SUMMARY OF ALMOND RESEARCH 2005

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Biology of the *Ferrisia gilli* mealybug: potential for biological controls

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Summary

A new insect pest has shown up in California's pistachio and almond orchards – a mealybug named Ferrisia gilli. Mealybugs damage crops by secreting honeydew, which promotes sooty mold growth, contaminating the fruit or nuts, and vectoring plant pathogens. This insect pest is currently isolated to a relatively small portion of the pistachio acreage, and is primarily located in Madera and Kings County. Insecticides will be the first option and one of us (D.R. Haviland) has conducted research investigating insecticide controls and crop damage. While guidelines for insecticide use are developed, the pistachio, grape and almond industries are exploring the option of biological controls. Here, we describe initial investigations towards the development of a biological control program for the gilli mealybug, focusing on parasitoid species rather than predators, as parasitoids most commonly provide effective mealybug control.

We surveyed pistachio and almond sites infested with the gilli mealybug. At all but one almond site, the mealybug populations were depleted by early summer, either by effective insecticide applications or by natural enemies. We did not rear any parasitoids out of the pistachio orchards sampled (all received insecticides for either bugs, worms, or both). In an untreated almond block, five parasitoid species were reared. These are the Pseudaphycus sp. nr. meritorius, Chrysoplatycerus sp. nr. splendens, Anagyrus pseudococci, Allotropa sp., and a "hyperparasitoid" (Chartocerus sp.). Of these, the Pseudaphycus was the most common, and was most responsible for the dramatic reduction of gilli mealybug in the almond orchard sampled.

We also conducted a literature search to determine if other parasitoid species might be available for importation. Because the "gilli" mealybug is a newly described species, there are no references to natural enemies attacking this mealybug. However, the closely related "striped" mealybug is a worldwide pest and there are >40 described parasitoids listed. The literature suggests that worldwide efforts against the "striped mealybug" have used a number of common and relatively polyphagous (attacking a number of different mealybug species) natural enemies, such as Leptomastix dactylopii and Anagyrus pseudococci.

Work on the mealybug biology was initially delayed because the gilli mealybug is not officially resident in Fresno County. We now have set up a colony of the gilli mealybug at the UC Berkeley quarantine, where the work on both mealybug and parasitoid biology has begun. Work on the parasites has just begun, and we have established colonies of Pseudaphycus sp. nr. meritorious, Anagyrus pseudococci, Leptomastix dactylopii, and Leptomastidea abnormis, either

on the gilli mealybug or the vine mealybug. Studies of the biology of Anagyrus pseudococci have been conducted, using the vine mealybug as a host. Results show that this species prefers to attack the older, larger mealybug stages. We believe that the numbers of this parasitoid are low because of a long overwintering period. – or mealybugs later in the their development

There is great potential for the biological control of the gilli mealybug. In 2006, we will screen different insecticides against the common gilli mealybug parasitoids to determine what combinations of materials or application timing can be used to control the targeted pistachio pests, without disrupting gilli mealybug biological controls. We also plan to continue survey work to document resident parasitoid species composition and effectiveness and to study the mealybug and parasitoid biologies to determine how growers can manipulate parasitoid (or mealybug) densities to improve biological controls.

Introduction

During the past few years a new insect pest has increased in importance in California pistachio and almond orchards – a mealybug named Ferrisia gilli. Mealybugs damage crops by secreting honeydew, which promotes sooty mold growth, contaminating the fruit or nuts, and vectoring plant pathogens (Golino et al. 1999, Geiger and Daane 2001, Gullan et al. 2003). We propose to determine the potential for a biological control program through studies that survey natural enemies in California, detail pest and natural enemy biologies, and import new natural enemies (if needed and available).

Background. A recent taxonomic description of Ferrisia gilli as a "newly named insect" was combined with a field study of its biology on Central Valley pistachios (Gullan et al. 2003). When this mealybug was initially found infesting pistachios (and other crops), it was considered to be the more common "striped" mealybug (F. virgata) or a close relative (F. malvastra). Using the best available taxonomic key, mealybugs collected on pistachio were identified as F. malvastra, but there were differences in adult morphology and its biological importance that prompted Gullan et al. (2003) to complete morphological and molecular studies that led to the new name (F. gilli is named after Ray Gill at CDFA, hereafter refer to as the "gilli" mealybug).

To properly identify this mealybug as a new species, Gullan et al. (2003) collected gilli mealybugs from a range of host plants in Alabama, California, Georgia, and Louisiana. The Ferrisia genus is probably of New World origin, and Gullan et al. (2003) suggest that the gilli mealybug may be native to the southeastern United States. While both F. malvastra and F. virgata (which is what the gilli mealybug was probably called) have become economic pests around the world, their pest status in California agriculture crops was never great. We suggest that the relatively sudden increase in the damage caused by the gilli mealybug may reflect its relatively new arrival on pistachio, almonds and grapes. Therefore, because this pest may be from the southeast USA and is not known as a major pest of agricultural crops in that region, then effective biological control agents may be present and easily available for importation.

***Immediate Action*.** The pistachio industry will need immediate control solutions while a biological control / sustainable program is being developed. Insecticides will be the first option and David Haviland (Farm Advisor, Kern County) has conducted research investigating insecticide controls and crop damage. As stated in last year's proposals, "*Insecticides will be found that can provide immediate relief. For example, in collaboration with Walt Bentley (Area wide Entomologist), we have developed insecticide programs for the vine mealybug. It is likely that some of the same materials will work well against the gilli mealybug – insect growth regulators (e.g., Applaud) are good contact insecticides that may work best*…." From David Haviland's studies, this has certainly shown to be true and this readily available control tool will reduce any potential damaging from gilli mealybug population.

Nevertheless, we believe that the pistachio, grape and almond industries should continue to explore the option of biological controls – especially as this mealybug may be native to the United States, which will make importation and release of any natural enemies more easily (bureaucratically) processed. In 2005, we began the investigation of a biological control the gilli mealybug, focusing on parasitoid species rather than predators, as parasitoids most commonly provide effective mealybug control. Our objectives (2005) were to:

1. Survey the gilli mealybug on pistachio and other host plants for natural enemies.
2. Conduct a literature search to summarize (and not repeat) previous work.
3. Import (out side of California) parasitoids of the gilli mealybug to screen in quarantine.
4. Study gilli mealybug and parasitoid biology that might impact biological control options.

Procedures

Survey for natural enemies. Three pistachio blocks, two almond blocks and a persimmon block were sampled – all located in the Central Valley. At each site, infested plant sections (leaves, twigs, fruit or nuts) were collected, taken to the laboratory, and placed in parasitoid emergence cages. Adult parasitoids that emerged were identified to genus or species, with help from Dr. Serguei Triapitsyn (Entomologist, UC, Riverside). We also report on the identification of parasitoids reared from the gilli mealybug, collected on grapes in El Dorado County and submitted to Dr. Triapitsyn by one of us (Dr. Godfrey).

Literature search. We conducted a literature search to summarize the worldwide efforts for control of the striped mealybug – the closest relative of the gilli mealybug. This was necessary as the gilli mealybug was so recently named that there is no little information on its natural enemies. Three data bases were used (BIOS, AGRICOLA, WEB OF SCIENCE, CAB ABSTRACTS). Key words were "Ferrisia," "virigata," "malvastra," "striped mealybug," "meracus," "meritorius," "advena," and "insularis." An additional catalog of natural enemies was completed using information provided in Noyes and Hyatt (1994) and Kromblein et al. (1978).

Import natural enemies. Parasitoids have been brought to the UC Berkeley Insectary and Quarantine for the biological control of the vine mealybug (Planococcus ficus). Material includes Anagyrus pseudococci from Italy and Coccophagoides peregrinis from South Africa, which will be screened for efficacy against the gilli mealybug. Both parasitoid species can be released into the Central Valley as "biotypes" of these species are already present in California.

Conduct studies on mealybug and parasitoid biologies. Colonies of the gilli mealybug and parasitoids (Pseudaphycus meritorious, Anagyrus pseudococci, and Coccophagoides peregrinis have been established. Studies will begin in 2006.

Previously, working with the vine mealybug, we sought to determine if temperature plays a role in A. pseudococci overwintering and spring emergence patterns. We placed newly parasitized mealybugs at ambient temperatures from late fall through spring. For each inoculation date tested, sprouting potatoes were inoculated with ~100 mealybugs (third instar to pre-ovipositional stages) and then placed in a plastic container with an organdy-screened lid for ventilation. After 1 day, the mealybugs were exposed to A. pseudococci for a 24 hour oviposition period. Six containers were prepared on each inoculation date, with three containers randomly selected to remain in the Kearney Agricultural Center insectary (control treatment) and three placed outside the insectary at ambient air temperatures (the containers were sheltered from direct sunlight, rain and wind). The mealybugs were checked weekly until there were outward signs of parasitism, thereafter, the containers were checked daily and all adult parasitoids found were collected and their gender determined. The experiment was repeated each month with inoculations dates on 18 October, 15 November, 12 December, 23 January, 28 February, and 15 March.

Results and Discussion

Survey gilli mealybug populations. We surveyed pistachio and almond sites infested with the gilli mealybug. At all but one almond site, the mealybug populations were depleted by early summer, either by effective insecticide applications or by natural enemies. We did not rear any parasitoids out of the pistachio orchards sampled, which were treated with insecticides for either (or both) bugs and worms. At the one almond site, which was not treated with insecticides in the spring/summer, only a few trees were infested with the gilli mealybug. In that almond block, circumstantial evidence of “mummified” mealybug skins – left after a parasitoid has emerged – suggested there was very high level of parasitism throughout the summer period. Five parasitoid species were reared. These are the Pseudaphycus sp. nr. meritorius, Chrysoplatycerus sp. nr. splendens, Anagyrus pseudococci, Allotropa sp. and a “hyperparasitoid" (Chartocerus sp.). Of these, the Pseudaphycus was the most common, and was most responsible for the dramatic reduction of gilli mealybug in the almond orchard sampled.

Identification of parasitoids. There is some question on the identification of the Pseudaphycus species. Samples of Pseudaphycus were first sent from Kris Godfrey to Serquei Triapitsyn, with material reared from gilli mealybug collected on wine grapes in El Dorado County. Dr. Triapitsyn’s initial identification was not definite, and his correspondence (14 January 2005) with Kris Godfrey is as follows, “The parasitoid of F. gilli from Alabama is Pseudaphycus meritorius Gahan, 1946. This species was originally described from Virginia from Ferrisia virgata; was recorded also from MD (Maryland). Our collection also has specimens of supposedly the same species, reared from F. virgata in Florida, but I cannot confirm they are really P. meritorius because the condition of the specimens is very poor. Anyway, P. meritorius appears to be an eastern US species associated with Ferrisia spp.” A second set of parasitoid samples, collected by David Haviland with material reared from gilli mealybug on almonds in Kings County was then sent to Triapitsyn. His correspondence (10 November 2005) to David Haviland is as follows, “I finished the identifications of your material from F. gilli...

Pseudaphycus meracus Gahan or a species near it. It is clearly the same species as a female from Camino, El Dorado Co., CA sent to me previously by Kris. Because the description of P. meracus (from the Eastern US) is very bad and has no illustrations, any further identification of this species is practically impossible; the entire group was revised long ago by Gahan very poorly, without good slides.... The signiphorid .... is a Chartocerus sp. (known hyperparasitoids). Its further identification to the species is impossible. Finally, as I wrote to you earlier, the primary parasitoid (from vial 4) is a male of Chrysoplatycerus sp.

Since Dr. Triapitsyn's identifications, we have collected two other species, as mentioned above. Anagyrus pseudococci and an Allotropa sp. Both species were collected late in the season (September) and probably moved into the almond block. Both of these species have been reared from vine mealybug. We note that information presented in the literature implies that the Pseudaphycus species released in California may against the striped mealybug may be Pseudaphycus debachi (DeBach and Warner 1969, Rosen 1981).

Literature search. Because the "gilli" mealybug is a newly described species, there are no references to natural enemies attacking this mealybug. However, the closely related "striped" mealybug is a worldwide pest and we used the literature base on this species to catalog pest status and past control efforts, Certainly, some of the literature is actually based on the gilli mealybug, that would have been lumped in with the striped mealybug until Gullan et al. (2003).

There were >400 citations on the striped mealybug, its control or its natural enemies. From these, about 100 articles provided useful information, while others dealt with mealybug taxonomy, its use in laboratory studies, or it relationship with other mealybugs, especially the cassava mealybug. The mealybug's pest status rose dramatically in worldwide importance as a novel pest of crops in Africa (such as cassava) and India (such as guava and coffee). While suspected to be native to North America, and probably to the Southeastern USA, the striped mealybug now has a worldwide distribution. It is recorded as a pest status in practically all tropical and subtropical regions, and an incomplete list includes South Africa (Walton and Pringle 2004, Wakgari and Giliomee 2005), Sierra-Leone (James and Fofanah 1992), Israel (Ben-Dov 1978), Yemen (Marotta et al. 2001), India (Mani and Krishnamoorthy 1990a,b), Australia (Bellis et al. 2002), South Pacific islands (Bellis et al. 2004), Ghana (Campbell 1983), Southeast Asia (Thirasack 2001), the Philippines (Lit et al. 1998), Cuba (Angeles-Martinez 2001), Mexico (DeBach and Warner 1969), and Argentina (Trjapitzin and Tjapitzin 1999).

While the mealybug can be a direct pest of the crop, as it is on pistachios and almonds, it has received considerable attention as a vector of viral pathogens, such as the badnavirus of black pepper (Bhat et al. 2003, Govindan et al. 2003) and swollen shoot of cocoa (Bigger 1981). This is similar to the pest status of some of the grape infesting mealybug species that can vector closteroviruses (Golino et al. 1989).

There are a number of insecticide materials that have been tested for striped mealybug control, most are organophosphates (Price 1979, Litsinger and Apostol 1994, Prasad-Kumar et al. 1998, Baskaran et al. 1999) or permethrins (Price 1979), but the lists include some novel products such as Rimon (Novaluron 10 EC) (Paul and Ghosh 2004), botanicals such as neem and oil (Saminathan and Jayaraj 2001) and pathogens such as Verticillium lecanii (Kulkarni et al. 2003).

Some researchers have shown common insecticides, especially organophosphates, kill natural enemies of the striped mealybug, including the important parasitoids Aenasius advena and Blepyrus insularis in India (Mani 1992), thereby reducing biological controls. We suspect the same type of disruption occurred in the pistachio orchards sampled in 2005 and, for this reason, we will look at the impact of common insecticides on gilli mealybug in the 2006 season.

On many crops and in many countries, natural enemies have been reported controlling striped mealybug populations. Insect predators were often listed as present in infested fields and sometimes were considered to be quite important in mealybug suppression. The predator species listed most often included lacewings and lady beetles (Rawat and Modi 1969, Lapis 1970, Kiyindou et al. 1990, Mani and Krishnamoorthy 1990a,b, Padmaja et al. 1995, Rahiman and Vijayalakshmi 1998).

Parasitoids were less commonly reported in field surveys, but when present were more often credited with striped mealybug control. The parasitoid species most often cited as providing mealybug suppression in Africa and India include Blepyrus insularis (Mani and Krishnamoorthy 1990, Balakrrishnan et al. 1991) and Aenasius advena (Rawat and Modi 1968, Pillai and Gopi 1990). Strangely, these parasitoid species have not been found in our surveys, and may be potential candidates for importation. Another species, Anagyrus kamali, is often mentioned on websites as an important parasitoid species. Still, work in the North and Central America, where the mealybug may have originated and where we expect to find the effective parasitoid species, provides a different list of parasitoid species.

We note that when classical biological control programs were initiated in Africa and India (references from the 1950-60s are not provided) many of the imported parasitoids *came from California*! First, this material (in California) was initially from other regions. Second, the parasitoids species were parasitoids of the citrus or Comstock mealybug biological control efforts in California. Third, the species were some of the more polyphagous (attacking many different mealybugs) species, and included the well-known Anagyrus pseudococci, Leptomastix dactylopii, and Leptomastidea abnormis. We suspect that at the time of these importations, little was known about the striped mealybug parasitoid complex, or the origins of the striped mealybug. Not until the large and enormously successful cassava mealybug biological control program in Africa was there a clear understanding of the striped mealybug natural enemy complex – which was studied as a minor cassava pest and as a host mealybug for some of the parasitoid species attacking the cassava mealybug (Pijls and vanAlphen 1996, Dorn et al. 2001).

Gahan (1946) was the first taxonomist to detail a few of the parasitoids specific to the striped mealybug in North America, providing descriptions of Pseudaphycus meritorius and Pseudaphycus meracus (although these species remain difficult to separate). Kerrich (1953) and Highland (1956) provide some of the first descriptions of natural enemy impact on the striped mealybug in North and South America. They list Zarhopalus inquisitor, Pseudaphycus meritorius, and Apoanagyrus trinidadensis as important striped mealybug natural enemies.

Of most importance for this work was the initial biological control program against the striped mealybug, by DeBach and Warner (1969). We briefly summarize their finds. The striped mealybug was first recorded in California in 1963 as a pest on ornamental plants in the Imperial

County. A survey of natural enemies found many predators (the same predator groups found in David Haviland's survey and elsewhere) were present but did not provide adequate control. The striped mealybug was considered t be native to Mexico or southeastern USA and surveys were undertaken to find and import natural enemies. Surveys in Mexico found the pest to be under "excellent natural control" and the following parasitoid species were imported and released.

Imported / Released	Imported / Not Released
Acerophagus texanus	Anagyrus sp. #2
Aenasius advena	Apoanagyrus trinidadensis
Anagyrus sp. #1	Leptomastidea abnormis
Blepyrus insularis	Leptomastidea sp. #2
Leptanusia pseudoccoi	
Pseudaphycus sp. #1	

Of these parasitoids, only Acerophagus texanus was listed as being established in California; however, there have been no follow-up studies. The Pseudaphycus species was later described as Pseudaphycus debachi (Rosen 1981). We note that Pseudaphycus debachi and Pseudaphycus angelicus are closely related and the later is a common parasitoid species of the grape mealybug and is present in the Central Valley (Geiger and Daane 2001). Similarly, Acerophagus texanus is closely related to another grape mealybug parasitoid, Acerophagus notativentris, which is also common in the Central Valley (Geiger and Daane 2001).

We conclude that, if needed, parasitoids can be imported. However, the literature clearly suggests that parasitoids resident in the southeastern United States and, perhaps, here in California, may be the most effective natural enemies of the striped mealybug, and we assume of the gilli mealybug as well. The more important mealybug parasitoid species can be easily reared, as suggested by insectary production of the striped mealybug and its natural enemies, such as Blepyrus insularis (Gautam and Kataria 1986, Mani and Krishnamoorthy 1991). We suggest that work in 2006 should focus on studies that determine what factors impede natural enemies already present in California, before any studies are undertaken on the relatively expensive and time-consuming importation and quarantine process for exotic natural enemy species.

Gilli mealybug and parasitoid biology studies. Work on the mealybug biology was initially delayed because the gilli mealybug is not officially resident in Fresno County. For this reason, we have set up a colony of this mealybug and some parasitoid species at the UC Berkeley quarantine, where the work on both mealybug and parasitoid biology has begun.

We provide part of work completed on one of the less common parasitoid species recovered, Anagyrus pseudococci, to explain why this species was found late in the season (Daane et al. 2004, funding provided by the grape commodities). Under ambient winter temperatures, emergence of adult A. pseudococci in the spring was relatively well-synchronized, regardless of when (October through March) vine mealybugs were exposed to A. pseudococci (Fig. 1). These results suggest that cues other than a simple accumulation of warm days in spring are required to stimulate development and emergence of overwintered A. pseudococci. We believe temperature relationships may be an important component of A. pseudococci effectiveness in California's San Joaquin Valley, and cause a delay in its emergence from its winter resting period. This is important for the gilli mealybug as A. pseudococci may not build to numbers that can control the mealybug until the second (July-August) gilli mealybug generation, after insecticide treatment decisions have already been made.

Conclusions and Practical Applications.

Summary. There is great potential for the biological control of the gilli mealybug. Results from the survey suggest that many resident parasitoids (and predators – see David Haviland's report) are already present in California pistachio and almond orchards. The level of parasitism varied greatly among surveyed fields, and we suspect that insecticides used to target hemipteran pests early in the growing season may have reduced or eliminated resident parasitoids in the surveyed pistachio orchards. We also completed a literature search and found that there are, worldwide, many parasitoid species that attack the striped mealybug and that could be imported to help suppress the gilli mealybug. Before we release any exotic parasitoid species, we intend to first test parasitoid species resident in California or newly imported for the vine mealybug as possible biological control agents.

Future Plans. We have completed the literature search. We plan to continue survey work to document resident parasitoid species composition and effectiveness. Studies on the mealybug and parasitoid biologies will also be conducted to determine how growers can manipulate parasitoid (or mealybug) densities to improve biological controls and reduce the need for insecticides directed at the gilli mealybug. We have also added an insecticide trial to the objectives. We believe that this work is important to determine what insecticide products, commonly used in pistachio and almond, can be used for other pest species (e.g., bug and worm pests) without disrupting the apparent (e.g., the one almond site) excellent biological control supported by resident natural enemies (Walton and Pringle 1999). We note that no changes in products may be needed, just a change in spray schedules during the season.

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References

Angeles-Martinez, M. 2001. New hosts of Ferrisia virgata (Cokerell) Homoptera: Pseudococcidae in Cuba. Revista de Proteccion Vegetal 16(1): 68.

Balakrrishnan, M., M. Sreedharan, K. Venkatesha, K. Bhat, and P. Krishnamoorthy. 1991. Observations on Ferrisia virgata (Ckll.) (Homoptera: Pseudococcidae) and its natural enemies on coffee, with new records of predators and host plants. J. Coffee Res. 21(1): 11-19.

Baskaran, R.K.M., L.G. Lakshmi, and S. Uthamasamy. 1999. Coccids and their management in guava intercropped with coconut. Pest Management in Hort. Ecosystems 5(1): 28 31.

Beardsley, J.W. 1976. A synopsis of the Encrytidae of the Hawaiian Islands with keys to genera and species (Hymenoptera, Chalcidoidea). Proc. Hawaiian Entomol. Soc. 22: 181-228.

Bellis, G.A., J.F. Donaldson, M. Carver, D.L. Hancock, and M.J. Fletcher. 2004. Records of insect pests on Christmas Island and the Cocos (Keeling) Islands, Indian Ocean. Australian Entomol. 31(3): 93-102.

Bellis, G.A.; J.F. Donaldson, M. Carvers, D.L. Hancock, and M.J. Fletcher. 2002. Records of insect pests on Christmas Island and the Cocos (Keeling) Islands, Indian Ocean. Australian Entomol. 31(3): 93-102.

Ben-Dov, Y. 1978. The striped mealybug (*Ferrista virgata*), a potential pest new to Israel. Hassadeh 58(6): 1199-1200.

Bennett, F.D. 1955. Encyrtidae from Trinidad BWI 1. Three species of *Pseudaphycus* reared from mealybugs. Can. Entomol. 87: 413-416.

Bennett, F.D. 1957. Trinidad Encrytdae II. Some additional mealybug parasites. Can. Entomol. 89: 569-572.

Bhat, A.I., S. Devasahayam, Y.R. Sarma, and R.P. Pant. 2003. Association of a badnavirus in black pepper (*Piper nigrum* L.) transmitted by mealybug (*Ferrisia virgata*) in India. Current Science 84(12): 1547-1550.

Bigger, M. 1981. The relative abundance of the mealybug vectors (Hemiptera: Homoptera: Coccidae and Pseudococcidae) of cocoa swollen shoot disease in Ghana. Bull. Entomol. Res. 71 (3): 435-448.

Burks, B.D. 1952. A new mealybug parasite (Hymenoptera: Encyrtidae). J. New York Entomol. Soc. 60: 172-182.

Campbell, C.A.M. 1983. The assessment of mealybugs Pseudococcidae and other Homptera on mature Cocoa trees in Ghana. Bull. Entomol. Res. 73(1): 137-152.

Castillo, L. J.A., and A.C. Bellotti. 1990. Diagnostic characters of four mealybug species (Pseudococcidae) in cassava crops (*Manihot esculenta*) and observations on some of their natural enemies. Revista Colombiana de Entomologia. 16(2): 33-43.

Compere, H., and G. Zinna. 1955. Tre nuovi generi e cinque nuove especie di Encrytidae. Bol del Lab di Entomol Agricul Filippo Silvestri 14: 94-116.

Compere H. 1938. A report on some miscellaneous African Encrytidae in the British Museum. Bull Entomol Res 29:315-337.

Daane, K.M., R. Malakar-Kuenen, and V.M. Walton. 2004. Temperature development of *Anagyrus pseudococci* (Hymenoptera: Encyrtidae) as a parasitoid of the vine mealybug, *Planococcus ficus* (Homoptera: Pseudococcidae). Biol. Contr. 31: 123-132.

Daane, K.M., W.J. Bentley, V.M. Walton, R. Malakar-Kuenen, G.Y. Yokota, J.G. Millar, C.A. Ingels, E.A. Weber, and C. Gispert. 2006. Sustainable controls sought for the invasive vine mealybug. Calif. Agricul. 60: 31-38.

DeBach, P., and S.C. Warner. 1969. Importation and colonization of natural enemies of the striped mealybug, *Ferresia virgata* (Homoptera: Homoptera: Pseudococcidae) in California. Ann. Entomol. Soc. Am. 62: 1117-1119.

Dorn, B., L. Mattiacci, A.C. Bellotti, and S. Dorn. 2001. Host specificity and comparative foraging behaviour of *Aenasius vexans* and *Acerophagus coccois*, two endo-parasitoids of the cassava mealybug Entomol. Exp. Appl. 99 (3): 331-339.

Dozier, H.L. 1937. Descriptions of miscellaneous chalcidoid parastioids from Puerto Rico (Hymenoptera). J. Agricul. Univ. Puerto Rico 21: 121-135.

Gahan, A.B. 1920. New reared parasitic Hymenoptera from the Philippines. Philippine J. Sci. 17: 343-351.

Gahan, A.B. 1946. Eight new species of chalcid-flies of the genus *Pseudaphycus* Clausen, with a key to species. Proc. U.S. Nat. Mus. 92: 41-51.

Gautam, R,D, and B,S, Kataria. 1986. Feasibility of mass-multiplication of white tailed mealybug, Ferrisia virigata (Cockerell) (Pseudococcidae: Homoptera), its parasitoid-predator complex together with bibliography. J. Entomol. Res. 10(1): 1-8.

Geiger, C.A., and K.M. Daane. 2001. Seasonal movement and sampling of the grape mealybug, Pseudococcus maritimus (Ehrhorn) (Homoptera: Pseudococcidae), in San Joaquin Valley vineyards. J. Econ. Entomol. 94: 291-301.

Golino, D.A., S. Sim, R. Rill, A. Rowhani. 1999. Four species of California mealybugs can transmit leafroll disease. Am. J. Enol. Viticul. 50: 367-368.

Govindan, M., M. Joy, and K.M. Sreekumar. 2003. Viral diseases of black pepper and their management. Indian J. Arecanut, Spices and Medicinal Plants 5(3): 96-102

Gullan, P.J., D.A. Downie, and S.A. Steffan. 2003. A new pest species of the mealybug genus Ferrisia Fullaway (Hemiptera: Pseudococcidae) from the United States. Ann. Entomol. Soc. Am. 96: 723-737.

Highland, H.A. 1956. The biology of Ferrisiana virgata, a pest of Azaleas. J. Econ. Entomol. 49(2): 276-277.

James, B.D., and M. Fofanah. 1992. Population growth patterns for Phenococcus manihoti Mat-Ferr on cassava in Sierra-Leone. Tropical Pest Management. 38(1): 89-92.

Kerrich, G.J. 1953. Report on Encyrtidae associated with mealybugs on cacoa in Trinidad, and some other species related thereto. Bull. Entomol. Res. 44: 789-810.

Kerrich, G.J. 1967. On the classification of the Anagyrine Encyrtidae, with a revision of some of the genera (Hymenoptera: Chalcidoidea). Bull. British Mus. (Nat. Hist.) 20: 143-250.

Kerrich, G.J. 1978. A revision of the dinocarsiine Encrytidae with a study of the genus Pelmatencyrtus DeSantis (Hymenoptera: Chalcidoidea). Zoo. J. Linnean Soc. 62: 109-159.

Kiyindou, A., B. Leru, and G. Fabres. 1990. The numerical response of two coccinellids preying on the cassava mealybug to changes in the nature and abundance of the prey. Entomophaga 35(4): 611-620.

Kulkarni, R., J.R. Kadam, and U.N. Mote. 2003. Efficacy of Verticillium lecanii against mealy bugs on pomegranate. J. Appl. Zool. Res. 14(1): 59-60.

Lapis, E.B. 1970. The biology of the grey mealybug, Ferrisia virgata (Cockerell) (Pseudococcidae, Homoptera). Philippine Entomol. 1(5): 397-405.

Lit, I.L., M. Caasi-Lit, and V.J. Calilung. 1998. The mealybugs (Pseudococcidae, Coccoidea, Hemiptera) of eggplant (Solanum melongena Linn.) in the Philippines. Philippine Entomol. 12(1): 29-41.

Litsinger, J.A., and R.F. Apostol. 1994. Control of foliar insect pests on eggplant with systemic granular insecticides. Philippine Entomol. 9(3): 286-301.

Mani, M. 1992. Contact toxicity of different pesticides to the encyrtid parasitoids, Aenasius adevena and Blepyrus insularis of the striped mealybug Ferrisia virgata. Tropical Pest Management 38 (4): 386-390.

Mani, M., and A. Krishnamoorthy. 1990a. Natural suppression of mealybugs in guava orchards. Entomon 15(3-4): 245-247.

Mani, M., and A. Krishnamoorthy. 1990b. The impact of the predator Cryptolaemus montrouzieri Mulsant, on pesticide-resistant populations of the striped mealybug, Ferrisia virgata (Ckll.) on guava in India. Insect Sci. Appl. 11 (2): 167-170.

Mani, M., and A. Krishnamoorthy. 1991. Breeding of Blepyrus insularis (Hym., Encyrtidae) on Ferrisia virgata (Hemip., Pseudococcidae). Entomon 16(4): 275-277.

Marotta, S., A. Harten van, M.A. Mahyoub, and G. Pellizzari. 2001. Mealybugs found on agricultural crops in Yemen. Bollettino di Zoologia Agraria e di Bachicoltura. 33(3): 233-238.

Noyes, J.S., and M. Hayat. 1994. Oriental mealybug parasitoids of the Anagyrini (Hymenoptera: Encyrtidae). University Press. Cambridge UK.

Padmaja, C., T. Babu, R. Ramesh; D.D.R Reddy, and M. Sriramulu. 1995. Biology and predation potential of Scymnus coccivora Aiyar (Coleoptera: Coccinellidae) on mealybugs. J. Entomol. Res. (New Delhi) 19(1): 79-81.

Paul, S., and A.B. Ghosh. 2004. Effect of Novaluron 10EC against Planococcus minor (Maskell), Ferrisia virgata (Cockerell) (Pseudococcidae) and Icerya aegyptiaca (Douglas) (Margarodidae). Environ. Ecol. 22(4): 729-732

Pijls, J.W.A.M., and J.M. vanAlphen. 1996. On the coexistence of the cassava mealybug parasitoids Apoanagyrus diversicornis and A. lopezi (Hymenoptera: Encyrtidae) in their native South America. Bull. Entomol. Res. 86 (1): 51-59.

Pillai, S.R.M., and K.C. Gopi. 1990. Epidemic outbreak of mealy bug Ferrisiana virgata (Cockerell) (Pseudococcidae: Homoptera) in su babul (Leucaena leucocephala (Lam.) de Wit) plantations. Indian Forester 116(10): 822 824.

Prasad Kumar, B.N., N.K. Divakar, B.S. Hegde, and B.S. Ganigara. 1998. Nature of damage and efficacy of insecticides against mealybug, Ferrisia virgata (Ckll.) on black pepper cuttings. Pest Management Hort. Ecosystems. 4(1): 52-53.

Price, J.F. 1979. Control of mealybugs on caladiums. Proc. Florida State Hort. Soc. 92: 358-360.

Prinsloo, G.L., and D.P. Annecke. 1979. A key to the genera of Encyrtiade from the Ethiopian region, with descriptions of three new genera (Hymenoptera: Chalcidoidea). J Entomol. Soc. Southern Africa 42: 349-382.

Rahiman, P.A., and C.K. Vijayalakshmi. 1998. Spalgius epius Westwood (Lepidoptera: Lycaenidae): A potential predator of coffee mealy bugs. J. Entomol. Res. 22(2): 191 192.

Rawat, R.R, and B.N. Modi. 1968. A record of natural enemies of Ferrisia virgata Ckll. in Madhya Pradesh (India). Mysore J. Agric. Sci. 2(1): 51-53.

Rawat, R.R, and B.N. Modi. 1969. Studies on Nephus regularis (Coleoptera: Coccinellidae) as a predator of the striped mealybug in Madhya Pradesh India. Ann. Entomol. Soc. Am. 62(5): 953-956.

Risbec, J. 1951. Les Chalcidodes de l'Afrique occidentale françasie. Memmoires de l'Institute Francaise d'Afrique Noire 13: 7-409.

Rosen, D. 1969. A systematic study of the genus Acerophagus F. Smith with descriptions of new species (Hym., Encrytidae). Hilgardia 40: 41-72.

Rosen, D. 1981. Pseudaphycus debachi new species (Hymenoptera: Encyrtidae) with notes on the Pseudaphycus angelicus group. Entomophaga 26 (3) : 251 264.

Rosen, D. 1981. Redescription of Anusioptera aureocincta Brues (Hym.: Encyrtidae), a parasite of the striped mealybug. Boll de Lab Entomol Agraria Filippo Silvestri 38: 53-59.

Saminathan, V.R., and S. Jayaraj. 2001. Evaluation of botanical pesticides against the mealybug, Ferrisia virgata Cockrell (Homoptera: Pseudococcidae) on cotton. Madras Agricul. J. 88(7/9): 535-537.

Thirasack, S. 2001. Cotton seed treatment in Lao PDR. Kasetsart J. Natural Sci. 35(4): 416-426.

Trjapitzin, S.V., and V.A. Tjapitzin. 1999. Parasites of the mealybugs on cultivated grapes in Argentina, with description of a new species of the genus Aenasius Walker (Hymenoptera, Encyrtidae). Entomologicheskoe Obozrenie 78(1): 174-180.

Wakgari, W.M., and J.H. Giliomee. 2005. Description of adult and immature females of six mealybug species (Hemiptera: Pseudococcidae) found on citrus in South Africa. African Entomol. 13(2): 281-332.

Walton, V.M., and K. L. Pringle. 2004. A survey of mealybugs and associated natural enemies in vineyards in the Western Cape Province, South Africa. S. Afr. J. Enol. Viticul. 25(1): 23-25.

Table 1. An incomplete list of parasitoid species reported attacking the striped mealybug

Genus	species	Country/Region	Reference (often one of many)
Acerophagus	luteolus	Trinidad	Rosen 1969
	notativentris	USA	Rosen 1969
	texanus	USA / Mexico	Beardsley 1976
	myrmicoides	Trinidad / Mexico	Kerrich 1978
Aenasius	advena	Worldwide	Prinsloo & Annecke 1979
	frontalis	Trinidad	Bennett 1957
	hyettus	Trinidad	Bennett 1957
	personatus	Trinidad	Kerrich 1967
	regularis	Trinidad	Kerrich 1967
Anagyrus	agraensis	Asia	Noyes & Hayat 1994
	ananatis	South America	Noyes & Hayat 1994
	brevicornis	India	Noyes & Hayat 1994
	coccidivorus	Haiti	Noyes & Hayat 1994
	dactylopii	India	Noyes & Hayat 1994
	indicus	India	Noyes & Hayat 1994
	kamali	India	Noyes & Hayat 1994
	kivuensis	India	Noyes & Hayat 1994
	mirzai	India	Noyes & Hayat 1994
	qadrii	India	Noyes & Hayat 1994
	subproximus	Africa	Risbec 1951
Anathrix	argyrus	USA	Burks 1952
Anusioptera	aureocincta	Mexico	Rosen 1981
Apoanagyrus	trinidadensis	Trinidad	Kerrich 1953
Blepyrus	insularis	Worldwide	Noyes & Hayat 1994
Bothriocraera	bicolor	Trinidad	Compere & Zinna 1955
Chrysoplatycerus	splendens	Worldwide	Gautam & Kataria 1986
Gyranusoidea	citrinia	Kenya	Compere 1938
	dispar	Trinidad	Kerrich 1953
	bahiensis	Caribbean	Noyes & Hayat 1994
	pseudococci	Mexico	DeBach and Warner 1969
Holanusomyia	pulchripennis	Philippines	Noyes & Hayat 1994
Leptomastidea	abnormis	Worldwide	Gahan 1920
	antillicola	Puerto Rico	Dozier 1937
Leptomastix	dactylopii	Africa	Noyes & Hayat 1994
	trilongifasciata	Indonesia	Noyes & Hayat 1994
	tsukumiensis	Philippines	Noyes & Hayat 1994
Pseudaphycus	debachi	Mexico	Rosen 1981
	ferrisianae	Africa	Bennett 1955
	meracus	USA	Gahan 1946
	meritorius	USA	Gahan 1946
Yasumatsuiloa	orientalis	Indonesia	Noyes & Hayat 1994
Zarhopalus	inquisitor	USA	Kerrich 1978

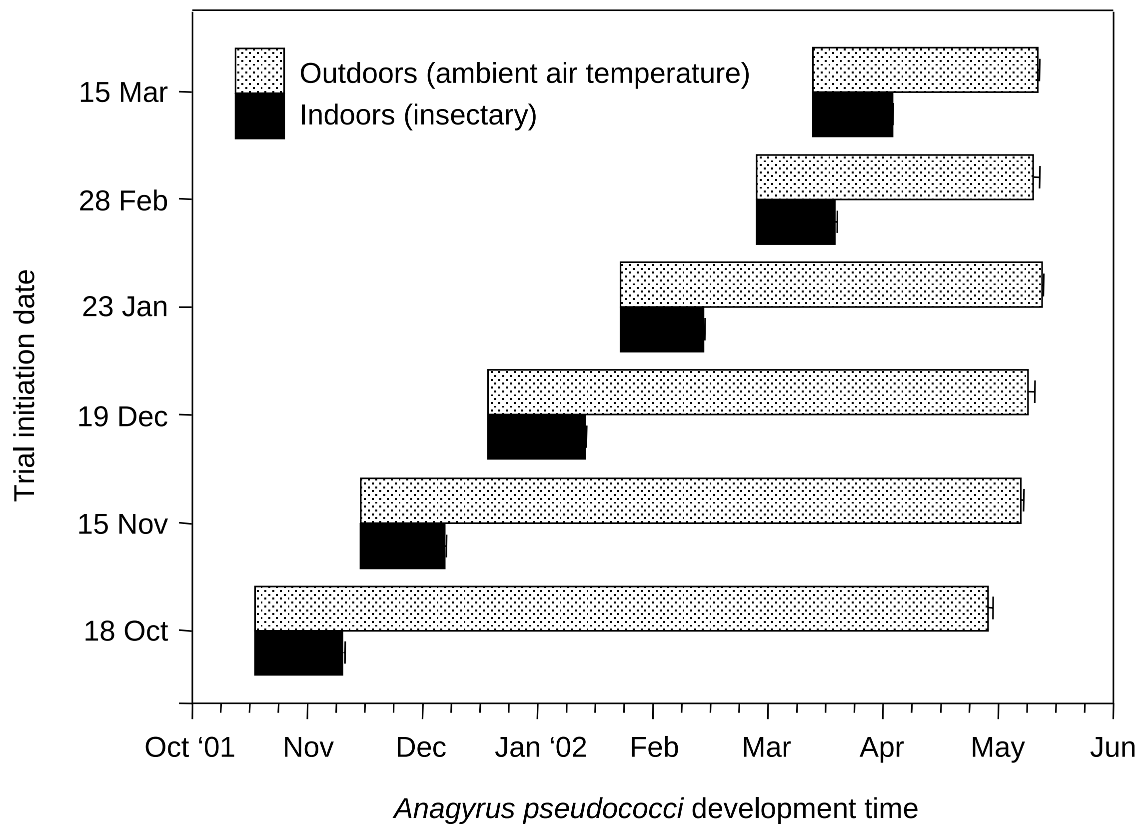

Figure 1. Average (± SEM) emergence periods for A. pseudococci on vine mealybug that were exposed to the parasitoid at different periods, from October through March, and then stored either inside at 22 ± 2°C or outside at ambient air temperatures (from Daane et al. 2004).