In-Season Management of Leaffooted Bug in Almonds

Project No.: **07-ENTO4-Haviland**

Project Leader: David Haviland
Entomology Farm Advisor
University of California Cooperative Extension - Kern County
1031 S. Mount Vernon Ave.
Bakersfield, CA 93307
(661) 868-6215
dhaviland@ucdavis.edu

Project Cooperator: Kent Daane, University of California Cooperative Extension Specialist, University of California - Berkeley

Interpretive Summary:

During 2006 leaffooted bug was a significant pest of almonds in the lower San Joaquin Valley. Damage from leaffooted bug in 2006 was documented for 15 varieties at the Kern County Regional Almond Variety Trial, and is reported in the 2007 Annual Report of the Almond Board of California. This damage was correlated to nut characteristics in 2007, which explained that varietal differences in susceptibility to damage are a result of differences in hull thickness in April and May, and is not a direct effect of shell hardness. We also documented the effects of simulated leaffooted bug feeding on 8 almond varieties during April and May 2007. For most varieties, nuts stung in April either aborted or became sticktights, with most damaged nuts in May becoming developed, stained kernels. By late May no simulated feeding resulted in nut abortion, 0 to 36% of the nuts became sticktights, and 38% to 84% of the nuts would have been offgraded at harvest. The remaining nuts could have been sold. We also documented the effects of several insecticide treatments when they come in direct contact with leaffooted bugs, or when bugs are introduced onto treated surfaces.

Objectives:

1) Evaluate interactions between leaffooted bug size, nut developmental stage (time of year), and variety on the type and severity of damage to the almond crop
2) Evaluate the effects of chemical insecticides on leaffooted bug adults

Introduction:

During 2006 many almond growers in the lower San Joaquin Valley experienced significant damage from leaffooted bug. This sporadic pest uses needle-like mouthparts to penetrate the almond hull and feed on the kernel. Depending on when the feeding occurs, damaged kernels can either cause the nut to abort, result in a sticktight with no kernel, or result in a harvested nut with a black stain. Each of these types of damage reduces either the quality or quantity of nuts.

Leaffooted bug damage in 2006 was common in the lower San Joaquin Valley, sporadic in the upper San Joaquin Valley, and reported in a few isolated orchards in more northern production regions. In the areas most impacted, growers' responses to this pest were to spray tens of thousands of acres with the organophosphate, chlorpyrifos (Lorsban 4E). In Kern County, for example, acres treated with chlorpyrifos increased from 14,156 acres in 2005 compared to 89,430 in 2006. While we were fortunate that this product was effective, the use of this product and at this timing goes against some of the major objectives of the Almond Board and the Department of Pesticide Regulation.

Widespread use of Lorsban has several negative impacts that the almond industry is going to have to reconcile. The first is that chlorpyrifos is an organophosphate, and significant increases in OP counter the Almond Board's efforts to increased IPM adoption. Lorsban 4E is also recognized as a high emitter of volatile organic compounds (VOCs). VOCs enter the air stream and undergo photochemical reactions to create ozone. The San Joaquin Valley is currently classified as being in extreme non-attainment for ozone pollution, and the May and early June treatment timings used in almonds for leaffooted bug control in 2006 were within the 6 month period where VOCs have the greatest negative impact on air quality. This means that it is imperative for the almond industry to identify ways to reduce the use of, or find alternatives to, in-season applications of Lorsban 4E.

The purpose of this project was to improve leaffooted bug IPM by increasing our understanding of how leaffooted bugs interact with the almond crop. This was done through a combination of field studies that evaluated crop response to simulated leaffooted bug feeding and evaluations of possible mechanisms for varietal differences in susceptibility to leaffooted bug damage. We also evaluated insecticides that could be used as alternates to chlorpyrifos.

Materials and Methods:

Interactions between leaffooted bug damage and injury to the crop were evaluated during weekly and biweekly field experiments during the spring of 2007 in the Kern County Regional Variety Trial. Experiments were conducted in 8 almond varieties, which were each planted in a single orchard row. The eight varieties represented early, mid-season, and late-harvested varieties; soft and hard-shelled varieties; and varieties that in 2006 were shown to be highly susceptible, moderately susceptible, or relatively immune to damage by this pest. The varieties included Nonpareil, Sonora, Padre, Butte, Aldrich, Mission, Fritz, and Monterey.

In the first set of experiments we artificially simulated leaffooted bug feeding to each variety and measured the response. On April 9, 18, & 30 and May 8, 17 & 25, 2007 we selected 100 almond nuts from each variety, marked them with an orange paint, and pierced them with a small pin (size 1) used for pinning insects. Nuts were pierced from the side and to a depth that ensured that the nut embryo was penetrated. We then tracked the fate of each nut through harvest. Nuts were initially classified as to whether they aborted or remained in the tree. Of those that remained in the tree, each was picked in early August and classified as having an undeveloped kernel, developed but stained kernel, or developed and unstained kernel. Data were analyzed by charting the percentage of nuts falling into each category and looking for trends among varieties, or across different sting dates.

We also conducted an experiment to try to determine the mechanisms that led to the varietal differences in susceptibility that were reported in 2006. On each evaluation date we collected 100 random nuts from each variety and made measurements of hull thickness and shell hardness. Hull thickness was measured by cross-sectioning each nut and measuring the distance from the hull surface to the developing embryo or kernel. Shell hardness was measured by piercing the hull surface at two random locations with a penetrometer. Data on hull thickness and shell hardness were evaluated by drawing correlations between the percentage of aborted nuts from natural leaffooted bug populations during the previous season in 2006 and the characteristics of the nuts in 2007. The 2006 data and procedures for how it was collected are available in the 2007 Almond Board Report related to this project.

The final objective was to evaluate the effectiveness of insecticides for control of leaffooted bug, with special emphasis on determining if alternative exist for chlorpyrifos. We conducted two bioassays. In the first bioassay we evaluated the effects of 6 insecticides when sprayed directly onto adult female leaffooted bugs. For each treatment, insecticides were mixed up to a 200GPA dilution and then sprayed to runoff with a hand-held spray bottle onto 3 sets of 5 adult leaffooted bugs. Once the bugs were dry they were placed into a plastic container containing a pomegranate as a food source. Mortality of the leaffooted bugs was evaluated at 48 hours after treatment and data were analyzed by ANOVA as a CRD with means separated by Fisher's Protected LSD.

The second bioassay tested the effect of residues on a treated surface for its effects on leaffooted bugs, as would occur if a field was treated and then the bugs migrated into the field. For this bioassay we placed adult leaffooted bugs onto pomegranate fruits that had been treated with one of six insecticides, and then evaluated the mortality of the bugs at 24 hour intervals through 4 days after treatment. For each treatment an insecticide was mixed with water at a dilution that would be equivalent to an application at 200 GPA. Three pomegranates were immersed in the solution for 5 seconds and then allowed to air dry. Approximately 1 hour after the residue was dry, the pomegranates were placed into separate plastic containers with ventilation and 5 adult leaffooted bugs were introduced. Mortality was evaluated at 24, 48, 72, 96, and 120 hours after treatment (HAT). Data were analyzed by ANOVA with means separated by Fisher's Protected LSD.

Results and Discussion:

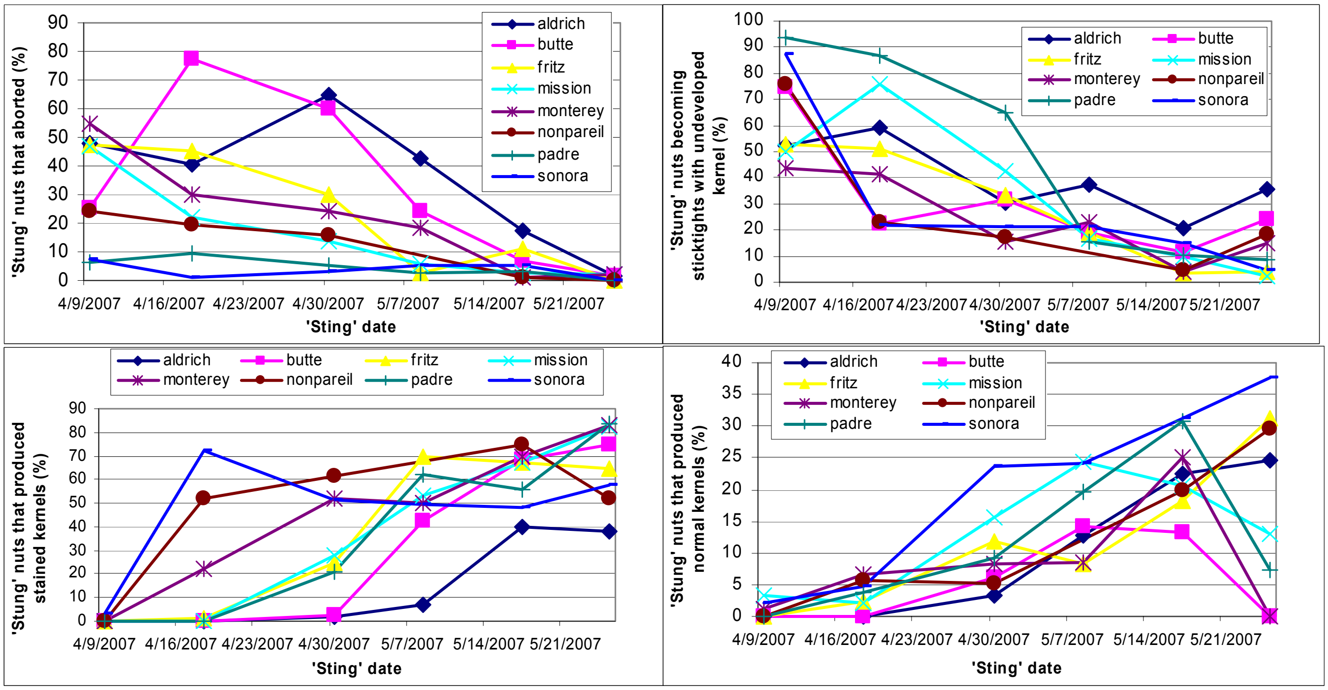
Simulated leaffooted bug feeding:

Artificial simulations of leaffooted bug damage documented that damage type and severity depend on when the feeding occurs (Figures 1-4). In general, nearly 100% of the nuts stung in early April either aborted or became sticktights. In mid-April, approximately 50 to 70% of the stung Nonpareil and Sonora (both early harvested varieties) nuts had developed kernels with stains on them, followed by 20% for Monterey. Damage to other varieties on this date still produced aborted or sticktight nuts, suggesting that kernel maturity is a key factor in determining the type of damage.

For most varieties, early May is when the greatest shift in damage type occurred, with most nuts in April either being aborted or sticktights, and most damaged kernels in May turning into developed, stained kernels. By late May no simulated feeding resulted in nut abortion, 0% to 36% of the nuts became sticktights, and 38% to 84% of the nuts would have been offgraded at harvest. The remaining nuts could have been sold.

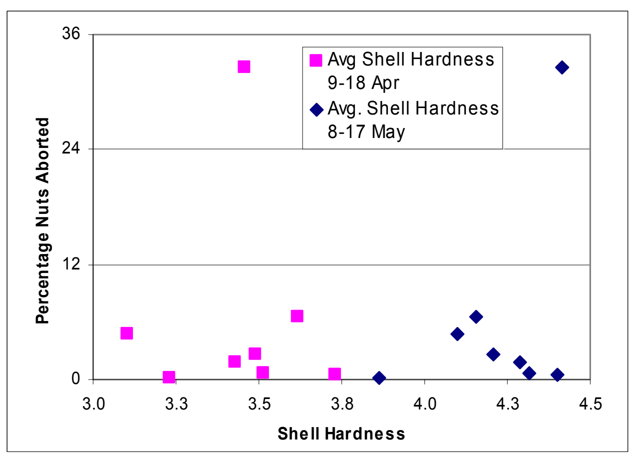
One concern with this data, however, is that simulated leaffooted bug damage resulted in more sticktights and less aborted nuts than what has been observed from real leaffooted bug damage. Aborted nuts from simulated damage also took weeks to fall off of the tree compared to the 7-10 day period observed by many growers for actual leaffooted bug damage. This suggests that the rapid nut abortion of nuts fed on by leaffooted bug is likely influenced by some other factor, such as the injection of a toxin or other substance into the kernel, and not solely a result of the physical effects of the leaffooted bug's mouthparts probing and penetrating the kernel.

Figures 1-4. Effects of simulated leaffooted bug feeding on the percentages of nuts that aborted, became sticktights, had stained kernels, or developed normally.



Mechanisms for varietal differences:

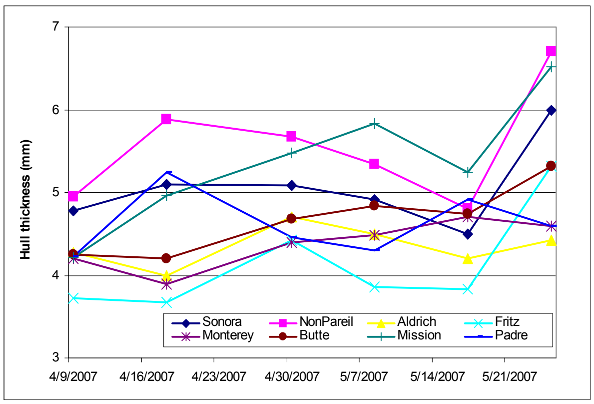
Fig. 5. Correlation between shell hardness (Apr. and May 2007) and percentages of nuts damaged by leaffooted bugs (same orchard in 2006)

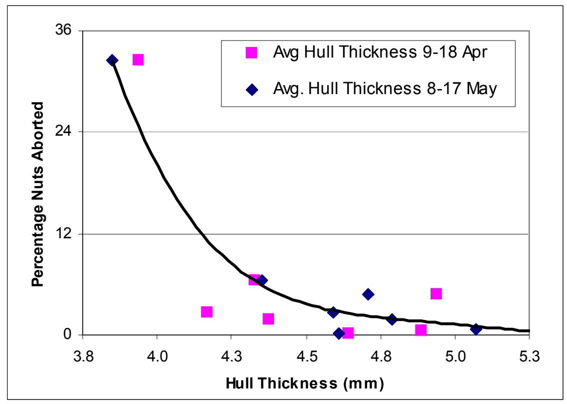


Correlations between the percentage of nuts aborted in 2006 and physical nut characteristics in April and May of 2007 are shown in Figures 5, 6 and 7. Figure 5 shows the correlation between shell hardness (April sampling dates combined and May sampling dates combined), and the percentage of nuts aborted. There were no trends in the data, suggesting that differences in shell hardness in April and May do not affect varietal susceptibility to damage. Most likely this is because varieties such as 'Mission' that are classified as hard-shelled, are still relatively soft shelled during April and May. This lack of correlation was further documented when comparing soft to hard-shelled varieties. While it is true that the only two hard-shelled varieties (Mission and Padre), had limited damage, soft varieties had some of the greatest (Sonora) and least (Nonpareil and Winters), amounts of damage.

On the other hand, differences in hull thickness appear to be the primary factor that influences differences in varietal susceptibility (Figures 6 and 7). Fritz, which was by far the most susceptible variety in the trial to leaffooted bug damage, also has the thinnest hull during April and May at less than 4 mm. This means that the bug has to penetrate a shorter distance to reach the kernel, and that the elevated levels of susceptibility to damage could simply be that the bugs are more likely to penetrate to the kernel. This correlation was also documented with the other varieties as an inverse relationship with the percentage of the nut abortion decreasing as hull thickness increased. Second order polynomial regressions of the dataset defined the relationship as $y=24x^2-239x+593$ (April; $R^2=0.65$) and $y= 20.7x^2 -212x + 538$ (May; $R^2=0.94$).

Fig. 6-7. Hull thickness in April and May 2007 of 8 almond varieties, and correlations of that hull thickness to the percentages of nuts damaged by leaffooted bugs (same orchard 2006)





<u>Insecticide studies:</u>

Table 1 shows the effects of insecticide treatments that come in direct contact with adult leaffooted bugs. Mortality 48 HAT ranged from 40 to 93% for bugs treated with Brigade, Lorsban, Agri-Mek, Imidan and Sevin when treated at one tenth the label rate, and at 67% or higher for bugs treated at one third the label rate. Brigade and Lorsban provided 100% control of leaffooted bugs at the one third label rate, and Brigade, Lorsban and Agri-Mek all provided 100% control with the full label rate. Imidan and Sevin also provided some good control compared to the Untreated Check.

Table 1. Mortality of adult leaffooted bugs 48 hours after treatment when directly exposed to insecticides.

		Percentage mortality at 48 hours after treatment		
Treatment	Full rate/ac	0.1X	0.33X	1.0X
Brigade	1 lb	93a	100a	100a
Lorsban	4 pt	80ab	100a	100a
Agri-Mek	10 fl oz	78ab	67ab	100a
Imidan	5 lb	60bc	67ab	87a
Sevin	4 qt	40cd	87a	93a
Intrepid	24 fl oz	13d	40bc	33b
Untreated	-	20d	17c	13c
F		9.0	7.19	51.75
P		0.0004	0.0012	<0.0001

Table 2 shows the effects of the residues of six insecticides on the mortality of adult leaffooted bugs. Lorsban, Carbine, Brigade, Sevin and Warrior all caused significant levels of mortality to adult leaffooted bugs at all evaluation dates. Brigade, Warrior and Carbine had the most immediate results 24 HAT, followed by Lorsban and Sevin, all of which were significantly higher than the Untreated Check or Agri-Mek. By 48 HAT, there were no significant differences among the 5 best treatments, all of which resulted in 100% mortality of leaffooted bugs prior to the final evaluation date, compared to the Agri-Mek and Untreated Check treatments where only 7% mortality occurred.

Table 2. Mortality of adult leaffooted bugs 1 to 4 days after feeding on a pomegranate fruit exposed to insecticides.

		Percentage mortality				
Treatment	Rate/ac	24 HAT	48 HAT	72 HAT	96 HAT	120 HAT
Lorsban 4E	4 pt	60ab	93a	93a	100a	100a
Carbine 50WG	2.8 oz	87a	100a	100a	100a	100a
Brigade WSB	24 oz	93a	100a	100a	100a	100a
Sevin XLR	4 qt	40b	100a	100a	100a	100a
Warrior	4 fl oz	93a	100a	100a	100a	100a
Agri-Mek 0.15EC	10 fl oz	0c	0b	7b	7b	7b
Untreated	-	0c	7b	7b	7b	7b
F		11.2	171.2	106.1	163.3	163.3
P		0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Conclusions:

During this two-year study we made significant progress in trying to understand the damage from leaffooted bugs that occurred in the lower San Joaquin Valley in 2006, and why it occurred. We documented the differences in susceptibility of 15 varieties to damage by leaffooted bug and determined that hull thickness in April and May is the most plausible mechanism to explain varietal differences in susceptibility to damage. We also documented changes in the types of damage that occur from early April to late May, and determined that classic categorizations of varieties (i.e., hard shell vs. soft shell, or early vs. middle vs. late-season), fail to explain trends in varietal susceptibility.

We also determined that alternative insecticide programs exist to chlorpyrifos. We determined that Brigade, Imidan, Agri-Mek and Sevin all provided good control when sprayed directly onto leaffooted bugs. We also determined that Lorsban, Carbine, Brigade, Sevin and Warrior can provide good leaffooted bug control when residues exist on a treated surface, and then the bugs are introduced (or migrate into a field). The problem with some of these products, such as Warrior and Brigade, is that each has been documented to, or has the potential to flare mites in almond orchards when used in April or May. However, each of these products also has the potential benefit of helping to control lepidopterous pests such as navel orangeworm and peach twig borer, just as Agri-Mek has the added benefit of controlling spider mites.