Pacific Spider Mite Control in the Lower San Joaquin Valley

Project No.: 06-ENTO4(a)-Haviland

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Interpretive Survey:

Pacific spider mite is one of the most important arthropod pests of almonds in the lower San Joaquin Valley. In average years most acreage is sprayed for this pest one to two times, with additional applications being made in years, such as 2005, when pest pressure is particularly high. Applications early in the season (April or May) are almost exclusively Agri-Mek, whereas a applications later in the season have primarily been Omite, with lesser uses from other miticides like Vendex, Nexter, Acramite, or Oil. However, there have recently been several new miticides that have received, or are about to receive, registrations for almonds, including Onager, Zeal, Kanemite, Fujimite, Desperado, Ecotrol, and Envidor (likely registered for 2007). Each of these products has the potential to improve the ability to manage spider mites. The goal of this research project is to conduct miticide trials during the 2006 and 2007 growing seasons to help determine the best fit for each of these new products into an IPM program.

Objective:

1) Evaluate the effects of miticide applications on Pacific Spider mite control
   a) during the spring (April/May timing)
   b) during the summer (hull split timing)

Materials, Methods and Results:

Trial 1. Screening field trial, 1st year almonds, single tree treatments in August

This experiment was conducted during the late summer during 2005 in a 1-yr-old commercial block of almonds located in western Kern County, CA. Due to the sporadic nature of the density of spider mites, we did a visual survey of trees in an area of approximately 2 acres and chose the 85 most infested trees. These trees were randomly assigned to one of 5 repetitions each of 14 treatments, an Oil alone treatment, a Water Check, and an Untreated Check. Miticides were applied on 12 Aug with a CO_2 powered backpack sprayer. Applications were made at 30 psi using an 8002 fan jet nozzle. The spray solution was prepared by mixing the miticides to a 200 gpa dilution and then spraying each individual tree with 500 ml of that solution. At the time of application it was over 100°F, the leaves were very hardened off and dusty, and there was a large amount of webbing covering many of the leaves.

Mite populations were evaluated one day prior to treatment on 11 Aug and then again 3 DAT (15 Aug), 7 DAT (19 Aug), 14 DAT (26 Aug), and 21 DAT (2 Sept). On each evaluation date 10 random leaves were collected from each tree and evaluated for the total number of Pacific spider mite eggs and motiles (juveniles + adults). Average motiles and eggs per leaf were calculated for each experimental plot. These data were transformed using a standard sqrt transformation and analyzed by ANOVA with means separated by Fisher's Protected LSD at $\alpha \leq 0.05$. Data are presented as the mean of the average mites per leaf with means separation reported from analyses using transformed data.

This trial was a good side-by-side comparison of how miticides perform when there is heavy mite pressure with hardened off, webbed over leaves under temperature conditions over 100°F. Even under these sub-optimal conditions, several newer miticides, including Kanemite, Zeal, Envidor + Oil, both rates of Onager, Fujimite, and Acramite did well. The least effective of the miticides were the two abamectin products (Agri-Mek and A-8612), which are best known for their effectiveness prior to when leaves harden off.

Table 1 shows the effects of miticide treatments on the number of motile spider mites per leaf. There were no significant differences in pre-counts which ranged from 29.5 to 96.2 mites per leaf. By 3 DAT Kanemite, Zeal, Fujimite, Envidor + Oil, and Acramite had mite densities significantly lower than the Untreated Check. Mite densities in plots of all other treatments were numerically, but not significantly, lower than the Untreated Check.

By 7 DAT, all treatments (except for water alone) resulted in significant reductions in mite density. The lowest densities of mites were in plots treated with Zeal, Envidor + Oil, Onager 16oz, Kanemite, Acramite, and Onager 24oz. These treatments were statistically inseparable from the seven next best products. Agri-Mek + Oil and Spray Oil alone had egg densities significantly higher than the best six treatments but that were still significantly lower than the Untreated Check.

By 14 DAT the lowest mite densities (under 1 mite per leaf) were achieved by Envidor + Oil, Kanemite, Omite, the high rate of Onager, and Zeal. These were statistically comparable to all other treatments except for the two abamectin treatments (Agri-Mek + Oil and A-8612) which were both statistically comparable to the Untreated Check. By

21 DAT the density of spider mites in all treated plots (0.2 to 7.3 mites per leaf) was numerically, but not statistically, decreased compared to the Untreated Check (7.4

Spider mite eggs:
Table 2 shows the effects of miticide treatments on the number of spider mite eggs per treatment. There were no significant differences in pre-counts or in data 3 DAT. By 7 DAT there were some significant differences in mite egg densities. Lowest densities were in plots treated with Kanemite. The number of eggs in Kanemite plots was statistically lower than that of Omite, Onager 16, Onager 24, Water, and the Untreated Check; but was statistically equivalent to all other treatments. Despite the fact that all treatments produced numerical reductions in the number of mite eggs compared to the control, statistically significant reductions were achieved by Agri-Mek + Oil, Desperado, Envidor + Oil, Fujimite, Kanemite, Zeal, and Oil alone.

By 14, 21, and 28 DAT the numbers of mites per leaf dropped and there were no longer any significant differences in the densities of spider mite eggs.

Table 1. Effects of miticide treatments (to single trees) on the number of spider mites per leaf.

		Average motile (juvenile + adult) mites per leaf				
Treatment/formulation	Rate per acre	Pre	3 DAT	7 DAT	14 DAT	21 DAT
Acramite 50 WS	1 lb	80.1 a	9.9 abc	3.3 a	4.3 abcd	0.6 a
Acramite 50 WS + 1% oil	1 lb	93.8 a	22.0 abcd	3.4 ab	3.6 abcd	0.1 a
Agri-Mek 0.15EC + 1% oil	10 fl oz	28.2 a	24.8 bcd	24.2 cd	9.9 ef	4.9 a
A-8612 0.15EC + 1% oil	10 fl oz	29.5 a	26.1 abcd	10.3 abc	6.4 def	5.7 a
Desperado 54AS	1 gal	71.4 a	16.5 abcd	5.6 abc	4.6 abcde	1.7 a
Envidor 240SC	18 fl oz	66.8 a	34.3 d	5.3 abc	2.7 abcde	3.4 a
Envidor 240SC + 1% oil	18 fl oz	60.2 a	7.6 abc	0.9 a	0.6 abcd	0.5 a
Fujimite 5EC	2 pt	43.6 a	5.8 ab	7.1 abc	2.4 abcd	1.4 a
Kanemite 15SC	31 fl oz	36.7 a	3.6 a	2.9 a	0.2 ab	0.5 a
Omite 30WS	8 lb	89.8 a	21.6 abcd	11.8 abcd	0.5 abc	1.2 a
Onager 11.8EC	16 fl oz	82.4 a	37.7 d	1.9 a	2.2 abcd	0.1 a
Onager 11.8EC	24 fl oz	32.1 a	25.2 abcd	3.6 a	0.1 a	0.3 a
Vendex 50WP	2.5 lb	76.4 a	23.4 cd	8.4 abcd	1.4 abcd	0.3 a
Zeal 72WDG	3 oz	60.8 a	3.9 abc	0.8 a	0.2 ab	0.2 a
Spray Oil (415F)	2%	51.3 a	16.6 abcd	19.5 bcd	5.1 abcde	7.3 a
Water Check		65.7 a	37.8 d	25.5 e	2.6 abcd	3.9 a
Untreated Check		96.2 a	39.0 d	60.9 e	16.3 f	7.4 a

Means in a given column followed by the same letter are not significantly different (Fisher's protected LSD). Data are reported as original numbers with means separation from a sqrt(value + 0.5) transformation.

Table 2. Effects of miticide treatments (to single trees) on the number of spider mite eggs per leaf.

Treatment/formulation	Rate per acre	Average eggs per leaf Pre	3 DAT	7 DAT	14 DAT	21 DAT
Acramite 50 WS	1 lb	31.7a	6.0a	1.5a	4.3a	1.3a
Acramite 50 WS + 1% oil	1 lb	48.4a	8.0a	2.4abcd	2.4a	0.1a
Agri-Mek 0.15EC + 1% oil	10 fl oz	18.1a	3.8a	8.4abcd	7.6a	1.2a
A-8612 0.15EC + 1% oil	10 fl oz	10.9a	6.9a	3.9abcd	6.7a	5.2a
Desperado	1 gal	27.0a	3.3a	1.5ab	7.7a	0.5a
Envidor 240SC	18 fl oz	17.1a	5.9a	2.4abcd	2.7a	2.8a
Envidor 240SC + 1% oil	18 fl oz	17.2a	1.7a	0.4a	0.6a	1.4a
Fujimite 5EC	2 pt	36.6a	2.7a	5.6abcd	0.8a	1.1a
Kanemite 15SC	31 fl oz	15.4a	0.4a	0.2a	0.3a	2.0a
Omite 30WS	8 lb	24.5a	10.6a	4.8abcd	0.1a	2.3a
Onager 11.8EC	16 fl oz	57.6a	12.7a	0.5a	1.6a	0.0a
Onager 11.8EC	24 fl oz	16.0a	9.4a	1.8ab	0.2a	0.3a
Vendex 50WP	2.5 lb	47.2a	4.3a	4.2abcd	1.2a	0.1a
Zeal 72WDG	3 oz	27.0a	4.2a	1.4ab	0.2a	0.2a
Spray Oil (415F)	2%	15.7a	3.0a	12.2de	2.6a	0.8a
Water Check		35.2a	13.2a	12.3cde	1.7a	1.6a
Untreated Check		27.1a	14.6a	26.8e	5.4a	7.6a

Means in a given column followed by the same letter are not significantly different (Fisher's protected LSD). Data are reported as original numbers with means separation from a sqrt(value + 0.5) transformation.

Trial 2. Large scale miticide trial, non-bearing almonds, July timing

This trial was conducted near Blackwell's Corner, Kern Co. CA. to evaluate the effects of miticides on mite density in two-year old, non-bearing almond trees. Approximately 110 ac of trees were divided into 50, 2.1 ac plots that each contained 6 rows by approximately 30 trees at a 21 by 24 ft spacing. Each plot was assigned to one of nine treatments or an untreated check in a RCBD with 5 blocks. Plots were sprayed at night on 14 July using commercial air-blast sprayers at 200 GPA. All treatments were done with the addition of either 1% 415 Oil, which is noted in the tables, or with 16 fl oz of the non-ionic surfactant Exit™ (Miller Chemical and Fertilizer Corp., Hanover, PA). Due to a large amount of mite-induced damage in the untreated check, these five plots were oversprayed with a miticide on 8 August (25 DAT).

Mite densities were evaluated in each plot prior to treatment on 13 July and then 3, 6, 13, 20, 27, and 33 DAT on 17, 20, and 27 July and 3, 10, and 16 August. On each evaluation date two random leaves were collected from each of 20 trees in the center two rows of each plot. Leaves were transported to a laboratory where the total number of Pacific spider mite motiles (larvae, nymphs, and adult) and eggs were counted. Numbers of predatory mites and predatory mite eggs were also recorded, but are not reported since only 4 were found during all evaluation dates. Average numbers of Pacific spider mite motiles and Pacific spider mite eggs per leaf were calculated per plot and data were analyzed by ANOVA using transformed data (squareroot (x+0.05)) with means separated by Fisher's Protected LSD at P>0.05.

Table 3 shows the effects of miticides on the density spider mites per leaf. There were no significant differences in precounts which ranged from 0.4 to 4.8 mites per leaf. On evaluation dates 3, 6, 13, and 20 DAT all treatments resulted in significant reductions in mite density compared to the untreated check, yet there were no significant differences among treatments. All treatments on these evaluation dates resulted in mite densities less than or equal to 0.3, 0.3, 1.8, and 2.7 mites per leaf compared to 1.9, 3.6, 27.5, and 55.9 mites per leaf respectively in the untreated check. By 21 DAT Envidor, Fujimite and Omite maintained mite densities below 2 per leaf at a level significantly lower than Acramite or the untreated check; other miticides were also lower than the untreated check but were inseparable from any other treatments. By 33 DAT, mite densities in plots treated with Fujimite and Omite were the only ones with mite densities at or below those when the trial began (2.3 mites per leaf average in the precounts).

Table 4 shows the effects of miticide treatments on spider mite eggs. All treatments caused significant reductions in spider mite eggs through 27 DAT. These reductions, and the relationships among treatments very closely paralleled the results previously described for motile forms of spider mites. As with data on motile forms of mites, Fujimite and Omite consistently had the lowest mite densities.

Table 3. Effects of large scale miticide treatments on the number of spider mites per leaf.

			Spider mites per leaf					
Treatment	Rate	Precounts	3 DAT	6 DAT	13 DAT	20 DAT	27 DAT	33 DAT
Acramite 50WS + Oil	1 lb	3.7a	0.1a	0.1a	0.9a	2.4a	11.1b	20.6c
Ecotrol 10EC	96 fl oz	4.3[a]	0.1a	0.0a	0.0a	0.4a	3.4ab	6.8ab
Envidor 2SC+ Oil	18 fl oz	3.1a	0.2a	0.2a	0.2a	0.4a	0.7a	3.5ab
Fujimite 5EC + Oil	32 fl oz	1.4a	0.1a	0.0a	0.0a	0.2a	1.0a	1.4a
Kanemite 15SC	31 fl oz	0.9a	0.3a	0.1a	1.8a	2.2a	9.8ab	13.8bc
Omite 6E	64 fl oz	1.7a	0.0a	0.0a	0.1a	0.1a	1.5a	1.4a
Onager 1EC	20 fl oz	0.9a	0.1a	0.2a	1.8a	2.7a	14.7ab	14bc
Vendex 50WP	2.5 lb	1.7a	0.1a	0.0a	0.2a	0.2a	3.8ab	3ab
Zeal 72WDG	3 oz	0.4a	0.2a	0.3a	0.5a	0.5a	3.7ab	6.5ab
Untreated Check		4.8a	1.9b	3.6b	27.5b	55.9b	*76.6c	*12.4bc

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

*Due to mite-induced damage, untreated check plots were oversprayed with a miticide on 9 August (25 DAT). Data for the untreated check 27 DAT were collected on 9 August (25 DAT) prior to the spraying, and data shown 33 DAT represent mite densities 8 days after retreatment.

Table 4. Effects of large scale miticide treatments on the number of spider mite eggs per leaf.

Treatment	Rate	Spider mite eggs per leaf						
		Precounts	3 DAT	6 DAT	13 DAT	20 DAT	27 DAT	33 DAT
Acramite 50WS + Oil	1 lb	2.1a	0.1a	0.2a	1.0a	4.1b	6.2a	7.8d
Ecotrol 10EC	96 fl oz	1.9a	0.0a	0.0a	0.2[a]	0.5ab	4.2a	3.2abcd
Envidor 2SC + Oil	18 fl oz	3.2a	0.1a	0.0a	0.3a	0.5ab	0.7a	2.1abc
Fujimite 5EC + Oil	32 fl oz	2.0a	0.0a	0.0a	0.0a	0.1a	1a	0.1a
Kanemite 15SC	31 fl oz	0.3a	0.3a	0.0a	2.0a	2.3ab	5.8a	3.9bcd
Omite 6E	64 fl oz	1.8a	0.1a	0.0a	0.0a	0.2a	1.5a	0.4abc
Onager 1EC	20 fl oz	1.0a	0.2a	0.0a	1.8a	3.5ab	7.6a	5.2cd
Vendex 50WP	2.5 lb	0.8a	0.2a	0.0a	0.2a	1ab	4.4a	1.3abc
Zeal 72WDG	3 oz	1.2a	0.4a	0.1a	0.2a	1ab	2.1a	2.9abc
Untreated Check		3.4a	1.4b	2.2b	27.0b	36.5c	*48.1b	*2.9abc

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

*Due to mite-induced damage, untreated check plots were oversprayed with a miticide on 9 August (25 DAT). Data for the untreated check 27 DAT were collected on 9 August (25 DAT) prior to the spraying, and data shown 33 DAT represent mite densities 8 days after retreatment.

Results and Discussion:

Thus far during year one of this grant we have focused our trials on the traditional hull-split timing in almonds in an effort to identify potential Omite replacement products. The newer contact miticides Acramite, Kanemite and Fujimite can all provide excellent knock-down of mites. Residual effects of Acramite and Kanemite lasted for about three weeks, and were comparable to that of Vendex. Fujimite, however, suppressed mites for five to six weeks for a period comparable to that of plots treated with Omite. The mite growth regulators Zeal, Onager, and Envidor also had excellent knock-down of mites, with residual effects of Onager lasting about three weeks and the residual of Zeal and Envidor lasting about 5 weeks. The organic product Ecotrol also performed very well in the large scale trial we performed, with residual effects lasting approximately three weeks.

Field Evaluations of Varietal Susceptibility to Damage by Leaffooted Bug

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Interpretive Summary:

Leaffooted bug is an established pest of California's Central Valley that periodically reaches sufficient population levels to cause economic damage to almonds. During 2006, growers reported damage throughout most of the lower San Joaquin Valley, with sporadic damage occurring in the northern San Joaquin and Sacramento Valleys. The most common damage reported was nut abortion during the month of May, with some of the more susceptible varieties in hard-hit areas having an excess of 50% crop loss. Additional economic expenses occurred due to the widespread use of chlorpyrifos to prevent further damage to orchards. In response to the damage during 2006, this project focused on documenting what occurred during this season in hopes to help growers and pest control advisors be more prepared should it happen again

Objective:

1) Evaluate varietal differences in the susceptibility of 15 almond varieties to leaffooted bug damage
   a) Evaluate differences in bug-induced nut abortion prior to June
   b) Evaluate differences in the percentage of damaged kernels at harvest

Materials and Methods:

Leaffooted bug damage was documented during 2006 at the Kern County Regional Almond Variety Trial. This trial was planted in 1993 near Shafter, Kern Co. CA with a tree density of 86 per acre. The trial includes a total of 33 varieties that are each planted in one, unreplicated, orchard row.

In the spring of 2006 natural populations of leaffooted bug entered the variety trial and caused significant damage to many varieties. Quick observations noted that this damage was similar to what was being reported from orchards throughout much of the San Joaquin Valley.

In an effort to document 2006 damage, and differences among varieties to that damage, we collected data 15 different almond varieties that represented early, middle, and late season varieties, as well as those with both soft and hard-shelled nuts. For each variety we collected and counted all nuts off of the ground that had been aborted by the middle of June from 5 random trees of each variety. In these counts we excluded any nut that aborted due to lack of pollination. We also made general observations that nearly all nuts that were aborted were due to leaffooted bug damage, as was evidenced by external gummosis associated with a puncture wound through the hull and into the kernel. A very low amount of natural drop in 2006 allowed us to attribute nearly all nut abortion to damage by the pest. Numbers of nuts aborted per tree in each variety were compared to the total number of nuts per tree at harvest. Additionally, at harvest we collected one 500-nut sample from each of the 15 varieties in the trial and evaluated the kernels for leaffooted bug damage.

Table 1 shows the effects of leaffooted bug damage to 15 almond varieties. The average number of nuts aborted per tree ranged from 20 to 2179, which was the equivalent of 0 to 33% of the total crop. At harvest, the percentage of nuts that would be considered rejects from leaffooted bug damage ranged from 0 to 30%. When combined, Fritz was the most susceptible variety, with 63% of the total crop lost due to leaffooted bug, followed by Sonora, Aldrich, Livingston, Monterey and Carmel. Other varieties had 2% or less total damage from leaffooted bug in the trial.

Results and Discussion:

Mechanisms for varietal differences in leaffooted bug damage are still a mystery, though data do demonstrate some interesting trends. The first is that time of harvest appears to have no correlation to varietal susceptibility (Fig. 1). While it is true that Nonpareil and Price (the earliest harvested varieties) had some of the lowest damage, late varieties such as Mission, Ruby, and Winters also had equally low levels of damage. Likewise, the highest damage was in the latest harvested variety, Fritz, yet the second most susceptible variety was one of the earliest harvested, Sonora.

There was also no correlation between shell hardness and levels of damage. While it is true that both hard-shelled varieties in the trial, Mission and Padre, had very low levels of damage, so did two of the softest, Non-Pareil and Winters; yet another soft-shelled variety, Sonora was the second most susceptible.

Based on these data it appears that varietal susceptibility to leaffooted bug damage is much more complex than simply harvest date or shell hardness. It is likely that other factors such as plant volatiles, hull thickness, or shell hardness (as defined in April and May when bugs are present, and not as defined in the standard method at harvest), also play a role in varietal susceptibility. It should also be noted that susceptibilities of varieties are relative. For example, in our trials we note that Wood Colony is relatively unsusceptible to leaffooted bug damage. Growers and PCAs we interviewed reported this to be true when more susceptible varieties such as Fritz and Sonora were mixed in the same field. However, if Wood Colony was in a field in combination with varieties like Nonpareil and Carmel, that are both not highly preferred, then damage did occur to Wood Colony. This is to say that leaffooted bug prefers certain varieties, however, in the absence of a more preferred variety, leaffooted bug will remain in the orchard and feed on the most preferable of the relatively unpreferred varieties present.

Data suggest that the best way to monitor for leaffooted bug is to focus your attention on the most susceptible variety in the field. Gummosis and nut drop in that variety will serve as an indicator of what is going on in the field. Data also suggest that growers with Fritz, Sonora, Aldrich and Livingston should be extra vigilant in scouting for this pest each year. If leaffooted bugs become present, pesticide applications should be considered quickly. On the other hand, much less concern is needed in an orchard where all of the varieties are relatively unsusceptible.

These data also dispelled a myth of many growers and PCAs that all nuts damaged by leaffooted bug abort in June, such that leaffooted bug damage is primarily an issue of yields and not of quality of nuts at harvest. Our data showed that a portion of damaged nuts can still remain in the tree and result in rejected kernels at harvest. The next step will be to determine when the damage to those kernels occurred, and what are the factors that cause a kernel to abort verses remain in the tree until harvest. Addressing issues such as these will be the focus of the second year of this research project.

Table 1. Comparison of damage from leaffooted bug to 15 different almond varieties

Variety	Harvest season	Shell Character-istics	Nuts per tree	Number aborted due to leaffooted bug	Percentage aborted	Percentage offgraded	Total percentage loss
2-19E	Early/Mid	Semi	12092	73	1	0	1
Aldrich	Mid	Semi	19544	1279	7	2	8
Butte	Mid	Semi	19209	341	2	0	2
Carmel	Mid	Semi	1566	36	2	1	3
Fritz	Late	Semi	6689	2176	33	30	63
Livingston	Mid	Semi	10547	537	5	1	6
Mission[1]	Late	Hard	9277	30	0	0	1
Mission[1]	Late	Hard	4873	36	1	0	1
Monterey	Late	Semi	5856	156	3	1	4
Nonpareil[1]	Early	Soft	17373	118	1	1	1
Nonpareil[1]	Early	Soft	13866	94	1	0	1
Padre	Mid	Hard	14217	35	0	0	1
Price	Early	Semi	6723	52	1	1	2
Ruby	Late	Semi	7321	20	0	0	0
Sonora	Early/Mid	Soft	10699	509	5	7	12
Winters(13/1)	Late	Soft	6377	38	1	0	1
WoodColony	Mid	Semi	8341	59	1	0	1

[1]Evaluations were made on two independent rows of Mission and Nonpareil (on opposite sides of the orchard) as a way to evaluate the consistency of leaffooted bug pressure across the orchard as well as consistency of the data. Data from all other varieties are from 5 random trees in a single, unreplicated row of trees of that variety.