Biology and Management of the Gilli Mealybug, *Ferrisia gilli,* in Almonds

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Project Leader: David R. Haviland (UCCE Kern County)

Project Cooperators: Robert Beede (UCCE Kings Co.) and Kent Daane (UC Berkeley)

Introduction

Ferrisia gilli is a new mealybug pest that has been found infesting deciduous nut and fruit trees in the San Joaquin and Sacramento Valleys. It is primarily a pest of pistachios, and now infests over 3,000 acres of pistachio trees from southern Tulare County up through Colusa County. Sporadic infestations in almonds have been found in both Tulare and Stanislaus Counties, and more infestations are expected as the percentage of infested pistachio orchards increases.

F. gilli is a relatively large mealybug that feeds by sucking plant juices. Feeding on almonds can cause sufficient stress to induce mid-summer defoliation of trees. Large amounts of honeydew, which acts as a substrate for sooty mold, can also damage trees by blackening the surfaces of leaves, and thereby rendering them photosynthetically inactive.

Very little is known about this new mealybug pest, primarily because it was only described as a new species in 2002; prior to that it was though to be a related species, *Ferrisia virgita*, which is commonly referred to as the striped mealybug. Due to the rapid spread of this mealybug to numerous counties in California, and the fact that we knew very little about this species, it was important to begin a research program on this pest. Initial needs were to develop information on pest biology, biological control, monitoring programs, chemical control, etc., to begin the process of piecing together an integrated pest management for this pest.

Objectives

The objectives of this project were 1) to develop information on the basic biology of *F. gilli*, 2) determine what biological control organisms naturally begin to provide control of this pest, 3) conduct insecticide efficacy trials, 4) monitor within-orchard spread of the mealybugs in an infested orchard, and 5) to determine the effects of mealybugs on yield and quality of nuts.

Methods and Results

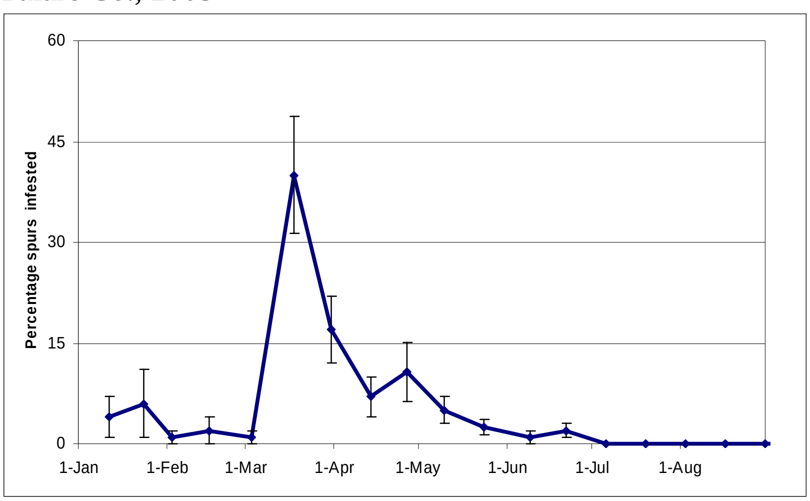
<u>Mealybug Biology</u>

Basic biological information was collected beginning in October 2004 through the end of September 2005. Between October and December we took periodic 3-inch diameter circular core samples of bark from locations on tree trunks where mealybugs had aggregated. They were evaluated to determine the overwintering stage of the mealybugs and to document any biological control organisms. In January we switched to spur samples to begin evaluating movement out of overwintering sites and into the tree canopy. The first sample was taken on 12 Jan 2005 by evaluating 10, 6-inch stem pieces containing spurs from each of 10 untreated almond trees. Spurs were inspected for mealybugs, and when mealybugs were found, the number of mealybugs and location on the spur sample was noted. This process was repeated on the same ten trees every two weeks through the end of September, 2005.

F. gilli primarily overwinters in the immature stages in cracks and crevices under bark on the trunk and main scaffolds of the tree. Smaller numbers were also found hiding underneath the bark of limbs and underneath bud scales. Mealybugs appeared to be in the second instar stage, though this information was not verified morphologically under a microscope.

Figure 1 shows the percentage of spur samples infested during biweekly evaluations. Percentage of spurs infested with mealybugs started low from January through the first of March. During this time the mealybugs were still in their overwintering sites under bark on the trunk and other parts of the tree. Some time during the early weeks of March the mealybugs migrated out of their overwintering sites, resulting in 40% of the spurs being infested with at least one mealybug on the 18 March evaluation date. At this time, most mealybugs were medium sized nymphs. After 18 March mealybug populations began to decrease as mealybugs became more evenly distributed in the tree (and not just concentrated on the lower spurs we were sampling), and as mealybug populations were reduced by predation, parasitism, and other natural causes of mortality. By late June and early July, mealybugs had developed into the adult stage and began to reproduce. Soon thereafter, and without the influences of any insecticides, the mealybug populations disappeared such that we did not find a single mealybug on any of the samples collected during the remainder of the year. This was very interesting since in the previous year mealybug populations skyrocketed late in the summer such that those same trees became defoliated prior to harvest. Then, after harvest, very dense aggregations of mealybugs were found migrating towards the trunk and main scaffolds in preparation for the winter.

Figure 1. Mean ± SEM of the percentage of 6-inch spur samples infested with *F. gilli*. Pixley, Tulare Co., 2005



Biological Control

Observations indicate that biological control was the primary cause of the mealybug disappearance. Bark samples from the trunk during the winter showed a combination of parasitoids and predators. These included at least two species of parasitoid wasps, lacewing larvae, and a predatory beetle. The two species of wasps were reared repeated times from mealybug mummies from October 2004 through spring 2005. Parasitoids appear to overwinter inside mealybug mummies on the bark of the tree, and then emerge as temperatures warm up in the spring. Currently, key points we have learned about the parasitoids are that there are at least two species of them, that they found the mealybugs on their own (indicating that they are something already established), that they survive the winter, and that each parasitoid is capable of producing multiple offspring from each mealybug. These parasitoids have also been reared from additional almond locations with mealybug infestations as well as a persimmon block near Ducor, Tulare County. Samples of these parasitoids in alcohol have been sent to taxonomists for identification, and live specimens have been provided to K. Daane for his team's work on biological control of this pest.

The predatory beetle found was a small, mottled brown, coccinelid. Larval stages mimic mealybugs due to white fibrous secretions that cover their bodies. We recovered these beetles at a high percentage of independent almond and pistachio orchards where the mealybug has been present for at least one year.

The California grey ant (field ant) also interacts heavily with *F. gilli*. Field ants are attracted to mealybugs and were often found in close association with them. Since these ants are primarily sugar feeders, it is likely that they were harvesting honeydew from the mealybugs as a food source. Field ants were also periodically seen moving adult female mealybugs below ground, presumably to use them as a direct food source. It is likely that predation on the crawler stages that appeared in mid June could explain the abrupt disappearance of the mealybugs for the remainder of the season, especially since there were lots of field ants, no insecticides were used, and there were no mealybug "mummies" left behind that would indicate populations were reduced through parasitism.

<u>Chemical Control</u>

Two chemical control trials were conducted in a mature almond orchard near Pixley, Tulare County. The first trial evaluated common dormant treatments for San Jose Scale that might also have effectiveness against the mealybug. The trial consisted of five treatments plus a control. Treatments were Asana (esfenvalerate) plus oil, Centaur (buprofezin) plus oil, Lorsban (chlorpyrifos) plus oil, Seize (pyriproxifen) plus oil, and oil alone.

The trial was organized as a completely randomized design with 9 repetitions per treatment. Since mealybug densities in the block were highly erratic, we chose 63 of the most heavily infested almond trees out of an area approximately 2.5 acres in size and randomly assigned each tree to one of the treatments. Trees were sprayed on 17 December using a John Beene sprayer equipped with a hand gun at 150 P.S.I. Applications were made at 200 G.P.A. with the hand gun adjusted to provide a spray pattern with optimal coverage.

The effects of insecticide treatments on mealybug populations were measured using bark samples from December through March and then spur samples in April and May. Bark samples were taken 1, 4, 7, and 12 WAT by excising a 3-inch diameter core sample of bark in an area of each tree trunk where there were aggregations of mealybugs. Cores were brought back to a laboratory and the number of live mealybugs was recorded. Spur samples were taken by evaluating 20 random spurs per tree for the number of live mealybugs present.

Table 1 shows the results of insecticide treatments on the number of live mealybugs on bark samples. One week after treatment (WAT) there were no significant differences in mealybug densities. By 4 and 7 WAT, trees treated with Lorsban were the only trees to have significant reductions compared to the untreated control. Pest density in plots treated with Centaur were not significantly lower than the untreated control on either evaluation date, but the fact that the same reduction pattern existed on the 4 and 7 WAT treatment dates suggest that the reduction is legitimate. By 12 WAT there were no significant differences among treatments, though trees treated with Lorsban still had the lowest pest density.

Table 1. Effects of dormant insecticide treatments in December on mealybug populations on the trunk. Pixley, Tulare Co., 2004-2005.

Treatment	Rate/A Product	Mealybugs per 3 inch diameter circle of bark							
		1 WAT (23 Dec)		4 WAT (12 Jan)		7 WAT (3 Feb)		12 WAT (8 Mar)	
Asana + Oil	16 fl oz + 1.5%	24.3	a	35.3	b	8.3	b	2.1	a
Centaur + Oil	64 oz + 1.5%	27.8	a	8.2	ab	4.6	ab	3.7	a
Lorsban + Oil	4 pt +1.5%	16.5	a	0.1	a	0.1	a	0.4	a
Seize + Oil	16 fl oz + 1.5%	63.3	a	31.3	b	14.4	b	2.3	a
Oil	1.5%	63.3	a	13.8	b	11.3	b	5.0	a
Untreated		62.0	a	12.3	b	22.0	b	2.3	a

All data are presented as original numbers with means separation, F, and P values from square root transformed data. Values followed by the same letter are not significantly different based on Fisher's Protected LSD at P>0.05.

Spur sample taken in April and May demonstrated that a delayed effect of Centaur resulted in superior overall control compared to all other treatments (Table 2). Centaur is an insect growth regulator that kills mealybugs by inhibiting their ability to molt. Since mealybug did not molt between December and March, the effects of Centaur were not seen. However, spur samples in April and May, once overwintering mealybugs had molted, resulted in excellent control of the pest by this product, followed by Lorsban. Asana, Seize, and Oil alone did not significantly reduce mealybug density on any evaluation date.

Table 2. Effects of dormant insecticide treatments in December on mealybug populations in the spring. Pixley, Tulare Co., 2004-2005

Treatment	Rate/A Product	Spurs infested (%)				Total mealybugs (per 30 spurs)			
		April		May		April		May	
Asana + Oil	16 fl oz + 1.5%	4.8	ab	10.0	a	1.3	abc	3.7	a
Centaur + Oil	64 oz + 1.5%	0.6	a	0.6	a	0.2	a	0.1	a
Lorsban + Oil	4 pt +1.5%	3.0	ab	2.8	a	1.1	ab	0.7	a
Seize + Oil	16 fl oz + 1.5%	8.9	bc	10.6	a	4.0	abc	4.0	a
Oil	1.5%	13.3	c	17.8	a	7.4	bc	6.8	a
Untreated		11.9	bc	9.4	a	8.9	bc	5.7	a

All data are presented as original numbers with means separation, F, and P values from square root transformed data. Values followed by the same letter are not significantly different based on Fisher's Protected LSD at P>0.05.

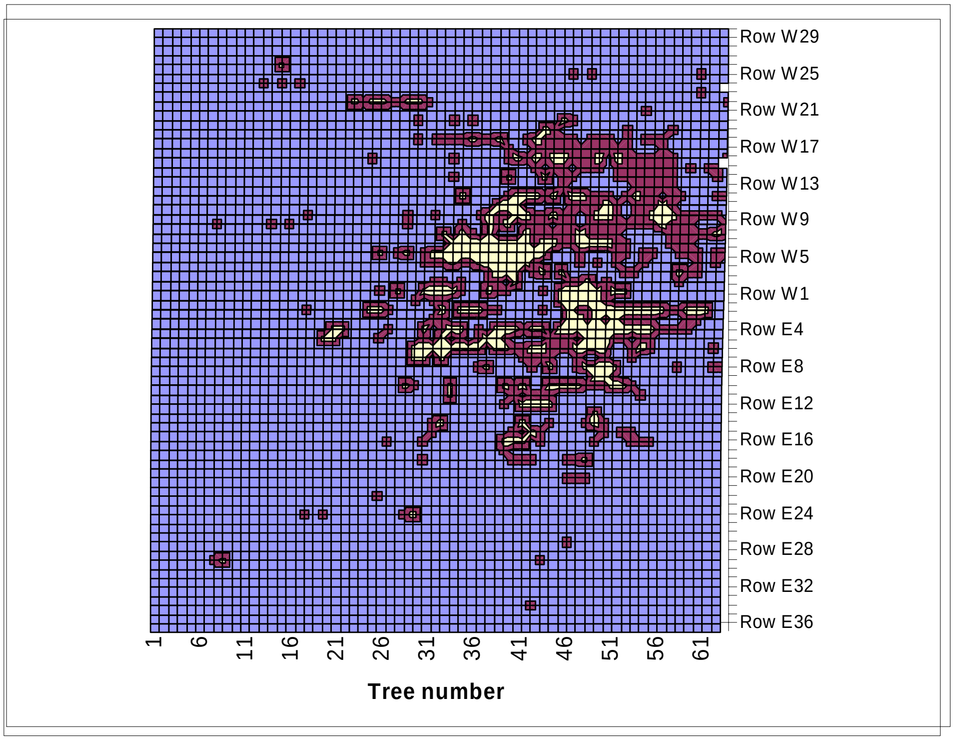
The second insecticide trial was sprayed on 1 June, 2005. This date was chosen to coincide the the emergence of first generation crawlers from the overwintering mealybugs that had now reached maturity. This trial was organized into a randomized complete block design with 6 replications of seven treatments and a control. Treatments included Lorsban, Centaur, Seize, Assail, two formulations of Provado, and an experimental compound. Plots were treated as in the dormant insecticide trial.

Plots were sampled the day prior to treatment and at 2, 4, and 8 WAT. Sampling consisted of evaluating 20 spurs per tree for live mealybugs. Precount mealybug densities ranged from 1.7 to 5.0 adult females per 20 spurs. However, overall mealybug populations completely crashed such that mealybug densities in the control plots 2 and 4 WAT were 0.5 and 0.0 mealybugs (now in the crawler stage) per 20 spurs respectively. This trail therefore was unable to compare the effectiveness of the insecticide treatments.

Within-field Distribution

Surveys of an infested mature almond orchard in Pixley, Tulare Co., were conducted to determine within-field distribution of F. gilli. We surveyed a total of 3999 trees in an area just over 40 acres. Of these trees, 219 (5.4%) of the trees were heavily infested, 347 (8.7%) had light to moderate infestations, and 3433 (85.8%) of the trees were not infested. Patterns of infestation shown in Figure 2 demonstrate that mealybug distribution is highly clumped, with a tendency for mealybugs to spread in the direction of the rows instead of across rows. This is likely due to spread by the movement of equipment.

Figure 2. Within-field distribution of mealybugs in a mature almond orchard near Pixley, Tulare Co., December 2004. Light areas indicate trees with high densities of mealybugs. These are surrounded by areas of trees with light to moderate infestations, which are surrounded by uninfested trees.



<u>Effect of Mealybugs on Nut Yield and Quality</u>
Our goal in 2005 was to develop information on the effects of different mealybug densities on the yield and quality of almond nuts. We set up two trials within the field shown in Figure 2. However, mealybug populations in this field decreased to undetectable levels by mid summer such that we were not able to do any experiments related to the effects of mealybugs on harvest.

Conclusions
The first year of this project has already made significant advances in the development of information of value in an integrated pest management program for *F. gilli*. The project has documented information on basic pest biology, beneficial organisms, and chemical control. Research suggests that the goal of growers faced with this new pest should be to temporarily reduce pest populations until biological control organisms can arrive and suppress the pest naturally. This appears to occur over a period of about two to three years. It can be accomplished through a dormant or June application of Centaur (buprofezin), which is highly effective against immature stages and can reduce mealybug populations in a manner that is relatively safe to predators and parasites. Alternatively, Lorsban (chlorpyrifos) provided excellent control when sprayed in the dormant season and would likely do the same in-season. Dormant treatments, however, would be preferred since they should be relatively safe to parasitoids due to their state of dormancy inside of mealybug ‘mummies’. It is anticipated that further research as we begin year two of this project will continue to advance our understanding of this pest and how to control it.