FINAL PROJECT REPORT

Project Title: Spotted Wing Drosophila management on sweet cherry

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Other funding sources

Agency Name: **WSDA Specialty Crop Block Grant**
Amount awarded: **$**170,241, 2 years, 10/1/2011 through 12/31/2013
Notes: Previous SWD project used as match for SCBG; Co-PIs Beers & Yee

Agency Name: FAS-TASC
Amt. requested/awarded: $72,096 for year 1 (Beers, Walsh; includes indirect costs).
Notes: Grantees are California Grape and Tree Fruit League and the Northwest Horticultural Council; Beers & Walsh are Washington PIs. (Funding is yearly, with a planned 3-year term).

Agency Name: **USDA-SCRI**
Amt. requested/awarded: ca. $20,000/year, 5 years.
Notes: Walton et al.; amount above is portion to E. Beers via WSU subcontract.

Total Project Funding: $150,000

Budget History:

Item	2012	2013	2014
Salaries	12,000	12,480	12,979
Benefits	4,829	5,023	5,224
Wages	15,925	15,925	15,925
Benefits	12,199	12,199	12,199
Equipment	0	0	0
Supplies	2,395	1,722	1,022
Travel	2,652	2,652	2,652
Plot Fees	0	0	0
Miscellaneous	0	0	0
Total	50,000	50,000	50,000

Objectives

1. Provide a crop protection alert system to cherry/stone fruit producers and seasonal phenology information through a regional SWD trapping program.
2. Determine timing of cherry fruit susceptibility in the field.
3. Test standard trap types for capture efficiency of SWD (in collaboration with SCRI-SWD regional group).
4. Test pesticide efficacy for control of SWD in cherries in laboratory, field-laboratory, and field settings.

Significant Findings

- SWD population densities followed the same general pattern each year (low in winter-mid-summer, increasing in late summer/fall), but the absolute numbers varied widely. In some years, SWD were captured during each month.
- The years with earliest first capture profiles tended to have the highest densities overall.
- Green cherries are not susceptible to attack by SWD, but all subsequent stages are. This indicates a potential control period essentially the same as Western cherry fruit fly. Only a late first capture of SWD should delay control measures for this pest.
- Red and yellow were found to be attractive colors for SWD, and should be incorporated into future trap designs. Other design features may depend on the type of lure being used (wet bait versus synthetic).
- The spinosyns (Entrust, Delegate) are generally the most active and long residual materials for control of SWD; Warrior and Diazinon are intermediate, while Sevin and Malathion have a very short residual.

Results and Discussion

Regional Trapping Alert system. The website http://www.tfrec.wsu.edu/pages/swd has served as the portal to information on activity of SWD in eastern Washington throughout the three years of the project (2012-2014), as well as in the previous project (2011). The database consists of trap captures in 200-300 traps distributed from the Canadian border to the Oregon border, checked weekly by the Beers, Walsh, and Yee programs, and volunteer fieldmen from throughout the state. The majority of the traps are in cherry orchards, but other known or potential sources were also trapped. The essential feature of this is a table listing the first capture of SWD in ca. 17 growing districts (Fig. 1), coupled with advice that if fruit are susceptible and flies are active, control measures should be taken; control recommendations were also posted on the website. The first capture in each region was sent to an email list developed by Tim Smith; visitors to the website could subscribe to the list from the website. The website also allowed users to graph individual or groups of traps, and provided links to other information on SWD.

Region	Traps deployed	Flies first recorded
Oroville/Tonasket	Yes	May 28th
Okanogan/Omak	Yes	May 30th
Brewster/Pateros	Yes	May 23rd
Chelan/Manson	Yes	May 30th
Orondo-Beebe Bridge	Yes	May 17th
Entiat	Yes	May 17th
Wenatchee/E Wenatchee/ Wenatchee River Valley	Yes	May 16th
Stemilt Hill/Wenatchee Heights	Yes	May 23rd
Rock Island/Malaga	Yes	May 30th
Quincy/Moses Lake	Yes	May 17th
Royal City	Yes	May 23rd
Othello	Yes	May 24th
Mattawa/Desert Aire	Yes	May 22nd
Yakima/Tieton	Yes	May 28th
Union Gap/Zillah	Yes	June 7th
Sunnyside/Prosser	Yes	Feb 7
Tri-Cities	Yes	May 24th

Fig. 1. Regional trapping alert system – first SWD capture by region (2013)

SWD phenology. The pattern of SWD phenology has remained relatively constant throughout the five years of trapping (Fig. 2), but the absolute numbers have varied widely from one year to the next. While part of the variation can be ascribed to changes in traps and lures with differing capture efficiencies, it is likely that the biological differences are real. The pattern that we have seen is low densities (or trap activity) in the winter months through mid-summer, with capture levels rising in mid-August, and peaking in the fall (October-November). The lateness of the high capture rates is limited by freezing temperatures. In 2013, captures were recorded in every month of the year. The extremely high populations in 2013 and 2014 may reflect better establishment of this pest coupled with moderate winters. The extremely low captures in 2011 followed a severe freeze event in late November of 2010, and seems the most likely explanation of the low numbers. What is clear is that SWD is not limited in terms of distribution by the climate of eastern Washington (either by high or low temperatures), but fluctuations in density may be a result of unusually high or low temperatures.

Dates of first capture also varied from year to year, as well as among regions. Although only 5 years of data have been collected so far, there appears to be a correlation between earliness of capture and overall higher seasonal captures. Two extremes are represented by the 2011 year (late first capture, low seasonal means) and 2013 (early first capture, high seasonal means).

Cherry fruit susceptibility. Three years of experiments have demonstrated that if flies are active, fruit that is straw or blush in color is susceptible to attack by ovipositing females. This principle was demonstrated with four cultivars (Sweetheart, Bing, Lapins, and Rainier) irrespective of maturation period. Two approaches were used to ensure consistent results: a lab bioassay (cherries brought in weekly and challenged with adult female SWD) (Fig. 3), and caged tree trials, where flies from a laboratory colony were released into a cage for a one-week period throughout the maturation period (green fruit through post-harvest). Ovipositions and successful adult emergence were recorded from the fruit, and corresponding data were taken to characterize their maturity (firmness, size, color, brix, titratable acidity, pH).

Trap style. One of the requests of the Advisory Panel of the SCRI-SWD project was to develop a standard trap for SWD. A large collaborative effort was devoted to this objective, all using apple cider vinegar (ACV) as the bait. Some of the basic principles were established in the first study (Lee et al., 2012), which correlated increasing trap captures with larger entry areas, and possibly broader surface area (Haviland) from which the odor of the bait could diffuse. However, the bait volume was

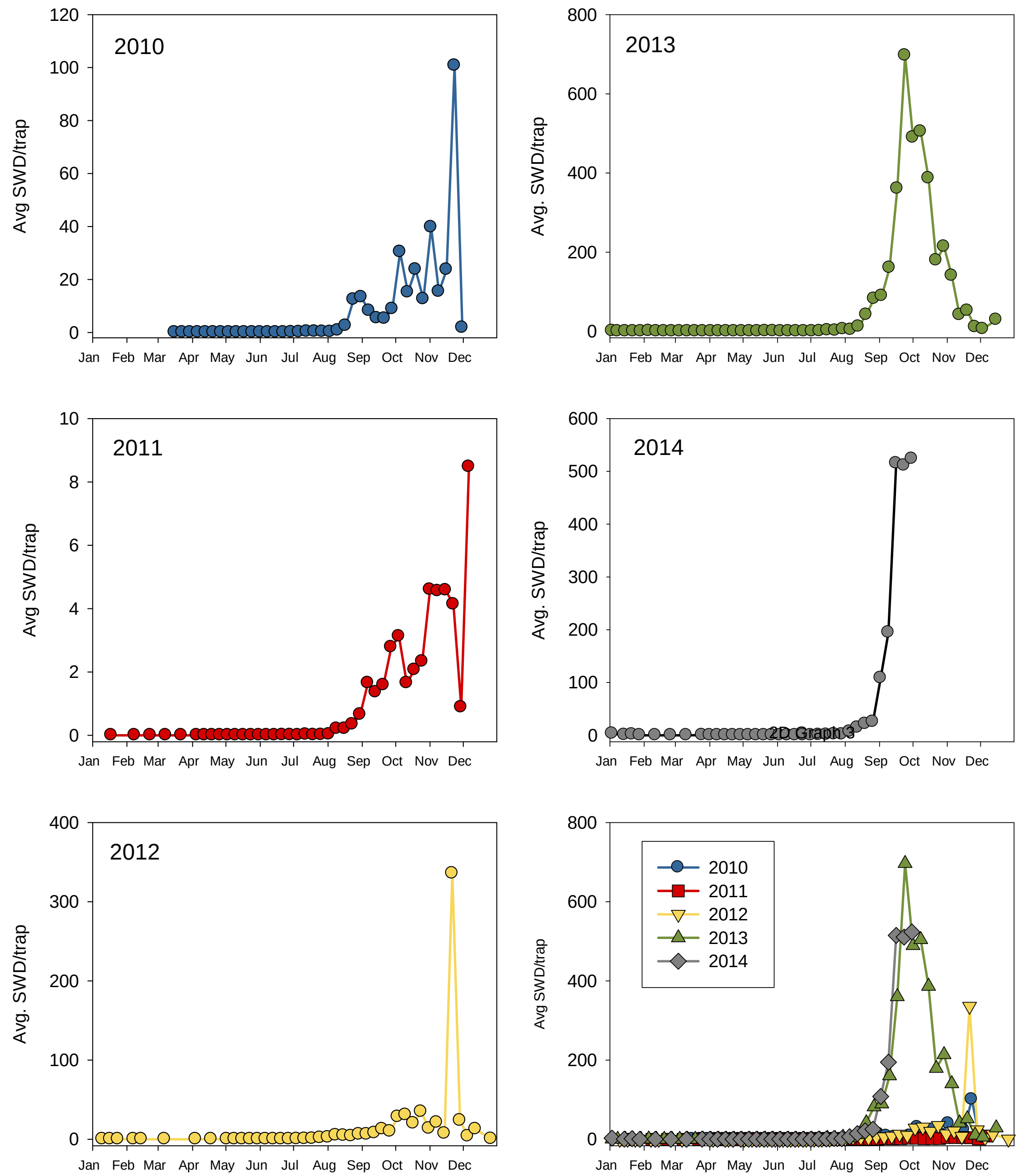

Fig. 2. Phenology of SWD in eastern Washington, 2010-2014.

not held constant among the different traps. A second regional effort portioned out the effect of trap color from other design features (Lee et al., 2013). However, the early trap tests were comparisons of mostly custom-fabricated traps whose designs arose out of convenience or necessity, rather than a rigorous investigation of the underlying principles. We conducted two experiments that looked at specific factors (e.g., bait volume, bait surface area, and distance from the surface to the entry point) while holding other parameters constant. In the first test, we found that increasing bait volume and surface area increased trap captures; in the second, bait volume increased trap captures, but the effect of surface area was inconsistent.

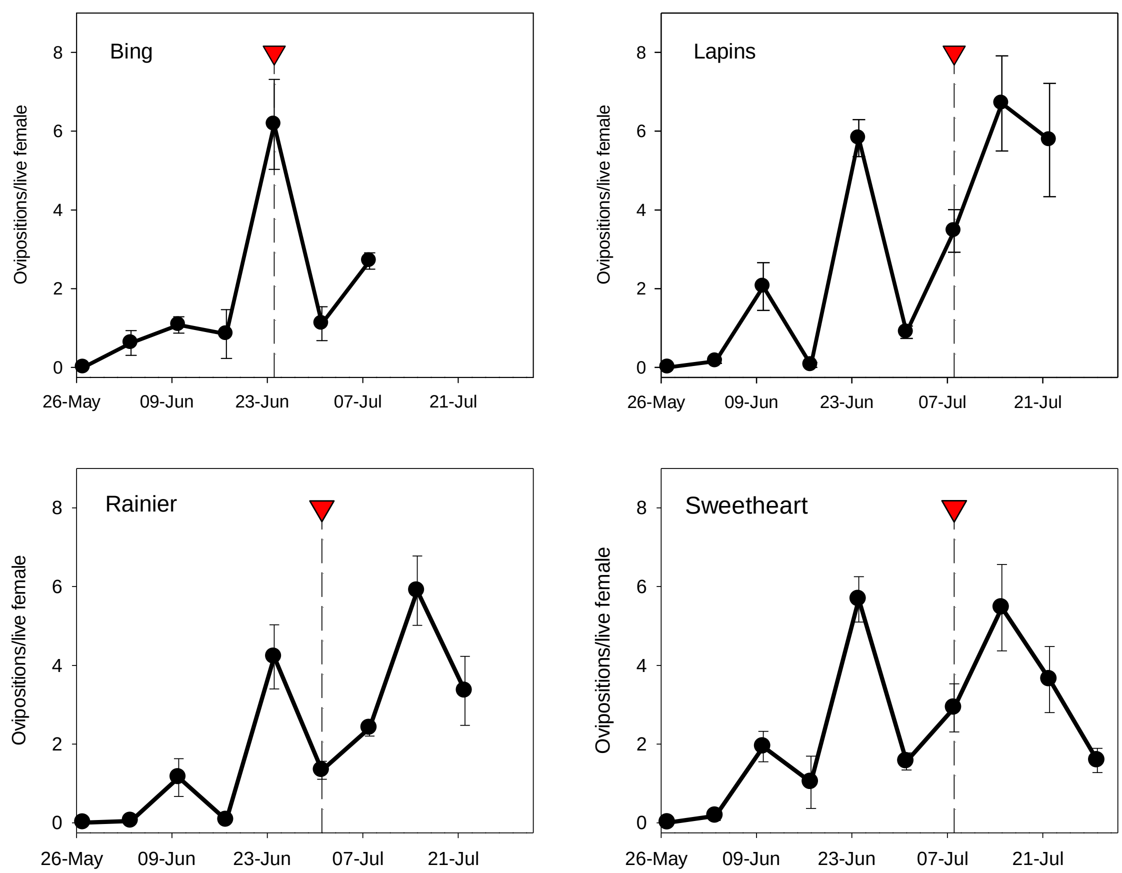

Fig. 3. Susceptibility of four cultivars of cherry to SWD, 2014.

Bait. Although ACV was considered a standard and effective bait, a number of other compounds were tested. These included a yeast-sugar-water mixture, various types of wine-vinegar mixtures (one including molasses), and a commercial bait product made from corn steep liquor (Monterey Ag Bait). Other regions had great success with the yeast bait, however, tests in Washington indicated its seasonal capture was lower. This may be due to poorer performance at low temperatures relative to vinegar or wine-vinegar mixtures, which is typically the time when the greatest number of flies are available. At warmer temperatures (those prevailing during the cherry fruit maturity period), it out-performed ACV in some tests, but not others.

A shift in approach occurred with experiments designed to determine which of the volatile components of the wine-vinegar mixture were biologically active. This was determined through iterative testing by electroanntenagram. Four components were found to be key to attraction (Cha and Landolt, 2013), allowing the synthesis of a dry lure. Two companies (Trécé and Scentry) produced synthetic lures in 2013 and 2014, respectively, and were field tested under eastern Washington conditions. In 2013, the Trécé lure (with or without ACV as the drowning fluid) captured more flies in June and July than the yeast bait, a wine-vinegar bait, or ACV alone (Fig. 4). In 2014 (June-mid-August), the Scentry lure caught ca. 17x more flies than ACV, and ca 3x more than the Trécé lure with water or ACV as the drowning fluid (Fig. 5).

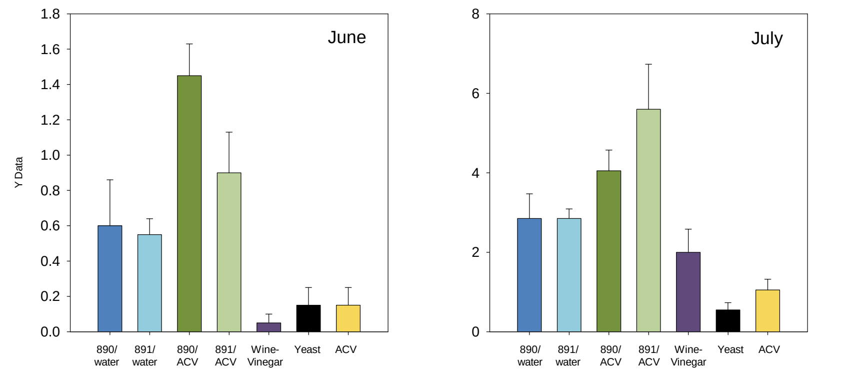

Fig. 4. Mean weekly captures of SWD by different baits or lures, 2013

However, a more appropriate measure of the efficiency of the trap is not just the total number of flies caught, but how early the capture occurs. Early comments on the ACV trap were that fruit were already infested by the time the ACV trap caught flies. We examined sensitivity (earliness of capture) of the new lures in 2013 in seven replicate orchards. In all replicates, one of the new Trécé lures caught the first SWD, in advance of the ACV trap by 7-28 days. The Scentry lure was added to the test in 2014, and deployed in 10 replicate orchards. One of the new lures caught the first fly in 6 out of 10 replicates, preceding capture in the ACV trap by 13-35 days. In the remaining four replicates, a new lure captured the same week as the ACV. Thus, the new lures are often more sensitive, and never less sensitive, than the ACV trap. The two dry lures hold considerable promise to provide the needed sensitivity to develop an action threshold for treatments on an individual block basis, replacing the regional capture system.

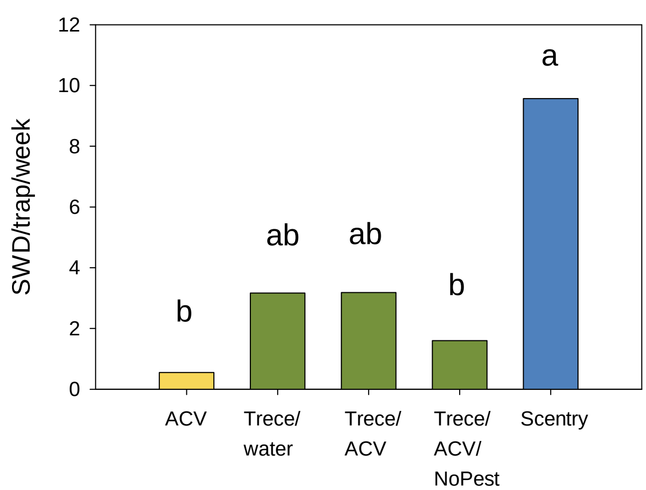

Fig. 5. Mean weekly captures of SWD with five baits or lures, 2014

Pesticide Efficacy. The efficacy of candidate insecticides for SWD control was tested over the three-year span of the project. Early laboratory screening efforts by small fruit researchers (Bruck et al., 2011).and cherry researchers (Van Steenwyk et al., 2012; van Steenwyk and Novotny, 2011) were used to select the most likely products for use in eastern Washington cherry production. Because the research orchard failed to develop a natural infestation during the course of the study, a field-lab bioassay approach was used to ensure consistent evaluation of efficacy and protection. Pesticides were applied in the field (Sunrise blk 4 'Sweetheart' cherries) using an airblast sprayer at 100 gpa, and fruit and leaves collected at intervals post-spray to determine residual control. The residues were challenged with lab-reared flies in an arena that included treated leaves and fruit from the field, and we measured adult mortality, oviposition, and successful emergence of adults from the ovipositions. In addition, fruit maturity measurements were made in conjunction with the bioassays to link the susceptibility to attack with maturity.

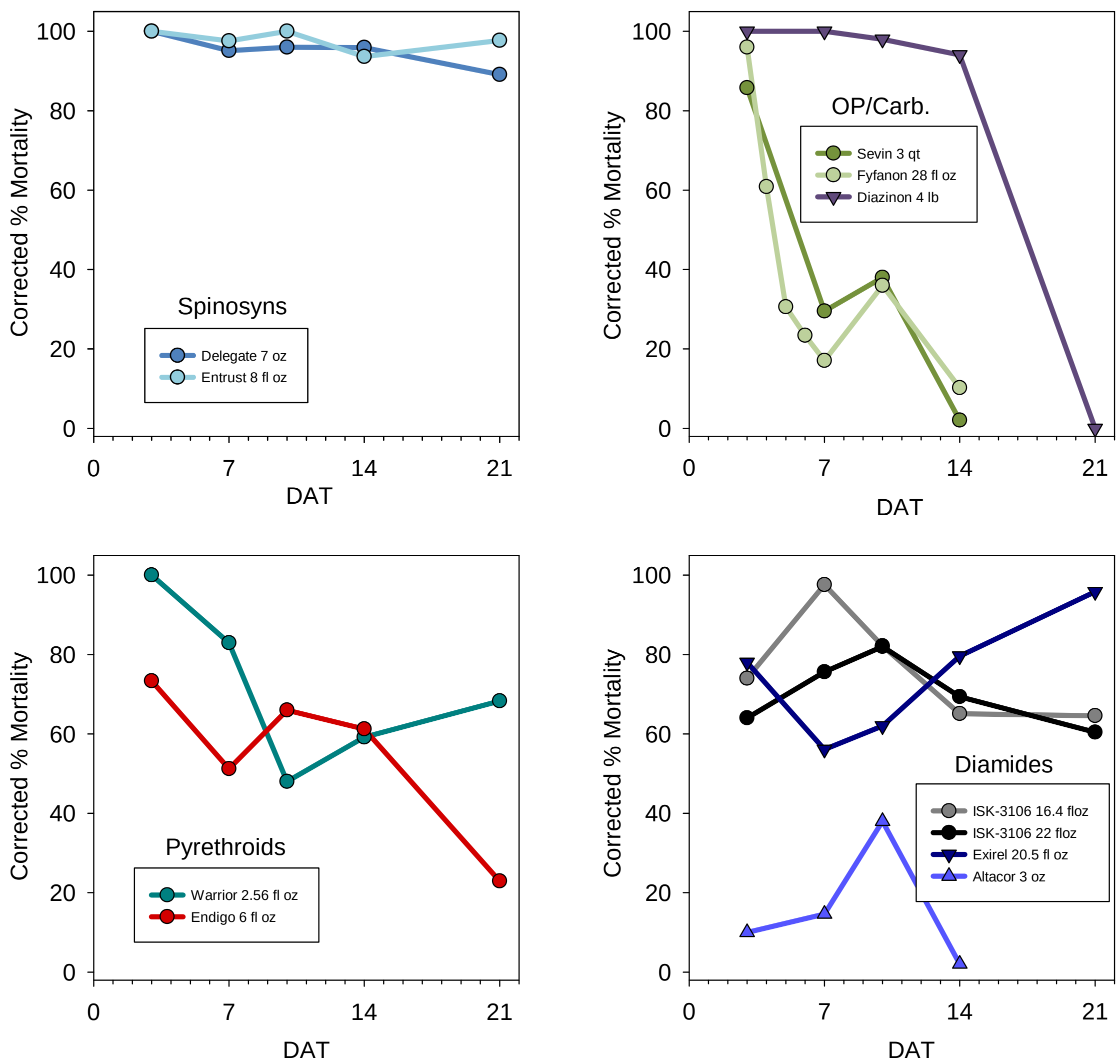

Fig. 6.. Residual control of adult SWD by single applications of various pesticides, 2014.

In 2012, treatments consisted of programs of insecticides (Warrior and Entrust) based on their respective re-treatment and preharvest intervals. Bioassays were timed for the presumed weakest point in coverage, the day before next application. Fly mortality in the Warrior treatment dropped off rapidly after the single 14 days before harvest (DBH) application. Protection from oviposition by females was high initially, but decreased to ca. 40% reduction compared to the check by harvest. Unsurpisingly, the 3-spray program of Entrust (either the 80W or 2SC) provided more consistent levels of mortality and fruit protection over the 17-day period.

A preliminary study in late summer of 2012 indicated that using a higher gallonage might be helpful in extending the period of coverage. This was tested during the preharvest period of 2013 using Warrior at different application volumes (400 and 100 gpa airblast, and handgun, estimated 187 gpa). However, all three treatments provided excellent control through 10 DAT, and did not differ statistically from one another.

A second study in 2013 examined the length of residual control of various pesticides following a single application. While single applications are unlikely in commercial settings, this approach helps evaluate individual products, so that growers can build programs with appropriate coverage, taking PHI into consideration. Fyfanon caused high levels of mortality through 4 DAT; Sevin and Diazinon through 10 DAT, and Entrust and Delegate through 14 DAT. Fruit protection dropped off much more quickly. Rimon+Warrior provided high levels of mortality through 21 DAT, but the effect of Rimon on oviposition and emergence needs to be re-examined.

A similar study was performed in 2014, but with an expanded range of treatments. All were applied on 23 June, about 2 weeks before commercial harvest. A pattern of differences among different groups of insecticides was evident (Fig. 6). The spinosyns (Delegate and Entrust 2SC) provided high levels of mortality though 21 DAT, and were the longest-residual materials tested. The pyrethroids were intermediate; while there is still significant mortality at 21 DAT, the rate of decline was steeper. There was quite a bit of variability in the OP/carbamate insecticides tested; Diazinon provided good mortality through 14 DAT, but declined sharply thereafter, while Sevin and Fyfanon (whose PHIs are much shorter) provided mortality for only a few DAT. Three of the diamide treatments (two rates of a numbered compound, ISK 3106, or cyclaniliprole, and Exirel/cyantraniliprole) provided higher levels of mortality throughout the test period, and while never as high as the spinosyns, it remained relatively steady. Altacor (chlorantraniliprole) was relatively weak against SWD in terms of acute toxicity.

References Cited

Bruck, D.J., Bolda, M., Tanigoshi, L.K., Klick, J., Kleiber, J., DeFancesco, J., Gerdeman, B., Spitler, H., 2011. Laboratory and field comparisons of insecticides to reduce infestation of *Drosophila suzukii* in berry crops. Pest Manag. Sci. 67, 1375-1385.

Cha, D., Landolt, P.J., 2013. A four-component synthetic attractant for *Drosophila suzukii* (Diptera: Drosophilidae) isolated from fermented bait headspace. Pest Manag. Sci.

Lee, J.C., Burrack, H.J., Barrantes, L.D., Beers, E.H., Dreves, A.J., Hamby, K., Haviland, D.R., Isaacs, R., Richardson, T., Shearer, P.W., Stanley, C.A., Walsh, D.B., Walton, V.M., Zalom, F.G., Bruck, D.J., 2012. Evaluation of monitoring traps for *Drosophila suzukii* (Diptera: Drosophilidae) in North America. J. Econ. Entomol. 105, 1350-1357.

Lee, J.C., Shearer, P.W., Barrantes, L.D., Beers, E.H., Burrack, H.J., Dalton, D.T., Dreves, A.J., Gut, L.J., Hamby, K.A., Haviland, D.R., Isaacs, R., Nielsen, A.L., Richardson, T., Rodriguez-Saona, C.R., Stanley, C.A., Walsh, D.B., Walton, V.M., Yee, W.L., Zalom, F.G., Bruck, D.J., 2013. Trap designs for monitoring *Drosophila suzukii* (Diptera: Drosophilidae). Environ. Entomol. 42, 1348-1355.

Van Steenwyk, R., Novotny, L., Wise, C., 2012. Pre-harvest control of spotted wing drosophila in cherry, 2011. Arthro. Mgmt. Tests 37, Report B2.

van Steenwyk, R.A., Novotny, L., 2011. Control of Spotted Wing Drosophila in Cherry, Orchard Pest and Disease Management Conference, Portland, OR, p. 41.

Executive Summary

This three-year project focused on key management issues for a new, invasive pest of sweet cherries in eastern Washington, spotted wing drosophila (SWD). Four objectives were addressed in the course of the project: 1) Provide a crop protection alert system to cherry/stone fruit producers and seasonal phenology information through a regional SWD trapping program; 2) Determine timing of cherry fruit susceptibility in the field; 3) Test standard trap types for capture efficiency of SWD (in collaboration with SCRI-SWD regional group); 4)~~.~~ Test pesticide efficacy for control of SWD in cherries in laboratory, field-laboratory, and field settings.

The first objective was met by creating a regional alert system for SWD, which was posted on a dedicated website http://www.tfrec.wsu.edu/pages/swd. The core information for the website was a network of SWD traps located from the Canadian border to the Oregon border. Traps were checked weekly, and results uploaded within 24 h of retrieval. Trap retrieval and counting SWD were performed jointly by the Beers, Walsh, and Yee programs, and volunteer fieldmen. A table on the front page of the website informed visitors of which cherry growing regions in eastern Washington had caught at least one adult SWD, and the date of that capture. Recommendations for control (also posted on the website) advised that control measures should begin if 1) fruit were susceptible (see Obj. 2) and the first fly had been detected in the region. In addition, an email list developed by Tim Smith (with the option to subscribe posted on the website) sent notification for each new region with a first capture, and other news of note on SWD activity in the state.

The trap network also served to establish the phenology of SWD in our region, which was unknown at the time of invasion (2010). Five years of data show a similar seasonal pattern (low in winter through mid-summer, rising in late summer and peaking in fall). However, the relative numbers captured (even allowing for year to year differences in traps with different efficiencies) varied widely among the 5 years. Severe winter temperatures are the most likely explanation for some, but not all, of this variation, and needs further exploration.

Significant progress has been made on fabricating a more efficient trap. With the wet-bait (apple cider vinegar trap), higher bait volumes, and to a lesser extent, greater surface area, correspond to higher capture rates. The development of synthetic lures from Trécé and Scentry, ~~)~~ and commercial traps (Biobest, Contech) hold promise for greater sensitivity and ease of use. The issue of sensitivity (earliness of capture) may allow traps to be used for an action threshold on an individual block basis, rather than spraying all cherry orchards in a region based on a single fly.

Candidate pesticides have been screened for length of residual control and fruit protection against SWD. The spinosyns (Delegate, Entrust) provide a high level of activity, and the longest residual control of the compounds tested. The pyrethroids (Warrior, Endigo) also provide a high level of initial control, but residual control was more variable. Diazinon was similar to Warrior in that it provided at least 2 weeks of control. The other older materials (Sevin and Fyfanon, or ULV malathion) have short PHIs, and correspondingly short lengths of residual control (<1 week). The diamides are variable, with little mortality caused by Altacor, and higher levels by Exirel and a currently unregistered compound, cyclaniliprole.