Arthropod Pest Management in the Lower San Joaquin Valley

Project No.: 15-ENTO6-Haviland

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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 the effectiveness of hull split insecticide treatment timings as larvicides for navel orangeworm
4) Maintain a University-based research and demonstration orchard for almond pest management research in the San Joaquin Valley

Interpretive Summary:

Arthropod management is a key component to effective production of almonds. This ongoing project seeks to help improve the ability of almond growers and their pest control advisers to utilize integrated pest management approaches that fulfill sustainability goals of the almond industry. During the 2015-16 research cycle we focused our efforts on spider mite and navel orangeworm management. For mites we evaluated ten different miticides for their effects on Pacific spider mite. Particular emphasis was given to three new METI inhibitors including a new formulation of fenpyroximate (Fujimite XLO), and two new miticides that recently gained registration in California almonds (cyflumetofen = Nealta, and fenazaquin = Magister). Data showed that all three of these miticides, as well as other standards used in the trial, provided significant reduction in spider mites. However, due to a massive influx of sixspotted thrips that quickly ate up mites in the experimental orchard we were unable this year to generate guidelines regarding longevity of control

During 2015 we also conducted a second year of research on herbivore-induced plant volatiles (HIPVs) and the use of sticky traps for monitoring natural enemies of spider mites. HIPVs are chemicals produced by many plants that are under attack by spider mites in an effort to assist natural enemies that are searching for food. In our trials, sticky traps were a very effective way to monitor for natural enemies, with traps in our experimental orchard capturing 232 sixspotted thrips, 2 spider mite destroyer beetles, 1 minute pirate bug, and 1.2 lacewing larvae per trap per week over a 5-week period when mite pressure was high. Evaluation of traps containing

different HIPV lures did not result in any statistical differences among treatments that would suggest that the individual lures were attractive.

For navel orangeworm we conducted an insecticide trial that focused on ‘soft’ pesticide chemistries that provide an alternative to organophosphates and pyrethroids. Application of these larvicides and ovi-larvicides on 20 Jun (ahead of the start of the second flight, but when 75% of the nuts were already split due to severe drought conditions) did not result in any reduction in NOW damage. However, when these products were applied on 7 July (during the second flight), significant reductions in damage ranging from 35.3 to 56.2% were seen in plots treated with Altacor, Intrepid, Intrepid Edge, Belt, Harvanta (not registered), and Delegate. Efficacy of these same insecticides when applied on both dates was similar to the efficacy seen in plots treated only on 7 Jul. These data show that these ‘softer’ chemistries can provide similar levels of control as the broad-spectrum organophosphate and pyrethroid insecticides that typically provide damage reductions in the range of 30 to 50%.

Materials and Methods:

Objective 1. Spider mite Management

During 2015 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 seven-year-old orchard (20 ft x 22 ft 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 10 treatments and two untreated checks. Treatments were applied on 18-19 Jun to individual trees with a hand gun at 150 PSI with a water volume of 200 gpa.

Mite densities were evaluated in each plot prior to treatment on 16 Jun and then on 22 Jun (3 DAT), 29 June (10 days after treatment [DAT]), 6 Jul (17 DAT) and 13 Jul (24 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) and eggs 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 10, 17, 24 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).

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

There is significant interest within the almond industry for tools that can help predict whether or not spider mites need to be treated. Historically this is done using presence-absence sampling programs where thresholds change slightly depending on whether or not natural enemies are present. However, not all natural enemies are created equal and monitoring programs for natural enemies are in their infancy, despite the fact that most PCAs can tell you that some predators, such as sixspotted thrips, are highly effective if and when they arrive in an orchard each year.

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-Washington State University) and California (Nick Mills- UCB) has evaluated the use of HIPVs (herbivore induced plant volatiles) such as geraniol, methyl salicylate, and 2-phenylethanol, and a combination of these products (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 2015 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 26 Jun, 2 Jul, 9 Jul, 15 Jul and 24 Jul. 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. Each week the traps were rotated within each block such that after 5 weeks each trap had spent 1 week in each of the five plots within each block. The original lures were not replaced weekly, meaning that the same lures were used for the entire five weeks of the study. On each evaluation date we also collected 40 almond leaves, placed them in a small paper sack, refrigerated the sack, and then evaluated the leaves in a laboratory for the presence of natural enemies. Data on the average number of beneficials caught each week were analyzed by ANOVA using transformed data (square root (x + 0.5)) with means separated by Fisher's Protected LSD ($P = 0.05$)

<u>Objective 3. Larvicides for NOW at hull split</u>

Navel orangeworm continues to be the primary insect pest within almond production systems in California. Control is based on winter sanitation in combination with the use of chemical insecticides, early harvest when possible, and in some cases mating disruption. There are several chemicals available to almond growers in CA. These include broad-spectrum pyrethroids such as bifenthrin and lambda-cyhalothrin, broad-spectrum organophosphates such as chlorpyrifos, and several ‘softer’ pesticides that primarily attack the egg and larval stages of NOW. Our trial focused on the effects of these softer materials, including anthranilic diamides (Altacor, Belt, Harvanta), a growth regulator (Intrepid), an avermectin (Proclaim), a spinosyn (Delegate), and a combination product (Intrepid Edge) by doing a side-by-side comparison of efficacy.

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 with six blocks 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, Intrepid (methoxyfenozide) at 16 fl oz/ac, Intrepid Edge (methoxyfenozide + spinetoram) at 12 fl oz/ac, Proclaim (emamectin benzoate) at 4.5 oz/ac, and Harvanta (cyclaniliprole) at 22 fl oz/ac . Treatments were applied to individual trees with a hand gun at 200 GPA at 150 PSI on either 20 Jun, 7 Jul or both. All treatments were harvested by hand on 23 Jul by collecting 300 to 400 nuts per tree into brown paper sacks. 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 ($P = 0.05$).

<u>Objective 4. Maintain a research orchard</u>
Funding provided by the Almond Board of California allows us to maintain 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 20' by 22' 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 orchard is made available to any researchers we can accommodate, both public and private, that have interest in doing research that will be of benefit to the almond industry. To date, the majority of the research conducted in this orchard is related to the management of insects and weeds due to our ability to allow pest pressure that is higher than what is tolerated in commercial orchards, and due to our ability to apply non-registered pesticides without the risks related to crop destruct in commercial orchards. Costs for this orchard are distributed evenly between the Almond Board of California and donations from other companies within the almond industry that benefit from the research.

Results and Discussion:

<u>Objective 1. Spider mite Management</u>
Spider mite densities throughout the trial were very low (**Table 1, 2)**. Across all treatments the density of spider mites during precounts was 0.06 mites per leaf. Mite densities remained low 3 DAT and then started to increase to 1.19 and 0.50 mites per leaf in the two sets of untreated checks by 10 DAT. On this date there were significant reductions in mite density in all treated plots (<0.09 per leaf) compared to one untreated check (1.19 per leaf) but not the other untreated check (0.50 per leaf). By 17 DAT large numbers of sixspotted thrips migrated into the orchard and the density of spider mites in all plots, as well as the untreated check, was less than one mite per four leaves in all plots for the remainder of the trial.

As a result of the low mite density we do not feel comfortable drawing conclusions from this trial other than that all of the products worked on at least one evaluation date. It would not be appropriate to draw any conclusions regarding the relative efficacy of different miticides, nor make any statements about the residual activity of any individual product. This is unfortunate because at the time of treatments trees on the edges of the field (outside of the trial area) were starting to get webbed over and we applied a broad-spectrum insecticide to try to minimize beneficials. Nevertheless, despite our efforts sixspotted thrips demonstrated the quality of mite control that can be provided by natural enemies.

Table 1. The effects of miticide treatments on the density of Pacific spider mite in almond, Shafter 2015.

Treatment	Rate form. product/ac	Mean spider mites per leaf					
		Precounts	3 DAT	10 DAT	17DAT	24 DAT	Mite-days[1]
Acramite 50 WS + 415 Oil	1.5 lb 2 gal	0.08	0.00	0.01 a	0.13	0.15	1.5 ab
Vigilant + 415 Oil	24 fl oz 2 gal	0.00	0.05	0.00 a	0.20	0.00	1.8 ab
Fujimite XLO + 415 Oil	32 fl oz 2 gal	0.00	0.00	0.05 a	0.00	0.06	0.6 ab
Magister + 415 Oil	32 fl oz 2 gal	0.00	0.00	0.00 a	0.01	0.00	0.1 a
Nealta + 415 Oil	13.5 fl oz 2 gal	0.00	0.00	0.05 a	0.08	0.06	1.2 ab
Envidor 240 SC + 415 Oil	18 fl oz 2 gal	0.00	0.01	0.00 a	0.06	0.00	0.5 ab
Onager 1EC + 415 Oil	24 fl oz 2 gal	0.23	0.39	0.09 a	0.15	0.23	5.7 bc
Zeal 72WP + 415 Oil	3 oz 2 gal	0.40	0.01	0.01 a	0.15	0.01	1.3 ab
GOP 1 meal + GOP 1	56 oz 2 gal	0.00	0.00	0.01 a	0.14	0.03	1.2 ab
415 Oil (1% v/v)	2 gal	0.00	0.01	0.06 a	0.10	0.08	1.6 ab
Untreated Check	-	0.08	0.00	1.19 b	0.25	0.09	12.2 c
Untreated Check	-	0.03	0.15	0.50 a	0.06	0.08	6.2 bc
F (df =11, 3)		0.96	0.98	3.45	0.96	1.72	2.60
P		0.4970	0.4793	0.0028	0.4989	0.1118	0.0167

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 is 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 2015.

Treatment	Rate form. product/ac	Mean spider mite eggs per leaf				
		Pre-counts	3 DAT	10 DAT	17 DAT	24 DAT
Acramite 50 WS + 415 Oil	1.5 lb 2 gal	0.18	0.00	0.00 a	0.23	0.30
Vigilant + 415 Oil	24 fl oz 2 gal	0.00	0.14	0.00 a	0.39	0.00
Fujimite XLO + 415 Oil	32 fl oz 2 gal	0.00	0.00	0.03 ab	0.00	0.04
Magister + 415 Oil	32 fl oz 2 gal	0.00	0.00	0.06 ab	0.06	0.01
Nealta + 415 Oil	13.5 fl oz 2 gal	0.00	0.00	0.13 ab	0.01	0.84
Envidor 240 SC + 415 Oil	18 fl oz 2 gal	0.00	0.00	0.00 a	0.06	0.01
Onager 1EC + 415 Oil	24 fl oz 2 gal	0.33	0.14	0.29 ab	0.50	0.35
Zeal 72WP + 415 Oil	3 oz 2 gal	0.85	0.01	0.18 ab	0.08	0.10
GOP 1 meal + GOP 1	56 oz 2 gal	0.00	0.06	0.00 a	0.46	0.00
415 Oil (1% v/v)	2 gal	0.00	0.06	0.08 ab	0.93	0.09
Untreated Check	-	0.40	0.00	1.09 c	0.30	0.34
Untreated Check	-	0.10	0.18	0.48 b	0.14	0.01
F (df = 11, 3)		0.92	0.66	3.34	0.78	1.67
P		0.5331	0.7636	0.0035	0.6614	0.1240

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.

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

During 2015 we had an excellent trial with large numbers of natural enemies that came in response to spider mites with the experimental orchard. Over the duration of the trial the yellow panel traps captured 28,990 six-spotted thrips (*Scolothrips sexmaculatus*), 255 mite destroyer beetles (*Stethorus picipes*), 134 minute pirate bugs (*Orius* spp.) and 158 adult green lacewings (*Chrysopa* spp. and *Chrysoperla* spp.). The captured insects were almost exclusively adults.

Captures of each group of insect are shown in **Table 3** (by week) and **Figures 1-2** (average across weeks). 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 if using a standard P-value of 0.05.

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.

Leaf samples during the trial failed to document significant numbers of mite predators. In total, out of 5,000 leaves collected in the field and evaluated in the lab, we only collected 13 sixspotted thrips, 23 lacewings, 0 mite destroyer beetles, and 0 minute pirate bugs. We suspect that this was primarily due to sampling methods that allowed for adult natural enemies to fly off of the leaves before they were placed in bags, or to leave the leaves some time before the leaves were evaluated. For future work we have determined that any assessment of insect predators will need to be done immediately in the field before they have the chance to fly away.

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 opportunities exist for improved natural enemy monitoring using sticky cards and that further work in this area is justified.

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				
	25-Jun	2-Jul	9-Jul	15-Jul	23-Jul
Methyl Salicylate	9.2	217.4	112.0bc	425.2	141.2
Geraniol	17.4	245.2	251.8a	581.2	207.6
Phenyl Ethanol	23.0	241.2	231.0ab	617.2	158.4
MS+GE+PE	16.4	230.8	171.6abc	834.0	186.8
Card only	22.2	169.4	90.6bc	439.2	158.0
F =	1.11	0.49	2.43	1.22	0.57
P =	0.3876	0.7433	0.0900	0.3427	0.6874

	Average spider mite destroyer beetles (*Stethorus picipes*) per trap				
	25-Jun	2-Jul	9-Jul	15-Jul	23-Jul
Methyl Salicylate	0.0	3.4	0.2c	0.6b	1.0
Geraniol	0.0	4.2	0.2c	3.0ab	1.2
Phenyl Ethanol	0.0	2.8	0.4bc	1.6ab	3.0
MS+GE+PE	0.0	6.4	1.2ab	6.0a	3.4
Card only	0.0	4.2	1.4a	3.4a	3.4
F =	-	0.54	3.83	2.80	0.73
P =	-	0.7079	0.0229	0.0614	0.5837

	Average minute pirate bugs (*Orius* spp.) per trap				
	25-Jun	2-Jul	9-Jul	15-Jul	23-Jul
Methyl Salicylate	0.0	0.2	0.6	1.2	3.6a
Geraniol	0.0	0.0	0.4	1.8	0.6b
Phenyl Ethanol	0.0	0.0	0.6	0.4	1.2ab
MS+GE+PE	1.0	0.8	0.2	2.0	3.4ab
Card only	0.0	1.4	0.4	3.2	3.8a
F =	1.0	0.75	0.18	1.63	2.62
P =	0.4362	0.5699	0.9435	0.2150	0.0742

	Average adult lacewings (*Chrysopa* spp. and *Chrysoperla* spp.)				
	25-Jun	2-Jul	9-Jul	15-Jul	23-Jul
Methyl Salicylate	2.6	2.0ab	1.4	1.8	1.4
Geraniol	1.0	0.4c	1.0	1.2	1.0
Phenyl Ethanol	0.2	0.2c	0.4	2.2	0.6
MS+GE+PE	1.0	0.6bc	1.4	2.0	0.4
Card only	2.6	2.0a	2.0	1.8	0.4
F =	1.69	3.94	1.41	0.16	0.50
P =	0.2021	0.0206	0.2755	0.9536	0.7383

Means in a column followed by the same letter are not significantly different ($P > 0.10$, Fisher's protected LSD) with square root (x + 0.5) transformation of the data. Untransformed means are shown.

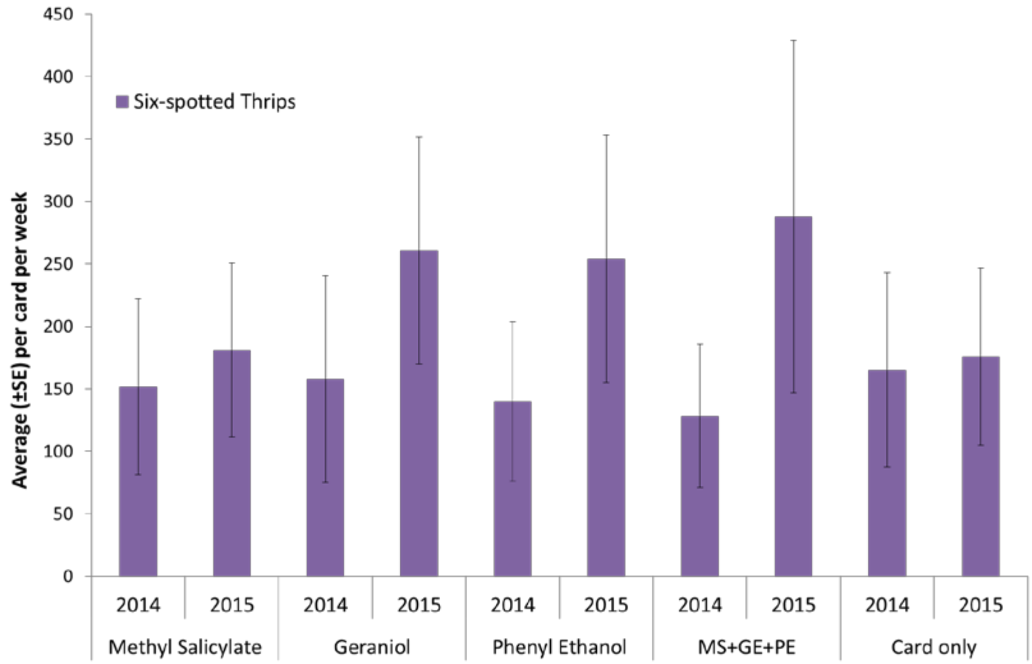

Figure 1. Average weekly captures of sixspotted thrips during 2014 and 2015 trials in traps with lures containing herbivore-induced plant volatiles.

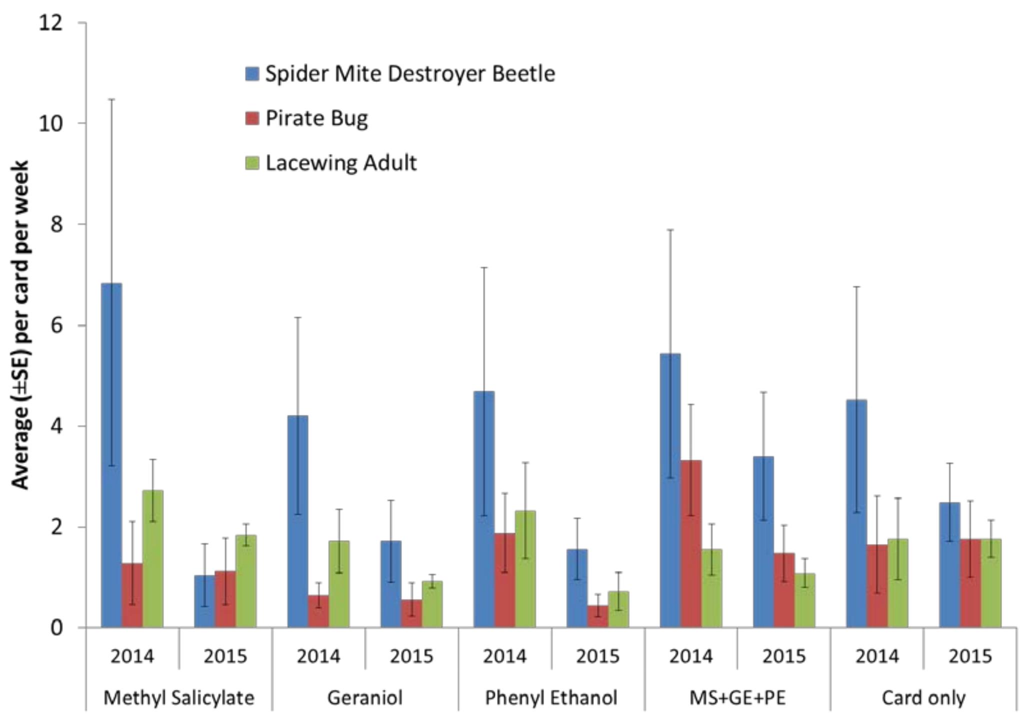

Figure 2. Average weekly captures of spider mite destroyer beetles, minute pirate bugs, and lacewing adults 2014 and 2015 trials in traps with lures containing herbivore-induced plant volatiles.

Objective 3. Larvicides for NOW at hull split

During our 2015 trial we had an extremely difficult time trying to determine when to treat. In a normal year the first NOW application is typically made in late June or early July at a time when hull split is initiating and the second NOW flight starts. However, in 2015, due to the extreme drought this timing was much more difficult to determine. At the time of the 20 Jun application date degree-day data showed that the second NOW flight had not yet started, yet the trees were already at 75% split due to extreme drought conditions associated with a zero allocation of surface water and a well going dry within the experimental orchard. We considered this timing early, but didn't want to wait until nuts were 100% split before making the first insecticide application. At the time of the second application the second NOW flight was underway and hulls split had been at 100% for more than a week.

Because our first timing was made prior to the start of the second NOW flight the larvicides and ovi-larvicides that were tested had no effect. There were no significant differences in NOW damage for any treated plots compared to the Untreated Check for any of the products applied on 20 Jun (F=1.23; P=0.3076) (**Figure 3**). However, when applications were made on 7 July, differences occurred (F=2.71; P=0.0214). There were significant reductions in damage levels for plots treated Altacor, Harvanta, Intrepid, Intrepid Edge, Belt and Delegate (6.0 to 8.8% damage) compared to the untreated check (13.7%). Damage in plots treated with Proclaim was statistically equivalent to all treated and untreated plots except for Altacor. Evaluation of data from trees treated on both dates showed similar damage levels as trees that were only treated on 7 Jul. This makes sense based on the assumption that the first application had no effect and that any reductions in NOW damage in trees treated twice would have been the result of the second application date.

The levels of NOW damage in plots treated on 7 Jul represented percentage reductions in damage of 16.5% for Proclaim and from 35.3 to 56.2% for all other treatments (**Figure 4**). Anthranilic diamides (Altacor, Belt, Exirel) performed well in the trial with an average 46.7% reduction in damage compared to the UTC. The percentage reduction in damage for Intrepid Edge (premix of Intrepid and Delegate) was similar to the reductions when each product was used individually (42.1% for Intrepid and 35.3% for Delegate).

The levels of control provided by the larvicides and ovi-larvicides evaluated in this trial were right on par with the results of previous trials showing that one properly-timed insecticide application typically provides a 40 to 50% reduction in damage. The results are also right on par with data from other research trials showing that NOW are becoming resistant to new generation pyrethroids that often provided 75% or greater reductions in damage when they were first introduced, but that are now only providing efficacy similar to what was achieved by softer chemistries in this trial due to resistance. Our data also showed that using newer larvicides and ovi-larvicides too far in advance of the second NOW flight can result in a lack of any appreciable benefit from the application.

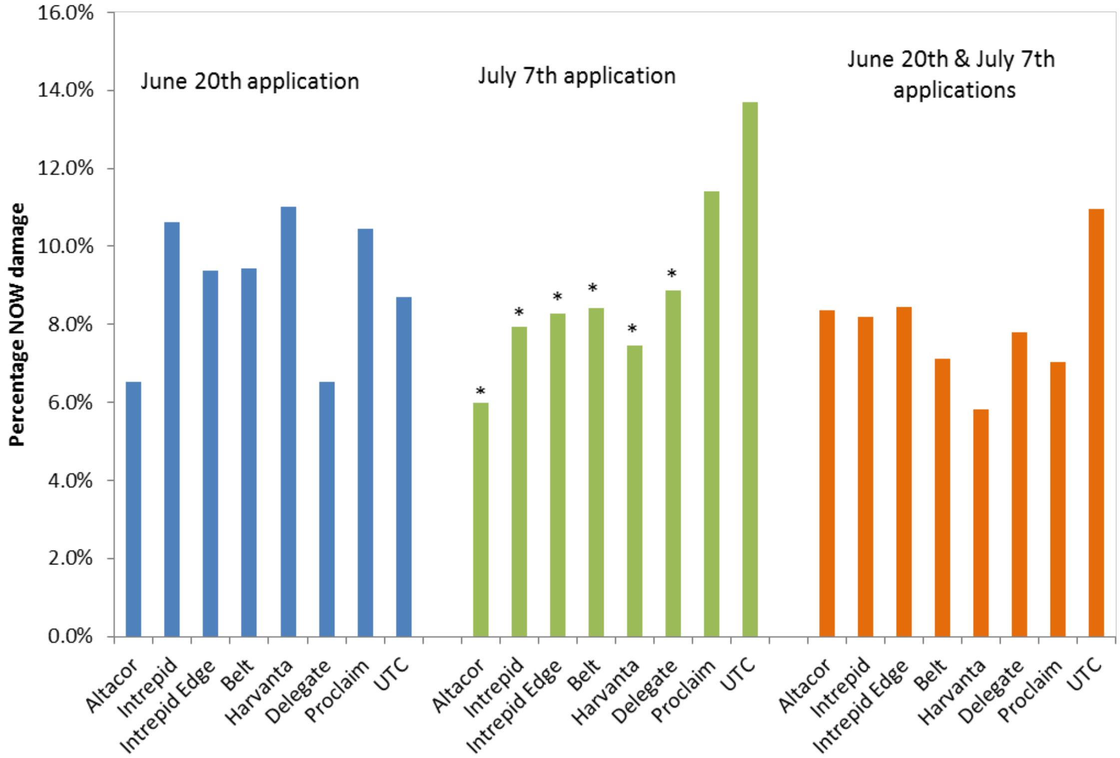

Figure 3. Percentage NOW damage to almond kernels on 23 Jul in trees treated with seven different insecticides on 20 Jun, 7 Jul, or both dates in 2015. Asterisks indicate damage levels that are statistically lower than the untreated check for that application date.

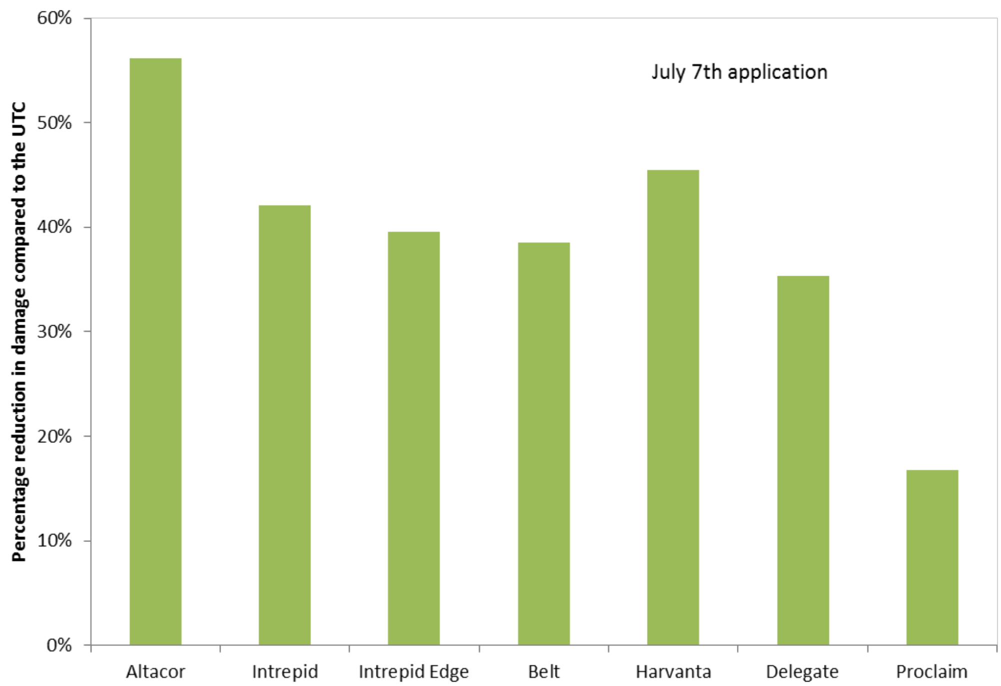

Figure 4. Percentage reduction in NOW damage on 23 Jul in trees treated with seven different insecticides on July 7, 2015.

Objective 4. Maintain a research orchard

During 2015 there were a total of seven research projects completed at the research orchard in Shafter that is maintained in part by funding from the Almond Board of California. This included trials on spider mite, navel orangeworm, and herbicide management. This included trials that were completed exclusively at the station, such as herbicide and insecticide trials, as well as providing support for researchers in other locations, such as individuals needing large numbers of infested mummy nuts for evaluations of pesticide resistance or large numbers of mummies for use in insecticide bioassays in the spring. Principal investigators of the trials included academics at the University of California, a researcher associated with an almond producer, and a researcher associated with a company that produces products for crop protection. In total since 2010, this orchard, and a parallel orchard funded by the Almond Board of California at the Westside Research and Extension center through 2013, have hosted or provided support for 51 unique research trials.