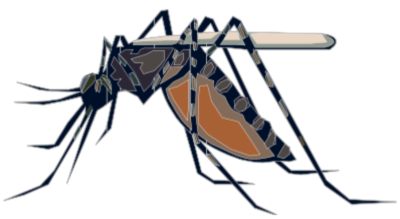
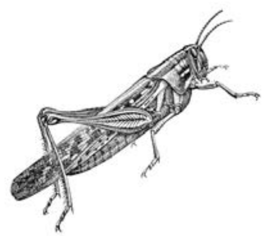
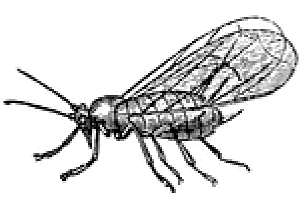
RESEARCH REPORTS

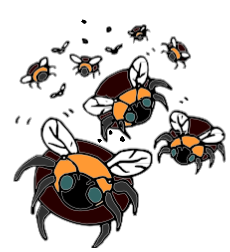
74th ANNUAL PACIFIC NORTHWEST INSECT MANAGEMENT CONFERENCE

HILTON HOTEL
PORTLAND, OREGON
JANUARY 12 AND 13, 2015









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

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74th ANNUAL PACIFIC NORTHWEST INSECT MANAGEMENT CONFERENCE

January 12 and 13, 2015

PAPERS

Note: ""denotes student papers.*

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SECTION II: Bees and Pollinators

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PROGRAM

74th ANNUAL PACIFIC NORTHWEST INSECT MANAGEMENT CONFERENCE

HILTON HOTEL, PORTLAND, OREGON
JANUARY 12 and 13, 2015

MONDAY, JANUARY 12th

Registration	9:00AM
Call to Order Business Meeting	10:00AM
Section I	10:30AM
Lunch (on your own)	11:45AM
Section I and Section II	1:00PM
Break	3:00PM
Sections III and IV	3:30PM
Adjourn	4:30PM

TUESDAY, JANUARY 13th

Registration	8:00AM
Call to Order	8:30AM
Section V	8:35AM
Break	10:00AM
Student Presentations	10:30AM
Lunch (on your own)	11:45AM
Sections VI, VII, and IX	1:00PM
Final Business Meeting	3:30PM
Adjourn	4:30PM

SECTION I

Invasive Pests, Emerging Pests, and Hot Topics of Interest

Moderator: Amy Dreves

SPOTTED WING DROSOPHILA: TIMING EARLY SEASON TREATMENTS

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Introduction

Sound and effective management practices for *Drosophila suzukii* , spotted wing Drosophila (SWD), rely upon predicting the initial timing of female oviposition in a susceptible host crop. A thorough understanding of SWD developmental events and activity, such as overwintering survival, occurrence of first damage, and when female ovaries are mature help schedule early treatment to knock down SWD before 1st generation egg-laying. A degree-day model was developed that is part descriptive, in that it reflects our current understanding of lab and field behaviors, and part predictive, in that it intends to provide management decision support by forecasting first feeding activity and reproduction, and number of generations. Degree-day models depend on a linear response to temperature (at least between thresholds). Over time, errors due to non-linear responses are expected to cancel out. Validation of degree-day models can be readily expressed as +/- days error for a given prediction.

Methods

In an effort to correlate crop damage with SWD trap counts to determine when to treat for SWD, trap counts during the pre-harvest and early harvest periods over a four-year period were used to help predict SWD oviposition. A trap study was carried out in no-spray non-crops, cherries, and blueberries between June 2011 - June 2014, using red and clear traps baited with a yeast/sugar or apple cider vinegar/soap mixture. Traps were serviced and the contents counted weekly, though counts of trap contents were carried out once every two weeks during the late fall-winter period. To determine SWD infestation rates, marketable fruits from plants nearby trapped plants were collected 3 to 4 times during the harvest period and reared in individual cups in the lab. Degree-days were calculated using the online model for SWD for the Corvallis, OR Hyslop Farm (CRVO) weather station, available at http://uspest.org/cgi-bin/ddmodel.us?spp=swd. Data was analyzed by looking at 5 parameters including: 1) substantial increases in trap counts, 2) first detection of fruit infestation; 3) sex shift in traps from predominately females to adult males, 4) initial oviposition by backtracking degree-days, and with 5) supporting data of ovary maturity ratings and crop phenology.

Results

Fly captures alone in individual traps were not reliable predictors of damage. Limitations of using adult counts only include: dependency on trap placement and number of traps placed, bait and trap design, crop type, ability to identify SWD correctly, and misrepresentation of population levels. By looking closely at the 5 parameters listed above, we were able to predict timing of oviposition by backtracking developmental degree-days in cherries (Fig. 1) and in the blueberry crop. The use of this degree day model (lower and upper thresholds, 10C and 30C, with a biofix of Jan. 1) does not provide precision regarding timing or need for treatments beyond initial implementation, nor does it predict the beginning of overwintering behaviors, which we are currently pursuing. Thus the degree-day model may be more effective in forecasting rapid rises in infested fruit than traps, which are competing with ripe fruit and thus not always a sufficient indicator or warning system.

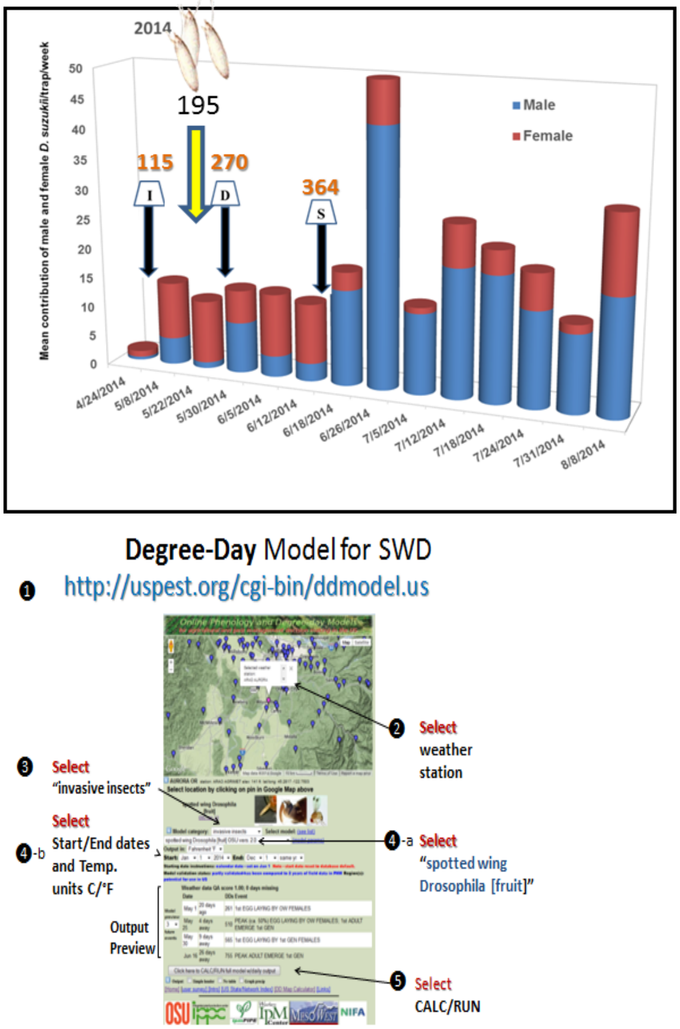

Fig. 1. Mean number of male (blue) and female (red) flies caught in monitoring traps (n=3) placed in cherry in the mid-Willamette Valley in 2014. Note: degree-days computed for events/activity: I= time when substatial increase in trap activity in spring; D= first detection of infestation (fruit damage); and S= when count shifts to males (reflecting next generation).

Initial SWD infestation levels were observed for trap counts varying from 0.6 SWD/trap/week in 2011 to 5.2 SWD/trap/week in 2013. The wide variation in these trap counts indicates that traps are not currently reliable, timely, or sensitive enough to predict damage, and underscores the necessity of investigating alternative prediction and verification methods. The cold winter of below freezing temperatures in 2014, decreased SWD survival and delayed spring activity by several weeks. In these studies, we found that using degree-day accumulations helped establish the timing of first treatments, in place of, or in addition to using trap counts. This tool will aid in predicting early SWD fly activity events, lead to appropriate timing of treatments and reduced use of unnecessary treatments; when used in combination with other methods such as regular larval extractions of fruit to determine whether fruit is infested.

THINK IPM: MONITORING AND MULTIPLE TOOL APPROACHES

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Introduction

Development of a multi-tool approach for managing spotted wing Drosophila (SWD), *Drosophila suzukii*, requires 1) a thorough understanding of SWD's seasonal population levels, 2) when SWD female ovaries are mature with readiness to lay eggs, 3) where SWD seasonally concentrate, and 4) gaining knowledge about SWD's behavior and needs not only in a commercial crop but also in the adjacent landscape. Areas in which SWD inhabit may act as a resting place, protective refuge with favorable conditions, a food resource, or provide a host oviposition site for the fly. Trap counts and fruit damage within a crop may therefore be directly impacted by adjacent vegetation. This paper will describe new baits/lures and trap designs, mass trapping technology, attract and kill use; and a strategy for tackling SWD in 2015.

Baits/Lures

Two commercial long-lasting lures (Trécé Incorporated and Scentry Biologicals, Inc.) were tested on a wild 'Himalaya' blackberry border adjacent to a diversified, organic farm in Corvallis, Oregon over a 10-week period. A Pherocon Trécé side-mesh 950 mL clear deli trap with a water/soap drowning solution was used to compare lure efficacy. Trap contents were collected weekly and male and female SWD and other *Drosophila* were counted.

Trap Designs

Pherocon side mesh | Trappit

In addition, several trap designs ("Pherocon Trécé side-mesh" 950 mL clear deli, 20-hole Red Stripe 950 mL clear deli, 40-hole 530 mL red cup, "Sombrero" large spice container (USDA-Knight), McPhail-type yellow dome (Trappit), and a homemade "Squatty Botty"(OSU-Dreves) 950 mL side-mesh with yellow, black, and red colors were tested with the aim to improve trap catch. Each trap contained 250 mL of 50% Chinese Vinegar. Traps were serviced weekly and evaluated for male and female SWD and other *Drosophila* spp. A commercial insecticide strip was added inside the lid of some of the traps to evaluate if a killing agent (a.i. concentrations of dichlorvos at 10%, 18.6% ai; and a 2 x 2 cm square of "No-Pest" at 18.6%ai) can increase catch by reducing escapees. In addition, a boric acid-sugar spray was tested on the outside of 40-hole red cups, in hope to kill those that land on the cup, but decide to not enter.

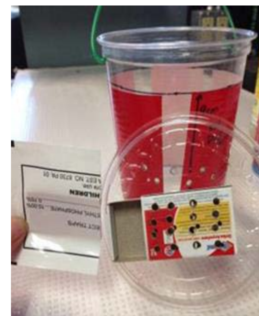
40-hole red

Mass Trapping

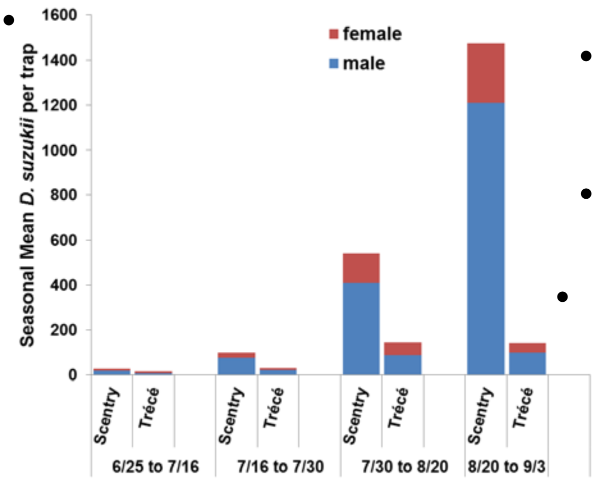
Two field trials were conducted in Corvallis, Oregon to assess the use of mass trapping (100 traps/acre) in a mid-season blueberry crop to reduce SWD levels, hence to minimize damage. Traps were constructed from 18 oz red party cups (SOLO) with forty 1/8-inch holes punched in three rows starting approximately 1 inch below the cup rim (8.5 cm width- about 40% around cup). Each trap was evenly sprayed over the entire outside surface with 2.8 mL boric acid (5%)/sucrose (10%)/carmine red dye (0.1%) solution. Baits were changed weekly to biweekly: apple cider vinegar (5% acetic acid) and 10% EtOH mix, 50% rate of Chinkiang Vinegar (rice & wheat bran-based), yeast (*S. cerevisia)*/sugar water solution, and Suzukii Trap bait® (Spain). Marketable fruits were collected from plants in trapped and untrapped areas during the harvest period; and a larval extraction was performed along with a sample set placed in individual cups in lab to confirm infestation.

Summary of results

- Significantly more SWD captures, male-dominated, and less SWD-specific Drosophila was recorded from traps with the Scentry pouch lure compared to traps with the Trécé lure. However, increased efficacy was observed using 50% Chinese Vinegar compared to Scentry lures for attracting SWD (see figure below).
- The addition of a toxicant (irrespective of type) increased fly capture among all trap types.--→

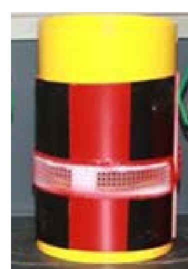


"Red stripe" with insecticide strip

- 

- Fly capture was higher in traps coated with a boric-acid sugar spray compared to traps without a boric acid spray on the outside of traps.
- There was seasonal variation in fly capture between trap types, however increased catch with increased trap volume.
- No significant differences in blueberry damage were observed in trapped versus untrapped plants at a dry & open site 1. Increased damage was recorded in the trapped plot compared to untrapped plot at site 2, most likely due to differing environmental conditions (adjacent to riparian and diversified forest, with increased shade and humidity versus the untrapped plot that was in an open, windy, no shaded area; and no close-by diversified edge). Overall, these studies give insight into, and raise questions pertaining to, the use of mass trapping, best trap designs and baits, and how to use attract-and-kill strategies as tools to minimize *D. suzukii* before infestations arise. Understanding the nature of the fly (e.g., numerous generations, high reproductive potential, multiple fruit hosts, expansive mobility) is important for an effective strategy. Once potential hotspots of SWD activity are identified, management tactics can be targeted to these areas, in hopes that immigration is minimal.

"Sombrerro"



"Squatty"

HOST RANGE TESTING OF *TRISSOLCUS JAPONICUS*, A POTENTIAL BIOLOGICAL CONTROL AGENT OF BROWN MARMORATED STINK BUG IN OREGON

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The brown marmorated stink bug (BMSB), *Halyomorpha halys* (Hemiptera: Pentatomidae), has become established in Oregon in recent years. Recognizing its wide host range and potential threat to Oregon's specialty crop industries, Oregon Department of Agriculture (ODA) joined efforts with USDA and Oregon State University (OSU) in developing a potential biological control method for this emerging pest. In 2011, we started a colony of the egg parasitoid *Trissolcus japonicus* (Hymenoptera: Platygastridae) at OSU's quarantine facility in Corvallis, Oregon. We maintained the parasitoid colony on eggs of BMSB and have been testing host range and host preference of the parasitoid. The goal is to test the parasitoid against commonly found pentatomid species from Oregon, and to determine if the parasitoid is a good candidate for eventual biological control releases against BMSB.

The parasitoid colony was maintained, and all non-target testing was conducted, in OSU's quarantine facility, using two growth chambers set at 20° C, 60% RH, and 16L:8D light cycle. Non-target pentatomid species were field collected in various locations in Oregon during the Spring and Summer from 2012-2014. These species were brought into laboratories in either Salem or Corvallis and were reared on cut plants or vegetables inside screened cages, which were monitored daily for stink bug eggs. We conducted two sets of non-target host tests: 1) no-choice test and 2) choice test. In the no-choice test, we introduced a mated female parasitoid to a single cluster of non-target stink bug eggs, ≤ 24-hr old, in a 10 dram plastic vial. The stink bug eggs were adhered to a strip of heavy duty paper. The non-target eggs exposed to the parasitoid in the vial for 24 hr, after which the parasitoid was removed from the vial. Exposed eggs were monitored for 6 wk for parasitism. In the choice test, the procedure was the same except parasitoids were offered a choice between eggs of BMSB and those of non-target on the same paper strip. Host acceptance and host preference were assessed after all parasitoids emerged from egg clusters. Choice-tests were performed only for a non-target species if it was determined that parasitoids could successfully parasitize eggs of that species in no-choice tests.

In no-choice tests, 16 species have been tested against the parasitoid including the target host species, BMSB. In addition to BMSB, nine non-target species showed some successful parasitism by *T. japonicus* (Fig. 1). No-choice tests for some species are still ongoing.

In choice tests, we observed a trend in completed tests (n > 20 replications) that BMSB eggs exhibited greater mean parasitism compared to non-target host eggs (Fig. 2). The percent of parasitized BMSB eggs was significantly higher when compared to *Banasa dimidiata* eggs (V = 117.5, p = 0.006, Wilcoxon signed rank test) and *Thyanta custator* eggs (V = 71.5 p = 0.008). Parasitism of *Chinavia hilaris* eggs was not significantly different from that of BMSB (V=107.5, p = 0.225). Choice tests on other species are still ongoing.

Of the species whose eggs were successfully parasitized, most produced wasps that had a greater mean sex ratio (% males of adults that emerged) than BMSB. Only two species tested produced greater numbers of female parasitoids (Fig 3). However, the sample size for these ratios is relatively small and highly variable among species. This is partially due to the fact that only no-choice tests in which some adult parasitoids successfully emerged were included. Based on measurements of wasp head capsule and host egg diameter, we also observed a trend in which the size of the wasp was positively correlated to the size of the host egg (Fig. 4). Research evaluating *Trissolcus japonicus* as a potential biological control agent will continue through 2015.

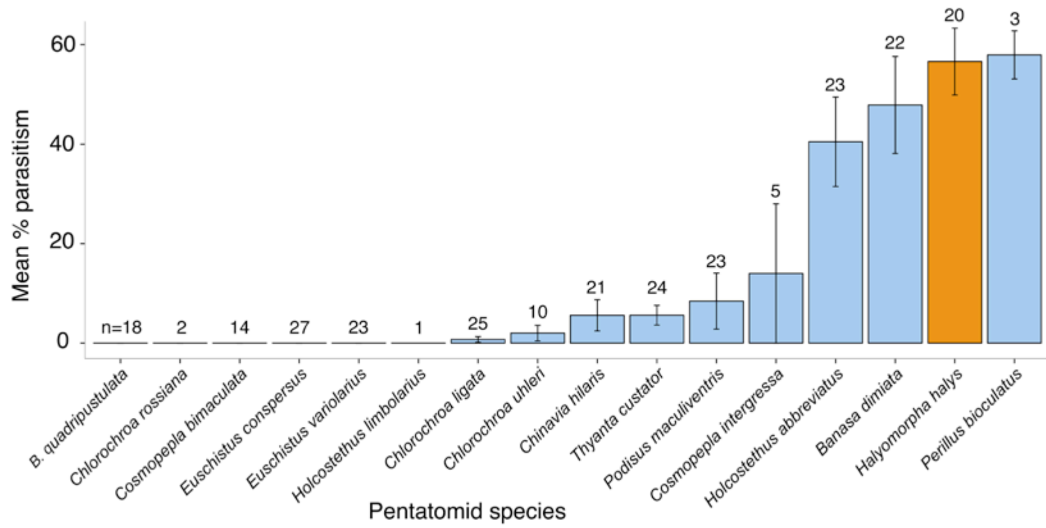

Figure *1*: Mean percent parasitism of host egg clusters after exposure to *T. japonicus* in no-choice tests. Error bars indicate standard error of the mean. n = number of replications for that species.

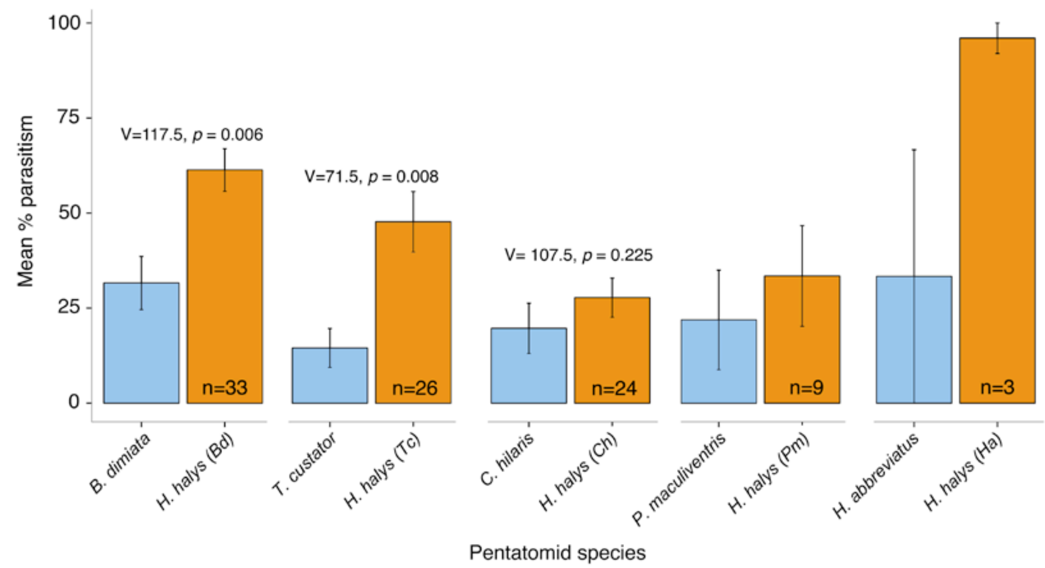

Figure *2*: Mean percent parasitism of host egg clusters after exposure to *T. japonicus* in choice tests. Error bars indicate standard error of the mean. n= number of replications for that species. Wilcoxon signed rank test (R-Stat 2014). *P. maculiventris* and *H. abbreviatus* choice tests are ongoing.

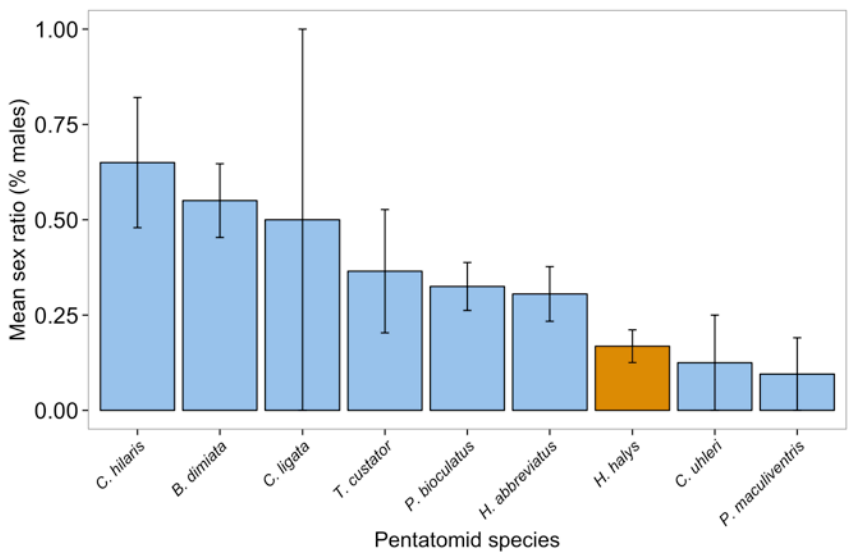

Figure 3: Mean sex ratio (percent males) of emerged *T. japonicus* adults from parasitized pentatomid host eggs. Error bars indicate standard error of the mean.

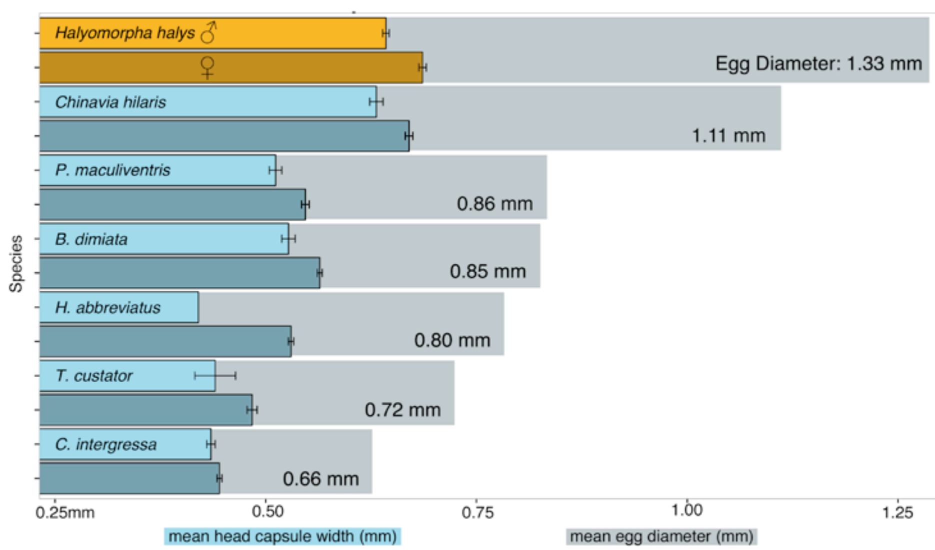

Figure 4: Mean head capsule width of adult *Trissolcus japonicus* wasps emerged from pentatomid host eggs and mean of Pentatomidae host egg diameter. Upper bars of Pentatomidae host species indicated male head capsule size, lower bars, female. Error bars indicate standard error of the mean.

DETECTION OF THE DARK STRAWBERRY TORTRIX, AND OTHER JUST DESSERTS

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In 2012, a live larval tortricid specimen was submitted to entomologists by a citizen surveyor during a biological inventory ("Bioblitz") of Forest Park, a large natural area in Portland, Oregon. Following pupation and emergence, the adult specimen was identified and confirmed as *Syricoris (Celypha) lacunana* Denis & Schiffermüller (Lepidoptera; Tortricidae), a new North American record. The species is native to Europe, where it feeds on wide range of herbaceous plants, ferns, shrubs and trees.

Sometimes referred to as the dark strawberry tortrix (DST), *S. lacunana* is an occasional pest of strawberry, blackberry, and raspberry. Due to concerns for this species to become plant pest, the USDA's New Pest Advisory Group (NPAG) issued recommendations to conduct delimitation surveys in the area, to determine: 1) if a population of the species has established, and 2) the local distribution of that population.


female *Syricoris lacunana* (photo E. LaGasa)

In spring and summer of 2014, APHIS-PPQ conducted surveys in Forest Park for DST, working with Oregon Dept. of Agriculture, Washington Dept. of Agriculture (WSDA), Portland Parks and Recreation (PPnR), and the Forest Park Conservancy. Sampling for immature Lepidoptera produced a total of 167 larval specimens, collected from 29 species of host plants in three areas of Forest Park. Since no clear morphological characters were available to separate DST larvae from similar tortricid species in the region, all larval specimens were reared to adult life stage by feeding them the host plant species on which they were collected. A total of 66 larvae were reared to adult life stages. No *Syricoris lacunana* specimens were found during the 2014 larval survey.

Blacklight survey for adult DST occurred twice per month between June 2nd and August 27th, deploying four battery-powered blacklight bucket traps a targeted area of Forest Park. A total of 56 adult tortricid specimens were collected during larval and blacklight surveys. Only one additional specimen of *S. lacunana* was collected from a blacklight trap during the 2014 surveys.

In 2015, APHIS-PPQ will continue delimitation survey in Forest Park and surrounding neighborhoods. USDA's Center for Plant Health Science and Technology (CPHST) is currently exploring new survey methods for *Syricoris lacunana*, including the development of a semiochemical lure for survey in 2015.

Non-target tortricid moth species collected from the 2014 DST survey were retained and identified (Table A). Of significance to local land managers, seven new tortricid species records were added to PPnR's Forest Park invertebrate inventory, including *Acleris variegana* (Denis & Schiffermüller, 1775), *Epinotia solandriana* (Linnaeus, 1758), *Epinotia subviridis* Heinrich, 1929, *Clepsis persicana* (Fitch, 1856), and a recent new arrival to Oregon *Pandemis cerasana* (Hübner, 1786).

TABLE A. Tortricid specimens collected during 2014 DST survey.

Genus	Species		number of specimens	method
Acleris	*variegana*	(Denis & Schiffermüller,1775)	1	blacklight trap
Archips	*rosanus*	(Linnaeus, 1758)	4	blacklight trap
Celypha	*lacunana*	Denis & Schiffermüller	1	blacklight trap
Choristoneura	*rosaceana*	(Harris, 1841)	28	blacklight trap
Choristoneura	*freemani*	Freeman, 1967	1	blacklight trap
Clepsis	*peritana*	(Clemens, 1860)	4	blacklight trap
Clepsis	*persicana*	(Fitch, 1856)	2	larvae reared, host= *Oemlaria cerasiformes* and *Rubus bifrons*
Ditula	*angustiorana*	(Haworth, 1811)	1	larvae reared, host= Rubus ursinus
Epinotia	*radicana*	(Heinrich, 1923)	3	blacklight trap
Endothenia	*hebesana*	(Walker, 1863)	1	blacklight trap
Epinotia	*solandriana*	(Linnaeus, 1758)	2	blacklight trap
Epinotia	*subviridis*	Heinrich, 1929	1	blacklight trap
Olethreutes	*deprecatorius*	Heinrich, 1926	1	blacklight trap
Pandemis	*cerasana*	(Hübner, 1786)	1	blacklight trap
Proteoteras	*aescalana*	Riley, 1881	1	blacklight trap
Olethreutes	*sp.*		3	blacklight trap
Rhopobota	*naevana*	(Hübner, 1814)	1	blacklight trap
Syricoris	*lacunana*	Denis & Schiffermüller		
unknown	Archipini		3	blacklight trap
Archips	*rosanus*	(Linnaeus, 1758)	2	larvae reared, host= Rubus ursinus

FOOD BAITS CAN REDUCE SELECTION PRESSURE FOR INSECTICIDE RESISTANCE IN MANAGEMENT PROGRAMS FOR ADULT SPOTTED WING DROSOPHILA, *DROSOPHILA SUZUKII* (MATSUMURA), (DIPTERA: DROSOPHILIDAE)

Alan L. Knight[1], Wee Yee[1], Rick Hilton[2], Cletus Kurtzman[3], and Esteban Basoalto[2]
[1] USDA, ARS, Wapato, WA; [2] Oregon State, Medford, OR, [3] USDA, ARS Peoria, IL

Drosophila suzukii has become a major pest of fruit crops, including cherry in the western United States. We evaluated whether the addition of sugary baits could improve the efficacy of two classes of insecticides not considered to be sufficiently effective for this pest, including diamides and spinosyns in laboratory and field trials in cherry from 2011 to 2014. The addition of *Saccharomyces cerevisiae* with sugar and Monterey Insect Bait (corn steeped liquor) significantly improved the efficacy of both diamide and spinosyns insecticides. Inclusion of these two insecticide classes in spotted wing drosophila management programs may alleviate the strong selection pressure currently being imposed on a few mode-of-action insecticide classes for growers to maintain nearly season-long fly suppression.

BROWN MARMORATED STINK BUG IN EASTERN OREGON

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Brown marmorated stink bug (BMSB), *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae), is a severe invasive pest of Asian origin with wide range of host in the U.S. including small and tree fruits, nuts, vegetables such as corn, pepper, tomatoes and soybean. In response to the devastating economic impacts of BMSB insecticide use has increased dramatically. Spray programs for BMSB rely on prophylactic use broad-spectrum materials. In September 2013, BMSB was found in eastern Oregon solely in Catalpa trees. This is a tree native to warm temperate regions that thrives in dry areas. After a wide press release by local newspapers, numerous phone calls were received alerting us of the presence of this pest. Twenty six of these reports were positive for BMSB. The remaining ones were boxelder bugs or seed bugs. In 2014, BMSB was found in the same hosts but more widely distributed in the area. By the end of November, few were found inside buildings.

In an effort to determine the efficacy of chemicals in our area, pesticides were tested for controlling BMSB. The following chemicals were tested: Beleaf (T1), Transform WG (T2), and Asana XL (T3). The experiment was set up as a Randomized Complete Block Design with four replicates per treatment. Pinto Beans were used as host plant. Plots were 3-rows wide X 22 inch row spacing X 30 feet long. Normal agricultural practices were followed. Insecticides were applied using a CO^2 propelled backpack sprayer. BMSB were artificially infested onto bean plants using fine mesh bags to contain the insects. Each plot received three bags placed on bean plants in the center row.

Efficacy data was taken a 1, 3, and 7 days after treatment (DAT). At each sampling date, one bag per plot was removed and taken back to the lab for counting. 4^{th} or 5^{th} instar nymphs were used per bag. All treatments showed relatively low activity 1 DAT probably due to “older” stink bugs tolerance to chemicals. Three and 7 DAT, mortality increased (Fig. 1). Some mortality was observed in the Untreated Control (UTC).

Residual data collected was conducted by reinfesting the plants and the next week and sampling 1, 2, and 3 weeks later. We used 2^{nd} instar nymphs at an infestation rate of 1 nymph per bag. Results showed good residual efficacy of Asana and Transform. Again the control showed high amount of mortality (Fig. 2).

Although high mortality in the control skewed the evaluations of our chemical treatments, the trial helped us to determine a protocol for future research involving this pest.

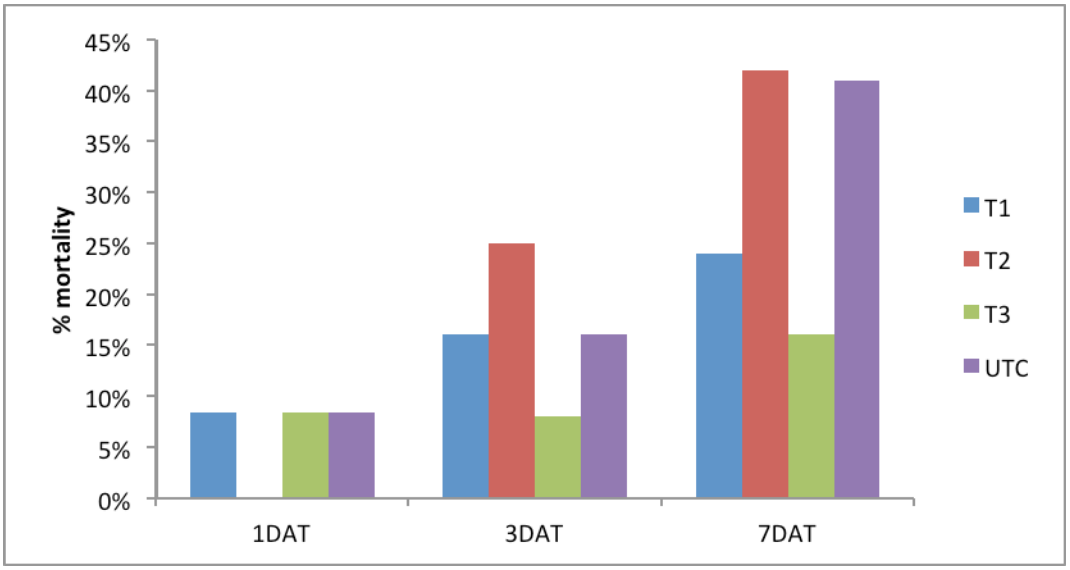

Fig. 1. Efficacy of pesticides in controlling BMSB, Hermiston, OR.

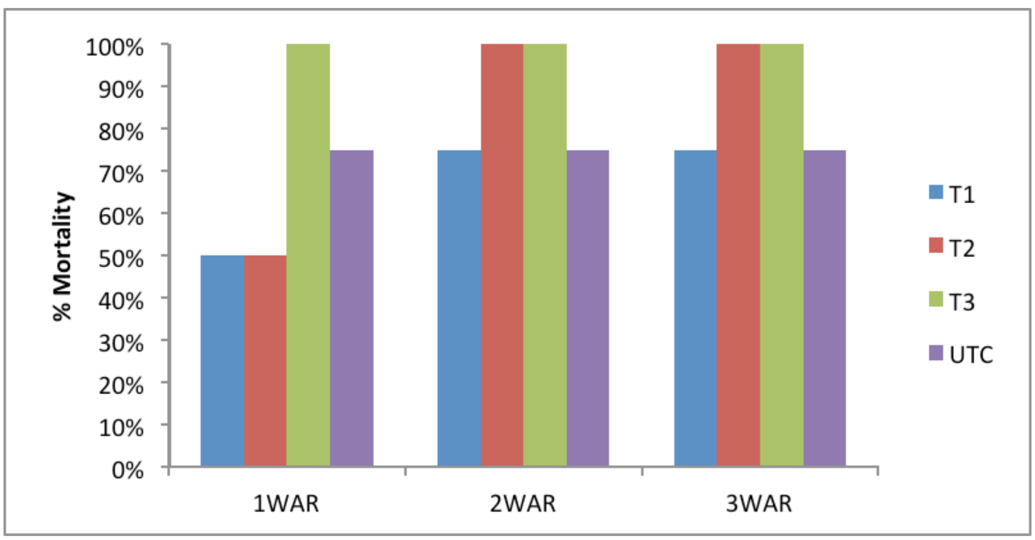

Figure 2. Residual Efficacy of selected pesticides on BMSB, Hermiston, OR.

FIELD DECLINE, MRLS, AND EFFICACY OF SPINOSYNS IN CONTROLLING SPOTTED WING DROSOPHILA (*DROSOPHILA SUZUKII*) IN HIGHBUSH BLUEBERRY

Wei Q. Yang[1], Lynell K. Tanigoshi[2], Beverly S. Gerdeman[2] and Heather Andrews[1]
[1]Oregon State University, North Willamette Research and Extension Center, Aurora, OR
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Introduction

Spotted wing drosophila, *Drosophila suzukii* (Diptera:Drosophilidae), is an invasive vinegar fly which poses a serious threat to the eastern and western small and stone fruit crops in the United States. Following its introduction to the US in 2008, *D. suzukii* has wreaked havoc on many growers' crops, and is estimated to potentially cause yield losses of up to 40% in blueberries, 50% in caneberries and 33% in cherries in Oregon, Washington and California (Bolda 2010). Due to its potential to cause such serious damage, many growers begin treating fruit with insecticides as soon as fruit starts to ripen, and they continue to make regular applications up until all fruit has been harvested.

Since insecticide applications have markedly increased due to the threat posed by this pest, there is also an increased risk that farmers could exceed the Maximum Residue Levels (MRLs) of pesticides allowed to remain in/on fruit. This is of particular concern to growers who sell fruit to overseas markets because many countries differ in the levels of certain pesticides allowed to remain on the fruit (Fig.1). One important tool which can help growers determine how far in advance they need to apply a pesticide in order for residues to decline to acceptable levels are residue decline curves, which are developed by sampling for residues following a chemical application over the course of time. After residue levels are analyzed, they are plotted against time, and then a curve can be developed, which is then used to forecast where residue levels will be at a given time.

The length of time a pesticide is effective against a pest is another very important factor to be considered. Many of the insecticides currently being used against *D. suzukii* only provide up to one week of adequate protection, and this tends to be an even shorter amount of time when considering naturally derived insecticides, which often degrade more rapidly in the field than synthetic insecticides. Due to such short residual activity, growers must reapply insecticides regularly. Increasing the amount of pesticides applied also increases the pressure on the pest to develop resistance, particularly when there are a very limited number of effective pesticides (and therefore modes of action) available for growers to use.

Since growers need to know not only how long an insecticide will combat a certain pest, but also how long it will take to degrade to acceptable levels, it is essential to have both residue decline and efficacy data that can be readily available in an easy to comprehend format. During the summer of 2013, a series of experiments were carried out to test the efficacy and field decline of the insecticides Malathion, Mustang Max and Danitol for use against *D. suzukii*. During the summer of 2014, we wanted to test the efficacy and field decline rate of a couple of additional insecticides, spinosad (Success) and spinetoram (Delegate), which use a different mode of action for killing pests. Spinosad, a derivative from a bacterial fermentation product, acts upon susceptible insects via a neural mechanism, which eventually leads to disruption of neurotransmission and death (Meihua et. al 2007). Spinetoram uses an identical mode of action, but has been chemically modified to enhance its specificity and longevity. By testing insecticides that use a novel mode of action, we hope to add to growers' knowledge regarding the efficacy and decline rate of spinosyn insecticides.

Maximum Residue Levels (MRLs) for USA, Codex, EU/UK, Canada, Japan, Korea, and Taiwan
Oregon Blueberries – December 10, 2014

(MRLs for other countries can be found at: www.mrldatabase.com)

		MRLs (ppm)						
Chemical Name (a.i.)	Product Name*	USA	Codex	EU, UK	Canada	Japan	Korea	Taiwan
Insecticides & Miticides								
Spinetoram	Delegate	0.25	0.2	0.2	0.5	0.5	0.2	0.2
Spinosad	Success, Entrust	0.25	0.4	0.4	0.5	0.3	1.0	NT

Figure. 1. Excerpt from maximum residue chart of insecticides registered for use in OR and WA blueberries for management of *D. suzukii*, and considerations for their use. Note, only spinetoram and spinosad are shown because they were the insecticidal agents tested in this trial.

Methods

The first trial was conducted at the OSU North Willamette Research and Extension Center (NWREC) in Aurora, OR in ripening Elliot highbush blueberries following an application of Delegate at 4 oz/A in early August. Berry and leaf samples were collected -1, 0, 1, 3, 5 and 7 days following application. The second trial was conducted at Pan-American Berry Growers (PBG) in Salem, OR in late-season ripening Aurora highbush blueberries. Sampling commenced following an application of Success at 6 fl oz/A via airblast sprayer in late August, and was performed in an identical manner to that used for the Delegate trial. A third trial was conducted in September at PBG following an application of Delegate at 6 oz/A. Samples were collected -1, 0, 1, 3, 5 and 6 days following application. Following the sampling for all trials, both berries and leaves were frozen, and then sent away to Synergistic Pesticide Laboratory, LLC in Portland, OR for residue analysis. A subset of leaves was set aside before samples were frozen, and these were shipped overnight to Washington State University, where bioassays were conducted using lab-reared *D. suzukii*.

Results

According to our results, there is a direct correlation between a decline in pesticide residues and mortality of *D. suzukii* (Fig 2-4). Average mortality of *D. suzukii* exposed to leaves treated with spinosad was only about 50% immediately following treatment, rose slightly the day after treatment, and then dropped off significantly (Fig. 2). Average mortality of *D. suzukii* exposed to leaves treated with spinetoram during the first spinetoram trial was close to 100% immediately following treatment, and then did not fall below 60% throughout sampling (Fig. 3). However, the pre-treatment bioassay yielded a high average mortality of 82%, which could have resulted from residual activity from prior insecticidal treatments. During the second spinetoram trial at PBG, average mortality was only 48% immediately following treatment, and then fell to just below 40% by day six (Fig. 4).

Average spinosyn residues on berries were low immediately following applications of both spinetoram and spinosad, and had fallen to nearly zero seven days after treatment (Figs. 2-4).

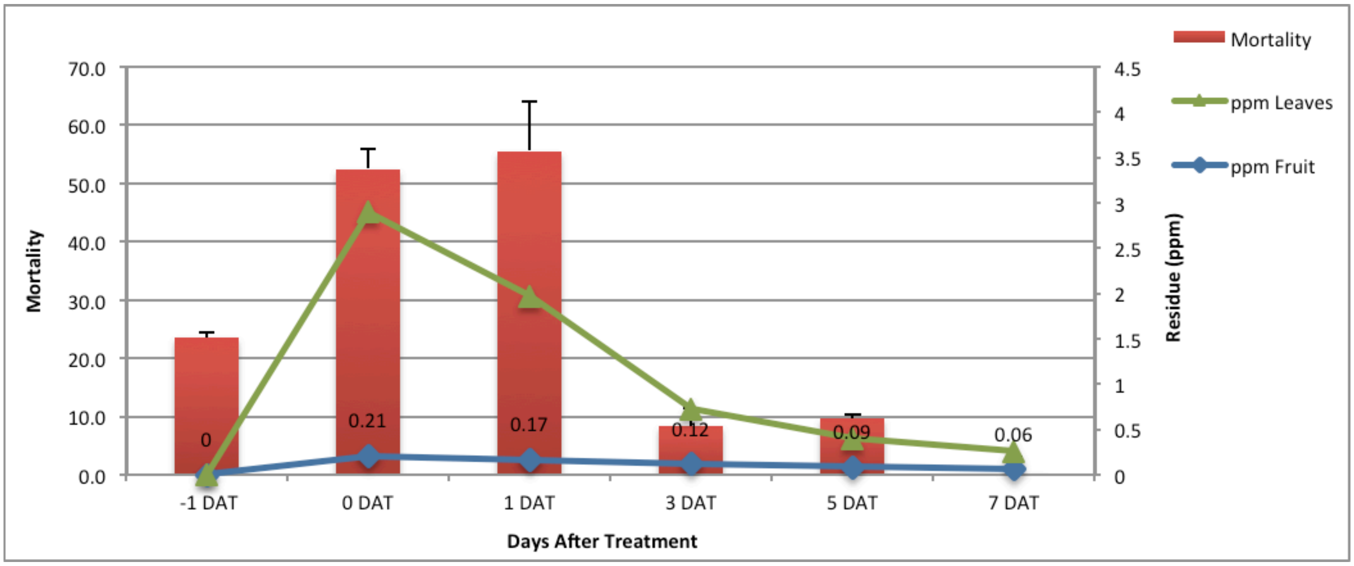

Figure 2. Spinosad (Success) residue decline in blueberry leaves and fruit with *D. suzukii* mortality at Pan-American Berry Growers in 2014.

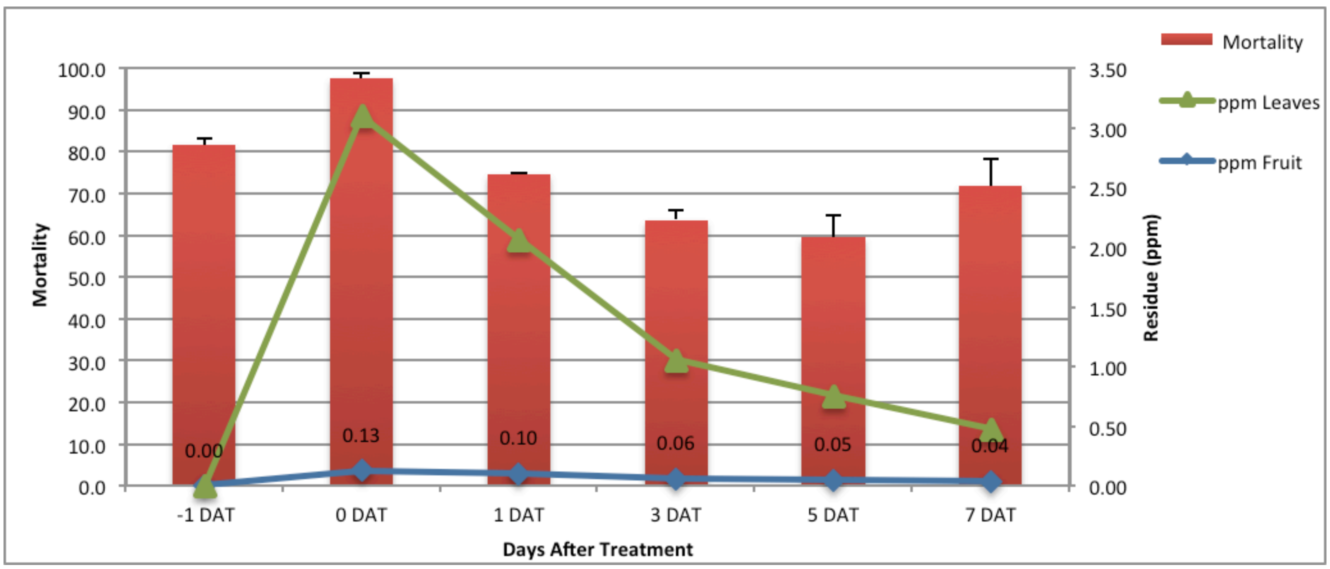

Figure 3. Spinetoram (Delegate WG) residue declines in blueberry leaves and fruit with *D. suzukii* mortality at the OSU North Willamette Research and Extension Center in 2014.

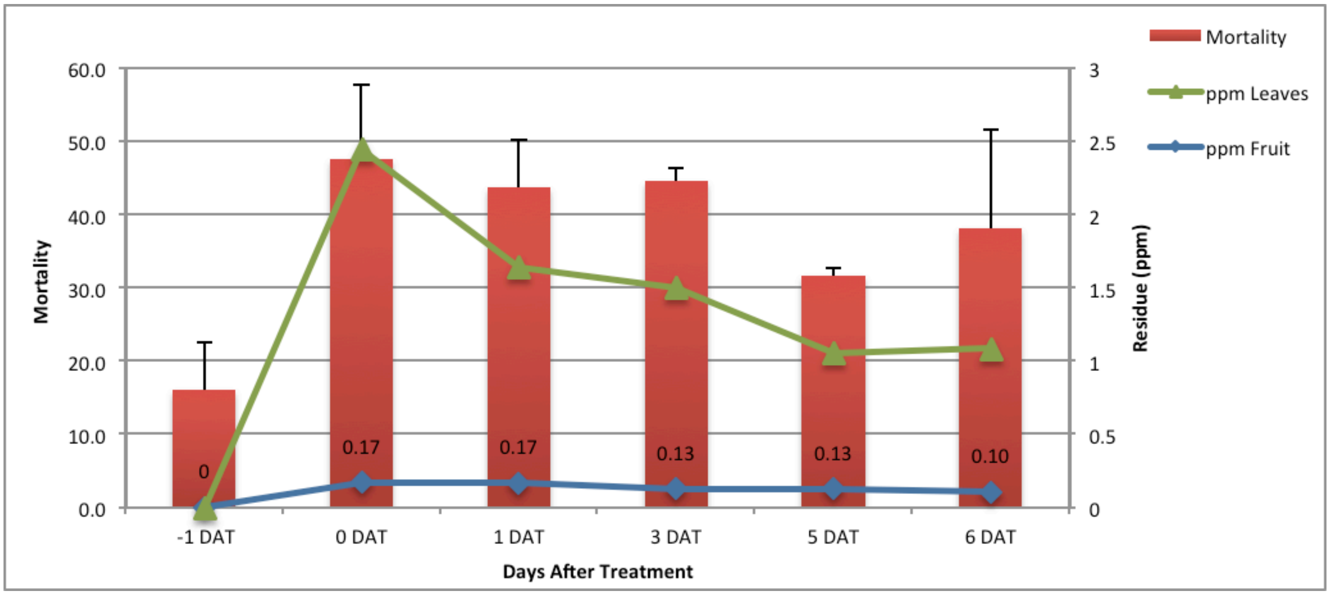

Figure 4. Spinetoram (Delegate WG) residue declines in blueberry leaves and fruit with *D. suzukii* mortality at Pan-American Berry Growers in 2014.

Discussion

It appears that crop protection against *D. suzukii* with spinosad is fairly low immediately following application, and then drops off extremely rapidly after a couple of days. Spinetoram appears to provide longer lasting protection, particularly when used as part of a spray regime that includes other effective insecticides. Mortality of *D. suzukii* was remarkably high during the first spinetoram trial at NWREC, and efficacy remained fairly high during the entire seven-day trial. Since mortality prior to spinetoram application was fairly high at 82%, it can be assumed that a prior insecticidal application was exerting residual activity against *D. suzukii*. However, since insecticidal activity remained high, spinetoram may have prolonged protection against *D. suzukii*, and it can therefore be assumed that using spinetoram in rotation with other effective insecticides will provide adequate protection for an extensive time period while offering a different mode of action than many other commonly used insecticides.

After the pre-harvest interval (PHI) of three days has passed, residues on fruit were at acceptable levels for all markets worldwide when spinetoram was applied at either the 4 oz/A or 6 oz/A rate (Figs. 1, 3 and 4). Residues of spinosad on fruit had fallen to acceptable levels after the required PHI of three days for all markets except Taiwan (Figs. 1 and 2).

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SECTION II

Bees and Pollinators

Moderator: Tim Waters

WHY DO BUMBLE BEES DIE AFTER FORAGING ON LINDEN TREES?

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Linden (*Tilia* spp.; Malvaceae), also known as lime or basswood, is a common ornamental tree in urban landscapes. It produces an abundance of fragrant flowers that draws diverse pollinators. In 2013 and 2014, massive numbers of one bumble bee species, *Bombus vosnesenskii* (Apidae), died after visiting linden trees in western Oregon. Bee deaths were linked to neonicotinoid insecticides applied for control of aphid pests. However, mortality of bees feeding on *Tilia* species has been reported from Europe since the late 1970s, long before neonicotinoids were developed as an insecticide. Investigations by European researchers suggest that the causal factor is the presence of the sugar mannose in the nectar of linden. Mannose is speculated to be toxic to honey bees because it disrupts the glycolysis cycle by competing with glucose for the enzyme hexokinase. However, there is no information on the impact of mannose and other sugars on bumble bees. Information is also lacking on other pollinators that visit linden in Oregon and that were likely affected by the neonicotinoid sprays. The objectives of this study were to: 1) Assess the diversity and abundance of pollinators foraging on linden trees; 2) Determine the impact of mannose and other sugars on honey bees and bumble bees.

<u>Diversity and abundance of pollinators associated with linden</u>: Three *Tilia* species, *T. americana, T. cordata* and *T. platyphyllos* in Corvallis were monitored in the summer of 2014. Bloom in each *Tilia* species lasted for 2-3 weeks with a slight overlap in bloom between *T. americana* and *cordata.* Insect visitors to the trees included European honey bees, bumble bees, halictids, vespids and dipterans. Of these, honey bees and dipterans were the most abundant (Fig. 1).

<u>Impacts of mannose and other sugars on bees</u>: Three laboratory experiments were conducted using honey bees and bumble bees (when available). Sugars were presented to 10 bees per mesh cage for 24 hours at 33° C and 50% RH. The experiments were set up as a randomized block design with 8 replications.

a) <u>Comparison of impacts of different sugars on honey bees and bumble bees</u>. 1 M solutions of mannose, galactose, glucose, fructose, sucrose, and water (control) were evaluated. Mortality with mannose and galactose was similar to mortality with water (starvation). The impacts of mannose and galactose were greater on honey bees than on bumble bees (Fig. 2A).
b) <u>Determination of the dose-response of sugars on honey bees</u>. Mannose, galactose, glucose, and water (control) were tested at 0.5, 1 and 2 M concentrations. No difference in mortality was observed for galactose and mannose among the three concentrations tested. Even the lowest dose (0.5 M) for each sugar was highly toxic compared to glucose (Fig 2B).
c) <u>Determination of the impact of toxic sugars when presented in combination with glucose</u>. The following treatments were evaluated: 1 M solutions of glucose-mannose (GLU:MAN) and glucose-galactose (GLU:GAL) at 90:10, 50:50, 10:90 ratios. Bee mortality was significantly lower with the lowest ratio for each toxic sugar (90:10 GLU:MAN and GLU:GAL) compared to the higher ratios (50:50 and 10:90; GLU:MAN and GLU:GAL) (Fig. 2C).

The results indicate that while bumble bees were the key pollinator that were documented to be affected by the neonicotinoid sprays in Oregon, several other insects also visit linden during bloom. The study documented that mannose and galactose are toxic to honey bees and bumble bees.

However, the impact depended on the amount of non-toxic sugars simultaneously presented to the bees. Based on the results, it is possible that mannose and galactose cause bee mortality by limiting the amount of the enzyme hexokinase available for metabolism of the glucose. Further research is needed for determining the presence of the toxic sugars in the nectar of linden and the biochemical basis for the toxicity.

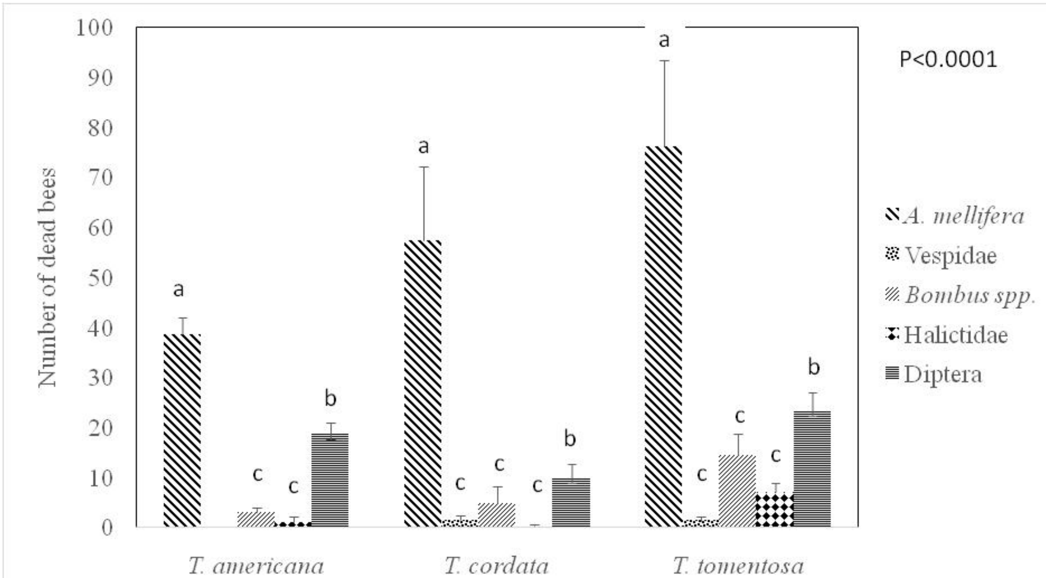
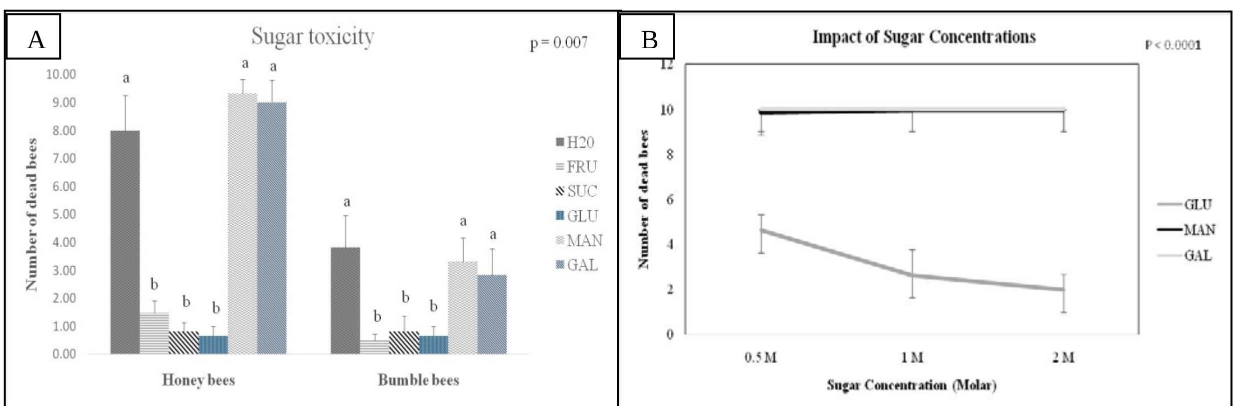


Fig. 1 Diversity and abundance of insects that visited linden trees in 2014.



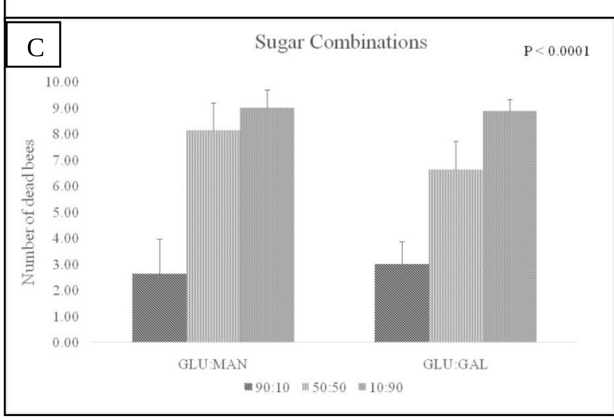


Fig. 2. Impacts of sugars on bees. **A**. Mortality of honey bees and bumble bees when presented various sugars. FRU=fructose; SUC=sucrose; GLU=glucose; MAN=mannose; GAL=galactose. **B**. Dose response of sugars on honey bees. **C**. Mortality of honey bees presented with combinations of glucose with mannose and galactose.

PROJECT INTEGRATE CROP POLLINATION IN OREGON BLUEBERRIES

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Introducing Project ICP: The Rao lab at Oregon State University is part of a large Small Crop Research Intuitive grant on Integrated Crop Pollination. This involves multiple scientists across the United States and B.C., Canada, and crops ranging from apples and blueberries in MI, pumpkins in PA, blueberries and watermelon in FL, and almonds and melons in CA. At Oregon State University we are focused on blueberries.

There are six objectives that are part of the SCRI project; four are focused on research, and two on outreach and information dissemination. We are involved in three of the research objectives: 1) pollinator contributions to yield, 2) the impact of enhanced floral resources for pollinators, and 3) economics and modeling. We are working on 12 blueberry farms in the central part of the Willamette Valley to address these questions.

The primary component of the first objective is determining if blueberry yields are pollination limited, i.e., would yields be higher if each flower had received more bee visits. Honeybees are stocked at the rate 2-3 hives per acre, and we want to know if their pollination services, and those of native pollinators, are adequate for full yield. We are particularly interested in whether native bees are playing a significant pollination role in blueberries. We examined these questions by having three pollination treatments on each test plant: 1) Closed- clusters enclosed in a mesh bag, 2) Open- open to insect pollinators, and 3) Hand- open plus hand pollinated. In the Closed pollination treatment flower clusters are bagged to exclude pollinators just before the flowers open. The Open pollinated flowers are exposed to pollinators. 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 the all the flowers petals (corolla) drop.

We applied each treatment on ten plants at each of at 0, 25, 50 and 100 m distances into the field from a natural vegetation edge. Native bees 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 are also interested in how several landscape features may influence pollination services by honeybees and native bees. These are: the intensity of management activities within and adjacent to the blueberry fields, e.g., mowing frequency; fungicide, herbicide, and pesticide use; nearby crops; and nesting and flowering resources within a 2 km range of each field. The second primary objective is to examine whether flower resources (flower enhancements adjacent to fields) will increase abundance of native bees and reduce any identified pollination deficits. We will not address these Project ICP components during this talk.

Initial Results: In this talk we will present our initial analysis of the pollination limitation study we ran on 12 farms in 2014. We will focus on differences among blueberry varieties (Bluecrop and Draper), and the three pollination treatments. We will address the Distance variable at a later time.

The first question is whether there are differences in the proportion of berries in the mature, intermediate and immature categories. We found significant differences between varieties and among the pollination treatments, and their interaction, for the percent of mature (marketable berries). Over both varieties Open and Hand treatments were higher than the Closed, but not from each other. The interaction term documented that percent mature berries was higher for Draper than Bluecrop in the Open and Hand treatments, but lower for Draper in the Closed.

Only the variety and pollination treatment affected the number of intermediate berries (marketable size but not ripe). There were more Bluecrop in this category in all three pollination treatments. The Open treatment had a greater percent intermediate berries than Closed or Hand. Only the pollination treatment affected the percentage of immature berries, the Closed treatment had around 3 times more immature berries than the Open and Hand treatments.

The Hand pollination treatment always showed the effect of the addition of extra pollen by having a higher mean percent mature berries, and fewer intermediate and immature berries, than the Open treatment; however the differences were generally not significant.

We also examined the average weight of the berries. Draper is known to have a larger berry, which showed up in our analysis, so that is not of much interest. We will focus on pollination treatment effects and their interaction with variety. For this analysis we combined the mature and intermediate berry categories. Draper berries were heavier than Bluecrop in the Open and Hand treatment, but not the Closed. The Open and Hand treatments were about 2.5 times heavier than the Closed. Over both varieties the Hand pollinated treatment was 6% heavier than the Open treatment, showing the benefit of the additional pollen deposition with our paint brushes.

These experiments will be repeated in 2015.

Conclusions:

1) Blueberries do require outcrossing pollination by insects in order to achieve marketable fruit. Draper is particularly is sensitive to self-fertilization, typically not producing even a tiny berry in the Closed treatment.
2) There is some evidence of pollination limitation in blueberries in Oregon. The mean percent of berries in the Mature category was higher in the Hand pollination treatment, although this was not significant. The higher weight of the berries in the Hand treatment was significant. These difference may have been greater if we were able to hand pollenate each flower 3 times (as planned), rather than just two.

INVESTIGATING EFFECTS OF POLLEN NUTRITION ON *NOSEMA CERANAE* INFECTION AND PERSISTENCE IN HONEY BEE COLONIES

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Introduction

There is an ever-increasing need for pollination services in our modern agriculture systems. Honey bees provide the majority of that pollination for commercial agriculture worth $ 2.5 billion in the Pacific Northwest. Healthy honey bee colonies are crucial to sustain Oregon's agricultural economy. Due to the alarming honey bee colony losses attributed to Colony Collapse Disorder, the need to understand honey bee health is dire.

Bees, along with most organisms require adequate nutrition to grow and develop properly. Since honey bees obtain their food from plants, they are directly affected by land management practices. Due to increased urbanization and current farming techniques, land use has dramatically changed and regional pollen diversity continues to decline possibly affecting bee health (Naug 2009). Previous research has shown that bees fed on a variety of different pollen types live longer (Schmidt et al. 1987) and have increased immune functions (Alaux et al. 2010).

There are many pests and diseases which constantly threaten honey bee health. *Nosema ceranae* is a microsporidian gut parasite which has recently been discovered in honey bees. The spores germinate inside the host midgut and reproduce intracellularly (Gisder 2011). *Nosema ceranae* has been shown to increase winter colony losses and decrease bee immune responses to other diseases (Higes et al. 2006). The biology and epidemiology of this new pest is still relatively unknown; thus, continuing research is necessary to better understand this pathogen.

Since immune functions can depend so heavily upon nutrition, it is important to understand the relationship between nutrition and disease load. There is no literature that we are aware of which demonstrates the relationship between nutrition and the prevalence and intensity of *Nosema ceranae*. It is our hypothesis that a nutritionally deficient diet will result in an increased rate of *Nosema ceranae* parasitization and honey bee mortality. Our objectives in this experiment were to investigate if optimal nutrition will reduce the prevalence and intensity of a *Nosema ceranae* infection.

Methods

Frames with emerging brood were pulled from sister queen hives in OSU's apiaries. Frames were randomly placed in cardboard nucleus hives and emerged in the incubator at 33^{o}C with the relative humidity at 55% to simulate conditions in the hive. Newly emerged bees (less than 24 hours old) were brushed into a large container where they were mixed thoroughly by hand to remove variances between the individual colonies. After the bees were homogenized, they were placed inside cylindrical wire cages (6306 cm^3) and returned to the incubator. Each cage contained 250 bees. On the top of each cage were two inverted vials of 100ml of water and 50% sucrose solution provided *ad libitum*. Bees inside the cage were also exposed to varying diet treatments.

In order to vary the amounts of nutrients amongst the cages, treatments consisted of wild flower pollen and α-cellulose powder(Sigma®) in the following ratios: 1:0, 1:1, 1:2, 1:3, and 0:1 respectively. There was also a control diet which included 1:0 and was not inoculated with *Nosema ceranae* spores. There were 6 different diet treatments with 6 replicates of each treatment for a total of 36 cages. 35 ml of 33% sucrose solution was mixed into 300g of the diet treatment mixture to hold the blend together. The mixture was then measured out to 25g and packed into petri dishes. The petri dishes were then placed at the bottom of each cage.

Five days after emergence and being exposed to the diet treatment *ad libitum*, each cage was then mass inoculated with *Nosema ceranae* spores. Spores were purified through centrifugation and calculated to inoculate 250 bees with 10,000 spores per bee. The spore inoculant was formulated in 30ml of 50% sucrose solution. The inoculums were left for 24 hours and then the feeders were topped up with uncontaminated 50% sucrose solution to total 100ml.

Every other day the consumption of water and sugar syrup from each cage was measured and replaced. The diet treatment consumption was measured and replaced weekly. Bee mortality was observed every other day and dead bees were removed at time of diet treatment replacement for convenience.16 days after the bees were inoculated with *Nosema* spores, 20 bees were culled from each cage for analysis. 20 bee abdomens were used to estimate the *Nosema* prevalence and intensity. The prevalence and intensity of the *Nosema* infection was determined by light microscopy techniques followed by (Cantwell 1970). Each bee was checked individually for *Nosema ceranae* infection.

Data analysis was carried out with SAS 9.3. *Nosema* intensity and prevalence data were analyzed by generalized mixed linear model analysis (PROC MIXED; SAS 9.1) for differences due to various treatments. Mean separations were performed using Fisher's protected least significant difference (LSD) test ($P < 0.05$). After statistical analysis, means were back-transformed as needed for presentation herein.

Results

Nosema prevalence (% infection in each treatment) data were transformed by square root transformation. Prevalence ranged from 23 to 27 % among various inoculated treatments which are on par with each other with no significant difference ($P = 0.3066$). Treatments that were inoculated with *Nosema* differed significantly ($P = 0.0001$) in intensity (mean spores per bee). Significantly higher intensities were observed in the 1:0 and 1:1 compared to the other diet treatments. 1:3 and 0:1 showed lowest intensity of *Nosema* and were on par with each other (Figure 1.).

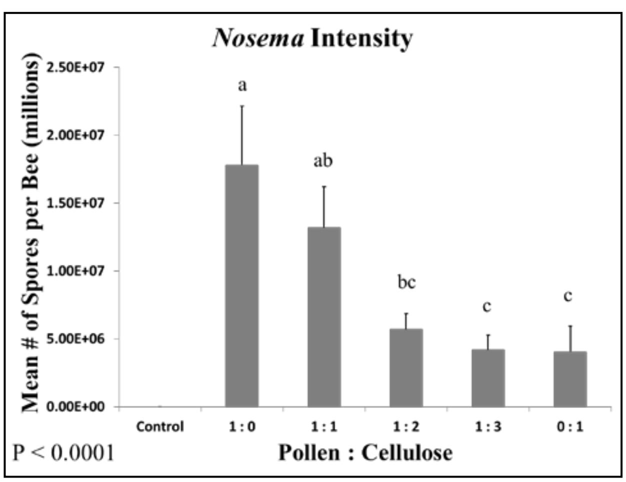

Figure 1. The mean number of spores in each treatment.

Honeybee survival data followed a normal distribution, so no data transformations were performed. Treatments differ significantly in survival ($P < 0.0001$). The total number of honey bees survived was significantly higher in the un-inoculated control (125 honey bees) which is on par with the 1:0 and 1:1 treatments compared to other treatments (Figure 2.). In general it was observed that as the pollen concentration decreased in the diet, the number of surviving honey bees also decreased. The 0:1 treatment had lowest (20) survival.

Discussion

The results of this study support the idea that nutrition plays a role in *Nosema ceranae* parasitization. The diet type provided to the bees resulted in different levels of infection and survival. This suggests that not only does the availability of pollen matter, but also the quality.

The fact that our treatments with the best nutrition had the highest intensity of infection confirms that host nutrition is vital for the parasite's success. One speculation is that the availability of pollen in the diet affects the gut pH, which is responsible for the higher reproduction of the spores. Another speculation could be that the spores, which are dependent upon the host's epithelial cells for replication, require a bee with more nutrients.

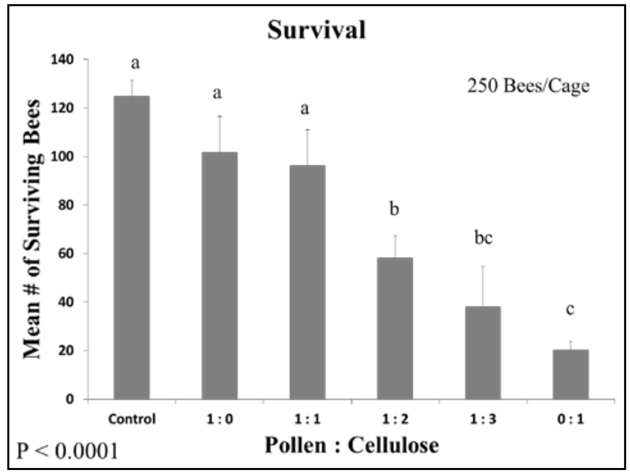

Figure 2. The mean number of surviving bees in each treatment.

Contrary to our hypothesis, the cages with the highest number of surviving bees were the same cages that had the highest intensity of *Nosema ceranae* infection. Better nutrition seems to compensate for the parasitic damage caused by *Nosema ceranae*. This could potentially have major implications on the way beekeepers manage for *Nosema*, shifting the focus from chemical treatment of anti-biotics to increasing colony nutrition.

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SECTION III

Environmental Toxicology and Regulatory Issues

Moderator: Amanda Koppel

PESTICIDE DEGRADATION TO MEET MRLS OF BLUEBERRY EXPORT MARKETS

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Blueberry growers continue to face the challenges of effective pest management in their fields while also attempting to develop a pesticide spray program that will allow them to ship fruit to foreign markets. The arrival of spotted wing drosophila (SWD) has caused blueberry growers to make more insecticide applications than ever before, with those applications needing to be close to harvest and, in some situations, between harvests. As with any commodity, residue levels of blueberry fruit must be below the allowable Maximum Residue Level (MRL) for a given country, otherwise the shipment can be rejected. Knowing how close to harvest a pesticide can be used without the risk of an MRL violation will help growers develop a pest management strategy, and choose the most favorable pesticides, for their particular export market.

Thirteen insecticides commonly used in blueberry production were included in this 2014 study, with one field site in Oregon and, in collaboration with Alan Schreiber, Lynell Tanigoshi, and Steve Midboe, three in Washington, and in collaboration with Rufus Isaacs, one in Michigan (Table 1). Each site followed the same field protocol (i.e. rate, number of applications, spray interval, etc.) and used commercially available products from the same source (Table 2). All samples were analyzed at Synergistic Pesticide Laboratory in Portland, OR. However, cultivar, plant age, application method, plot size, and spray volume varied from site to site. Treatments 1 and 3 included the same pesticides in the tank mix but Treatment 3 included two applications, one week apart, whereas Treatment 1 had just one application. The Oregon and Washington sites conducted a similar study in 2013 with many of the same insecticides.

Approximated one pound of fruit was harvested from each replicate for each treatment at 1, 4, 9, 13, 17, and 21 days after the last application of each treatment. On each sampling date, mature, ripe berries were collected into plastic bags and placed on ice until all sampling was completed for the day, and then frozen within hours at the completion of the day's sampling. Samples were delivered to the laboratory in a frozen state.

Table1. Site, Application and Sampling Parameters – 2014

Code	Location	Age/Height	Cultivar	Applic. Dates	Gallonage	Sprayer Type and PSI
OR	Corvallis Benton Co.	8 yr/5 ft.	Bluecrop	6/25 & 7/2	75 GPA	CO_2 Backpack; 3-nozzle boom (#80002vs); 40psi
WA1	Eltopia, Franklin Co.	6 yr/ 4 ft.	Duke	7/18 & 7/25	50 GPA	Rears Airblast w/ 3 nozzles 75psi
WA2	Mt. Vernon, Skagit Co.	7 yr/5 ft.	Duke	7/25 & 8/1	50 GPA	Rears Over-the-Row Boom 75psi
WA3	Lynden, Whatcom Co.	2 yr/2 ft.	Duke	7/22 & 7/29	75 GPA	Motorized Hypro-pump at 60psi w/ four 8006 nozzles
MI	?	?	?	?	?	?

Table 2. Treatment rates and number of applications

TRT #	Active Ingredient	Product Name	Rate (lb a.i./A)	Rate (product/A)	No. of Apps
1	Bifenthrin	Brigade 2EC	0.1	6.4 fl oz	1
	Imidacloprid	Admire Pro	0.1	2.8 fl oz	1
	Malathion	Malathion 8Flowable	2.5	40 fl oz	1
	Methomyl	Lannate LV	0.9	48 fl oz	1
	Spinosad	Entrust SC	0.1	6 fl oz	1
	Zeta cypermethrin	Mustang Max	0.025	4 fl oz	1
2	Carbaryl	Sevin 4F	2.0	2 qt	1
	Cyantraniliprole	Exirel	0.088	13.5 fl oz	1
	Esfenvalerate	Asana	0.05	9.6 fl oz	1
	Fenpropathrin	Danitol	0.3	16 fl oz	1
	Phosmet	Imidan 70W	1.0	1.33 lb.	1
	Spinetoram	Delegate	0.09	6 oz	1
	Thiamethoxam	Actara	0.06	4 oz	1
3	Bifenthrin	Brigade 2EC	0.1	6.4 fl oz	2
	Imidacloprid	Admire Pro	0.1	2.8 fl oz	2
	Malathion	Malathion 8Flowable	2.5	40 fl oz	2
	Methomyl	Lannate LV	0.9	48 fl oz	2
	Spinosad	Entrust SC	0.1	6 fl oz	2
	Zeta cypermethrin	Mustang Max	0.025	4 fl oz	2

Results:
Data from all sites are still being analyzed; results are preliminary. However, below are examples from a few of the treatments. All are based on one application unless otherwise notes.

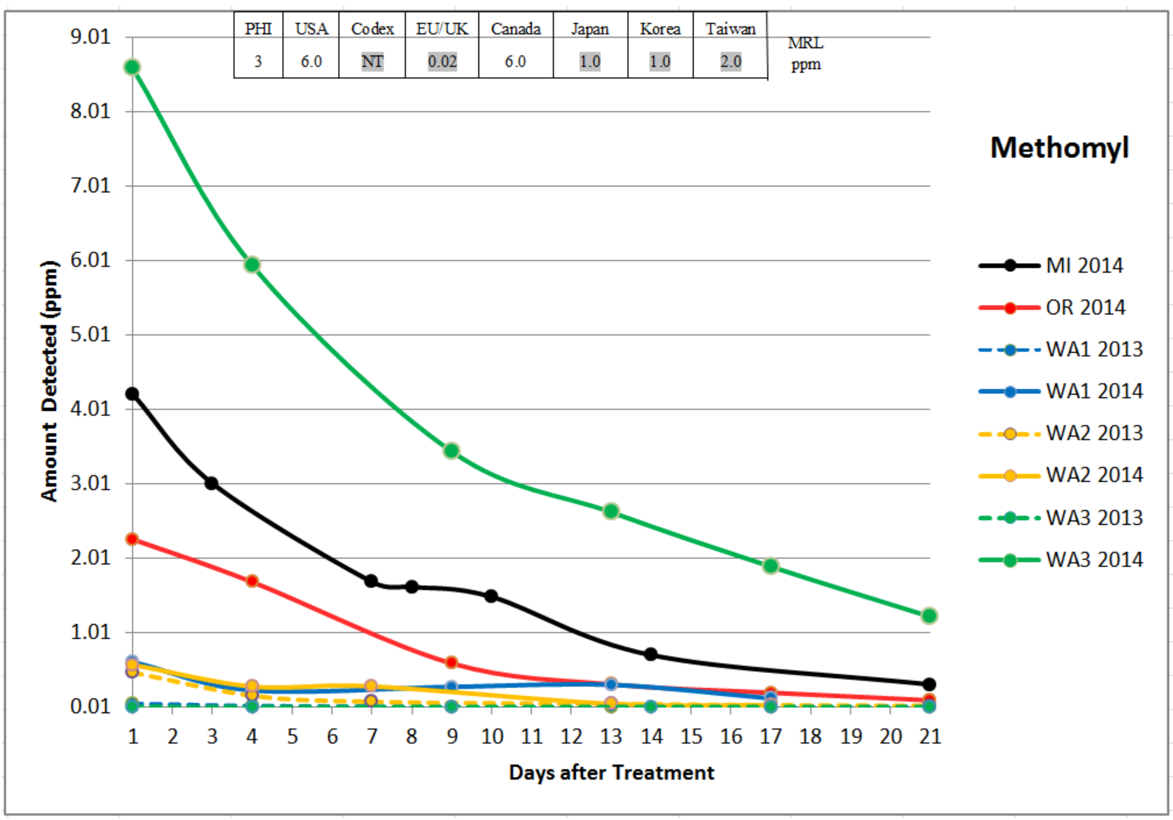

Figure 1. Decline of methomyl residues on blueberry fruit, one application, 2013 and 2014.

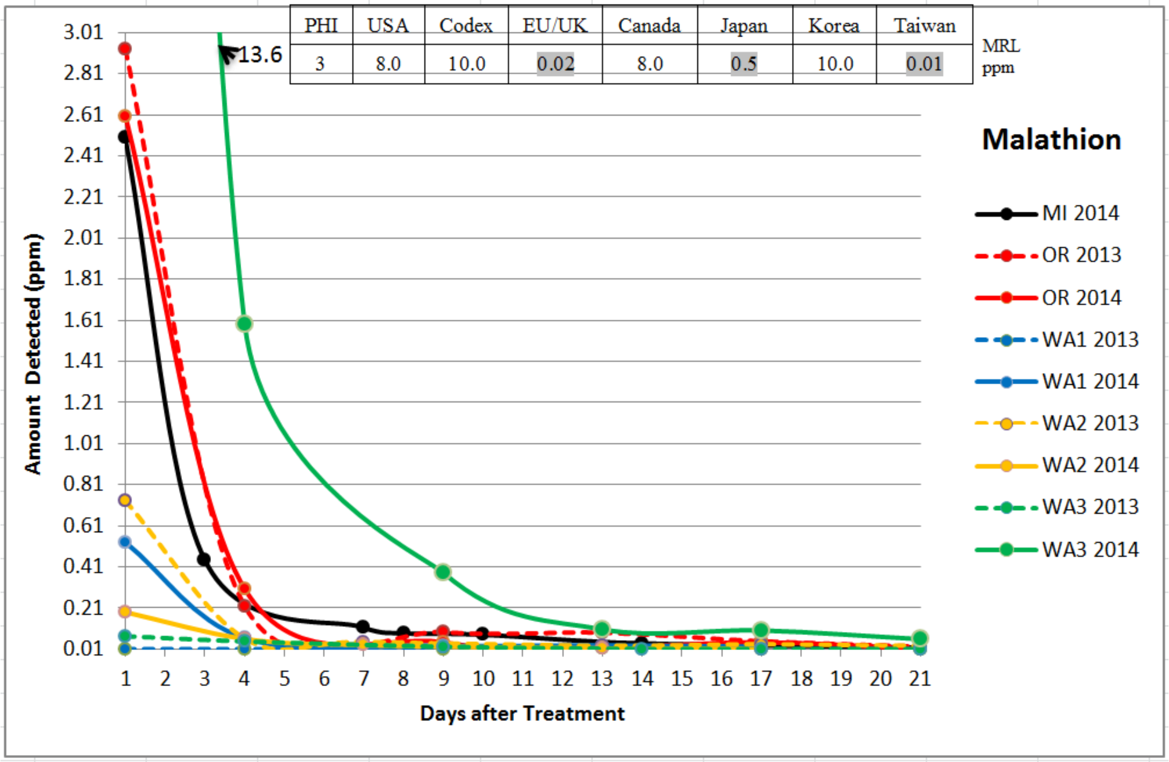

Figure 2. Decline of malathion residues on blueberry fruit, one application, 2013 and 2014.

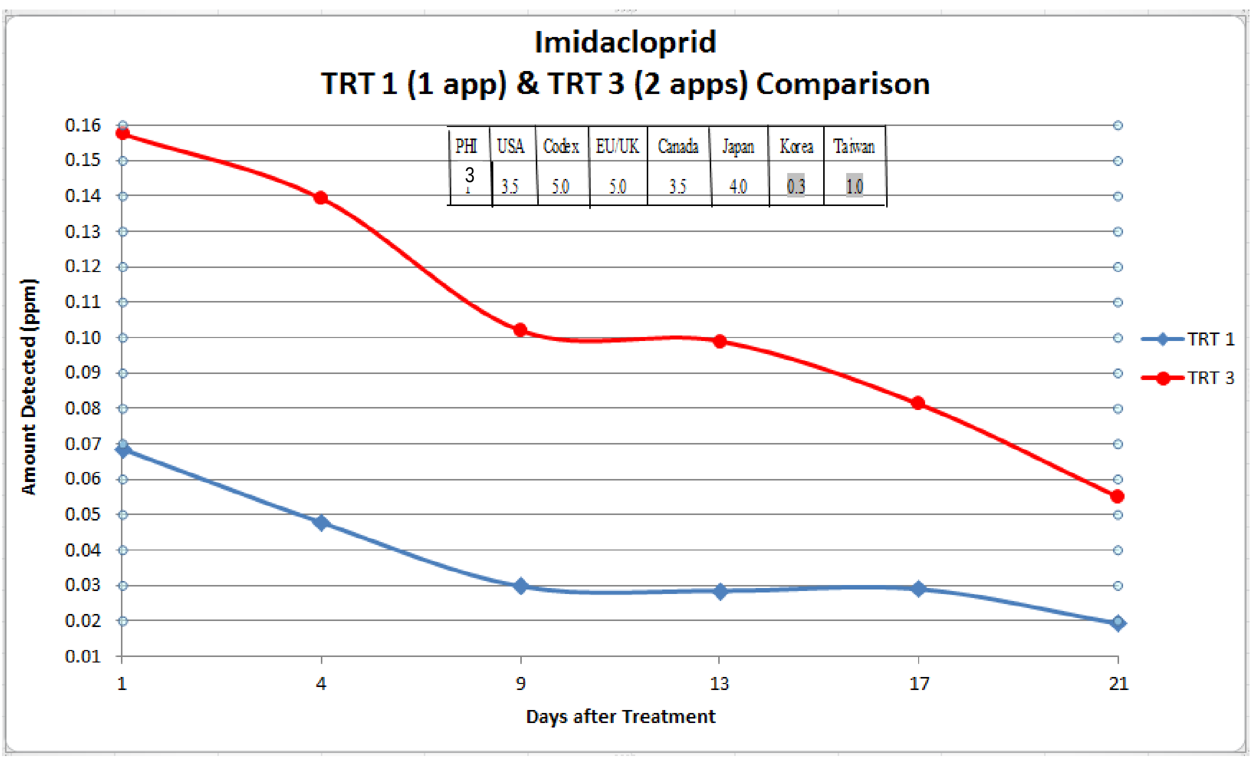

Figure 3. Oregon site: one application vs. two applications, apps made one week apart, 2014

Discussion:

The data for methomyl (Figure1) shows how the decline graph can be used to adjust pesticide applications to meet the MRL of certain countries. If blueberries are harvested according to the labeled PHI (3 days), the Michigan berries, for example, had residues that would likely not meet the MRL of Japan, Korea or Taiwan. However, if Michigan waited 6 to 7 days, they would meet the Taiwan MRL; if they waited about 13 days, they would meet the MRL in Japan and Korea.

The degradation graph for malathion (Figure 2) shows the rapid decline in residues over a four day period. This confirms suspicions that malathion is not providing the residual control that growers have expected from this compound.

Figure 3 shows a trend applicable to all the pesticides included in this study. Residues with two applications, applied one week apart, where higher than residues with one application.

CHRONIC TOXICITY OF RYNAXYPYR 20%SC, AN ANTHRANILIC DIAMIDE INSECTICIDE, ON THE ECTO-LARVAL PARASITOID, *BRACON BREVICORNIS* WESMAEL

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Biological control is an important tool of Integrated Pest Management of agricultural pests. Pesticides can reduce natural enemy effectiveness either by directly causing mortality or by influencing their both different biological and physiological activities. Exposure to lethal doses of pesticides causes direct mortality to natural enemies as well as sub lethal doses of pesticides have different adverse effect on insect biology and physiology. Rynaxypyr 20% SC, an anthranilic diamide, is used on broad range of crops to control a range of pests belonging to the Order Lepidoptera and some Coleoptera, Diptera and Isoptera species. The following programme is proposed to be undertaken to study it's chronic toxicity on *B. brevicornis* Wesmael, an important ecto-larval parasitoid of Lepidopteran crop pests.

Newly emerged adults of *B. brevicornis* Wesmael were repeatedly exposed for 48 h (once in each generation) to the recommended field dose (0.008%) and half of recommended field dose (0.004%) of rynaxypyr 20%SC, an anthranilic dyamide group of insecticide, up to 10thgeneration following leaf disc method. Adult mortality was recorded after the exposure period. From the treated population, 10 pairs of adults were separated and each pair was released in a glass tube (5cm dia.) along with honey solution as food and each of the containers was then supplied with 5 full grown larvae of *C. cephalonica*, sandwiched between two facial tissue papers. Remaining adults were used for further multiplication of the bulk culture for the experiment. After each exposure, observations were taken on various biological parameters of the treated population and their off springs.

Effect of insecticidal treatments was compared with the 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.

The mortality of treated *B. brevicornis* adults, adult longevity, fecundity, egg hatchability, pupation, adult emergence and sex ratio of the off springs were adversely affected due to exposure to insecticidal treatments that intensified gradually with increase in the number of exposures. Duration of life cycle of the off springs was not adversely affected by insecticidal treatments.

SECTION IV

Field Crop Pests

Moderator: Silvia Rondon

ENTOMOPATHOGENIC FUNGI AS A POTENTIAL BIOCONTROL STRATEGY FOR CLOVER ROOT BORER MANAGEMENT

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Entomopathogenic fungi offer great potential as biological control agents for soil dwelling pests. They produce spores that can effectively infect pests developing below ground that are a challenge to control with insecticides. One such subterranean pest is the Clover Root Borer (CRB) which damages red clover plants when raised for seed, and prevents the crop from being raised beyond two years thus causing economic hardship to growers. In the past, CRB was effectively controlled by application of organochlorine insecticides. Due to their persistence and non-target negative impacts, this group of insecticides was banned in the 1970's and currently, no insecticide is labeled for this pest. Meanwhile, naturally occurring insect pathogens (entomopathogens) have had an opportunity to build their populations over the years and may be suppressing CRB populations. However, there is no information about the association of CRB with naturally occurring entomopathogenic fungi and their virulence. Hence, the objectives of this study were to: 1) Determine the naturally occurring entomopathogenic fungi of CRB; 2) Assess the virulence of entomopathogenic fungi against CRB.

<u>Naturally occurring entomopathogenic fungi of CRB</u>: Soil samples were collected from fields growing red clover for seed production in the Willamette Valley. CRB were collected from the soil samples and pathogens observed growing on dead CRB were isolated and plated on appropriate media. In addition, soil baiting with wax moths was used for isolating pathogens from soil samples. Two species of entomopathogenic fungi, *Beauveria bassiana* (Fig. 1) and *Isaria fumosorosea* (previously known as *Paecilomyces fumosoroseus)*, were isolated from the fields. Two strains were isolated for each fungal species (Table 1). Thus, in all, 4 isolates of entomopathogenic fungi were collected from red clover seed fields in western Oregon.

<u>Virulence of entomopathogenic fungi against CRB</u>: Four strains of entomopathogenic fungi collected from the field and 2 commercial products, *Metarhizium anisopliae* and *Isaria fumosorosea*, were evaluated for their virulences against CRB. Ten adult beetles per petri dish were dipped in fungal spore solutions (10^8 spores/ml). The trial was conducted as a randomized block design with six replicates. The number of infected CRB was recorded daily for two weeks. All 6 strains of entomopathogenic fungi caused more than 70% mortality of CRB adults (Fig. 2).

The results of the study suggest that two naturally occurring entomopathogenic fungi, *B. bassiana* and *I. fumosorosea*, are present in red clover seed production fields in western Oregon. The absence of pesticide applications may have facilitated growth and development of these entomopathogenic fungi, and more species and strains may be present. Additionally, the study documented that field-isolated entomopathogenic fungi had similar levels of virulence compared to commercial products. Thus, *Beauveria bassiana*, *Isaria fumosorosea* and *Metarhizium anisopliae* have potential as biological control agents for CRB. Further research is needed to evaluate the efficacy of these fungi in suppressing CRB populations in fields in western Oregon.

Fig. 1. CRB adult infected by naturally occurring *B. bassiana.*

Table 1 Naturally occurring entomopathogenic fungi collected from clover seed production fields in the Willamette Valley in 2014.

Isolate No.	Isolate Source	Species of entomopathogenic fungus	Total number of isolates
1.	Soil	*Beauveria bassiana* A	4
2.	Dead CRB and Soil	*Beauveria bassiana* B	6
3.	Soil	*Isaria fumosorosea* A	2
4.	Soil	*Isaria fumosorosea* B	1

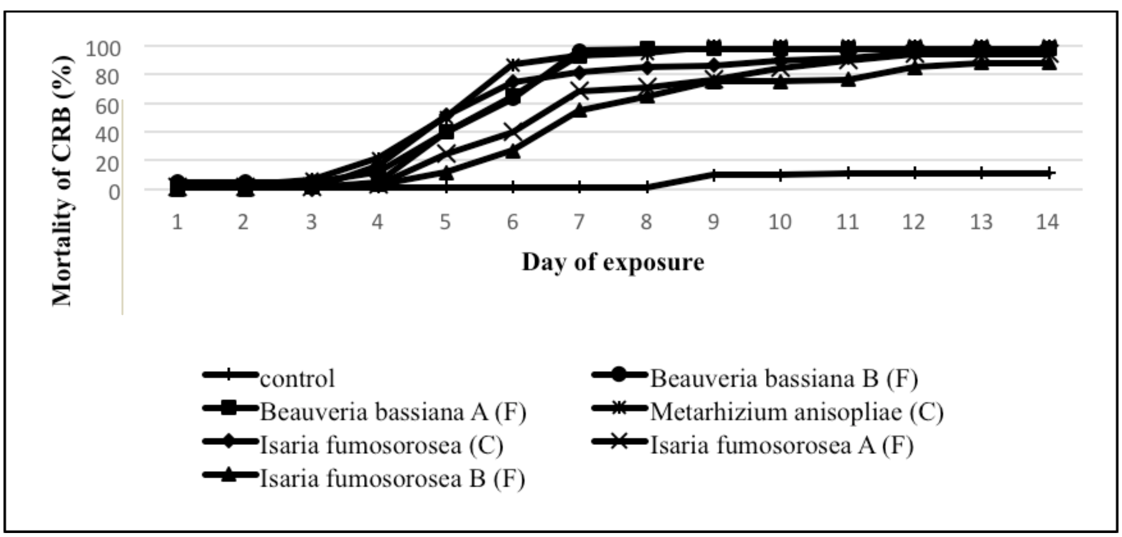

Fig. 2. The virulence of entomopathogenic fungi against CRB. Mortality (%) of adult CRB exposed to spores of field-isolated and commercial strains. (C) = Commercial product; (F) = Field collected.

SOAK OR SPRAY: CONTROL OF *POLYDRUSUS IMPRESSIFRONS* ON UN-ROOTED HYBRID POPLAR CUTTINGS

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Hybrid poplars are an irrigated perennial monoculture propagated by un-rooted branch cuttings. Leaves emerge during May and June, roughly two weeks following planting. Adults of the European species *Polydrusus impressifrons* (Coleoptera: Curculionidae) emerge and begin feeding on new leaf growth of hybrid poplars, and other nearby crops, starting in mid-May through late June. This pest has caused significant crop loss (cutting mortality, yield reduction, and stem malformations) on the Boardman Tree Farm (BTF) since 2010. Since first noted on the farm in 2004 *P. impressifrons* has continued to expand its distribution across BTF. Roughly 3,500 acres are treated annually for this pest with a fixed-wing aircraft. While quick and ultimately effective, this type of treatment leads to a large portion of the insecticide landing on bare ground and not the relatively small surface area of an emerging leaf. Previous studies have shown that soaking cuttings in an imidacloprid solution for 24-48 hrs has reduced *P. impressifrons* herbivory and increased first year growth. The objective of this study was to evaluate the efficacy of three techniques (soak, spray and load) to protect new cuttings from *P. impressifrons* herbivory.

This study examined two hybrid poplar clones (BC-79 & BC-82) that GreenWood Tree Farm Fund has deployed in their biomass plantings on BTF. Biomass stands are planted at a density of ~1,500 stems per acre, with each cutting being placed at an emitter along the drip tube. Planting material is gathered from nursery stands during January and February of the planting year and held in cold storage until planting in late-April and May. The soak treatment was initiated 48 hrs prior to planting in a solution of Admire Pro® (5.25 fl oz./ac). The spray treatment consisted of Coragen® (3 fl oz./ac) applied by backpack sprayer approximately one week following leaf flush. The load treatment consisted of Admire Pro® (5.25 fl oz./ac) applied in August of the previous year to the nursery stock via chemigation. Cuttings of each treatment (48 hr soak, 24 hr soak, load, spray & control) were hand planted the first week of May in a Latin Square design in Stand #805-4 at BTF. Leaf bunches and *P. impressifrons* adults were collected for no-choice feeding assay on 22 May 2014. These no-choice feeding assays were evaluated 48 & 96 hrs following initiation. Data collection and analysis was conducted by WSU Franklin County Extension Service.

Results indicate that spray and soak treatments had more *P. impressifrons* mortality than either the control or load treatments at both sampling times (Figures 1 & 2). These results also indicate that mortality increased over time across all treatments. Mortality in the spray and soak treatments were not significantly different at either sampling periods. This indicates that both these control techniques provide equivalent control of *P. impressifrons* on new cuttings in the hybrid poplar system.

While a spray or soak application may have the same efficacy on controlling the target pest, each treatment has its own challenges for the Boardman Tree Farm. Spray treatments generally result in a majority of pesticide not reaching the targeted new cutting leaves during this time of year. While soaking 500,000 cuttings presents logistical challenges (space, timing, worker exposure) to the grower, but does ensure that the pesticide is only applied to targeted area. It is likely that the Boardman Tree Farm will incorporate both of these control techniques into their pest control program based on these results.

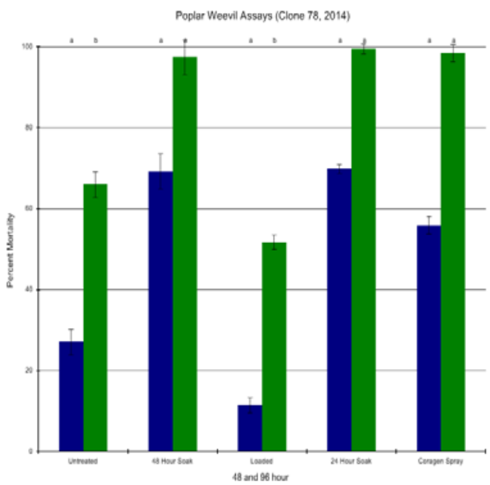

Figure 1. Results of no-choice feeding assay of hybrid poplar clone BC-78. *Polydrusus impressifrons* adults were placed in 16 oz. deli cups with small terminal branch of a new cutting. Spray = Coragen® (3 fl oz./ac), 24 & 48 hr Soak = Admire Pro® (5.25 fl oz./ac) & Load = Admire Pro® (5.25 fl oz./ac).

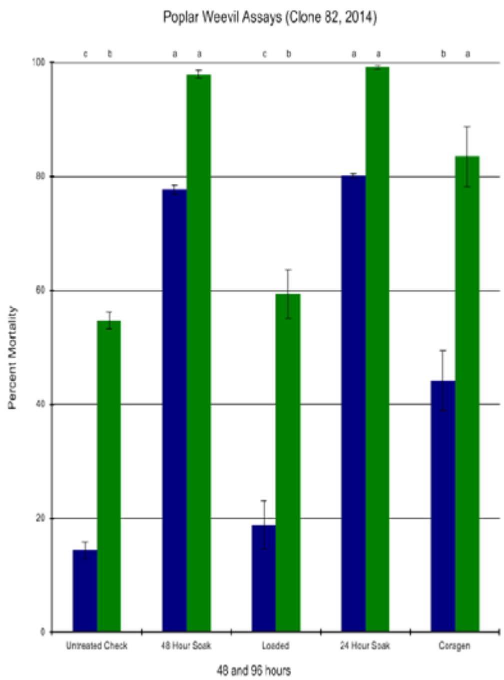

Figure 2. Results of no-choice feeding assay of hybrid poplar clone BC-82. *Polydrusus impressifrons* adults were placed in 16 oz. deli cups with small terminal branch of a new cutting. Spray = Coragen® (3 fl oz./ac), 24 & 48 hr Soak = Admire Pro® (5.25 fl oz./ac) & Load = Admire Pro® (5.25 fl oz./ac).

INSECT ABUNDANCE AND ITS ASSOCIATION WITH ERGOT DISEASE OF GRASS SEED CROPS

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Ergot, a seed replacement disease caused by a fungal pathogen *Claviceps purpurea*, is a great challenge for Kentucky bluegrass (KBG) and perennial ryegrass (PRG) seed producers in the Columbia Basin region of Oregon and Washington. This disease reduces yield, hinders seed certification efforts, and has been particularly difficult to manage even with multiple fungicide applications. The fungus infects the unfertilized flowers and results in the production of conidia carried in a sugary exudate known as honeydew which is believed to attract feeding insects and thus may contribute to disease spread. The ovarian content is replaced by fungal mycelium resulting into sclerotia formation instead of seed. Growers' concerns and inadequate information about insect vectors prompted the initiation of this study to understand the role of insects in ergot dispersal. Furthermore, insect population structures may shift with changes in climate and crop management practices over the years. Therefore, the first year of a multiyear survey was conducted to study insect population dynamics and seasonal diversity in PRG and KBG field.

Arthropod diversity was monitored in KBG fields during the 2006-2008 growing season. Sampling methods included pitfall traps, sweep netting, and sod sampling. Coleopterans (beetles) were the most abundant group (44% of total insects collected) closely followed by dipterans (flies, 22%) and hemipterans (true-bugs, 16%) (http://cropandsoil.oregonstate.edu/seed-ext/Pub/2007/18-Rondon.pdf). An additional survey was carried out to monitor the relative abundance of insects in both KBG and PRG field during April-June 2009. The species composition (Fig.1) indicated that higher populations of beneficial insects, including ground beetles occurred in KBG fields consistent to our previous results. In contrast, higher numbers of hymenopterans and flies were present in PRG fields. The difference in the population structure in these two crops could be due to the differences in the crop, management practices or food availability. Therefore, a subsequent study was done to determine the population dynamics and association of insects with ergot infection.

Insect abundance was monitored in four commercial KBG and PRG fields each from May to June 2014. The sampling techniques included universal black light traps, delta traps, yellow sticky cards, and modified sweep netting. Insects were sorted, counted and stored at −20ºC until microscopic examination for the presence of fungal spores. Ergot presence in or on insects was confirmed using a high-fidelity polymerase chain reaction (HF-PCR) developed in this study. Ergot incidence in the commercial fields was calculated based on the number of infected seed heads out of 100 seed heads collected from each quadrant of field sampled. Correlations between ergot incidence and insect abundance were calculated.

Dipteran insects comprised 60% of the total insect collected during the sampling period (Fig. 2) indicating that muscid flies comprised a larger proportion of the insect community in grass seed crops. These results confirm our previous findings in 2009 as higher population of *Fannia canicularis* (L.) (Muscidae), the lesser house fly occurred in PRG fields, suggesting the favorability of food resources. A significant positive association existed between insect abundance and ergot incidence in PRG fields surveyed (Fig. 3). However no association could be established in KBG fields because ergot incidence was negligible (data not shown). Microscopic examination revealed the presence of ergot conidia in the insect gut which was then confirmed with HF-PCR. Representative samples were cloned and sequenced to confirm *Claviceps purpurea*. Up to 35% of flies and 27% of moths tested positive (Fig. 4) for ergot using HF-PCR. Understanding the importance and the mechanism of insect-mediated ergot dispersal may aid in developing new strategies to manage this disease.

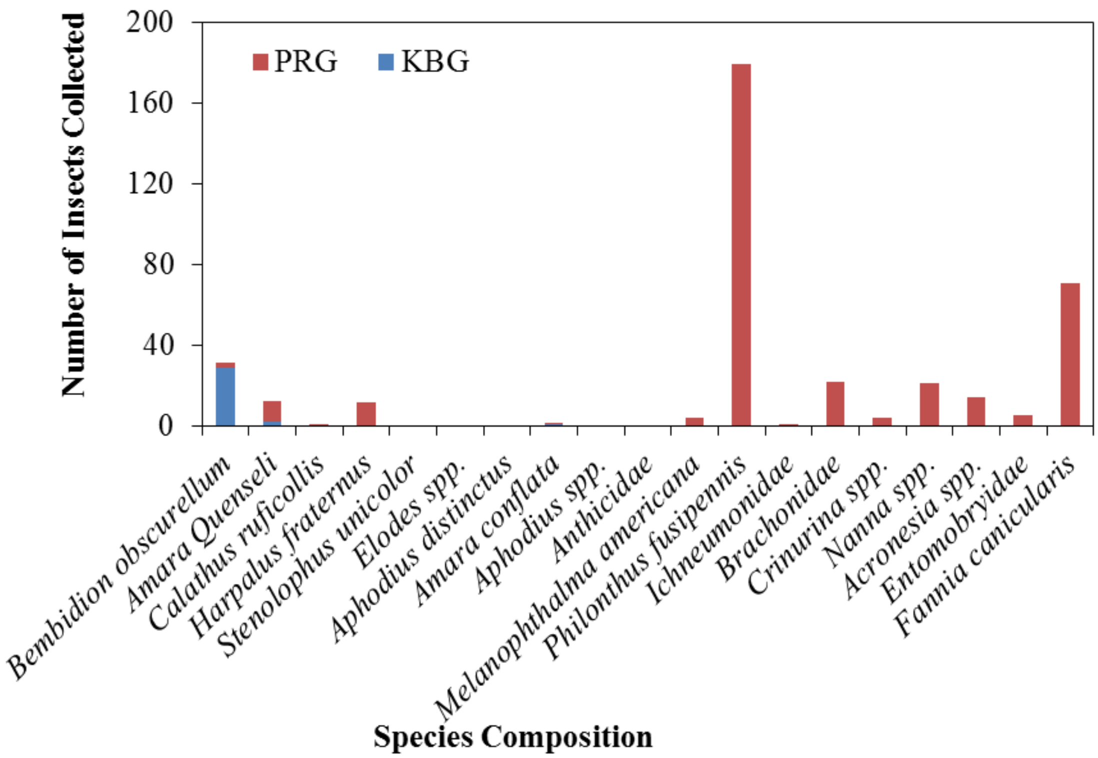

Fig. 1. Species abundance in perennial ryegrass and Kentucky bluegrass fields between April and June 2009.

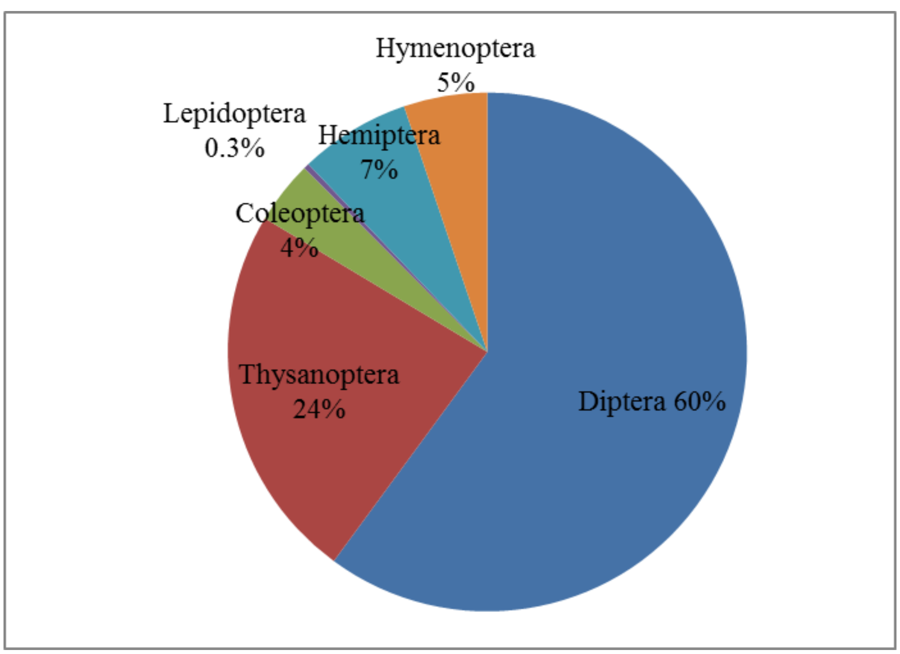

Fig. 2. Relative abundance of insect groups collected from commercial Kentucky bluegrass and perennial ryegrass seed fields during May and June 2014.

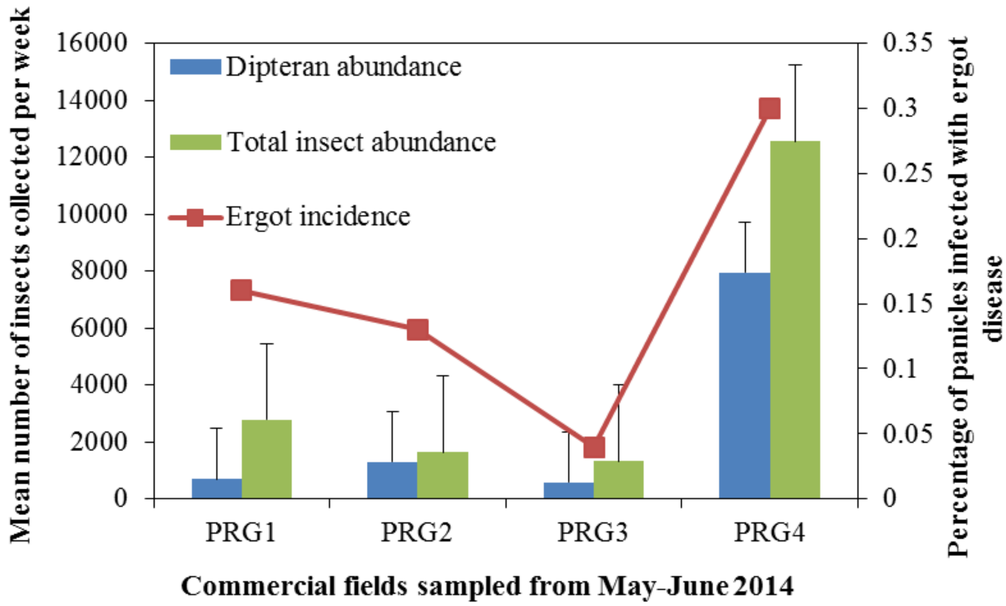

Fig. 3. A significant positive correlation (r = 0.9, P< 0.05) existed between insect abundance and ergot incidence in four commercial perennial ryegrass (PRG) fields during May and June 2014.

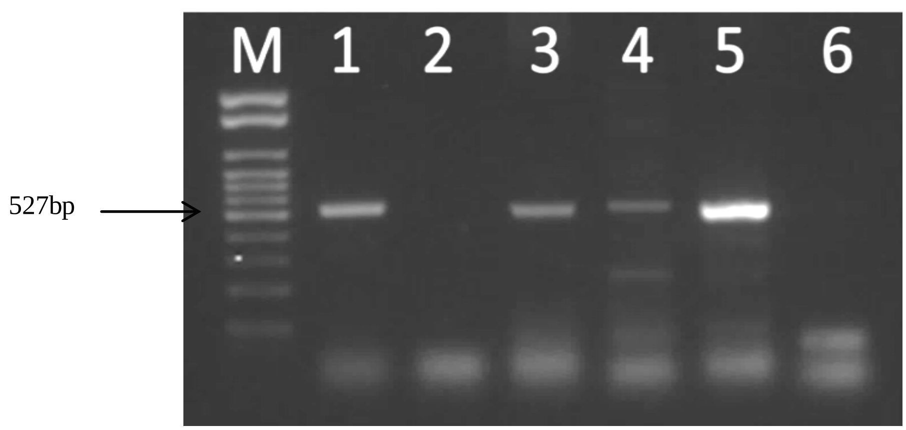

Fig. 4. Agarose gel results obtained from a high-fidelity polymerase chain reaction used to detect the presence of ergot on/in insects. M= molecular marker; Lane 1 = positive control; Lane 2 = negative control; Lanes 3-6 = insect samples collected from perennial ryegrass fields with ergot. The ergot beta-tubulin gene amplification product occurs at ~527bp length.

THRIPS CONTROL ON DRY BULB ONIONS

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Abstract
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. Additionally, we have evaluated the timing of initiation of insecticide applications in order to try to determine a thrips treatment threshold in dry bulb onions in the Columbia Basin. 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 Verimark all decreased thrips populations when applied via sprinkler chemigation as well. Starting insecticide applications before a population of 4 thrips per plant is reached reduced season long thrips numbers and preserved yield.

Materials and Methods
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. On April 2, 2014, an onion plot 120 feet wide and 350 feet long was established with two double rows of onions planted on each 44 inch wide bed. Double rows are 2 ½ inches apart with 3 inches in row spacing. Lorsban™ 15G (chlorpyriphos) was applied at planting and incorporated over the double row at the rate of 3.7 oz./1,000 row feet. 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 CO_2 pressurized three point tractor mounted research plot sprayer applying 30 gallons of water carrier per acre at 35 psi. Sprinkler chemigation applications were made with a trailer mounted research sprayer applying 0.12 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. At the end of the growing season onion yield and size were evaluated for comparison among treatments.

Results/Discussion
Figure 1 shows the average thrips per plant throughout the season for the treatment threshold study. Application timings resulted in different starting populations of thrips per plant at treatment initiation. This experiment can in turn be utilized to determine the treatment threshold. The treatments are labeled by 'Start Week' or the week of the trial in which treatments began. The trial resulted in evaluation of thresholds ranging from 1.1 to 8.2 thrips per plant. Figure 2 lists the starting populations, total average thrips per plant per week, and overall resulting yield. Weeks 8, 9, and 10 should be ignored for the analysis since the onions were becoming a poor host for thrips, and thrips populations began to naturally reduce in numbers prior to the initiation of the treatments. This can be observed when looking at the untreated check going from nearly 10 per plant to less than 2 per plant in a week's time (Fig. 1). Figure 2 illustrates significant differences in the season average thrips per plant at various starting populations. Yields do not differ significantly from one another, but the numeric trend is that lower

starting populations result in higher yields. The data demonstrates that if applications begin prior to 2 thrips per plant, thrips numbers can be kept low throughout the season and yields remain high. Yields in the section of the field used for this study were lower than the overall field average. If this experiment is conducted in a field with a more uniform crop, yields will probably differ more significantly between treatments.

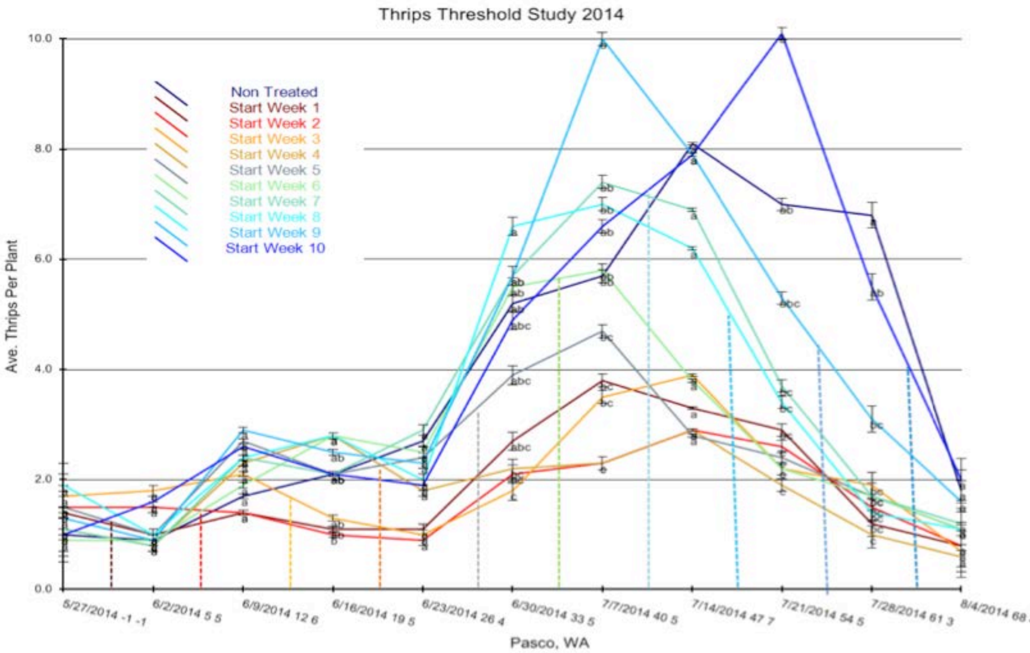

Figure 1. Average thrips per plant vs treatments on a weekly basis. Dashed lines indicate the date when applications for that color coded treatment began. Treatments with the same letters are not statistically different from one another (P=0.05 Student-Newman-Keuls test)

Treatment Start	Beginning Population (thrips per plant)	Season Average (thrips per plant)	Total Yield (tons per acre)
Week 1	1.1	2.00c	40.6a
Week 2	1.5	1.79c	36.7a
Week 3	1.4	2.07c	38.3a
Week 4	2.3	1.88c	39.9a
Week 5	4.0	2.48bc	35.2a
Week 6	6.0	2.78bc	41.1a
Week 7	8.2	3.59ab	33.1a
Week 8	3.5	3.43ab	34.1a
Week 9	3.1	4.18a	34.8a
Week 10	2.0	4.43a	35.3a
Non Treated Check	NA	4.11a	32.6a

Figure 2. Thrips per plant at start of treatments, season thrips average, and overall yield. Treatments with the same letters are not statistically different from one another (P=0.05 Student-Newman-Keuls test)

Figure 3 depicts the average thrips per onion plant by three different insecticides applied via sprinkler chemigation in comparison to an untreated check. The blue dashes indicate application dates. After two applications, the treated plots began to separate from the untreated check, all containing fewer thrips than the untreated, indicating that the insecticides were effective. They remained lower for the duration of the season and also had a significantly lower season average of thrips per plant. Figure 4 illustrates the onion size profile and overall yield for the same experiment. There were not statistically significant differences in the treatments, but the treated plots had a numerically higher yield than the untreated check, though all plot yields were quite low. Radiant and Verimark performed as well as Lannate, which is a standard product applied via sprinkler chemigation. This will give growers more late season options for thrips control reducing the likelihood of thrips developing resistance to commonly used Lannate.

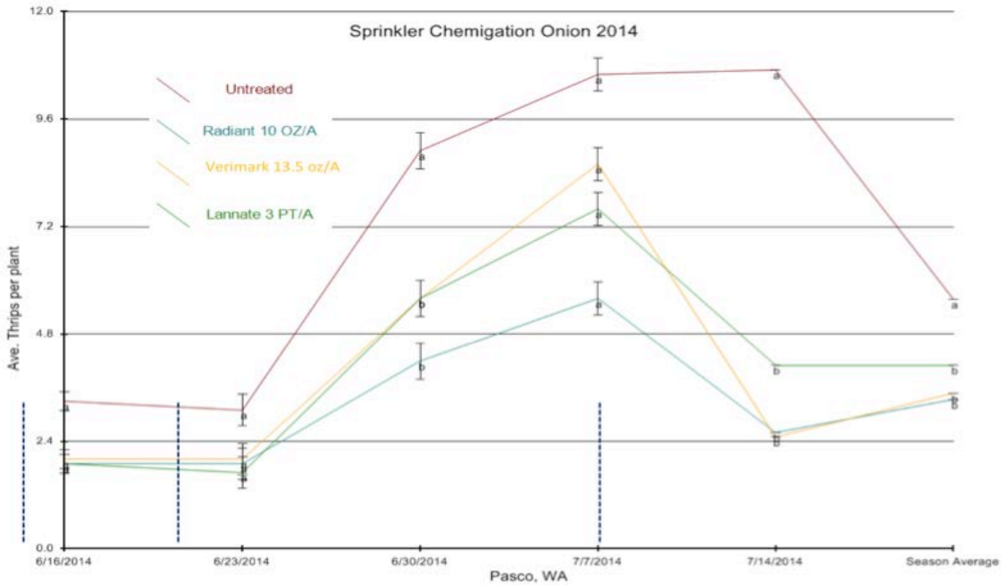

Figure 3. Thrips per plant versus sprinkler chemigation treatments by date and season average. Three applications were made of each product as indicated by the vertical blue dashed lines. Treatments with the same letters are not statistically different from one another (P=0.05 Student-Newman-Keuls test)

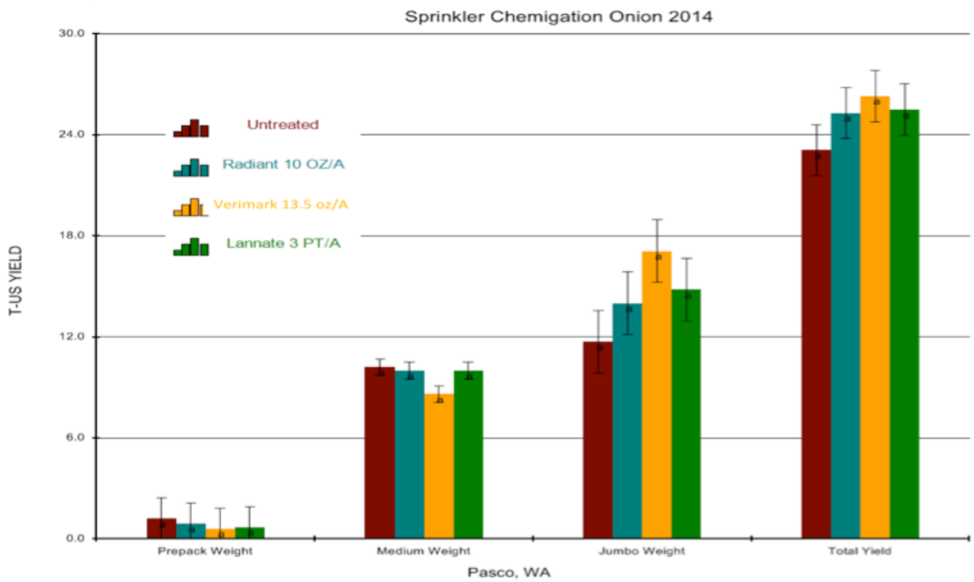

Figure 4. Onion size profile and overall yield versus chemical treatments. Treatments with the same letters are not statistically different from one another (P=0.05 Student-Newman-Keuls test)

Conclusions
Using insecticides that are effective at controlling thrips increases yield and size class of dry bulb onions. Chemigation proved to be an effective way to apply Lannate, Verimark and Radiant. Verimark was also effective when applied via drip injection. The threshold study indicates that applying insecticides before thrips reach a population of 4 per plant will prove to be effective for season long management.

Not all compounds tested are currently registered for use on Onions in Washington State. Do not use unregistered compounds. Consult your local Extension office and read and follow label directions. Oregon and Washington labels (PICOL):
http://cru66.cahe.wsu.edu/LabelTolerance.html

Funding for this project was provided by: the Washington State Commission on Pesticide Registration; Pacific Northwest Vegetable Association , Carr Farms, Cascade Specialties, Easterday Farms, Grigg Farms, Mercer Canyons, McCain Foods USA, River Point Farms, Roloff Farms, Sunheaven Farms, Brandt Monterey, Syngenta, Nichino, Dow Agrosciences, and DuPont. **Technical assistance and in kind support was provided by**: Don Kinion, WSU Extension, Greg Jackson, Two Rivers Terminal, Bob Middlestat, Clearwater Supply. **Plot evaluations were conducted by the WSU Vegetable Extension Bug Counters**: Cassandra Comstock, Dylan Vermul, Justin Scozylas, Nathan Roberts and Carol Hernandez.

SECTION V

Potato Pests

Moderator: Joe DeFrancesco

SAMPLING POTATO PSYLLID *(BACTERICERA COCKERELLI)*: AN ANALYSIS OF MULTIPLE MONITORING TECHNIQUES AND INTERACTIONS WITH CROP ENVIRONMENT

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The potato psyllid, *Bactericera cockerelli* (Sûlc, 1909), is an agricultural pest that has been reported on over 20 families of plants. In potatoes, *Solanum tuberosum* L., the psyllid can cause feeding damage, but more importantly it can transmit a bacterium known as *Candidatus* Liberibacter Solanacearum, which causes Zebra Chip disease. Tubers affected by the disease are unacceptable for sale or consumption.

Growers, use various methods to monitor their fields for potato psyllids and often use that information to make management decisions. However, different monitoring techniques are not necessarily directly comparable and can lead to incorrect management decisions if not interpreted correctly. In this study, the numbers of potato psyllids collected with yellow sticky cards, inverted leaf blowers, leaf samples, and pheromone plus unbaited cards were compared in multiple crops.

Potato psyllids have been collected on wheat and corn, two non-host crops, but it is speculated that this occurrence is due to psyllids locating and feeding on volunteer potatoes in those crops. Therefore, in this study, the comparison of sampling techniques was made in diverse crop environments to elucidate any interactions between sampling method and crop. Potatoes, corn, wheat, and corn planted with volunteer potatoes, and wheat planted with volunteer potatoes were arranged in a Latin Square design. In each plot, psyllid adults were collected with inverted leaf blowers and sticky cards, while eggs and nymphs were collected with leaf samples. In a separate study, 10 pheromone lures (provided by Alpha Scents Inc.) and an unbaited control were tested in a randomized complete block design.

Results indicate that the highest mean psyllids were found in potato, although only significantly higher than corn (Fig. 1). These results provide evidence that volunteer potatoes have the potential to support populations of potato psyllids in other crops. No significant differences exist between inverted leaf blowers and yellow sticky cards; data from leaf samples will also be analyzed and presented. As for the pheromone trial, no lures were significantly more attractive than an unbaited control (Fig. 2-3). These results have the potential to lead to more effective sampling, and by extension, control of the potato psyllid.

Fig. 1

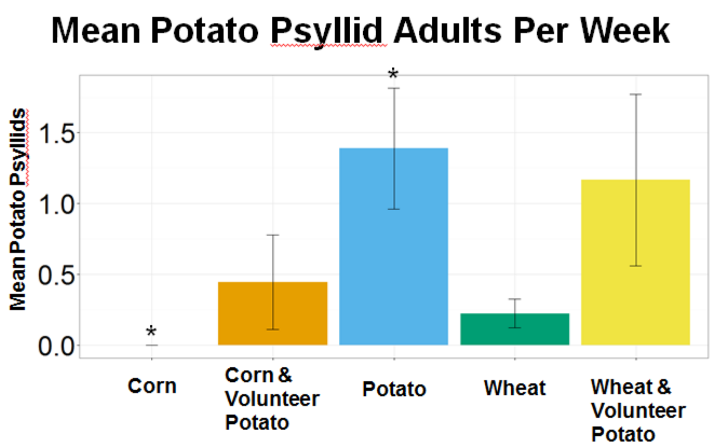


Fig. 2

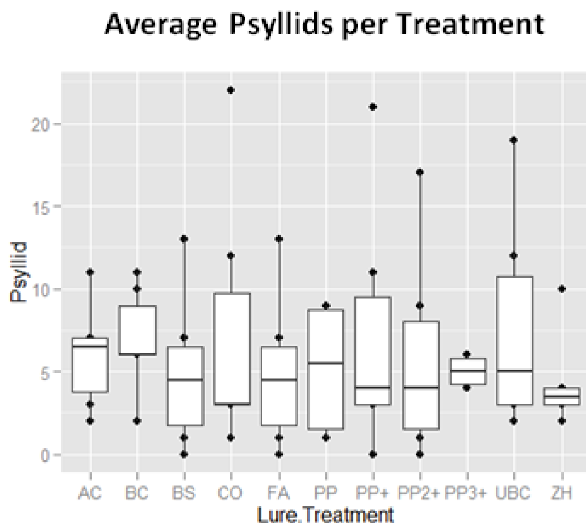
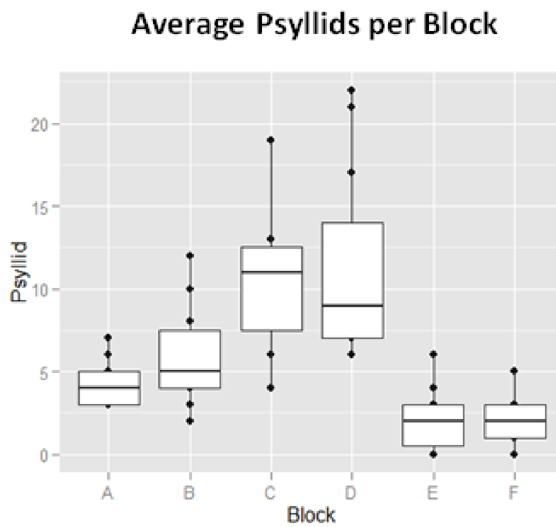


Fig. 3



COLORADO POTATO BEETLE RESEARCH IN OREGON

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Colorado Potato Beetle (CPB) is a significant pest of potatoes but it also causes significant damage to other Solanaceous crops such as tomatoes or eggplants. Besides its unbelievable feeding capability (see Figure 1), CPB has a high fecundity rate and the ability to develop resistance to almost every chemical commercially available. In potatoes, populations can build quickly and defoliation occur rapidly causing significant yield loss if left uncontrolled.


Figure 1

The beetles overwinter in the soil as adults, with the majority aggregating in areas adjacent to fields where they have spent the previous summer. In the Pacific Northwest, the emergence of the majority of these beetles is synchronized with potatoes emergence. Although this insect can fly, the next field may just be a walk away from the overwintering sites. Once in a new field, first adults feed and then mating begins. The feeding and reproduction continues until diapause is induced by the short-day photoperiod.

Unmanned Aerial Vehicle and CPB

An unmanned aerial vehicle (UAV), commonly known as a "drone" is an aircraft without a human pilot aboard that uses as research premise that high frequency UAV visits utilizing high quality imagery can deliver critical, actionable crop intelligence at a level of cost and efficiency that will open the agriculture market to large scale deployment of UAV. In 2014, a project concentrated on the ability of UAV-based sensors to detect CPB infestations; compare crop yield between a UAV-based threat response, and a standard prescription methodology; and the development of algorithms to reduce data and response latency. Some promising results showed the capability of high quality imaging can potentially detect insect and/or damage presence (Figure 2).

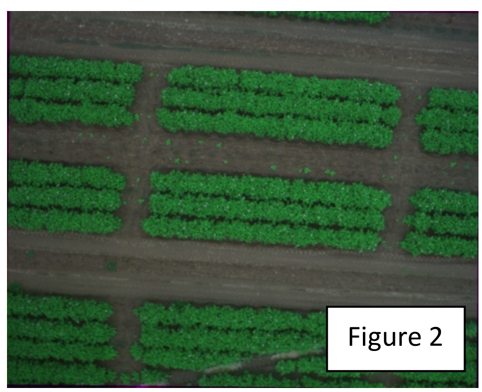
Figure 2

Chemical Control and Insecticide Resistance

Hundreds of compounds have been tested against the CPB and insecticides still remain the foundation of the CPB control on commercial potato farms. Over 30 active ingredients are registered for use against this pest in the U.S. but the efficiency varies from region to region. Insecticide resistance has been historically problematic from the Northeastern United States. In that region, resistance problems reached critical levels in the early 1990s. So far, no resistance problems have occurred in the Pacific Northwest (PNW) but vigilance is needed. As far as we know, there is one isolated case where chemicals failed to control CPB but further investigation is needed. The PNW area produces more than 55% of the potato production in the U.S. producing the highest yields in the world. Exact reasons for the apparently more severe resistance problems in the Northeastern U.S. remain unknown. The CPB evolutionary group that we are part of speculates the evolutivity nature of this pest. The favorable climate moderated by the Atlantic Ocean allows high beetle survival and multiple generations per year; this is further enhanced by the fact that grower use of late maturing varieties, irrigation, high rates of synthetic fertilizers, and not killing vines until late in the season; also, grower practices emphasize chemical control over crop rotations and other non-chemical pest management, thus creating strong selection pressure on beetle populations. Isolation of Northeastern potato fields may also favor local selection for insecticide resistance. In the western U.S., it is imperative that a judicious use of chemicals is followed in order to preserve active ingredients for further use.

Since 2005, several chemicals (Table 1) have been tested at the Irrigated Agricultural Entomology Program at the Hermiston Agricultural Research and Extension Center in Hermiston, OR. Experimental plots are 4 rows wide x 30' feet long; 34" row spacing (25,000 plants/a); Randomized Complete Block (RCB) with four replications per treatment. Normal commercial production practices are followed throughout the season (e.g. fertilization, herbicide, fungicide, etc). Information related to performance of some commercial products and its viability will be presented.

Table 1. Chemical products tested against the Colorado Potato Beetles in the Columbia Basin, OSU-HAREC-IAEP.

Group	Active ingredient	Trade name
6	abamectin	Agri-mek
28	chlorantraniliprole	Coragen
22	indoxacarb	Avaunt
15	novaluron	Rimon
5	spinetoram	Radiant
5	spinosad	Blackhawk
21a	tolfenpyrad	Torac
4A	imidacloprid	Tops MZ Gaucho
4A	imidacloprid	Admire Pro
4A	thiamethoxam	CruiserMaxx
4A	thiamethoxam	Platinum
4A	clothianidin	Belay

Blue, ground or aerial treatment; yellow, seed treatments; green, in furrow applications.

CASE STUDY OF A COLORADO POTATO BEETLE CONTROL FAILURE IN THE PACIFIC NORTHWEST

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In the latter half of September Alan Schreiber was made aware of a failure to control Colorado potato beetle (CPB) in two fields of potatoes in Oregon. Schreiber contacted WSU Area Extension agent, Dr. Tim Waters, about this as his name was mentioned as someone who knew about the incident. Waters described the situation as a terrible CPB infestation that had defoliated entire sections of two circles of potatoes despite a seemingly aggressive insecticidal control program. Waters and Schreiber had a teleconference with the crop advisor to find out more about what happened. Waters and Schreiber have visited the fields in questions three times. The authors feel that communicating what was observed and what happened in these fields is important to the greater potato growing community. Here is the background:

A farm had five fields of potatoes, three were harvested early, and two were to be harvested at the end of September. The three early fields had CPB control challenges but due to early harvest the damage to the field was less severe than that observed in the two fields harvested later in the season. The remainder of this report will focus on the two late fields of potatoes.

The two fields were planted in April with seed treated with Cruiser (thiamethoxam) with Vydate applied in furrow. Plants along the edges of the field become infested from CPB emigrating from other fields in May. Of particular note is that some plants were attractive to beetles and were in the process of being defoliated in the rosette stage while other adjacent plants were unaffected by CPB. The crop advisor became concerned about the CPB infestation as the infestation spread from the edges of the field to past the first three wheel tracks of the pivot. Early season CPB pressure was much higher than what is usually observed on this farm and region. The crop advisor had the field treated with Belay (chlothianidin) on May 20 at a labeled rate. On May 24th an application of Vydate (oxamyl) was applied by ground in a band over six inch rosette potatoes for nematode control but with the expectation that it help with CPB control. The applications seemed to make a difference and reduced CPB populations to lower levels; however the CPB population soon resurged to a level of intensity greater than prior to the treatment. Vydate applications were made on June 3 and 18 by chemigation with the expectation that the applications would reduce the CPB to an acceptable level. By July 7th, CPB had defoliated parts of field and the crop advisor felt more aggressive measures were necessary and had the field treated with a tank mix of 4 ounces of Coragen (rynaxpyr) and Vydate by chemigation. The application was done on a fast lap at a water volume of 0.12 acre inches of water. This treatment reduced the CPB population significantly, but in two weeks the population was "raging back again". On July 22nd, another Vydate application was made. By early August large portions of the field were being defoliated so an application of 12 oz of Athena (package mix of abamectin and bifenthrin) was made on August 8th by air with 7 gallons of water and a silicon surfactant. This application seemed to kill most of the larvae but did not have the desired effect on the adult. On August 15th, Coragen was applied at roughly a 5. oz rate by air at 10 gallons with 1% MSO surfactant (Pierce). This application provided some reduction in CPB populations, but did not reduce the population to an acceptable level. By this time defoliation in the field was severe in the hardest hit areas.

On August 23rd, 8 oz of Radiant (spinetoram) was applied by air at 10 gallons with MSO and Wetsit at 1 quart per hundred gallons. When Tim visited the field in August and in mid-September, he described the fields as the worst CPB damaged he had ever seen. A number of agrichemical company representatives with products involved in the CPB control program were asked to visit the field to see if they had an insight into why the CPB population could not be controlled. Jim Zahand, Dow AgroSciences, said that this was the worst CPB damage he had ever seen in over 30 years. I visited the field on September 25th and why I saw could only be considered shocking. Large areas of the field were dead from defoliation. CPB had eaten the plants to the ground, were eating stubs of stems down into the ground and eating exposed tubers. Acres and acres of the fields look like the untreated check in a CPB efficacy trial in a heavy pressure situation. Commercial fields do not have CPB problems like this field did.

Field defoliation by CPB-several of the green plants are weeds, although some are potato plants. If you look carefully you will see stems, but no leaves. Curious that some potato plants seem unscathed.

In review, the fields received the following treatments of insecticides with CPB activity in this order; Cruiser/Vydate at planting, Belay, Vydate, Vydate, Coragen/Vydate, Athena, Vydate, Coragen and Radient, or a total of nine insecticide applications of six different products. In hindsight it might be easy to pick over what happened and think that the crop advisor should have done something different, but the authors suspect if any one were to have been asked in advance if the above program would keep CPB under control, we all would say not only yes, but such a program would probably be more than necessary. During the season, particularly as the season progressed, some individuals were either suggesting that resistance to CPB had finally arrived in the Columbia Basin and, why not when almost every significant potato growing state with CPB outside the PNW has resistant populations. Oregon State University put out the following statement at the end of September.

Late-season populations of Colorado potato beetle
Colorado Potato Beetle (CPB) has developed very high levels of resistance to insecticides in many parts of the country. Most populations in the Pacific Northwest are still susceptible to most labeled products so please be aware.

***Carefully rotating chemical modes of action is critical to slow the development of insecticide resistance**. The choice of insecticide should be based on effectiveness and not pricing. Also, while providing good coverage of the plants, products should be applied at the full recommended effective dose. Young larvae are the most susceptible to insecticides; adults are more difficult to control.*

Because Schreiber does significant insecticide related research in potatoes and his Ph.D. dissertation was on monitoring and analyzing field resistant populations of insects, he was interested in this problem. Waters supplied Schreiber with a couple of hundred larvae collected from the field on September 18th. On the 19th, Schreiber conducted a laboratory bioassay on third and fourth instar CPB larvae. Schreiber was most concerned about neonicotinoid resistance (having a population that seemed to have come through both thiamethoxam and chlothianidin would be alarming to say the least) he screened the population against the highest label rate of Platinum (thiamethoxam), imidacloprid and clothianidin, as well as esfenvalerate (at the time it was not known what pyrethroid had been applied) and rynxapyr.

Potato leaves were treated with the high field rate of imidacloprid, clothianidin, thiamethoxam, rynaxypyr and esfenvalerate. Five larvae were placed on each treated leaf. The leaves were placed in a petri dish and taped closed. They were held at room temperature. Each treatment was replicated four times for a total of 20 larvae. We placed the same number and type of larvae on untreated leaves as a check. Five larvae each, replicated four times for each treatment, for a total of 120 larvae for the test.

The results at 24 hours were strikingly clear. Every larva in every dish in every insecticidal treatment was dead or dying. Every larva in every dish in the untreated dishes was alive. Furthermore there was virtually no feeding on the treated leaves. The untreated leaves were completely devoured within 24 hours. These results indicate that the CPB larvae that I tested from the field in question do not appear to have resistance (as defined by the ability to survive a field rate of an insecticide that was previously known to control that pest).

Bioassay of CPB larvae. At 24 hours the larvae in the check had defoliated the leaves and all insecticidal treatments have virtually no feeding. All larvae were dead at 24 hours.

On September 25th, Schreiber visited the two fields. Virtually no CPB larvae were present although they had been widely present 7 days earlier when Waters visited the field. Presumably in the interim they had dropped to the ground and entered the soil to overwinter. Schreiber easily collected CPB adults as they were stunningly present.

The adults Schreiber collected were from the second field that had a control problem and not from the field that Waters had collected larvae from the previous week. Schreiber repeated the laboratory bioassay procedure used on the larvae on the adults. He treated leaves with the high label rates of active ingredients used against the CPB in this field, with the exception of oxamyl (Vydate). Active ingredients tested were thiamethoxam, chlothianidin, rynaxpyr, abamectin, bifenthrin and spineotram. Five adults were placed on a leaf and both were treated with the full labeled rate of each active ingredient. Each treatment was replicated six times. As a check, adults were placed on leaves and sprayed water. Schreiber was able to find nine larvae in 90 minutes of collecting, while passing over approximately 1,000,000 adult CPB. The larvae were placed 3 to a leaf and the 3 leaves were placed in 3 petri dishes. The dishes were taped closed. The CPB were evaluated at 24 and 48 hours.

Results of adult bioassay. The adult bioassay results were remarkably different from that of the larval bioassay. A liberal definition of alive was used. If the insect was obviously alive or if it would move when prodded, it was considered alive.

	24 hours			48 hours		
	Alive	Dead	% mortality	Alive	Dead/dying	% mortality
Untreated	30	0	0	30	0	0
Abamectin	3	27	90	3	27	90
Thimethoxam	5	25	83	0	30	100
Clothianidin	21	9	30	18	12	60
Bifenthrin	26	4	13	23	7	77
Rynxapyr	22	8	73	29	1	3
Spinetoram	20	10	66	14	16	53

It is very important to note that in virtually every case, that although these beetles were alive, they were not healthy in appearance and did not appear to be in a state that could cause crop damage. Virtually all beetles that were not dead appeared to be intoxicated, paralyzed or incapacitated. Beetles exposed to each insecticide had a unique set of features that seemed diagnostic to the active ingredient.

Abamectin – The few beetles exposed to abamectin alive at 48 hours were upright, standing off of the plant, could walk but were not feeding but had antenna that were twitching.

Thiamethoxam – thiamethoxam exposed beetles were off the plant, lying on the sides or on their back with legs moving in an unproductive manner. They could not right themselves. After 48 hours, three beetles seem to recovered enough to walk, but were never observed feeding.

Clothianidin – these beetles acted very much like thiamethoxam exposed beetles, lying on their sides or back with legs moving in an unproductive manner. In some beetles the elytra was raised and did not return to a closed a position.

Bifenthrin – surviving beetles either stood on the leaf or slowly walked around the petri dish. None were observed feeding. None were on their sides or back unless they were dead.

Rynaxpyr – these beetles seemed to be less affected with the living beetles upright, mostly on the leaves, acting more typical, although a few wandered around the petri dish. None were observed feeding.

Spinetoram – spinetoram exposed beetles appeared intoxicated, were holding on the leaf but not feeding. No beetle appeared functional.

Schreiber's first observation of the beetles was at 24 hours. At that time, some feeding had occurred however, no beetles were observed feeding after 24 hours. When observing the beetles, a vision kept returning to Schreiber. The beetles reminded me of cattle in a winter snow storm, hunkered down and trying to ride out the adverse conditions. It is curious and important to note that in some cases, the beetles seem to recover to some degree. This was most notable in the rynaxpyr (Coragen) treatment where I had rated 73% of beetles as dead at 24 hours and at 48 hours, I rated 3% dead. In a commercial field, Schreiber estimates that many of the beetles rated as alive would have been either on the ground or would have been holding on to leaves not feeding.

Radiant Larval Bioassay. All nine larvae treated with Radiant were dead at 24 hours.

Resistance or Not? We are defining resistance as the ability for a pest population to survive a field rate of a pesticide that formerly gave acceptable level of control. Not a perfect definition, but for this situation, it should work.

Clearly based on the larval bioassay, this population is not resistance to thiamethoxam (Cruiser), imidacloprid (Admire Pro), clothianidin (Belay), esfenvalerate (Asana) or rynaxpyr (Coragen). The situation is murkier for the adult bioassay as we had beetles that were alive at 48 hours for every insecticide tested. Because we did not have a known susceptible lab strain, we cannot conclusively state that there is or is not resistance. However, we make an argument for the position that resistance is not present.

1. The larvae tested susceptible/not resistant for five different active ingredients from three modes of action (Group 4a, Group 5 and Group 28). It is rare, but not unheard of for an insect pest to have susceptible larvae but resistant adults. This does happen, with houseflies being the most commonly represented of this type. This type of resistance occurs because insecticide applications are directed at adults and there is no selection pressure against the immature stages. In CPB, resistance is almost always occurs in the larval stages as well as the adult stages as there is always simultaneous exposure.
2. In the OSU statement on CPB resistance, they say "*Young larvae are the most susceptible to insecticides; adults are more difficult to control.*" When talking to registrants regarding efficacy of their product against CPB, most of them have said that efficacy against larvae is greater than

against adults. It is probable that adults are just more tolerant than larvae and the adults survived due natural tolerance as opposed to resistance.

3. The fieldman stated that there was no problem controlling CPB in potatoes in previous years on this farm. A control failure like this has ever happen on this farm or on any field in the region in any year in his career, he said. When one considers the number of modes of actions used against this population; Cruiser/Belay (4a), Coragen (28a), Vydate (1a), Athena (Group 6, Group 3) and Radiant (Group 5), which total six modes of action, some of which were used simultaneously; the likelihood of resistance developing within a year is vanishingly low.
4. Although many adult beetles survived a field rate of an insecticide, and for some insecticides most beetles were alive at 48 hours and in some cases, beetles that initially appeared dead at 24 hours were alive at 48 hours, these beetles did not survive because they were resistant to the insecticide. They succumbed to the insecticide and would have been on the ground, not feeding and would not have been mating and laying eggs. It was an eye opening experience to watch these beetles so closely and observing their behavior. (Schreiber spent a weekend watching 45 petri dishes with CPB.)

Conclusion. *Considering the balance of these facts and observations, we are concluding this population is not resistant to any of the nine insecticides screened against CPB larvae and adults.*

CAN THIAMINE TREATMENT REDUCE POTATO VIRUS Y ON POTATOES?

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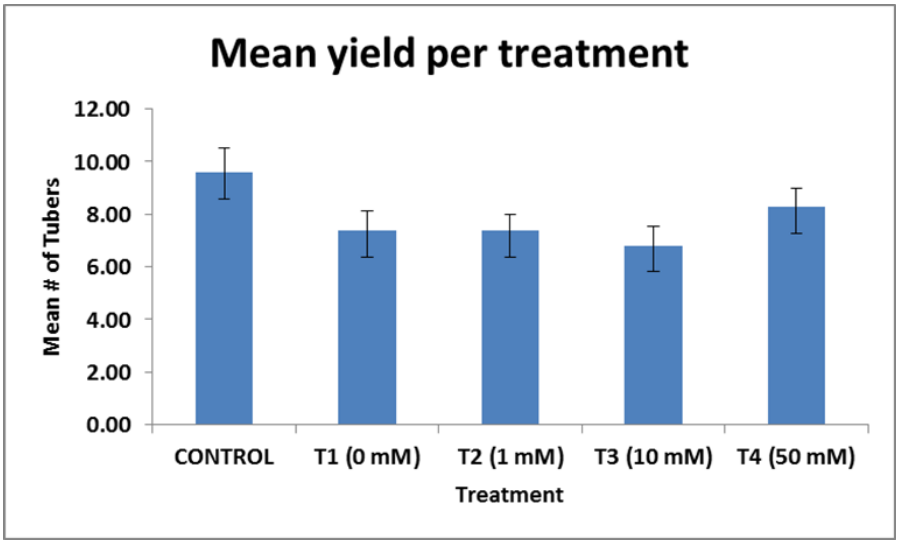
Potatoes are a large commodity for Oregon and the Pacific Northwest; 56% of the United States potatoes are grown in Idaho, Oregon, and Washington. Potato Virus Y (PVY) is a major pathogen affecting potato fields in the Pacific Northwest. PVY is an extremely important disease of potato worldwide that causes significant yield losses depending on the strain and the potato cultivar. It is a non-persistent virus transmitted by aphids. Foliar symptoms include mosaic, chlorosis, leaf drop and with certain PVY strains and potato cultivars can lead to Potato Tuber Necrotic Ringspot Disease (PTNRD) in tubers. Thiamine, or vitamin $B_{1,}$ has been shown in many crops to boost the plant's immunity and increase its tolerance to diseases, thereby increasing resistance against pathogens by inhibiting disease progression and reducing pest populations. Our objective for this study was to test the effect of thiamine application on potato resistance to PVY, an economically important disease vectored by aphids. This is the first time that thiamine was tested using potatoes as a model crop.

Thus, a screenhouse study was conducted to determine whether thiamine provided resistance against aphids and PVY. We tested different densities of aphids (1, 5, and 10 per plant) on potatoes using four treatments of thiamine at different concentrations (0, 1, 10 and 50 mM) in a randomized complete block design. We released aphids negative for PVY into clip cages on our two "clean" plants in each plot, and mechanically inoculated two "hot" plants in each plot with $PVY^{N:O}$. We collected weekly leaf samples and made visual observations of foliar symptoms. ELISA will be used to determine PVY presence in leaflets and whether thiamine delays disease expression. Plants were individually hand-harvested and tubers were individually weighed and checked for PTNRD symptoms.

Treatment 4 (50 mM thiamine) was the only treatment with a similar yield to the control. All other treatments (T1, T2, and T3) had significantly lower mean yields compared to the control (Figure). However, it is possible that thiamine application delayed disease expression. ELISA testing is ongoing. Foliar symptoms in all treatments were mild, moreover, plants were still very green and upright when we harvested plots in early October 2014. These are preliminary results for the first attempt of thiamine as a control measure on potatoes that will be repeated in 2015.



EVALUATING SEASON-LONG INSECTICIDE PROGRAMS TO IMPROVE POTATO INSECT IPM

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Abstract
Potato crop managers routinely make decisions regarding when and what insecticide to use on their fields to protect the crops profitability. Those decisions are influenced by one or more sources of information. Typically, a potato field has a diverse array of insects in the field when these decisions are made, complicating an already difficult and expensive decision. This aim of this project is to establish the impact of specific insect management programs on pestiferous and beneficial insects in potato fields in the Columbia Basin of Washington State. Too often insecticide efficacy trials focus on evaluating one pest insect, when often times numerous pests and beneficial insects occur on and around the potato plant during these trials. The overall objective is to evaluate insecticide management techniques based on insect densities to establish season long management tactics. Pest insect densities varied with treatment as will be discussed further. Also, overall yield, quality, and economic returns varied with treatment numerically, but not statistically.

This project aims to investigate the direct and indirect impact of specific insect management programs on the population abundance of pest and beneficial insects in Columbia Basin potatoes. Key targets will include Colorado potato beetle, aphids, psyllids, leafhoppers, caterplillars, and spider mites. Traditionally, insecticide efficacy trials have focused on evaluating single pest species, in single-insecticide-per-treatment experiments. Developing robust IPM strategies requires us to consider the full range of pest and beneficial insect species in the potato agro-ecosystem. Our overall objective is to evaluate insecticide management techniques based on sampling and insect thresholds in season long management programs and subsequently use tools available from the WSU Potato Horticulture program and private potato processing collaborators to quantify yield and quality impacts on potatoes grown under these various integrated pest management programs.

Materials and Methods
The project was established and maintained to mimic a commercial Ranger Russet potato field in the Columbia Basin. All plots received a fungicide seed treatment, post plant pre-emergence herbicide, and foliar fungicides as needed to avoid disease outbreaks. Plots were arranged in a Latin Square design. Plots were four rows wide and twenty five feet in length with 4 feet in between tiers and one blank row adjacent to each plot. The four treatments evaluated in this study were as follows: an untreated check plot, the ‘Risk Adverse’ treatment, the ‘Inexpensive Choice’ treatment, and the ‘Most Effective Choice’ treatment. The products used and date applied are listed in Table 1. Treatments were be applied by CO2 backpack sprayer at a water carrier rate of 20 gallons per acre.

Evaluations of plots were made weekly with the following methods: Yellow sticky traps, 20 leaf/plot samples, and vacuum samples. Each arthropod captured with the aforementioned methods were quantified weekly during the growing season in order to make treatment decisions. At the end of the season, 10 foot by 2 row sections of each plot were dug and harvested to quantify yield and grade. Additionally, a subset of 25 tubers per plot were cut into fries and cooked to assess internal defects that can result from some insect vectored disease. The remaining sample was then graded at the WSU Othello Research Station using their automated system.

Date Applied	4/17/2013	6/21/2013	6/27/2013	7/3/2013	7/10/2013	7/24/2013	7/31/2013	8/6/2013	8/15/2013	8/23/2013	9/4/2013	Total Cost $/Acre
Untreated												0
Risk Averse	Cruser Maxx ST	Movento	Movento	AgriMek	Fulfil	AgriMek	AgriMek	Oberon	Oberon	Warrior + Rimon	Coragen	361
Inexpensive Choice						Warrior	Warrior		Warrior	Warrior	AgriMek + Coragen	85
Most Effectice Choice	Cruser Maxx ST			AgriMek		AgriMek	Fulfil		Oberon	AgriMek + Warrior	Coragen	209

Table 1. Treatment programs by date with trade name of insecticides applied. Costs included in the last column do not include costs of surfactants or application, just insecticide.

Results/Discussion

Figure1 illustrates the total numbers of potato psyllids per treatment for the entire season by trapping method. This figure gives a good impression of the overall psyllid pressure on the plots and the relative effectiveness of each method. The sticky traps were an effective means of measuring psyllid emigration into the plot areas, but do not seem to be an effective metric for measuring efficacy of treatments. It is my opinion based on this trials and others conducted (data not included) that yellow sticky cards will be helpful in determining when infestations of psyllids begin, but are probably not an effective measure of success of insecticide applications as psyllids seem to continually infest fields. Figure 2 further supports this premise and seems to illustrate a peak period of emigration into the field toward the middle and end of August, shortly after nearby commercial fields were desiccated and harvested.

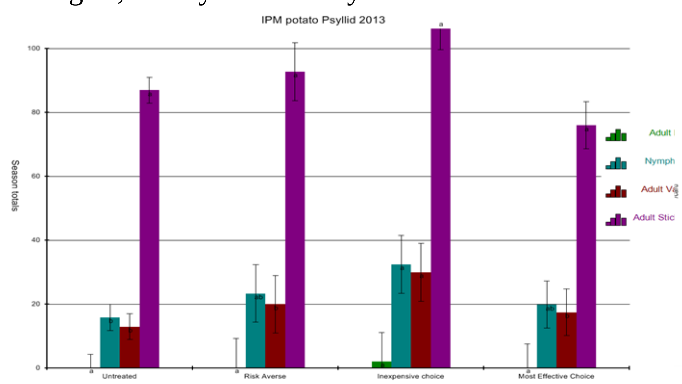

Figure 1. Potato psyllid total numbers by treatment and sampling method for adults and nymphs. Means with different letters are statistically significant from one another (p=.05 Student-Newman-Keuls test).

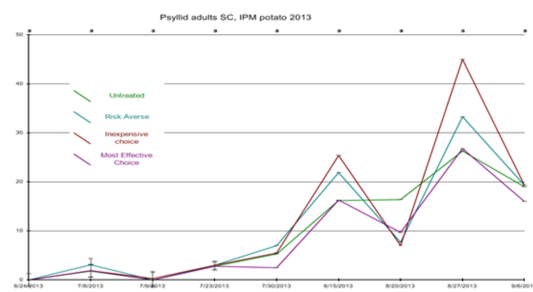

Figure 2. Potato psyllid adults collected using yellow sticky cards by date and treatment. Means with different letters are statistically significant from one another (p=.05 Student-Newman-Keuls test).

Adult psyllids were also sampled using a vacuum sampler (Fig. 3) and leaf samples (data not shown). The leaf samples had very low numbers of adult psyllids and were highly variable. Adult psyllids tend to jump readily when disturbed and the leaf collection method does not lend itself to be an effective method for collecting adults and discerning insecticide treatment efficacy. Prior to the sharp increase in adult psyllids collected in the Inexpensive Choice treatment plots on August 19th, 3 successive applications of Warrior insecticide were applied (Fig. 3). The data is not significantly significant, but the trend indicates that Warrior insecticide was ineffective for psyllid control (Fig. 3). The adult psyllid numbers sharply declined in all treatments in the beginning of September, likely as a result of the foliage beginning to senesce and significant defoliation in the untreated check plots as a result of Colorado potato beetle (CPB) feeding. Figure 4 further illustrates the previous statement regarding psyllid increases in the Inexpensive Choice treatment following 3 Warrior applications, as psyllid nymph numbers sharply incline at the same time period and are statistically in significantly higher numbers than in the other treatments. The untreated check numbers drop dramatically and do not rebound as they did in the treated plots, largely due to the extensive defoliation from CPB.

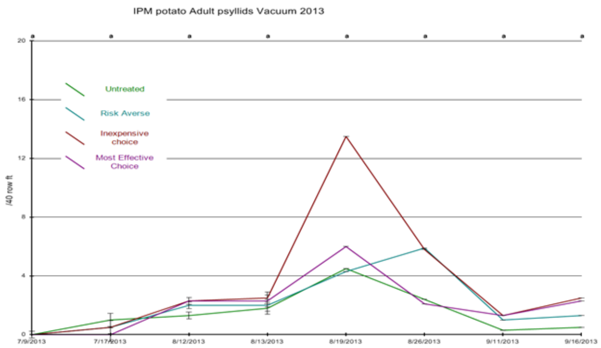

Figure 3. Potato psyllid adults collected using vacuum sampling by date and treatment. Means with different letters are statistically significant from one another (p=.05 Student-Newman-Keuls test).

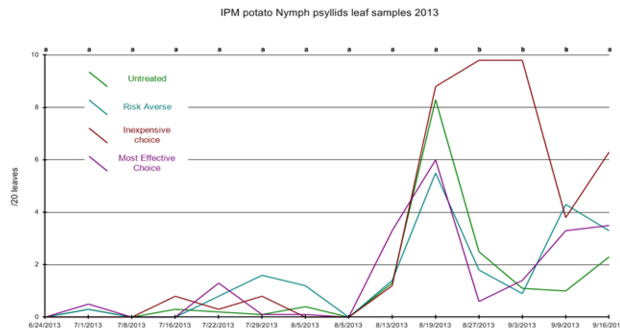

Figure 4. Potato psyllid nymphs collected using leaf sampling by date and treatment. Means with different letters are statistically significant from one another (p=.05 Student-Newman-Keuls test).

Figure 5 is a cumulative pest insect count for the sampling season by treatment. This figure illustrates how low the overall pest pressure at our site was, with the only overall statistically significant difference being in total CBP larvae numbers. The Risk Averse and Most Effective Choice treatments were treated with a neonicotinoid seed treatment (Cruiser, thiamethoxam) and were essentially free of CPB colonization. The Inexpensive choice treatment became colonized, but numbers were quite low. Though total wingless aphid counts did not differ statistically from one another, there was a sampling point where treatments varied significantly. There were very low aphid numbers in the two treatments with Cruiser applied as a seed treatment until the end of June when wingless aphid counts increased. An application of Fulfill at the end of July eliminated aphids from the Most Effective choice treatment for two weeks while the application of Warrior and Agri-Mek in the Inexpensive Choice and Risk Averse treatments respectively had no affect on wingless aphid counts. As was the case with most producers in the Columbia Basin, we were primarily targeting potato psyllids with our applications. Leafhopper numbers did not vary significantly on any sample dates (data not shown).

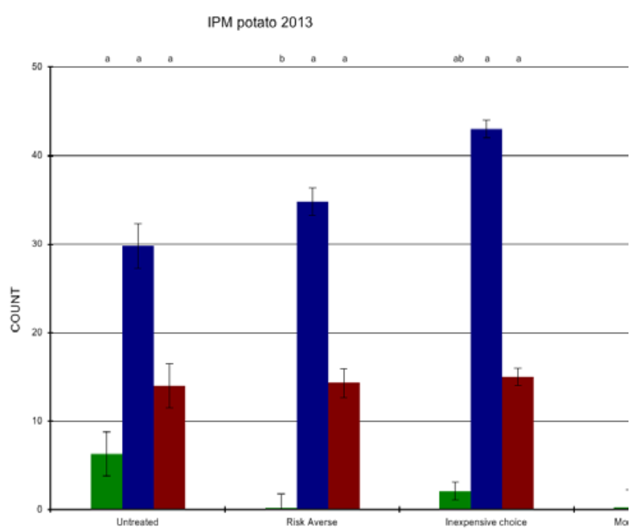

Figure 5. Cumulative pest numbers for the entire season for CPB, aphids, and leafhoppers.
Means with different letters are statistically significant from one another (p=.05 Student-Newman-Keuls test).

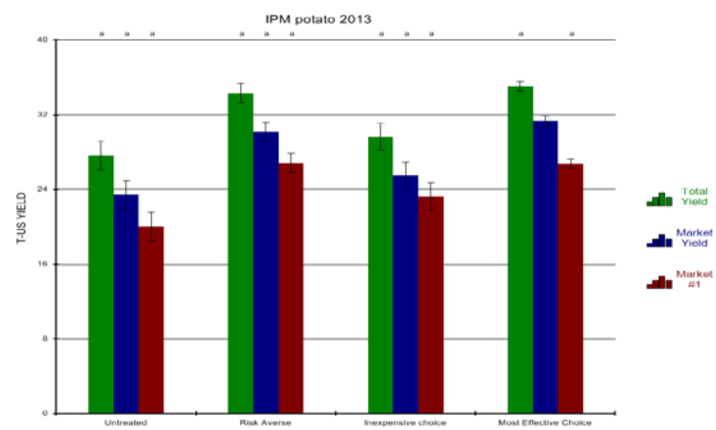

Figure 6. Total yield, market yield, and Market US No. 1 by treatment in tons/acre. Means with different letters are statistically significant from one another (p=.05 Student-Newman-Keuls test).

One of the main goals of this project was to determine how insect management impacts yield and quality. Figure 6 shows total yield, market yield, and market yield of US No. 1 tubers in tons per acre. There were no statistically significant differences, but the numeric trends favor using the Risk Averse and Most Effective Choice programs over the untreated and Inexpensive Choice treatments. High variability among plots caused the results to not vary statistically, but the trend in my opinion warrants further investigation. Additionally, Table 2 illustrates the gross increase in potential profitability of the insecticide treatment programs. These estimates are based on a processing contract for Ranger Russet potatoes, and do not include deductions for internal defects and other maladies not detected with the potato sizing machine. These are merely estimates to compare treatment programs to an untreated control, but the data, though not statistically significant, makes an indication that insecticides should be chosen carefully in order to sustain profitability.

Treatment	**Insecticide Cost $/A**	**Gross Increase Over Untreated ($/A)**			
Untreated Check	0	0			
Inexpensive Choice	85	312			
Risk Averse	361	823			
Most Effective Choice	209	1,101			

Table 2. Insecticide product cost per acre and estimated gross increase over untreated treatments using processing contract Ranger potatoes.

Conclusion

One season of data is not sufficient to draw significant conclusions or make solid recommendations, but several trends were noted that will be evaluated in coming seasons. For example, we found good evidence that sticky cards are a good indicator of emigrating psyllids, which is good information for growers and field men, but they are not a good indicator of product efficacy. Leaf samples appear to be a good metric for evaluating psyllid nymphs and product efficacy against psyllids. Additionally, we found that pyrethroid insecticides, although inexpensive are not an effective management strategy for potato psyllid. Seed treatments of neonicotinoids did appear to provide good early season control of both aphids and Colorado potato beetle, while Fulfill appeared to be an effective aphid control when applied to foliage. Monitoring of natural enemies needs to be refined as overall capture of those insects was quite low with the vacuum sampler. Potato yields did not differ significantly, but the trends indicated that programs that utilized more effective insecticides may increase yield and quality over ineffective inexpensive compounds. Further, the economic data indicates that careful selection of pesticides based on insect densities (Most Effective Choice Program) may increase economic returns to growers while calendar based programs (Risk Averse Program) and the least expensive alternative (Inexpensive Choice) may not be the best choice for producers to remain profitable.

Acknowledgements:

This project was funded by the Washington State Potato Commission and the Washington State Commission on Pesticide Registration. In-kind contributions were provided by Elite Seed, Two Rivers Terminal, numerous chemical companies. Technical Assistance was provided by Don Kinion, and the Potato Team at the WSU Research Unit in Othello.

SECTION VI

Pests of Wine Grapes & Small Fruits

Moderator: Todd Murray

CONTROL OF SPOTTED WING DROSOPHILA IN ORGANIC BLUEBERRIES

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Description of Problem. Eight 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 is a leading source 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. This year, 2012, was different from previous years. 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. SWD pressure in 2013 was higher than in 2012 in later season blueberries.

For fresh blueberries, detection of a single larvae per pallet results in rejection. Processed blueberries have lower standards, but they are still impossible to meet without a competent SWD control program. Several shipments of blueberries from eastern and western Washington were rejected due to the presence of SWD. The administrator of 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 done a good job of evaluating these products. Unfortunately to date, only a single organically approved insecticide (Entrust, spinosad, Dow AgroSciences) has been demonstrated to have sufficient efficacy against SWD. Organic blueberry growers rely very heavily on this product and the Washington (and California and Oregon) organic blueberry industry are 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.

SWD has been documented as having developed resistance to Entrust in blueberries in the Watsonville area of California. While strong 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 a year in a pest known to develop resistance is a risky situation.
The Washington blueberry industry is desperate to develop new organic products for SWD.

In 2013, Schreiber started using blackberry (Triple Crown) as a surrogate crop for efficacy trials for SWD. Based on information learned in that year, a more ambitious trial was initiated in 2014. Results from 2014 will be presented and the implications for the Washington organic blueberry industry will be discussed.

Efficacy of 17 Programs Against SWD in Blackberries in WA in 2013

Trt No.	Type	Treatment Name	Rate of Application		Appl Code	Total SWD Larvae	
3	INSE	ENTRUST	6	oz/a	ABC	167	f
16	INSE	ENTRUST	4	oz/a	ABC	175	f
16	INSE	AZA-DIRECT	3.5	pt/a	ABC		
2	INSE	ENTRUST	4	oz/a	ABC	180	ef
14	INSE	ENTRUST	6	oz/a	ABC	213	def
14	INSE	GRANDEVO	2	lb/a	A		
4	INSE	ENTRUST	4	oz/a	ABC	214	def
4	INSE	GRANDEVO	1	lb/a	ABC		
6	INSE	ENTRUST+BAIT		4oz/a	ABC	220	def
17	INSE	JET AG	1	% v/v	ABC	237	cdef
13	INSE	ENTRUST	6	oz/a	ABC	240	cdef
13	INSE	PYGANIC	64	fl oz/a	A		
13	INSE	NEEMAZAD	16	oz/a	A		
10	INSE	AZA-DIRECT	3.5	pt/a	ABC	253	bcde
15	INSE	DES-X2	gal/100 gal		ABC	262	abcd
5	INSE	GRANDEVO	2	lb/a	ABC	273	abcd
7	INSE	GRANDEVO+BAIT		1/a	ABC	300	abc
11	INSE	PYGANIC	64	fl oz/a	ABC	305	abc
11	INSE	NEEMAZAD	16	oz/a	ABC		
12	INSE	PYGANIC	64	fl oz/a	ABC	311	abc
12	INSE	AZA-DIRECT	3.5	pt/a	ABC		
9	INSE	NEEMAZAD	16	oz/a	ABC	320	ab
1	CHK	UTC				325	ab
8	INSE	PYGANIC	64	fl oz/a	ABC	335	a

MRLS, MAGNITUDE OF RESIDUES, BLUEBERRIES AND SPOTTED WING DROSOPHILA – YEAR 2

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Eight years ago, Washington produced 18 million pounds of blueberries; in 2014 it produced 96 million pounds. The WBC estimates that in six more years it will produce as much as 190 million pounds and be among the largest blueberry growing regions in the world. 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 that Washington produces, the industry is developing an ambitious program to develop export markets. Conversely, the loss of existing export markets would be crippling.

Unfortunately, the recent arrival of the spotted wing drosophila (SWD) into Washington has created a tremendous obstacle to development of export markets. Washington has 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 pesticide applications having to be made between pickings. As a result, Washington growers have had to make more insecticide applications than ever before and applications closer to harvest. When faced with short preharvest intervals, limitations on the number of applications and efficacy limitations, blueberry growers often have limited options. This situation has resulted in many residue related issues. Although it was once 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 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.

INSECTICIDES/MITICIDES		US	Codex	EU	Canada	Japan	Taiwan
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	---	2	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	---

--- = 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 and 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 exports of blueberries 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. It is thought that although the violative samples were in fresh blueberries, testing is expected to be expanded to processed blueberries, our larger export market. 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, Each one of these shipments was an approximate $30,000 loss. 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 add to it the impact of SWD, no issue is more important.

In 2013, trials were set up in Franklin County (eastern Washington), Skagit and Whatcom counties, representing the three main blueberry growing regions in Washington. At each location; malathion, phosmet, esfenvalerate, zeta cypermethrin, spinosad, spinetoram, imidacloprid, thiamethoxam, carbaryl and methomyl were applied to blueberries at the high labeled rate a single time and malathion, zeta cypermethrin, spinosad, imidacloprid and malathion were applied at the high rate twice at 7 days apart. Samples were collected at zero, 1, 5, 9, 14, 17 and 21 days apart. Residue decline curves were generated for each treatment (15) at each of the three locations. These trials were repeated in 2014 with addition of bifenthrin and fenpropathrin. A roughly comparable trial was carried out in the Willamette Valley by OSU's Joe DeFrancesco. Rufus Issacs of Michigan State University initiated a similar project in 2014.

The results and implications from two years of research on the PNW blueberry industry will be discussed.

EVALUATION OF SEVERAL WEEVILICIDES FOR THE CONTROL OF ROUGH STRAWBERRY ROOT WEEVIL IN STRAWERRY, 2014

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Rough strawberry root weevil, *Otiorhynchus rugosostriatus* (Goeze) (RSRW) is one of four to five species of root weevils that remain perennial pests for strawberry growers in the Pacific Northwest. However, RSRW has emerged as the dominant root weevil pest in Washington and Oregon strawberries over the past decade. Growers commonly overlook RSRW's presence in PNW summer varieties because it normally does not cause characteristic notching of leaves used to detect a weevil infestation. Adult RSRW were collected from a heavily infested 2 year-old 'Totem' field in Salem, OR on 18 June 2014. On 20 June, five 'Totem' leaves were dipped in field solutions of 6 registered insecticides equivalent to 100 gpa. These leaves were individually placed on cotton absorbent pads in 100 x 15 mm Petri dishes. Five adult RSRW were placed on drying foliage/arena and replicated 5 times. Arenas were held at under lab conditions and observed at 24 and 48 hours after treatment (HAT) for adult mortality. Moribund adults were also scored as dead.

After 24 HAT, all adults were dead on the foliar residues of Brigade (Table 1). Other than Athena, the remaining treatments were significantly different from the UTC. Mortality was 100% for both formulations of thiamethoxam (i.e., Platinum, Actara) and unregistered Exirel (cyantraniliprole, IRAC 28). The excellent contact activity for both neonicotinoids and 75% mortality for Admire after 48 HAT were unexpected, given past trends for slower and often incomplete population knockdown in the field. The dual modes of action Athena (bifenthrin + avermectin) was disappointing given its near equivalent concentration of bifenthrin compared with Brigade. We will reevaluate its activity next season with and without a non-ionic or organosilicone surfactant.

Table 1. Efficacy of foliar residues to RSRW adults on strawberry, 2014

Treatment	Rate/acre	24 HAT	48 HAT
Platinum 75SG	4.01 oz	96.5±3.5a	100.0±0.0a
Actara 25WG	4 oz	90.0±5.8a	100.0±0.0a
Admire Pro	14 fl oz	60.0±0.0b	75.0±9.6b
Brigade WSB	32 oz	100.0±0.0a	
Athena	17 fl oz	10.0±5.8c	15.0±5.0c
Exirel	20.5 fl oz	95.0±5.0a	100.0±0.0a
Untreated check		0.0±0.0c	15.0±15.0c

Means within columns followed by the same letter are not significantly different (Fisher's Protected LSD, $P<0.05$), PRC ANOVA SAS.

WESTERN FLOWER THRIPS CONTROL ON STRAWBERRY, 2014

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The trial consisted of 5 treatments and UTC replicated four times in a RCB design. Treatments were applied on 22 and 29 July with an R&D CO_2 backpack sprayer equipped with two TJ60-8002 nozzles arranged at 14" spacing and delivering 110 gpa at 60 psi. Ten randomly selected flowers per 23 ft x 28 inch wide plots were collected from a 2 year-old, day-neutral 'Albion' plants grown under a high tunnel in Burlington, WA at 1, 2, 6, 7 and 1 DAT following a second application. Each flower was placed in an 8 oz condiment cup with 70% ETOH and agitated to wash western flower thrips, *Frankliniella occidentalis* (Pergande) (WFT) free from within the flowers.

Based on the UC pest management guideline for WFT on strawberry, we provisionally set our economic threshold at 10 WFT/flower for 'Albion' growing under a high tunnel. The UTC indicated population increase had exceeded the economic threshold at 7 DAT. As did Danitol, Assail and Athena treatments (Table 1). Though not significantly different from the other treatments, Radiant and IGR Rimon averaged <10 WFT/flower. At 1 DAT and following the second application, Radiant WFTs populations were significantly less than the UTC. These results indicate day-neutral 'Albion' grown under high tunnels will experience rapid numerical increase of WFT in mid-summer in WA. California research indicates 'Albion' can tolerate >10 WFT/flower without causing significant damage or bronzing of the fruit near the calyx. Western flower thrips continues to be a non-economic pest on our regional summer bearing strawberries. Given the field performance of the spinosad Radiant, we expect the Entrust formulation of spinosad will provide acceptable control for organically grown strawberries.

Table 1. Average motile stages of WFT/10 flowers, 2014

Treatment	Rate/acre	23 July	24 July	28 July	29 July	30 July
Danitol EC	16 fl oz	54.8±0.7c	82.0±11.0a	91.8±18.9a	100.5±6.8ab	100.0±7.4ab
Assail 30SG	6.9 fl oz	89.8±2.8b	74.5±4.8a	92.5±7.8a	112.5±15.1ab	95.8±5.2b
Athena	17 fl oz	73.3±5.6bc	66.8±7.2a	78.3±2.3a	127.8±12.5a	108.5±6.7ab
Radiant SC	10 fl oz	126.5±16.1a	37.5±8.0b	63.5±8.9a	95.5±8.3b	50.0±105c
Rimon 0.82 EC	12 fl oz	78.8±4.8bc	67.3±7.1a	69.5±7.9a	92.8±5.7b	98.8±11.8ab
UTC		75.5±5.2bc	72.8±3.0a	80.5±5.9a	109.3±11.0ab	121.8±9.1a

Means within columns followed by the same letter are not significantly different (Fisher's Protected LSD, $P<0.05$), PRC ANOVA SAS.

TWOSPOTTED SPIDER MITE CONTROL ON STRAWBERRY, 2014

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A pretreatment sample of 25 leaflets/plot was taken from 2 year-old 'Albion' strawberries grown under a high tunnel in Burlington, WA on 2 June 2014. Treatments of five acaricides were applied on 2 June with an R&D CO_2 backpack sprayer equipped with four D3 25 nozzles arranged two over the top of the row and two attached to drop tubes and angled upward at 45 deg to penetrate underside of foliage. Treatments were applied at 60 psi to deliver 100 gpa at 2 mph. Each treatment plot is 23 feet long by 28 inches wide. Plots were organized into a RCB design with 4 blocks of 5 treatments and an untreated check. Samples were processed with a mite-brushing machine onto a 13 cm diameter glass plate coated with a fine layer of liquid detergent. Estimated average number of motile life stages per leaflet was determined with a dissecting microscope.

This trial was conducted at pretreatment levels above 75 mites/leaflet. These extreme densities were 3-4 fold above the UC IPM strawberry economic threshold of 15-20 mites/mid-tier leaflets after berry set. By early June, canopy leaves were beginning to look dry, reddish and average densities/leaflet expressed high standard errors across all treatments. Fujimite and tank mix of Acramite + Savey provided economic suppression of motile TSSM at 7 days posttreatment (Table 1). Their control levels remained comparable along with the contact IRAC 20B MoA Kanemite at 14 days posttreatment.

Table 1. Evaluation of acaricides for control of twospotted spider mites, 2014

Treatments	Rate/acre	0 DAT	3 DAT	7 DAT	14 DAT
Acramite 50 WP + Savey DF	16 oz 6 oz	27.5±20.0a	85.0±63.1a	26.3±11.4a	3.8±2.4b
Oberon 2SC	16 fl oz	96.3±68.4a	198.8±106.6a	141.3±80.3a	147.5±88.6a
Kanemite 15SC	31 fl oz	127.5±72.2a	180.0±105.6a	45.0±26.3a	22.5±17.9b
Zeal	3 oz	115.0±105.2a	143.8±96.3a	156.3±95.7a	85.0±4.8ab
Fujimite 5EC	32 fl oz	7.5±1.4a	56.3±43.9a	3.8±2.4a	7.5±4.8b
UTC		151.3±146.3a	256.3±238.0a	110.0±100.0a	26.3±18.1b

Means within columns followed by the same letter are not significantly different (Fisher's Protected LSD, P<0.05), PRC ANOVA SAS.

SECTION VII

Pests of Turf and Ornamentals

Moderator: Robin Rosetta

INTELLIGENT SPRAY SYSTEM ADVANCEMENT IN OREGON NURSERY PRODUCTION

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A team of scientists from USDA/ARS, Oregon State University, The Ohio State University, and University of Tennessee developed and evaluated two different types of intelligent variable-rate spray systems in nursery production. In Oregon evaluations were conducted for the two prototype spray systems using either laser or ultrasonic sensors to detect targeted plant presence and size and adjust the spray output to match the tree row characteristics. In nine separate efficacy trials in commercial shade tree nurseries in four years, reductions in spray volume of the variable rate spray applications compared to the constant rate applications ranged from 34% to 76.8% while maintaining equivalent control of the insects and diseases sampled. Economic analyses of six trials in 2013 and 2014 showed the use of the intelligent sprayer resulted in reductions of chemical costs, in a range from 32.5% to 78.7% to control insects and from 54.8% to 72.1% to control diseases, when compared with a conventional air-blast sprayer using best management practices. The new spray systems significantly advanced the technology for efficient pesticide spray applications to increase growers' production profitability, worker safety and environmental stewardship while maintaining tree quality.

SECTION VIII

New & Current Product Development*

Moderator: Josh Adkins

No papers submitted for this section.

Section IX

Extension & Consulting: Updates and Notes from the Field

Moderator: Alan Schreiber

THE GREY SUNFLOWER WEEVIL, *SMICRONYX SORDIDUS*

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The Grey Sunflower Weevil is a very small member of the Genus *Smicronyx*, which are about 4 mm in length. There are 70 species in this genus, all of which bore in plants and cause galls.

Another species is the Red Sunflower Weevil, common in the Northern Great Plains. This small size coupled with a later invasion of *Helianthus annuus* makes this complex much greater as pest species in the Northern Plains where commercial black oil sunflower production is important as a crop. *Smicronyx sordidus* appeared in my garden in the summer of 2013. This is another complex of closely related species.

They are very elusive when any potential predator approaches, moving behind stems or dropping to the ground.

They also bite oviposition holes at the leaf axils of elongating plants. The larvae are tiny and are similar to those of artichoke weevil reported previously.

As the season progresses the plants wilt and fail to produce seed. Some healthier plants will develop seed heads but weevil adults will feed in the heads and emerge. Apparently they overwinter in the soil.

Commercial fields are sprayed at the appearance of adults in the late spring. Mechanical controls including tillage and crop removal are essential.

Sunflower is produced in the Columbia Basin but this pest is a new species to the area as far as I know at present.