STUDIES ON LEAFFOOTED BUG MORTALITY AND ABILITY TO DAMAGE ALMOND KERNELS FOLLOWING EXPOSURE TO INSECTICIDES AND AGED INSECTICIDE RESIDUES

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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 a 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).

Results

Insecticide treatments had varied effects on leaffooted bug mortality (Table 1). 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.

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. 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.

The impacts of insecticide residues on caged leaffooted bugs affected the amount of kernel damage found at harvest. 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.

Conclusions

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 products are not currently registered for use in almonds.

Table 1. The effects of direct application of insecticides onto leaffooted bugs in a laboratory bioassay.

		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
Bridgade 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

Means in a column followed by the same letter and 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.

Table 2. 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
Bridgade 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

Table 3. 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
Bridgade 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