Arthropod Pest Management in the Lower San Joaquin Valley

Project No.: **14-ENTO6-Haviland**

Project Leader: David Haviland
Entomology Farm Advisor
UCCE - Kern County
1031 S. Mount Vernon
Bakersfield CA 93307
661.868.6215
dhaviland@ucdavis.edu

Project Cooperators and Personnel:
Stephanie Rill, UCCE - Kern County
Kris Tollerup, UC Statewide IPM Program, Kearney REC
Brad Higbee, Wonderful Orchards

Objectives:

1) Evaluate the effectiveness of miticides for use against Pacific spider mite
2) Determine if herbivore induced plant volatiles (HIPVs) can be used to monitor for natural enemies of spider mites
3) Evaluate hull split treatment timings on the effectiveness of larvicides for navel orangeworm
4) Evaluate baiting strategies for fire ant management
5) Screen new reduced-risk insecticides for their effectiveness against leaffooted bug
6) Maintain a University-based research and demonstration orchard for almond pest management research in the San Joaquin Valley

Interpretive Summary:

Insect pests, such as navel orangeworm, spider mites, ants, and leaffooted bug, are a significant concern to almond growers in the lower San Joaquin Valley. Management of each of these pests relies on integrated pest management practices including monitoring and treatment programs. During 2014 we conducted a series of experiments to evaluate different components of an IPM program. Miticide trials showed that industry standard miticides, including Envidor, Fujimite, Onager, Vigilant and Zeal continue to be effective. Evaluations of a low-odor formulation fenpyroximate (Fujimite XLO) were equally effective as its predecessor Fujimite 5EC. Evaluations of the newly-registered miticide Nealta showed that it has similar efficacy to industry standards whereas another new product that is still in the process of being registered, Magester, did not perform as well in our 2014 trials as it did in trials the previous year. We also evaluated two biological miticides that did not provide any mite control.

Three different herbivore-induced plant volatiles were evaluated to determine if they could be used with yellow sticky cards for monitoring predators of spider mites. Data showed that none of the lures resulted in additional captures compared to when the cards were used on their own. However, high captures of certain predators, particularly sixspotted thrips, on traps without lures suggests that there may still be an opportunity using traps for monitoring populations of natural enemies of mites.

Navel orangeworm trials were used to evaluate seven different insecticides that work primarily by affecting egg and larval development. Data showed that applications made at the initiation of hull split were more effective than applications made two weeks later. However, despite significant navel orangeworm pressure in the trial ranging from 15 to 25% for most treatments, we were not able to determine any statistical differences among treatments when data were analyzed independently by application timing or by the number of applications.

Ant bait trials documented that Clinch continues to be effective against southern fire ants and that control is achieved approximately 8 weeks after application. This is to give time for the bait to control the queen and ultimately the colony. In comparison, evaluations of the new ant bait Altrevin showed that effects on ant populations are almost immediate and can be seen as early as 3 days after treatment (DAT). However, over time the longevity of control was not as good as traditional baits. For that reason, almond growers can now choose between two different baiting strategies. The first is an early application of a product like Clinch, as well as Esteem or Extinguish, which take a long time to work but last a long time. The second is an application close to harvest (but still fulfilling PHI requirements) of Altrevin that provides more immediate effects but offers shorter residual effects.

Leaffooted bug trials documented that the industry standard Lorsban (chlorpyrifos) provides excellent contact activity on adult bugs and about one week of residual control. Two pyrethroids, Brigade and Warrior II, also provided excellent contact activity and four full weeks of residual control. This means that following application of these products, adult bugs that fly into the orchard during the next four weeks are still likely to die. However, there are significant concerns about using pyrethroids in March or April when leaffooted bug treatments are most common due to their effect on biological control organisms, particularly the ones that assist in spider mite control. Evaluations of other ‘soft’ insecticides for leaffooted bug revealed that Agri-Mek has excellent contact activity if sprayed directly on adult bugs, but that it has no activity once the residue dries. Other ‘soft’ insecticides provided partial control of leaffooted bug when sprayed directly on the bugs, but none of them provided any residual control.

Materials and Methods:

<u>Objective 1. Spider mite management</u>
During 2014 we conducted a trial in Shafter, CA to evaluate the effects of miticides on the density of Pacific spider mites in almond. The trial was located in a six year old orchard (20 x 22 spacing) that contained alternating rows of the varieties Nonpareil and Monterey. Plot size was three trees long by one row wide. The plots were organized into a randomized complete block design with 4 blocks of 12 treatments and an untreated check. Treatments were applied on 16 Jun to individual trees with a hand gun at 150 PSI with a water volume equivalent to 200 gpa.

Mite densities were evaluated in each plot prior to treatment on 13 Jun and then on 19 Jun (3 DAT), 23 Jun (7 DAT), 30 Jun (14 DAT), 7 Jul (21 DAT), 14 Jul (28 DAT) and 21 Jul (35 DAT). On each sampling date a total of 20 leaves were collected per plot. This included six to seven random leaves per tree from each of the three trees per plot. Leaves were transported to a laboratory where motile Pacific spider mites (larvae, nymphs, and adults) were counted. For each evaluation date the average number of motiles and eggs per leaf were analyzed by ANOVA using transformed data (square root (x + 0.5)) with means separated by Fisher's Protected LSD (*P* = 0.05).

The number of mite-days was also analyzed across all evaluation dates. This was done by calculating the cumulative number of mite-days (1 mite for 1 day) found in each plot. Steps to do this were: 1) Multiply the number of mites 3 DAT by 3 days, 2) For data 7, 14, 21, 28 and 35 DAT calculate the average mites per leaf for the current and previous sample date, and then multiply each by 7 days, and 3) calculate the sum of the mite-days from all evaluation dates. Mite-days were analyzed by ANOVA using transformed data (square root (x + 0.05)) with means separated by Fisher's Protected LSD (P=0.05).

<u>Objective 2. Monitoring natural enemies with herbivore-induced plant volatiles</u>
In recent years sixspotted thrips has become one of the most important predators of spider mites in California. When sixspotted thrips arrive, complete control of spider mites is typically achieved within a few weeks. The problem is that we currently have no way to determine when they will arrive, and we don't have an easy way to monitor their populations once they arrive.

When spider mites feed on trees the tree responds by releasing volatile compounds into the air that indicate that the tree is being attacked. These volatiles can act as kairomones to natural enemies such as predatory thrips who sense these volatiles and use them as a way to locate potential food sources. Research during the last few years in Washington (Vincent Jones-WSU) and California (Nick Mills- UCB) has evaluated the use of HIPVs (herbivore induced plant volatiles) such as geraniol, methyl salicylate, and 2-phenylethanol (known as GMP) as a way to monitor for natural enemies of a wide range of pests, and as a method for potentially attracting natural enemies into orchards. Different blends of HIPVs have been found to be attractive to lacewings, syrphid flies, parasitoids, and other natural enemies. However, none of the places HIPVs were tested have predatory thrips, such as sixspotted thrips.

During 2014 we conducted a field trial to evaluate captures of mite predators using HIPVs in an almond orchard with a heavy spider mite infestation. The trial was organized as a randomized complete block design with four treatments and an untreated check. Plot size was 5 trees by 4 rows (100 ft x 88 ft) and at the center of each plot we hung a lure at the top of a 5-in by 7-in yellow panel trap with stickum on both sides of the trap. Lures were made by heat-sealing the end of rolled plastic tubing, adding a dental wick to the bag, pipetting the lure onto the wick, and then heat-sealing the other end of the bag to make a 2-inch by 1.25-inch sealed lure packet. Lures (= treatments) contained geraniol (2 ml in a 1.5mm thickness bag with a medium wick), methyl salicylate (3.5 ml in a 4mm thickness bag with a large wick), 2-phenylethanol (1 ml in a 1.5mm thickness bag with a small wick), and a combination of all three lures hung together. Panel traps with their associated lures were hung in the almond orchard and were evaluated on a weekly basis for five weeks on 21 Jul, 28 Jul, 4 Aug, 11 Aug and 18 Aug. Each week the sticky panel was removed, covered with saran wrap, stored for further evaluation and replaced by a new sticky panel for the following week. The original lures were not replaced weekly, meaning that the same lures were used for the entire five weeks of the study. For each evaluation date the average numbers of each of the predators per card were analyzed by ANOVA using transformed data (square root (x + 0.5)) with means separated by Fisher's Protected LSD (*P* = 0.05)

Objective 3. Larvicides for NOW at hull split

Navel orangeworm management programs rely primarily on winter sanitation and in-season insecticide sprays. There are several options for chemical control, thought he most common insecticides include broad-spectrum pyrethroids and 'softer' products that are principally known as larvicides. This includes the growth regulator Intrepid, the anthranilid diamides Altacor and Belt, and the spinosyn Delegate. During 2014 we conducted an insecticide trial in Shafter, CA to provide a side-by-side comparison of efficacy of the principal non-pyrethroid insecticides available to almond growers.

The trial was established in Kern County at the Shafter Research Farm. A total of 144 Nonpareil trees were organized into a randomized complete block design of 21 treatments and three sets of untreated checks. Treatments included Altacor (chlorantraniliprole) at 4 oz/ac, Belt (flubendiamide) at 4 oz/ac, Delegate (spinetoram) @ 6.4 oz/ac, Exirel (cyantraniliprole at 20.5 fl oz/ac, Intrepid (methoxyfenozide) at 16 fl oz/ac, Intrepid Edge (methoxyfenozide + spinetoram) at 12 fl oz/ac, and Proclaim (emamectin benzoate) at 4.5 oz/ac. Treatments were applied to individual trees with a hand gun at 200 GPA at 150 PSI on either 27 Jun, 11 Jul or both. Treatments that had both applications (27 Jun and 11 Jul) were also treated with a third application on 6 Aug. The Jun treatments corresponded with the second flight of navel orangeworm and the initiation of hull-split on the Nonpareil trees. All treatments were harvested by hand on 1 Aug by collecting 300 to 400 nuts per tree into brown paper sacks. Treatments that had applications on 6 Aug were also harvested on 22 Aug with the same method. Samples were taken to the lab and allowed to dry for approximately three weeks. At that time they were placed into a walk-in refrigerator to stop development of navel orangeworm until the nuts could be processed. All nuts from each sample were cracked to determine the percentage nuts from each tree that were infested by navel orangeworm. Data were analyzed by ANOVA with means separated by Fisher's Protected LSD (*P* = 0.05).

Objective 4. Ant bait programs

Southern fire ant is an important pest of almonds due to its ability to feed directly on the kernel during the period of harvest when nuts are on the ground. Currently, the standard practice for ant management is to make one or two applications of protein-based baits between April and June. Worker ants collect the baits, take them back to the colony, and feed them to the brood and queen. Over a period of one or two months this causes the queen to die or become sterile, thus resulting in a reduction in the number of worker ants that can feed on almond kernels during harvest.

During 2014 we conducted a trial near Shafter, CA to evaluate the effects of three insecticidal ant baits on the density of southern fire ants in almonds. The trial was located in a 45-acre portion of a second-leaf orchard that contains alternating rows of the varieties Nonpareil and Monterey. Each plot was 15 rows wide by 15 trees long (2.3 ac.) on a 20 ft by 22 ft spacing. The plots were organized into a randomized complete block design with four blocks of three treatments and an untreated check. The treatments were: 1) Altrevin at a rate of 1.5 lbs/ac, 2) Clinch at a rate of 1.0 lb/ac, 3) Seduce at a rate of 34.0 lb/ac and 4) an untreated check. Applications were made using a Herd Spreader GT77 mounted to the back of an all-terrain vehicle (ATV) with a 0.576” diameter hole within plate for Seduce applications and a #2 plate for Altrevin and Clinch applications on 27 Jun.

Southern fire ant densities were evaluated in each plot prior to treatment on 26 Jun and then on 30 Jun (4DAT), 3 Jul (7DAT), 7 Jul (11DAT), 10 Jul (2 WAT) and then weekly starting 17 Jul through 5 Sept (10 WAT). On each sample date, 24 plastic vials baited with 0.5 inch slices of hot dog were placed next to the irrigation hose in rows 5, 7, 9, and 11 starting at tree 3 and going every other tree until tree 13. After 1.5 hrs to 3 hrs, depending on environmental conditions on the evaluation date, vials were picked up, sealed closed and placed in a freezer. Vials of frozen ants were removed from the freezer at a future date and were evaluated for the number of ants in each vial. Data were organized for each plot to determine the average number of ants per vial. Data was analyzed by ANOVA after square root (sqrt(x+0.5)) transformation of the data. Means for all data were separated using Fisher's Protected LSD at $P = 0.05$.

<u>Objective 5. Insecticides for control of leaffooted bug</u>
During 2014 we conducted a series of trials to evaluate the effects of 10 different insecticides on leaffooted bug, *Leptoglossus zonatus* (Dallas). This included a laboratory bioassay to evaluate mortality of insects that were sprayed directly with the insecticides and a field study where adult bugs were caged on treated almond branches at weekly intervals after the foliage and nuts were treated. The goal was to determine the strengths and weaknesses of each insecticide and potential fits within an integrated pest management program.

The laboratory contact bioassay was started on 10 Sept 2014 using leaffooted bugs collected from abandoned pomegranate trees near Arvin, Kern Co., CA. Insects were collected from the field, returned to the laboratory, and sorted by age and gender to produce 48 petri dishes that each contained 3 adult male and 3 adult female leaffooted bugs as well as another 48 petri dishes that each contained 6 mixed-gender 2nd or 3rd instar nymphs. Petri dishes were assigned randomly to the 12 treatments that included 10 insecticides plus Dyne-Amic as a surfactant, a surfactant-only control, and an untreated check. Petri dishes were placed into a walk-in cooler for approximately 30 minutes and then the cover was removed and the insects were sprayed to light runoff using an 800-ml hand-held spray bottle that contained the insecticide mixed to a 200 GPA of water dilution. After treatment covers were restored to the petri dishes and the insects were allowed to stay in the dish for approximately 15 minutes. At the conclusion of the 15-min period insects were transferred to a clean petri dish containing a green bean and slice of carrot and all dishes were left on a laboratory countertop at ambient temperatures of approximately 75 to 80 degrees F for the remainder of the study. Mortality was evaluated 2 DAT and 8 DAT by counting the number of insects that were alive, moribund (unable to control their motor functions), or dead. For each evaluation date the percentage of dead insects and percentage of dead + moribund insects were evaluated by ANOVA with means separated by Fisher's Protected LSD (P=0.05)

The effects of insecticide residues on leaffooted bug mortality were evaluated in a 6th leaf almond orchard near Shafter, CA. On 16 Apr thirty-six Nonpareil trees were selected and assigned randomly in groups of three to the twelve treatments. Each group of three trees was sprayed with one treatment using a hand gun at 150 PSI in a water volume equivalent of 200 GPA. The effects of insecticide residues were evaluated by placing four adult leaffooted bugs

(2 male and 2 female) into each of 60 5-gal paint strainer bags. Bags were then assigned randomly to the treatments and each of five cages was placed over a single almond branch containing and average of 12.6 (range 8 to 18) nuts. This process was repeated on 17 Apr (1 DAT), 24 Apr (7 DAT), 1 May (14 DAT), 8 May (21 DAT), and 15 May (28 DAT). Mortality within each cage was recorded 7 and 14 days after placement in the field, after which insects were removed from the cages and cages were place back on the almond branch until harvest. On 30 Jul all nuts within cages were harvested and cracked to determine percentage of nuts within each cage that had leaffooted bug damage. For each evaluation date the percentage mortality and percentage damaged kernels were analyzed by ANOVA with means separated by Fisher's Protected LSD (P = 0.05).

Objective 6. Maintain a research orchard in Kern County

Funding provided by the Almond Board of California has historically allowed us to maintain two research orchards in the San Joaquin Valley. The first site is a 7-acre orchard in Shafter in Kern County on land that used to be part of the UC Shafter Research and Extension Center. The orchard is planted on a 22' by 20' spacing with alternating rows of Nonpareil and Monterey. Irrigation is set up using microsprinklers with the capability to turn water on and off on each individual row. The orchard has a total of 700 trees that were harvested for the first time in 2011

The second orchard is 5 acres and is located at the UC West Side Research and Extension Center in Five Points, Fresno Co. The orchard is planted on a 22' x 15' spacing with a three-tree alternating pattern down each row of Nonpareil, Carmel and NePlus Ultra. The orchard was designed and planted under the direction of Dr. Brent Holtz in 2008 to conduct research on almond diseases. It is now utilized for trials related to pest management. However, due to the recent lack of surface water availability at the station combined with two years of irrigating the trees with high salinity groundwater, the quality of trees in the orchard has decreased significantly over the past two years and it was decided by the Almond Board Production Research Committee to abandon this orchard for pest management research during the 2014-15 funding cycle.

Results and Discussion:

Objective 1. Spider mite management

The average mite density across all treatments prior to the initiation of the trial was 2.3 mites per leaf (**Table 1**). This mite density is typical for the pest pressure that would trigger a miticide treatment during June or July. Plots treated with all miticides had mite densities that were numerically lower than the untreated check 3 DAT, 7 DAT and 14 DAT; however, these reductions were not significantly different for any of the three evaluation dates due to the patchy and clumped nature of mite infestations in the orchard. Statistical differences in mite density were first documented 21 DAT. The lowest mite densities of less than 5 mites per leaf were in plots treated with Zeal, Nealta, Envidor, and Fujimite XLO compared to 24.6 mites per leaf in the untreated check. All other miticide treatments except for Magister, GOP-1 Meal and 415 Oil were statistically equivalent to the best miticide treatments. By 28 DAT mite densities increased rapidly compared to the previous week. Treatments with 10 or fewer mites per leaf were Envidor, Vigilant, Fujimite XLO, Onager, Fujimite 5EC and Zeal compared to 20.3 mites per leaf in the untreated check. By 35 DAT large numbers of mite predators swept through the trial and treatment differences disappeared.

Table 2 shows the effects of miticide treatments on the density of spider mite eggs. Patterns in the relative efficacy of different miticides were very similar to the patterns seen in the densities of motile spider mites shown in **Table 1**.

Table 1. The effects of miticide treatments on the density of Pacific spider mite in almond, Shafter 2014.

Treatment	Rate form. product/ac	Mean spider mites per leaf						
		Pre-counts	3 DAT	7 DAT	14 DAT	21 DAT	28 DAT	35 DAT
Envidor 240SC + 415° Oil	18 fl oz + 2 gal	0.9	1.6	1.8	1.5	4.9abc	4.2a	4.5
Fujimite 5EC + 415° Oil	32 fl oz + 2 gal	2.2	0.8	0.5	1.2	14.0abcd	10.0abc	9.9
Fujimite XLO + 415° Oil	32 fl oz + 2 gal	0.7	0.6	0.7	3.1	5.0abc	7.9ab	2.4
Magister 10EC + 415° Oil	32 fl oz + 2 gal	1.5	0.8	1.0	3.9	21.1bcd	13.8bc	18.2
Nealta 20SC + 415° Oil	13.5 fl oz + 2 gal	3.5	0.1	0.5	0.3	2.9ab	13.2bc	15.9
Onager 1EC + 415° Oil	24 fl oz + 2 gal	1.6	1.5	4.7	1.9	9.4abcd	9.2ab	7.7
Vigilant 4SC + 415° Oil	24 fl oz + 2 gal	2.8	0.9	0.9	2.4	5.3abc	7.0ab	9.8
Zeal 72WP + 415° Oil	3 oz + 2 gal	2.8	0.3	2.1	0.8	2.2a	10.0ab	9.4
PFR-97 + 415° Oil	2 lb + 2 gal	4.6	0.2	1.7	2.7	10.1abcd	17.1bc	15.8
GOP-1 Meal + GOP-1 Oil	56 fl oz + 2 gal	1.8	0.4	1.8	1.2	18.4cd	12.4abc	8.4
415° Oil	2 gal	1.3	0.5	1.1	3.1	23.2d	22.2c	10.3
Untreated	--	3.8	1.8	5.5	7.9	24.6d	20.3c	11.0
F (df = 11,33)		0.36	0.94	1.51	1.66	2.28	2.26	1.04
P		0.9614	0.5132	0.1747	0.1278	0.0330	0.0346	0.4322

Means in a column followed by the same letter are not significantly different (P>0.05, Fisher's Protected LSD) after square root (x + 0.5) transformation of the data. Untransformed means are shown.
[1]Mite-days are a cumulative measurement that is determining by adding the average mites per leaf for each of the 35 days of the trial.

Table 2. The effects of miticide treatments on the density of Pacific spider mite eggs in almond, Shafter 2014.

Treatment	Rate form. product/ac	Mean spider mite eggs per leaf						
		Pre-counts	3 DAT	7 DAT	14 DAT	21 DAT	28 DAT	35 DAT
Envidor 240SC + 415° Oil	18 fl oz + 2 gal	1.4	0.9	2.1	3.2	5.6a	11.2	1.0
Fujimite 5EC + 415° Oil	32 fl oz + 2 gal	3.3	1.2	0.3	2.2	9.6ab	7.4	0.5
Fujimite XLO + 415° Oil	32 fl oz + 2 gal	0.7	0.8	1.2	6.1	3.7a	10.8	0.6
Magister 10EC + 415° Oil	32 fl oz + 2 gal	1.2	1.5	0.6	9.7	12.3ab	19.5	7.4
Nealta 20SC + 415° Oil	13.5 fl oz + 2 gal	2.3	0.8	0.4	0.4	4.8a	23.3	4.2
Onager 1EC + 415° Oil	24 fl oz + 2 gal	1.3	2.0	3.1	2.4	5.4a	12.3	1.3
Vigilant 4SC + 415° Oil	24 fl oz + 2 gal	4.6	3.0	0.6	1.4	4.8a	10.9	3.7
Zeal 72WP + 415° Oil	3 oz + 2 gal	2.1	1.1	2.0	1.2	6.7a	16.8	4.7
PFR-97 + 415° Oil	2 lb+ 2 gal	5.4	0.3	2.1	2.3	10.2ab	12.5	5.1
GOP-1 Meal + GOP-1 Oil	56 fl oz+ 2 gal	0.3	0.8	1.4	2.8	11.8ab	11.2	0.6
415° Oil	2 gal	1.6	1.3	1.9	4.6	18.8b	19.9	2.1
Untreated	--	1.6	2.2	4.1	10.0	19.7b	18.1	1.2
F (df = 11,33)		0.47	0.45	1.52	1.75	2.31	0.71	0.68
P		0.9114	0.9193	0.1717	0.1056	0.0315	0.7175	0.7432

Means in a column followed by the same letter are not significantly different (P>0.05, Fisher's Protected LSD) after square root (x + 0.5) transformation of the data. Untransformed means are shown.

The purpose of this trial was to evaluate industry standard miticides compared to new products that were recently registered or that are being considered for registration. Industry standard miticides included Envidor, Fujimite 5EC, Onager, Vigilant and Zeal. Cumulative mite-days in plots treated with these products were all statistically equivalent (**Figure 1**).

The trial contained several new products that have recently become registered or that are in the process of being registered. Fujimite XLO (fenpyroximate) is a new, lower-VOC version of Fujimite 5EC. Efficacy was statistically equivalent to the best of the treatments. Magister (fenazaquin) is a new METI I acaricide. It has the same mode of action as Fujimite. Mite densities in plots treated with Magister were statistically equivalent to the untreated check on all evaluation dates. This is in comparison to trials we did in 2013 where Magister provided mite control comparable to industry standard miticides. Nealta (cyflumetofen) is a new METI II acaricide that represents a new mode of action for miticides in almonds. Nealta works primarily on contact and resulted in mite densities that were statistically equivalent to the best of the grower standard miticides. PFR-97 and GOP-1 are two new experimental miticides. Mite densities in plots treated with these miticides were statistically equivalent to the untreated check on all evaluation dates. Further analysis of the data shows that these products plus oil performed similarly to plots treated with oil alone (415° Oil).

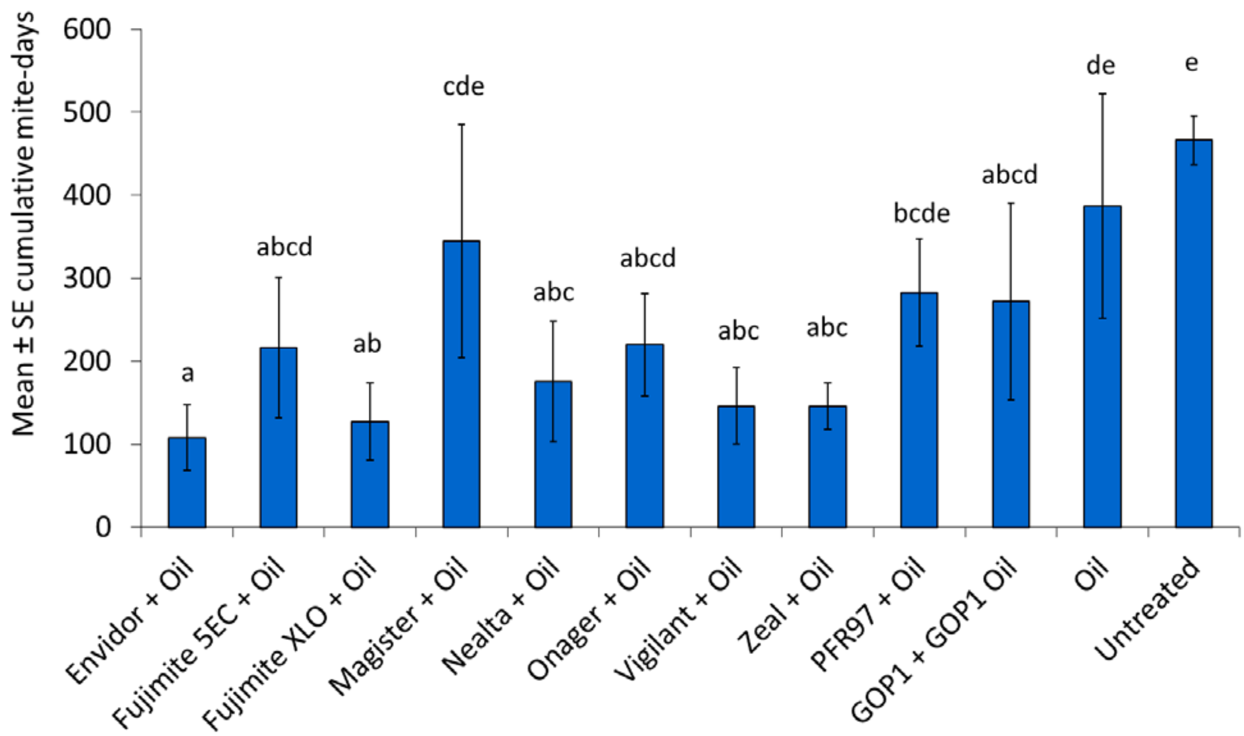

Figure 1. The effects of miticide treatments on the density of Pacific spider mite in almonds. Columns with the same letter are not significantly different ($P > 0.05$, Fisher's protected LSD) following square root (x + 0.5) transformation of the data. Untransformed means are shown.

Objective 2. Monitoring natural enemies with herbivore-induced plant volatiles

During the study we had a heavy population of spider mites that attracted excellent numbers of natural enemies to the trial site. Over the duration of the trial yellow panel traps captured 18,565 six-spotted thrips (*Scolothrips sexmaculatus*), 642 mite destroyer beetles (*Stethorus picipes*), 219 minute pirate bugs (*Orius* spp.) and 252 adult green lacewings (*Chrysopa* spp. and *Chrysoperla* spp.). The captured insects were almost exclusively adults.

Weekly captures of each group of insect are shown in **Table 3**. The predominant predator captured was sixspotted thrips. However, no lure resulted in increased captures compared to the negative control that only contained a card without the lure on any of the five evaluation dates. The only datapoint that was significantly different than the negative control was the MS+GE+PE combination treatment on 11 Aug where the lure may have slightly deterred the presence of thrips.

Similar patterns held true for mite destroyer beetles, minute pirate bugs, and green lacewings. We were unable to obtain any data suggesting that cards with lures captured more beneficials that cards without lures.

Despite the fact that we were unable to show the effectiveness of lures for monitoring spider mite predators, the trial did demonstrate that yellow panel traps by themselves are attractive to key spider mite predators, especially sixspotted thrips. These data suggest that future research on the use of yellow panel traps as a quick and easy way to determine the presence of predators of spider mites may be warranted.

Table 3. Captures of spider mite predators on yellow panel traps associated with lures containing three different herbivore-induced plant volatiles.

	Average six-spotted thrips (*Scolothrips sexmaculatus*) per trap				
	21 Jul	28Jul	4 Aug	11 Aug	18 Aug
Methyl Salicylate	192	406	98	40a	21
Geraniol	176	470	96	28abc	20
Phenyl Ethanol	185	362	114	19bc	19
MS+GE+PE	186	318	108	16c	14
Card only	208	444	123	31ab	19
F =	0.02	2.17	0.38	4.02	0.38
P =	0.9988	0.1191	0.8194	0.0192	0.8171

	Average spider mite destroyer beetles (*Stethorus picipes*) per trap				
	21 Jul	28Jul	4 Aug	11 Aug	18 Aug
Methyl Salicylate	20	9.0	2.0	1.8	1.2
Geraniol	8	9.6	2.0	0.4	0.8
Phenyl Ethanol	13	7.6	1.8	0.4	0.6
MS+GE+PE	14	6.6	3.2	2.8	0.2
Card only	10	9.8	1.2	0.8	0.6
F =	2.08	0.63	0.34	2.37	1.92
P =	0.1316	0.6508	0.8500	0.0997	0.1561

	Average minute pirate bugs (*Orius* spp.) per trap				
	21 Jul	28Jul	4 Aug	11 Aug	18 Aug
Methyl Salicylate	4.2ab	2.0bc	0.2	0.0	0.0
Geraniol	1.2c	1.2c	0.6	0.2	0.0
Phenyl Ethanol	2.6bc	3.6abc	3.2	0.0	0.0
MS+GE+PE	6.8a	4.2ab	3.0	2.6	0.0
Card only	2.0bc	5.2a	1.0	0.0	0.0
F =	3.84	3.83	1.51	2.17	-
P =	0.0225	0.0229	0.2463	0.1192	-

	Average adult lacewings (*Chrysopa* spp. and *Chrysoperla* spp.)				
	21 Jul	28 Jul	4 Aug	11 Aug	18 Aug
Methyl Salicylate	4.0	3.8	0.8	1.8	3.2a
Geraniol	3.4	3	0.8	1.2	0.2b
Phenyl Ethanol	5.0	4.2	1.2	0.8	0.4b
MS+GE+PE	3.2	2.2	0.4	1.2	0.8b
Card only	4.8	2.0	0.6	1.0	0.4b
F =	0.47	1.03	0.35	0.23	10.21
P =	0.7543	0.4230	0.8378	0.9174	0.0003

Means in a column followed by the same letter are not significantly different ($P > 0.05$, Fisher's protected LSD) with square root (x + 0.5) transformation of the data. Untransformed means are shown.

Objective 3. Larvicides for NOW at hull split

During our 2014 trial the two application timings corresponded to the initiation of hull split and approximately two weeks later. **Figure 2** shows the percentage reduction in NOW damage during our harvest on 31 Jul for plots treated with seven insecticides when applied at the initiation of hull split (27 Jun), two weeks later (11 Jul), or at both timings. In general, when damage is averaged across all treatments within application timing, the earlier application date provided increased control of NOW (average reduction of 20.9%) compared to the applications two weeks later (average reduction of 11.3%). Damage in plots treated twice (21.4% reduction) was similar to damage in plots treated at only the first timing (20.9% reduction), meaning that in general the second application timing two weeks after the initiation of hull split was not very effective.

Within each application date there were no significant differences among treatments ($P > 0.11$) when data were analyzed as a RCBD using original damage numbers or after completing an arcsine (sqrt) transformation of damage percentage.

Evaluation of data from the second harvest date of 22 August of plots treated with each insecticide three times is shown in **Figure 3**. Average damage among treatments ranged from 14.5 to 25.6%. However, none of the insecticides caused a reduction in NOW damage that was statistically significant compared to the untreated check ($P = 0.1046$).

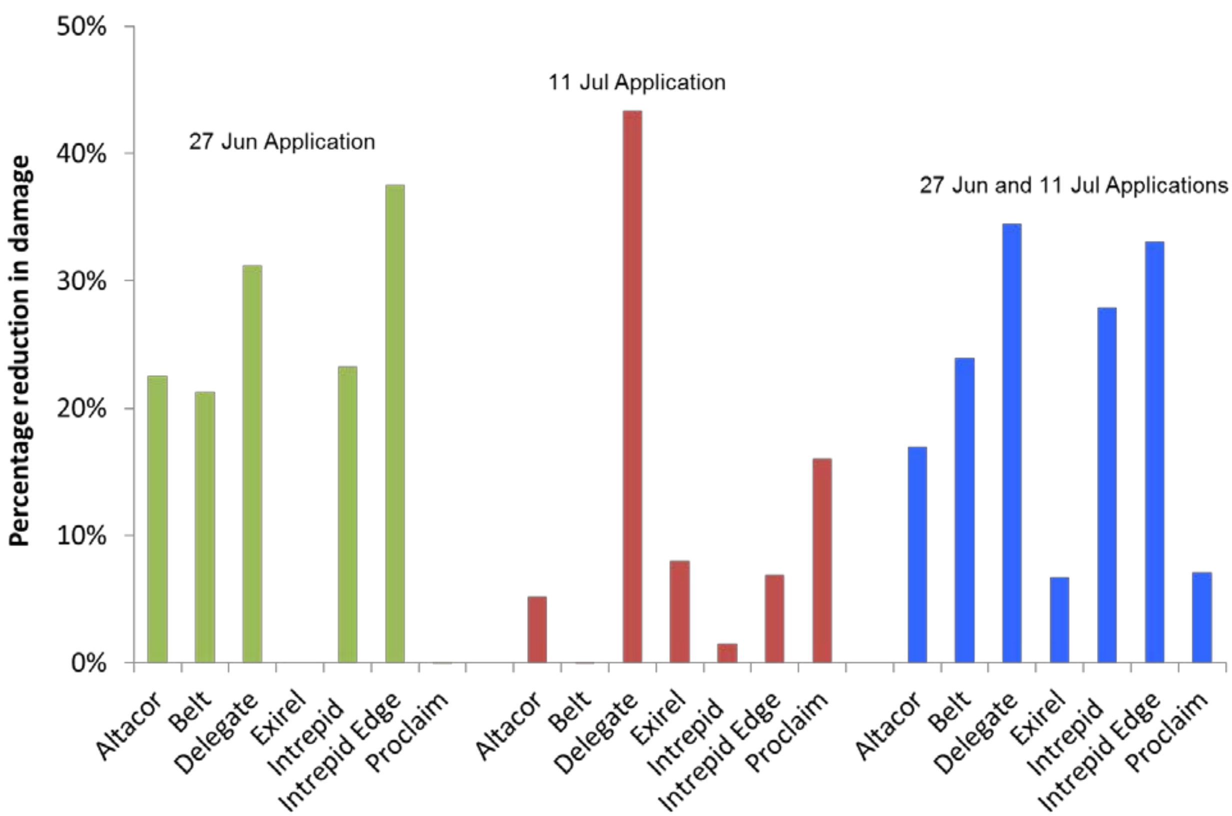

Figure 2. Percentage reduction in NOW damage on 31 July following applications of seven insecticides on 27 Jun, 11 Jul, or on both dates.

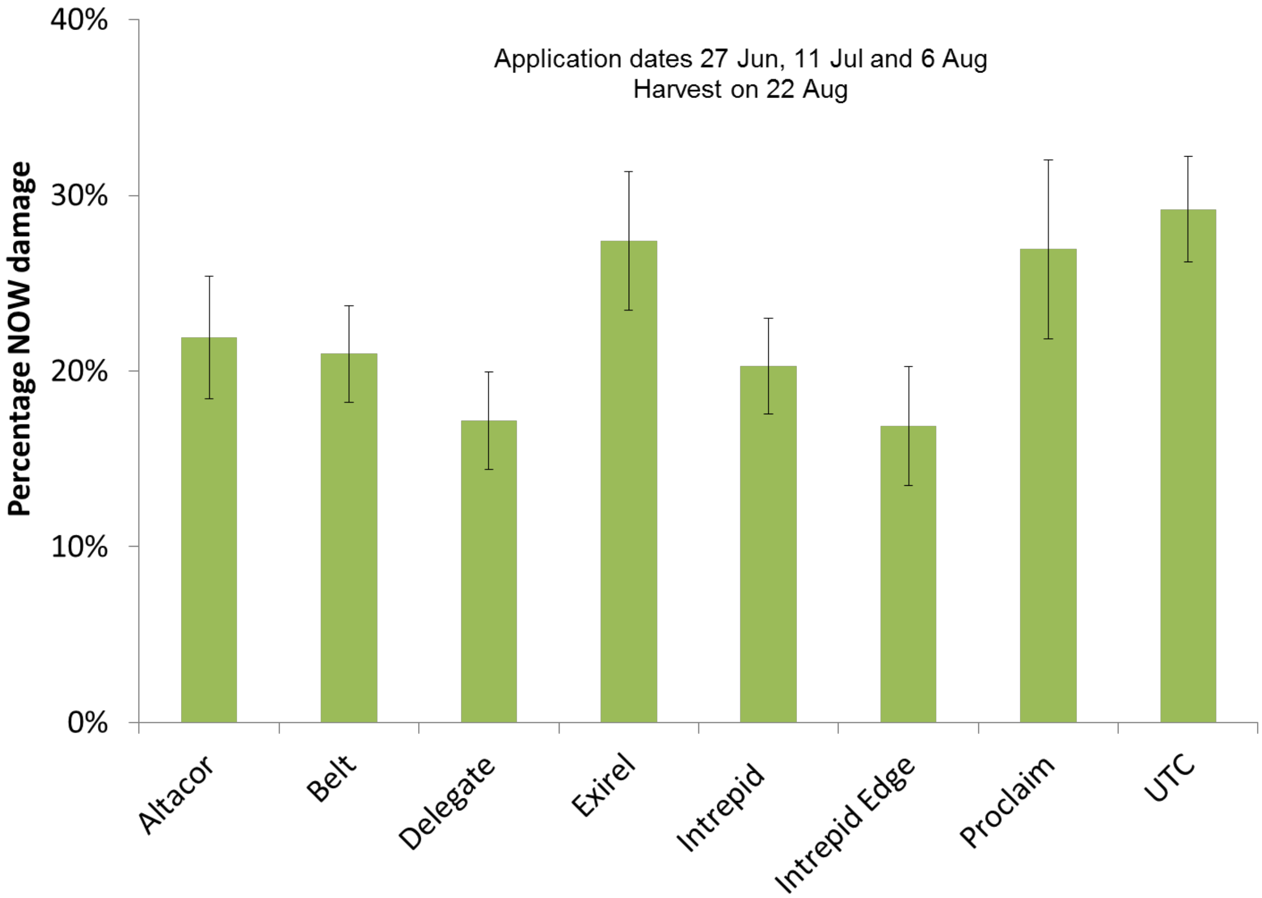

Figure 3. The effects of seven insecticides and an untreated check on navel orangeworm damage in late August following insecticide applications on 27 Jun (initiation of hull split at the start of the second flight), 11 Jul (initiation of pollinator split and mid-second flight), and 6 Aug (initiation of third flight and normal date of Nonpareil harvest).

Objective 4. Ant bait programs

The orchard contained large populations of southern fire ants that were fairly evenly distributed throughout the trial. In precounts the average number of ants per vial ranged from 375 to 451 for the four treatments (**Table 4, Figure 4**). Following treatment ant populations in plots treated with Altrevin were immediately reduced by 87 to 89% on evaluations 4 and 7 DAT. Ant density remained significantly reduced by 50 to 77% compared to the untreated check through 7 WAT. From 8 to 10 WAT ant densities were reduced by 28 to 44% to levels that were not significantly different than the untreated check.

In plots treated with Clinch there was a short-lived drop-off in ant foraging 4 DAT suggesting some contact mortality of foraging ants may have occurred. By 7 DAT foragers returned and ant density was only 8% lower than the untreated check. From 11 DAT through 10 WAT there was a steady increase in ant control with percentage reductions compared to the untreated check starting out at 28% (9 DAT) and increasing to 76% (9 WAT). It is possible that the greatest level of ant suppression with Clinch could have been achieved after the end of the trial when you consider that the greatest level of ant suppression was in the final evaluation date with a continued upward trend in control each week prior to that date.

In plots treated with Seduce there were significant reductions in ant density of 51 and 47% compared to the untreated check 4 DAT and 7 DAT, respectively. For all other evaluation dates there were no significant differences compared to the untreated check. On those dates percentage reduction ranged from 6 to 22%, which is almost equivalent to the 17% lower populations that were present in these plots compared to the untreated check in the precounts. This means that ant suppression by Seduce did not last as long as traditional baits like Clinch or work as fast as the new bait Altrevin. However, Seduce does have OMRI and is therefore an option for growers with organic certification.

These data suggest that traditional baiting programs with Clinch, and as well as other traditional baits such as Esteem and Extinguish, should continue to be used at least 8 weeks prior to the initiation of harvest to give them enough time to provide maximum control. Altrevin, on the other hand, works in a very different way. It provides excellent knock-down of ants within one week and can therefore be used near harvest at a date close to the preharvest interval. However, data suggest that the effects do not last as long as traditional insecticides. This means that applications of Altrevin close to the initiation of harvest should provide excellent ant control for Nonpareil harvest, but there are still unanswered questions about the level of control that will be provided when the last of the pollinators to be harvested are on the ground. As for Seduce, it did not provide as much knock-down or residual control as the other ant baits. However, it has OMRI approval, meaning that it is an option for orchards that have organic certification.

Table 4. The effects of ant bait applications on the density of southern fire ant workers collected in hot dog bait stations.

		Treatment, rate/acre					
		Altrevin 1.5 lb	Clinch 1.0 lb	Seduce 34 lb	Untreated Check		
Evaluation date		Average No. of ants per vial				*F*	*P*
26-Jun	Precount	389	379	375	451	1.29	0.335
30-Jun	4 DAT	48a	243b	232b	470c	21.39	0.0002
3-Jul	7 DAT	43a	309bc	178b	337c	14.96	0.0008
7-Jul	11 DAT	126a	296b	323b	416b	13.13	0.0012
10-Jul	2 WAT	60a	173b	218b	272b	12.39	0.0015
17-Jul	3 WAT	88a	206b	250bc	321c	24.5	0.0001
24-Jul	4 WAT	70a	145ab	196b	247b	4.64	0.0318
31-Jul	5 WAT	168a	148a	268b	345b	8.57	0.0053
8-Aug	6 WAT	156a	110a	270b	310b	5.96	0.016
14-Aug	7 WAT	82a	60a	195b	207b	18.52	0.0003
21-Aug	8 WAT	145b	58a	176b	225b	6.4	0.013
29-Aug	9 WAT	156b	61a	263c	281c	36.19	<0.0001
5-Sep	10 WAT	168b	55a	206b	234b	16.54	0.0005

Means in a row followed by the same letter are not significantly different (*P* > 0.05, Fisher's protected LSD) with square root (x + 0.5). Untransformed means are shown.

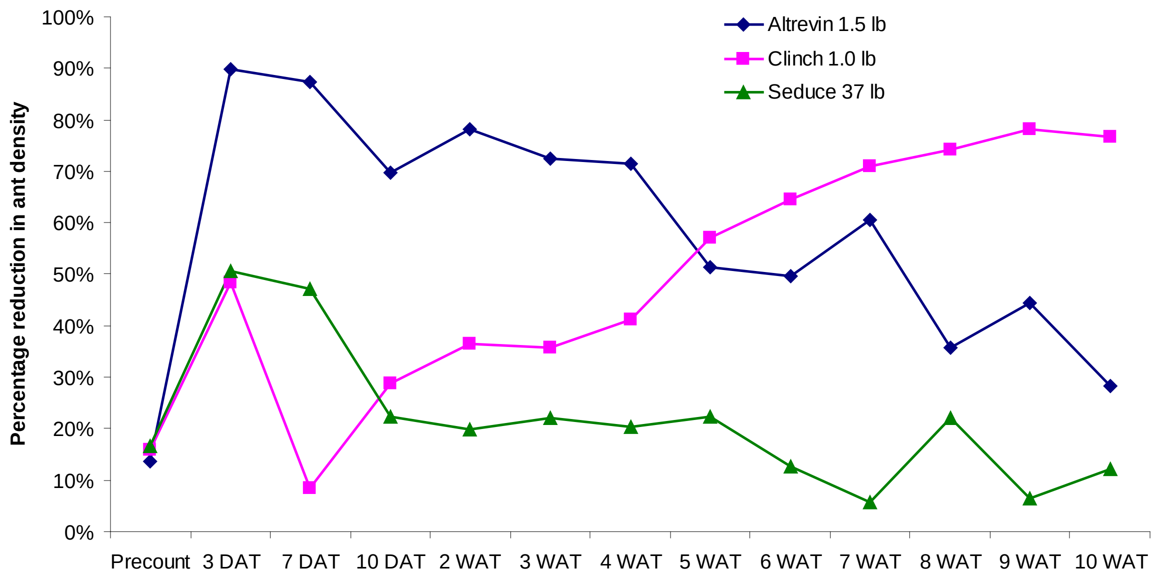

Figure 4. Percentage reductions in the density of foraging southern fire ant following applications of ant baits, Shafter, 2014.

Objective 5. Insecticides for control of leaffooted bug

Insecticide treatments had varied effects on leaffooted bug mortality (**Table 5)**. On the first evaluation date 2 DAT there were a total of seven insecticides that caused 13 to 50% LFB mortality (dead) with 58 to 100% of the insects showing symptoms of intoxication (dead or moribund). This included Brigade, Warrior, Lorsban, Agri-Mek, Belay, Bexar, Closer and Exirel. By 8 DAT >95% of the insects treated with Brigade, Lorsban, or Agri-Mek were dead or moribund. Moderate mortality of 67 to 83% occurred to insects treated with Warrior II, Belay, Bexar, Closer and Exirel. It is also worth noting that in the cases of Warrior II and Exirel the percentage of dead and moribund leaffooted bugs went down from 2 DAT to 8 DAT. This was due to some of the moribund insects 2 DAT recovering from toxicity and having their motor functions restored.

The impacts of insecticide treatments on leaffooted bug nymphs were very similar to the impacts that the same products had on adults. Greater than 90% mortality occurred to bugs treated with Brigade, Warrior and Lorsban Advanced whereas 58 to 83% mortality occurred in plots treated with Agri-Mek, Belay, Bexar, Closer and Exirel. Throughout the trial there were no significant differences in adult or nymph mortality in plots treated with Beleaf or Sivanto compared to the untreated check and mortality was negligible in both the untreated check as well as the surfactant-only control sprayed with Dyne-Amic.

Table 5. The effects of direct application of insecticides onto leaffooted bugs in a laboratory bioassay. Means in a column followed by the same letter and not significantly different (P>0.05. Fisher's Protected LSD)

		Adults				Nymphs			
		Dead		Dead or moribund		Dead		Dead or moribund	
Treatment[1]	Rate/ac.	2 DAT	8 DAT	2 DAT	8 DAT	2 DAT	8 DAT	2 DAT	8 DAT
Brigade WSB	32 oz	30bc	100a	100a	100a	25a	100a	100a	100a
Warrior II	2.56 fl oz	71a	71b	100a	79ab	25a	100a	100a	100a
Lorsban Adv.	4 pts	0d	96a	92ab	96ab	0b	100a	96a	100a
Agri-Mek SC	4.25 fl oz	46b	100a	92ab	100a	25a	83ab	71bc	92ab
Belay	4 fl oz	17cd	67b	71bc	71b	29a	79ab	79ab	79abc
Beleaf	2.8 oz	0d	4c	0d	4c	0b	25c	8ef	25d
Bexar 15SC	27 fl oz	42b	83ab	88ab	88ab	29a	67b	50c	71bc
Closer SC	4.5 fl oz	13cd	83ab	58c	83ab	17ab	63b	25de	63c
Exirel	20 fl oz	50ab	71b	96a	79ab	25a	58b	48cd	71bc
Sivanto	12 fl oz	0d	8c	4d	29c	0b	21c	4ef	21d
Dyne-Amic	8 fl oz	0d	17c	0d	17c	0b	0c	0f	0d
Untreated	-	0d	8c	0d	8c	0b	17c	0f	17d
	F	10.55	30.49	29.45	14.21	3.30	12.65	23.81	13.85
	P	<0.0001	<0.0001	<0.0001	<0.0001	0.0032	<0.0001	<0.0001	<0.0001

[1]All treatments except Dyne-Amic were made with the addition of the surfactant Dyne-Amic at a rate of 4 fl oz per 100 gallons of water.

In the insecticide residue field studies there was 100% mortality of leaffooted bugs caged on residues of the pyrethroids Brigade and Warrior II for 14 days beginning 1, 7, 14, 21 and 28 DAT (**Table 6**). In plots treated with Lorsban Advanced residues killed 95% of the leaffooted bugs that were caged 1 DAT, but there were minimal impact on bugs caged 7 or more days after treatment. The residues of all other treatments caused less than 20% mortality to leaffooted bugs exposed to residues 1-7 DAT and less than 45% to bugs exposed 1-14 DAT. In one or more cases the mortality caused by Bexar, Exirel, Closer and Beleaf was statistically higher than in the untreated check for cages placed on the residues 1 or 7 DAT. However, from a practical standpoint the reductions would at best be called suppression.

Table 6. The effects of aged pesticide residues on the mortality of leaffooted bug adults caged onto almond branches for 7 to 14 day intervals beginning each week from 0 to 4 weeks after application.

	Percentage Mortality (Days after treatment of exposure to residues)									
Treatment[1]	1-7	1-14	7-14	7-21	14-21	14-28	21-28	21-35	28-35	28-42
Brigade WSB	100a	100a	100a	100a	100a	100a	100a	100a	100a	100a
Warrior II	100a	100a	100a	100a	100a	100a	100a	100a	100a	100a
Lorsban Adv.	95a	95a	5c	15cd	20b	40b	0c	20b	0b	10b
Bexar 15SC	15bc	25c	25b	30bc	15b	15b	0c	30b	-	-
Agri-Mek SC	5cd	15cd	5c	10d	-	-	-	-	-	-
Belay	5cd	20cd	5c	10d	-	-	-	-	-	-
Beleaf	0d	10cd	5c	30bc	-	-	-	-	-	-
Closer SC	10bcd	25c	5c	15cd	-	-	-	-	-	-
Exirel	20b	45b	10bc	35b	-	-	-	-	-	-
Sivanto	5cd	5d	5c	5d	-	-	-	-	-	-
Dyne-Amic	0d	10cd	0c	5d	25b	25b	-	-	-	-
Untreated	5cd	5d	5c	10d	20b	40b	20b	30b	10b	35c
F	92.36	31.58	47.92	24.14	15.52	11.35	153.14	31.05	121.0	61.27
P	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Means in a column followed by the same letter are not significantly different (P>0.05, Fisher's Protected LSD).
[1]All treatments except Dyne-Amic were made with the addition of the surfactant Dyne-Amic at a rate of 4 fl oz per 100 gallons of water

The impacts of insecticide residues on caged leaffooted bugs affected the amount of kernel damage found at harvest (**Table 7**). Damage was negligible in plots where bugs were caged on residue of Brigade and Warrior II that were one to four weeks old. Mortality of leaffooted bugs from Lorsban resulted in a reduction in damage 1-14 DAT, but not thereafter. When considering all other treatments, the only ones to cause a significant reduction in damage were Exirel and Closer 7-21 DAT.

Table 7. Percentage almond kernels with leaffooted bug damage at harvest in cages exposed to leaffooted bugs for two week intervals beginning 1, 7, 14, 21 and 28 days after treatment with insecticides.

	Percentage Damaged Kernels at Harvest (days after treatment that LFB were caged on residues)				
Treatment[1]	1-14	7-21	14-28	21-35	28-42
Brigade WSB	2.9a	3.7a	0.0a	0.0a	0.0a
Warrior II	0.0a	0.0a	0.0a	0.0a	0.0a
Lorsban Adv.	10.5ab	57.2cde	70.5b	74.1b	52.4b
Bexar 15SC	35.6bc	48.7bcd	67.6b	94.4b	-
Agri-Mek SC	61.4de	70.7de	-	-	-
Belay	41.0cd	69.8de	-	-	-
Beleaf	55.8cde	87.3e	-	-	-
Closer SC	41.7cd	23.5abc	-	-	-
Exirel	35.3bc	17.6ab	-	-	-
Sivanto	74.6e	72.4de	-	-	-
Dyne-Amic	68.5e	82.5de	64.2b	-	-
Untreated	37.2cd	81.1de	70.9b	69.0b	74.1c
F	7.46	6.61	9.85	23.11	56.50
P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Means in a column followed by the same letter are not significantly different (P>0.05, Fisher's Protected LSD).
[1]All treatments except Dyne-Amic were made with the addition of the surfactant Dyne-Amic at a rate of 4 fl oz per 100 gallons of water

The current industry standard for leaffooted bug management is Lorsban Advanced. In our trials Lorsban provided excellent contact activity on leaffooted bugs and one week of additional activity for any insects that might fly into the orchard after treatments were made. However, increased regulatory scrutiny of this product suggests that alternative options for control need to be explored. Compared to Lorsban, the pyrethroids Brigade and Warrior II provided better contact activity and much longer residual. In fact, data suggests that insects that fly into the orchard and remain in the trees and feed on the nuts for a 7-day period 4 weeks after application are still going to die. The primary concern with pyrethroids in almonds is the potential to incite flare-ups of spider mites following applications early in the season.

Our study evaluated several newer and reduced-risk insecticides for leaffooted bug control. Excellent mortality was achieved when Agri-Mek was sprayed directly on leaffooted bugs. However, this product provided no activity when insects were caged on dried residues. Other advantages and disadvantages of this product are that Agri-Mek is commonly used for spider mite control in almonds during the period of time leaffooted bug treatments are made, through there are concerns over its effects on sixspotted thrips that serve as one of the primary predators of spider mites. Moderate levels of mortality were achieved when Belay, Bexar, Closer and Exirel were applied directly to leaffooted bug. These four products also had a small suppressive effect when leaffooted bugs were caged on treated surfaces during the first week after application. However, that suppression was not sufficient to prevent damage to the almond kernels at harvest, and the latter three of these products were still pending registration in almonds as of late 2014.

Objective 6. Maintain a research orchard in Kern County

During 2014 there were a total of six research projects completed at the research orchard in Shafter that is maintained in part by funding from the Almond Board. This included trials on spider mite, navel orangeworm, and herbicide management. During 2014 we did not do any research at the research almond orchard at the West Side Research and Extension Center due to a defunding of that part of our proposal by the Almond Board. As a result, the Fresno County orchard will no longer be used for pest management research and ownership has been transferred to UCCE pomology farm advisors for use in production research projects. In total over the past five years (2010-2014) these research orchards have been used for a total of 45 field trials.