Seasonal Phenology of *Ferrisia gilli* (Hemiptera: Pseudococcidae) in Commercial Pistachios

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ABSTRACT The mealybug *Ferrisia gilli* Gullan is a serious new pest of pistachios in California. It was first found near the town of Tulare in the late 1990s and has since spread to orchards in most pistachio-producing regions of the state. The seasonal phenology of *F. gilli* was evaluated in a commercial pistachio orchard in Tulare County during 2005 and 2006. During both seasons *F. gilli* overwintered as small nymphs and had three complete generations per year. Mealybug population densities were low and remained as immatures in March and April; by late May adult females formed and averaged (±SE) 1.3 ± 0.3 and 1.2 ± 0.3 per 0.75 m of sample branch in 2005 and 2006, respectively. The first in-season generation occurred from early June through mid-July, with mealybug densities ranging from 17.6 ± 5.6–26.4 ± 6.2 mealybugs per 0.75 m sample branch. The second in-season generation occurred from late July through September and had peak densities of 408.6 ± 93.9 and 182.0 ± 34.2 mealybugs per branch. In March and April mealybugs were located primarily on the buds and branch wood; in May the population was on branch wood as well as the rachis; from June through September the population was located primarily in the pistachio cluster. *F. gilli*'s seasonal phenology described herein was used to develop a management program.

KEY WORDS *Ferrisia*, *Pistacia*, Pseudococcidae, pistachio, mealybug

The mealybug *Ferrisia gilli* Gullan (Hemiptera: Pseudococcidae) is an important new pest of pistachios, *Pistacia vera* L., in California. Mealybug infestations in pistachio orchards near Tipton, Tulare Co., CA, were discovered in 1997, with the pest initially identified as the striped mealybug, *Ferrisia virgata* (Cockerell), or its close relative *Ferrisia malvastra* (McDaniel) (Gullan et al. 2003). However, differences in adult morphology and its population dynamics in pistachios prompted Gullan et al. (2003) to complete morphological and molecular studies that led to the new species name, *F. gilli.*

Many mealybugs are known to be plant pests and damage crops by secreting honeydew, which promotes sooty mold growth, contaminating the fruit or nuts, and vectoring plant pathogens (Ben-Dov 1995). Whereas both *F. malvastra* and *F. virgata* have become economic pests around the world, their pest status was never reported to be of great importance on any of California's agriculture crops (McKenzie 1967). The relatively sudden increase in the damage caused by the *F. gilli* may reflect its recent arrival on pistachio; even though it has been present in California since at least 1968 (earliest definite record is from Shasta Co.) (Gullan et al. 2003). These authors reported that by mid-2002, *F. gilli* was found in 325 acres of pistachio trees and eight acres of almond trees in the San Joaquin Valley. Haviland (2005) estimated that the pistachios acreage infested with *F. gilli* in Tulare Co. increased from ≈20 to over 3,000 acres from 2002 to 2005. By 2012, *F. gilli* has been authoritatively identified in 12 counties in California (California Department of Food and Agriculture [CDFA] 2012), representing all major pistachio production regions of the state. *F. gilli* was probably introduced into California from the southeastern United States where it had been collected in Alabama, Georgia, and Louisiana (Gullan et al. 2003).

Concerns about the establishment of *F. gilli* in California pistachio orchards began in the early 2000s when growers in Tulare County reported mealybug infestations in their orchards coupled with localized spread of this pest. Growers of infested pistachio orchards reported rapid increases in mealybug density during the summer that led to clusters at harvest that were heavily infested with mealybugs, their excrement and honeydew, and sooty mold. Pistachio growers were also concerned with the lack of biological control of *F. gilli*, presumably because of the use of broad-spectrum insecticides for control of plant bugs (Miridae) (Haviland et al. 2006). The initial response from growers was to try to control *F. gilli* ~1 mo before harvest with broad-spectrum organophosphate insec-

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ticides that were registered for use on navel orangeworm, *Amyelois transitella* (Walker), though these products proved ineffective. As a result, in 2005, the grower-funded California Pistachio Commission put out a special request for research to develop information on the biology of *F. gilli* and methods for its control. The studies we report were completed as a direct response to that request.

Little is known about *F. gilli* biology because of its relatively recent designation as a new species. The importance of *F. gilli* as a pest of pistachio, almond, and grape (Haviland et al. 2005, Daane et al. 2011) in California, warrants further study of this new pest. The aim of this project was to conduct a 2-yr study in pistachios to determine the seasonal abundance of developmental stages, preferred feeding locations, and number of generations per year. The gathered data are discussed with respect to management of *F. gilli* in pistachio, with the primary goal to develop information on mealybug biology that forms the basis of an effective integrated pest management (IPM) program.

Materials and Methods

Mealybug seasonal phenology and population distribution on the tree were determined through a field study conducted in a mature commercial pistachio orchard, located near Tipton, CA (Tulare Co.). In February of 2005 and 2006, five and seven female pistachio trees, respectively, were selected at random from trees that had visual evidence on the trunks and main scaffolds of a mealybug infestation during the previous seasons. The trees were mature 'Kerman' cultivar pistachios, the predominant cultivar planted in California (Kallsen et al. 2009), and were farmed using standard pistachio management practices for disease control, pruning, and harvest operations, with the exception that no insecticides were applied to the sampled trees.

Samples were collected every 2–4 wk from mid-March through harvest in September in 2005 and 2006. On each sample date a total of 5 to 20 branches, depending on the seasonal period and study year, were randomly selected and evaluated on each tree: 5 branches per tree were used in March and April 2005, 10 in May through August 2005, 20 in September 2005, and 10 were used on all sample dates in 2006. The terminal 0.75 m of a tree branch, containing at least one cluster, was the sample unit. Each sample branch was subdivided into buds or wood, leaf petiole, leaf, cluster rachis, or hull (the external part of the nuts in each cluster).

On each sample date, the number of mealybugs was determined on each sampled branch, categorizing the mealybug population into three development categories: crawlers (first-instar), nymphs (second and third instars), and adults; as well as the location of each mealybug (buds or wood, petiole, leaf, rachis, or hull). A hand lens was used when needed to count mealybugs or differentiate development stages. Qualitative observations of mealybug densities, stage development, and crop damage throughout the entire tree were also made during each sample date.

Statistical Analysis. Data within each tree were averaged to determine the mean number of crawlers, nymphs, and adults per branch as well as the percentage of the mealybug population located on the different subdivisions of the sampled branch. The number of mealybug generations per year was determined by plotting (mean ± SEM) mealybugs per branch in each developmental stage over time. These figures were also used to determine when peaks in each life stage occurred, the duration of each generation, and to estimate population trends among generations. Data of mealybug location were analyzed for each sample date by one-way analysis of variance (ANOVA), with means separated using Fisher Protected least significant difference (LSD) ($P < 0.05$) after transformation (square root $(x + 0.5)$) of the data to satisfy model assumptions regarding homogeneity of variances (SAS Institute 2009). Data of mealybugs per leaf petiole and leaf were combined for all analyses.

Results

Seasonal Density. *F. gilli* had three generations per year in both 2005 and 2006. Total mealybug density was low throughout the winter, decreased further during the spring, and increased rapidly thereafter with each of the two in-season summer generations (Fig. 1). The density of the overwintering generation steadily declined from 8.7 ± 3.4–1.3 ± 0.3 mealybugs per branch between 31 March and 19 May 2005, and from 9.7 ± 2.6–1.2 ± 0.3 mealybugs per branch 24 March and 31 May 2006. This left just over one surviving mealybug per branch at the end of overwintering generation in May, in both study years, to produce crawlers of the first in-season generation, which then increased 15–20 fold in June. Average mealybug densities per branch ranged from 17.6 ± 5.6–26.2 ± 7.1 from 9 June to 7 July 2005, respectively, and from 19.2 ± 3.7–26.4 ± 6.2 from 14 June to 11 July 2006, respectively.

Mealybug densities were highest during the second generation (Fig. 1). In 2005, mealybug densities ranged from 90.9 ± 11.2–408.6 ± 93.9 per branch, between 20 July and 21 September, with the highest density occurring on 3 August at the peak of crawler emergence. In 2006, mealybug densities ranged from 104.2 ± 21.8–182.0 ± 34.2, between 9 August and 21 September, with the highest density again coinciding with the peak of crawler emergence on 9 August.

The initial density of the overwintering generation could not be fully recorded because of harvest and the behavior of adult females to migrate out of the sampling area (terminal 0.75 m branch section) and onto the trunk and main scaffolds before producing crawlers. When the whole tree is considered, mealybug density is likely highest in late September to early October when crawlers of the overwintering generation are present throughout the tree. We observed that trees with tens of thousands of crawlers per tree after harvest only have a few mealybugs per sampling

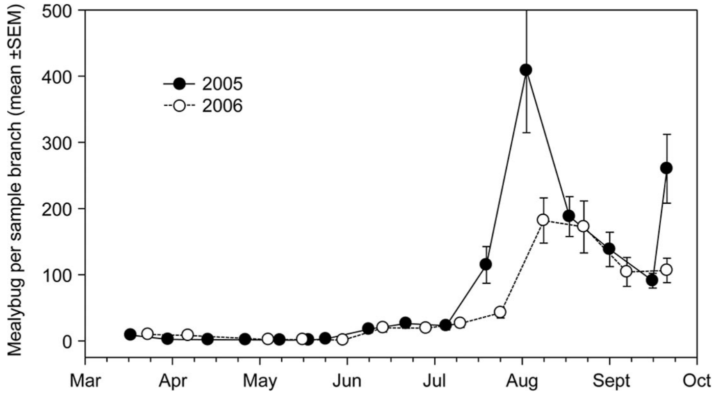

Fig. 1. Total (all development stages recorded) *F. gilli* on pistachio branch samples (terminal 0.75 m branch sections); data were collected in 2005 and 2006 field seasons, Tulare Co., California.

area the following spring, suggesting that overwintering mortality is high.

Development Stage Phenology. For the development of an IPM program, it was important to record development stage occurrence as well as total density. Crawlers of the first generation began to hatch in early June and peaked at an average of 16.4 ± 6.3 and 19.2 ± 6.6 crawlers per branch on sample dates of 22 June 2005 and 14 June 2006, respectively (Fig. 2A). Second and third instar nymphs developed in June and early July and peaked at 19.4 ± 5.2 and 8.8 ± 1.3 nymphs per branch on 22 June 2005 and 29 June 2006, respectively (Fig. 2B). First generation nymphs developed into adults by mid-July, and peaked at 11.6 ± 3.2 and 5.3 ± 1.2 adults per branch on 20 July 2005 and 11 July 2006, respectively (Fig. 2C).

Second generation mealybugs were found from mid-July through harvest in mid-September. Crawlers emerged from mid-July through early August and peaked at 401.8 ± 92.0 and 162.0 ± 32.1 crawlers per branch on 3 August 2005 and 9 August 2006, respectively (Fig. 2A). Second-generation nymphs were found primarily in August and peaked at 57.0 ± 10.9 and 63.3 ± 9.3 nymphs per branch on 18 August 2005 and 23 August 2006, respectively (Fig. 2B). Adults were found in early September before harvest and peaked at 114.1 ± 2.4 and 57.1 ± 12.5 per branch on 1 September 2005 and 7 September 2006, respectively (Fig. 2C).

Crawlers of the third generation of mealybugs emerged during September. Third-generation crawlers were initially collected on 16 September 2005 and 7 September 2006. By harvest on 21 September crawler density was 236.0 ± 49.6 and 87.3 ± 15.2 per branch in 2005 and 2006, respectively (Fig. 2A). However, as noted previously, it was observed that large numbers of adult females of the second generation had migrated outside of the sampling area to the trunk and main scaffolds of the tree, where they were producing crawlers. These insects were not quantified in this study. On 21 September 2005 and 2006, we observed that crawlers of the overwintering generation were either removed from the tree during the harvest operation (the branches are mechanically shaken) or had migrated to cracks and crevices on the trunk and scaffolding, where they would overwinter. Movement back to the terminal branch sampling area coincided

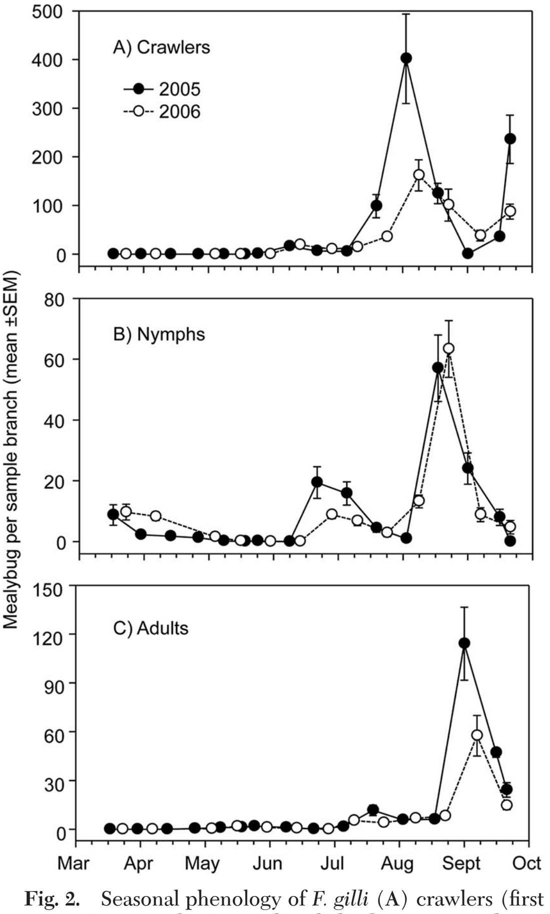

Fig. 2. Seasonal phenology of *F. gilli* (A) crawlers (first instars), (B) nymphs (second and third instars), and (C) adult development stages on pistachio branch samples (terminal 0.75 m branch sections); data were collected in 2005 and 2006 field seasons, Tulare Co., California.

Table 1. ***Ferrisia gilli*** **pop distribution on pistachio terminal branch sections (mean ± SE); data are from 2005 samples**

Sample date	Sample location					Statistic parameters	
	Bud or wood	Petiole	Leaf	Rachis	Hull	*F*	*P*
18 Mar.	8.7 ± 3.4a	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	14.15	<0.0001
14 April	1.7 ± 0.4a	0.0 ± 0.0b	0.1 ± 0.1b	0.0 ± 0.0b	0.0 ± 0.0b	24.94	<0.0001
9 May	0.4 ± 0.2a	0.0 ± 0.0c	0.0 ± 0.0c	0.7 ± 0.1b	0.0 ± 0.0c	16.52	<0.0001
19 May	0.4 ± 0.1a	0.0 ± 0.0c	0.0 ± 0.0c	1.0 ± 0.2b	0.0 ± 0.0c	22.79	<0.0001
25 May	0.9 ± 0.2a	0.0 ± 0.0b	0.0 ± 0.0b	2.0 ± 0.8a	0.1 ± 0.1b	10.23	0.0003
9 June	0.4 ± 0.0a	0.0 ± 0.0a	2.3 ± 0.8ab	5.2 ± 0.9bc	9.8 ± 4.8c	8.05	0.0009
22 June	0.6 ± 0.2ab	0.3 ± 0.1a	1.3 ± 0.6ba	2.5 ± 0.6b	21.5 ± 5.9c	35.97	<0.0001
6 July	0.0 ± 0.0a	0.2 ± 0.1a	2.1 ± 1.0b	2.8 ± 0.8b	17.8 ± 4.6c	37.93	<0.0001
20 July	0.0 ± 0.0a	1.2 ± 0.7a	1.8 ± 0.5a	12.4 ± 2.7b	99.4 ± 24.8c	32.16	<0.0001
3 Aug.	0.1 ± 0.6a	1.7 ± 0.2a	3.4 ± 1.5a	9.9 ± 4.8a	393.4 ± 90.5b	52.65	<0.0001
18 Aug.	0.4 ± 0.1a	0.1 ± 0.1a	1.2 ± 0.8a	4.2 ± 1.0a	182.2 ± 29.1b	109.65	<0.0001
1 Sept.	0.1 ± 0.1a	0.0 ± 0.0a	0.0 ± 0.0a	13.1 ± 6.6b	125.1 ± 21.7c	64.03	<0.0001
16 Sept.	5.2 ± 0.5a	0.7 ± 0.2b	2.5 ± 1.6ab	23.0 ± 3.7c	152.6 ± 19.4d	145.59	<0.0001
21 Sept.	5.4 ± 1.6a	0.6 ± 0.2a	3.5 ± 3.2a	60.1 ± 22.6b	450.8 ± 80.0c	74.41	<0.0001

Means within a row followed by the same letter are not significantly different ($P < 0.05$; Fisher's protected LSD). Data are reported as original means, statistical analysis was performed after square root (X + 0.5) transformation of the data; for all columns, df = 4, 16.

with the initiation of bud swell in mid-March to early April. At this time, mealybugs were exclusively nymphs, with peak densities at 8.7 ± 3.4 and 9.7 ± 2.6 nymphs per branch on 18 March 2005 and 24 March 2006, respectively (Fig. 2B). The first adults were found on 9 May 2005 and 5 May 2006 and peaked at 1.9 ± 0.6 and 1.8 ± 0.4 adults per branch on 25 May 2005 and 17 May 2006 (Fig. 2C).

Distribution on the Branch. The preferred feeding location changed seasonally as the *F. gilli* population moved to different branch locations (Tables 1 and 2; Fig. 3). Mealybug distribution, on all evaluation dates, differed significantly among sample branch locations, with highly significant differences ($P \leq 0.0001$) on 25 of the 27 sampling dates (Tables 1 and 2).

During March and April of both years >95% of the mealybugs were located on the bud or wood (Tables 1 and 2; Fig. 3). In May, significantly more mealybugs were on the sample branch wood or rachis than on the leaf, petiole, or hull for all evaluation dates across both years with the exception of 5 May 2006 (Tables 1 and 2). For each evaluation date, >96.4% of the mealybugs were located either on the branch wood or rachis: during the three evaluation dates in May 2005 there were more mealybugs on the rachis (28.4–33.9% on the wood compared with 62.5–71.6% on the rachis), whereas during the three evaluation dates in May 2006 there were more mealybugs on the wood (64.5–81.5% on the wood compared with 18.5–35.5% on the rachis) (Tables 1 and 2; Fig. 3).

The first half of June marked a shift in mealybug location feeding preference (Tables 1 and 2; Fig. 3). This occurred as overwintering mealybugs that had settled on the wood or rachis in May produced first-generation crawlers that were highly mobile and were observed moving to new locations on the branch. On 9 June 2005, 85.4% of the mealybugs were located on either the rachis or hull; on 14 June 2006 the highest percentage was on the leaves (petiole and leaf) (56.1%).

During the second half of June through harvest-time, there were significantly more mealybugs on the hull than at any other location (Tables 1 and 2). The percentage of mealybugs on the hull from 22 June to 21 September 2005 ranged from 78.0 to 97.0%; from 29 June to 21 September 2006 it ranged from 86.1 to 94.8% (Fig. 3). Of the mealybugs that were not on the hull, the majority were on the rachis: on all evaluation dates from July through September the percentage of

Table 2. ***Ferrisia gilli*** **pop distribution on pistachio terminal branch sections (mean ± SE); data are from 2006 samples**

Sample date	Sample location					Statistic parameters	
	Bud or wood	Petiole	Leaf	Rachis	Hull	*F*	*P*
4-Mar	9.7 ± 2.6a	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	35.78	<0.001
7-Apr	8.3 ± 1.4a	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	110.96	<0.0001
5-May	1.5 ± 0.5a	0.0 ± 0.0b	0.0 ± 0.0b	0.3 ± 0.1b	0.0 ± 0.0b	13.73	<0.0001
17-May	1.3 ± 0.3a	0.0 ± 0.0b	0.0 ± 0.0b	0.7 ± 0.2c	0.0 ± 0.0b	19.04	<0.0001
31-May	0.9 ± 0.2a	0.0 ± 0.0b	0.0 ± 0.0b	0.3 ± 0.1c	0.0 ± 0.0b	20.31	<0.0001
14-Jun	0.9 ± 0.2a	0.7 ± 0.3a	10.9 ± 3.7b	3.3 ± 1.5ac	4.9 ± 1.9c	11.26	<0.0001
29-Jun	0.0 ± 0.0a	0.1 ± 0.1a	0.5 ± 0.1a	0.4 ± 0.2a	18.2 ± 3.6b	81.73	<0.0001
11-Jul	0.2 ± 0.1a	0.1 ± 0.1a	0.1 ± 0.0a	1.6 ± 0.6a	24.5 ± 5.6b	45.99	<0.0001
25-Jul	0.0 ± 0.0a	0.4 ± 0.2a	0.6 ± 0.3a	1.2 ± 0.3a	40.3 ± 7.8b	72.35	<0.0001
9-Aug	0.5 ± 0.2a	0.9 ± 0.5a	7.7 ± 1.6b	16.1 ± 1.8b	156.8 ± 30.9c	83.52	<0.0001
23-Aug	1.1 ± 0.4a	0.4 ± 0.2a	2.7 ± 1.1a	13.8 ± 3.0b	154.2 ± 35.5c	64.81	<0.0001
7-Sep	0.9 ± 0.3a	0.4 ± 0.2a	1.3 ± 0.8ab	6.3 ± 2.1b	94.8 ± 19.9c	59.63	<0.0001
21-Sep	1.2 ± 0.5ab	0.1 ± 0.05a	3.3 ± 1.3ab	4.7 ± 1.3b	97.1 ± 16.7c	81.04	<0.0001

Means within a row followed by the same letter are not significantly different ($P < 0.05$; Fisher's protected LSD). Data are reported as original means, statistical analysis was performed after square root (X + 0.5) transformation of the data; for all columns, df = 4, 24.

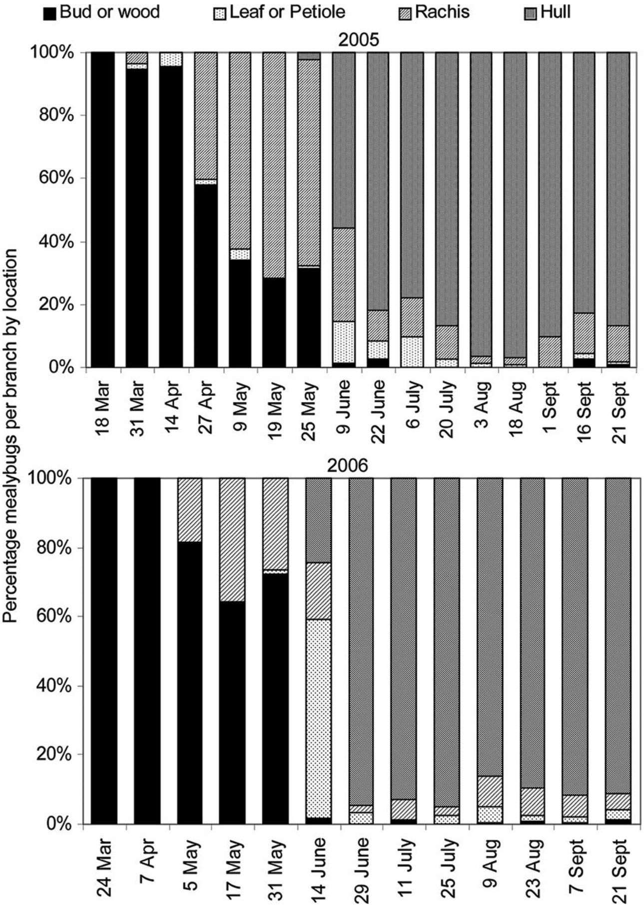

Fig. 3. Seasonal changes in the location of *F. gilli* on pistachio branches samples subdivided into bud or wood, leaf or petiole, fruit cluster rachis, and fruit cluster hull; data were collected in 2005 and 2006 field seasons, Tulare Co., California.

mealybugs on the rachis was greater than the sum of the percentages on the bud or wood, petiole, and leaves (Tables 1 and 2).

Discussion

We showed that *F. gilli* has three complete generations per year on commercial pistachio trees in California's Central Valley, with a relatively low density in the overwintering generation and a rapid increase with each successive summer or in-season generation. This is the first quantitative description of *F. gilli* seasonal phenology on any crop; in fact, all prior published studies focused primarily on its identification or phylogenetic relationship with other *Ferrisia* species (Gullan et al. 2003, 2010; Daane et al. 2011). Nevertheless, prior researchers noted the potential importance of the newly described *F. gilli* as a crop pest. Gullan et al. (2003) not only provided the initial molecular and taxonomic description and also provided qualitative observations of *F. gilli* on pistachios that closely matches information described herein: three annual generations, overwintering as nymphs, movement to the base of new shoots by April; overwintering females producing offspring beginning in May, a rapid increase in population during the summer months through harvest, and an overwintering population residing primarily in bark cracks and crevices on the main trunk. We documented the same seasonal pattern, but also described changes *F. gilli* population density as the overwintering nymphs migrated to the newly expanding bud and begin to feed and develop from March through May (Figs. 1 and 3; Tables 1 and 2). During the spring, mealybug density is at the lowest of the entire season (Fig. 1). In early June, highly mobile crawlers of the first generation disperse along the branch and settle on the hulls of the pistachio fruit cluster where they complete their development by mid-July (Tables 1 and 2). The second generation of mealybugs remained, primarily, on the hulls from mid-July through harvest (Fig. 3), and by mid-September adult females produced crawlers, resulting in peak density counts (Fig. 1) and the nymph population that would migrate from the clusters to the protected regions of the trunk to overwinter.

Mealybug feeding location (Fig. 3) corresponded with carbohydrate allocation in the pistachio tree as shown in Spann et al. (2008). In both 2005 and 2006 the migration from overwintering sites to the branches coincided with budbreak when carbohydrates in the tree shifted acropetally from the roots to the buds. In March and April, mealybugs fed on the bud or new wood, as the pistachio began to push out buds and leaves and, in May, the population moved into the rachis and hulls as fruit clusters began to become differentiated (Tables 1 and 2). As nuts were mature and the tree began to shift carbohydrates basipetally to the roots for the winter, mealybugs began to migrate out of the tree canopy. The same pattern of migration has been noted in vineyards for the pink hibiscus mealybug, *Maconellicoccus hirsutus* Green (Mani 1989), grape mealybug, *Pseudococcus maritimus* Ehrhorn (Geiger and Daane 2001), and *Planococcus ficus* (Signoret) (Walton and Pringle 2004). Most mealybug species are phloem feeders (McKenzie 1967) and their populations would naturally follow movement of plant nutrients, resulting in *F. gilli*'s infestation of the developing pistachio fruit cluster and the resultant crop damage. Surprisingly, the closely related *F. virgata* was reported to rarely feed in the phloem tissue of cacao trees (Entwhistle and Longworth 1963) producing little honeydew, whereas as *F. gilli* feeding in pistachio clusters produced copious amounts of honeydew (Gullan et al. 2003). Both the direct contamination of pistachio clusters by the mealybug and the resulting accumulation of honeydew and associated plant diseases have the potential to cause crop loss.

Given the large numbers of mealybugs found feeding within the clusters of infested pistachio orchards (Gullan et al. 2003, Haviland et al. 2006) and increasing geographic range of the mealybug populations, management programs for *F. gilli* were needed. For most pistachio growers, initial efforts are directed at preventing *F. gilli* from establishing in the orchard, which can be a difficult task. Pistachio harvest in California is accomplished mechanically; nuts within the cluster (and any mealybugs present on the hull) are shaken from the tree, caught in catch-frames, and then transported in fruit bins to a processor, typically within several hours after harvest. Our studies show that at harvest-time 86.6% (2005) and 91.2% (2006) of all mealybugs were located on the hull and that 90.7% (2005) and 82.0% (2006) of all mealybugs were in the highly mobile crawler stage of development (Figs. 1 and 3). This location and stage information, coupled with high pest densities at harvest and the rapid movement of equipment and nuts, suggests that equipment sanitation, particularly during harvest, should be an integral part of management programs to limit *F. gilli* spread to previously uninfested orchards.

Once orchards become infested management programs need to shift to chemical and/or biological controls. Worldwide there are several parasitoid species that attack *Ferrisia* sp. (Noyes and Hayat 1994), but most published records cite the importance of predators as control agents (Mani et al. 1990, Staubli et al. 1997, Mani and Krishnamoorthy 2008). Little is known, however, about natural enemies that attack *F. gilli*, due primarily to its recent designation as a new species (Gullan et al. 2003, 2010). California surveys of *F. gilli* in alternate hosts such as almond, grape, and persimmon have found parasitism by wasps in the genera *Pseudaphycus, Chysoplatycerus,* and *Anagyrus* (Haviland et al. 2006). However, to date, parasitism of *F. gilli* in pistachios has been negligible due, we suspect, to applications of broad-spectrum insecticides routinely applied to control bugs (Miridae, Rhopalidae, Pentatomidae, and Coreidae) and other pistachio insect pests (Haviland et al. 2006, Bentley et al. 2010). Because of the lack of biological controls and no known cultural controls, *F. gilli* control has relied primarily on insecticides. Before 2005 an application of phosmet or carbaryl was made in early August, near hull split, to control both mealybugs and navel orangeworm. This program only provided partial mealybug suppression and a better program was needed (Haviland et al. 2006). Based on *F. gilli* phenology provided herein, a new control program was tested and developed using buprofezin applied in early June during peak crawler emergence from the first *F. gilli* generation (Haviland 2006). Insect growth regulators (IGRs) had long been known to be effective against mealybugs (Hamlen 1977), were currently being used in California vineyards for *P. ficus* (Daane et al. 2006), and provided a better fit with IPM programs than more broad spectrum materials (James 2003). The program was widely adopted by pistachio growers in Tulare County and is now in use throughout California in orchards where *F. gilli* is present (Haviland 2006, Bentley et al. 2010): the June application was chosen because mealybug densities are still relatively low (Fig. 1), mealybugs are primarily in the crawler stage of development (Fig. 3) that is highly susceptible to IGR insecticides, and proper insecticide coverage was more easily attained because of the relatively small size of the tree canopy and nuts within the cluster. At this time, buprofezin is still the primary material used for *F. gilli* in pistachios, although registrations of acetamiprid, imidacloprid, and spirotetramat (CDPR 2010) have provided growers with alternative materials (Bentley et al. 2010).

Management programs that target crawler emergence need to be associated with a monitoring program to be successful. The seasonal phenology presented herein suggests that monitoring should begin in May when mealybugs are primarily found on the rachis or terminal branch wood (Tables 1 and 2) and are exclusively in the adult female stage (Fig. 3), which are easier to see. Because of the limited movement of preovipositional adult female *F. gilli*, branches where mealybugs are found can be marked in May and monitored weekly thereafter to determine the period of crawler emergence, thus indicating the optimal treatment timing (Haviland et al. 2006, Bentley et al. 2010). Monitoring in May can also benefit an IPM program by allowing an assessment of pest density. Currently the value of this information is limited because of a lack of research that correlates early season mealybug density to damage at harvest. Nevertheless, data from this project can be used as a general reference point: during this study branches in 2005 and 2006 there was approximately a 100- to 250-fold increase in mealybug densities from samples collected in May to those collected at harvest-time. Obviously, these data are with untreated populations, but suggest that far less than one mealybug per branch in May can lead to damaging populations at harvest-time if not treated. For this reason, CA pistachio growers have widely adopted a program that includes monitoring two or three times in late-May to early June to find mealybug populations and, when discovered, treating the entire block with an insecticide. Chemical control programs are likely to continue to be the backbone of *F. gilli* IPM programs in pistachio until more sustainable approaches, particularly with biological control, can be developed and implemented.

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