Biology of the *Gill's* Mealybug and Leaffooted Bug: Potential for Improved Control

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Interpretive Summary:

Work conducted in 2006/07 focused on the leaffooted bug. In spring 2006, many California almond and pistachio orchards had significant crop loss from adult leaffooted bugs (*Leptoglossus* species). The occurrence of leaffooted bug populations covered a wide geographic range, including nut producing regions from the northern, western, and southern Central Valley. However, leaffooted bug densities and damage varied considerably, with some growers reporting significant bug densities and more than 50% crop loss, while nearby growers reported few leaffooted bugs and little crop damage. Regardless, spring 2006 was the worst leaffooted bug year over the past 20 years. Here, we sought to complete studies conducted in 1998-2000, the most recent period of widespread leaffooted population damage. Specifically, we investigated the potential number of leaffooted bug generations per year and adult leaffooted bug overwintering habits, particularly aggregations.

Results suggest that, under 2006-2007 conditions, there were 3 leaffooted bug generations annual, with the possibility of a partial 4th generation of nymphs that probably do not survive the winter. Adults from each generation were long-lived, often depositing eggs over a 3 months period. There was considerable overlap of generations, with adult from one generation living beyond the period when their offspring became adults and produced eggs of the next generation. Results are discussed with respect to insecticide use and timing. To improve sampling programs, we also began studies to determine overwintering cues for leaffooted bugs to form

aggregations. In field studies, we manipulated leaffooted bug aggregations to determine if "resident" leaffooted bugs could be drawn into artificial shelters. Unfortunately, we were unable to attract resident adult leaffooted bugs to the artificial chambers. Another study of aggregation cues utilized large cages, with artificial leaffooted bug aggregations manipulated inside each cage and adult bugs added and allowed to disperse. In this study, we did find aggregations, although there was no clear pattern to the cues that we provided (e.g., virgin females). Instead, aggregations formations seemed to be based on temperatures, with the aggregations forming overnight and the individual bugs dispersing during the day time to forage and feed, only to reform aggregations again the following evening. These results are discussed with respect to possible control solutions.

Work on the Gill's mealybug has again been delayed as we were unable to find populations of the mealybug in almonds in order to collect and study the parasitoids. That we could not complete this study because of the lack of pests in almonds is, actually, great news for the almond industry.

Objectives:

Objectives in 2006/07 focused on the leaffooted bug, although we have ongoing plans to complete work on the "Gill's" mealybug, which has proved to be, at this time, a minor pest in almonds. Are specific objectives are to:

1. determine the potential number of leaffooted bug generations per year, and when the adult population begins its overwintering period;
2. determine overwintering cues that result in leaffooted bug aggregation – and to determine if these aggregations can be manipulated for monitoring or control; and
3. complete studies of mealybug parasitoids in almonds and pistachios.

Materials and Methods:

Objective 1 – Number of generations per year. We utilized small cages to collect information on leaffooted bug development. At the Kearney Agricultural Center, adult leaffooted bugs were collected during the winter. This cohort was placed into small tree cages placed outside and held at ambient temperatures. The leaffooted bugs were fed peanuts and provided with an Italian cypress as food and structural support. During each egg-laying period, additional cages were established for each consecutive generation produced. We then determined the longevity of the adults, their egg-laying period, and the number and length of each successive generation. There were three cages per generation. This work is a continuation of studies begun in spring 2006.

Objective 2 – Overwintering aggregation and spring movement. We studied cues that might lead to winter and spring aggregation.

a) In the first study, we artificially created small aggregations of leaffooted bug adults in the field to determine if aggregations of the resident population could be manipulated.

To begin, nymphs and adults reared during the fall (2006) were collected and isolated to produce three groups: i) newly mated pairs of males and females, ii) unmated females, and iii) unmated males. Each group was isolated in small screened cages provisioned with food (peanuts) and water (photo 1). These artificial aggregations were than placed in an artificial shelter, a "leaffooted bug overwintering chamber," constructed of four 1 × 2 foot plywood sections stacked on each other with a tapered 0.5 to 1 inch spacing between the sheets.

The goal was to create a protected location where the bait (other leaffooted bugs) would attract resident leaffooted bugs to form overwintering aggregations. The baits tested was one of the three groups of caged leaffooted bugs. In winter 2006/07, the overwintering chambers were placed on the edges of orchards that reported high numbers of leaffooted bugs in fall 2006. There were three locations, using four chambers per group (photo 2). The number of resident leaffooted bug adults that approach and aggregate in the cages were recorded.

Photo 1. Screened cage with artificial aggregation of adult leaffooted bugs, provided with food (peanuts) and water. The aggregations were either: females only, males only, or both sexes.

Photo 2. Wooden shelter, which housed the artificial leaffooted bug aggregations, were placed in orchards to help determine if adult leaffooted bug dispersion and aggregations could be manipulated

b) In the second study, we used large (10 × 12 foot) cages to manipulate leaffooted bug aggregations. In each of the four corners of the cage a potted tree was placed as a "substrate" for the leaffooted bugs to form an aggregation upon. In each cage either Italian cypress or citrus (each known to be an overwintering tree) (photos 3 and 4). All four trees were provided with food (peanuts and beans) and water, and one of the trees was provided with an artificial aggregation of 20 leaffooted bugs, isolated in the screened cages described previously. The artificial aggregation were tested three treatments: females only, males only, and both females and males. Only one treatment was used in each cage for each trial.

Once the plot was established, three leaffooted bug adults were released in the center of each cage and their movement was observed periodically over a 48 hour period. For each trial, the position of the trees and location of the artificial aggregation was reassigned. There were five trials.

c) In the third study, we followed overwintering aggregations in commercial citrus and almond fields, where there has historically been leaffooted bug pest problems in almonds in the spring. we used a number of different sampling programs to follow the dispersing adult leaffooted bugs as they moved from one field to another and began to form aggregations.

Photo 3. A "large cage" trial with citrus trees in each corner of the cage; on one tree an artificial bug aggregation was used to attract released adult bugs in the cage.

Photo 4. A natural aggregation in citrus. Adults disperse each year from a nearby pomegranate site to form these aggregations, which are often exposed.

Objective 3 – Parasitoids of the Gill's mealybug . In collaboration with David Haviland, we attempted to find and collect parasitized mealybugs from almond or pistachio orchards.

Results and Discussion:

Objective 1 – Number of generations per year. Results suggest that, under 2006/07 conditions, there were three leaffooted bug generations from January to October 2006. As reported previously the overwintered adults began depositing eggs in April, and continued to deposit eggs through May, possibly longer. Nymphs reared from these egg masses passed through five nymphal stages, with the first nymph developing to the adult stage on 23 June 2006. Altogether, we collected 165 adult leaffooted bugs (from 23 June to 12 July 2006), which formed the adults for the first summer generation. These adults were placed into new cages, provisioned as before, and began depositing egg masses on 7 July 2006. Egg deposition continued until late September, with first instar nymphs hatching from these egg masses from 12 July to 10 October 2006. To be clear, adults formed from eggs deposited from the overwintered adult cohort are considered to be adults of the first summer generation. These adults were active from July through October, depositing eggs over a 4 month period. Over 2000 eggs were deposited from the original 165 adults. The resulting nymphs formed the second summer generation. Adults from this second summer generation were first observed on 20 August 2006 and, to date (25 October 2006), there are still live adults from this generation that are depositing eggs. Eggs deposited from the second generation were first observed reaching the adult stage on 17 October 2006, no eggs were found from these adults until the following spring, although we suspect that temperatures will be high enough from October to December for some egg deposition.

In 2007, new egg deposition began in late March and continued until May. The overwintered adults died off soon after egg deposition ceased. With the offspring derived from the 2006/07 overwintered adults, we obtained nymphs and the trial was fully repeated in 2007, and is currently ongoing. Although the data from this has not yet been analyzed, observations suggest the same pattern of adult longevity, overlapping generations, and egg deposition, and three complete generations per year was present.

Clearly, adult leaffooted bugs are long-lived and deposit eggs throughout most of their lifetime, often depositing eggs over a 3 months period. This results in considerable overlap of generations, with adults from one generation living beyond the period when their offspring became adults and produced eggs of the next generation. The overlap of leaffooted bug stages makes insecticides applications based on short residual insecticides very difficult because there are always adults that can migrate into the orchard. Typically, control is based on April or May applications of chlorpyrifos (e.g., Lorsban), pyrethroids, or permethrin to kill overwintering adults that have migrated into the orchard. The biggest concern with these products is the potential to flare spider mites later in the season.

There is also some question about the longevity of the different insecticide materials. Because the adult population can migrate into the orchard, materials with longer residual activity might be preferred for the spring application. We are currently testing common materials against adult leaffooted bugs to determine how long after application any residual contact can kill or repel adults..

In general, control in June is not needed because populations of overwintering adults have declined and most nymphs are too small to penetrate into the kernel. By July, however, large nymphs and new adults may be of sufficient size to cause kernel damage, although most of their attempts to reach the kernel fail because of the hardened shell.

Objective 2 – Overwintering aggregation and spring movement. Leaffooted bugs overwinter as adults, typically in aggregations located in protected areas, such as in woodpiles, barns, under the bark of eucalyptus trees, in cypress trees or juniper trees. These pests can also overwinter in the orchard in plant debris, pump houses, or cracks along the tree trunk. In April and May, adults disperse to find food sources. There is little known about the overwintering and aggregation cues. Adult leaffooted bugs may aggregate in areas simply because there shelter. It is also possible that males call females using a sex pheromone or that clustered leaffooted call in others using an aggregation pheromone. We conducted three trials to investigate overwintering biology and aggregation cues.

a) In the first study, we artificially created small aggregations of leaffooted bug adults in the field to determine if aggregations of the resident population could be manipulated. The wooden leaffooted bug overwintering chambers were placed in a citrus orchard that was adjacent to a heavily infested pomegranate orchard, and an almond orchard that where leaffooted bugs have consistently come into the orchard from overwintering sites nearby.

Result found few resident leaffooted bugs were attracted to the artificial aggregations. No true aggregations of resident bugs were formed and, therefore, we can make no comments on the attractiveness of the four treatments (virgin females, males, female and male aggregations and a shelter with food only). The obvious conclusion is that our artificial shelters were not attractive, even with caged aggregations of leaffooted bugs and food. It is as likely that the shelter were placed into the field too late (October/November). We observed, while establishing the plots, that much of the dispersing leaffooted bug population moved in October. For example, while we continued to observe aggregations of nymphs in the pomegranate orchard, most of these nymphs never developed to adults or dispersed from the pomegranates to an overwintering site in the citrus orchard. Rather, these nymphs typically died from exposure in the pomegranate field.

For this reason, we believe the adult dispersion from almonds may occur much early (September/October) before cold temperatures begin to develop. In fact, as detailed below, aggregations that were formed in October often remained throughout the winter, even when the aggregation site provided poor protection. The adult leaffooted bugs simply remained in the aggregation in the exposed sites and slowly died from winter temperatures.

b) In the second study, we used large (10 × 12 foot) cages to manipulate leaffooted bug aggregations. In each of the four corners of the cage a potted tree was placed as a "substrate" for the leaffooted bugs to form an aggregation upon. We then added to one of the cages an artificial aggregation of caged leaffooted bug adults.

Results were similar to the field trial as the freely released leaffooted bugs did move towards the aggregation cage in any of the trials. As before, we suspect that either the design is flawed, or that the trial was conducted too late in the season. Aggregation cues might be a combination of changing climate, from summer to fall, as well as an insect cue, such as an aggregation pheromone, sound, or vibration cue (or a combination of many cues). Support for this observation is the aggregations that formed in the small cages used to conduct the study of leaffooted bug generations. Through the fall winter and spring, we observed aggregations forming in the early morning hours (photo 5) and, as the temperatures warmed each day, the insects would begin to break from the aggregation and move about the cage.

c) In the third study, we followed overwintering aggregations in commercial citrus and almond fields, where there has historically been leaffooted bug pest problems in nearby orchards in the spring. We used a number of different sampling programs to follow the dispersing adult leaffooted bugs as they moved from one field to another and began to form aggregations.

From our winter/spring sampling, we predicted (in February) that the 2007 leaffooted bug adult population would be considerable lower than last season's – a result of the cold winter temperatures. The prediction appeared to hold true throughout the spring and early summer – the critical period for leaffooted bug damage. The results suggest that through a relatively small group effort, regional "hot-spots" can be sampled from December to February and get a reasonable prediction of the leaffooted bug population size for the spring. We believe that we can establish annual winter monitoring programs that will help to forecast spring bug abundance, thereby giving managers a warning about bad years.

Results from two "hot spots" are as follows: In October/November 2006, leaffooted bugs were observed leaving a pomegranate field (Tulare County) and an almond field (Fresno County) and aggregating on eucalyptus and citrus trees in adjacent fields. There were several aggregates of 15-40 adults tightly clustered on the terminals branches, often exposed. The aggregations were usually on the sunny side of the tree and towards the outside of the tree. Leaffooted bugs were also observed under the bark of the trunk of a palm tree nearby. We have previously observe leaffooted bugs under loose bark of eucalyptus trees the winter and under the tarps of a covered tractor. They have usually been observed above the ground during the winter.

After the hard freeze in January the leaffooted bugs in the citrus were dead and falling to the ground. No alive leaffooted bugs were observed in that citrus field after the freeze. Several leaffooted bugs under the bark of the palm tree were more protected and had survived. We suspect that the bugs must form the aggregation in a protected area by November / December as after temperatures drop there was little movement to more protected places. In other words, if the aggregation formed in October was in an exposed location, the bugs would rarely move unless the temperature was warm enough.

Throughout the winter we observed leaffooted bug adults dying, dropping directly from the aggregation to the ground. We estimate about 90% of the individuals in the more exposed aggregations (e.g., on a citrus branch) died. Individuals in protected locations (e.g., in palm trees) survived – at least 50% of the population.

In March, the aggregations began to break out and adults started to move back into almonds. In an almond field near Orosi, surrounded by foot hills, citrus fields and some eucalyptus trees, we sampled 100 almond trees were observed for one minute in each field. In April, observations were made by circling the tree and looking for leaffooted bug adults and randomly checking 10 nuts for damage. Damaged nuts had sap coming out of the nut from the feeding site. A four foot long pole was used to beat the higher branches to make the leaffooted bug take flight. This was only effective when the temperature was at least 80 degrees F. The leaffooted bug's flight is distinctive in that it makes a buzzing sound and is not a fast flier.

We noted that most of the damage and leaffooted bug were on the south side of the tree which is the sunny side. As a possible faster alternative sampling technique to cover more trees, we tried doing a 15 second search only on the south side for damage and leaffooted bugs. We noted that by looking mainly for damage we were able to detect more damaged nuts and find more leaffooted bug because many of the bugs were still next to damaged nuts. Since it is early in the season and relatively cool, and the leaffooted bugs are mating and have plenty to feed on, they seem not to be moving much and they can be seen near the damaged nuts.

In summary, the winter sampling program provided information on the leaffooted bug population size. It showed high mortality of exposed leaffooted bugs, and reinforced the importance of nearby protected shelters for overwintering survival. Spring sampling in almonds found both adult and damage but could not show the adult migration into the orchard before damaged nuts were found.

Growers and PCAs will still need to make their own decision on whether or not a spray is needed. Important factors to consider are the number of bugs and damage found, the time of season (early-season is when most damage occurs), the bug development stage, the susceptibility of the almond cultivar (soft shelled cultivars are more susceptible), and the tolerance for damage in the crop (e.g., crop load). PCAs basing treatments on gummosis and nut drop should also recognize that there can be a 7-10 days lag time between when feeding takes place and when gummosis and nut drop occurs – so the dispersing insects may already have moved to another block. Therefore, a helpful tool would prior knowledge to the possible leaffooted bug densities before they arrive in the orchard… in other words, a winter sampling program.

Objective 3. Recovery efforts from field collections did not turn up any parasitoids as no Gill's mealybug were found in almonds and relatively few mealybugs were found in pistachios.

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Recent Publications:

Haviland, D., Beede, R. Godfrey, K. and Daane, K. 2006. *Ferrisia gilli*: A new mealybug pest of pistachios and other deciduous crops. *Univ. Calif. Agriculture and Natural Resources,* Publication No. 8203.

Daane, K. M., Haviland, D. R., Viveros, M., and Holtz, B. A. 2006. Leaffooted bug hammers almonds, pistachios. *Pacific Nut Producer* 12(7): 4-7, 26.

Bentley, W. J., Beede, R. H., Daane, K. M., and Haviland, D. R. 2007. University of California IPM Pest Management Guidelines: Pistachio, Insects and Mites. *University of California ANR Publication 3461.*

Three additional peer-reviewed publications are planned.

<u>Recent Presentations:</u>

Leaffooted plant bug biology, identification and parasitism. *2006 Almond Field Meeting-UCCE Madera County.* July 2006. Madera, CA. ~50 growers.

Leaffooted bug: 2006 Update. *Pacific Nut Producer Annual Meeting.* Turlock, CA. Dec. 2006. ~150 growers / PCAs.

Biology of the leaffooted bug and the *Ferresia gilli* mealybug. *34th Annual Almond Industry Conference.* Modesto, CA. Dec. 2006. 10 min presentation, ~150 PCAs, farmers and UCCE personnel.

Insect pests in organic production. *Going Organic – Tree and Vine Production.* Selma, CA. Jan. 2007. 45 min presentation, ~100 PCAs, farmers and UCCE personnel.

Leaffooted plant bug. *2007 Annual Pistachio Day.* Visalia, CA. Jan. 2007. two - 30 min presentations, ~200 growers and PCAs.

Leaffooted plant bug biology and management. *2007 Regional Almond Meeting.* Madera, CA. Jan. 2007. 30 min presentation, ~100 growers and PCAs.

Leaffooted plant bug: What happened in 2006? *Fresno-Madera CAPCA meeting.* Fresno, CA. Mar. 2007. 30 min presentation, ~115 PCAs.

Leaffooted plant bug: damage and control. *91st Pacific Branch Entomological Society of America.* Mar. 2007. Portland, OR.