, at each ranch, one paddock was planted with a seed mix consisting of 22 plant species provided by Grassland Oregon, while a second paddock was maintained as a control with no addition of the seed mix. The following spring, observations were made on native bee populations and plant bloom for determining the impact of the addition of the seed mix to the pastures.

Native bee diversity and abundance around pastures. Native bee abundance and diversity were assessed by placement of two blue vane traps (Figure 1) at each seeded and control paddock. Bees captured over a one week period in April and May were collected and identified. In addition, for assessing nesting by mason bees, two nesting blocks with 12 nesting reeds (Figure 2) were set up in each paddock in March, and collected in August. The numbers of plugged reeds and mature cocoons were recorded. The cocoons are being maintained over the winter for emergence of adults.



Figure 1. Blue vane trap for monitoring native bees.

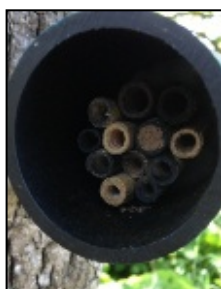


Figure 2. Mason bee nesting block with reeds.

Native bee foragers on flowering plants in pastures. For assessing food resource availability for native bees, plants in bloom and the abundance of bloom in each species, in seeded and control paddocks, were estimated using 0.5 m x 0.5 m grid. For assessing plant utilization by bees, counts of bee foragers on flowers were made during a 10-minute walk in each paddock. Foraging bees and flowers on which they were present were recorded.

Results

Native bee diversity and abundance around pastures. Across the four ranches, blue vane traps captured honey bees and 19 species of native bees belonging to nine genera in the families Andrenidae, Apidae, Halictidae and Megachilidae (Table 1). At Ranch B, three of the nesting blocks had six plugged reeds with 34 cocoons while at Ranch C one nesting block had four plugged reeds with 26 cocoons.

Native bee foragers on flowering plants in pastures. Of the 22 plant species in the seed mix, 12 plant species belonging to three plant families were observed in bloom in the seeded paddocks during the study (Table 2). At each ranch, three to eight plant species were observed in bloom but only balansa clover was observed blooming at all four ranches. The greatest number of plants was observed in bloom during May.

Native bees belonging to at least 13 species in eight genera, besides honey bees, were observed foraging on flowers of 10 plant species in the seeded paddocks across the four ranches (Table 2). A few foraging bees could not be identified due to their rapid flight. The genera *Andrena*, *Bombus*, *Halictus* and *Synhalonia* were observed foraging on at least four plant species (Table 2). However, some species such as *B. mixtus*, *B. nevadensis*, *A. texanus* and *A. virescens* were observed foraging on a single plant species. Plants visited by most species of bees included purple top turnip and radish. Although alsike and persian clover were observed in bloom, no bee foragers were recorded on them. In the control paddocks, white clover and hairy vetch were recorded in bloom and 6 pollinator visits by honey bees, *Andrena* sp, and *Synhalonia* sp. were recorded.

Summary. Based on observations made in spring 2015, a greater diversity and abundance of native pollinators was observed in paddocks planted with the seed mix compared to the control paddocks. Bloom was observed in 12 plants included in the seed mix, and 10 of these were visited by at least 13 species of native bees and honey bees. *Bombus appositus* and *Osmia* spp. that were present in the surrounding regions, based on blue vane trap captures, were not observed foraging on flowers in the seeded paddocks during the sampling periods. In contrast, *B. griseocollis*, *B. nevadensis* and *Nomada* sp. that were observed foraging on flowers were not captured in the traps. This could be because trapping periods and the flower observation periods did not always coincide. Based on preliminary observations made in the study, pastures have the potential for large scale native bee conservation.

Table 1. Average numbers of bees captured in blue vane traps at four ranches in the Willamette Valley in western Oregon in spring 2015.

Bee Family	Bee species ²	Number of bees ¹							
		Ranch A		Ranch B		Ranch C		Ranch D	
		Control	Seeded	Control	Seeded	Control	Seeded	Control	Seeded
Andrenidae	<i>Andrena</i> sp.	---	---	1.67	---	---	0.67	---	---
Apidae	<i>Apis mellifera</i>	0.33	---	2.33	0.67	0.33	---	2.33	2.00
	<i>Bombus appositus</i>	---	0.33	---	0.33	---	---	---	---
	<i>Bombus californicus</i>	---	---	1.33	0.33	0.33	2.00	---	1.00
	<i>Bombus mixtus</i>	---	0.33	1.00	1.00	---	0.67	---	---
	<i>Bombus vosnesenskii</i>	---	---	---	0.67	0.33	0.33	---	0.33
	<i>Ceratina acantha</i>	---	---	---	47.00	---	---	8.33	0.33
	<i>Ceratina micheneri</i>	---	---	---	---	---	---	1.00	---
	<i>Synhalonia</i> sp.	0.33	0.67	0.33	3.00	2.00	1.33	0.67	0.67
Halictidae	<i>Agapostemon texanus</i>	---	---	---	1.33	0.67	1.00	0.67	---
	<i>Agapostemon virescens</i>	2.00	1.67	1.33	1.33	11.00	7.00	3.33	6.33
	<i>Halictus farinosus</i>	---	---	3.00	---	---	---	0.33	---
	<i>Halictus ligatus</i>	---	---	---	1.33	---	---	0.33	3.33
	<i>Halictus rubicundus</i>	---	---	0.67	1.00	---	1.67	---	---
	<i>Halictus tripartitus</i>	---	2.33	14.33	98.67	---	0.67	---	0.33
	<i>Lasioglossum</i> spp. (2)	9.67	15.67	18.67	21.67	4.33	2.00	1.67	14.33
	<i>Sphecodes</i> sp.	---	---	0.67	0.67	---	---	---	0.33
Megachilidae	<i>Osmia</i> spp. (2)	---	1.33	0.33	0.33	---	0.33	0.33	---

¹ Average numbers of bees/trap/week.

² Numbers in parenthesis represent the estimated numbers of species.

Table 2. Blooming period of plant species in seeded paddocks and genera of bees observed foraging on them.

Plant Family	Plant species	Plant Bloom			Bee species foraging on flowers
		March	April	May	
Apiaceae	Parsley				
Asteraceae	Blanket flower				
	Chicory				
	White Yarrow				
Brassicaceae	Forage rape		X		<i>Halictus</i> spp.
	Kale		X		<i>Andrena</i> sp., <i>Apis mellifera</i> , <i>Bombus californicus</i> , <i>Halictus</i> spp.
	Purple top turnip	X	X	X	<i>Agapostemon texanus</i> , <i>Andrena</i> sp., <i>Apis mellifera</i> , <i>Bombus griseocollis</i> , <i>B. vosnesenskii</i> , <i>Halictus</i> spp. <i>Lasioglossum</i> spp., <i>Nomada</i> sp., <i>Specodes</i> sp.
	Radish	X	X	X	<i>Andrena</i> sp., <i>Apis mellifera</i> , <i>Bombus californicus</i> , <i>B. griseocollis</i> , <i>B. mixtus</i> , <i>B. vosnesenskii</i> , <i>Halictus</i> sp., <i>Synhalonia</i> sp.
Fabaceae	Alfalfa				
	Alsike Clover			X	
	Balansa Clover		X	X	<i>Agapostemon virescens</i> , <i>Apis mellifera</i> , <i>Bombus griseocollis</i> , <i>B. vosnesenskii</i> , <i>Halictus</i> spp., <i>Synhalonia</i> sp.
	Berseem Clover				
	Birdsfoot Trefoil				
	Crimson Clover		X	X	<i>Apis mellifera</i> , <i>Bombus californicus</i> , <i>B. griseocollis</i> , <i>B. nevadensis</i> , <i>B. vosnesenskii</i>
	Hairy Vetch			X	<i>Andrena</i> sp., <i>Apis mellifera</i> , <i>Synhalonia</i> sp.
	Persian Clover			X	
	Red Clover				
	Rose Clover			X	Unidentified ¹
	Strawberry Clover				
	White Clover			X	<i>Andrena</i> sp. , <i>Synhalonia</i> sp., Unidentified ¹
	Yellow Sweet Clover				
Hydrophyllaceae	Lacy Phacelia			X	<i>Apis mellifera</i> , <i>Bombus vosnesenskii</i> , <i>Halictus</i> spp., <i>Lasioglossum</i> spp.

¹ Unidentified due to rapid movement.

POLLINATION LIMITATION IN OREGON BLUEBERRIES

George Hoffman and Sujaya Rao

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Last year we introduced Project Integrated Crop Pollination (ICP), a Small Crop Research Intuitive grant involving multiple scientists across the United States and B.C., Canada. The fruit crops ranged from apples and blueberries in MI, pumpkins in PA, blueberries and watermelon in FL, to almonds and melons in CA. At Oregon State University we are focused on blueberries.

We are involved in three of the Project ICP research objectives: 1) pollinator contributions to yield; 2) the impact of enhanced floral resources for pollinators; and 3) economics and modeling. Today I will be talking about objective 1; focusing on pollination limitation and the contribution of honey bees and native bees to blueberry pollination. This work is taking place on 12 blueberry farms in the central part of the Willamette Valley.

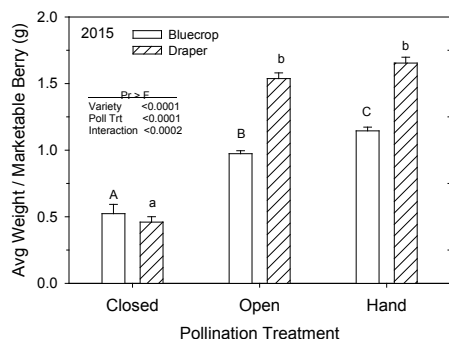
Pollination limitation describes the reduction in fruit weight (and the number seeds) in flowers that have received less than the optimal number of pollinator visits / pollen transfer. Honey bees are stocked at the rate 2-4 hives per acre in blueberries, and we want to know if their pollination services, and those of native pollinators, are adequate for maximum yield. We examined these questions by having three pollination treatments on each test plant: 1) Closed- flower clusters enclosed in a mesh bag prior to flower opening; 2) Open- flowers open to insect pollinators; and 3) Hand- open plus hand pollinated. In the the Hand pollination treatment flowers have additional pollen placed on the stigma (female part) 2 or 3 times during the bloom period. This is done with a tiny paint brush dipped in blueberry pollen. The latter two treatments are bagged after all the flowers drop.

In this talk we present our analysis of the pollination limitation studies in 2014 and 2015. We applied each treatment on ten plants at each of 0, 25, 50 and 100 m distances into the field from a natural vegetation edge. Native bees often utilized natural vegetation adjacent to production fields for nesting sites and food resources, and are likely to be visiting blueberry flowers near the field edge. We documented the visitation of all pollinators at each distance several times throughout blueberry bloom.

We will focus on differences among blueberry varieties (Bluecrop and Draper), distance from the field edge, and the three pollination treatments. The variables of interest are the percent of berries that are of marketable size, the average weight of those berries, and the number of seeds per fruit (both mature and immature). The number of seeds has a direct influence on the size of the blueberry fruit.

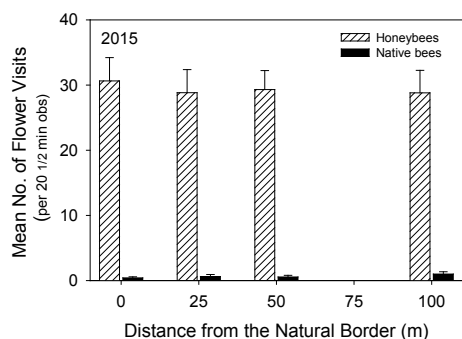
Selected 2014 and 2015 Results. We will start by saying there was no distance effect for any of our variables.

In 2014 and 2015 we found significant differences between varieties and among the pollination treatments, and their interaction, for the percent of marketable-size berries. There were about three



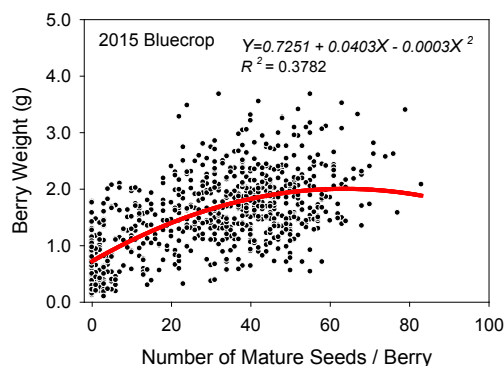
times more marketable berries in the Open and Hand pollinated treatment than the Closed. Draper was more sensitive to lack of pollinators than Bluecrop. i.e., Bluecrop self-pollinated more readily in the Closed treatment. Those berries that were produced in the Closed treatment were of barely marketable size. In 2014, Closed treatment berries were less than half the weight of the Open and Hand treatments. In 2015, Bluecrop berries in the Closed treatment were again less than half the size of the Open treatment, while the Draper was approximately one-third the weight of the other two treatments. Berries in the Hand pollinated treatment were always larger than in the Open treatment, but only in 2015 for Bluecrop were those differences significantly different (Figure 1).

The number of mature seeds per berry was influenced by variety in 2014, with more seeds in the Bluecrop fruits across all pollination treatments. Pollination treatment was significant in 2014 and 2015. There were from 4 to 8 times more mature seeds in the Open and Hand Pollination treatments compared to the Closed treatment. In 2014 there were significantly more mature seeds in the Hand versus Open treatment for both varieties, while in 2015 there were only more mature seeds in the Hand pollination treatment for Bluecrop.



What potentially accounts for these patterns? In both 2014 and 2015 there were 45-50 times more honey bee visits to blueberry flowers than visits by native pollinators. The number of honey bee visits from 0 m (field edge) to 100 m was the same (Figure 2). These visit numbers were equivalent to approximately 240 honey bee visits per plant per hour in the afternoon, and these rates appeared to be sufficient to produce close to the potential maximum berry size.

In both 2014 and 2015 there was a less impact of the variety and pollination treatments on berry weight compared to seed number. This can be explained by looking at the relationship between seed number and berry weight. Figure 3 shows that for Bluecrop in 2015, as mature seed number increased so does berry weight, up to around 40 mature seeds per fruit. Above 40 seeds there is no further increase in fruit weight. A similar relationship holds for Draper. For Bluecrop the number of immature seeds was also important in determining berry weight. So after a point, more bee visits results in more mature seeds, but not larger fruits. Also note the large “unexplained” variability in berry weight.



MORTALITY OF BUMBLE BEES ASSOCIATED WITH LINDEN: A REVIEW

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Globally, there have been reports of declines in populations of bumble bees which have been attributed to changes in land use that have led to loss of foraging resources and nesting habitats, diverse pathogens, and pesticides associated with agricultural crop production. Other factors may also be responsible for bumble bee mortality but these have received little attention. For minimizing future losses, it is critical that bee mortality factors are determined. Risks associated with foraging behaviors are particularly critical as bees spend considerable time seeking food resources. Bees forage on multiple plants, and hence species that pollinate crops are affected by negative factors across the landscape.

In 2013, over 50,000 bees died after foraging on linden (*Tilia* spp.; Malvaceae) trees in one location in Oregon, and there were concerns about impacts on cropping systems in surrounding areas. The sudden and dramatic reduction in pollinators impacted crops with blooming periods succeeding the linden-bee kill in the same year, and crops requiring bee pollination the following year. Linden is a common, profusely flowering, bee attractive ornamental tree, and since 2013, linden-associated bee mortality has been observed annually, in Oregon and nationwide. Based on investigations by the Oregon Department of Agriculture, neonicotinoid insecticides accounted for the bee deaths at some locations but, at others, no insecticide residues were detected.

While linden-bee deaths are a new phenomenon in the US, mortality of bees feeding on linden has been reported from Europe since the late 1970s (Crane 1977). Also, linden-bee deaths in Europe were reported many years before neonicotinoids were developed as an insecticide in the mid-1980s. Clearly, factors besides neonicotinoids are responsible for mortality of bees associated with linden. Two hypotheses have been proposed to account for the bumble bee deaths:

1. **Mannose Hypothesis:** Under drought conditions, the sugar mannose is produced, and this is toxic to bees.

Von Frisch (1928) documented the toxicity of mannose to honey bees, while Argoti and Rao (2015) documented its toxicity to bumble bees. Mannose is a monosaccharide that is very similar in structure to glucose (Figure 1) which is used by bees as a carbohydrate source. Hence, the toxicity of mannose was speculated to be due to disruption of glucose metabolism resulting from imbalance between enzymes associated with the glycolysis cycle that provides energy for bees (Sols et al. 1960). However, subsequent studies refuted the competitive inhibitor of glycolysis hypothesis (Saunders et al. 1969). The basis of mannose toxicity to bees remains unknown.

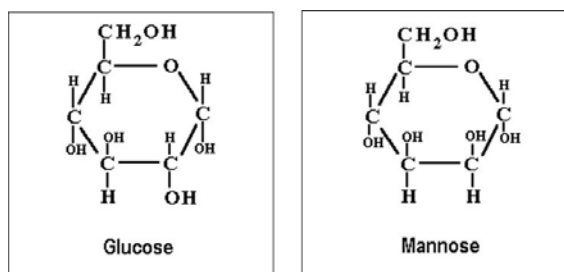


Figure 1. Structure of glucose and mannose.

2. **Starvation Hypothesis:** Massive bloom in linden draw bumble bees which forage even when nectar flow is low, and hence die out of starvation.

In a study by Baal et al. (1992), when bumble bees under linden trees that were still alive but unable to fly were exposed to fresh linden flowers before they died, the bees revived. No further supporting evidence was provided for this hypothesis.

Interestingly, while greater numbers of honey bees than bumble bees forage on linden, only bumble bees deaths have been associated with linden. Honey bees are susceptible to neonicotinoids and yet few dead honey bees were observed under linden in the 2013 incident. Researchers have speculated that the differential response is because honey bees are better able to access nectar levels and hence they do not die due to starvation. Also, honey bees have, on occasion, been observed to be deterred by pesticides applied to plants. The hypothesis that when honey bee worker recruiters die after foraging on linden no further workers are recruited has little support from honey bee researchers.

Other factors associated with nectar may be toxic to bees (Adler 2000). Bees are not deterred by naturally occurring levels of nectar toxins and thus succumb to the toxicity. Nectar toxins kill fewer bees than the massive neonicotinoid-associated bee kills observed in 2013. However, they are likely to occur more widely, and remain undocumented in most instances.

The linden-bumble bee mortality phenomenon is intriguing; future research is critically needed for addressing the various unanswered questions for minimizing future losses.

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EFFECTS OF FLOWERING COVER CROPS AND LANDSCAPE HETEROGENEITY ON NATIVE BEE DIVERSITY IN VINEYARDS

J. S. Wong¹ and H. Wilson²

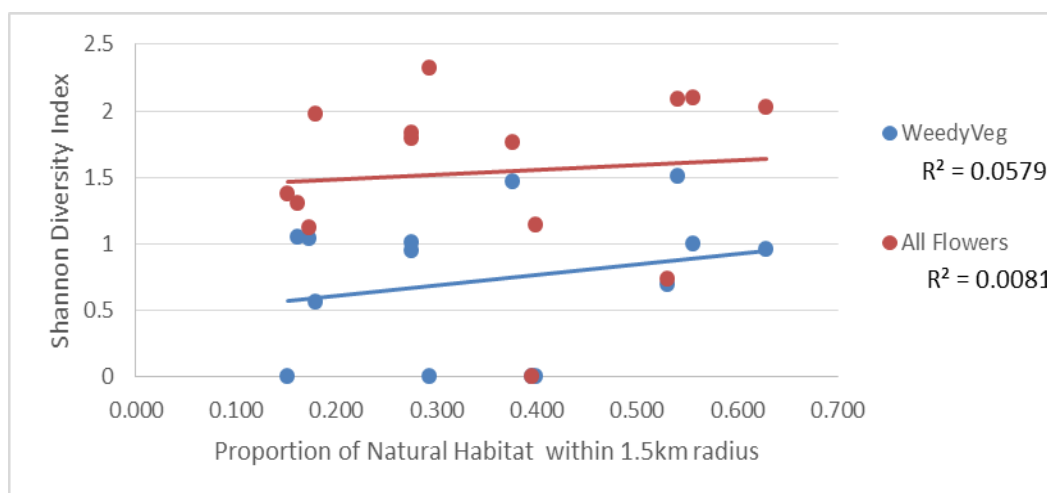
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Expansion of vineyards in California's North Coast wine grape growing region have fragmented oak woodland habitats and reduced the amount of floral resources available to native bees. Increasing floral diversity in vineyards may provide resources for native bees and reduce the negative effects of this habitat fragmentation. Some have theorized that landscape diversity will determine how native bees respond to localized on-farm diversification practices.

In this study, native bees were collected from paired vineyard plots with and without flowering summer cover crops. In order to evaluate the interaction between landscape and field-scale habitat diversity, the vineyard sites were located along a continuum of landscape diversity (ranging from low to high diversity). Flowering cover crop species included *Phacelia tanacetifolia*, *Ammi majus*, and *Daucus carota*. At peak bloom, the flowers were sampled for native bees, at the same time bees were collected from grasses and weedy vegetation in the paired control plots.

Our results indicate that, overall, flowering cover crops attract a greater abundance and diversity of bees than more common ground cover such as grasses or resident weedy vegetation. Additionally, the native bee populations found on flowering cover crops appear to be influenced by changes in landscape heterogeneity, although the influence varied for each species of flower. Planting flowering cover crops in vineyards can attract native bees and increase bee diversity in fragmented landscapes, but providing floral resources may not do much to improve the population of native bees if there are no suitable areas for nesting within their foraging range.



SECTION III

Environmental Toxicology and Regulatory Issues

EFFECT OF REPEATED EXPOSURES OF TOLFENPYRAD 15% EC AT SUBLETHAL DOSES ON THE EGG PARASITOID, *Trichogramma chilonis* ISHII

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Insecticides act as the most limiting factor in the establishment of introduced natural enemies, conservation of natural enemies and efficacy of augmentative releases. In most of the toxicity studies against natural enemies, insecticides are screened for mortality due to acute toxicity only, while effects of sublethal doses on development, behavior and reproduction are overlooked. Hence, effect of sublethal doses of insecticides need to be quantified in addition to acute toxicity in order to accurately predict the total impact of a pesticide on a natural enemy. In this context, a program was undertaken to assess the effect of repeated exposure of sublethal doses (LC₂₅ and half of LC₂₅) of tolfenpyrad 15% EC, which shows broad insecticidal activities against important and difficult to control pests such as Hemiptera, Diptera, Coleoptera, Lepidoptera, Thysanoptera and acarines, on the egg parasitoid, *Trichogramma chilonis* Ishii.

Corcyra cephalonica egg card containing the pupal stage of *T. chilonis* were exposed repeatedly (once in each generation) to the LC₅₀, LC₂₅ and half of LC₂₅ of tolfenpyrad 15% EC (0.000146%, 0.000079% and 0.0000395%). After adult emergence 10 pairs of adults were collected and each pair were placed separately in a small glass tube along with small egg cards, containing about 100 *Corcyra* eggs for parasitisation. The Remaining adults were provided with a large egg card @ 30 eggs / adult for continuation of the bulk culture for the experiment. Similarly, in another set, parasitized egg cards were dipped in water to serve as control treatment. Adult parasitoids were fed with 50% honey solution. After each exposure observations were taken on mortality of pupae, longevity of adults, number of eggs parasitized / female, duration of life cycle, percent adult emergence and sex ratio of the off springs. The process was repeated till the viable adults were available in insecticide treated population. The experiment was conducted at a temperature of 27 ± 1°C and 70 ± 5% R.H. Effect of exposures was compared with control in each generation and also among different generation. Data were subjected to test of significance following General linear model using SPSS and SAS packages.

When *Trichogramma chilonis* pupae were exposed to LC₅₀ of tolfenpyrad 15% EC, the emerged adults died without parasitizing the host eggs successfully. Repeated exposure of *T. chilonis* pupae to LC₂₅ and half of LC₂₅ doses of tolfenpyrad adversely affected the survival and biology of the egg parasitoid and the parasitoid could survive up to 6th and 8th exposure, respectively. After 5th exposure to LC₂₅ of tolfenpyrad adult emergence was very low and the obtained females showed very low rate of parasitization in bulk culture, when this parasitized egg card was further exposed to the insecticide, most of the pupae died and a few adults that emerged from these eggs died soon after their emergence and the experiment was terminated automatically. However, the females emerged from the pupae after the last exposure to half of LC₂₅ of tolfenpyrad failed to parasitize any egg. Both the doses of the insecticide had immense adverse impact on biological parameters like, egg parasitization, adult emergence and sex ratio, which intensified with the number of exposures, whereas, the duration of life cycle was almost unaffected.

Table 1: Chronic toxicity of LC₂₅ of Tolfenpyrad 15% EC to *T.chilonis*

Exposure	Corrected Mortality (%)	Longevity (days)		No. of eggs parasitized/female	Duration of life cycle (days)	Adult Emergence Percentage	Sex ratio	
		Male	Female				Female	Male
1	24.99 E (29.98)▪	1.5	2.0	53.3 A(7.3)**	8.0	90.08 A (71.74)*	1.61	1
2	29.16 E (32.60)	1.0	2.0	44.2 B(6.6)	8.0	80.25 B (63.74)	1.59	1
3	37.44 D (37.70)	1.0	1.0	33.3 C(5.8)	8.0	70.13 C (56.88)	1.57	1
4	46.71 C (43.11)	1.0	1.0	33.4 C(5.8)	8.0	60.40 C (51.01)	1.53	1
5	60.92 B (51.31)	0.5	0.5	15.0 D(3.6)	10.0	31.47 D (32.10)	1.30	1
6	73.83 A (59.25)							

▪ Represents Duncan's Grouping, * Parentheses contain angular transformed values, **Parentheses contain square root transformed values

Table 2: UNTREATED CONTROL

Exposure	Percent Mortality	Longevity (days)		No. of eggs parasitized/female	Duration of life cycle (days)	Adult Emergence Percentage	Sex ratio	
		Male	Female				Female	Male
1	2.22 (8.88)	2.0	3.0	70.6 •A (8.4)**	8.0	97.43 A (80.36)*	1.63	1
2	1.11 (6.47)	2.0	3.0	70.9 A (8.4)	8.0	97.47 A (80.46)	1.62	1
3	2.22 (8.88)	2.5	3.0	71.0 A (8.4)	8.0	96.23 A (78.92)	1.62	1
4	2.22 (8.88)	2.0	2.5	70.8 A (8.4)	8.0	96.51 A (79.42)	1.61	1
5	3.33 (11.29)	2.0	3.0	69.9 A (8.3)	8.0	96.42 A (79.24)	1.63	1
6	2.22 (8.88)	2.5	3.0	70.0 A (8.3)	8.0	96.35 A (79.37)	1.62	1
7	2.22 (8.88)	2.0	2.5	70.1 A (8.3)	8.0	96.58 A (79.55)	1.62	1
8	1.11 (6.47)	2.0	3.0	70.5 A (8.4)	8.0	96.44 A (79.25)	1.62	1
9	2.22 (8.88)	2.0	3.0	69.8 A (8.3)	8.0	96.44 A (79.25)	1.62	1
10	1.11 (6.47)	2.0	3.0	70.2 A (8.4)	8.0	97.27 A (80.44)	1.63	1

▪ Represents Duncan's Grouping, * Parentheses contain angular transformed values, **Parentheses contain square root transformed values

Table 3: Chronic toxicity of half of LC₂₅ of Tolfenpyrad 15% EC to *T.chilonis*

Exposure	Corrected Mortality (%)	Longevity (days)		No. of eggs parasitized/female	Duration of life cycle (days)	Adult Emergence Percentage	Sex ratio	
		Male	Female				Female	Male
1	14.76 •G (22.57)*	1.5	2.0	58.5 A (7.6)**	8.0	91.35 A (73.18)*	1.62	1
2	19.08 F (25.89)	1.5	2.0	57.2 A (7.5)	8.0	83.69 B (66.22)	1.62	1
3	19.31 F (26.06)	1.5	2.0	42.5 B (6.5)	8.0	76.42 BC (60.99)	1.60	1
4	27.28 E (31.49)	1.5	2.0	40.4 B (6.4)	8.0	75.08 BC (60.08)	1.60	1
5	36.36 D (37.08)	1.5	2.0	32.0 C (5.7)	8.0	70.57 CD(57.16)	1.46	1
6	42.03 C (40.42)	1.0	1.0	31.2 C (5.6)	8.0	62.13 D (52.03)	1.43	1
7	54.52 B (47.59)	0.5	1.0	23.6 D (4.5)	8.0	48.11 E (41.73)	1.37	1
8	76.40 A (60.94)	0.5	0.5	10.0 E (2.9)	8.0	39.29 E (36.01)	1.33	1

• Represents Duncan's Grouping, * Parentheses contain angular transformed values, **Parentheses contain square root transformed values

Table 4: UNTREATED CONTROL

Exposure	Percent Mortality	Longevity (days)		No. of eggs parasitized/female	Duration of life cycle (days)	Adult Emergence Percentage	Sex ratio	
		Male	Female				Female	Male
1	2.22 (8.88)	2.5	2.5	70.8 • A (8.4)**	8.0	96.46 A (79.28)*	1.63	1
2	1.11 (6.47)	2.0	3.0	71.0 A (8.4)	8.0	96.50 A (79.29)	1.63	1
3	2.22 (8.88)	2.0	3.0	71.1 A (8.4)	8.0	96.51 A (79.33)	1.64	1
4	2.22 (8.88)	2.0	3.0	71.2 A (8.4)	8.0	96.36 A (79.14)	1.63	1
5	2.22 (8.88)	2.0	3.0	70.2 A (8.3)	8.0	96.28 A (79.07)	1.62	1
6	2.22 (8.88)	2.5	3.0	70.6 A (8.4)	8.0	96.47 A (79.27)	1.63	1
7	2.22 (8.88)	2.0	2.5	69.8 A (8.3)	8.0	96.33 A (79.22)	1.63	1
8	1.11 (6.47)	2.5	3.0	70.1 A (8.4)	8.0	96.31 A (79.06)	1.63	1
9	1.11 (6.47)	2.0	3.0	70.0 A (8.4)	8.0	96.43 A (79.16)	1.64	1
10	1.11 (6.47)	2.0	3.0	70.7 A (8.4)	8.0	96.33 A (79.07)	1.63	1

• Represents Duncan's Grouping, * Parentheses contain angular transformed values, **Parentheses contain square root transformed values

SECTION IV

Field Crop Pests

Section IV: Field Crop Pests

SEEDCORN MAGGOT CONTROL IN ONION

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Seedcorn maggot, *Delia platura*, can significantly reduce field stand establishment in several crops in the Columbia Basin including dry bulb onion. Trials were established in 2013 and 2015 in commercial fields to determine which insecticide treatments provided adequate control of seedcorn maggot in dry bulb onion. Previous studies showed good efficacy with Lorsban (chlorpyrifos) and FI500 (thiamethoxam+spinosad)(maxim+dynasty+apron), but we wanted to evaluate other insecticides that producers had been using. Plant stand counts were used as the measure to determine efficacy.

A trial in Boardman, OR (Fig. 1) showed that the standard Lorsban was still effective, and that the FI500 treatment was equally effective at control of seedcorn maggot. Coragen and Warrior applied post planting were ineffective, providing further evidence that seed treatments and at plant insecticide were still the best options for control.

Another trial conducted in 2013 in an onion field near Plymouth, WA was designed to compare FI500 to F300 (maxim+dynasty+apron), and Sepresto (clothianidin+imidacloprid)(thiram+allegiance+coronet) (Fig. 2). At this trial site, pest pressure was low, and there were no significant differences in treatments at the first evaluation interval. At the second evaluation, the plant stands were lower in the Sepresto treated plots. Since there were no differences between FI500 and F300, it is likely that the stand loss was from soil fungal pathogens rather than seedcorn maggot.

During 2015, further experiments were established to determine if Sepresto and FI500 were equal in their ability to control seedcorn maggot. At the trial site in a commercial field near Patterson, WA, there was relatively low pest pressure and no difference in treatments during the first stand evaluation (Fig. 3). At the second evaluation at that site, stands were numerically improved with seed treatments, but there was not significant improvement except with the grower treatment of FI500.

A second experiment in 2015 had much higher pest pressure, and as such all treatments (FI500, Sepresto, and Lorsban) improved stands over the untreated check (Fig. 4).

After several years of evaluation, it seems that the seed treatments Sepresto, and FI500 provide control of seedcorn maggot that is equivalent to the standard Lorsban in commercial onion production in the Columbia Basin. Seed treatments are an added expense, but with a high value crop such as onion, stand loss cannot be tolerated.

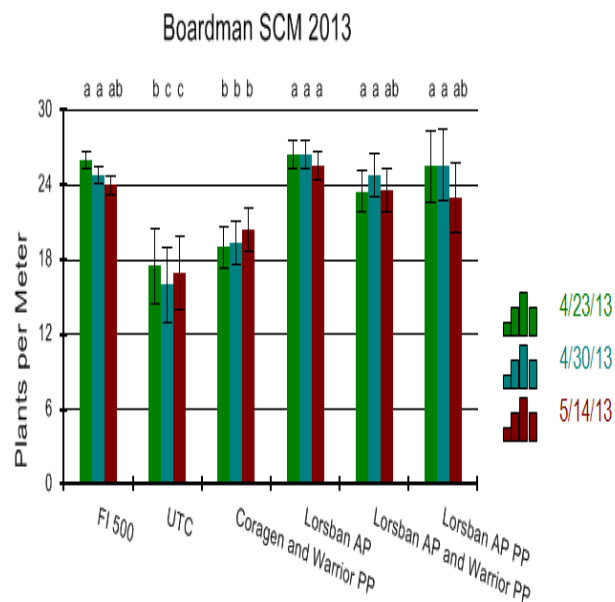


Figure 1. Plant stand vs. treatment at various sampling dates. Treatments with different letters are significantly different from one another.

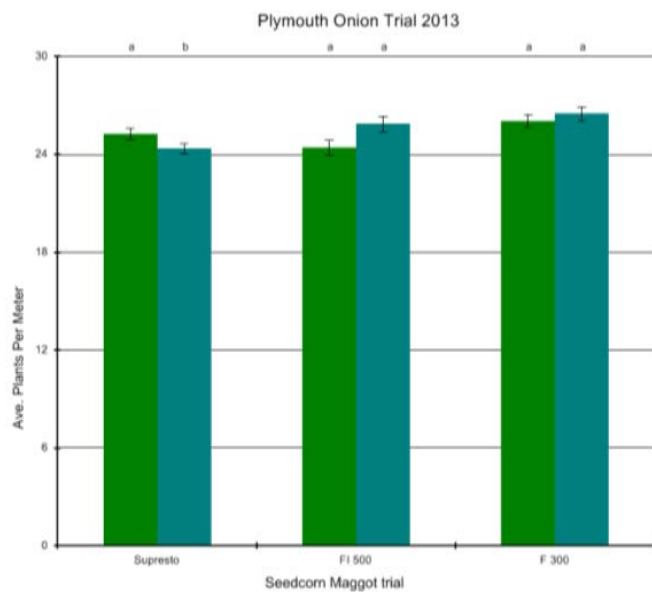


Figure 2. Plant stand vs. treatment at various sampling dates. Treatments with different letters are significantly different from one another.

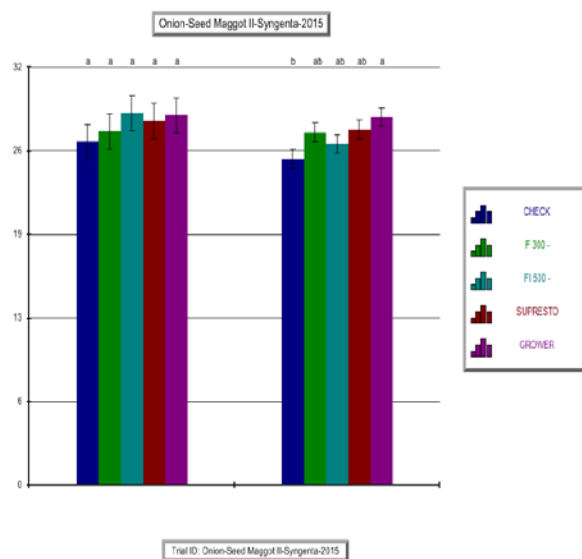


Figure 3. Plant stand vs. treatment at various sampling dates.
Treatments with different letters are significantly different from one another

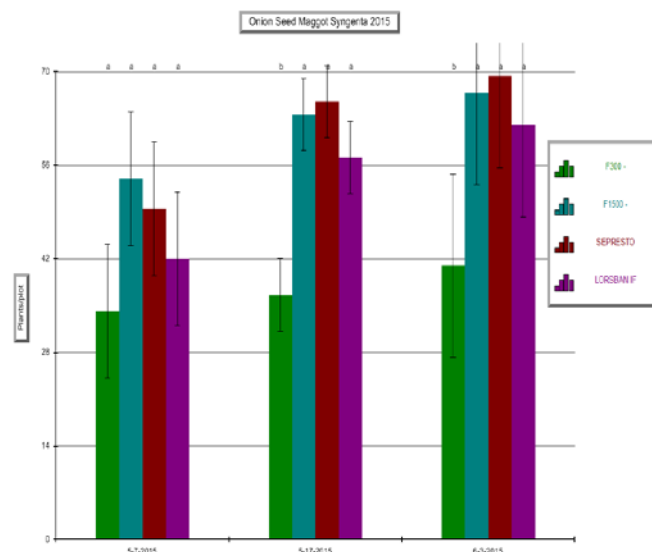


Figure 4. Plant stand vs. treatment at various sampling dates.
Treatments with different letters are significantly different from one another

SYSTEMIC PROTECTION OF HYBRID POPLAR DURING STAND ESTABLISHMENT

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Hybrid poplars are an irrigated perennial monoculture propagated by un-rooted branch cuttings. While the planting stock is relatively cheap to produce and plant, any failed establishment represents a large economic loss to the grower. The Boardman Tree Farm (BTF) alone plants roughly 500,000 trees across 3,500 acres. This is due to the inability for replacement trees ever to obtain the size of the original stand cohort. During the first year of growth, poplar trees are extremely vulnerable to attack from several species of herbivores. Cottonwood leaf beetle (CLB) (*Chrysomela scripta* (Coleoptera: Chrysomelidae), Pale Green Weevil (*Polydrusus impressifrons* (Coleoptera: Curculionidae), and Gluphisia (*Gluphisia septentrionis* (Lepidoptera: Notodontidae) are the main herbivores attacking establishing hybrid poplars in Eastern Oregon and Washington. While multiple insecticide treatments with fixed wing aircraft have been the standard control practice, this strategy is costly and often leads to a large portion of the insecticide landing on bare ground. The objective of this study was to examine the efficacy of treating establishing stands of poplar with a novel systemic insecticide.

This study evaluated six insecticides in the most commonly planted hybrid poplar variety (OP-367) on BTF. Stem density of the stand alternated with each row from 290 stems per acre to 1,500 stems per acre. Trees were planted in mid to late May, with the experiment being conducted later in the summer. The insecticides (Exirel, Verimark, Coragen, Wrangler, Silvanto, and Transform) were all applied through the drip via direct injection to the target rows. Treatments were three row sets, with the middle row receiving the injection. These treatments were equally spaced across a 40 acre block. Efficacy was determined by field observation of insect attack and presence within the treatments. These observations were taken a week after application and roughly two months following application.

Results indicate that Wrangler, Exirel, Verimark, and Coragen all provided an adequate level of control of the main pests, specifically CLB. Both Silvanto and Transform did not exhibit control of these pests during the trial. This data, paired with other trials, have led BTF to pursue the addition of drip application to the 24c label of Coragen. These results are also promising to growers as a viable alternative to aerial applications.

USE OF XXPIRE IN CONTROL OF *CHRYSOMELA SCRIPTA* IN HYBRID POPLARS

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Cottonwood leaf beetle, *Chrysomela scripta* causes significant damage to hybrid poplars in north eastern Oregon. This study was conducted to identify alternative insecticides to neonicotinoids. Beetles overwinter as adults, underneath leaf litter and bark until bud break occurs at which time they begin to mate and feed on young buds and developing leaves. Egg clusters are laid on the bottom of leaves where first instars emerge to feed. Larvae feed on young leaf tissue between veins, reducing total photosynthetic area and tree virility during the growing season. Given a sufficient amount of available food, beetles will complete several generations in a single season.

Two different chemicals were applied to a three year old block of poplar plantings on August 6, 2015. Leaves were collected on August 7, 2015 for placement in a forced feeding trial. Each assay held two, young, fully expanded leaves and 10 larvae, all of medium size, collected simultaneously from untreated areas. Beetle larvae were placed in each container by use of larval forceps. Inspection of assays for insect mortality occurred at 48 and 96 hours after application.

At the 96 hour mark results were definitive in that all applied chemicals show improved control of the insect compared to the untreated check (Fig. 1). This indicates that both insecticides are acceptable alternatives in the treatment of cottonwood leaf beetle.

Treatment	48 hours after application			96 Hours after application		
	Alive	Dead	Moribund	Alive	Dead	Moribund
Untreated	9.29 a	0.17 a	0.54 b	9.00 a	0.67 b	0.33 b
Coragen	6.92 bc	0.46 a	2.63 a	0.04 b	4.21 ab	5.75 a
Xxpire	5.62 c	1.54 a	2.83 a	0.46 b	5.13 a	4.42 a

Figure 1. Fisher's LSD of treatments 48 and 96 hours after application out of 10 alive, dead, or moribund. Means followed by different letters are significantly different than each other (P = .05).

THRIPS CONTROL IN DRY BULB ONIONS

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Onion thrips are the key direct insect pest of dry bulb onions. We have evaluated candidate chemistries by foliar, overhead chemigation, and drip chemigation for their ability to suppress thrips populations in dry bulb onions in Washington State. The most effective insecticides for controlling thrips were Lannate™ (methomyl), and Radiant™ (spinetoram). The insecticides Agri-Mek™ (abamectin), Verimark/Exirel™ (cyazypyr) and Movento™ (spirotetremat) provided adequate control of thrips. Lannate, Radiant, and Exirel all decreased thrips populations when applied via sprinkler chemigation as well.

In the experiments detailed below, field plots of onion (var. ‘Sabroso’ Nunhems, Parma, ID) were established at the WSU Research Farm in Pasco, WA and grown using drip irrigation and standard grower practices for agronomic and pest management inputs excluding thrips treatments. Plots were established in a random complete block design with four replications. In each instance, plots were 7.5 feet wide and 25 feet long. Foliar applications were made with a CO₂ pressurized three point tractor mounted research plot sprayer applying 30 gallons of water carrier per acre at 25 psi. Sprinkler chemigation applications were made with a trailer mounted research sprayer applying 0.1 inches of water per application with in line injection of insecticide. Drip applications were made by injecting insecticide into individual drip lines via a check valve with an electric diaphragm pump. Efficacy was evaluated four or five days after applications by counting the number immature and adult thrips per plant on 10 individual plants per plot in the field. All data for each sample date were analyzed by ANOVA and treatments means were compared to thrips population means from non-treated control plots in pairwise *t*-tests

New candidate compounds were evaluated for efficacy against thrips. Figure 1 shows the season long thrips numbers for several different treatments. During most sampling periods, there were no significant differences among treatments. The exception is the third week of evaluations where Verimark, Vydate followed by foliar Exirel, and Exirel applied by overhead chemigation plots contained significantly fewer thrips than the untreated check. Though thrips numbers did not differ significantly, all treated plots had significantly fewer medium and more jumbo bulb yield than the untreated check (Figure 2). This demonstrates that slightly reducing thrips numbers can have a dramatic impact on onion bulb sizing and yield.

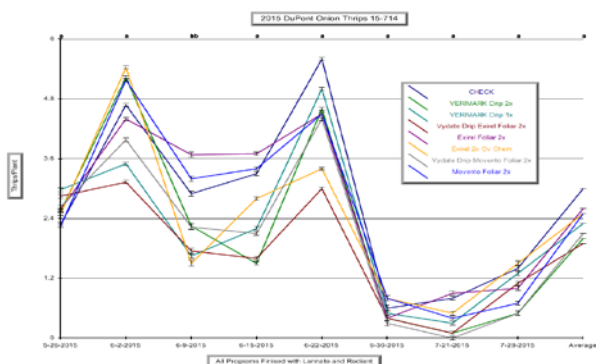


Figure 1. Thrips per plant versus chemical treatments. Applications were made on 10 day intervals. Treatments with the same letters are not statistically different from one another ($P=0.05$ Student-Newman-Keuls test).

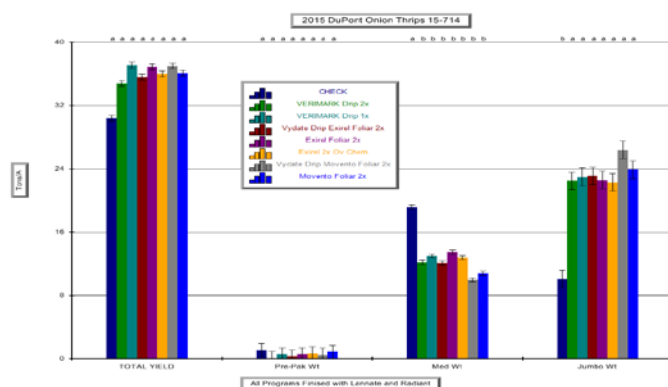


Figure 2. Onion size profile and overall yield versus chemical treatments. Treatments with the same letters are not statistically different from one another ($P=0.05$ Student-Newman-Keuls test).

An experiment was conducted to compare two thrips management programs where one began with Movento applications and the other began with Radiant applications, both being compared to an untreated check. Both treatments were followed with the same insecticide programs. Beginning the treatment programs with Radiant provided significantly better thrips control than beginning the treatment program with Movento (Figure 3). The yields did not differ significantly, but the Radiant treated plots yielded higher numerically (data not shown).

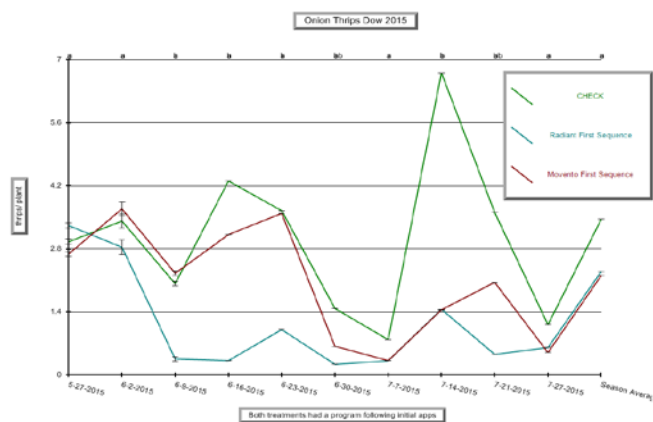


Figure 3. Thrips per plant versus chemical treatments. Applications were made on 7 day intervals. Treatments with the same letters are not statistically different from one another ($P=0.05$ Student-Newman-Keuls test).

An apparatus designed to mimic center pivot sprinkler chemigation has been used in previous studies to evaluate insecticide efficacy. In previous experiments, this simulator showed excellent efficacy of Lannate (methomyl) and good efficacy with Radiant and Verimark compared to water applied untreated check plots for controlling thrips in onions. During 2015, Radiant, Lannate, and Exirel were evaluated for control of thrips by overhead chemigation. Exirel is a less expensive formulation of cyazypyr, the same active ingredient in Verimark that was tested in previous seasons. Two applications were made on June 3 and 18. All treatments significantly reduced thrips numbers for the week following the first application (Figure 4). After the second application, thrips numbers were significantly lower in the Radiant and Lannate treated plots one week after treatment and remained significantly lower in the Lannate treated plots for two weeks.

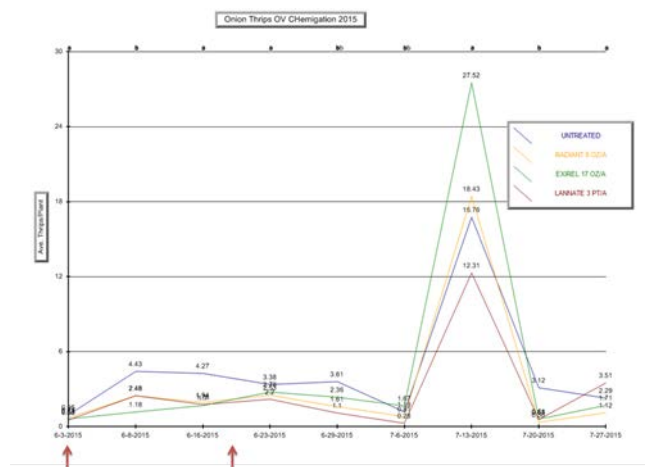


Figure 4. Thrips per plant versus sprinkler chemigation treatments by date and season average. Two applications were made of each product as indicated by the red arrow lines. Treatments with the same letters are not statistically different from one another (P=0.05 Student-Newman-Keuls test)

Using insecticides that are effective at controlling thrips increases yield and size class of dry bulb onions. Radiant and Lannate were found to be the most effective products while Movento, Verimark/Exirel and AgriMek provided good suppression of onion thrips. We also found that Radiant was more effective in the early season when compared to Movento. It is important for producers to consider the mode of action of the different chemistries when integrating them into their control programs. Chemigation proved to be an effective way to apply Lannate, Exirel and Radiant. Verimark was also effective when applied via drip injection.

SECTION V

Potato Pests

TAKING A SECOND LOOK AT *LYGUS* BUGS IN THE PACIFIC NORTHWEST

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This project is directed at enhancing our understanding of the epidemiology of the beet leafhopper transmitted virescence agent (BLTVA) by examining the ability of *Lygus* (Heteroptera: Miridae) bugs to transmit the pathogen to potato, *Solanum tuberosum* L. In the Columbia Basin of Washington and Oregon, BLTVA, a phytoplasma, is the primary cause of potato purple top disease and is known to be transmitted to potato primarily by the beet leafhopper (BLH), *Circulifer tenellus* Baker (Heteroptera: Cicadellidae). Plants infected with BLTVA usually express flagging of leaflets, leaves, small stems and swollen nodes. In the summer of 2014, *Lygus* bugs were observed in the field in association with potato plants expressing purple top symptoms. Currently, it is not known if *Lygus* bugs are competent vectors of BLTVA. Reports from growers in the region also suggest a decline in the numbers of BLH in potato fields while *Lygus* bugs are more abundant in potato fields than previous years. Thus, the present study evaluated: (1) the abundance and species composition of *Lygus* bugs in commercial potato in the PNW, (2) the incidence of BLTVA in *Lygus* in commercial potato fields and (3) whether *Lygus* harbors the same strain of BLTVA as symptomatic potato plants.

Materials and Methods

In 2015, *Lygus* were collected from 34 potato fields in Oregon using a hand-held inverted leaf blower. Samples were collected at three time points: early, mid, and late season and the total number of *Lygus* bugs were estimated for each location. Samples were sorted and identified using the dichotomous key developed by Muller et al. (2003). Based on the 16S rRNA gene, we used the nested PCR technique described by Crosslin et al. (2006), to estimate the incidence of BLTVA in field-collected *Lygus*. PCR products were visualized on 1% agarose gel to confirm the presence of BLTVA. To determine if *Lygus* harbors the same strain of BLTVA as symptomatic potato plants, we cloned PCR products from *Lygus* and potato samples, sequenced both products then compared DNA sequences of BLTVA from *Lygus* and potato. Comparing BLTVA sequences from both *Lygus* and potato allows us to determine if *Lygus* is carrying the same BLTVA as symptomatic potato and whether or not we should worry about *Lygus* as potential vectors of BLTVA.

Results and Discussion

Morphological identification: In Oregon, the *Lygus* complex in potato is dominated by *Lygus hesperus*, *L. elisus* and *L. lineolaris* (Figs. 1A, B, and C). The 3 species are primarily distinguished by the unique pattern of frons, pronotum and wing membrane as well as the presence/absence of spots on the propleura (side of the pronotum).

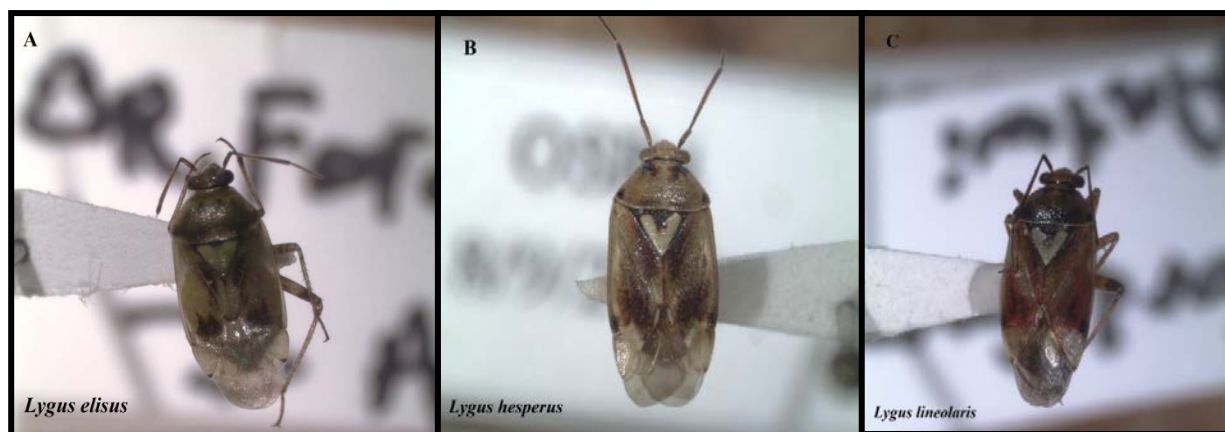
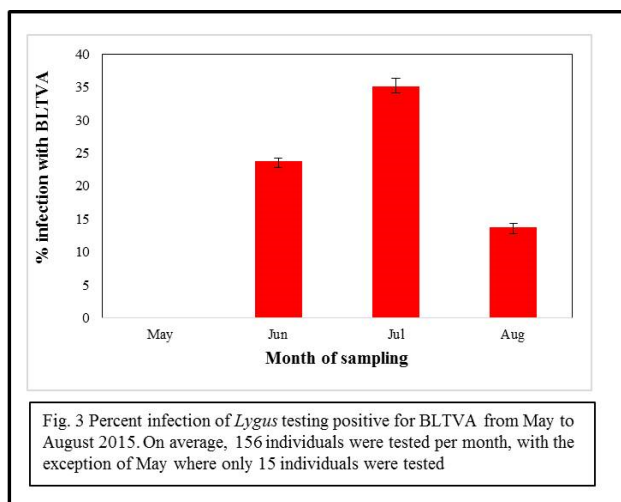
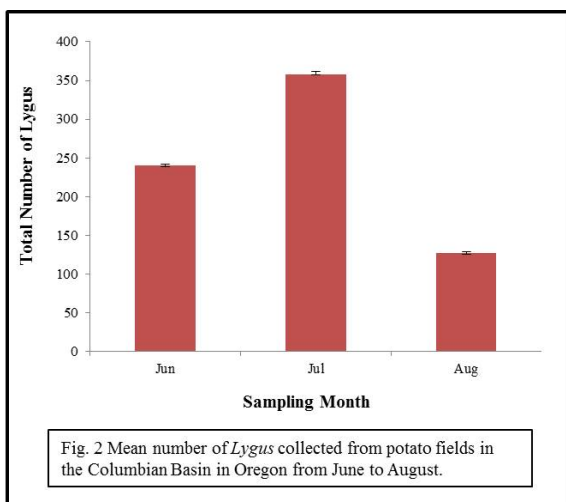


Fig. 1 Three major *Lygus* species identified in potato fields in the Columbian Basin in Oregon. Photo by OSU-IAEP (Rondon lab by J. Antwi).

***Lygus* population dynamics:** In general a total of 240, 358 and 127 *Lygus* were collected in June July and August, respectively (Fig. 2). Across all sampling sites, we collected an average of 7 *Lygus* per location; where the highest average (42 *Lygus* per site) occurred at location 14 and lowest average (1 *Lygus* per site) occurred at location 12 (see map and location of traps at <https://andersongeog.maps.arcgis.com/apps/webappviewer/index.html?id=e857a721431642188fa27b04c2f7c270>). All *Lygus* were tested for BLTVA; 0, 25, 36 and 12 % of the samples tested positive in May, June, July and August, respectively (Fig. 3).



BLTVA in potato and *Lygus*: 16S DNA sequences of BLTVA showed that field-collected *Lygus* carry/harbor the same strain of BLTVA in symptomatic potato (data not shown), suggesting that *Lygus* is acquiring and/or transmitting BLTVA to potato. A preliminary transmission assay demonstrated that BLTVA can indeed be transmitted by *Lygus* (unpublished data); however the mode of the transmission and the efficiency is unknown. We are currently undertaking more studies to further our understanding of the interaction between *Lygus* and BLTVA and whether or not *Lygus* bugs cause significant economic damage to potato.

The role of *Lygus* and its associated impact on potato production are unknown and need to be further investigated. If *Lygus* is a pest of potato, then, there is a strong need to focus our attention towards this problem.

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COLORADO POTATO BEETLE CONTROL IN THE BASIN

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Colorado Potato Beetle (CPB) is a significant pest of potatoes. Populations can build quickly and defoliation occur rapidly causing significant yield loss if left uncontrolled. Additionally, CPB have a notorious reputation for rapidly developing resistance to chemical control if chemistries are not rotated. Because of this fact, new chemistries for control of this pest are always needed by growers to develop smart management strategies. Thus, the objective of this study was to compare the efficacy of selected registered and experimental insecticides (**Table 1**) for controlling CPB in potatoes. All studies were conducted at the Hermiston Agricultural Research and Extension Center in Hermiston, OR (45.8411° N, 119.2917° W).



CPB damage. Photo credit OSU IAEP (Rondon's lab)

Materials and methods

Treatments were applied by tractor with a mounted 12 foot boom sprayer with overlapping XR Tee Jet AI110002VS nozzles spaced 20" apart. Plots were 4 rows wide x 25' feet long; 34" row spacing (25,000 plants/a). Experiment was set up as a Randomized Complete Block (RCB) with four replications per treatment. Normal commercial production practices were followed throughout the season (e.g. fertilization, herbicide, fungicide, etc).

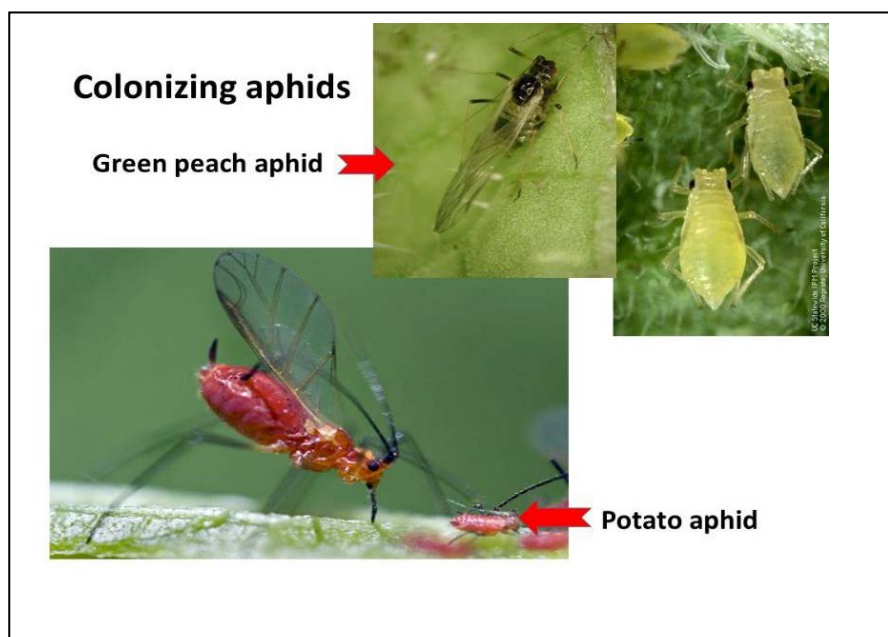
Sampling CPB. Ten leaves were randomly selected and inspected; egg clusters, larvae and adults were counted once a week until chemicals had ceased effectiveness. Data was taken from the center two rows of each plot. Samples were taken 0, 7, 14, 21, 28, 35, 42, and 49 days after treatment (DAT). Data was analyzed within sampling dates using ANOVA followed by student-Newman-Keuls multiple comparisons all data analyses were performed using ARM 2015. Treatment Product Rate (fl oz/a) Timing T1 Untreated Check - - T2 Cyclaniliprole 16.40 A C E T3 Cyclaniliprole 11.00 A C E T4 Coragen 5.00 A C E T5 Torac-15 EC 17.00 A C E T6 Torac XLO 17.00 A C E T7 Dimilin 8.00 A C E T8 Dimilin 12.00 A C E T9 Dimilin 16.00 A C E T10 Double Take 4.00 A B C D E T11 Warrior II 1.92 A B C D E T12 Rimon 0.83 ec 12.00 A C E

Treatment	Product	Rate (fl oz/a)	Timing
T1	Untreated Check	-	-
T2	Cyclaniliprole	16.40	A C E
T3	Cyclaniliprole	11.00	A C E
T4	Coragen	5.00	A C E
T5	Torac-15 EC	17.00	A C E
T6	Torac XLO	17.00	A C E
T7	Dimilin	8.00	A C E
T8	Dimilin	12.00	A C E
T9	Dimilin	16.00	A C E
T10	Double Take	4.00	A B C D E
T11	Warrior II	1.92	A B C D E
T12	Rimon 0.83 ec	12.00	A C E

MONITORING APHIDS IN SEED AND COMMERCIAL POTATO FIELDS IN OREGON

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Aphids (Homoptera: Aphididae) are soft-bodied insect pests with sucking mouth parts that cause direct damage to plants due to feeding and indirect damage via transmission of viral pathogens. Aphids are a continue threat to the potato industry in the Pacific Northwest (PNW). Each growing season, the potato crop can experience potential infection threat from numerous pathogens which, in some cases, may lead to additional quality issues during storage. A key virus disease efficiently transmitted by several aphid species is the Potato Virus Y (PVY). PVY is transmitted in a non-persistent manner by up to 50 different aphid species; the transmission efficiency varies depending on species, making the insect/disease interaction complex difficult to understand. Potato aphid (*Macrosiphum euphorbiae* Thomas) and Green peach aphid (*Myzus persicae* Sulzer) are considered to be the most efficient PVY vectors.



The current project was initiated in 2015 to develop a comprehensive management strategy for PVY in the PNW which includes fine-tuning current sampling techniques and to quantify virus incidence and diversity in the region. Specific objectives are to: (1) test different types of traps to identify the presence/absence of aphid species in potato fields; (2) determine aphid abundance in potato fields; and (3) determine trap efficiency. Study locations included seed potato fields in Morrow, and Union counties and commercial potato fields in Klamath, Umatilla and Morrow counties (**Fig. 1**). Yellow sticky traps, yellow bucket traps and tile traps were placed in four different locations around the fields (**Fig. 2**). Aphids were collected weekly; sorted and identified based on morphological characteristics; voucher specimens of “unidentified aphids” were prepared for future barcoding studies.

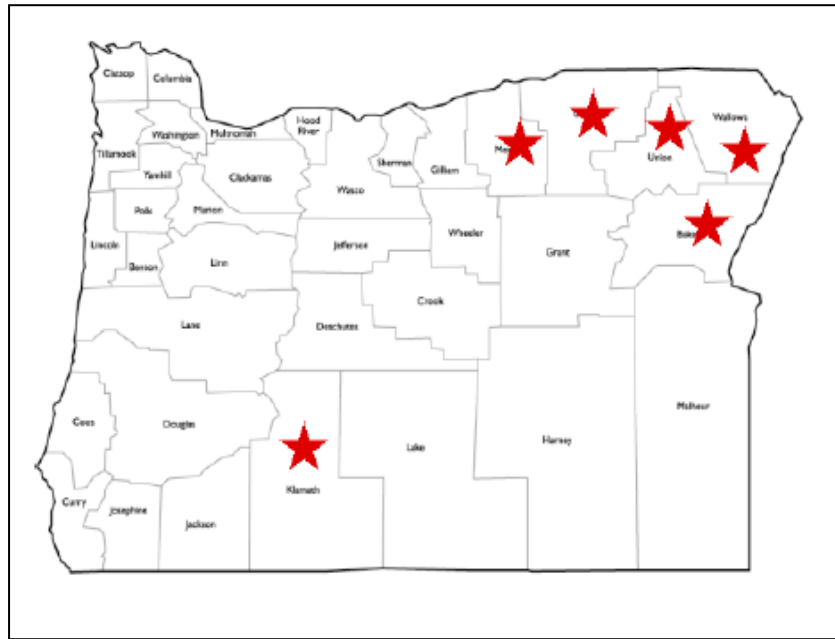


Fig. 1 “Red stars” indicate counties where study was conducted in Oregon, 2015



Fig 2 Different types of traps were placed in the first 2-3 rows in each field. Traps were 5 m apart from each other. Each group was placed at the minimum distance of 50m

Preliminary data analysis show that the highest numbers of aphids were collected in Klamath followed by Umatilla, Union, and Morrow counties (**Fig. 3**). The bucket traps design was determined to be more effective when compared to sticky cards and tile traps design. The numbers of aphids captured in traps were also influenced by environmental factors, landscape and more importantly cultural practices (data not shown).

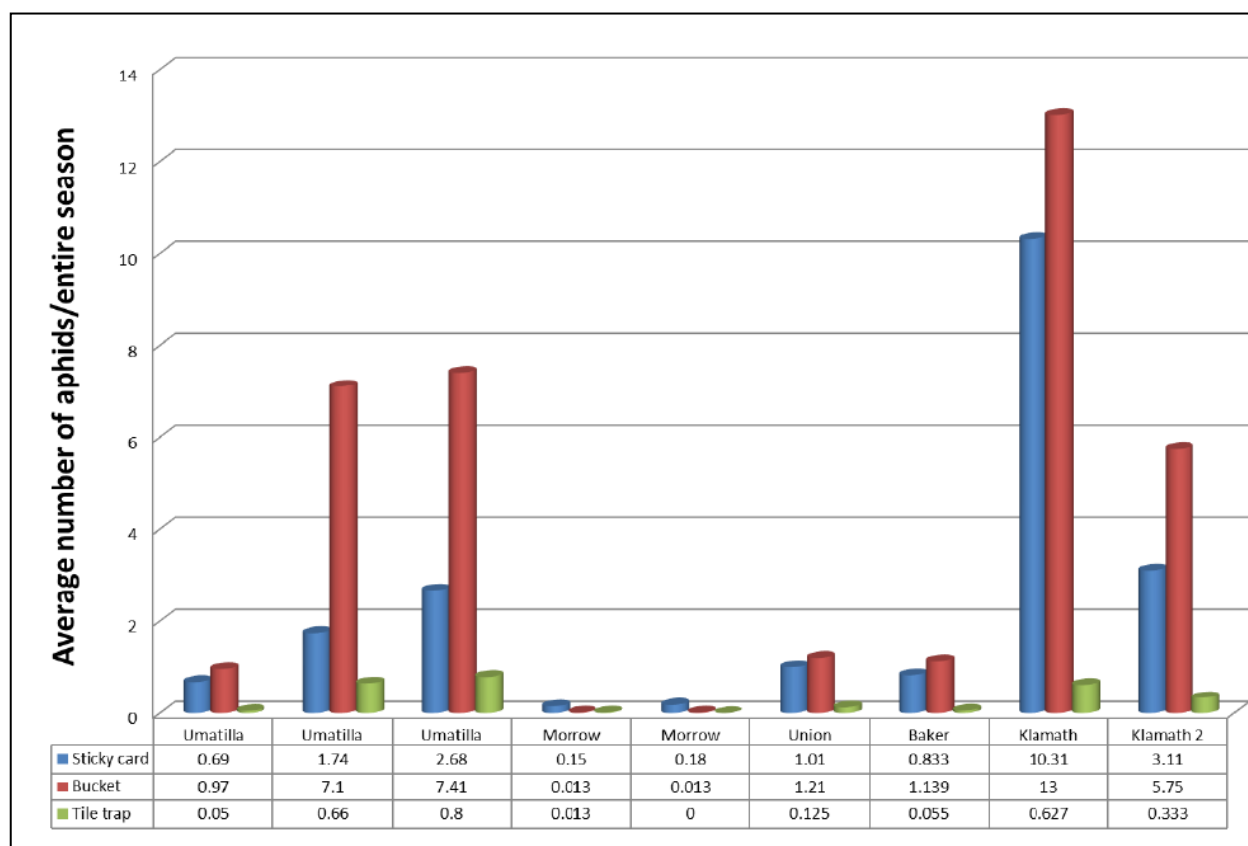


Fig. 3 Average number of aphids collected by using sticky cards, bucket and tile trap design.

SPATIAL AND TEMPORAL ANALYSIS OF APHIDS IN EASTERN OREGON

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Geographic distributions of insect populations are driven by factors inherent to the species, such as developmental rate, within-species behavior, resource use patterns (Fievet et al. 2007), and by environmental variability in time and space (Nestel et al. 2004). Quantification of insect population dynamics through analysis of spatial-temporal variability may lead to enhanced pest management decisions. One foundation of integrated pest management (IPM) is that control measures are taken only when and where a pest population reaches or exceeds an economic threshold (Kogan 1998). However, efficient site-specific management tools can only be implemented if spatial distribution and temporal dynamics are sufficiently determined and modeled (Park and Tollefson 2005), and complemented with pest damage estimates from adequate monitoring. The challenge is that in field settings this does not always occur since increased monitoring efforts can be limited by time and cost constraints (Cullen et al. 2000).

Since the late 1970s, a trapping network consisting of roughly 30 traps across the lower Columbia Basin has been maintained by Oregon State University in order to provide potato growers with information on presence of key agricultural pests. Of the numerous potato pests that are routinely monitored, data on the Potato Aphid (PA) *Macrosiphum euphorbiae* Thomas (Hemiptera: Aphididae) and Green Peach Aphid (GPA) *Myzus persicae* Sulzer (Hemiptera: Aphididae) are routinely sought after by growers. Both, GPA and PA, can cause direct feeding damage but their ability to efficiently transmit viruses makes them a top priority of study. More recently, the Bird Cherry Oat Aphid (BCOA), *Rhopalosiphum padi* L. (Hemiptera: Aphididae), and upwards of 30 other aphid species have also been identified in or near potato fields (Murphy et al. 2013).

In the past, this trapping network was used to spatially analyze both potato tuberworm, *Phthorimaea operculella* Zeller (Lepidoptera: Gelechiidae) and beet leafhopper *Circulifer tenellus* Baker (Heteroptera: Cicadellidae) populations, but until this study, no spatial analysis has been conducted on aphid populations in the region. To accomplish this task, we compiled spatially referenced data from 2006 to 2014 on GPA, PA, and other aphids (OA). Using ArcGIS 10.2.2 we developed predictive distribution maps using a method known as indicator kriging. Indicator kriging is a non-parametric method of spatial mapping where count data are mapped as a probability of exceeding a predetermined threshold and the technique is robust enough to estimate whole distributions based off irregularly spaced point sources. We also charted aphid counts over time to visualize temporal dynamics. It is anticipated that complete analysis of these data will accurately represent regions at high risk and those at low risk for aphid colonization in a given year.

No precise economic thresholds exist for aphid control in commercial potatoes, which could be leading to unnecessary insecticide use. Reductions and/or more precise applications of various insect control tactics can potentially be achieved through the development of site-specific thresholds, the initiation of which requires accurate spatial-temporal data.

SECTION VI

Pests of Wine Grapes & Small Fruits

EVALUATION OF HELICOPTER APPLIED INSECTICIDES AGAINST SWD IN PNW Highbush BLUEBERRY

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Introduction

Ever since its detection in the United States in 2009, spotted wing drosophila (SWD) has greatly disrupted integrated pest management (IPM) regimes in numerous crops, and growers continue to battle with this pest, despite improved management practices and regular pesticide applications. Many growers must make 5-10 insecticide applications to produce marketable fruit, whereas prior to SWD's introduction, many crops, such as blueberries, required few if any insecticide applications. Blueberries are among SWD's favorite hosts, and Oregon and Washington account for a large portion of the market, with 2014 resulting in a total combined yield of 182 million pounds of fruit valued at over \$227 million (NASS 2014).

One of the biggest challenges blueberry growers face when their fruit ripens in fields that have closed canopies is the fruit drop that occurs when machines are driven up and down the rows when a pesticide application must be made. Since the loss can be severe, some growers will opt to apply insecticides via helicopter late in the season. Due to low delivery volume, pesticides applied with a helicopter may not reach the middle to lower levels of the canopy. The purpose of this study was to test the efficacy of several insecticides applied via helicopter in their ability to control SWD in blueberries.

Methods

Helicopter insecticide applications (10 gal/acre) to mature highbush blueberry with closed canopies were evaluated for SWD efficacy between 2011 – 2014 in Salem, Oregon. In 2011, evaluations included screened bioassay cages, each containing 10 SWD from the WSU NWREC colony (Fig. 1). Cages were positioned at different heights (upper, middle and lower) within 5 randomly selected bushes, to evaluate penetration by the helicopter applications. Percent mortality was calculated at 2, 12 and 26 hours after treatment (HAT) (Figs. 3, 4, 5 & 6). Evaluations of helicopter treatments in 2012 were made using leaf residue bioassays consisting of leaves collected from upper, middle and lower positions on each side of randomly selected plants. Bioassays conducted in 2013 contained leaves from upper and middle positions (not evaluated separately), and bioassays in 2014 contained leaves from upper and middle canopy positions (evaluated separately). Each bioassay consisted of 3 leaves, and 5 mixed-sex SWD adults in a Petri dish (Fig. 2), and these were evaluated for percent mortality 24 hours after being assembled.



Figures 1 and 2. Bioassay cage with water sensitive paper affixed to lid in picture on left, and leaf bioassay with SWD in picture on right.



Results

Four insecticide applications were evaluated in 2011: 3 July, Malathion[®] 8 Aquamul (1.8pts/A); 30 July, Success[™] (1.8pts/A); 10 August, Lannate[®] LV (1.5pts/A) and 2 September, Lannate[®] LV (1.8pts/A) (Figs. 3, 4, 5 & 6). Mortality was highest in cages placed high in the canopy, and the lowest mortality rates were seen in cages placed in low positions. Both Malathion[®] 8 Aquamul and Lannate[®] LV were extremely effective against SWD positioned high in the treated canopy according to 26 HAT evaluations.

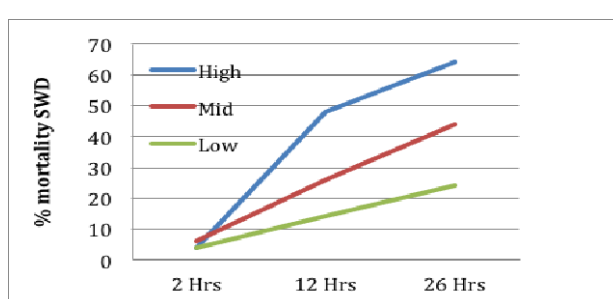
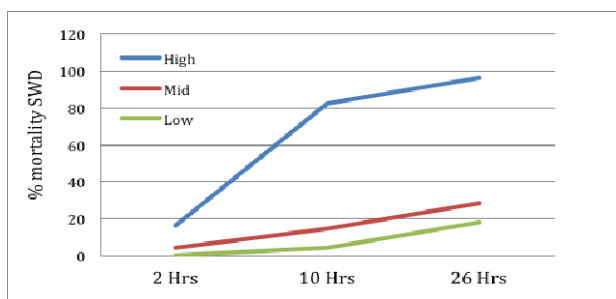


Figure 3 and 4. Percent mortality of SWD in bioassay cages following a helicopter application of 1.8pts/A Malathion[®] 8 Aquamul on 3 July 2011 in graph on left, and percent mortality of SWD in bioassay cages following a helicopter application of 1.8pts/A Success[™] on 30 July in graph on right.

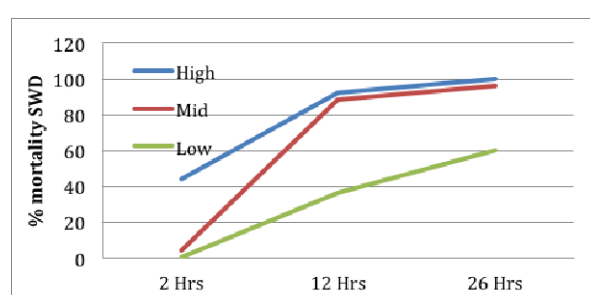
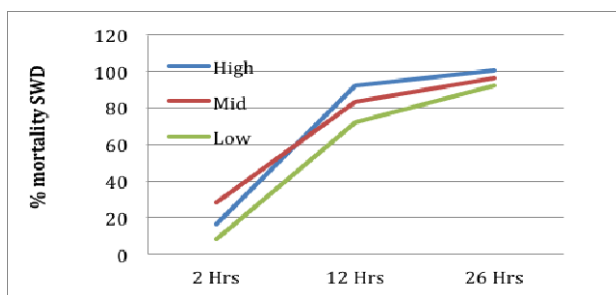
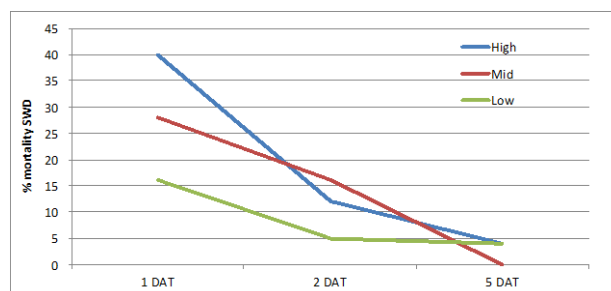
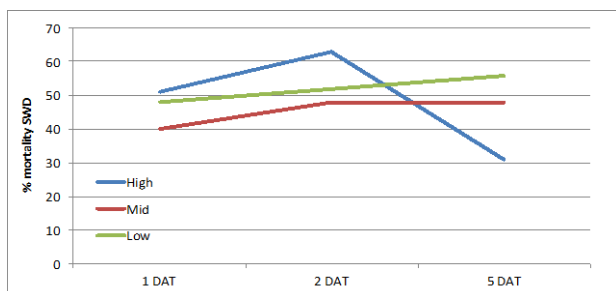


Figure 5 & 6. Percent mortality of SWD in bioassay cages following a helicopter application of 1.5pts/A Lannate[®] LV on 10 August 2011 in graph on left and percent mortality of SWD in bioassay cages following a helicopter application of 1.8pts/A Lannate[®] LV on 2 September in graph on right.

Three insecticide applications were evaluated in 2012 via leaf bioassays: 22 July, Mustang Maxx[®] (4oz/A) (Fig. 7); 22 July, Lannate[®] (1.8pts/A) (Fig. 8); 22 July, Imidan 70W (1.33lbs/A) (Fig. 9). Leaves were collected from three different canopy positions- high, middle and low, and evaluated separately. Mortality rates followed a similar trend compared with data from 2011, although this was not always consistent. Leaves high in the canopy treated with Mustang Maxx[®] provided adequate control of SWD for the first couple of days after treatment, while leaves high in the canopy treated with Imidan 70W provided excellent SWD control for the first couple of days before dropping off.



Figures 7 and 8. Percent mortality of SWD in bioassays on field-aged leaf residues following a helicopter application of Mustang Maxx[®] at 4oz/A on 22 July 2012 in graph on left and percent mortality of SWD in bioassays on field-aged leaf residues following a helicopter application of Lannate[®] at 1.8pts/A on 22 July in graph on right.

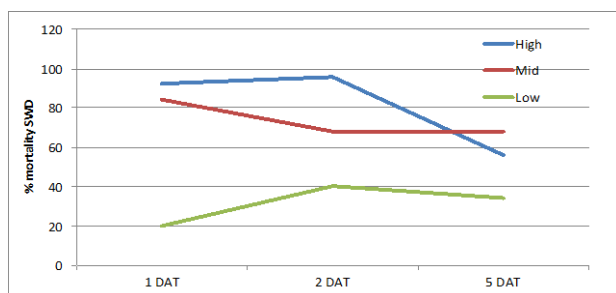


Figure 9. Percent mortality of SWD in bioassays on field-aged leaf residues following a helicopter application of Imidan 70W at 1.33lbs/A on 22 July 2012.

On 4 August 2013, 4oz/A of Mustang Maxx[®] were applied by helicopter to mature ‘Bluecrop’ and a bioassay was performed on leaves collected from 2 canopy locations, but these were not evaluated separately as they had been during other years (Fig. 10). Mortality rates were higher in bioassays containing leaves treated with the helicopter-applied insecticide compared with the control. In 2014, 8oz/A Mustang Maxx[®] + 4oz/A Abound[®] were applied 20 July. Bioassays were performed at -1, 0, 1, 3, 5 and 7 DAT, and leaves collected from high and middle level canopy positions were evaluated separately (Fig. 11). Mortality rates were similar between bioassays containing leaves from high and middle level canopy positions.

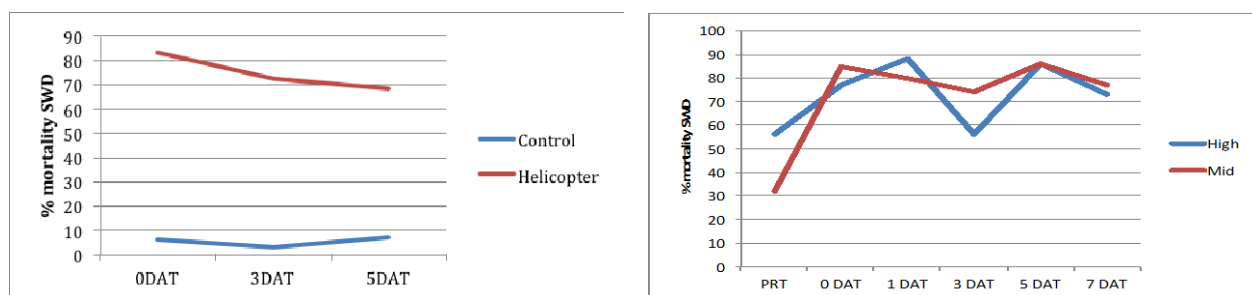


Figure 10 & 11. Percent mortality of SWD in bioassays on field-aged leaf residues following a helicopter application of Mustang Maxx[®] at 4oz/A, 4 August 2013 in graph on left, and SWD bioassay of field-aged leaf residues following a helicopter application of 8oz/A Mustang Maxx[®] + 4oz/A Abound[®], 20 July 2014.

Discussion

Based on the results obtained from these trials, it was demonstrated that helicopter-applied insecticides can provide adequate coverage on the canopy surface, but may not penetrate the canopy, depending on the chemicals and the extent of canopy closure. It can therefore be concluded that insecticides applied by helicopter will provide quick knockdown against SWD in large fields however, this form of application is expensive and is only economical in large fields.

Works cited

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http://www.nass.usda.gov/Statistics_by_State/New_Jersey/Publications/Blueberry_Statistics/2014%20Blueberry%20Statistics.pdf. Accessed 11/24/15.

NOT CONTROLLING SWD IN ORGANIC BERRIES

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Nine years ago, there was an estimated 600 acres of organic blueberries in the United States. By the end of 2015, Washington will have in excess of 2,500 acres of organic blueberries and has established itself as the leading producer of this crop in the world. Acreage of this crop is expanding due to the favorable prices received and the relative lack of insect and disease pressure the industry has enjoyed. Approximately 90% of organic blueberries are located in eastern Washington. Prior to 2012, virtually no insecticides or fungicides had been applied to blueberries grown in eastern Washington. [Blueberries produced in western Washington have significant disease and insect pressure.] Spotted wing drosophila (SWD) was detected in eastern Washington in 2010 but was not sufficiently widespread, present in sufficient numbers or was not noticed prior to 2012. The year 2012 was a turning point for blueberry production. Several growers deployed significant SWD programs, other growers less aware of the pest or less sophisticated in the SWD control programs suffered significant losses due to the insect.

For fresh blueberries, detection of a single larvae per pallet results in rejection. Processed blueberries have lower standards, but production of blueberries for the processed markets require a competent SWD control program. Several shipments of blueberries from eastern and western Washington have been rejected due to the presence of SWD. The Washington Blueberry Commission is under significant pressure to respond to this situation. For conventional growers, there are a number of insecticidal options available and WSU's Lynell Tanigoshi has evaluated these products. Unfortunately, only one organically approved insecticide (Entrust, spinosad, Dow AgroSciences) has been demonstrated to have sufficient efficacy against SWD, prior to the beginning of this research program. Organic blueberry growers rely heavily on Entrust and the Washington (and California and Oregon) organic blueberry industry is very dependent on this product. One of the challenges growers have is that there is a limit on the amount of the product that can be made during the course of the season, resulting in growers using lower rates in order to extend coverage throughout the season. The registrant of Entrust, Dow AgroSciences, now requires use of an alternative, effective insecticides after every two applications. Growers currently question whether there is anything effective enough to rotate with Entrust.

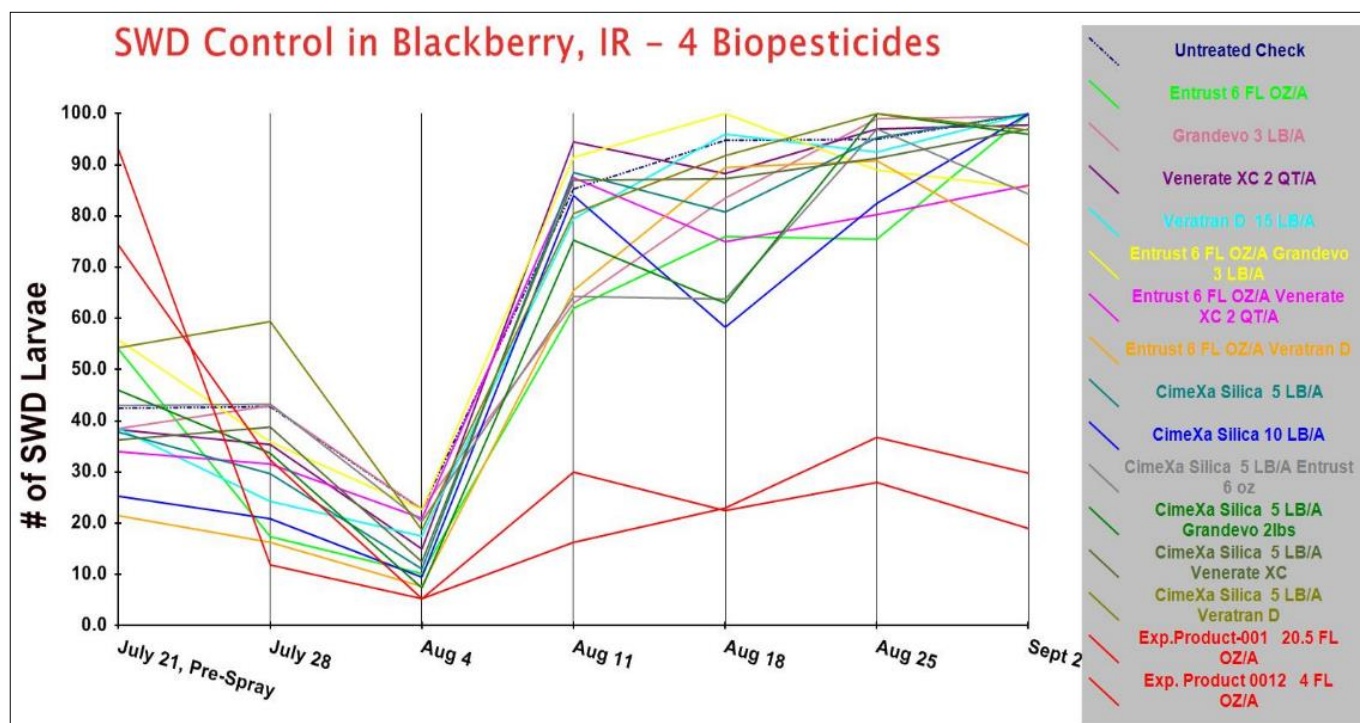
SWD has been documented as having developed resistance to Entrust in blueberries in the Watsonville area of California. While strong scientific data may be lacking demonstrating resistance in SWD to Entrust, two things are known: 1) Entrust is not working as well as it once did against SWD in the areas where it has been used the longest and 2) such heavy reliance on a single mode of action, year after year in a pest with a propensity to develop resistance is a risky situation. The Washington blueberry industry is desperate to develop new organic products for SWD control. In a late season SWD blackberry trial, Schreiber's group has developed successful data for three organic products demonstrating that 1) he can complete a SWD trial, 2) addition of sugar improves efficacy of products not previously known to control SWD and 3) there are other products potentially available. The data collected at present is not sufficient enough to call them equivalence to Entrust.

The 2015 research project was conducted in concert with a national effort looking at organic controls for SWD. Our effort in 2015 took a wrong turn when we agreed to trial a number of treatments involving an organic product that turned out to have no efficacy against SWD. It had previously been shown to have

efficacy against bed bugs and other household pests. As a result, we have less to show for 2015 results than in previous years.

Discussion of Results:

2015 was characterized by a mild winter and a very warm summer. It is believed that SWD were more successful overwintering due to the mild temperatures, and because of the warmer summer they were present earlier and in higher numbers than has ever been seen in the region. As a result, the first sampling of newly ripe fruit for SWD was already heavily infested. Treatments ranged from an average of 1 to 5 larvae per fruit and this was before we started spraying. Our first application was on July 21, two weeks earlier than we have ever treated for SWD in blackberry before.



Once SWD becomes established it is difficult if not impossible to control the pest organically in berries. No treatment provided commercially acceptable levels of control. The most effective organic treatment was Entrust at 4 oz mixed with corn syrup, followed Entrust at 6 oz and Entrust rotated with Veratran. The addition of corn syrup to Entrust has for the past two years has been the most effective of treatments. It is unknown what caused the decline in SWD numbers during the August 4th sampling date.

****For comparative purposes, two conventional insecticides (Exirel and Mustang Maxx) were included in the trial. It is clear that the organic treatments simply do not provide the level of control as does a commercial conventional synthetic insecticide. These results demonstrate the need to start control programs early, as soon as fruit starts to turn color. In a year of unusually warm weather, applications should begin earlier than what a grower would intuitively think to start spraying. Applications should have intervals of 5 to 7 days, at higher rates and the additional of a feeding stimulant appears to approve efficacy.**



Photo #1 (above) – Over the Row multi treatment CO₂ sprayer that was used to make research applications to the organic SWD blackberry trial in Eltopia, WA.

RESIDUE DECLINE CURVES OF BLUEBERRY INSECTICIDES

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In cooperation with Joe DeFrancesco, Oregon State University; Rufus Isaacs, Michigan State University; Lynell Tanigoshi, Washington State University; Steve Midboe, Cenex Harvest States.

Five years ago, Washington produced 18 million pounds of blueberries; in 2015 it produced 100 million pounds. The WBC estimates that in five more years it will produce over 150 million pounds and is already the largest blueberry growing regions in the United States. The Washington blueberry industry simply has no choice but to aggressively develop export markets to help manage supply. Due to its location, quality and quantity of berries available, and the sophistication of the blueberry products Washington produces, it is developing an ambitious program to develop export markets. Conversely, the loss of existing export markets would be crippling.

Unfortunately, the recent arrival of spotted wing drosophila (SWD) into Washington has created a tremendous obstacle to the development of export markets. Washington blueberry growers have not had to deal with a serious insect problem in blueberries before, and more importantly, not an insect pest that occurs so close to harvest, with applications having to be made between harvests. As a result, Washington growers have had to make more insecticide applications than ever before, including applications closer to harvest. When faced with preharvest intervals, numbers of applications and efficacy restrictions, growers today have limited options. This situation, inadvertently, has resulted in residue issues. Although it is believed that growers with an aggressive SWD program can control the insect and stay under U.S./ tolerances, it was discovered in 2012 that they cannot always keep under the MRL limits placed on blueberries by our major export markets.

Below is a list of US tolerances for blueberries insecticides as compared to those of our export markets.

		US	Codex	EU	Canada	Japan	Taiwan
INSECTICIDES/MITICIDES							
Chemical	Trade Name						
Acetamiprid	Assail	1.6	---	0.01	0.6	2	0.01
Azinphos-methyl	Guthion	5	5	0.05	2	5	0.5
Bifenthrin	Brigade	1.8	---	0.05	---	---	1
Carbaryl	Sevin	3	---	0.05	7	7	0.5
Diazinon	Diazinon	0.5	---	0.01	---	0.1	0.5
Endosulfan	Thionex/Thiodan	0.3	---	0.05	---	0.5	0.01
Esfenvalerate	Asana	1	---	0.02	---	1	1
Fenpropathrin	Danitol	3	---	0.01	---	5	3
Imidacloprid	Admire/Provado	3.5	5	5	1	3.5	1
Indoxacarb	Avaunt	1.5	---	1	---	---	0.01
Malathion	Malathion	8	10	0.02	8	0.5	0.01
Metaldehyde	Deadline	0.15	---	0.05	---	---	---
Methomyl	Lannate	6	---	0.02	6	1	2
Methoxyfenozide	Intrepid	3	4	4	---	---	---
Novaluron	Rimon	7	7	0.01	---	---	---
Phosmet	Imidan	10	10	10	5	10	0.02
Piperonyl Butoxide	PBO	8	---	---	8	8	---
Pyrethrins	Pyganic	1	---	1	1	1	---
Pyriproxyfen	Esteem	1	---	0.05	---	1	0.5
Spinetoram	Delegate	0.25	---	0.05	0.5	---	---
Spinosad	Spintor/Esteem	0.25	---	0.3	0.5	1	---
Tebufenozide	Confirm	3	3	3	---	3	---
Thiamethoxam	Actara	0.2	0.5	0.05	0.2	0.2	0.01
Zeta-Cypermethrin	Mustang Max	0.8	---	0.05	---	0.5	---

List last updated 9/28/2011

--- = No MRL established

= Tolerance below U.S. MRL

Just as the Washington blueberry industry was realizing it would have a problem in regards to MRL issues in our export market, Japan detected MRL violations in West Coast blueberries for Intrepid (California) and malathion (Oregon) in 2012. All of the blueberries were under the U.S. tolerances. There were reasonable assurances that applications were legal, and made according to the label, but the blueberry products were in violation of Japanese standards. As a result, all fresh blueberry exports to Japan had to be screened for residues. This resulted in a partial shutdown of blueberry exports because everyone was unsure of residue levels of blueberries. In November, 2012, Taiwan detected Sevin and Lannate in blueberries and initiated mandatory testing of blueberries from Washington State. As a result of the 2012 detections in Taiwan and Japan, South Korea stepped up its testing of U.S. blueberries. Detections and rejections for Washington blueberries occurred in 2013, and also included bifenthrin. Two shipments of 10,000 polybags each were rejected due to bifenthrin detection. One of these rejections

cost hundreds and hundreds of thousands of dollars. This is a very, very serious problem for the U.S. and the Washington blueberry industry. It ranks as one of our most critical issues, and combined with SWD, it is the most critical issue facing the Washington blueberry industry.

In 2013, Schreiber, in cooperation with Lynell Tanigoshi, Steve Midboe and Joe DeFrancesco (OSU) conducted the first year's work on this project. Additional work was conducted in 2014 and 2015. The results are being finalized. Recommendations on how to use common blueberry insecticide while minimizing the potential for violations of maximum residue limits are in the process of being formulated.

POTENTIAL FOR FENPROPATHRIN (DANITOL) AS AN ALTERNATIVE TO BIFENTHRIN (BRIGADE) AS A CLEANUP SPRAY IN RED RASPBERRY

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Bifenthrin is the industry standard cleanup spray in red raspberry. It is a pyrethroid with broadspectrum activity against both insects and mites. Fenpropathrin is also a pyrethroid like bifenthrin, and is known for its long residual activity against SWD infesting another small fruit, blueberry. The current industry 7-day spray interval for SWD is unsustainable but so far no alternative has been identified, which could potentially reduce the number of sprays/season and still maintain maggot-free berries. SWD bioassays have indicated Danitol® 2EC, exhibits long field residual in blueberry but nothing is known about its persistence in red raspberry. While long residual activity is normally a desirable quality, persistent residues may trigger MRL violations if they are above target market tolerances. We performed an MRL degradation study to determine the levels or ppm at 0, 3, 5, 7, 14 and 21 days after treatment (15 June) (Figs. 1 & 2). Bioassays were performed using SWD from the WSU NWREC colony to test residual efficacy of foliar applications (Fig. 3).

Figure 1. ppm Danitol (fenpropathrin) detected over 3 weeks.

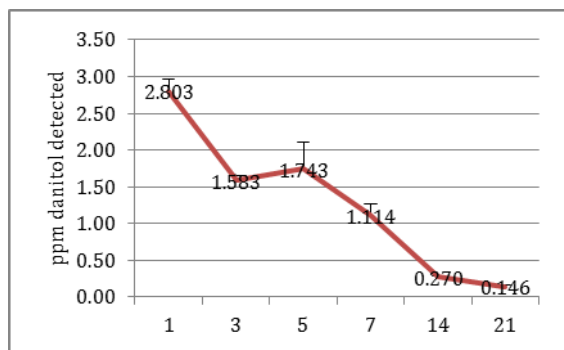
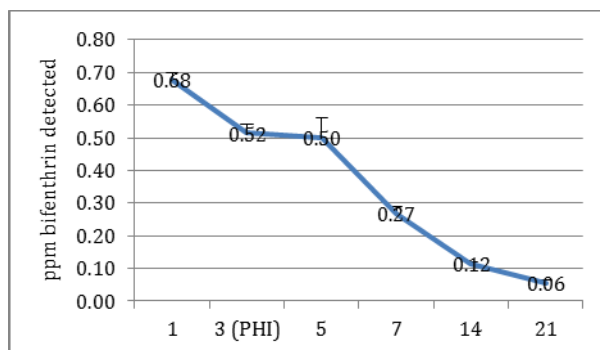


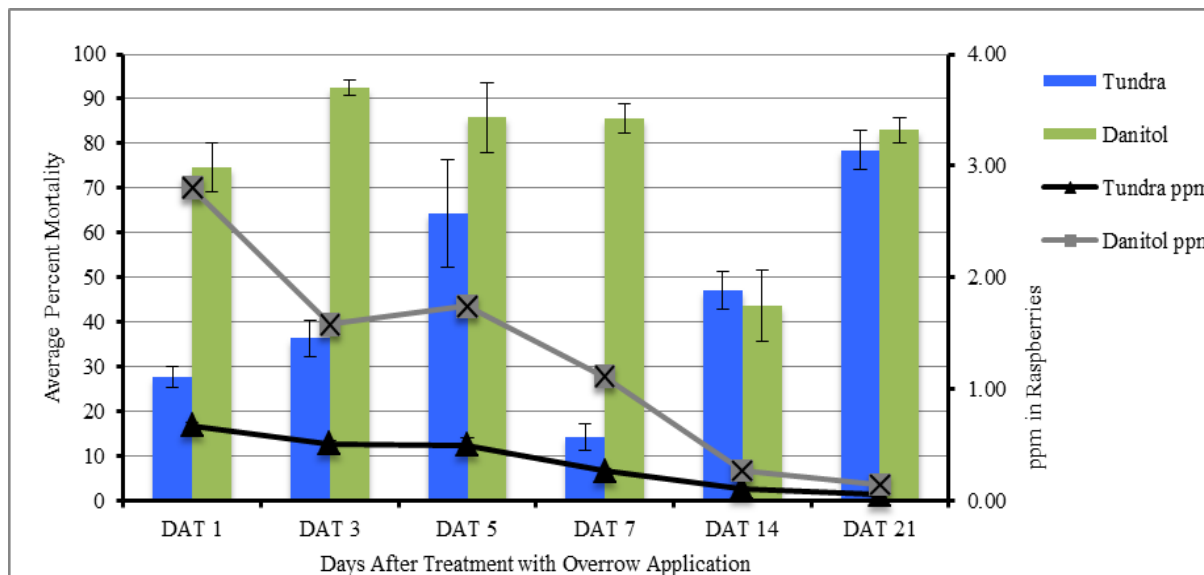
Figure 2. ppm bifenthrin detected over 3 weeks.



The figures above compare residual activity between the two pyrethroids. Pyrethroids typically exhibit a more gradual decline curve than organophosphates as seen above (Figs 1 & 2). At 3 DAT, when fruit can be harvested following a bifenthrin cleanup application, detectable residues have reached 0.52 ppm meeting the tolerance levels of the US (1), Japan (1), S. Korea (1), Taiwan (1) and Australia (3). Canada and China are not compatible and have no tolerance levels allowed (NT). Although ppm of fenpropathrin is higher than ppm of bifenthrin the MRLs are still compatible with most of the preferred Pacific Rim trading partners. At 3 DAT, when fruit can be harvested following a Danitol application, residue levels have reached 1.583 ppm approximately a 7-fold lower residue level than the MRL for the US (12) and Canada (12). AT 3

day PHI the residues are low enough to meet tolerances by China (5), Japan (5) and Taiwan (3) but levels remain detectable and it would be risky to export to countries like S. Korea (0.5) and Australia (NT).

Figure 3. Field residual and SWD % mortality.



Bioassays performed with field-aged residues (colored bars, Fig. 3) indicated Danitol was more persistent than Tundra[®] EC. Tundra was oversprayed with Malathion[®] at 7DAT and Both Tundra and Danitol were oversprayed with Mustang Maxx[®] at 14DAT, resulting in the increases in % mortality observed on those days.

Summary

Results of the MRL degradation curves for bifenthrin and fenpropathrin indicate fenpropathrin is more persistent and exhibits increased efficacy after 7 days compared with bifenthrin. As long as MRLs are favorable with target market trading partners, its efficacy appears greater than that of bifenthrin, indicating it could be a suitable substitute for the traditional cleanup spray at the beginning of the harvest season saving the second shot of bifenthrin for later use.

- *Restriction management Tundra[®] EC - Limited to 2 sprays/year, (0.2 lb a.i./acre/season) 3PHI.*
- *Danitol 2EC – Limited to 2 pt (0.6 lb. ai/acre/season) 3 PHI*

SECTION VII

Pests of Turf and Ornamentals

(No papers submitted for this section.)

SECTION VIII

New & Current Product Development

NEW SEMIOCHEMICAL TOOLS BEING DEVELOPED FOR TORTRICIDS

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Apple and pear growers have adopted the use of sex pheromones for mating disruption of their key pest, codling moth, *Cydia pomonella*. Hand-applied dispensers and aerosol units are the two most widely-adopted technologies. Research has continued to develop new improved technologies, including combined applications of sex pheromone and pear ester. Now, we have two additional avenues of improving mating disruption: sprayable technology and potent bisexual lures for leafrollers. The new sprayable formulation for codling moth follows the development of the microencapsulated pear ester product, DA-MEC by Trécé Inc. Studies conducted in 2015 found that the efficacy of this new formulation for codling moth compared with the one existing sprayable product is significantly longer-lasting under field conditions and under overhead watering for sunburn protection. The efficacy of this new product when applied with pear ester was demonstrated to be comparable to sex pheromone dispensers in a small field trial. Research will continue for another year prior to eventual registration.

New plant-derived compounds have been identified that are highly attractive to the suite of leafrollers and eyespotted budmoth that are pests of fruit crops in North America. The lures catch both sexes of moths and appear to have the potential to be used in mass trapping efforts. Studies conducted in 2015 evaluated lures for three species including *Pandemis pyrusana*, *Choristoneura rosaceana*, and *Spilonota ocellana*. In orchards treated with sex pheromones for the latter two species the new lures were effective in tracking both the phenology and population density of these pests. In comparison, traps baited with sex pheromone lures caught almost no moths. Research is continuing on the use of these lures for monitoring and mass trapping for the next two years. Tortricid pests of crops other than tree fruits should be evaluated.

SECTION IX

Extension & Consulting: Updates and Notes from the Field

APPLICATION EFFICIENCY OF THREE DIFFERENT TYPES OF SPRAYERS IN WESTERN PACIFIC NORTHWEST BLUEBERRIES

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Effective and target specific agricultural sprayer applications are some of the major factors to achieve better pest management. Such factors also govern cost of the pest management to the growers and associated impact to the orchard ecosystem. . In order to reduce the off target drift and for improved sprayer application efficiency, one needs to consider effective sprayer designs, appropriate nozzles and orientation adjustments for desired spray pattern, and use of appropriate spray adjuvants.

Therefore, this study investigated three different types of sprayers towards their applications efficiency in blueberry crop production management. An airblast, Cannon sprayer, and Electrostatic, were evaluated in this study. The application treatments were performed with water soluble Pyranine 10G[®] fluorescent tracer as spray mix. To compare each of the sprayers' efficiency, deposit and spray drift samplers from the respective treatment row canopy zones and adjacent row middles (air and ground drift samplers) were analyzed using fluorometry technique.

Preliminary results showed that all three sprayers were effective in terms of coverage (spray deposition) at each canopy zone in blueberries. The Electrostatic sprayer displayed the highest levels of coverage followed by Airblast and then Cannon sprayer (Figure 1).

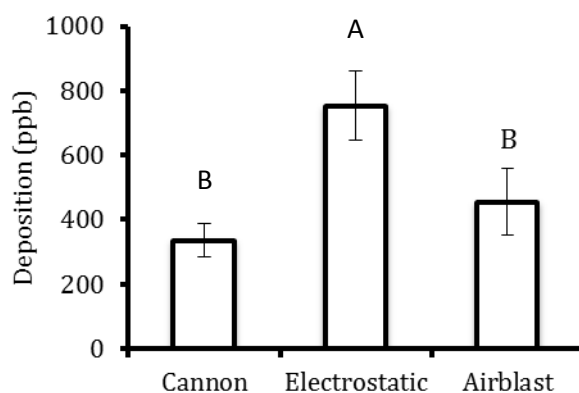


Figure 1. Spray deposition of all spray zones combined on blueberry plants (different letters show significant difference at 5% level)

The aerial spray drift analysis, displayed increased levels of tracers in all of the measured zones combined for Cannon and Airblast sprayers. Significantly decreased spray material drift was observed for the field applications using the Electrostatic sprayer (Figure 2).

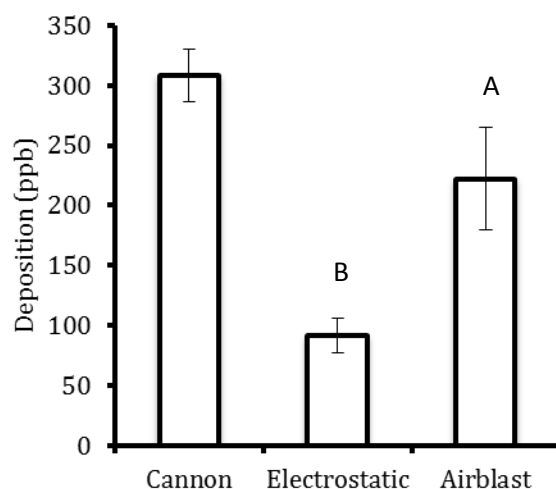


Figure 2. Comparison of in-field aerial drift deposition levels in blueberry plants (different letters show significant difference at 5% level)

In-field ground drift samplers analysis indicated that high levels of spray material were deposited in the Airblast sprayer followed by the Electrostatic sprayer and the Cannon sprayer (Figure 3).

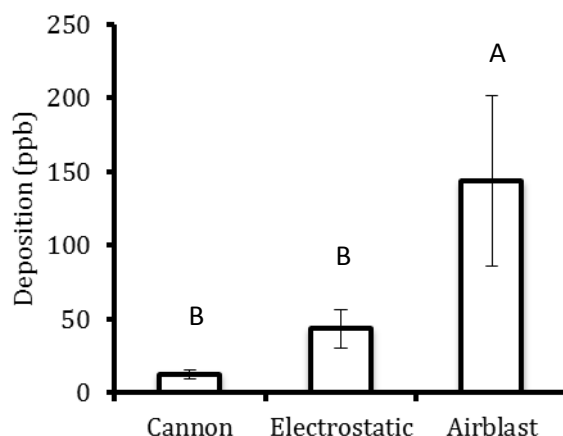


Figure 3. Comparison of in-field ground drift (different letters show significant difference at 5% level)

Increased aerial drift results are expected for the Cannon and Airblast sprayer. This is because Cannon designed to get increased spray coverage over several rows. Previous results show that this sprayer can be used with some success when doing border spray applications. Airblast sprayers are designed to use large volumes of air movement in order to get improved coverage of the target areas. Such design may also results in increased aerial drift d and a numerically higher level of coverage over the Cannon sprayer. Electrostatic sprayers are designed to provide coverage by applying compounds in every row. Experiments were conducted under ideal conditions during the period of the treatments and were 60-75°F and 0-3 mph wind speed and 50-75%, respectively. Results may vary dependent on an increased wind speeds, temperature, and humidity. These results are preliminary and additional results are needed under other environmental conditions. The results indicate advantages and shortcomings for all of the sprayers tested. Growers can use these results in order to provide the best management options for their unique conditions.