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MONITORING, DAMAGE, NATURAL ENEMIES AND CONTROL OF AVOCADO LACE BUG, *PSEUDACYSTA PERSEAE* (HEMIPTERA: TINGIDAE)

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Abstract. **Trends in seasonal abundance, natural enemies, damage and control of the avocado lacebug (ALB) *Pseudacysta perseae* (Heideman) (Hemiptera: Tingidae) were investigated in Dade County, Florida. Avocado lacebug population densities increased during the dry season (November - February), and declined during spring and summer. The cultivars 'Waldin', 'Booth 8' and 'Loretta' had the highest natural infestation levels. The most susceptible cultivar appears to be "Booth 8" with damage levels of 20-28% to the leaf area. Leaf photosynthesis was reduced by 50% when the leaves sustained 40% damage. Cultivars (Simmonds) with 100% of their leaves infested exhibited an early leaf drop and a total reduction of fruit set. By contrast the West Indies × Guatemala hybrid was scarcely affected by the pest. Four major biological control agents were observed. Two egg parasitoids, *Oligosita* sp., and an unidentified mymarid wasp, the green lace wing *Chrysoperla rufilabris,* and a predacious mirid, *Hyaliodes vitripennis.* Several pesticides, M-pede (soap), citrus oil, Mycotrol (*Beauveria bassiana*) were applied to an avocado orchard with an average of 15-28 ALB /leaf. Seven days after spray application, ALB densities were significantly reduced by Mycotrol, and by M-Pede compared with the untreated control. Mycotrol (3 qts/ 100 gal) significantly reduced ALB densities for 29 days compared to the untreated control.**

Introduction and Review of Literature

The avocado lace bug (ALB), *Pseudacysta perseae* was described in 1908 as *Acysta perseae* from Florida specimens and considered a minor pest of avocado. However, persistent population outbreaks of *P. perseae* observed since the mid 1990s in Florida and in the Caribbean region, reveal that made *P. persae* has become one of the most important pests of avocado (Medina-Gaud et al., 1991, Abud Antun, 1991). *Pseudacysta persae* is found in Florida and Georgia in the United States, Bermuda, Dominican Republic, Puerto Rico and Mexico (Mead and Peña 1991). The common hosts for this pest besides avocado are red bay, *Persea borbonia* (L.) and camphor, *Cinnamomum camphora* (L.). The life cycle of *Pseudacysta persae* was reported by Abud-Antum (1991) to require 22 days from egg stage to adult. The most complete description of adults and late instar nymphs was elaborated by Heidemann (1908).

Pseudacysta persae confines its attack to the lower surface of the foliage, causing chlorosis, necrosis and a severe defoliation of avocado, and probably reduced yields. This bug usually lives in colonies, depositing eggs upright in irregular rows in clusters on the lower leaf surface. This insect opens an avenue of penetration for the leaf anthracnose fungus, *Colletotrichum gloeosporioides* (Mead and Peña 1991). Since the avocado lacebug was previously not considered an important pest, it is suggested that in recent times suitable natural enemies were decimated by application of pesticides or by some other type of environmental desequilibrium. The objectives of this study were (1) to monitor populations of the avocado lace bug and attempt to discover its endemic biological control agents, (2) to test efficacy of such resident biocontrol agents, and (3) to evaluate the effect of feeding on photosynthesis and (4) observe if there is a relationship between cultivars and avocado lace bug populations.

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Materials and Methods

Seasonality and monitoring

The study was conducted from January 1995 through May 1997 in four avocado orchards approximately 6 km N of Homestead in Dade County, Florida. Ten trees were selected randomly and each tree inspected bimonthly from 1995 through 1997. On each sampling date one twig with an average of 9-12 leaves was cut from each tree, placed in a plastic bag, transported to the laboratory, and examined with a dissecting microscope. The numbers of *P. perseae* eggs, nymphs and adults and the percentages of leaf area damaged were recorded. The means of counts were calculated on each sampling date.

Natural enemies

Survey. Leaves from the orchards mentioned above that contained eggs, nymphs and adults of *P. perseae* were observed and the presence of entomophagous insects recorded. Leaves were held individually for parasitoid emergence in 1-liter paper cartons. These cartons were the held in the laboratory at 22 ± 3°C, and 75-80% RH for 1 month. Parasitoids that emerged were removed from containers, counted and identified by J. Pinto (University of California, at Riverside) or by the authors. Seasonal trends of the parasitoids and predators were assessed using the numbers of parasitoids emerging or the number of predators collected from infested leaves.

Effectiveness of Chrysopa rufilabris as predator of avocado lace bug. In tests where avocado lace bugs were offered as prey, 50 nymphs of the *P. perseae* were placed daily, for 12 days, on leaves that contained 1 *C. rufilabris* larva. Based on the feeding capacity of *C. rufilabris,* the number of *P. perseae* nymphs provided daily per arena were increased to 100 from day 13 to day 20 after initiation of the experiment. The prey and predator were confined in 20.5 cm in diameter petri dishes. The experiment was performed in the laboratory at a temperature of 23 ± 3°C and RH of 75-80%. To determine natural mortality, the same numbers of *P. perseae* were introduced into arenas without the predator. Each treatment was replicated 10 times.

Effectiveness of Hyaliodes vitripennis as predator of avocado lace bug. One hundred *P. perseae* nymphs were offered daily as prey to 1 *H. vitripennis* adult held in similar predator-prey arenas as described above. The number of *P. perseae* killed or pierced by the predator were recorded during four consecutive days.

Damage

The second objective of our research was to identify the damaging levels of avocado lace bug in different avocado varieties. Avocado cultivars belong to one of three races based on their evolutionary center of origin. The majority of avocado cultivars grown commercially in Florida are West Indian, Guatemalan and Guatemalan × West Indian hybrids (Crane 1992, Schaffer 1995). The cultivars, Booth 8, Loretta, and Waldin were evaluated. Each cultivar was grown in 2 gallon containers. There were 10 single-plant replicates per treatment. Trees were infested by placing adults and nymphs of *P. perseae* on five tagged leaves and by recording the number of *P. perseae* eggs, nymphs and adults on the tagged leaves during 6 weeks. Percent leaf damage was determined visually. At the end of the experiment the leaf was detached and the undamaged leaf area and damaged leaf area measured using a video image analysis system (Bioscan Optimas version 4.0, Bioscan Incorporated, Edmons, WA) following a procedure developed by Schaffer et al. (1997).

Effect of leaf damage on photosynthesis

An experiment to test the effect of percent leaf damage and net photosynthesis was conducted in February 1996. Ten trees of the cultivar Booth eight were selected and five leaves from each tree sampled. Each leaf was divided into different areas, distal, central and proximal area. Net photosynthesis was determined with a LCA-3 portable gas exchange system with a PLC-3B leaf cuvette (Analytical Development Corporation, Hoddesdon, Herts., England) as described by Larson et al. (1991). After photosynthetic determinations, the total area of each leaf was measured with a LiCor LI-3000 leaf area meter (LiCor, Inc., Lincoln, Nebraska) and the amount of leaf area damaged determined by multiplying the total leaf area by the fraction of the leaf area that was damaged.

Effect of Lacebug on Avocado Yield

Avocado lacebug populations, damage caused by the insect and effect of the insects on yield (number of fruits per tree) were studied following the same methods used for the population survey in five different avocado cultivars, 'Simmonds', 'Choquette', "Unknown", 'Pollock' and a West Indies × Guatemalan hybrid. Before harvest, the number of fruit per tree were counted and their number related to the amount of *P. perseae* damage.

Microbial and Chemical control of avocado lace bug

The effect of a strain of *Beauveria bassiana* (BbHa) on *P. perseae* populations was evaluated under laboratory and orchard conditions.

Laboratory Tests. P. perseae infested avocado leaves were sprayed with a *Beauveria bassiana* (BbHa) spore suspension (4.83×10^7 CFU). Leaves were allowed to dry for 10 min and placed individually in 500 ml plastic containers. A similar number of leaves were left untreated Subsequently, each container was covered with cheesecloth to allow proper ventilation. Each treatment was replicated 20 times. Lace bug infections were recorded 6 and 11 days after treatments.

Field Test 1. Trials were conducted to evaluate *B. bassiana* treatments for control of an avocado lacebug infestation in a 19-year-old avocado orchard. Treatments were applied to 4-tree plots and were replicated four times. One unsprayed buffer tree separated trees within rows and one tree separated trees between rows. Sprays were applied with a hand gun sprayer at 170 psi, 2000 rpm. Five leaves were examined at random for adults and nymphs around the canopy 4 days before treatment and eight and 20 days after treatment.

Field Test 2. Treatments were applied during the early spring of 1997 to mature (greater than 20 years) avocado (cv. Booth eight) trees located the University of Florida Tropical Research and Education Center. Most trees had feeding and necrotic spots showing symptoms of lace bug activity. Treatments were arranged in a RCB design with four replicates, three trees per replicate for a total of 12 trees per treatment. Applications were made on March 15, 1997 using a hand gun sprayer set at 250 psi. Mean numbers of dead adults and nymphs per leaf were evaluated 8, 15, 21 and 29 days after treatments were imposed.

Results and Discussion

Seasonality and Monitoring

Approximately 20,000 leaves were inspected between January 1995 and May 1997 to determine the presence of *P. perseae* adult and immature stages. *P. perseae* density and the percent of damaged leaf area increased from October through March and declined sharply from April through August (Fig. 1). The most likely reasons were: (1) increases in avocado lacebug population density are related to development of the avocado canopy after the bloom period, and (2) the applications of pyrethroids against phytophagous mirids and thrips (i.e., *Daghbertus sp.*, and *Frankliniella kelliae*), reduced predators and parasitoids of *P. perseae.* Injured leaves offer portals of entry for *Colletotrichum gloeosporioides.* The latter causes increases in leaf necrosis and premature defoliation. *P. perseae* populations reached their highest peak (12-15 ALB/leaf) in January and March 1995 and declined between April to May (0-1 ALB/leaf). *P. perseae* began a steady build up from

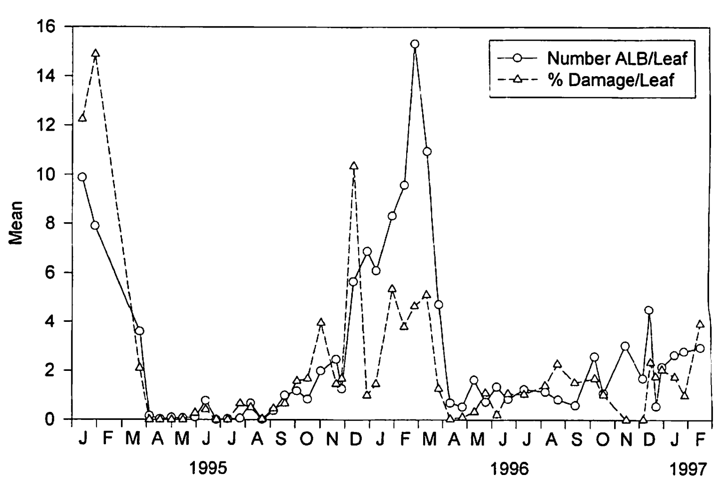

Figure 1. Seasonality of *P. perseae* and its levels of damage to avocado leaves, January 1995 through 1997.

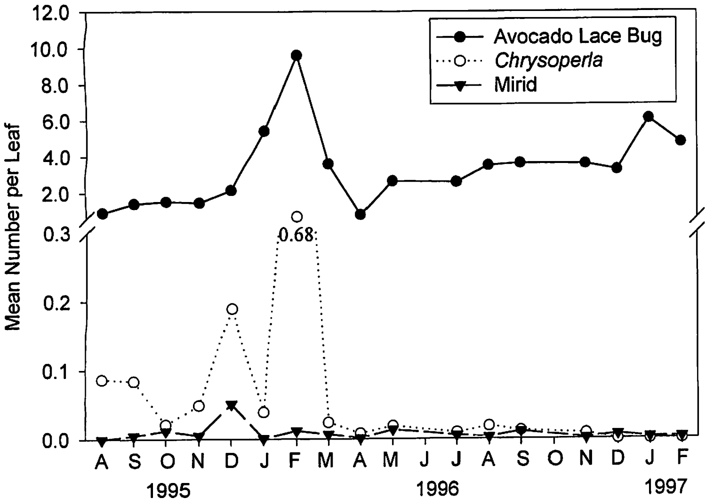

Figure 2. Population build-up of the green lace wing, *Chrysoperla rufilabris* and the predaceous mirid *H. vitripennis,* August 1995 through 1997.

July through March (3- 6 ALB/leaf) (Fig. 1). Avocado lacebug populations can survive in fallen leaves, and they begin to recolonize the tree as soon as the new leaves appear.

Natural Enemies

Four major biological control agents were collected in Homestead, FL and were identified as two egg parasitoids, *Oligosita* sp (Hymenoptera: Trichogrammatidae) and a unidentified mymarid (Hymenoptera: Mymaridae) species, the predators, green lace wing, *Chrysoperla rufilabris* (Neuroptera: Chrysopidae) and a predacious mirid, possibly, *Hyaliodes vitripennis* (Hemiptera: Miridae). The egg parasitoid *Oligosita* was the most frequent during the first major peak in the *P. perseae* population, whereas the green lacewing, *C. rufilabris* was quite common in the avocado orchards between August and December, when populations of the ALB are low (Fig. 2).

Effectiveness of Chrysopa rufilabris as predator of avocado lace bug. C. rufilabris attacked nymphs of *P. perseae.* Only 13% of the initial nymph population was eaten during the first day of the study. Feeding increased progressively in the next five days. Thirteen days after *P. perseae* exposure to the predator,

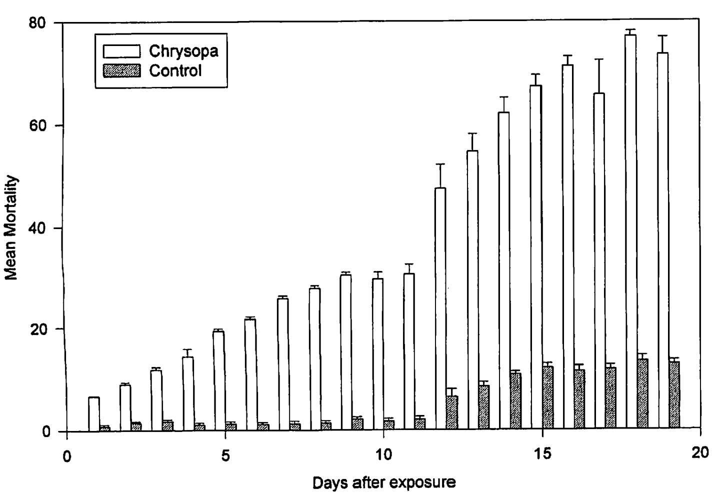

Figure 3. Mortality caused by the predator *Chrysoperla rufilabris* to *P. perseae* under laboratory conditions.

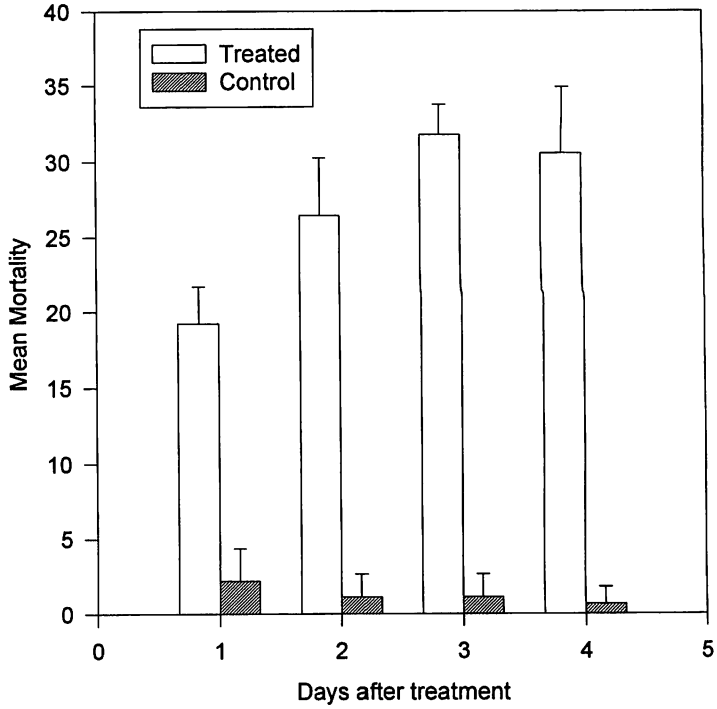

Figure 4. Mortality caused by the predator *Hyalodes vitripennis* to *P. perseae* under laboratory conditions.

consumption increased to 54% and reached 73% at 20 days. In the absence of the predator, mortality was 6-7% and reached 13% at the end of the experiment (Fig. 3). Our laboratory studies showed that green lace bug larvae cause a cumulative mortality of 75% of the avocado lacebug population (n = 50) during a 20-day exposure period. *C. rufilabris* prefers feeding on *P. perseae* nymphs over eggs and adults.

The predacious mirid, *Hyaliodes vitripennis* feeds on lacebug (n = 100) eggs and nymphs causing 30% reduction of *P. perseae* immature forms during a 4-day observation period (Fig. 4). These preliminary findings, allow us to hypothesize that the inadvertent and indiscriminate reductions of parasitoids and predators by applications of pyrethroids may have caused imabalances of the populations of the lacebugs and have allowed them to attain outbreak levels.

Damage

During a greenhouse trial, the cultivars, Waldin, Booth 8 and Loretta had damage levels fluctuating between 20 and 28% of necrosis in the leaf surface. The most susceptible cultivar appeared to be 'Booth 8' (Table 1). Defoliation occurred when an average 36.90 *P. perseae* per leaf were recorded for 5 weeks after infestation. *P. perseae* levels re-

Table 1. Mean avocado lace bug density and damage in three avocado cultivars, 5 weeks after infestation.

	Mean avocado lacebug density/ leaf	Percent Leaf Damage	
Cultivar	1 week after infestation	5 weeks after infestation	5 weeks after infestation
Booth 8	36.90 ± 33.29	76.69 ± 347.24	14.00 ± 333.62
Waldin	4.92 ± 35.88	11.34 ± 311.64	2.14 ± 33.63
Loretta	12.92 ± 315.25	30.17 ± 350.91	2.23 ± 335.47

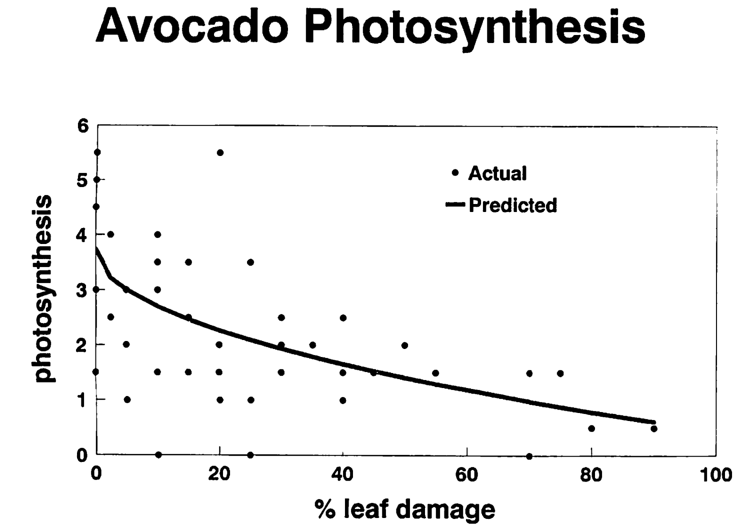

Figure 5. Effect of avocado lacebug on leaf photosynthesis, using the equation, $y = a + bx$, where y = PN, x = area damaged per leaf, $y = 3.09 - 0.03x$, $r^2 = 0.31; P = 0.0001$.

mained lower for the 'Waldin' cultivar. *P. perseae* densities increased up to 30 *P. perseae* per leaf in the 'Loretta' cultivar, however, the percent damage per leaf was similar to that obtained for 'Waldin'.

Effect of leaf damage on photosynthesis

In a different experiment, the photosynthetic activity of lacebug damaged foliage was compared with leaves without lacebug damage. Photosynthetic activity was reduced by about 50% when leaves sustained 40% or more damage (Fig. 5).

Effect of Lacebug on Avocado Yield

The cultivar 'Simmonds' sustained a total leaf drop early in the spring of 1996, that was preceded by 100% leaf infestation and severe necrosis and yellowing. The cultivar 'Choquette' had a late spring leaf drop, moderate leaf damage and less than 100% infestation. The "Unknown" variety was characterized by little leaf damage and minimum leaf drop during spring. The 'Pollock' and the WI × Guatemalan cultivars sustained no damage, and the avocado lace bug population remained very low. The largest number of fruit was collected from the West Indies × Guatemala hybrid (81.00 ± 9.33) followed by 'Choquette' (53.5 ± 8.41), 'Pollock' (30.70 ± 5.00) and 'Unknown' (23.80 ± 4.47). No fruits were harvested (0.00 ± 0.00) from the 'Simmonds' cultivar (Fig. 6). These results suggest that different cultivars very greatly in susceptibility to attack by the avocado lacebug.

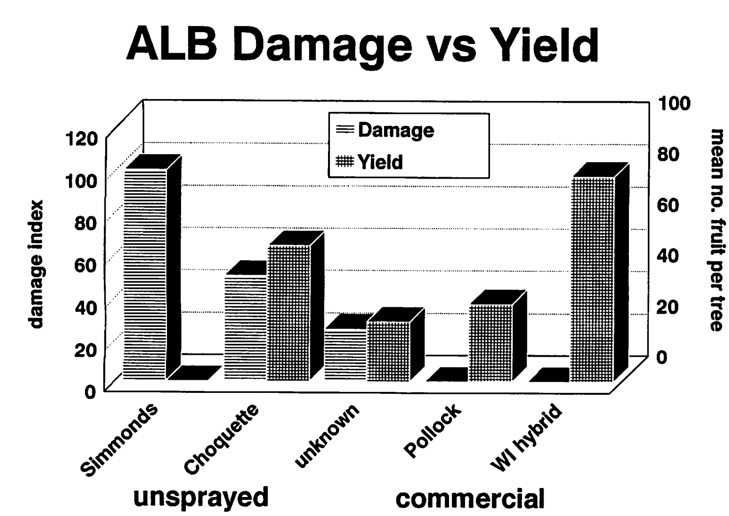

Figure 6. Avocado lace bug damage and its effect on yield in different avocado cultivars.

Table 2. Mean survival of avocado lace bug adults and nymphs after treatment with *Beauveria bassiana* under laboratory conditions.

Treatment	Adults per leaf			Nymphs per leaf			Lessions
	Alive	Dead	Infected	Alive	Dead	Infected/leaf	
Untreated	4.55a	0.058b	0.00b	8.41a	0.15a	0.00b	1.43a
Treated	0.30b	0.44a	2.97a	0.92b	0.08a	2.56a	1.14b

Means followed by the same letter within the same column were not statistically different ($P < 0.05$).

Microbial control of avocado lace bug

Data from the laboratory experiment are summarized in Table 2. Eleven days after treatment, adult lacebug mortality was 90% on *B. bassiana* treated leaves compared with 1.3% in the untreated leaves. Nymphal mortality on treated leaves was 72% compared to 2% for the untreated control. Mortality observed in the field trial was lower than that observed in the laboratory test. Nevertheless, the mortality levels observed in *B. bassiana* treated trees was significantly higher than that observed in the untreated plots (Table 3). Indeed a single application of *B. bassiana* was considered effective against *P. perseae.*

P. perseae densities were low during the 1997 experiment. Applications of Mycotrol, M-Pede and FC-435 oil appeared to increase *P. perseae* mortality during 8 days following their application. The Mycotrol treated leaves appeared to maintain

Table 3. Mean survival of avocado lacebug adults and nymphs after treatment with Beauveria bassiana of under field conditions.

Treatment	Adults per leaf			Nymphs per leaf		
	Alive	Dead	Infected	Alive	Dead	Infected
Untreated	4.41a	0.40a	0.04b	5.29a	1.83a	0.00b
Treated	0.87b	0.30a	2.25a	2.00b	0.32a	1.36a

Means followed by the same letter within the same column were not statistically different ($P < 0.05$).

Table 4. Mortality of avocado lace bug adults and nymphs under field conditions.

Treatment	Dose/	Mean Dead Lace Bug individuals per leaf				
	acre	1DBT	8DAT	15DAT	21DAT	30DAT
Untreated	—	0.02b	0.02c	0.13bc	0.05b	0.02b
Mycotrol	2 qts	0.12ab	0.92b	1.03a	0.05b	0.07ab
Mycotrol	3 qts	0.23a	1.33b	0.48b	0.23a	0.15a
Impede	250 oz	0.12ab	2.35a	0.03c	0.00b	0.00b
FC 435 oil	1 gall	0.05ab	1.25b	0.10bc	0.02b	0.00b

Means within columns followed by the same letter were not significantly different ($P < 0.05$).
DBT = Days before treatment
DAT = Days after treatment

a higher mortality than other insecticide treatments during 15 to 30 day post treatment period (Table 4).

Because of increasing concerns about the excessive use of pesticides, non pesticidal methods and environmentally friendly methods for controlling *P. perseae*, such as those discovered or tested in this study, should be given priority to be adapted or used by the Florida avocado industry.

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BIODYNAMICS OF *ANTHONOMUS MACROMALUS* (COLEOPTERA: CURCULIONIDAE), A WEEVIL PEST OF BARBADOS CHERRY IN FLORIDA

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Abstract. **The most important insect pest of Barbados cherry in Florida and the Antilles is the acerola weevil *Anthonomus macromalus* Gyllenhal. Major economic damage occurs when the weevil larvae develop in the flowers and fruit, causing premature fruit drop and loss in yields.**

Studies were done in Homestead, Florida in 1995 and 1997 to determine *A. macromalus* population dynamics, oviposition sites, emergence patterns from fruit, response to pheromones of other *Anthonomus* species and host volatiles, and feeding damage to Barbados cherry foliage. Barbados cherry study sites consisted of two commercial orchards [1) mature trees and 2) first year bearing trees] and one experimental planting of mature trees. Peak adult populations occurred during the summer (June-July) in 1995 at two commercial orchards (means of 64.0 and 1.45 adults/branch, respectively) whereas at an unmanaged experimental orchard, adult density reached a peak of 0.5 adults/branch. Weevil density was higher in the upper and middle strata compared with the lower stratum in mature trees (means of 0.25, 0.25, 0.11 weevils/branch, respectively). Eggs and larvae were found in flowers and fruit, and larvae were found individually in the stem terminals. Sixty-one percent (n = 205) of all fruit dissected were infested. Adult peak emergence was 17 days after fruit harvest and the highest density of weevils per fruit was 4.7 adults from the experimental planting. To determine if adult weevils respond to host semiochemicals, weevils were subjected to test stimuli in a dual-choice still air Petri dish bioassay. There was no significant response to host flowers, leaves, or fruit. Aerations of adult weevils yielded one intense electroantennogram detector active chemical, 1-octen-3-ol, a green leaf volatile. This chemical and pheromones from other *Anthonomus* species were tested on yellow sticky card traps in the field but did not increase trap efficiency. Leaf feeding damage was determined by leaf area measurements using a LI-COR-3000. Early season damage amounted to 4.9% of the leaf area.

Barbados cherry or acerola, *Malpighia glabra* (L.) (= *punicifolia* L.), is a tropical fruit native to the West Indies, Central America, and South America (Phillips, 1991). In Florida, Barbados cherry is grown in the southern part of the state in homeowner's yards and as a commercial crop.

The most important insect pest of Barbados cherry in Florida is the acerola weevil, *Anthonomus macromalus* Gyllenhal (= *A. flavus*, = *A. bidentatus*, = *A. malpighia*) [Coleoptera: Curculionidae]. This weevil is small (2.1-3.4 mm length) and dark brown. Members of this species are oligophagous within

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