DYNAMICS OF *BEAUVERIA BASSIANA* AND *METARHIZIUM ANISOPLIAE* INFECTING *HYPOTHENEMUS HAMPEI* (COLEOPTERA: SCOLYTIDAE) POPULATIONS EMERGING FROM FALLEN COFFEE BERRIES

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ABSTRACT

The aim of this research was to evaluate the effect of soil sprays of the entomopathogens *Beauveria bassiana* and *Metarhizium anisopliae* on coffee berry borer (cbb) adults, *Hypothenemus hampei*, emerging from fallen berries through time. Each fungus was applied to a plot 5000 m^2 in size of the Colombian variety in the third harvest year. The experimental plot was formed with 9 trees, and the experimental unit was the central tree. In this tree all the green uninfested berries were left and the whole tree covered with a screen cage to avoid further cbb infestation or escape. Nine treatments replicated ten times were arranged in a complete randomized design. Conidia of each fungus were suspended in emulsified oil and water and applied on the base of the trees at a dosage of 1×10^9 conidia/tree. Under each experimental tree 350 cbb-infested coffee berries were placed on the soil to serve as a source for aerial infestation of the trees. Infested berries were applied the same day of the spray and at 2, 5, 10, 15, 20, 25 and 30 days after fungus application. Results showed that infection levels of both fungi on cbb were the highest during the first five days after application, reaching nearly 30% for *B. bassiana* and 11% for *M. anisopliae*. However, the infection decreased for 20 days but peaked again at 25 days post-treatment with 24.3% for *B. bassiana* and 7.7% for *M. anisopliae.* These results are explained by the formation of propagules in the soil by these fungi, due probably to the accumulation of infective conidia on infected insects which infect other insects leaving the fruits. The two species were recovered from the soil even after two months and fluctuation in numbers of colony forming units was attributed to the rainfall during the study period and the fungus conidiation. *B. bassiana* was shown to be more infective than *M. anisopliae*, considering that the latter is more frequently associated to soil habitats. The authors believe efficiency of these fungi can be increased if improvements are made to the formulations, e.g., using a granulated formulation to avoid leaching of the conidia from the soil during heavy rainy seasons. During this study it was found that *H. hampei* is a new host of *Paecilomyces lilacinus*.

Key Words: Coffee berry borer, *Hypothenemus hampei*, *Beauveria bassiana*, *Metarhizium anisopliae*, *Paecilomyces lilacinus*

RESUMEN

Este estudio evaluó el efecto de aspersiones de *Beauveria bassiana* y *Metarhizium anisopliae* al suelo sobre la broca del café, *Hypothenemus hampei*, que emerge de frutos caídos, a medida que transcurre el tiempo después de depositar el hongo. Se seleccionaron dos lotes de café variedad Colombia de tercera cosecha con un área de 5000 m^2 y se evaluaron los dos hongos en lotes experimentales diferentes. La parcela se formó con 9 árboles y el árbol central se escogió como la unidad experimental. A este árbol se le dejó solo frutos verdes sin infestación por broca y se cubrió con una jaula entomológica para evitar nuevas infestaciones o escape de broca. Las conidias de los hongos utilizados se suspendieron en aceite emulsionable y agua usando una dosis de 1×10^9 conidias/árbol. En la base del árbol que sirvió como unidad experimental se as-

perjaron los hongos al plato de cada árbol y se depositaron 350 frutos brocados el mismo día de la aspersión y 2, 5, 10, 15, 20, 25 y 30 días después de la aspersión. Los resultados muestran niveles máximos de infección durante los cinco primeros días posterior a la aspersión de los hongos, cercanos al 30% para *B. bassiana* y 11% para *M. anisopliae*. Sin embargo la infección disminuyó y de nuevo alcanzó un nuevo pico hacia el día 25 de la evaluación. Después de este tiempo la infección se incrementó nuevamente hasta niveles similares a los alcanzados en los 5 primeros días, 24,3% y 7,7% para *B. bassiana* y *M. anisopliae* respectivamente. Estos resultados se pueden explicar por la formación de propágulos en el suelo por estos hongos, debido probablemente a la acumulación de conidias infectivas sobre insectos atacados que infectan otros insectos que salen de los frutos. Las dos especies se recuperaron del suelo aún después de dos meses y la fluctuación en el número de las unidades formadoras de colonia se atribuyó a la precipitación y a la conidiación del hongo. *B. bassiana* mostró un efecto superior al de *M. anisopliae*, si se tiene en cuenta que este último está más asociado a condiciones del suelo. La eficiencia de estos hongos se podría mejorar con formulaciones granuladas del hongo que permitan una mayor permanencia en el suelo para disminuir la lixiviación causada por las lluvias. Durante el estudio se constató que *H. hampei* es un nuevo huésped de *Paecilomyces lilacinus*.

The coffee berry borer (cbb), *Hypothenemus hampei* (Ferrari), was introduced into Colombia in 1988 and now is widespread in the major coffee producing area where it is the most important insect pest (Bustillo 1991). Infested coffee berries that fall to the soil are the main source of reinfestation of the coffee plantations at the end of the harvest period. Traditionally, the berries that fall during the harvest period are not harvested because this practice is very tedious and expensive. In Colombia, about 10% of the coffee berries are not harvested, resulting in berries ending up on the soil eventually (Chamorro et al. 1995).

Understanding the dynamics of cbb in the soil is important to the development of a control strategy. Studies carried out in Mexico (Baker 1984) and Colombia (Ruiz 1996) have demonstrated that high humidity caused by rainfall is the main trigger of cbb emergence from fallen berries. On the other hand, soil moisture stimulates expulsion and death to the immature stages inside the berry (Baker et al. 1994). When the soil is dry, the cbb remains in the berries in the soil and continues to reproduce. When the rainy season arrives, massive adult emergence occurs.

Several attempts have been made throughout the world to use mass-produced biopesticides based on entomopathogenic fungi. In Brazil, mass production of *Metarhizium anisopliae* (Metsch.) Sorokin has resulted in an intensive use to control a sugarcane pest, *Mahanarva posticata* (Stal) (Ferron 1981, Alves 1986). In several countries of Eastern Europe, *B. bassiana* is recommended to control *Leptinotarsa decemlineata* (Say) (Ferron 1981, Lipa 1990). To replace the use of chemical insecticides due to an embargo on trade with Cuba, Cuba has been forced to move in the development of biopesticides, especially with entomapathogenic fungi, to control different insect pests (Jaffé & Rojas 1993). In Africa, international attempts to develop more ecological control practices has resulted in the formulation of a commercial product "green muscle" based on *M. flavoviride* (Gams et Rozsypal) to control several species of the desert locust, *Schistocerca gregaria* Forskal (Lomer et al. 1997). In Colombia an intensive research program with entomopathogenic fungi is been conducted to control *H. hampei* (Bustillo & Posada 1996).

Beauveria bassiana (Balsamo) Vuillemin is the main natural mortality factor of cbb and is found in all the Colombian coffee regions infested by this insect (Bustillo &

Posada 1996, Ruiz 1996). This fungus is being investigated as a control tool in our coffee IPM programs. *M. anisopliae* is also a potential entomopathogen that could infect the cbb in the soil (Bernal et al. 1994). Our research was conducted to determine the role of both *B. bassiana* and *M. anisopliae* on the regulation of cbb adult populations that emerge from the fallen berries, and on persistence of fungi in the soil.

Materials and Methods

This study was conducted during 1996 at the Experiment Substation Maracay of Cenicafé near Armenia, Colombia. Two large plots each of 5000 m^2 with 2500 coffee plants of the Colombia variety were selected, one planting for each fungus. Soil pH was 5.1 with an organic matter content of 12% for the *B. bassiana* plot and16.5% for the *M. anisopliae* plot. The experimental plots had enough susceptible green berries in an optimal developmental stage for borer infestation. Plots contained nine trees in square with a three-row border in all directions. The central tree of each plot served as the sample unit. The tree was covered with a screen cage of translucid nylon cloth to prevent movement of borers. Prior to the study, trees were left with uninfested green berries suitable for borer infestation, and the berries on the ground were removed from the soil surface beneath the trees.

B. bassiana isolate Bb 9205 originally from *Diatraea saccharalis* (Fabricius) and *M. anisopliae* isolate Ma 9236 obtained from the CIAT fungi collection (accession #1773) maintained in liquid nitrogen, were inoculated and then reisolated from cbb adults and produced on rice (Antia et al. 1992). Previous studies (Bustillo & Posada 1996, Bernal et al. 1994) had shown effect of these fungi against cbb populations under field conditions. To assure good quality of fungi produced on rice medium, concentration and viability was checked, and pathogenicity on cbb adults was performed following the protocol established by Vélez et al. (1997). Fungal conidia were suspended in Tween-20® and an emulsified oil Carrier® in equal parts. Water was added to the mixture to give a concentration of 2×10^7 conidia/ml. The fungi were sprayed onto the ground at the base of the trees using a volume of 50 ml/tree with a manual backpack sprayer at a constant pressure of 40 psi, and a final dose of 1×10^9 conidia/tree.

Treatments consisted of a liquid application of fungus to the ground of the trees, and subsequent deposition of 350 infested berries on the ground immediately after fungal application or 2, 5, 10, 15, 20, 25 and 30 days after application. The study followed a completely randomized design for both experiments with 10 replications and control consisting of infestation with cbb but no fungal application. Hypothetically, cbb emerging from the infested berries will contact the fungus. Then adults will fly to the trees and infest the healthy berries and die from fungal infection. Infested berries were previously disinfected with NaOCl at 2.75% to avoid natural fungal contamination, and then dried for 12 h with the help of a fan.

Following infestation, on each tree 15 branches were randomly marked. Mycosis to cbb was made 30 days after berry infestation by recording the number of infected and healthy adults found in the 15 branches. The infested berries were dissected to confirm cbb adult mortality, and dead adults without signs of fungal infection were placed individually in humid chambers (90% RH, 25°C) for eight days to allow fungal expression on the cadavers.

To determine fungal persistence in the soil following application of conidia a dilution method was used to recover fungal propagules from the treated soil. Soil samples were collected weekly for two months from each tree by taking 10 g of soil/tree randomly from 5 sites. The 5 samples were pooled and homogenized and a subsample of 1 g was placed to reach a 10-ml suspension with sterile distilled water. From this sus-

pension, a 10^{-3} dilution was prepared and two 0.1 ml aliquots were used for counting. Isolation of *B. bassiana* and *M. anisopliae* was made using a selective media (Rivera & López 1992). This medium was prepared by adding to the one liter Saubouraud dextrose agar a mixture of 12 mg copper oxychloride, 26.6 μl cyproconazol and 1 ml of a 44% of lactic acid solution. Fungal spore density was estimated from the average of 10 counts per treatment and recorded as colony forming units (CFUs) /g of soil. Analysis of variance was made and Tukey's test ($P = 0.05$) to determine treatment differences using SAS statistical package version 6.11.

Results and Discussion

In all treatments, coffee berry borer infestation occurred in the aerial part of the tree as a consequence of the adult emergence from the infested berries on the soil (Tables 1 & 2). Although 350 berries were placed under each tree, different levels of infestation occurred in different plots. Levels of *B. bassiana* and *M. anisopliae* were significantly higher in treatments than in controls, demonstrating that the borers contacted the conidia in the soil. Maximum adult infection was 29.3% for *B. bassiana* (Table 1) and 11% for *M. anisopliae* (Table 2) when cbb infestation was made 0, 2, and 5 days after fungus application. Levels of infection decreased in the subsequent treatments (10, 15 and 20 days after spray), but at 25 days post-treatment an increase in infection was detected to levels similar to the ones registered at the initial treatments. The reason for this increase may be the conidiation of fungi on cadavers or the formation of new propagules from the existing inoculum, which is common when fungi are sprayed into the soils, as suggested by Fargues & Robert (1985). Similar results were found by López et al. (1995) with the isolate Bb9205 of *B. bassiana* active against the cbb. Under laboratory conditions propagules of this fungus were recovered from sterile and nonsterile soil even after 218 days of soil inoculation, and an unexpected increase of CFUs was recorded 41 days after inoculation.

TABLE 1. *BEAUVERIA BASSIANA* INFECTION OF *HYPOTHENEMUS HAMPEI* ON COFFEE TREES TREATED WITH FUNGAL APPLICATION TO THE SOIL.

Infestation interval (days after spray)	Average number of cbb adults[1] ± S. E[3]	Infection of cbb with *B. bassiana* (%)	Infection of cbb with *M. anisopliae* (%)	Infection of cbb with *P. lilacinus* (%)
0	551.4 ± 52.3	24.7 ab[2]	0.1 b	0.7 b
2	221.4 ± 35.9	29.3 a	0.5 a	0.2 a
5	46.8 ± 6.4	21.7 abcd	0.2 b	0.1 a
10	74.3 ± 9.7	10.3 cde	0.0 b	1.0 b
15	93.0 ± 9.9	8.4 de	0.2 b	1.6 b
20	91.9 ± 10.4	11.3 cde	0.0 b	0.8 b
25	243.8 ± 24.5	24.3 abc	0.0 b	0.0.a
30	49.1 ± 10.2	7.2 de	0.0 b	0.0.a
Control	170.7 ± 18.9	6.0 e	0.0 b	0.0.a

[1]Average number of coffee berry borers (cbb) adults in 15 branches/treated tree.
[2]Numbers followed by the same letter do not differ significantly according to the Tukey test ($P = 0.05$).
[3]Standard Error.

TABLE 2. *METARHIZIUM ANISOPLIAE* INFECTION OF *HYPOTHENEMUS HAMPEI* ON COFFEE TREES TREATED WITH FUNGAL APPLICATION TO THE SOIL.

Infestation interval (days after spray)	Average number of cbb adults[1] ± S. E[3]	Infection of cbb with *M. anisopliae* (%)	Infection of cbb with *B. bassiana* (%)	Infection of cbb with *P. lilacinus* (%)
0	527.7 ± 58.6	7.9 abc[2]	8.6 d	1.2 a
2	109.5 ± 14.5	11.0 a	15.0	1.5 a
5	60.1 ± 6.7	9.2 ab	4.5 cd	1.0 a
10	86.9 ± 9.5	6.7 abc	8.8 bc	1.2 a
15	102.7 ± 8.2	4.5 bc	3.4 cd	0.3 a
20	79.1 ± 7.1	4.9 abc	1.8 d	0.8 a
25	250.7 ± 26.2	7.7 abc	17.0 a	1.8 a
30	74.9 ± 11.6	4.7 bc	3.9 cd	0.6 a
Control	207.9 ± 31.2	1.7 c	4.1 cd	0.0 a

[1]Average number of coffee berry borers (cbb) adults in 15 branches/treated tree.
[2]Numbers followed by the same letter do not differ significantly according to the Tukey test ($P = 0.05$).
[3]Standard Error.

M. anisopliae infection of cbb differed from *B. bassiana* in that levels of infection were lower (Table 2). Infection fluctuated between 7.9% and 11% at 0-5 days post-treatment but decreased gradually thereafter. Another peak of infection was reached at the 25-day post-treatment (7.7%). These results for both *B. bassiana* and *M. anisopliae* are similar to those reported by Müller-Kogler & Zimmermann (1986); in studies to control *L. decemlineata* using *B. bassiana*, they found an unexpected increase in number of conidia after several months of fungus spray in the soil.

The incidence of *M. anisopliae* and *B. bassiana* was measured by quantifying the infection on *H. hampei* adults on the trees, but it is possible that a part of this population is not quantified since they may die before reaching the trees and are difficult to locate. Low levels of Infection of *B. bassiana, M. anisopliae* and *P. lilacinus* were recorded on cbb populations in plots where they were not sprayed (Tables 1 and 2). The same was observed from the soil samples (Figs. 1 and 2).

It was possible to recover *B. bassiana* and *M. anisopliae* from the soil even two months after application (Figs. 1 and 2). Interestingly, both species were recovered in each plot; however, *B. bassiana* was more abundant in both plots. This can be explained by previous use of *B. bassiana* and *M. anisopliae* at this Research Station in programs to control the borer.

No direct relationship was found between the abundance of fungi CFUs and rainfall, but a reduction in quantity of propagules was registered after heavy rains. In the case of *B. bassiana* in the soil, two peaks were observed, one at the beginning and other later in the experimental period, which corresponded to the high levels of fungal infection in cbb on the trees (Fig. 1). The dynamics of *M. anisopliae* in the soil was similar to *B. bassiana*, but with significantly lower recovery (Fig. 2).

During soil sampling in both plots, another entomopathogen was isolated frequently and identified as *Paecilomyces lilacinus* (Thom.) Samson by Harry C. Evans from IIBC in England. This is the first record of this fungus attacking *H. hampei* adults under natural conditions. *P. lilacinus* has been isolated previously from coffee soils in Colombia with high nematode (*Meloidogyne* spp.) populations, to which this fungus is

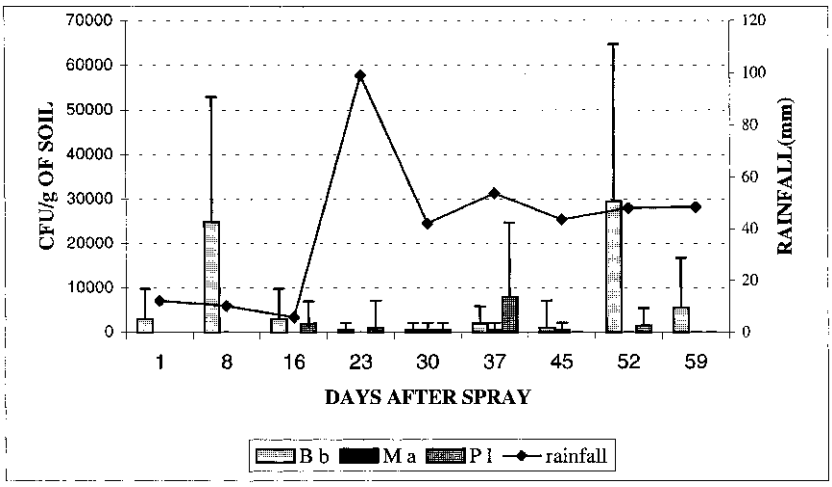

Fig. 1. Abundance (CFU/g) of *Beauveria bassiana* (*Bb*), *Metarhizium anisopliae* (*Ma*) and *Paecilomyces lilacinus* (*Pl*) in soil treated with *B. bassiana*. Vertical bars represent standard errors of the mean.

pathogenic (Cardona 1995). Although *P. lilacinus* was never applied, it was recovered from the soil in higher proportion than *M. anisopliae* in both plots (Figs. 1 and 2).

Successful infection of susceptible soil-inhabiting insects by soil-applied entomopathogenic fungi is largely dependent upon survival of an infective inoculum in the

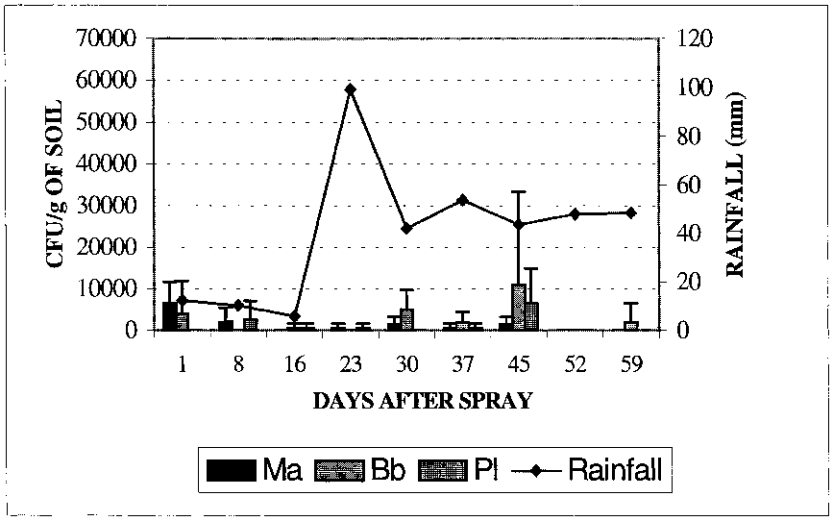

Fig. 2. Abundance (CFU/g) of *Metarhizium anisopliae* (*Ma*), *Beauveria bassiana* (*Bb*) and *Paecilomyces lilacinus* (*Pl*) in soil treated with *M. anisopliae*. Vertical bars represent standard errors of the mean.

soil. This study shows that conidia of both *M. anisopliae* and *B. bassiana* can persist for short periods of time in the soil. Other studies (Fargues & Robert 1985, Gaugler et al. 1989, Li & Holdom 1993, Studdert et al. 1990, Su et al. 1988) have shown that survival of these fungi may vary depending on fungal strain, type of soil, pH, microbial fauna present, and soil management. Lingg & Donaldson (1981) demonstrated that survival of *B. bassiana* conidia was primarily dependent on temperature and soil water content. In addition, microcyclic conidiation could be implicated in the high survival of conidia (Fargues & Robert 1985, Müller-Kogler & Zimmermann 1986). Due to the high variability of conidial survival of entomopathogenic fungi, its potential as a microbial insecticide is much greater in some soil environments than in others.

Fungal formulations play important roles in the persistence in soils. Propagules penetrate vertically in the soil when liquid formulations are used (Storey & Gardner 1988). Recovery of CFUs from *B. bassiana* in treated plots was 10 times greater using granular formulations than when liquid formulations were used (Storey et al. 1989). The efficacy of *B. bassiana* and *M. anisopliae* to control *H. hampei* could be improved by the use of more appropriate formulations such as a granular formulation. This kind of formulation could avoid the loss of conidia trough rainfall, maintain high conidia viability, and prevent movement from the upper layers of the soil where contact with the borer takes place.

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THE EFFECTS OF BURN FREQUENCY ON THE DENSITY OF SOME GRASSHOPPERS AND LEAF MINERS IN A FLORIDA SANDHILL COMMUNITY

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ABSTRACT

The frequency and intensity of wildfires are known to affect plant diversity and growth. We examined whether the periodicity of burning affected the density of insect herbivores. A Florida sandhill community in West-Central Florida was divided into ten sections, two sections of which each had a different periodicity of burning: one year, two years, five years, seven years, and control (zero years). Each burn cycle had been repeated many times, but all plots had been burnt in the summer of 1996, three months prior to the onset of our study. We censused the most common herbivores of the low-growing herbs: grasshoppers, and the most common herbivores of the trees: leaf miners, every month for a year. Grasshoppers were counted on two common flowering plants in the community, *Carphephorus corymbosus* (Nutt.) Torrey & A. Gray, and *Eriogronum tomentosum*, Michaux. Leaf miners were counted on the two most common trees, *Quercus geminata*, Small, and *Quercus laevis*, Walter. Grasshopper densities were significantly higher on the flowering plants in the 1 year, 2 year, and 5 year burned plots than on the 7 year or control plots. Leaf miner densities on the oaks were not significantly different between treatments. The differences in grasshopper densities could be due to a higher density of forbs and the occurrence of healthier forbs in the more frequently burned plots.

Key Words: burn frequency, Florida sandhill, oak trees, herbaceous plants, herbivore densities

RESUMEN

Es bien conocido que la frecuencia e intensidad de los incendios afectan el crecimiento y diversidad de las poblaciones de plantas. En este estudio se examinó si la frecuencia de los incendios afecta la densidad de insectos hervíboros. Una comunidad de dunas de arena en la parte centro-occidental de la Florida se dividió en diez secciones y en cada dos secciones se probaron las siguientes periodicidades de incendio: cada uno, dos, cinco, siete y cero (testigo) años. Los ciclos de incendio ya habían sido repetidos en varias ocasiones anteriores, pero todos los lotes fueron incendiados en el verano de 1996, tres meses antes de comenzar este estudio. Cada mes durante un año se hizo un censo de saltamontes (grasshoppers), los insectos hervíboros más comunes de las hierbas de porte bajo, y de minadores del follaje (leaf miners), los más comunes en los árboles. Los saltamontes se contaron en dos plantas con flor comunes en el sitio experimental, *Carphephorus corymbosus* (Nutt.) Torrey & A. Gray, y *Eriogronum tomentosum*, Michaux. Los minadores se contaron en las dos especies de árboles más comunes, *Quercus geminata* Small, y *Quercus laevis* Walter. Las densidades de saltamontes fueron significativamente más altas en las plantas con flor en los lotes incendiados cada uno, dos, y cinco años, que en los lotes incendiados cada siete años o en los que no fueron incendiados. Las densidades de minadores en los robles no variaron entre tratamientos. Las diferencias en las densidades de saltamontes podrían deberse a una mayor densidad de "forbs" (plantas herbáceas aparte de gramíneas) o a la presencia de forbs más saludables en los lotes con mayor frecuencia de incendio.

Periodic burning has long been known to be an integral factor in maintaining plant diversity. Fire removes species which would otherwise smother and prevent the growth of perennial grasses and herbaceous plants. Without fire, grass vegetation can be replaced by woody plants (Evans 1984). In Florida, spring burnings are an important tool in maintaining healthy sandhill communities. Sandhill requires frequent, low intensity, fires in order to thrive and the natural burn frequency in these communities is thought to be between 1 and 10 years (Menges and Hawkes 1998). Fire stimulates pine cones to release their seeds, furthermore, seeds of many species depend on the heat of fire to germinate. Fire can also protect longleaf pines from disease caused by fungus (Whelan 1995). In addition, the nutrients of the burned vegetation penetrate the soil with rainwater, providing nutrients for the remaining plants (Kozlowski and Ahlgren 1974).

Periodic burning may directly and indirectly affect the density and richness of insect herbivores by killing insects and by affecting the richness of the flora and the quality of the vegetation, which can improve subsequent to burning because of the nutrient flush (Bergeron and Dansereau 1993, Mutch 1970). In this study, the effect of fire periodicity on herbivorous insects was observed in study plots which had been subjected to controlled burning at various intervals: seven years, five years, two years, one year and unburned (control).

Study System

The study system was a typical Florida Sandhill community dominated by longleaf pine, *Pinus palustris* Mill. Deciduous oaks, such as turkey oak, *Quercus laevis* Walter, and sand live oak, *Quercus geminata* Small, underlie the pines, and wiregrass, *Aristida stricta* Michaux, is the primary ground cover (Myers and Ewel 1990). Turkey Oak is often stunted, up to 20m tall, but usually smaller, with long, oblong leaves with three, five, or seven pinnate lobes. Sand live oak is a shrub or small to medium-sized tree. Leaves are oblong, to elliptic, thick, and strongly revolute. Other plants common to this landscape include: *Carphephorus corymbosus* (Nutt.) Torrey & A. Gray, (Deer tongue), *Eriogonum tomentosum* Michaux (Dog tongue or Wild Buckwheat), and *Serenoa repens* (Bartr.) Small (Saw Palmetto). Deer tongue is a perennial herb (Compositae) with stems up to one meter tall and with purple/lilac paint brush flowers and lower spatulate leaves spread upon the ground. Dog tongue is a member of the Polygonaceae and exhibits small white or pinkish flowers in terminal and subterminal clusters.

Materials and Methods

The study was conducted in the 200 ha University of South Florida Ecological Research Area in Hillsborough County, Florida (28.05'N, 82.20'W) (see McCoy 1987 for details), which contains two one hectare replicates of five burn treatments: unburned (29 years since the last fire), one, two, five, or seven years. All the burning regimes began in 1976, except the seven year plots which began in 1975. By 1996 all regimes had run for at least twenty-one years. The seven year plots had been burned four times, the five year plots five times, the two year plots eleven times, and the one year plots twenty-one times. The control plots had not been burned in at least 29 years. In 1996 every plot received a burn treatment in July. Any subsequent differences in herbivore density between plots in 1996 and 1997 would then be attributable to the history of burn, not the year that the plots were last burned. This provided a good opportunity to examine the influence of fire on herbivorous insects.

Four plant species were examined for herbivores on each plot: two low-lying understory plants and two oak species. The understory species observed were *Carphephorus corymbosus* (Deer Tongue) and *Eriogonum tomentosum* (Dog Tongue), and the trees were *Quercus geminata* (Sand Live Oak), and *Quercus laevis* (Turkey Oak).

The number of herbivores was counted monthly on each plant species with a variation of counting technique for each plant species. Counts consisted of visual counts of 500 leaves for each of the flowering species (about 50 plants worth), and 500 leaves for one oak tree per plot. Most of the herbivores were sessile or unwinged juveniles that did not fly away during censuses. Counts were made every month for 13 months, starting in October, 1996 and ending in October, 1997. No fires were set in the plots during this period. Each month a count was performed, a random selection of plants was counted in each plot. Densities of each insect species were summed on each plot for the year. Comparisons of burn treatments on insect densities were then made using a one-way ANOVA on untransformed total counts, which were normally distributed.

The density of dog tongue and deer tongue on each of the plots was also determined. This was done by taking a 50 meter rope and counting the number of each of these two plant species that it touched as it cross-sected the plot. Unfortunately, it was not possible to collect data on plant quality in this study.

Results

In this study the most common visually censused herbivores of the flowering plants were two species of grasshoppers belonging to the genera *Melanoplus* and *Aptenopedes*. Both species had one generation a year at our study sites with wingless nymphs appearing in the spring and adults feeding until early fall. The most common herbivores of the oaks were species of the leaf mining genera *Buccalatrix, Stigmella, Cameraria,* and *Stilbosis* (Stiling and Simberloff 1991). These leaf miners were multivoltine and new mines could be found throughout the year. We therefore focused our study on these species.

In general, grasshopper densities on the flowering plants were significantly affected by burn frequency with higher numbers in one, two and five year plots than in the seven year plots or unburned controls (Fig. 1). However, densities of leaf mining insects on oaks were not affected by burn frequency (Fig. 2). There was no significant difference in plant density of dog tongue or deer tongue between the treatments (dog tongue: $F_{4,5} = 3.547$, $P = .099$; deer tongue: $F_{4,5} = 1.820$, $P = .263$). However, there was a trend for the highest densities to occur in the more frequently burned plots (Table 1), and lack of significance may have been due to low statistical power ($n = 2$). This trend was not so pronounced for dog tongue.

Discussion

Grasshopper densities on both deer tongue and dog tongue were the highest in the one year, two year and five year plots, and lowest in the seven year and control plots. This could be caused by at least two factors. First, the host plants could simply be less frequent in the seven year and control plots, than in the one, two or five year plots. Second, host plant quality could vary between plots. Although there was no significant difference in plant density between plots, the trend was for lower plant densities in less frequently burned plots. Although we do not have data on plant quality, it is known that fire replenishes nutrients by burning ground cover and allowing nutrients to quickly seep into the soil (Harvey 1994, Kozlowski and Ahlgren 1974, Maclean and Wein 1977). Protein content of prairie grasses has been shown to be higher on burned

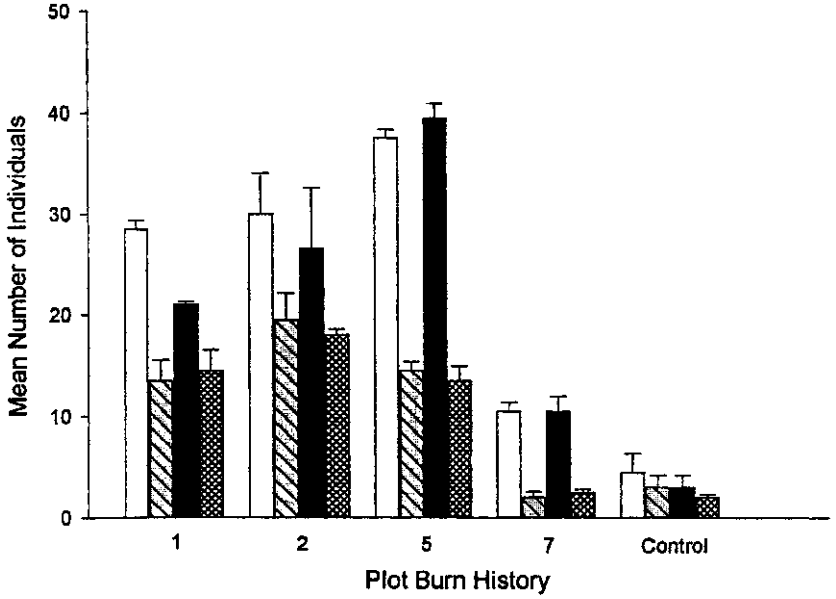

Fig. 1. Number of grasshoppers on plots with different burn periodicities (1 = 1 year, 2 = 2 years, 5 = 5 years, 7 = 7 years, control = never burned). Means and standard errors shown. ▭ = *Melanoplus sp.* on deer tongue, *Carphephorus corymbosus*. One way ANOVA: $F_{4,5} = 12.908$, P = .008. ▨ = *Aptenopedes sp.* on deer tongue. One way ANOVA: $F_{4,5} = 7.374$, P = .025. ■ = *Melanoplus sp.* on dog tongue, Eriogronum tomentosum. One way ANOVA: $F_{4,5} = 7.911$, P = .022. ▩ = *Aptenopedes sp.* on dog tongue. One way ANOVA: $F_{4,5} = 13.05$, P = .007.

than on unburned areas (Owensby et al. 1970, Smith and Young 1959). The plants in the more frequently burned (one year, two year and five year plots) appeared to us to be healthier than those in the seven year and control plots because they were a richer green color, the leaves were more abundant and appeared to be in better condition.

Leaf miner densities on the trees were unaffected by burn frequency, suggesting either that any post-fire nutrient pulse was not great enough to affect tree foliage quality or that trees behave differently to ground cover. In this regard, it is interesting that McCullough and Kulman (1991) found that young jack pine trees on burned areas had lower foliar nitrogen than trees on unburned sites, and that jack pine budworm, *Choristoneura pinus* Freeman, survival was related to foliar nitrogen concentration.

We can compare and contrast our results to the few other studies that have addressed the effects of burning herbaceous vegetation on insect densities. At the University of Missouri Tucker Prairie Research Station, Cancelado and Yonke (1970) found statistically greater numbers of Hemiptera and Homoptera on burned areas over unburned areas. Similarly, Rice (1932) found that many phytophagous insects quickly returned to burned areas because the vegetation grew more rapidly there. A study in a prairie grassland in Kansas found that the biomass of herbivores on burned land was significantly higher than on the unburned land and that most of the difference was caused by increased abundance of grasshoppers (Nagel 1973). Finally, a study of postfire insect succession in southern California chaparral indicated that due

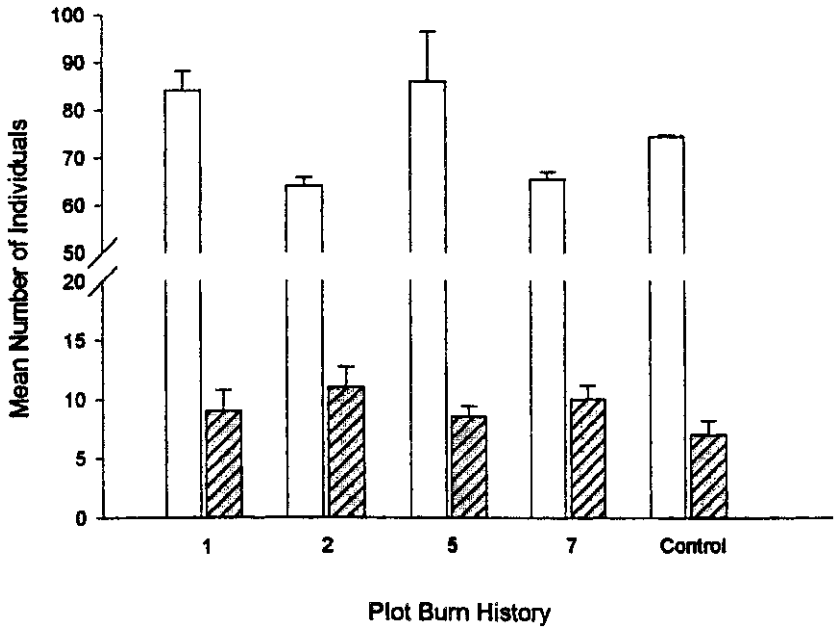

Fig. 2. Number of leafminers on plots with different burn periodicities (1 = 1 year, 2 = 2 years, 5 = 5 years, 7 = 7 years, control = never burned). Means and standard errors shown. ▭ = leafminers on sand live oak, *Quercus geminata*. One way ANOVA: $F_{4,5}$ = 1.330, P = .274. ▨ = leafminers on turkey oak, *Quercus laevis*. One way ANOVA: $F_{4,5}$ = .407, P = .798.

to increased plant richness and diversity after chaparral fire, the insect richness and diversity was also higher (Force 1981). These four studies, plus the present one, suggest that fire increases the density of some insects, particularly grasshoppers, on herbaceous vegetation and that increased plant quality may be the cause. Of three exceptions that we could find, one was a study by Bulan and Barrett (1971) who found Coleoptera, Homoptera, Hemiptera, and Diptera biomass to be significantly lower in burned oats grassland than similar unburned areas, probably because of decreased available producer energy and detritus. However, as Nagel (1973) points out, in natural systems burning is not likely to decrease available producer energy nearly as much as it does in annual plant monocultures. Another exception was a study of prairie grasslands in Kansas which showed forbs were killed by frequent fires and thus the densities of grasshoppers which fed on them were reduced in frequently burned plots, though the densities of grass-feeding grasshoppers were not (Evans 1984). This contrasts with our study where both the density of forbs and grasshoppers were elevated by fire. In does indicate, however, as Evans (1984) suggested, that grasshopper density can be intimately linked to forb density. Finally, a study by Porter and Redak (1997) showed reduced grasshopper density and biomass following spring burns in California, again because host plant densities were reduced. This again is the opposite to our study where the density of the forbs was increased by burning. Taken as a whole, these studies and our results suggest that frequent fire tends to increase the density of grasshoppers as long as it does not kill their host plants outright. This may

TABLE 1. DENSITY OF DEER TONGUE AND DOG TONGUE PER 50M TRANSECTS ON TREATMENT PLOTS WITH DIFFERENT BURN FREQUENCIES (MEANS AND STANDARD DEVIATION SHOWN).

Burn	Plant species	
Frequency years	Deer tongue	Dog tongue
1	35.0 + 21.2	15.2 + 4.9
2	21.5 + 5.0	14.5 + .7
5	25.0 + 21.5	10.0 + 2.8
7	4.0 + 1.4	5.0 + 2.8
Unburned	6.5 + 2.1	7.0 + 4.2

be because of increased plant quantity and quality due to the burns or, it may be due to lower chemical defense content of the plants. The reasons for the collapse in grasshopper densities between the 5 and 7 year burn regimes are not yet clear.

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PSOCOPTERA FROM THE CALAKMUL BIOSPHERE RESERVE, AND NEIGHBORING AREAS (CAMPECHE, MEXICO)

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ABSTRACT

A survey of the Psocoptera of the Calakmul Biosphere Reserve, Campeche, Mexico, was conducted in 1997 and early 1998. The collecting effort was 260 man-hours, excluding the operation of light and Malaise traps. A total of 1675 specimens was taken, representing 96 species, in 48 genera and 23 families. The ∝ Diversity Index for this collection was 22.12. Fifteen species constituted 66.7% of the total number of specimens, and 40 species constituted 3.9% of the same total. Only 18 of the 96 species present in the area are widely distributed locally, whereas 72 of the 96 species in the area showed restricted local distribution. The level of endemism is high (19.79% of the total number of species).

Key Words: Calakmul Biosphere Reserve, Campeche, Mexico, Psocoptera

RESUMEN

Durante 1997 y principios de 1998 se condujo un censo de Psocoptera en la Reserva de la Biósfera de Calakmul, Campeche, en el que el esfuerzo de colecta fue de 260 horas-hombre, sin contar el tiempo de operación de trampas de luz y trampas Malaise. Fueron capturados un total de 1675 ejemplares, que representan a 96 especies, en 48 géneros y 23 familias. El Indice de Diversidad ∝, calculado para ésta colección, fue de

22.12. Quince especies constituyeron el 66.7% del total de ejemplares recolectados, mientras que 40 especies constituyeron 3.9% del mismo total. Sólo 18 de las 96 especies registradas en la área tienen una amplia distribución local, y 72 del total de 96 especies tienen una distribución local muy restringida. El nivel de endemismo es alto (19.76% del total de especies).

The Calakmul Biosphere Reserve, in the Mexican state of Campeche, was created on 22 May, 1989, by decree of the then President of Mexico, Carlos Salinas de Gortari. The reserve is located at the base of the Yucatan Peninsula, in the southwestern corner of Campeche, between 17°49' and 19°11'N and between 89°08' and 90°08'W, bordering on the south with the Guatemalan Peten and partially to the east with the state of Quintana Roo. It covers approximately 7000 square kilometers, or about 14% of the total area of Campeche. It has a peculiar shape (Fig. 1), with two large areas, one to the north and one to the south of the highway Escarcega-Chetumal, separated by a pronounced narrowing that crosses the highway some 15 kilometers west of X'puhil. The defects in the design of the reserve have been widely pointed out and discussed by Galindo Leal (1997). All in all, it constitutes the largest humid forest reserve area in the country, with representation, in order of importance of area covered, of medium subperennifolious forest, low subperennifolious forest, secondary vegetation, perennifolius-subperennifolious evergreen forest, and aquatic vegetation (Gomez Pompa & Dirzo 1995). The area is inhabited by many species of wild animals, threatened or in danger of extinction, such as jaguar, ocelot, jaguarundi, spider and howler monkeys, curassow, harpy eagle and tapir. The area is also rich in Mayan archaeological zones of the Classic period, in architectural styles Peten, Chenes and Rio Bec (e.g. Calakmul, Hormiguero, Chicanna, Becan and Balamkum).

With respect to the Psocoptera fauna, the only notable reference is the record, by Mockford & Garcia Aldrete (1996), of 26 species in Campeche, which were the result of isolated, not systematic insect collecting in several localities in the state, none of these in the reserve area, with only some records from the vicinities of X'puhil. Most of the species recorded were neotropical or pantropical, widely distributed and also occurring in the Caribbean.

The purpose of this work was to survey the fauna of psocids in the reserve area and surroundings, to estimate the relative abundance and local distribution of the species present, and to determine the specific richness of the different sites sampled. The specimens collected are deposited in the National Collection of Insects (Departamento de Zoologia, Instituto de Biologia, UNAM, Apartado Postal 70-153, 04510, Mexico, D.F.)

Materials and Methods

In May and September, 1997, and in February, 1998, psocid collecting was conducted in the reserve area and some neighbouring places. The insects were taken by beating the vegetation, sifting litter, directly examining tree trunks and rock faces, and by using light and Malaise traps. During the first collecting event (1-9.V.1997), the effort was of 135 man-hours, then 70 man-hours during the second collecting event (19-25.IX.1997), and 55 man-hours during the third collecting event (15-19.II.1998). The specimens collected were preserved directly in 80% ethanol. Table 1 presents a list of the collecting localities and their geographic coordinates, and they are also indicated in Figure 1. It is pertinent to point out that no collecting was done in the northern segment of the reserve, nor in the nuclear zones.

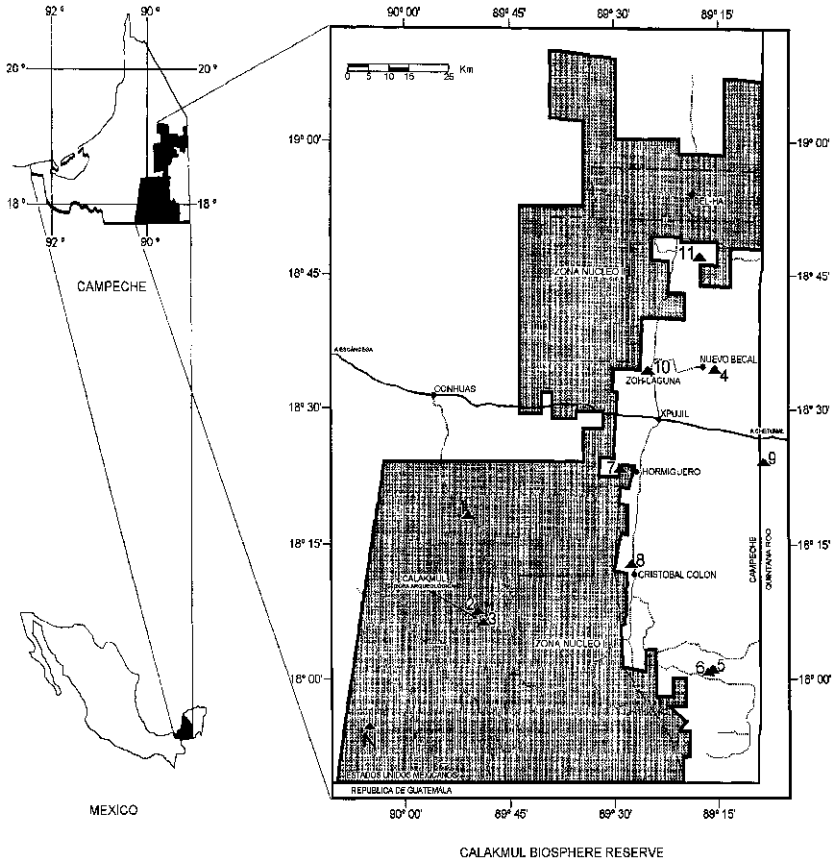

Fig. 1. Location of the Calakmul Biosphere Reserve, Campeche, and Psocoptera collecting localities in the area.

RESULTS

During the first collecting event, 708 psocid specimens were taken, with 58 species being represented. During the second collecting event, 449 specimens were taken, representing 41 species, 16 of which had not been taken during the first event, and during the third collecting event, 518 specimens were taken, representing 66 species, 22 of which had not been previously collected. A total of 1675 specimens was collected, representing 96 psocid species, in 48 genera and 23 families (Table 2).

Figure 2 shows the species accumulation curve for the collecting period. The slope of the line indicates that a fourth collecting episode would have been needed to determine if the curve was or was not in the asymptotic phase. With the evidence that in the third collecting event 22.9% of the total number of species were new additions, it is likely that more unrecorded psocid species could still be found in the area.

Table 2 lists the species of psocids collected in the area, the species and number of specimens taken in each collecting event, the relative abundance of each species, the

TABLE 1. COLLECTING LOCALITIES IN THE CALAKMUL BIOSPHERE RESERVE AND VICINITY.

1.	25 km N of Calakmul archaeological zone, 230 m.	18°17'49"N, 89°50'36"W
2.	Calakmul archaeological zone, ca. large "aguada", 265 m.	18°07'26"N, 89°48'56"W
3.	Calakmul archaeological zone, 265 m.	18°06'35"N, 89°48'17"W
4.	El Chorro, ejido Nuevo Becal, 130 m.	18°35'25"N, 89°15'28"W
5.	Laguna de Alvarado, 316 m.	18°01'54"N, 89°15'45"W
6.	Laguna de Alvarado, 322 m.	18°00'55"N, 89°16'10"W
7.	Hormiguero archaeological zone, 295m.	18°24'10"N, 89°29'13"W
8.	Arroyo Colon, ejido C. Colon, 420 m.	18°12'59"N, 89°27'23"W
9.	San Antonio Soda, ejido Diaz Ordaz, 200 m.	18°24'54"N, 89°08'19"W
10.	Zoh Laguna, ca. "aguada", 327 m.	18°35'21"N, 89°25'07"W
11.	La Mancolona, ejido 20 de Junio, 232 m.	18°48'38"N, 89°17'29"W

amplitude of distribution in the area sampled (A = number of localities in which each species was found), and the hierarchic order of each species (HOS), an ordering in which the species are placed in hierarchy, according to their importance values; in this case, the number of specimens/species was taken as importance value.

The 96 species found represent 48 genera in 23 families. The genus most diverse is *Lachesilla*, with 13 species, followed by *Tapinella, Caecilius* and *Archipsocus*, each with five species; then follow *Echmepteryx, Lithoseopsis* and *Peripsocus,* with four species each, and *Psyllipsocus, Liposcelis, Ectopsocus, Archipsocopsis, Blastopsocus* and *Ptycta,* with three species each. The genera *Cladiopsocus, Hemipsocus* and *Trichadenotecnum* are represented by two species each, and there is a large group of 32 genera represented by only one species each.

In terms of relative abundance, the 96 species are distributed in 38 ranks of hierarchic importance (Fig. 3). The species numerically most important is *Archipsocopsis* sp. 1, with 209 specimens, followed by *Ectopsocus titschacki* Jentsch, with 108 specimens, *Echmepteryx alpha* Garcia Aldrete, with 92 specimens, *Hemipsocus africanus* Enderlein, with 86 specimens, and *Caecilius totonacus* Mockford, with 78 specimens. Together, the 15 most abundant species constitute 66.7% of the total number of individuals, and, on the opposite end, 19 species are represented by one specimen, 16 species are represented by two specimens, and five species are represented by three specimens, so that 40 species constitute only 3.9% of the total of specimens collected.

The $\propto$ Diversity Index [$S = \propto \log (1 + N/\propto)$, cf. Taylor, Kempton & Woiwod (1976)], calculated for the Calakmul psocid collection, resulted in a value of 22.12, one of the highest recorded in the literature, surpassed only by the diversity indices for the Psocoptera of Chamela, Jalisco, Mexico ($\propto = 24.01$, N = 2863, S = 115), Panama Lowlands ($\propto = 24.5$, N = 10092, S = 148), and Los Tuxtlas, Veracruz, Mexico ($\propto = 32.45$, N = 4194, S = 158) (Broadhead & Wolda 1985; Garcia Aldrete 1988; Garcia Aldrete, Mockford & Garcia Figueroa 1997).

Table 3 presents the species and number of specimens of each species collected in each locality during this study; it also includes the habitats in which the species were collected. Since the collecting effort was not the same in each locality, the results are biased; however, the comparatively high species richness of localities 3, 7 and 10 probably reflect also intrinsic differences among the localities sampled. The richer ones are sites physically complex, varied, with several habitats sampled, such as the Calakmul archaeological zone, the Hormiguero archaeological zone or Laguna de Alvarado.

TABLE 2. PSOCOPTERA FROM THE CALAKMUL BIOSPHERE RESERVE, CAMPECHE AND VICINITY (N = NUMBER OF SPECIMENS, %T = PERCENTAGE OF THE TOTAL, A = NUMBER OF LOCALITIES IN WHICH EACH SPECIES WAS COLLECTED, HOS = HIERARCHIC ORDER OF SPECIES).

		1-9. V. 1997 (135 man hours)			19-25. IX. 1997 (70 man hours)			15-19. II. 1998 (55 man hours)						
		males	females	nymphs	males	females	nymphs	males	females	nymphs	N	%T	A	HOS
	TROGIOMORPHA													
	Lepidopsocidae													
1	*Thylacella cubana* (Banks), 1941			2		2				1	5	0,30	4	34
2	*Nepticulomima* Enderlein, 1906					7	14				21	1,25	2	19
3	*Proentomum personatum* Badonnel, 1949		7	12		5	10		3	6	43	2,57	10	12
4	*Soa flaviterminata* Enderlein, 1906		1	7					1		9	0,54	3	30
5	*Echmepteryx alpha Garcia Aldrete, 1984*		38	30		1	4		13	6	92	5,49	7	3
6	*E. falco* Badonnel,1949		4	8							12	0,72	2	27
7	*E. madagascariensis* (Kolbe), 1885		22	9		3	3		5	24	66	3,94	3	7
8	*E. intermedia* Mockford, 1974		5	4		1	2		2	3	17	1,01	4	23
9	*Neolepolepis caribensis* (Turner), 1975					3					3	0,18	1	36
	Psoquillidae													
10	*Rhyopsocus sp.*		1								1	0,06	1	38

TABLE 2. (CONTINUED) PSOCOPTERA FROM THE CALAKMUL BIOSPHERE RESERVE, CAMPECHE AND VICINITY (N = NUMBER OF SPECIMENS, %T = PERCENTAGE OF THE TOTAL, A = NUMBER OF LOCALITIES IN WHICH EACH SPECIES WAS COLLECTED, HOS = HIERARCHIC ORDER OF SPECIES).

		1-9. V. 1997 (135 man hours)			19-25. IX. 1997 (70 man hours)			15-19. II. 1998 (55 man hours)						
		males	females	nymphs	males	females	nymphs	males	females	nymphs	N	%T	A	HOS
	Psyllipsocidae													
11	*Psyllipsocus* Selys-Longchamps, 1872. sp. 1	12	14		1			5	3	1	36	2,15	3	13
12	*P.* sp. 2	8		1				4		5	18	1,07	3	22
13	*P.* sp. 3								1		1	0,06	1	38
	TROCTOMORPHA													
	Amphientomidae													
14	*Lithoseopsis* Mockford, 1993. sp. 1		3	9		2	1		1	4	20	1,19	5	20
15	*L.* sp. 2					1	1				2	0,12	1	37
16	*L.* sp. 3					8	4				12	0,72	1	27
17	*L.* sp. 4								1		1	0,06	1	38
	Compsocidae													
18	*Electrentomopsis variegatus* Mockford, 1967								1	1	2	0,12	1	37
	Liposcelididae													
19	*Belaphopsocus badonneli* New, 1971								2		2	0,12	1	37
20	*Embidopsocus cubanus* Mockford, 1987		1	1							2	0,12	1	37

TABLE 2. (CONTINUED) PSOCOPTERA FROM THE CALAKMUL BIOSPHERE RESERVE, CAMPECHE AND VICINITY (N = NUMBER OF SPECIMENS, %T = PERCENTAGE OF THE TOTAL, A = NUMBER OF LOCALITIES IN WHICH EACH SPECIES WAS COLLECTED, HOS = HIERARCHIC ORDER OF SPECIES).

		1-9. V. 1997 (135 man hours)			19-25. IX. 1997 (70 man hours)			15-19. II. 1998 (55 man hours)						
		males	females	nymphs	males	females	nymphs	males	females	nymphs	N	%T	A	HOS
21	*Liposcelis bostrychopila* Badonnel, 1931								2		2	0,12	2	37
22	*L. ornata* Mockford, 1978		2						1		3	0,18	2	36
23	*Liposcelis* Motschulsky, 1852		1								1	0,06	1	38
24	*Nanopsocus oceanicus* Pearman, 1928		13			2			6		21	1,25	3	19
25	*Tapinella maculata* Mockford & Gurney, 1926	2	6	2	2	3					15	0,90	7	24
26	*T. olmeca* Mockford, 1975	4	25	5	1	6	1		2		44	2,63	6	10
27	*T. vittata* Garcia Aldrete, 1993	2	17	3		4		2	23	2	53	3,16	6	10
28	*Tapinella* Enderlein, 1908. sp. 1		15						4		19	1,13	6	21
29	*T.* sp. 2		8						3		11	0,66	3	28
30	*Pachytroctes ixtapaensis* Garcia Aldrete, 1986								1	3	4	0,24	1	35
	PSOCOMORPHA													
	Epipsocidae													
31	*Epipsocus* Hagen, 1866		2	3					1		6	0,36	2	33
	Dolabellopsocidae													
32	*Dolabellopsocus roseus* Eertmoed, 1973		1								1	0,06	1	38

TABLE 2. (CONTINUED) PSOCOPTERA FROM THE CALAKMUL BIOSPHERE RESERVE, CAMPECHE AND VICINITY (N = NUMBER OF SPECIMENS, %T = PERCENTAGE OF THE TOTAL, A = NUMBER OF LOCALITIES IN WHICH EACH SPECIES WAS COLLECTED, HOS = HIERARCHIC ORDER OF SPECIES).

		1-9. V. 1997 (135 man hours)			19-25. IX. 1997 (70 man hours)			15-19. II. 1998 (55 man hours)						
		males	females	nymphs	males	females	nymphs	males	females	nymphs	N	%T	A	HOS
	Cladiopsocidae													
33	*Cladiopsocus garciai* Eertmoed, 1986							1	4	3	8	0,48	2	31
34	*C. ocotensis* Garcia Aldrete, 1996	1	4	3				1	1	3	13	0,78	2	26
	Ptiloneuridae													
35	*Loneura leonilae* Garcia Aldrete, 1995	1		1							2	0,12	1	37
36	*Triplocania spinosa* Mockford, 1957							3	5	7	15	0,90	2	24
	Asiopsocidae													
37	*Notiopsocus* Banks, 1913					1			3	7	11	0,66	2	28
	Caeciliidae													
38	*Caecilius casarum* Badonnel, 1931		2								2	0,12	1	37
39	*C. totonacus* Mockford, 1966	1	51	27							79	4,72	3	5
40	*Caecilius* Curtis, 1837. Sp. 1							1	4	4	9	0,54	3	30
41	*C.* sp. 2								1		1	0,06	1	38
42	*Xanthocaecilius* Mockford, 1989				1						1	0,06	1	38
	Amphipsocidae													
43	*Dasypsocus roesleri* (New & Thornton), 1975	1	1	7					3	13	25	1,49	4	18

TABLE 2. (CONTINUED) PSOCOPTERA FROM THE CALAKMUL BIOSPHERE RESERVE, CAMPECHE AND VICINITY (N = NUMBER OF SPECIMENS, %T = PERCENTAGE OF THE TOTAL, A = NUMBER OF LOCALITIES IN WHICH EACH SPECIES WAS COLLECTED, HOS = HIERARCHIC ORDER OF SPECIES).

		1-9. V. 1997 (135 man hours)			19-25. IX. 1997 (70 man hours)			15-19. II. 1998 (55 man hours)						
		males	females	nymphs	males	females	nymphs	males	females	nymphs	N	%T	A	HOS
	Lachesillidae													
44	*Anomopsocus* Roesler, 1940							1			1	0,06	1	38
45	*Nanolachesilla* Mockford & Sullivan, 1986								1		1	0,06	1	38
46	*Lachesilla bottimeri* Mockford & Gurney, 1956					1					1	0,06	1	38
47	*L. bifurcata* Garcia Aldrete, 1986								1		1	0,06	1	38
48	*L.* sp. (*forcepeta* group)	2	5	3	2	3	1		3	13	32	1,91	6	14
49	*L. cuala* Garcia Aldrete, 1988								2		2	0,12	1	37
50	*L. denticulata* Garcia Aldrete, 1988	3	2					5	18	35	63	3,76	5	8
51	*L. disjuncta* Garcia Aldrete, 1988	1	7	16				1	1	1	27	1,61	4	16
52	*L. nuptialis* Badonnel & Garcia Aldrete, 1980		5	1		7	5		10		28	1,67	8	15
53	*L. penta* Sommerman, 1946	1	3	17	2	8	1	3	9		44	2,63	7	11
54	*L. riegeli* Sommerman, 1946	1	1			1					3	0,18	2	36
55	*L. tropica* Garcia Aldrete, 1982	3	1			3	1				8	0,48	6	31
56	*L. yanomamioides* Garcia Aldrete, 1996	2	2	9	4	7	7	6	15	26	78	4,66	6	6
57	*Lachesilla* Westwood, 1840. sp. F9 B							2	2	7	11	0,66	1	28
58	*L.* sp. (*pedicularia* group)	1	2		3	1			4		11	0,66	7	28

TABLE 2. (CONTINUED) PSOCOPTERA FROM THE CALAKMUL BIOSPHERE RESERVE, CAMPECHE AND VICINITY (N = NUMBER OF SPECIMENS, %T = PERCENTAGE OF THE TOTAL, A = NUMBER OF LOCALITIES IN WHICH EACH SPECIES WAS COLLECTED, HOS = HIERARCHIC ORDER OF SPECIES).

		1-9. V. 1997 (135 man hours)			19-25. IX. 1997 (70 man hours)			15-19. II. 1998 (55 man hours)						
		males	females	nymphs	males	females	nymphs	males	females	nymphs	N	%T	A	HOS
	Ectopsocidae													
59	*Ectopsocus mexicanus* Garcia Aldrete, 1991							1			1	0,06	1	38
60	*E. titschacki* Jentsch, 1929	17	45	12	10	16	2	2	3	1	108	6,45	7	2
61	*E. vilhenai* Badonnel, 1955	4	6								10	0,60	3	29
	Peripsocidae													
62	*Peripsocus potosi* Mockford, 1971		1			3			1		5	0,30	3	34
63	*P. chamelanus* Badonnel, 1986					1			1		2	0,12	2	37
64	*P. ca. stagnivagus* Chapman, 1930		1						1		2	0,12	2	37
65	*P.* sp. 1		1						2		3	0,18	2	36
	Archipsocidae													
66	*Archipsocopsis* Badonnel, 1966. sp. 1	1	54	2	8	101	42		1		209	12,48	7	1
67	*A.* sp. 2		5			1	1				7	0,42	2	32
68	*A.* sp. 3	1	1								2	0,12	1	37
69	*Archipsocus* Hagen, 1882 sp. 1		2								2	0,12	1	37
70	*A.* sp. 2		7	1		4	1		33	11	57	3,40	9	9
71	*A.* sp. 3	1	1								2	0,12	1	37
72	*A.* sp. 4		2								2	0,12	2	37
73	*A.* sp. 5		1								1	0,06	1	38

TABLE 2. (CONTINUED) PSOCOPTERA FROM THE CALAKMUL BIOSPHERE RESERVE, CAMPECHE AND VICINITY (N = NUMBER OF SPECIMENS, %T = PERCENTAGE OF THE TOTAL, A = NUMBER OF LOCALITIES IN WHICH EACH SPECIES WAS COLLECTED, HOS = HIERARCHIC ORDER OF SPECIES).

		1-9. V. 1997 (135 man hours)			19-25. IX. 1997 (70 man hours)			15-19. II. 1998 (55 man hours)						
		males	females	nymphs	males	females	nymphs	males	females	nymphs	N	%T	A	HOS
74	*Pseudarchipsocus guajiro* Mockford, 1974				1	2					3	0,18	1	36
	Pseudocaeciliidae													
75	*Pseudocaecilius citricola* (Ashmead), 1879		1	1					3	2	7	0,42	4	32
76	*Heterocaecilius badonneli* Garcia Aldrete, 1989				4	6	4				14	0,84	1	25
77	*Scytopsocus* Roesler, 1940 (ca. coriaceous Roesler, 1940)					2	1		1	3	7	0,42	3	32
	Philotarsidae													
78	*Haplophallus* Thornton, 1959							2	1	3	6	0,36	3	33
79	*Aaroniella* Mockford, 1951								1	1	2	0,12	1	37
	Elipsocidae													
80	*Palmicola* Mockford, 1955		1	1							2	0,12	2	37
81	*Nepiomorpha brasiliana* Badonnel, 1973							1	14		15	0,90	2	24
	Hemipsocidae													
82	*Hemipsocus africanus* Enderlein, 1907	6	13	7	12	28	14	2	4		86	5,13	5	4
83	*H. pretiosus* Banks, 1930		2	5					1		8	0,48	1	31

TABLE 2. (CONTINUED) PSOCOPTERA FROM THE CALAKMUL BIOSPHERE RESERVE, CAMPECHE AND VICINITY (N = NUMBER OF SPECIMENS, %T = PERCENTAGE OF THE TOTAL, A = NUMBER OF LOCALITIES IN WHICH EACH SPECIES WAS COLLECTED, HOS = HIERARCHIC ORDER OF SPECIES).

		1-9. V. 1997 (135 man hours)			19-25. IX. 1997 (70 man hours)			15-19. II. 1998 (55 man hours)						
		males	females	nymphs	males	females	nymphs	males	females	nymphs	N	%T	A	HOS
	Psocidae													
84	*Blastopsocus* Roesler, 1943. Sp.1		1					2	2		5	0,30	3	34
85	*B.* sp. 2						1		1	16	18	1,07	2	22
86	*B.* sp. 3							1			1	0,06	1	38
87	*Cerastipsocus trifasciatus* (Provancher), 1876		1		1	1				14	17	1,01	3	23
88	*Metylophorus* Pearman, 1932								1		1	0,06	1	38
89	*Steleops* Enderlein, 1910			1							1	0,06	1	38
90	*Ptycta* Enderlein, 1925. sp. 1			1							1	0,06	1	38
91	*P.* sp. 2							1			1	0,06	1	38
92	*P. tikala* (Mockford), 1957				1						1	0,06	1	38
93	*Trichadenotecnum* Enderlein, 1909. sp. 1					1		1	1	2	5	0,30	2	34
94	*T.* sp. 2					1		1	2		4	0,24	2	35
	Myopsocidae													
95	*Lichenomima varia* (Navas), 1927				15	9	1	1			26	1,55	2	17
96	*Myopsocus* Hagen, 1866		5	1					3		9	0,54	4	30
TOTAL		76	423	212	68	256	122	50	240	228				
TOTAL			711			446			518		1675			
α DIVERSITY INDEX (S = α log (1+N/α)) =			22,12											

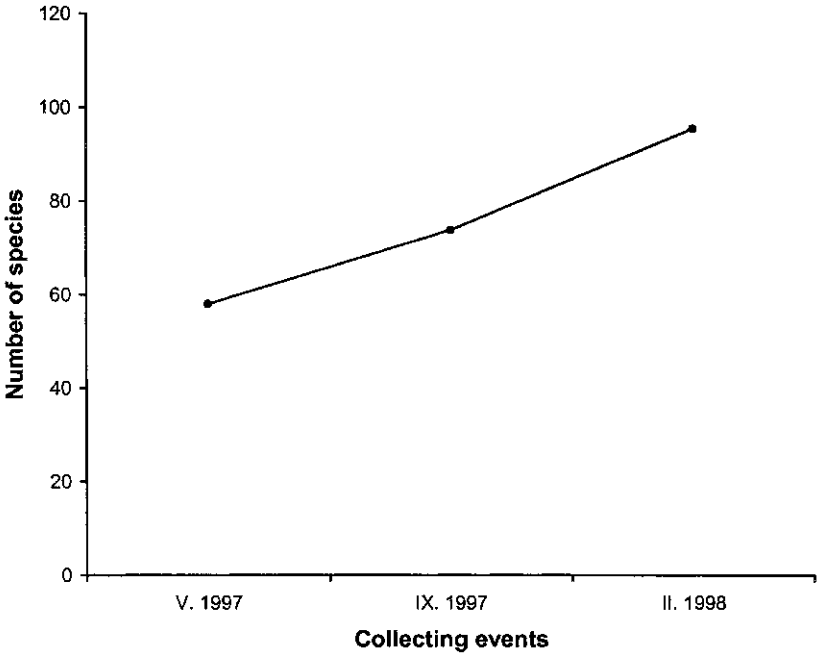

Fig. 2. Species accumulation curve for the Psocoptera of the Calakmul area. May 1997-February 1998.

The species of psocids collected in the Calakmul area, can be assigned to the following biogeographic categories:

I. Endemics and presumed endemics (19 species).

Nepticulomima sp., *Rhyopsocus* sp., *Psyllipsocus* sp. 2, *Lithoseopsis* sp. 4, *Liposcelis* sp., *Tapinella* sp. 1, *Xanthocaecilius* sp., *Nanolachesilla* sp., *Peripsocus* sp. 4, *Archipsocopsis* sp. 3, *Palmicola* sp., *Blastopsocus* spp.1, 2, and 3, *Metylophorus* sp., *Steleops* sp., *Ptycta* sp.1, and *Trichadenotecnum* spp. 1 and 2.

II. Tropical waifs (9 species).

Proentomum personatum Badonnel, *Soa flaviterminata* Enderlein, *Echmepteryx falco* Badonnel, *E. madagascariensis* (Kolbe), *Nanopsocus oceanicus* Pearman, *Ectopsocus titschacki* Jentsch, *E. vilhenai* Badonnel, *Pseudocaecilius citricola* (Ashmead) and *Hemipsocus africanus* Enderlein.

III. Cosmopolitan species (2 species).

Liposcelis bostrychophila Badonnel, *Caecilius casarum* Badonnel.

IV. Species widespread in tropical and subtropical America (9 species).

Thylacella cubana (Banks), *Belaphopsocus badonneli* New, *Liposcelis ornata* Mockford, *Tapinella maculata* Mockford & Gurney, *Dasypsocus*

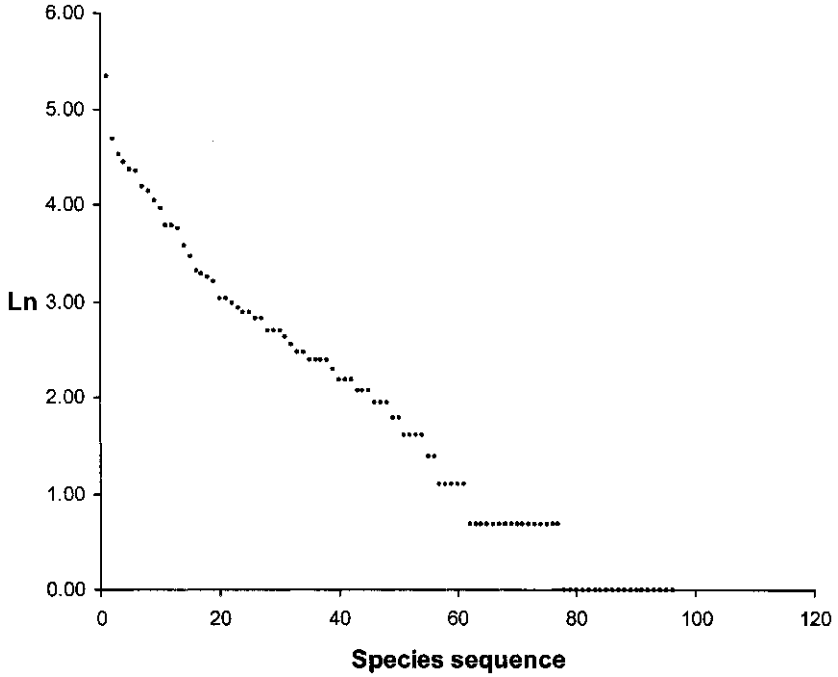

Fig. 3. Species abundance distribution of the collection of Psocoptera from the Calakmul Biosphere Reserve and surrounding areas. Log. of abundance ranked against species. $\propto = 22.12$.

roesleri (New & Thornton), *Lachesilla cuala* Garcia Aldrete, *Peripsocus potosi* Mockford, *Nepiomorpha brasiliana* Badonnel, and *Cerastipsocus trifasciatus* (Provancher).

V. Species occurring in Mexico and southeastern USA (2 species).

Lachesilla bottimeri Mockford & Gurney, *L. penta* Sommerman.

VI. Species occurring in tropical Mexico and Guatemala or Belize, not extending to Central America and the Caribbean (7 species).

Echmepteryx alpha Garcia Aldrete, *Cladiopsocus garciai* Eertmoed, *Triplocania spinosa* Mockford, *Anomopsocus* sp. *a, Lachesilla disjuncta* Garcia Aldrete, *L. nuptialis* Badonnel & Garcia Aldrete, *Ptycta tikala* Mockford.

VII. Species occurring in tropical Mexico, Central America and the Caribbean (2 species).

Lachesilla denticulata Garcia Aldrete, *L. riegeli* Sommerman.

VIII. Species occurring in tropical Mexico and the Caribbean (5 species).

Echmepteryx intermedia Mockford, *Neolepolepis caribensis* (Turner), *Tapinella olmeca* Mockford, *Lachesilla yanomamioides* Garcia Aldrete, *Hemipsocus pretiosus* Banks.

TABLE 3. PSOCOPTERA OF THE CALAKMUL BIOSPHERE RESERVE, CAMPECHE, AND VICINITY. NUMBER OF SPECIES TAKEN IN EACH LOCALITY, AND HABITATS IN WHICH EACH SPECIES WAS COLLECTED. I. BRANCHES AND FOLIAGE OF SHRUBS. II. LEAF LITTER. III. TREE TRUNKS AND BARK. IV. *TYPHA* FOLIAGE. V. DEAD PALM FRONDS. VI. BROMELIADS, ORCHIDS AND OTHER EPIPHYTES. VII. HERBACEOUS PLANTS. VIII. CALCAREOUS ROCK FACES. IX. ABANDONED TERMITE NEST. X. MALAISE TRAP. XI. LIGHT TRAP.

		Localities											Habitats										
		1	2	3	4	5	6	7	8	9	10	11	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
	TROGIOMORPHA																						
	Lepidopsocidae																						
1	*Thylacella cubana* (Banks), 1941	2		1		1							*	*								*	
2	*Nepticulomima* Enderlein, 1906										17	4	*								*	*	*
3	*Proentomum personatum* Badonnel, 1949		2	11	1	1	12	2	1	1	5	7	*	*			*	*	*		*	*	
4	*Soa flaviterminata* Enderlein, 1906			5			1	3						*				*					
5	*Echmepteryx alpha* Garcia Aldrete, 1984		12	23		10	5	29	6		7		*	*	*	*	*	*	*	*	*	*	*
6	*E. falco* Badonnel, 1949					6	6						*	*	*	*				*			
7	*E. madagascariensis* (Kolbe), 1885				14			45	7						*								
8	*E. intermedia* Mockford, 1974		3	5				5			4		*					*					

TABLE 3. (CONTINUED) PSOCOPTERA OF THE CALAKMUL BIOSPHERE RESERVE, CAMPECHE, AND VICINITY. NUMBER OF SPECIES TAKEN IN EACH LOCALITY, AND HABITATS IN WHICH EACH SPECIES WAS COLLECTED. I. BRANCHES AND FOLIAGE OF SHRUBS. II. LEAF LITTER. III. TREE TRUNKS AND BARK. IV. *TYPHA* FOLIAGE. V. DEAD PALM FRONDS. VI. BROMELIADS, ORCHIDS AND OTHER EPIPHYTES. VII. HERBACEOUS PLANTS. VIII. CALCAREOUS ROCK FACES. IX. ABANDONED TERMITE NEST. X. MALAISE TRAP. XI. LIGHT TRAP.

		Localities											Habitats										
		1	2	3	4	5	6	7	8	9	10	11	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
9	*Neolepolepis caribensis* (Turner), 1975		3										*										
	Psoquillidae																						
10	*Rhyopsocus* sp.								1													*	
	Psyllipsocidae																						
11	*Psyllipsocus* Selys-Longchamps, 1872. sp. 1			12			11	13												*		*	
12	*P.* sp. 2			7			9	2												*			
13	*P.* sp. 3			1																*			
	TROCTOMORPHA																						
	Amphientomidae																						
14	*Lithoseopsis* Mockford, 1993. sp. 1	2	1	13			2	2					*		*					*			
15	*L.* sp. 2			2																*			
16	*L.* sp. 3			12																*			
17	*L.* sp. 4										1				*								

TABLE 3. (CONTINUED) PSOCOPTERA OF THE CALAKMUL BIOSPHERE RESERVE, CAMPECHE, AND VICINITY. NUMBER OF SPECIES TAKEN IN EACH LOCALITY, AND HABITATS IN WHICH EACH SPECIES WAS COLLECTED. I. BRANCHES AND FOLIAGE OF SHRUBS. II. LEAF LITTER. III. TREE TRUNKS AND BARK. IV. *TYPHA* FOLIAGE. V. DEAD PALM FRONDS. VI. BROMELIADS, ORCHIDS AND OTHER EPIPHYTES. VII. HERBACEOUS PLANTS. VIII. CALCAREOUS ROCK FACES. IX. ABANDONED TERMITE NEST. X. MALAISE TRAP. XI. LIGHT TRAP.

		Localities											Habitats										
		1	2	3	4	5	6	7	8	9	10	11	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
	Compsocidae																						
18	*Electrentomopsis variegatus* Mockford, 1967			2											*								
	Liposcelididae																						
19	*Belaphopsocus badonneli* New, 1971							2							*								
20	*Embidopsocus cubanus* Mockford, 1987							2					*										
21	*Liposcelis bostrychopila* Badonnel, 1931			1				1									*						
22	*L. ornata* Mockford, 1978					2					1				*	*							
23	*Liposcelis* Motschulsky, 1852							1					*										
24	*Nanopsocus oceanicus* Pearman, 1928			18			1				2		*				*						
25	*Tapinella maculata* Mockford & Gurney, 1926	1			5	1		5	1	1		1	*				*		*				

TABLE 3. (CONTINUED) PSOCOPTERA OF THE CALAKMUL BIOSPHERE RESERVE, CAMPECHE, AND VICINITY. NUMBER OF SPECIES TAKEN IN EACH LOCALITY, AND HABITATS IN WHICH EACH SPECIES WAS COLLECTED. I. BRANCHES AND FOLIAGE OF SHRUBS. II. LEAF LITTER. III. TREE TRUNKS AND BARK. IV. *TYPHA* FOLIAGE. V. DEAD PALM FRONDS. VI. BROMELIADS, ORCHIDS AND OTHER EPIPHYTES. VII. HERBACEOUS PLANTS. VIII. CALCAREOUS ROCK FACES. IX. ABANDONED TERMITE NEST. X. MALAISE TRAP. XI. LIGHT TRAP.

		Localities											Habitats										
		1	2	3	4	5	6	7	8	9	10	11	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
26	*T. olmeca* Mockford, 1975		16	18	2			6		1	1		*				*		*				
27	*T. vittata* Garcia Aldrete, 1993		4	27	1	8		9			4		*	*	*		*	*		*			
28	*Tapinella* Enderlein, 1908. sp. 1		2	1		1	2	10			3		*							*			
29	*T.* sp. 2			7		1		3					*				*	*					
30	*Pachytroctes ixtapaensis* Garcia Aldrete, 1986			4									*										
	PSOCOMORPHA																						
	Epipsocidae																						
31	*Epipsocus* Hagen, 1866			1				5						*								*	
	Dolabellopsocidae																						
32	*Dolabellopsocus roseus* Eertmoed, 1973							1					*										
	Cladiopsocidae																						
33	*Cladiopsocus garciai* Eertmoed, 1986			7				1					*	*	*			*					

TABLE 3. (CONTINUED) PSOCOPTERA OF THE CALAKMUL BIOSPHERE RESERVE, CAMPECHE, AND VICINITY. NUMBER OF SPECIES TAKEN IN EACH LOCALITY, AND HABITATS IN WHICH EACH SPECIES WAS COLLECTED. I. BRANCHES AND FOLIAGE OF SHRUBS. II. LEAF LITTER. III. TREE TRUNKS AND BARK. IV. *TYPHA* FOLIAGE. V. DEAD PALM FRONDS. VI. BROMELIADS, ORCHIDS AND OTHER EPIPHYTES. VII. HERBACEOUS PLANTS. VIII. CALCAREOUS ROCK FACES. IX. ABANDONED TERMITE NEST. X. MALAISE TRAP. XI. LIGHT TRAP.

		Localities											Habitats									
		1	2	3	4	5	6	7	8	9	10	11	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
34	*C. ocotensis* Garcia Aldrete, 1996			5		8											*	*					
	Ptiloneuridae																						
35	*Loneura leonilae* Garcia Aldrete, 1995					2														*		*	
36	*Triplocania spinosa* Mockford, 1957			14				1							*					*			
	Asiopsocidae																						
37	*Notiopsocus* Banks, 1913			9							2		*					*				*	
	Caeciliidae																						
38	*Caecilius casarum* Badonnel, 1931				2												*						
39	*C. totonacus* Mockford, 1966					1	69	9					*	*									
40	*Caecilius* Curtis, 1837. sp. 1			6				1			2		*									*	
41	*C.* sp. 2			1									*										
42	*Xanthocaecilius* Mockford, 1989										1											*	

TABLE 3. (CONTINUED) PSOCOPTERA OF THE CALAKMUL BIOSPHERE RESERVE, CAMPECHE, AND VICINITY. NUMBER OF SPECIES TAKEN IN EACH LOCALITY, AND HABITATS IN WHICH EACH SPECIES WAS COLLECTED. I. BRANCHES AND FOLIAGE OF SHRUBS. II. LEAF LITTER. III. TREE TRUNKS AND BARK. IV. *TYPHA* FOLIAGE. V. DEAD PALM FRONDS. VI. BROMELIADS, ORCHIDS AND OTHER EPIPHYTES. VII. HERBACEOUS PLANTS. VIII. CALCAREOUS ROCK FACES. IX. ABANDONED TERMITE NEST. X. MALAISE TRAP. XI. LIGHT TRAP.

		Localities											Habitats										
		1	2	3	4	5	6	7	8	9	10	11	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
	Amphipsocidae																						
43	*Dasypsocus roesleri* (New & Thornton), 1975		2	18			2	3					*	*				*		*			
	Lachesillidae																						
44	*Anomopsocus* Roesler, 1940							1					*										
45	*Nanolachesilla* Mockford & Sullivan, 1986							1					*									*	
46	*Lachesilla bottimeri* Mockford & Gurney, 1956				1												*						
47	*L. bifurcata* Garcia Aldrete, 1986			1														*					
48	*L.* sp. (*forcepeta* group)		2	14				6	5	4	1		*						*				
49	*L. cuala* Garcia Aldrete, 1988										2		*										
50	*L. denticulata* Garcia Aldrete, 1988		4	29	1			23			6		*					*				*	*

TABLE 3. (CONTINUED) PSOCOPTERA OF THE CALAKMUL BIOSPHERE RESERVE, CAMPECHE, AND VICINITY. NUMBER OF SPECIES TAKEN IN EACH LOCALITY, AND HABITATS IN WHICH EACH SPECIES WAS COLLECTED. I. BRANCHES AND FOLIAGE OF SHRUBS. II. LEAF LITTER. III. TREE TRUNKS AND BARK. IV. *TYPHA* FOLIAGE. V. DEAD PALM FRONDS. VI. BROMELIADS, ORCHIDS AND OTHER EPIPHYTES. VII. HERBACEOUS PLANTS. VIII. CALCAREOUS ROCK FACES. IX. ABANDONED TERMITE NEST. X. MALAISE TRAP. XI. LIGHT TRAP.

		Localities											Habitats										
		1	2	3	4	5	6	7	8	9	10	11	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
51	*L. disjuncta* Garcia Aldrete, 1988		2	7		17		1					*					*					
52	*L. nuptialis* Badonnel & Garcia Aldrete, 1980		2	6	1	1	3	5			9	1	*	*								*	*
53	*L. penta* Sommerman, 1946		5	3		19	2	3		6	6		*										*
54	*L. riegeli* Sommerman, 1946							2			1		*										
55	*L. tropica* Garcia Aldrete, 1982					1	1	1	1	1	3		*						*			*	*
56	*L. yanomamioides* Garcia Aldrete, 1996		10	22		1		37		2	6		*					*					
57	*Lachesilla* Westwood, 1840. sp. F9B			11									*										
58	*L.* sp. (*pedicularia* group)	1	3	2				2	1	1	1		*						*				
	Ectopsocidae																						
59	*Ectopsocus mexicanus* Garcia Aldrete, 1991			1											*								
60	*E. titschacki* Jentsch, 1929		19	11	4	6	40	10			18		*	*		*	*	*		*			

TABLE 3. (CONTINUED) PSOCOPTERA OF THE CALAKMUL BIOSPHERE RESERVE, CAMPECHE, AND VICINITY. NUMBER OF SPECIES TAKEN IN EACH LOCALITY, AND HABITATS IN WHICH EACH SPECIES WAS COLLECTED. I. BRANCHES AND FOLIAGE OF SHRUBS. II. LEAF LITTER. III. TREE TRUNKS AND BARK. IV. *TYPHA* FOLIAGE. V. DEAD PALM FRONDS. VI. BROMELIADS, ORCHIDS AND OTHER EPIPHYTES. VII. HERBACEOUS PLANTS. VIII. CALCAREOUS ROCK FACES. IX. ABANDONED TERMITE NEST. X. MALAISE TRAP. XI. LIGHT TRAP.

		Localities											Habitats										
		1	2	3	4	5	6	7	8	9	10	11	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
61	*E. vilhenai* Badonnel, 1955				3			2	5				*									*	
	Peripsocidae																						
62	*Peripsocus potosi* Mockford, 1971			1				1			3		*										
63	*P. chamelanus* Badonnel, 1986							1			1		*										
64	*P. ca. stagnivagus* Chapman, 1930		1								1		*					*					
65	*P.* sp. 1		1	2									*					*					
	Archipsocidae																						
66	*Archipsocopsis* Badonnel, 1966. sp. 1		1	1		8	47	1		18	13		*	*								*	
67	*A.* sp. 2						5			2	3		*									*	
68	*A.* sp. 3						2							*									
69	*Archipsocus* Hagen, 1882 sp. 1						2						*										
70	*A.* sp. 2		1	9	1	2	2	2	1	3	36		*	*	*							*	
71	*A.* sp. 3						2						*										

TABLE 3. (CONTINUED) PSOCOPTERA OF THE CALAKMUL BIOSPHERE RESERVE, CAMPECHE, AND VICINITY. NUMBER OF SPECIES TAKEN IN EACH LOCALITY, AND HABITATS IN WHICH EACH SPECIES WAS COLLECTED. I. BRANCHES AND FOLIAGE OF SHRUBS. II. LEAF LITTER. III. TREE TRUNKS AND BARK. IV. *TYPHA* FOLIAGE. V. DEAD PALM FRONDS. VI. BROMELIADS, ORCHIDS AND OTHER EPIPHYTES. VII. HERBACEOUS PLANTS. VIII. CALCAREOUS ROCK FACES. IX. ABANDONED TERMITE NEST. X. MALAISE TRAP. XI. LIGHT TRAP.

		Localities											Habitats										
		1	2	3	4	5	6	7	8	9	10	11	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
72	*A.* sp. 4	1			1								*									*	
73	*A.* sp. 5						1													*			
74	*Pseudarchipsocus guajiro* Mockford, 1974									3			*										
	Pseudocaeciliidae																						
75	*Pseudocaecilius citricola* (Ashmead), 1879		1	1			1	4					*	*									*
76	*Heterocaecilius badonneli* Garcia Aldrete, 1989				14								*				*						
77	*Scytopsocus* Roesler, 1940 (ca. coriaceous Roesler, 1940)			3							3	1	*	*				*					
	Philotarsidae																						
78	*Haplophallus* Thornton, 1959			1				1			4		*										
79	*Aaroniella* Mockford, 1951										2		*										

TABLE 3. (CONTINUED) PSOCOPTERA OF THE CALAKMUL BIOSPHERE RESERVE, CAMPECHE, AND VICINITY. NUMBER OF SPECIES TAKEN IN EACH LOCALITY, AND HABITATS IN WHICH EACH SPECIES WAS COLLECTED. I. BRANCHES AND FOLIAGE OF SHRUBS. II. LEAF LITTER. III. TREE TRUNKS AND BARK. IV. *TYPHA* FOLIAGE. V. DEAD PALM FRONDS. VI. BROMELIADS, ORCHIDS AND OTHER EPIPHYTES. VII. HERBACEOUS PLANTS. VIII. CALCAREOUS ROCK FACES. IX. ABANDONED TERMITE NEST. X. MALAISE TRAP. XI. LIGHT TRAP.

		Localities											Habitats									
		1	2	3	4	5	6	7	8	9	10	11	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
	Elipsocidae																						
80	*Palmicola* Mockford, 1955					1	1						*		*								
81	*Nepiomorpha brasiliana* Badonnel, 1973			1				14					*										
	Hemipsocidae																						
82	*Hemipsocus africanus* Enderlein, 1907		1		58			6		16	5			*	*		*					*	*
83	*H. pretiosus* Banks, 1930			8										*			*						
	Psocidae																						
84	*Blastopsocus* Roesler, 1943. Sp.1			3				1			1		*		*					*			*
85	*B.* sp. 2			14							4		*		*			*					
86	*B*. sp. 3			1																*			
87	*Cerastipsocus trifasciatus* (Provancher), 1876		3	13				1					*										*
88	*Metylophorus* Pearman, 1932			1											*								

TABLE 3. (CONTINUED) PSOCOPTERA OF THE CALAKMUL BIOSPHERE RESERVE, CAMPECHE, AND VICINITY. NUMBER OF SPECIES TAKEN IN EACH LOCALITY, AND HABITATS IN WHICH EACH SPECIES WAS COLLECTED. I. BRANCHES AND FOLIAGE OF SHRUBS. II. LEAF LITTER. III. TREE TRUNKS AND BARK. IV. *TYPHA* FOLIAGE. V. DEAD PALM FRONDS. VI. BROMELIADS, ORCHIDS AND OTHER EPIPHYTES. VII. HERBACEOUS PLANTS. VIII. CALCAREOUS ROCK FACES. IX. ABANDONED TERMITE NEST. X. MALAISE TRAP. XI. LIGHT TRAP.

		Localities											Habitats										
		1	2	3	4	5	6	7	8	9	10	11	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
89	*Steleops* Enderlein, 1910				1										*								
90	*Ptycta* Enderlein, 1925. sp. 1							1					*										
91	*P.* sp. 2			1																*			
92	*P. tikala* (Mockford), 1957										1												*
93	*Trichadenotecnum* Enderlein, 1909. sp. 1			4								1	*										
94	*T.* sp. 2			3							1		*		*								
	Myopsocidae																						
95	*Lichenomima varia* (Navas), 1927		25	1											*					*			
96	*Myopsocus* Hagen, 1866			2		4	2	1							*		*	*		*		*	
Number of species		5	25	57	16	22	25	50	10	13	36	6	62	19	22	4	21	21	7	20	3	22	11
Number of individuals		7	126	408	110	102	231	290	29	59	298	15											

IX. Species occurring in tropical Mexico and Central America (5 species).

Caecilius totonacus Mockford, *C.* sp. 3, *Lachesilla tropica* Garcia Aldrete, *Scytopsocus* ca. *coriaceous* Roesler, *Lichenomima varia* (Navas).

X. Species restricted to the Yucatan Peninsula (5 species).

Psyllipsocus spp. 1 and 3, *Lithoseopsis* sp. 1, *Loneura leonilae* Garcia Aldrete, *Ptycta* sp. 2.

XI. Species occurring in the Yucatan Peninsula and neighbouring areas (6 species).

Lithoseopsis spp. 2 and 3, *Archipsocus* sp. 1, *Heterocaecilius badonneli* Garcia Aldrete, *Aaroniella* sp., *Myopsocus* sp.

XII. Species occurring in tropical Mexico (20 species).

Electrentomopsis variegatus Mockford, *Tapinella vittata* Garcia Aldrete, *Pachytroctes ixtapaensis* Garcia Aldrete, *Epipsocus* sp., *Dolabellopsocus roseus* Eertmoed, *Cladiopsocus ocotensis* Garcia Aldrete, *Caecilius* sp. 2, *Lachesilla bifurcata* Garcia Aldrete, *L.* sp. (*forcepeta* group), *L. pedicularia group*, *Ectopsocus mexicanus* Garcia Aldrete, *Peripsocus chamelanus* Badonnel, *P.* ca. *stagnivagus* Chapman, *Archipsocopsis* spp. 1 and 2, *Archipsocus* spp. 2, 3, 4, and 5, *Haplophallus* sp.

XIII. Species occurring in Cuba (2 species).

Embidopsocus cubanus Mockford, *Pseudarchipsocus guajiro* Mockford.

XIV. Species restricted to Guatemala or Belize (3 species).

Tapinella sp. 2, *Notiopsocus* sp., *Lachesilla* F9B.

Given the geographic location of Calakmul, the composition of its psocid fauna does not contain elements of surprise and it is rather as expected for an area near the edge of tropical Mexico, and close to Central America and the Caribbean; it is dominated by Mexican tropical species, with the addition of the species widespread in tropical America, plus the species also shared with Central America and the Caribbean region, plus the usual array of tropical waifs and cosmopolitans. Categories IX and X, of species restricted to the Yucatan Peninsula or occurring nearby, point to the biotic distinctness of that area (see also Barrera 1962). The category of endemics, comprising 19.79% of the fauna of Calakmul, gives it the element of uniqueness. It is pertinent to note that 18 of the 26 species previously recorded in Campeche, were found in the area of the Calakmul Reserve.

The results of this survey indicate that the psocid community of the Calakmul Biosphere Reserve area is rich in species, with a high proportion of endemics. It also indicates that the community shows fragility in that there is a large number of "rare" species (e.g. 40 species of which only 1-3 specimens were collected throughout the sampling period), and in that a large number of species have only a small amplitude of local distribution (e.g. 72 species collected in only one or two localities), with which environmental changes, either natural or anthropogenic, could result in local extinctions.

ACKNOWLEDGEMENTS

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DEVELOPMENT OF PARASITOID INOCULATED SEEDLING TRANSPLANTS FOR AUGMENTATIVE BIOLOGICAL CONTROL OF SILVERLEAF WHITEFLY (HOMOPTERA: ALEYRODIDAE)

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ABSTRACT

Methods are presented for producing banker plants, transplants that are used for augmentation of *Eretmocerus* parasitoids for biological control of *Bemisia argentifolii* in cucurbit crops. Preference tests were conducted with *B. argentifolii* and its parasitoid *Eretmocerus hayati* for ten cantaloupe varieties to determine their suitability for use as banker plants. *Bemisia argentifolii* showed a significant preference for the varieties Copa de Oro and Mission, whereas, *E. hayati* showed the greatest preference for Copa de Oro, Mission and Primo. The impact of imidacloprid on the development of parasitoid immatures on banker plants was evaluated. Thirteen days after release of *E. hayati*, banker plants treated with imidacloprid produced equivalent numbers of parasitoids as did control plants. Field trials, incorporating the use of banker plants and imidacloprid, were conducted for two seasons in spring cantaloupes and one season in fall watermelons. Numbers of parasitoid progeny produced per cantaloupe banker plant were approximately 94.6 and 102.1 in two trials during the Spring of 1997 and 1998. Field release rates per acre in cantaloupe were estimated to be 68,946 and 29,970 for the 1997 and 1998 trials, with banker plants incorporated with regular transplants at a ratio of 1:10 and 1:30 respectively. In the watermelon trial, the mean number of parasitoid progeny produced per banker plant was determined to be 94.6, with an estimated 4156 released per acre with a ratio of 1:30 banker to regular transplants. Banker plants were shown to be a reliable method for field delivery of *Eretmocerus* parasitoids in transplanted and direct seeded cantaloupe or watermelon crops. The methods used to produce parasitoid inoculated banker plants are discussed.

Key Words: augmentation, parasitoids, *Eretmocerus hayati, Bemisia argentifolii*, imidacloprid

RESUMEN

Se discuten métodos para la producción de "banker plants", transplantes en los que se liberan parasitoides de *Eretmocerus*, para el control biológico de la mosca blanca, *Bemisia argentifolii* (= *B. tabaci* biotipo B) en cucurbitáceas. Se realizaron pruebas de preferencia con *B. argentifolii* y su parasitoide *Eretmocerus hayati* en 10 cvs. de melón "cantaloupe" para determinar la efectividad de esta planta como banker. *B. argentifolii* mostró una preferencia significativa por los cvs. Copa de Oro y Mission, mientras que *E. hayati* mostró preferencia por Copa de Oro, Mission y Primo. Se evaluó el impacto de imidacloprid en el desarrollo de parasitoides inmaduros en plantas banker. Trece días después de la liberación de *E. hayati*, las plantas banker tratadas con imidacloprid produjeron la misma cantidad de parasitoides que las plantas no tratadas. Se llevaron a cabo experimentos de campo usando plantas banker e imidacloprid durante dos temporadas en melones de primavera y durante una temporada en sandía de otoño. La progenie de parasitoides producida por cada planta de melón

banker fue de 94.6 y 102.1 en dos ensayos efectuados durante la primavera de 1997 y 1998. En melón, la tasa de liberación en campo por acre se estimó en 68,946 y 29,970 para los ensayos efectuados en 1997 y 1998, en los cuales se incorporaron plantas banker en proporción de 1:10 y 1:30, respectivamente. En sandía, la progenie de parasitoides promedio por planta banker fue 94.6. La cantidad de parasitoides liberada por acre se estimó en 4,156, con una proporción de plantas banker de 1:30. El uso de plantas banker representa un método confiable para la distribución de parasitoides *Eretmocerus* en el campo, tanto en melón o sandía de transplante o siembra directa. Se discuten los métodos empleados para la producción de plantas banker inoculadas.

Bemisia argentifolii (=*Bemisia tabaci* Biotype B), Silverleaf whitefly (SLWF), continues to be a serious pest of annual row crops such as cotton, cole crops, cucurbits, okra, sesame, and tomato, in the subtropical growing areas across the US and worldwide (DeQuattro 1997, Legaspi et al. 1997, Riley & Ciomperlik 1997). Damage is caused not only by direct feeding but also through transmission of geminiviruses (Brown & Bird 1992, Brown 1994, Polsten & Anderson 1997). Estimates of the monetary costs to U.S. agriculture due to crop loss, job displacement and cost of control are now approaching one billion dollars (Bezark 1995, De Barro 1995, Henneberry et al. 1996). Imidacloprid has temporarily reduced the impact of *Bemisia* in some crops, however resistance is now documented (Prabahker et al. 1997). Silverleaf whitefly control strategies are needed which decrease dependence on single control tactics. To this end, over 38 exotic populations of *Bemisia* parasitoids from 16 countries have been imported and evaluated in a comprehensive multi-state, multi-crop biological control program (Kirk et al. 1993, Nguyen & Bennett 1994, Goolsby et al. 1996, Goolsby et al. 1998, Rose & Zolnerowich 1998). Recently, imported exotic *Eretmocerus* spp. have been integrated with selective insecticides and cultural controls into a biological control based Integrated Pest Management (BC-IPM) program (Ciomperlik et al. 1997). This strategy is proposed as the basis for long term sustainable management of silverleaf whitefly.

Several biological control strategies including importation of new natural enemies (classical), natural enemy refugia (conservation), and inoculative releases (augmentation) have been evaluated for management of *B. argentifolii* (Roltsch & Pickett 1995, Carruthers et al. 1996, Corbett 1996, Henneberry et al. 1996, Simmons et al. 1997, Ciomperlik et al. 1997). Implementation of biological control strategies has been difficult in the subtropical agricultural areas where the impact of *B. argentifolii* is most severe. Several reasons may account for this difficulty such as: discontinuity of annual crops, high use of pesticides for other pests, and the lack of refugia for natural enemies, particularly parasitoids (Hoelmer 1995). Augmentation biological control shows potential for overcoming the difficulties of working in these ephemeral cropping systems. Early season releases of *Eretmocerus* spp., integrated with the use of selective insecticides, such as imidacloprid can provide season long control of *B. argentifolli* without the need for late season applications of broadspectrum insecticides (Simmons et al. 1997, Ciomperlik et al. 1997).

The high cost of producing and releasing natural enemies often limits the use of augmentative biological control. Although several field trials have shown that augmentative releases of natural enemies can suppress pests in field and orchard systems, the cost of application precludes their use (Pickett & Bugg 1998). Typically augmentative biological control is used in high value crops with a large budget for production costs, i.e. strawberries, glasshouse crops (Ravensberg 1992, Trumble &

Morse 1993). Cucurbit crops such as spring cantaloupe melons also fit these criteria making it economically feasible to use augmentative biological control. In all of these crops, increasing the efficiency of field delivery systems can reduce application costs. This is especially critical to short season annual crops where the window of time for effective pest management is short in contrast to perennial systems.

It has been demonstrated that releases of the newly imported exotic *Eretmocerus* spp. can suppress *B. argentifolii* populations in spring cantaloupe melon crops (Simmons et al. 1997, Ciomperlik et al. 1997). In these tests hand releases have been used to augment parasitoid populations. A method is needed which allows for efficient early season mass release of parasitoids in cucurbit crops. Herein we propose a novel approach for augmenting *Eretmocerus* that can increase the efficiency of delivery over hand releases.

Methods were developed and tested using greenhouse grown seedling transplants inoculated with parasitoids, called "banker plants," specifically for augmenting parasitoids in annual cucurbit crops, and with possible application in other transplanted vegetable crops such as tomatoes and cole crops. The term banker plant was used by Vet et al. (1980) to describe the use of parasitoid inoculated tomato plants for release of *Encarsia formosa* Gahan to control *Trialeurodes vaporarium* (Westwood) in greenhouses. Similarly, Bennison (1992) described the use of banker plants to augment aphid parasitoids in greenhouse cucumbers. We have extended the use of the term "banker plants" to describe parasitoid inoculated seedling transplants for use in field settings.

Banker plants have many advantages for field release of natural enemies in annual crops such as spring melons. Large numbers of transplants can be inoculated in the greenhouse, capitalizing on the inherent distribution system of transplant nurseries, and moved to many widely dispersed fields. Transplanting is mechanized which allows for efficient, large scale planting of banker and regular transplants in field crops. Parasitoids transported to the field by banker plants are immatures on the underside of the leaf which are not as susceptible to mortality factors such as rain, heat, wind, etc., as are adults or pupae released on clipped leaf material. Banker plants also aid in the dispersal of parasitoids within a field. As the transplants are planted, banker plants can be evenly spaced with regular seedlings to provide uniform distribution and emergence of parasitoids across the field. This should increase searching efficiency of parasitoids since they can search a smaller area before finding a host. This is critical during early season when pests are highly clumped in distribution and difficult to find. Lastly, banker plants allow for early season release of parasitoids in precise synchrony with the establishment of the crop and with timing of the insecticide imidacloprid, Admire®.

A series of field and lab experiments were conducted in 1996, 1997 and 1998 to develop methods for producing banker plants. Plant screening determined the suitability of varieties for use as banker plants. We predicted that some varieties would not be suitable for use as banker plants because of their susceptibility to *B. argentifolii*. Ten varieties were selected Riley's (1995) report, *Melon cultivar response to Bemisia*. The selections we made represented the most popular varieties in terms of acres planted and/or varieties which were listed as susceptible to *B. argentifolii.* Lab tests measured the impact of imidacloprid on developing parasitoids. This insecticide is systemic, widely used by melon producers, and is considered critical to season long whitefly control (Castle et al. 1996). Finally, field trials were conducted in spring cantaloupe and fall watermelon plantings to quantify the numbers of parasitoids produced using banker plants. *Eretmocerus hayati* Rose & Zolnerowich (accession # M95012) from Multan, Pakistan, was used in all the tests based on its performance in

previous laboratory and field evaluations (Goolsby et al. 1998). Our target release rate in cantaloupe was 23,000 per acre or one parasitoid per plant. This release rate was based on field studies conducted from 1993 to 1996 (Ciomperlik & Goolsby, unpublished data). Field tests during the Spring of 1997 with spring melons were conducted on the research farm at the Mission Biological Control Center, Moore Airbase, Mission, TX. Later trials were conducted with growers to determine the feasibility of large-scale transplanting of banker plants in commercial agriculture. In all of these trials we determined both the numbers of parasitoids produced per banker plant and release rate per acre. Efficacy of the augmentation program is discussed elsewhere.

Materials and Methods

Banker Plant Inoculation Methods

Cantaloupe and watermelon transplants used in the tests were grown in styrofoam flats with 128 cells 3.8 cm in diameter with a depth of 7.62 cm in a greenhouse held at 27 ± 2°C with a natural 14:10 L:D photoperiod. Flats were covered with an organza material shroud and were inoculated with adult *B. argentifolii* when the first true leaves were 1.8 cm across at the widest portion. Whitefly adults were collected from eggplants using a high volume, low velocity vacuum and transferred into clear one-gallon plastic containers for counting. The numbers of adult whitefly were estimated by counting the number of settled adults in ten separate 1 cm^2 discs located on the sides of the container. The average number of adults per cm^2 were multiplied by the surface area of the container to obtain the total estimated number of whitefly. Approximately 5000 adult whitefly were released per shrouded flat. Subsequent egg densities were determined by counting the number of eggs on a 1 cm^2 disc on the first true leaf of seedlings selected randomly from each flat.

Four hundred and fifty adult *E. hayati,* reared from *B. argentifolii* on eggplant, aged 24-48 h old, were released in each production flat. Parasitoids were collected from emergence cages in petri plates and had a male to female sex ratio of 40:60. Each plate was provisioned with a streak of honey and the parasitoids were held at 15°C until release. Parasitoids were released onto the plants when the majority of the whitefly eggs had hatched and the crawlers became settled first instars.

Counts to estimate the mean number of *E. hayati* per transplant were made 20 days after inoculation or when the majority of parasitoids had emerged. Counts were conducted in the laboratory using dissecting microscopes to determine the status of every individual on the 1 cm^2 leaf disc being recorded on a data sheet. Categories for the status of individual determinations were as follows: eggs; small nymphs (1st, 2nd, and 3rd instar), large nymphs (4th instar), (live, dead); emerged whitefly; parasitoid immatures; parasitoid mummies. Large nymphs were used to calculate percent parasitism because we could clearly determine if they were parasitized or not.

Cantaloupe Variety Screening

We used choice tests to evaluate the effect of cantaloupe variety on fecundity of SLWF and parasitoids. Ten varieties were tested: 'Primo', 'Explorer' (Rogers Seed), 'Cruiser' (Harris-Moran Seed), 'Marco Polo', 'Copa de Oro', 'Mission', 'Pacstart' (Asgrow Vegetable Seeds), 'Mainpak' (Sun Seeds), and 'Laredo', and 'Durango' (Peto Seed). Ten plants of each variety were planted in each of 4 flats. Cantaloupe seeds were planted at the same time and maintained in a greenhouse at 27°C with a natural

15:9 L:D photoperiod. Cages consisted of 100 seedlings in styrofoam transplant flats surrounded by an aluminum frame (38 × 80 × 40 cm), covered with organza. Seedlings were inoculated with adult whitefly and parasitoids using the methods described above. Twenty days after introduction of the parasitoids the leaf samples were removed and nymphal SLWF were analyzed with a stereo microscope to determine incidence of parasitism. Percent parasitism was calculated as the number of parasitized 4th instar nymphs and parasitoid mummies divided by the total number of parasitized and non-parasitized nymphs.

Statistical comparisons were analyzed using ANOVA and means were separated by the Tukey Studentized range test (SAS Institute 1998). The following parameters were compared: 1) total numbers of SLWF; 2) total numbers of parasitoids produced; and 3) percent parasitism. Percent parasitism data was arcsin transformed for the analysis.

Toxicity of Imidacloprid to Parasitoids

The impact of imidacloprid on immature *E. hayati* was measured. Eight flats of seedling plants were grown in a greenhouse at 32 ± 5°C under the natural 16:8 L:D regime which occurs during early summer. Cantaloupes *var.* 'Primo' were shrouded with organza and infested with whitefly and parasitoids using the same methods described above. Imidacloprid, Admire 2F®, was applied in a sequence to selected flats on days 0, 2, 4, 6, 8, 10, and 13 following release of the parasitoids. An eighth flat was not treated with imidacloprid and served as a control. Each flat was treated using a micro pipet with 0.53 mls imidacloprid per 2 gals of water, which is equivalent to the dose the same number of plants would receive in the field (pers. comm., S. Fraser, Miles, Inc.).

To assess the impact of imidacloprid on parasitoid immatures, the first true leaf from each plant was sampled 20 days after inoculation to allow live parasitoids to emerge. Categories for the status of individual determinations were as follows: small nymphs (1st, 2nd, and 3rd instar), large nymphs (4th instar), (live, dead); parasitoids (live, dead) and emerged whitefly. Unemerged parasitoids were considered to be dead.

Field Estimates of Release Rates

Banker plants used for transplanting were grown in a greenhouse and inoculated using the methods described above. Transplanting was conducted 2-6 after inoculation of whitefly with parasitoids, and depended on rainfall and grower schedules. Growers applied midacloprid by a drip system, in all of the tests, between one and three weeks after transplanting. No other insecticides were applied to the crop, however selected fungicides were used later in the season after emergence of the parasitoids.

To estimate the number of parasitoid progeny produced per banker plant, counts were made from a randomly collected field sample of banker plants. Similar emergence studies were conducted from a random sample of three banker plants from each flat held in the greenhouse. We sampled the first true leaf of the banker plants to estimate the numbers of parasitoids produced per plant. In some cases, we also counted the second true leaf if parasitoid pupae or mummies were observed.

To compare fruit yields between banker and regular transplants we counted the total number of marketable cantaloupes on 30 vines each respectively. We considered a marketable melon to be any size between #9 and #15 (Miller, 1997). Yield counts were conducted one day before the first initial harvest of the field. The numbers of fruit per vine between banker and regular transplants were analyzed by t-test (SAS Institute 1998).

Cantaloupe *var* 'Primo' was selected for both 1997 and 1998 field trials based on earlier screening work. The first field evaluation of banker plants was conducted in April of 1997 at the Biological Control Demonstration Farm at Moore Airbase. Banker plants were mechanically transplanted simultaneously with the regular transplants at a ratio of 1:10, banker to regular transplants. The second cantaloupe banker plant trial was transplanted at a ratio of 1:30 on Feb. 17, 1998 into a commercial field in San Juan, TX which was direct seeded on Jan. 20, 1998. In the Fall 1997, watermelon trials were conducted on a commercial farm in Mission, TX. At each location one half of the transplants were a triploid seedless watermelon *var.* Abbott & Cobb # 5441, in a mix of every other transplant with a diploid watermelon *var.* 'Royal Sweet'. We inoculated 1 out of 15 diploid watermelon transplants, which resulted in a ratio of 1:30 banker plants to regular transplants. The field in Mission, TX was hand transplanted on Aug. 1, 1997.

Results and Discussion

Cantaloupe Variety Evaluation

Varieties Copa de Oro and Mission had significantly higher densities of large nymphs than the other varieties tested ($F = 4.46$; $df = 9, 403$; $P < .0001$) (Fig. 1). Simmons and McCreight (1996) also found differences in whitefly preference for selected cantaloupe germplasm. We compared nymphal densities which may be an indicator of survival of nymphs after oviposition, more than an indicator of adult SLWF preference. However, mortality of the 1st instar crawlers was very low (<5%), based on the status of individual counts, which suggests that nymphal densities corresponded with adult oviposition rates. Copa de Oro, Mission, and Primo produced significantly more parasitoids than the other varieties ($F = 4.08$; $df = 9, 403$; $P < 0.0001$). Primo produced equivalent numbers of parasitoids to Asgrow and Mission, even though the latter two varieties had significantly higher SLWF densities. This suggests that parasitoids may show a preference for Primo. Primo also had the highest mean level of parasitism, but it was not significantly different from the other varieties ($F = 1.06$; $9, 403$; $P > 0.3948$). Based on these results, the cultivar Primo was selected for further development of the banker plant delivery system.

These tests indicate there may be differences between cantaloupe varieties that could influence densities of whitefly, and subsequently the number of parasitoids that can be produced on banker plants. It appears that Primo is a suitable variety for testing the banker plant delivery system. However, other varieties could likely be used as banker plants if whitefly densities were manipulated during infestation of the seedlings. Fortuitously, Primo is also one of the most commonly planted cantaloupe varieties in the Lower Rio Grande Valley of Texas.

Toxicity of Imidacloprid to Parasitoids

The effect of imidacloprid on the mean number of parasitoids produced was significant for treatment date ($F = 17.91$; $df = 7, 205$; $P < .0001$), (Fig. 2). It appears that imidacloprid caused high levels of mortality in developing parasitoid immatures up to six days after inoculation. By day 13, there was no significant difference in numbers of parasitoids produced as compared to the control.

The method by which the parasitoid larvae escaped the effect of imidacloprid is not known. One explanation may be that by day six the parasitoid larvae had matured to the point where it had killed the host. After death, the whitefly ceases to uptake plant

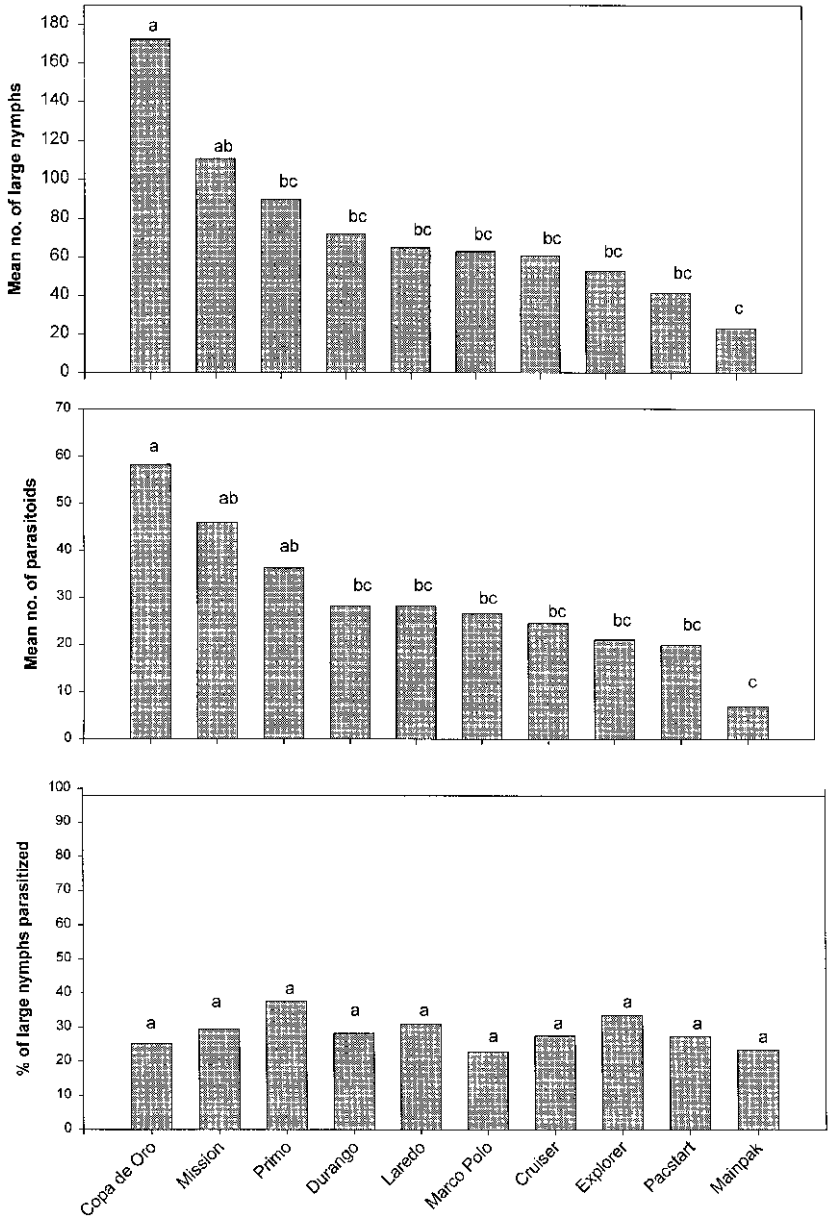

Fig. 1. Summary of cantaloupe variety evaluation. Numbers of *B. argentifolii* and parasitoids are per leaf (~ 25 cm^2). Bars with the same letter are not significantly different (P = 0.05).

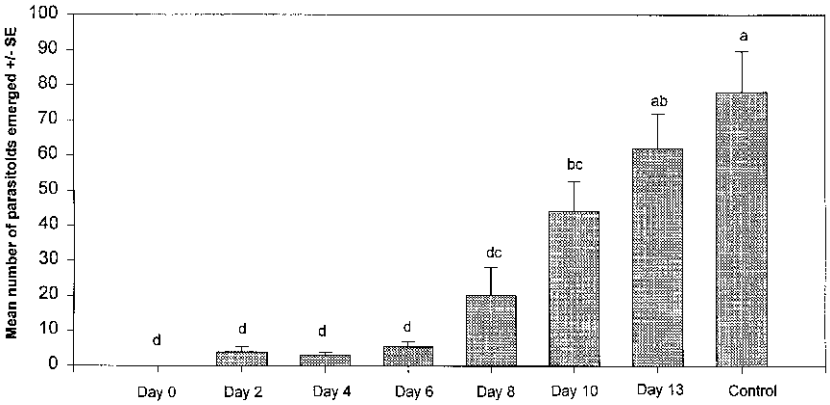

Fig. 2. Mean number of *E. hayati* adults produced per leaf (~ 25 cm^2) after application of imidacloprid insecticide. Bars represent the day banker plants were treated with imidacloprid following inoculation with parasitoids on Day 0. Bars followed by the same letter are not significantly different (P = 0.05) in total number of parasitoids produced.

fluids containing the imidacloprid. For practical purposes, if applications of imidacloprid could be delayed for one week after transplanting, or if banker plants could be planted one week after they are inoculated with parasitoids, the impact on developing parasitoids would be minimized. Timing of the imidacloprid application should be temperature dependent. If cool weather delays development of the whitefly immatures and parasitoids, the insecticide application may need to be delayed.

Field Production Estimates

1997 Cantaloupe. Numbers of whitefly and parasitoids used to inoculate the transplants are listed in Table 1. The egg density was estimated to be 88 per cm^2. Overall whitefly density appeared to have had an adverse effect on plant health due to early senescence of leaves. Egg and nymphal densities this high are routine in mass rearing procedures using mature eggplant and hibiscus plants (Goolsby, unpublished data). However, young cantaloupe seedlings may not be able to tolerate this level of infestation. Despite some early senescence of the parasitoid bearing 1st true leaves, parasitoid production met the target release rate (Table 2). Fecundity per female was high with a 26.7 fold increase across 40 flats of banker plants. In comparison, a 12 fold increase is typical in other outdoor rearing systems (Goolsby, unpublished data). The higher fecundity may be due to the confinement of the parasitoids with the whitefly infested transplants in the shroud cages along with moderate temperature and humidity found in the greenhouse environment. Field estimates of the number of parasitoids produced per banker plant was hampered by persistent rains that drenched the crop during the month of March. Hence, we were unable to sample the banker plants in the field to determine the release rate. We estimated the release rate based on subsample of banker plants which we held in the greenhouse to be approximately three times the target release rate of 23,000 per acre (Table 3). We determined from these trials that the ratio of banker plants per acre could be reduced to 1:30 while still producing the target release rate.

TABLE 1. WHITEFLY AND PARASITOID INPUTS PER BANKER FLAT.

	Cantaloupe Spring 97	Cantaloupe Spring 98	Watermelon Fall 97
Mean no. of adult whitefly released ± SE	6239 ± 302	4633 ± 342	5335 ± 177
Mean egg density ± SE	85.6 ± 8.8	43.9 ± 6.5	43.6 ± 4.9
Mean no. of parasitoid females released ± SE	246.4 ± 18.1	523.7 ± 13.7	296.6 ± 26.2
Sex ratio of parental material M:F	32:64	43:57	n/a

1998 Cantaloupe. Egg density was determined to be 43.9 per cm^2. This appears to be nearly the optimum density for health of the banker plant as compared to 88 per cm^2 recorded in the earlier 1997 trial. At this egg density, very few of the first true leaves senesced, which resulted in a higher mean number of inoculating parasitoids produced per banker plant (Table 2). Lower densities of nymphs and higher numbers of parasitoid females resulted in higher levels of parasitism as compared to the 1997 trial. Fecundity per female was also higher at 38.6 than the 97 trial (Table 2). Estimates of the mean number of parasitoid progeny produced per banker plant were 102.1 and 32.8 from the greenhouse and field, respectively. The actual number of progeny produced per plant is likely to fall between these two estimates. Field counts underestimate progeny production due to the fact that mummies may fall off after emergence of the parasitoid (Table 2). Other workers have also found that parasitoid mummies are sometimes dislodged from the plant leaf (Naranjo, pers. comm.). The mean number of parasitoids produced by pooling both estimates is 67.5 per banker plant which translates to 29,970 per acre (Table 3). This rate is slightly higher than the target rate of 23,000 per acre. Based on these estimates, the number of banker

TABLE 2. PRODUCTION ESTIMATES OF BANKER PLANT PRODUCTION.

	Cantaloupe Spring 97	Cantaloupe Spring 98	Watermelon Fall 97
Greenhouse Estimate			
Parasitoids per banker plant ± SE	94.6 ± 17.9	102.1 ± 14.5	94.6 ± 16.7
Mean percent parasitism	49.4%	57.3%	56.0%
Mean fecundity per female	26.7	38.6	40.8
Field Estimate			
Parasitoids per banker plant ± SE	n/a	32.8 ± 5.8	9.3 ± 7.2
Average percent parasitism	n/a	41.8%	71.8%
Mean fecundity per female	n/a	14.6	4

TABLE 3. FIELD RELEASE RATE BASED ON POOLED GREENHOUSE AND FIELD ESTIMATES.

	Cantaloupe Spring 97	Cantaloupe Spring 98	Watermelon Fall 97
No. of banker plants: regular transplants	1:10	1:30	1:0
No. of banker plants per acre	906	444	80
Estimated no. released per acre	68,946[1]	29,970	4,156
Target release rate	23,000	20,000	1,100
No. of acres in test	5	45	45

[1]Rate based on greenhouse estimate alone.

plants per acre could be lowered for several reasons. Spring cantaloupe fields in the LRGV are usually planted in January when whitefly levels arevery low (Riley & Ciomperlik 1998). Earlier banker plant trials were conducted with cantaloupes planted in March at ratios of 1:10. Banker to regular transplant ratios of 1:50 or 1:100 may be suitable for early planted spring crops when whitefly levels are low and augmented parasitoids have additional time to build their populations.

1997 Watermelons. Numbers of whitefly and parasitoids used to inoculate the watermelon transplants are listed in Table 1. The egg density was determined to be 43.6 per cm^2. This appears to be nearly the appropriate density for watermelons and cantaloupe banker plants. At this whitefly density, plants maintain good vigor throughout the seedling growth stage and in the field as transplants. Percent parasitism ranged from 56% in samples of greenhouse banker plants to 71.8% from the field collected material. This level of parasitism in watermelon is slightly higher than experienced in the cantaloupe trials, even though lower numbers of parasitoid females were used in their inoculation (Table 1). Similarly, the mean number of parasitoid progeny produced per female was higher in the watermelon transplants (40.8) as compared with cantaloupes (38.6). The higher level of parasitism and mean progeny production per female may be in part due to differences between the watermelon and cantaloupe transplants. Watermelon transplants are typically grown to about twice the size of the cantaloupe before transplanting. The larger transplant has two true leaves available for infestation with whitefly. Mutual interference of searching females may be minimized by the larger leaf surface area of the watermelon seedling.

Progeny production estimates of greenhouse and field grown banker plants were 94.6 and 9.3 respectively (Table 2). The large difference between the two estimates is likely due to the harsh field conditions experienced during August in the LRGV. When the field was transplanted, water stress and strong winds adversely affected the young seedlings. Some of the developing parasitoids may not have survived, and many of the parasitoid mummies may have been dislodged from the leaf. Pooling the two estimates leads to a field release rate of 4156 parasitoids per acre (Table 3). Given the high rate of whitefly migration into the young watermelons from surrounding areas of defoliated cotton, the current banker to regular transplant ratio in watermelons seemed appropriate for these growing conditions. Inoculating 2 diploid transplants out of 15 would increase the banker plant ratio to 1:15. Using the higher banker plant to transplant ratio may be advisable during periods of heavy whitefly migration.

This research demonstrates that the use of banker plants is a reliable method for augmenting *Eretmocerus* parasitoids in both cantaloupe and watermelon crops. Varietal differences in cantaloupes seemed to affect oviposition by *Bemisia* and rates of parasitism by *E. hayati*. However, differences were not so great as to exclude the use of a particular variety for use as a banker plant. Manipulation of adult whitefly and parasitoid numbers should overcome any varietal restraints. We recommend the same species of plant and variety be used for the banker plants as the field crop. Irrigation timing, weed control practices, fertility, etc., will be directed towards the crop. By using the same variety as the crop, unpredicted effects of different varieties or plant species can be avoided. In addition, the banker plant will produce a normal yield, thus offsetting the cost of the plant in using parasitoid inoculated transplants. In our tests, cantaloupe melon production was not significantly different between regular and banker plant vines (Table 4).

Laboratory studies document the potential for integrating imidacloprid with banker plants and augmentation strategies for management of SLWF. Our tests show that parasitoid immatures in the later stages of development were not effected by imidacloprid. Use of imidacloprid is standard practice in most subtropical growing areas of the U.S. and worldwide. Combining the use of imidacloprid, a density independent mortality factor, combined with parasitoids, a density dependent factor, may be synergistic in providing better control of *B. argentifolii* than would occur if the two factors were used separately. *Eretmocerus hayati* is capable of finding low density whitefly immatures that are typical after imidacloprid applications. This strategy may provide season long control of *Bemisia*, thus avoiding late season applications of broadspectrum insecticides, or unlabelled applications of imidacloprid which could increase the likelihood of resistance.

From our work using banker plants in direct seeded melon crops, another alternative for timing of imidacloprid became apparent. Imidacloprid could be applied to the direct seeded crop at planting providing full protection to the seedlings as they emerge. The banker plants could be held in the greenhouse until parasitoids have reached the late larval or early pupal stage and then be transplanted. If banker plants were held in the greenhouse for an additional week at 27°C, parasitoids on the transplants should not be affected by imidacloprid.

The production and use of banker plants for augmentation does not require any additional technological hurdles for implementation. Production of sufficient numbers of parasitoids for inoculation of banker plants for many thousand acres of cucurbits is feasible. Growers have the option of using banker plants with their regular transplants or in direct seeded crops, both of which have been demonstrated successfully in our field trials. Additional benefits from these augmentation programs may be

TABLE 4. COMPARISON OF CANTALOUPE FRUIT YIELDS BETWEEN BANKER PLANTS AND REGULAR TRANSPLANTS.

	Mean no. ± SE Fruits	
Year	Regular Plants	Banker Plants
1997	1.5 ± 0.2[a]	1.4 ± 0.1[a]
1998	1.1 ± 0.1[a]	0.8 ± 0.1[a]

Means within rows followed by the same letter are not significantly different (P = 0.05).

derived if the exotic parasitoid is able to migrate in sufficient numbers to surrounding summer crops such as cotton, soybean, and alfalfa, or to fall crops such as cucumber and cole crops. Whitefly may be regulated at lower levels if sufficient numbers of parasitoids colonize the summer and fall crops. Studies are needed to quantify the dispersal capabilities of *E. hayati,* from fields where it has been augmented, to surrounding fields. Banker plant delivery methods could be used to implement area-wide biological control programs directed against SLWF. Area wide releases of parasitoids via banker plants could potentially moderate whitefly levels at a regional level. Lastly, more detailed studies evaluating the efficacy of augmentation using banker plants as compared to other release methods are needed.

Parasitoid inoculated seedling banker plants represent a novel method for field release of parasitoids in field settings. Banker plant methods could be used to augment many different parasitoid species against a variety of pests. For instance, parasitoids could be augmented via cabbage and broccoli banker plants for control of SLWF. Likewise, parasitoids of *Plutella xylostella* (L.), the diamondback moth, could be augmented on broccoli using the banker plant delivery methods. In many cases, early season augmentation of parasitoids has already shown to be effective for controlling a variety of insect and mite pests (Parker & Pinnell 1972, Biever & Chauvin 1992, Hoffman & Frodsham 1993). Parasitoid inoculated banker plant methods could enable other augmentation programs and extend the use of biological control in annual cropping systems.

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MORPHOLOGY AND DISTRIBUTION OF THE SENSE ORGANS ON THE ANTENNAE OF *COPITARSIA CONSUETA* (LEPIDOPTERA: NOCTUIDAE)

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ABSTRACT

Five types of sensilla were found on the antennae of adult *Copitarsia consueta* (Walker) (Lepidoptera: Noctuidae) by scanning electron microscopy and light microscopy. Those sensilla were trichoidea, coeloconica, styloconica, basiconica and squamiformia. Two types of sexually dimorphic sensilla trichodea were found; type I is in the border of the sensory field of the flagellar segments and present only on male antennae. This suggests that the sensillum may contain the receptor sites for the female sex pheromone. Type II is located within the ventro-medial sensillar field where it is arranged without apparent pattern. Six types of sensilla chaetica were found around antennal segments, and were particularly abundant on the apical antennal segment. One sensillum styloconicum was identified per segment, except for the apical segment, where it varies in number. Each sensillum consists of a base, a stalk and a cone. Each flagellar segment bears several sensilla coeloconica on the ventral surface, situated on or near distal edge. Each sensillum consists of a depression surrounded by 15 to 17 "teeth" and one peg. Two types of sensilla basiconica were identified, type I is more curved and broader than type II.

Key Words: antennal morphology, sensilla types, sexual dimorphism

RESUMEN

Se reconocieron cinco tipos de sénsulos en la antena de la palomilla *Copitarsia consueta* (Walker) (Lepidoptera: Noctuidae) por medio de microscopía electrónica de barrido y microscopía de luz. Dos tipos de sénsulos tricoideos fueron observados; el tipo I se localizó en las partes laterales del área sensorial y estuvo presente sólo en la antena del macho, lo cual sugiere que este tipo de sénsulo puede ser el receptor de la feromona sexual de la hembra. El tipo II se localizó en la parte ventral y no tuvo ningún patrón de distribución. Además se observaron otros seis sénsulos quéticos alrededor de cada segmento, excepto en el segmento apical donde el número fue mayor. Se identificó un solo sénsulo estilocónico por segmento ubicado en la parte media distal, pero en el segmento terminal el número varió, este sénsulo consta de una base, un peciolo y un cono. Varios sénsulos celocónicos se identificaron en la superficie ventral, se observaron de la parte media a la distal del segmento antenal, cada uno estuvo formado de una depresión rodeada por 15 a 17 "dientes o espinas" y una "estaquilla". Dos tipos de sénsulos basicónicos fueron identificados; el tipo I fue más curvado en la parte final y más ancho en la base que el tipo II.

Copitarsia consueta infests various crops of economic importance throughout most of the Americas (Angulo & Weigert 1975). In Bolivia it is considered a pest of potatoes, (Munro, 1968), and in Mexico a pest of cabbage (Monge, 1984).

Rojas et al. (1995) identified the sites of sex pheromone production in *C. consueta* using morphological and histological evidence. Typically, the detection of the sexual pheromone in noctuid moths is by olfactory neurons in sensilla on the male antenna (Lavoie & McNeil 1987). A knowledge of the structure and distribution of sensory sensilla of the male is an important precursor to electrophysiological and behavioral studies.

In this paper we describe the sensory structures of male and female *C. consueta* antennae, as seen through scanning electron and light microscopes.

Materials and Methods

The insects were obtained from a colony raised on an artificial diet (Cibrián & Sugimoto 1992) in a laboratory at Colegio de Postgraduados, Estado de México at 25 ± 3°C, 60 ± 5% RH and a photoperiod of 14:10 hr L:D.

Scanning Electron Microscopy (SEM)

The antennae of 15 males and 15 females were separately placed in a solution of 70% ethanol and 2% formaldehyde for 24 hours. They were then dehydrated in 80%, 90%, and 100% ethanol for 8 hr each. Afterwards, they were dried at the critical point and finally gold coated (70 nm) for observation with a JEOL 35-C microscope at 5 and 10 kV (Wall 1978, Valdez 1991). The average length and basal diameter of the external part of each sensillum was calculated through 15 measurements taken from photomicrographs (Faucheux 1991).

Light Microscopy (LM)

The antennae of both sexes were macerated in 10% KOH at 80°C until they cleared (approximately 30 minutes). They were washed with distilled water of equal temperature and for the same amount of time. The scales were removed with a 60 Hz ultrasonic cleaner for one minute, and the antennae were then dehydrated in 70% and 100% alcohol for 30 and 60 minutes respectively. Finally, they were cleared with xylol and mounted in Canada balsam. The observations were made with a Meiji (40×) microscope. The sensilla were counted on each flagellar segment on the antennae of 10 males and 30 females (Faucheux 1991).

Results

General Morphology of the Antennae

The antenna of *C. consueta is* filiform and segmented, and the flagellum is spindle-shaped. Each antenna consists of two basal segments: the scape and the pedicel. On the antennae's dorsal surface are "Böhm" bristles. The number of flagellar segments is similar in males and females. A typical antennal segment is cylindrical and divided into two main areas. The dorsal surface has two rows of scales; the second row overlaps the first row of the following segment. The only obvious type of dorsal sensillum is of the squamiform type (Fig. 1). The ventral surface possesses most of the sensilla, and these are of various types (Fig. 2).

External Morphology and Distribution of Sensilla

The antenna of the male is approximately 11.22 mm long ± 0.08 (SEM). In the female the antenna measures 11.37 ± 0.09 mm. The number of segments is slightly greater in the flagellum of the female (77.3 ± 0.57) than in the male (75.6 ± 0.45) (average of 30 antennae, 15 insects in each case) (Table 1). The flagellar segments diminish in length and diameter from the base to the apex of the antenna and have the same general organization and pattern of sensory structures. The segments are larger in the male than in the female (Table 1). There are 5 types of sensilla on the flagellum: trichoid, basiconic, coeloconic, styloconic and squamiform sensilla.

Males and females have the same types of sensilla on the ventral surface of flagellar segments, except for the lateral chemoreceptive trichoid sensilla, which are present only in the male.

The chemoreceptive trichoid sensilla are the most numerous type. They can be divided into two groups according to their external structure and location. Type I, present only on the antenna of the male are the longest (Table 2). They are set in 4 or 5 parallel rows on the sides of the ventral sensory area of the proximal and median segments (Fig. 3). The number of sensilla decrease from 278 at the base of the flagellum (average of the first 5 segments of 5 antennae), to fewer than 100 (average of the segments 51 to 55 of 5 antennae) and disappear between segments 66 and 68. The total number of these sensilla was estimated to be 2814 ± 144.6 (Table 3).

Type II sensilla are localized on the ventral surface of each segment and are shorter than type I sensilla. They are not arranged in rows (Fig. 2), and are larger in the male than in the female (Table 2). Some of these sensilla are more curved than others (Fig. 4), but the differences are too small to reliably characterize two forms. The total number of these sensilla was larger in the male than in the female (Table 3).

Each segment the male and female antennae bear six mechanoreceptive sensilla chaetica, except the apical segment which has more than six (Fig. 5). Each sensillum is straight, wide at the basal part and slightly curved at the distal part, blunt (rounded), and without a pore. These sensilla can be divided into two groups according to their length. Long sensilla chaetica, found on the superior dorsal surface (2) and lateroventrally (2) (Fig. 5), are larger in the male than in the female (Table 2). The total number of these sensilla was calculated as 302.4 ± 1.82 in the male, and 309.2 ± 2.31 in the female (Table 3). Contrasting with this, are the short sensilla chaetica, localized on the medio-ventral surface (2) (Fig. 5). They are shorter and narrower in the male (65.17 ± 3.18 in length and 3.44 ± 0.35 in width at the base) than in the female (67.10 ± 4.61 in length and 3.55 ± 0.01 in width) (Table 2). The total number of short sensilla was estimated to be 151.13 ± 0.93 in the male and 154.53 ± 1.13 in the female (Table 3).

In both males and females there is a single styloconic sensillum (from the third segment onward) in the middle part of the distal edge of each segment (Fig. 6), however, their number varies on the terminal segment. The average length of the complete structure (stalk and cone) in males and females is 2.58 ± 0.04 and 2.20 ± 0.04 respectively (Table 2). On the antenna of the male there are approximately 72.6 ± 0.45 sensilla and on the female antenna 74.3 ± 0.58 (Table 3). The styloconic sensillum in *C. consueta* has a reticulated base, a relatively smooth (plain) petiole and a conic extremity; some of them have a double or triple apical structure (Fig. 6).

On each flagellar segment there are several coeloconic sensilla on the ventral surface (Fig. 7); they are situated mainly from the middle to the distal portion of the segment. Each sensillum consists of a depression surrounded by 15 to 17 cuticular "spines" and a porous peg with longitudinal striations on its surface, arising from the center of the depression (Fig. 7). The diameter of the coeloconic sensilla varies from

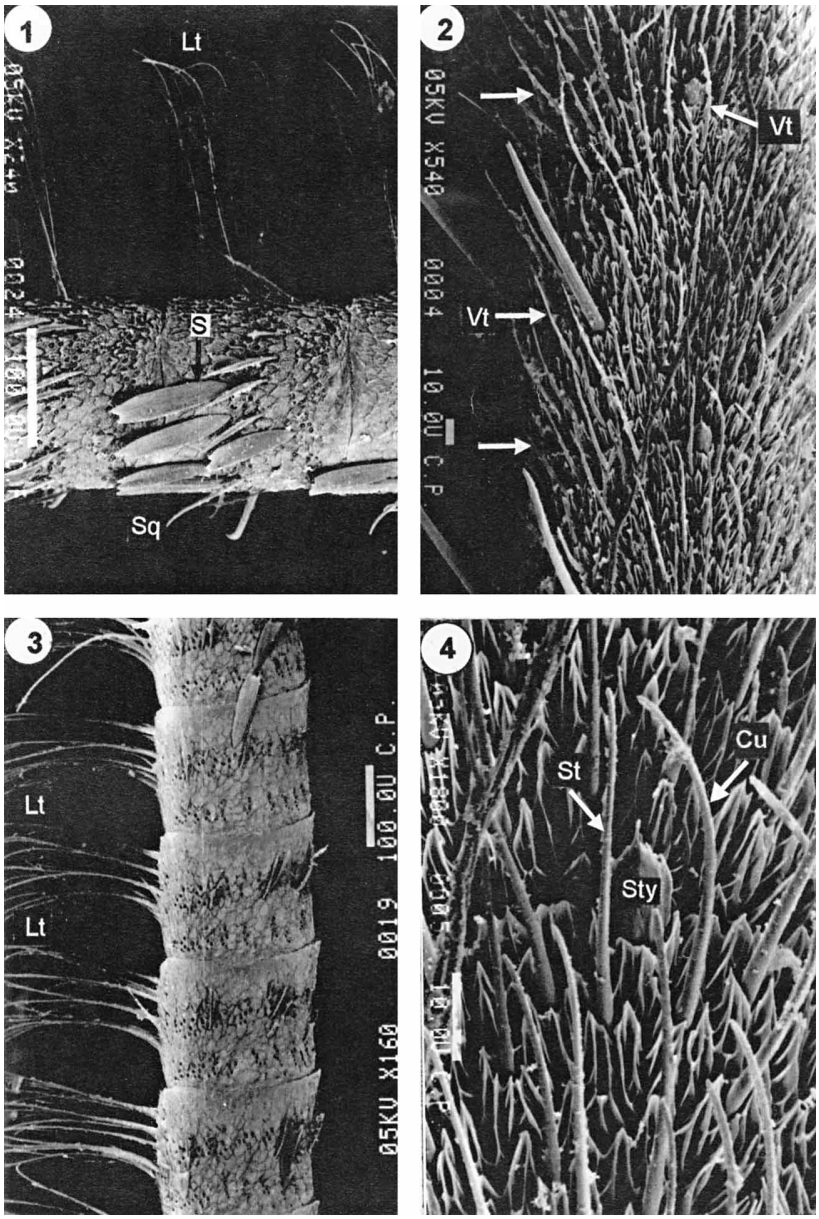

Fig. 1. Dorsal surface of a *C. consueta* male antenna. Sq = sensillum squamiformium. S = scales; Lt = lateral trichoid sensilla. Bar = 100 μm. Fig. 2. Ventral surface of a female antenna. Vt = ventral trichoid sensilla; Arrows indicate limits of one segment. Bar = 10 μm. Fig. 3. Laterodorsal surface of a male antenna. Lt = lateral trichoid sensilla. Bar = 100 μm. Fig. 4. Types of ventral trichoid sensilla. St = straight; Cu = curved; Sty = sensillum styloconicum. Bar= 10 μm.

TABLE 1. THE TOTAL LENGTH AND NUMBER OF SEGMENTS ($\bar{X}$ ± SEM) IN THE ANTENNAL FLAGELLUM OF MALE AND FEMALE *COPITARSIA CONSUETA* (WALKER).

Sex	Length of the antennae (μm)	Number of segments	Length of the segments (μm)	Width of the segments (μm)
Male	11.22 ± 0.08* (10.4-12)	75.6 ± 0.45* (71-80)	155.72 ± 12.4¤ (89.65-13.79)	139 ± 3.2¤ (117.24-158.62)
Female	11.37 ± 0.09* (10.2-12)	77.3 ± 0.57* (72-83)	150.86 ± 5.11¤ (120.68-175.86)	130.06 ± 2.56¤ (120.68-151.72)

*n = 30 antennae. ¤n = 15 segments (range in parentheses).

10.44 ± 0.45 in the male to 11.13 ± 0.55 in the female (Table 2). The number of sensilla per insect is similar in males and females, 422.9 ± 17.18 in males and 419.9 ± 2.97 in females (Table 3). There are fewer of them at the base (<3 per segment). The number increases in the central part (≈ 8) and diminishes again at the point (≈ 4).

Two types of basiconic sensilla, different in shape, can be observed on the ventral part of the antenna of *C. consueta* (Fig. 8). They are smaller than all but the coeloconic sensilla. Type I is more curved at the terminal part, and the base is wider than in type II, which has the shape of a small stake; both are rounded at the apex. There are approximately 2 sensilla of each type per segment.

The squamiform sensilla, positioned on the dorsal part of the antenna among the scales, are shorter and finer than the scales (Fig. 1).

DISCUSSION

The general structure of the antenna of *C. consueta is* similar to that in other noctuids: *Trichoplusia ni* (Hübner), *Helicoverpa zea* (Boddie), *Spodoptera ornithogalli* (Gueneé), *Spodoptera exigua* (Hübner) (Jefferson et al. 1970), and *Pseudaletia unipuncta* (Haworth) (Lavoie & McNeil 1987). Typically, scales occur along with sensilla on the surface of the noctuid antenna. Van der Pers et al. (1980), do not believe that scales protect the sensilla from mechanical damage, but rather suggest that their disposition contributes to the insect's ability to detect the direction of the stimulus. Wall (1978) argued that scales may be a mechanism to trap and concentrate odorous molecules.

The Böhm hairs of *C. consueta* are morphologically similar to those present in the scape and the pedicel of the antenna of *T. ni, H. zea, S. ornithogalli, S. exigua* (Jefferson et al. 1970), and a pyralid (Cornford et al. 1973). Schneider (1964) suggested they have a mechano-sensitive function. Similarly, Cuperus (1983) argues that these hairs in an yponomeutid may have a mechano-receptor function at the scape-pedicel junction.

There is sexual dimorphism in *C. consueta* antennae. The antenna of the male has a large number of long trichoid sensilla which are absent in the female. The presence of these sensilla has also been reported in other noctuids: *H. zea* (Callahan 1969), *T. ni, H. zea, S. ornithogalli* and *S. exigua* (Jefferson et al. 1970). It has been demonstrated in several moths that the long trichoid sensilla on the antenna of the male are receptors for the sex pheromone of the female (Boekh et al. 1965, Schneider & Steinbrecht 1968, Van der Pers & Den Otter 1978, Kaissling 1979, Zacharuk 1985).

Chaetica sensilla of *C. consueta* are similar in structure to those reported for other noctuids by Callahan (1969), Jefferson et al. (1970), and Liu & Liu (1984). They were suggested to be contact chemoreceptors in *T. ni, S. ornithogalli* and *S. frugiperda* (J. E. Smith) (Jefferson et al. 1970) and a tortricid (Albert & Seabrook 1973), but to have a mechanoreceptive function in a mosquito (Davis & Socolove 1975) and in

TABLE 2. DIMENSION OF THE SENSILLA ON THE ANTENNA OF *COPITARSIA CONSUETA* (WALKER).

	Dimension of the sensilla $\bar{X}$ ± sem (μm)			
	Male		Female	
Type of sensillum	Length	Width	Length	Width
Lateral chemoreceptive trichoid	218.4 ± 5.76 (160.7-261.2)	4.40 ± 0.09 (3.27-4.91)	—	—
Ventral chemoreceptive trichoid	74.2 ± 4.28 (45-100)	3.23 ± 0.1 2.38 ± 3.80	34.81 ± 1.34 (26.25-42.85)	1.76 ± 0.04 (1.7-2.17)
Long (4) mechanoreceptive chaetica	108.27 ± 12.47 (63.79-175.86)	4.96 ± 0.40 (3.44-6.89)	86.89 ± 6.79 (44.82-127.58)	4.62 ± 0.32 (3.44-6.89)
Short (2) mechanoreceptive chaetica	65.17 ± 3.18 (53.44-68.96)	3.44 ± 0.35 (3.10-3.79)	67.10 ± 4.61 (41.37-82.75)	3.55 ± 0.1 (3.44-5.17)
Styloconic	2.58 ± 0.04 (2.41-2.75)	—	2.20 ± 0.04 (2.06-2.41)	—
Coeloconic	10.44 ± 0.45* (8.62-13.79)	—	11.13 ± 0.55* (8.62-13.79)	—

n = 15 sensilla. *refers to diameter (range in parentheses).

TABLE 3. AVERAGE NUMBER OF SENSILLA ESTIMATED ON THE ANTENNA OF *COPITARSIA CONSUETA* (WALKER).

Type of sensillum	Number of sensilla $\bar{X}$ ± sem	
	Male	Female
Lateral chemoreceptive trichoid	2814 ± 144.6* (2481-3335)	—
Ventral chemoreceptive trichoid	3477 ± 36.4* (3266-3680)	3298 ± 186.64* (3168-3562)
Long (4) mechanoreceptive chaetica	302.4 ± 1.82¤ (284-320)	309.2 ± 2.31¤ (288-332)
Short (2) mechanoreceptive chaetica	151.13 ± 0.93¤ (142-160)	154.53 ± 1.13¤ (144-162)
Styloconic	72.6 ± 0.45¤ (68-77)	74.3 ± 0.58¤ (69-79)
Coeloconic	422.9 ± 17.18* (326-545)	419.9 ± 2.97* (405-463)

n = 10 antennae. ¤n = 30 antennae (range in parentheses).

yponomeutids (Van der Pers & Den Otter 1978). Type I has a constant length in all antennal segments, type II is smaller in the proximal segments, but increases in length towards the distal segments of the flagellum, equaling the previous ones in size in both sexes. These types also occur in *H. zea* (Callahan 1969), *P. unipuncta* (Lavoie & McNeil 1987), and a pyralid (Cornford et al. 1973). A similar, but distinct, form occurs in males of a tortricid (Wall 1978).

The presence of styloconic sensilla with double or triple apical structure is common in noctuids: *T. ni, H. zea, P. ornithogalli and S. exigua* (Jefferson et al. 1970), *P. unipuncta* (Lavoie & McNeil 1987) and *Mamestra configurata* Walker (Liu & Liu 1984). In another tortricid, (*Adoxophyes orana* F. von R.), similar structures have been reported as cuspiform organs (Den Otter et al. 1978).

Styloconic sensilla of *C. consueta* lack pores. However, pores occur on the stalk near the reticulated base in *P. unipuncta* (Lavoie & McNeil 1987), at the apex in a pyralid (Faucheux 1991), and at the side of the apex in a tortricid (Wall 1978). These pored sensilla are thought to be chemoreceptors (Albert & Seabrook 1973), or, as in *H. zea,* contact chemoreceptors (Callahan 1969). However, in yponomeutids, they may have some other sensory function because they are located under scales where contact chemoreception is not likely (Van der Pers et al. 1980).

Coeloconic sensilla, mostly present on each segment of males and females of *C. consueta* from the medial to the distal part have also been found in other noctuids, *S. unipuncta* (Lavoie & McNeil 1987) and *M. configurata* (Liu & Liu 1984), and a tortricid (Albert & Seabrook 1973), and a pyralid (Cornford et al. 1973). Three to four sensilla occur per segment of males and females in *C. consueta* and in pyralids (Cornford et al. 1973, Faucheux 1991). There was no size variation in these sensilla on the antennae of either sex of *C. consueta.* This was not the case in an a tortricid examined by Wall (1978). Such sensilla have been considered to be temperature receptors in a mosquito (Davis & Sokolove 1975) and a cockroach. In the latter insect, they are also sen-

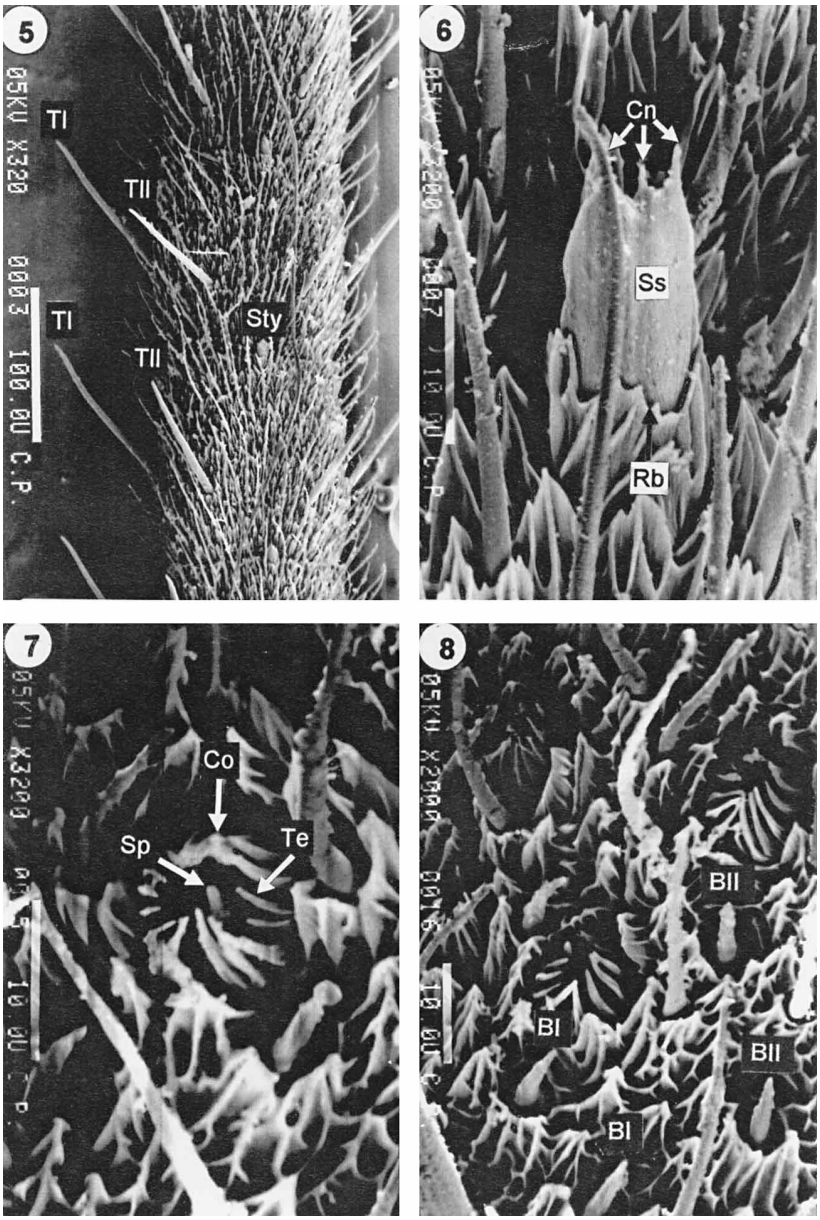

Fig. 5. Central portion of antennal flagellum of a female. Sensillum chaeticum type I = Ch I and type II = Ch II; Sty = sensillum styloconicum. Bar = 100 μm. Fig. 6. Sensillum styloconicum (Sty). Cn = conical extremity with triple apical structure; Rb = reticulated base; Ss = smooth stalk. Bar = 10 μm. Fig. 7. Sensillum coeloconicum (Co). Sp = spike, Te = teeth. Bar = 10 μm. Fig. 8. Basiconic sensilla. Type I = BI, Type II = BII. Bar = 10 μm.

sitive to humidity (Altner et al. 1977). However, their ultrastructure suggests they are olfactory receptors, possibly sensitive to volatile odors of plants (Van der Pers 1981).

Basiconic sensilla are shorter than the ventral chemoreceptive trichoids, the apex is rounded and they are located among the trichoids. Similar structures have been reported for a tortricid (George & Nagy 1984) and an yponomeutid (Cuperus 1983). Cuperus (1983) and Faucheux (1991) observed pores in a basiconic sensilla. The presence of this pores suggests an olfactory function, perhaps the reception of volatile odors of plants (Van der Pers 1981).

Squamiform sensilla are similar to those described in an yponomeutid by Cuperus (1983) and in a pyralid by Faucheux (1991). In the yponomeutid they were positioned on the scape, the pedicel, and the first 5 segments of the flagellum, but in *C. consueta* they occur as far as the middle of the flagellum. Lavoie & McNeil (1987) observed such sensilla laterally on the ventral surface of each antennal segment in *P. unipuncta,* but we found them in a transverse line on the entire ventral surface of the antennal segments of *C. consueta.*

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EVALUATION OF *ERETMOCERUS EREMICUS* AND *ENCARSIA FORMOSA* (HYMENOPTERA: APHELINIDAE) BELTSVILLE STRAIN IN COMMERCIAL GREENHOUSES FOR BIOLOGICAL CONTROL OF *BEMISIA ARGENTIFOLII* (HOMOPTERA: ALEYRODIDAE) ON COLORED POINSETTIA PLANTS

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ABSTRACT

The effectiveness of average weekly inundative releases of female *Eretmocerus eremicus* (evaluated in 2 greenhouses) and *Encarsia formosa* Beltsville strain (evaluated in 2 greenhouses) per plant for control of *Bemisia argentifolii* Bellow and Perring was determined on colored poinsettia plants grown under commercial conditions. Parasitoid efficacy was determined by making weekly population counts of *B. argentifolii* lifestages (excluding eggs) on plants exposed to parasitoids in biological control greenhouses and comparing final per leaf densities of *B. argentifolii* nymphs to those plants in insecticide treated greenhouses. At the 2 sites where *E. eremicus* was used, final nymphal densities ranged from 2-4 per leaf when a sales inspection protocol was employed at time of harvest. On insecticide-treated plants, nymphs ranged 0.02-0.18 per leaf but final whitefly densities in biological control greenhouses and insecticide greenhouses were commercially acceptable. Colored plants at one site where *E. eremicus* was used were harvested and sold without any insecticide use. At the second *E. eremicus* site, two sulfotepp applications were made at week 11 of the 16 week trial and colored plants were harvested without further use of insecticides. In comparison to insecticides, the cost of *E. eremicus* in 1995 ($2.70 per plant) was 30 times higher than using imidacloprid ($0.09 per plant) for *B. argentifolii* control. At the 2 sites where *E. formosa* Beltsville strain was released, trials were terminated early and insecticides were applied when *B. argentifolii* densities reached 4-6 live nymphs and pupae per leaf. Low emergence rates of *E. formosa* Beltsville strain may have been a major factor lowering the efficacy of this parasitoid in commercial greenhouses.

RESUMEN

En invernaderos comerciales se liberaron semanalmente hembras de *Eretmocerus eremicus* (dos invernaderos) y de *Encarsa formosa* raza Beltsville (otros dos invernaderos) para el control de *Bemisia argentifolii* Bellow y Perring en plantas de nochebuena colorida. La efectividad de los parasitoides se evaluó realizando conteos semanales de los estadíos de *B. argentifolii* (excepto huevecillos) en plantas expuestas a los parasitoides en invernaderos de control biológico y en invernaderos tratados con insecticidas. La densidad final de ninfas de *B. argentifolii* por hoja fue comparada entre plantas provenientes de invernaderos de control biológico y de aquellos tratados con insecticida. Cuando se empleó *E. eremicus*, las densidades finales de ninfas variaron de 2-4 por hoja en el momento de realizar una inspección de protocolo para venta de las plantas. En plantas tratadas con insecticida, la densidad de ninfas varió de 0.02-0.18 por hoja, pero la densidad final de mosquitas en plantas tratadas con control biológico o químico fue comercialmente aceptable. En uno de los invernaderos donde se utilizó *E. emericus,* las plantas fueron cosechadas y vendidas sin haberse empleado insecticidas. En el otro invernadero donde fue empleado *E. emericus*, las plantas recibieron dos aplicaciones de sulfotepp (semanas 11 y 16 del ensayo), después de lo cual

fueron cosechadas sin más uso de insecticidas. En 1995, el costo de controlar *B. argentifolii* con *E. emericus* fue 30 veces mayor al de usar el insecticida imidacloprid ($2.70 vs. $0.09 por planta). En los dos invernaderos donde se usó *E. formosa* raza Beltsville, los ensayos fueron suspendidos temprano y se aplicó insecticida cuando las densidades de *B. argentifolii* alcanzaron 4-6 ninfas vivas y pupas por hoja. Las tasas de emergencia de *E. formosa* raza Beltsville fueron bajas, lo cual pudo haber sido un factor importante en la baja efectividad de este parasitoide para controlar *B. argentifolii* en invernaderos comerciales.

Inundative biological control of whitefly pests infesting greenhouse-grown ornamentals is seldom practiced by commercial producers and chemically based pest control strategies prevail. Several reasons for lack of adoption of biological control by growers of greenhouse ornamentals have been identified and include: (1) the high cost of purchasing natural enemies for mass release makes pesticides more attractive financially; (2) inconsistent natural enemy quality, quantity, and availability from commercial suppliers can adversely affect programs making growers wary of biological control; (3) a paucity of rigorous research documenting efficacy and economic cost of biological control makes justification of biological control implementation difficult; (4) lack of crop and pest specific management guidelines with natural enemies for growers to follow means there is no established infrastructure similar to that available for pesticides with which growers are familiar (Cranshaw et al. 1996, O'Neil et al. 1998, Parrella & Jones 1987, Parrella 1990, Parrella et al. 1992, Hoddle et al. 1997, Wearing 1988). In this article we address issues which concern natural enemy efficacy and quality, and the cost effectiveness of biological control for silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring (Homoptera: Aleyrodidae), on colored poinsettias (*Euphorbia pulcherrima* Willd. ex Koltz.) grown under commercial conditions.

Eretmocerus eremicus Rose and Zolnerowich (Hymenoptera: Aphelinidae) has been identified as an effective natural enemy of *B. argentifolii* (Hoddle et al. 1998a). Weekly releases of three female parasitoids per plant per week obviated the need for pesticides on non-colored poinsettias commercially grown for cuttings, and use of *E. eremicus* is recommended for control of *B. argentifolii* on poinsettia stock plants in summer (Hoddle & Van Driesche 1999). However, the ability of *E. eremicus* to control *B. argentifolii* on colored poinsettia plants grown in the fall was uncertain at the time of this trial. Weekly releases of *E. eremicus* in small experimental greenhouses where the release rate was varied over time failed to control *B. argentifolii* on colored poinsettia plants grown in the fall suggesting that this parasitoid and release strategy may be unsuitable for use at this time of year (Hoddle et al. 1999). The efficacy of constant weekly releases *of E. eremicus* for *B. argentifolii* control on colored poinsettia plants during normal fall production periods had not been previously determined in commercial greenhouses at the time work presented here was done.

Encarsia formosa Gahan Beltsville strain (Hymenoptera: Aphelinidae) is a *Bemisia*-adapted strain of *E. formosa* (Heinz & Parrella 1994). Use of this parasitoid in small experimental greenhouses at a rate of three females per plant per week produced final densities of *B. argentifolii* on colored poinsettias that were indistinguishable from those on plants produced commercially with pesticides for sale at Christmas (Hoddle et al. 1997). However, in commercial greenhouses *E. formosa* Beltsville strain failed to control *B. argentifolii* on poinsettias grown for cuttings during summer whereas under similar conditions *E. eremicus* provided acceptable control of *B. argentifolii* (Hoddle & Van Driesche 1999).

These results suggest that *E. eremicus* is the more effective natural enemy for *B. argentifolii* control on stock plants grown in summer and that *E. formosa* Beltsville strain might be more effective on colored poinsettias grown in the fall. The ability of *E. formosa* Beltsville strain to control *B. argentifolii* on commercially produced colored poinsettias, however, has not been determined. Here we present results that compare the efficacy of *E. formosa* Beltsville strain to that of *E. eremicus* against *B. argentifolii* under commercial growing conditions on poinsettias grown in the fall for sale at Christmas.

MATERIALS AND METHODS

Experimental Greenhouses

This experiment was conducted with four commercial growers in Massachusetts, USA, using either *E. eremicus* (two growers) or *E. formosa* Beltsville strain (two growers) for *B. argentifolii* control in greenhouses on colored poinsettia plants grown for the Christmas market. Evaluation trials were run over the period 4 August to 7 December, 1995.

Site one was a 260-m^2 glass greenhouse containing 3,200 plants. Cultivars grown were "Red Sails", red "Lilo", and white and marble "Angelika". Site two was a 156-m^2 glass greenhouse containing 2,300 plants. Cultivars grown were white and marble "Annette Hegg", red "Lilo", red "Celebrate 2", and "Pink Peppermint". Sites one and two received weekly releases of *E. eremicus* and plants were reduced in number during the trial to satisfy spacing and sales requirements. Site three was a 168-m^2 plastic greenhouse with 1,800 plants. A single cultivar, white "Glory V-14", was grown at this site. Site four was a 307-m^2 glass greenhouse, stocked with 2,881 plants. Cultivars grown were "Celebrate 2", marble "Angelika" and pink "Gutbier V-14". Sites three and four received weekly releases of *E. formosa* Beltsville strain.

Estimating Initial Whitefly Infestation Levels and Augmentation of Whitefly Numbers

The colored crops at sites 1 and 2 were started from rooted cuttings produced by each grower in the spring, using cuttings that had been produced using *E. eremicus* as the sole control strategy for *B. argentifolii* (Hoddle & Van Driesche 1999). Cuttings at sites 3 and 4 were produced in-house by the growers and *B. argentifolii* had been controlled chemically on stock plants with foliar insecticides before cuttings were harvested and held for three weeks in misting units for rooting. At the time of potting at each site, 70-90 randomly selected cuttings were numbered. Each leaf on the numbered cuttings was examined and total numbers of live *B. argentifolii* nymphs and pupae (one sampling category), and adults per plant were recorded. The average number of nymphs and pupae, and adult whiteflies per plant was calculated for each site and compared using a one-way ANOVA in SAS (SAS 1989) and Tukey's Studentized Range Test ($P = 0.05$) was used for means separation. At sites 2, 3, and 4 control and parasitoid release cages were stocked with poinsettia plants infested at the same nymphal and pupal density as that occurring in their respective biological control greenhouses (see below for more details on the use of cages). At site 1, all plants examined were free of *B. argentifolii* and augmentative releases of adult whiteflies were made to establish a pest population in the biological control greenhouse. The control and parasitoid release cages were also artificially inoculated with adult whiteflies at the same rate as the biological control greenhouse.

Whitefly augmentation. Because no whiteflies were seen on cuttings at site 1, the whitefly population there was augmented by introducing adult male and female pairs of *B. argentifolii* from our laboratory colony. Our intention was to introduce adult whiteflies to produce similar average per plant densities as that observed across all greenhouses at the time of planting. To do this we released 332 adult whiteflies (166 mating pairs) into the biological control greenhouse which held 3,200 plants at time of release (week 2 of the trial). This produced an average of 0.1 adult whiteflies per plant. The control cage and parasitoid release cage at site 1 (all cages contained 10 plants) were stocked with one male-female pair of adult *B. argentifolii* at the same time.

Experimental Treatments & Weekly Population Counts for *B. argentifolii*

Three treatments were established in each of the four biological control greenhouses: uncaged plants (Treatment 1), cages with whiteflies only (Treatment 2), and cages with parasitoids and whiteflies (Treatment 3). Treatment 2 was the control, and Treatment 3 acted as a check for cage effects for whitefly development in the presence of parasitoids.

To estimate whitefly population densities on uncaged plants, three leaves (one from the bottom, one from the middle, and one from the top) of 90 plants in all experimental greenhouses were inspected weekly for the presence of *B. argentifolii*. The numbers of nymphs and pupae, adults, and whitefly exuviae from which either adult whiteflies or parasitoids had emerged were recorded along with numbers of visibly parasitized whitefly nymphs. Weekly population counts were made at each site until either the grower harvested colored plants or applied insecticides because whitefly numbers had reached unacceptable densities. Final densities of live nymphs and pupae per leaf for Treatment 1 in each greenhouse were compared using a nested ANOVA in SAS (SAS 1989) and Tukey's Studentized Range Test ($P = 0.05$) was used for means separation.

Establishing & Monitoring *B. argentifolii* Population Growth in Cages

Treatments 2 and 3 were established in single cages in each of the four biological control greenhouses. Cages measured 153 cm (length) × 92 cm (width) × 117 cm (height), were constructed of pvc piping, and were enclosed on all sides with polyester mesh screening with a 95 μm opening size. Access to plants within cages was via two sleeves in the front of the cage and whiteflies were counted through a clear acetate panel located between the sleeves. Each cage was stocked with 10 potted poinsettia plants that were chosen from those examined to estimate the initial infestation level at planting. We stocked cages with selected plants to achieve similar average densities of live nymphs and pupae per plant as those in the corresponding biological control greenhouses.

For Treatments 2 and 3, whitefly population density estimates were made weekly on eight randomly selected plants within cages. In Treatment 3, parasitoids were released into cages at a rate of three female parasitoids per plant per week. Based on an expected 50:50 sex ratio and an emergence rate of 60%, 100 *Trialeurodes vaporariorum* (Westwood) (Homoptera: Aleyrodidae) nymphs parasitized by *E. eremicus* were placed weekly in cages at sites 1 and 2 in a single release cup. In the *E. formosa* Beltsville strain release cages at sites 3 and 4, 50 parasitized *B. argentifolii* nymphs were placed in cages weekly. We assumed a 60% emergence rate and an all female population for this parasitoid.

Monitoring of Insecticide-Treated Greenhouses, end of Trial Whitefly Densities, & Cost Analysis

To measure the performance of parasitoids compared to conventional whitefly control practices, two greenhouses treated with insecticides, one at site one and one at site three, were monitored weekly. Live *B. argentifolii* nymphs and pupae were counted on each of three randomly selected leaves (one leaf from the bottom, middle, and top of the plant) on 90 randomly selected plants. Mean numbers of live whitefly nymphs and pupae per leaf were compared to those observed in the biological control greenhouses and parasitoid release cages.

The average number of live whiteflies per leaf was determined using a sampling protocol used from previous studies (Hoddle et al., 1998a, 1999). Fifteen plants were randomly selected from each experimental greenhouse and the number of live whitefly nymphs and pupae were recorded for each of six leaves (two leaves were chosen at random from the bottom, middle, and top of the plant.)

The cost of biological control versus the cost of insecticides was determined at site 1 by analyzing insecticide application records for the insecticide-treated greenhouse, and the cost of using *E. eremicus* in the biological control greenhouse at the same site. The cost of whitefly control using imidacloprid (a systemic chloronicotinyl compound [Cahill et al. 1996]) was based on 1995 catalogue prices for Marathon® (a granular insecticide of 1% imidacloprid, [Olympic Horticultural Products, Mainland, PA]). The cost of using *E. eremicus* was based on the 1995 retail figure of $22 for 1000 parasitized *T. vaporariorum* nymphs. *Encarsia formosa* Beltsville strain was sold to us for $9 per 1000 parasitized *B. argentifolii* nymphs.

Estimating Weekly Parasitoid Release Rates

Parasitoid releases in the biological control greenhouses and parasitoid cages began immediately after greenhouses were filled with poinsettias. The targeted weekly release rate for both parasitoid species was three females per plant per week. *Eretmocerus eremicus* is a bi-parental species (sex ratio is 1:1) and was supplied by Beneficial Insectaries, Oak Run, California USA, as loose parasitized *T. vaporariorum* nymphs which had been reared on tobacco. *Encarsia formosa* Beltsville strain is a uniparental parasitoid, which was reared on *B. argentifolii* on collard greens and supplied by American Insectaries, Escondido, California USA, 25 loose parasitized nymphs.

Parasitized nymphs were distributed throughout greenhouses and cages by placing them in plastic release cups (height 3 cm; diameter, 4 cm). Release cups were attached to stakes that were pushed into the potting media until cups were positioned below the crop canopy. To estimate the number of parasitoids released per plant per week, we measured the number of nymphs per unit weight of material sent by the supplier, the weight of the shipment, and the percentage of nymphs from which parasitoids successfully emerged under greenhouse conditions. Percentage emergence was determined by returning release cups every two weeks to the laboratory and recording the number of nymphs from which parasitoids did and did not emerge. We assumed a 1:1 sex ratio for *E. eremicus* in our calculations.

RESULTS

Initial Whitefly Infestation Levels on Cuttings at Potting

There was a significant difference across sites in the mean number (± SE) of live nymphs and pupae on cuttings at the time of planting ($F = 44.5$, $df = 3$, $p = 0.0001$). At

sites 1, 2, (both *E. eremicus*) 3, and 4 (both *E. formosa* Beltsville strain), the average number of live nymphs and pupae per plant was 0.00 ± 0.00 (n = 90 cuttings) (because no immature whiteflies were found at site 1 it was not included in the ANOVA), 8.19 ± 0.78 (n = 70) [a], 5.86 ± 0.84 (n = 90) [b], and 1.41 ± 0.18 (n = 90) [c], respectively. Means followed by the same letters are not significantly different from each other. Both the *E. eremicus* and *E. formosa* Beltsville strain treatments had one relatively high and one relatively low initial density of whiteflies.

There was also a significant difference across site in the mean number (± SE) of adult whiteflies per plant at time of potting ($F = 8.32$, $df = 2$, $p < 0.00001$). At sites 1, 2, 3, and 4, the average number of live adults per plant was 0.00 ± 0.00 (because no adult whiteflies were found at site 1 it was not included in the ANOVA), 0.06 ± 0.02 [a], 0.4 ± 0.09 [b], 0.1 ± 0.05 [a], respectively. Means followed by the same letters are not significantly different from each other. The average number of adult whiteflies per plant when averaged across all biological control greenhouses (n = 4) was 0.16 ± 0.03.

Actual Parasitoid Release Rates

Emergence rates of adult parasitoids in the two *E. eremicus* greenhouses averaged 53.8% ± 4.8% and 55.6% ± 3.9% for sites 1 and 2 across the entire trial periods, respectively (Table 1). In the two *E. formosa* Beltsville greenhouses, weekly percentage emergence of adult parasitoids averaged 33.0% ± 3.8% and 38.3% ± 5.6% for sites 3 and 4, respectively (Table 1). The average number of female parasitoids released per plant per week at sites 1 and 2 was 2.9 ± 0.2 and 3.7 ± 0.31 respectively, for the two *E. eremicus* greenhouses (Table 1). The average number of female parasitoids released at sites 3 and 4 was 1.9 ± 0.25 and 2.4 ± 0.37 per plant per week, respectively (Table 1). This average weekly release rate for *E. formosa* Beltsville strain were lower than the intended release rate of 3 females per plant per week because of poor emergence of parasitoids following deployment of parasitized *B. argentifolii* nymphs in greenhouses.

Population Density Trends for *B. argentifolii*

Population growth of *B. argentifolii* in cages in the absence of *E. eremicus* (Treatment 2) was substantially higher than that observed for populations receiving parasitoid releases (Treatment 3) (Fig. 1). In control cages at the end of the trials, numbers of live nymphs and pupae exceeded 29 and 117 per leaf at sites 1 and 2, respectively. At the end of the trials in cages treated with *E. eremicus*, populations of live *B. argentifolii* nymphs and pupae per leaf reached 8 and 2 at sites 1 and 2, respectively, (Fig. 1). Upon grower request, cages at sites 3 and 4 where *E. formosa* Beltsville strain was released were removed and trials were terminated in weeks 6 and 4, respectively when insecticides were applied for whitefly control. No useful data was obtained from cages studies at sites 3 and 4 because trials were terminated before *B. argentifolii* population trends became evident.

Colored poinsettia plants were harvested at site 1 without the use of any insecticides. Two insecticide applications were required at site 2 to reduce numbers of adult whiteflies on plants (Fig. 2). The biological control greenhouse was treated with two sulfotepp fumigations (Plantfume smoke generator, ai 15% sulfotepp [Plant Products Corporation, Vero Beach FL]) three days apart during week 11 of the trial. Parasitoid releases continued after fumigation and plants were harvested at week 16 without further insecticide intervention. In greenhouses receiving releases of *E. eremicus* (sites 1 and 2), densities of live nymphs and pupae were less than two per leaf when trials ended. This final density of live nymphs and pupae was acceptable to commercial growers producing colored poinsettias for sale at Christmas (Fig. 2).

TABLE 1. TOTAL NUMBER OF PLANTS, TOTAL NUMBER OF PARASITIZED NYMPHS PLACED IN GREENHOUSES, PERCENTAGE PARASITOID EMERGENCE, AND NUMBER OF FEMALE PARASITOIDS RELEASED PER PLANT IN BIOLOGICAL CONTROL GREENHOUSES TREATED WEEKLY WITH *ERETMOCERUS EREMICUS* AND *ENCARSIA FORMOSA* BELTSVILLE STRAIN.

Wasp	Site	Week no.	Plant no.	No. parasitized nymphs	Parasitoid Emergence (%)	No. females released/ plant
E. eremicus	1	1	3,200	no releases		
		2	3,200	29,023	88.6	4.02
		3	2,550	25,552	42.6	2.13
		4	2,550	25,238	55.3	2.74
		5	1,969	19,722	44.0	2.20
		6	1,219	12,360	42.6	2.16
		7	1,219	12,213	64.0	3.21
		8	1,500	6,572	—	—
		9	800	8,015	58.6	2.94
		10	1,081	10,816	70.6	3.53
		11	500	5,009	50.6	2.53
		12	500	8,339	34.6	2.89
		13	500	8,349	40.0	3.34
		14	500	8,343	—	—
mean (± SE)					53.8 ± 4.8	2.9 ± 0.2
E. eremicus	2	1	2,300	—	—	—
		2	2,300	23,023	63.3	3.17
		3	2,300	23,045	80.0	4.01
		4	1,250	12,518	67.3	3.37
		5	900	9,016	44.0	2.20
		6	621	6,219	46.6	2.33
		7	621	6,212	46.6	2.33
		8	621	6,217	65.0	3.25
		9	621	10,360	67.0	5.59
		10	621	10,370	56.0	4.68
		11	621	10,370	71.3	5.95
		12	621	10,369	50.0	4.17
		13	621	10,368	38.0	3.17
		14	621	10,361	34.0	2.84
		15	621	10,360	48.6	4.05
		16	621	10,360	—	—
mean (± SE)					55.6 ± 3.6	3.7 ± 0.31
E. formosa	3	1	1,800	9,000	31.3	1.57
		2	1,800	9,000	45.3	2.27

TABLE 1. (CONTINUED) TOTAL NUMBER OF PLANTS, TOTAL NUMBER OF PARASITIZED NYMPHS PLACED IN GREENHOUSES, PERCENTAGE PARASITOID EMERGENCE, AND NUMBER OF FEMALE PARASITOIDS RELEASED PER PLANT IN BIOLOGICAL CONTROL GREENHOUSES TREATED WEEKLY WITH *ERETMOCERUS EREMICUS* AND *ENCARSIA FORMOSA* BELTSVILLE STRAIN.

Wasp	Site	Week no.	Plant no.	No. parasitized nymphs	Parasitoid Emergence (%)	No. females released/ plant
		3	1,800	9,000	24.6	1.23
		4	1,800	18,007	26.6	2.66
		5	1,800	8,992	37.3	1.86
		6	1,800	15,875	—	—
mean (± SE)					33.0 ± 3.8	1.9 ± 0.25
E. formosa	4	1	2,881	20,000	23.3	1.60
		2	2,881	16,000	39.3	2.17
		3	2,881	16,281	40.0	2.26
		4	1,508	8,680	50.6	3.38
mean (± SE)					38.3 ± 5.6	2.4 ± 0.37

Parasitism Levels

Parasitism by *E. eremicus* in the biological control greenhouse was first recorded at week 2 at site 2, and steadily increased to reach a maximum of 43% before declining to 15% at the end of the trial (Fig. 3). In contrast, parasitism by *E. eremicus* at site 1 was not detected until week 6. Peak parasitism by *E. eremicus* at site 1 reached 30% at week 8 and then declined to 4-7% for the last four weeks of the trial (Fig. 3). Parasitism did not exceed 5% in the biological control houses at the two sites in which *E. formosa* Beltsville strain was released (Fig. 3).

Insecticide-Treated Greenhouses

Insecticide-treated greenhouses at sites 1 and 3 received one application each of imidacloprid (Marathon®) immediately after greenhouses were filled. This insecticide can give up to 12 weeks protection with a single application (Lopes 1994).

Whitefly Densities at Harvest

The protocol designed to evaluate the mean number of live nymphs and pupae per leaf at time of harvest on 15 randomly selected plants detected significant differences between both sites 1 and 2 treated with *E. eremicus* and to numbers recorded on plants in retail outlets ($F = 37.94$, $df = 2$, $p = 0.0001$) (Table 2). Weekly releases of *E. formosa* Beltsville strain failed to reduce *B. argentifolii* to non-damaging densities and trials at sites 3 and 4 were terminated early and insecticides were applied to the crop prior to the harvesting of colored plants. Consequently, similar comparisons of whitefly numbers in the biological control greenhouses at sites 3 and 4 with insecticide treated plants were not made.

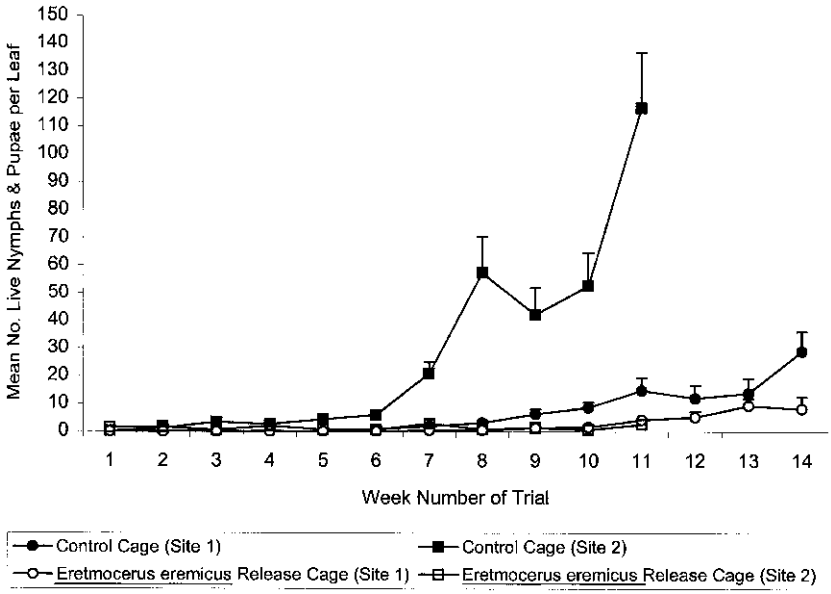

Fig. 1. Mean number of live *Bemisia argentifolii* nymphs and pupae (± SE) per leaf on poinsettia plants in the control and parasitoid release cages in the biological control greenhouses treated with *E. eremicus*.

Cost Analysis

At site 1, the total cost of controlling *B. argentifolii* with an average weekly release rate of 2.9 female *E. eremicus* per plant for 14 weeks was 30 times more expensive than the use of imidacloprid for whitefly control (Table 3). Cost analysis for use of *E. formosa* Beltsville strain at site 3 was not calculated as this trial was terminated early following grower intervention with foliar insecticide applications.

Discussion

Releases of *E. eremicus* at rates of 2.9-3.7 females per plant per week successfully suppressed *B. argentifolii* to non-damaging levels on colored poinsettias. The sales inspection protocol detected 2-4 live *B. argentifolii* nymphs and pupae per leaf and plants were marketable with this level of whitefly infestation at harvest. Mean densities of live *B. argentifolii* nymphs and pupae per leaf on the 90 randomly selected plants at sites 1 and 2 were both less than two (compared to 2-4 live nymphs and pupae from the sales inspection protocol) when trials were ended and plants were harvested. This larger sample size may have resulted in a more accurate assessment of final per leaf densities of *B. argentifolii* at time of harvest indicating that final densities of live *B. argentifolii* nymphs and pupae per leaf being less than two are commercially acceptable.

In one of the two *E. eremicus* greenhouses (site 1) the crop was harvested without any insecticide applications even though *B. argentifolii* were deliberately introduced to produce an initial infestation of 0.1 adult whiteflies per plant, a density similar to that seen in the other biological control greenhouses. At site 1, initial inspection of

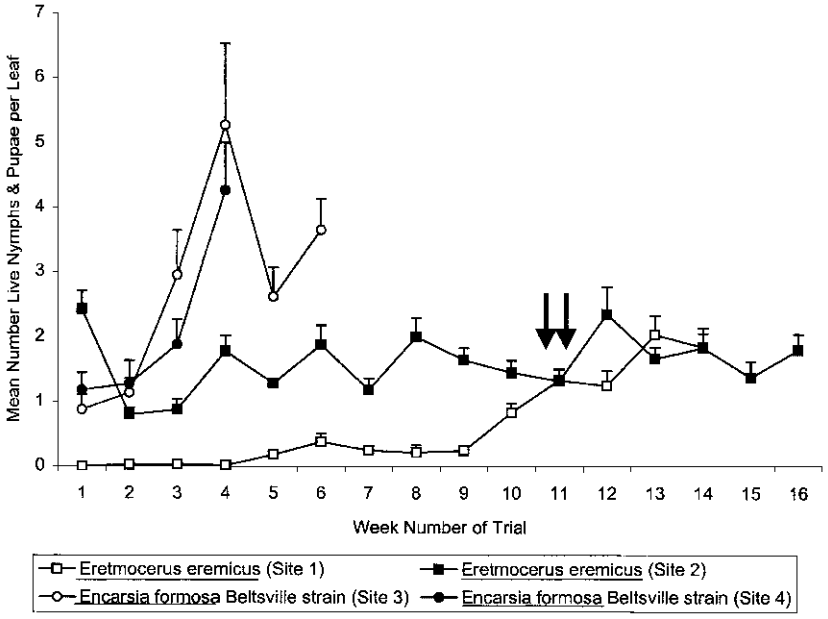

Fig. 2. The mean number of live *Bemisia argentifolii* nymphs and pupae (± SE) per leaf on uncaged poinsettia plants in the biological control greenhouses treated with *Eretmocerus eremicus* (sites 1 and 2) or *Encarsia formosa* Beltsville strain (sites 3 and 4). Trial duration times at sites 3 and 4 were reduced because growers intervened with chemical treatments to suppress *B. argentifolii* population growth. Arrows indicate times of insecticide applications at site 2.

cuttings failed to detect whitefly nymphs prior to parasitoid releases beginning and whitefly nymphs were not deliberately introduced to produce initial nymph densities similar to those seen in the other biological control greenhouses. Because initial whitefly densities at site one were low, whitefly numbers remained consistently lower throughout the duration of the trial and the test of *E. eremicus* for *B. argentifolii* control was not as rigorous as site 2. At the second *E. eremicus* release site (site 2) initial whitefly densities were higher than site 1, and biological control was successfully combined with two fumigatory sulfotepp applications to produce commercially acceptable colored plants.

Data collected at harvest indicates that growers and consumers are tolerant of light whitefly infestations on colored poinsettias and biologically based control programs do not have to achieve zero whitefly densities for plants to be marketable. Trials subsequent to this one have demonstrated that *E. eremicus* can also successfully control another common whitefly pest of poinsettia, *T. vaporariorum*, on colored plants and that growers are able to successfully manage their own biological control program using this parasitoid under commercial growing conditions (Van Driesche et al. 1999a).

A major obstacle to the use of *E. eremicus* for biological control of *B. argentifolii* on greenhouse grown poinsettias is the high cost of this parasitoid in comparison to insecticides for control of this pest. The use of *E. eremicus* for control *B. argentifolii* on

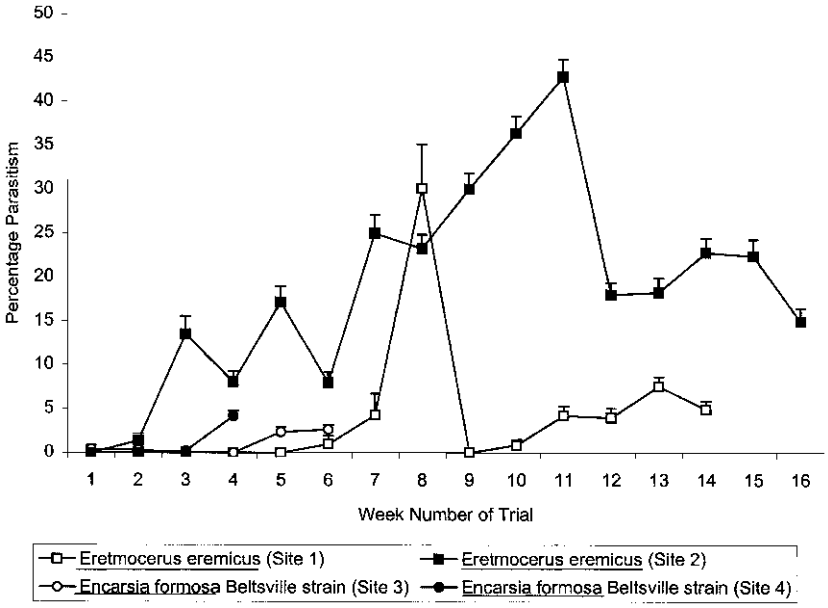

Fig. 3. Percentage parasitism of *Bemisia argentifolii* in biological control greenhouses treated with either *Eretmocerus eremicus* (sites 1 and 2) or *Encarsia formosa* Beltsville strain (sites 3 and 4).

poinsettias grown for cuttings in 1995 was 44 times more expensive than using imidacloprid (Hoddle & Van Driesche 1999). In this study with colored poinsettia plants, *E. eremicus* was 30 times more expensive than the same insecticide in 1995. Since 1995 when this work was done the cost of *E. eremicus* has decreased by 62% and this parasitoid currently retails for $8.30 per 1000 parasitized *T. vaporariorum* nymphs (Hoddle & Van Driesche 1999). At the 1999 cost the use of *E. ermicus* at site 1 in this trial would have been $1.02 per single stem plant, or just 11 times more expensive than imidacloprid.

The cost of using *E. eremicus* in a biologically based pest management program can be reduced further by reducing the numbers of parasitoids released weekly. One way of accomplishing a reduced weekly release rate is to combine *E. eremicus* with compatible insect growth regulators (IGRs). We have identified IGRs that can be successfully used with *E. eremicus* (Hoddle & Van Driesche unpublished). When *E. eremicus* is combined with two mid-season applications of Applaud 70 WP (ai 70% buprofezin [Agrevo USA Company, Wilmington DE]) the weekly parasitoid release rate can be reduced by 66%. Marketable colored poinsettias are produced under commercial conditions using this parasitoid-IGR program at a cost of $0.38 per single stem plant, a price more competitive with imidacloprid which can cost $0.09-$0.14 per plant (Van Driesche et al. 1999b).

Encarsia formosa Beltsville strain failed to provide adequate control of *B. argentifolii* at the two sites at which it was released. This result was due in part to low parasitoid emergence rates (33-38%) in experimental greenhouses. We did not determine whether environmental factors in greenhouses (e.g., aspects of commercial poinsettia

TABLE 2. INFESTATION STATISTICS FOR LIVE *BEMISIA ARGENTIFOLII* NYMPHS AND PUPAE ON POINSETTIA LEAVES FROM EXPERIMENTAL GREENHOUSES AT TIME OF HARVEST IN WHICH *ERETMOCERUS EREMICUS* HAD BEEN RELEASED, AND ON LEAVES OF COLORED POINSETTIAS RECORDED FROM RETAIL OUTLETS AT THE END OF THE 1995 GROWING SEASON.

Treatment	No. plants inspected	% Plants infested	No. leaves examined	% Leaves infested	Nymphs/ Leaf ± SE
Site 1 (*E. eremicus*)	15	87	45	58	3.8 ± 0.9a
Site 2 (*E. eremicus*)	15	93	45	56	1.9 ± 0.8b
Five retail outlets in Amherst, Massachusetts (chemical control)	75	11	225	4	0.08 ± 0.03c

Means followed by different letters are significantly different from each other at the 0.05 level of significance.

production that reduce efficacy of *E. formosa* Beltsville strain) or poor parasitoid quality were responsible for low emergence rates. Because of low rates of parasitoid emergence, 89% of releases failed to reach the intended release rate of three parasitoids per plant per week, a rate which has been shown to be efficacious in small greenhouse trials (Hoddle et al. 1997). During the course of our work (1994-1995) with *E. formosa* Beltsville strain two companies (one European and one American) attempted to commercialize this parasitoid. Restructuring of the European insectary resulted in *E. formosa* Beltsville strain being removed from its product line while persistent production problems (i.e., disease and hyperparasitism by *Encarsia pergandiella* Howard) hampered yield and promoted the ultimate loss of the only commercial *E. formosa* Beltsville strain colony in the USA.

In addition to uncertainty of supply and post-receipt quality, inherent biological attributes may have also prevented *E. formosa* Beltsville strain from being an effective natural enemy of *B. argentifolii* on poinsettias. Under time limited conditions in commercial poinsettia-production greenhouses, *E. formosa* Beltsville strain is disadvantaged because it is slower in discovering *B. argentifolii* patches, finds fewer

TABLE 3. COMPARISON OF THE COSTS OF *BEMISIA ARGENTIFOLII* CONTROL AT SITE 1 IN THE INSECTICIDE GREENHOUSE AND THE BIOLOGICAL CONTROL GREENHOUSE TREATED WITH *ERETMOCERUS EREMICUS*.

	Insecticide greenhouse	Biological control greenhouse
Total cost of imidacloprid	$288.00	NA
Total cost of *E. eremicus*	NA	$3,950.12
Treatment cost per plant	$ 0.09	$ 2.70
Cost m^2	$ 1.11	$ 15.19

patches, kills fewer whitefly nymphs upon patch discovery, and is observed less frequently on patches when compared to similar studies with *E. eremicus* (Hoddle et al. 1998b). The inability of *E. formosa* reared on either *B. argentifolii* or *T. vaporariorum* (the standard insectary host for this parasitoid) to control *B. argentifolii* on poinsettias grown for cuttings (Parrella et al. 1991, Hoddle & Van Driesche 1999) or for color (Hoddle & Van Driesche 1996) suggests this species cannot be recommended for *B. argentifolii* control on commercially grown poinsettias.

In contrast, the efficacy of *E. eremicus* for *B. argentifolii* control continues to be supported by results of trials in poinsettia crops under various growing conditions. Further work on developing programs which use *E. eremicus* in combination with selective insecticides such as IGRs is needed before this parasitoid will be economically competitive with currently employed control programs that rely exclusively on insecticides.

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ASSESSMENT OF COST AND PERFORMANCE OF *ERETMOCERUS EREMICUS* (HYMENOPTERA: APHELINIDAE) FOR WHITEFLY (HOMOPTERA: ALEYRODIDAE) CONTROL IN COMMERCIAL POINSETTIA CROPS

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ABSTRACT

Releases of *Eretmocerus eremicus* Rose and Zolnerowich (Hymenoptera: Aphelinidae) at release rates of 3.0-7.5 females per plant per week successfully suppressed whitefly populations on commercial poinsettia (*Euphorbia pulcherrima* Willd. ex Koltz.) crops in fall of 1996 at four Massachusetts commercial producers. At two sites, the whitefly populations consisted exclusively of greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), and at the other two sites exclusively of silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring. Parasitoids were received from commercial suppliers and monitored weekly to determine the sex ratio of newly emerged adults, as well as the rate of adult emergence. Commercially produced pupae were 48.1% (± 2.2 SE) female and had 58.1% (± 3.6 SE) emergence under greenhouse conditions. Plants from the four biological control greenhouses in this trial at the time of sale of the crop had an average of 0.55 (± 0.28 SE) nymphs per leaf. Chemically-protected poinsettias offered for sale at eight local retail outlets had an average of 0.16 (± 0.09 SE) nymphs per leaf. Final whitefly densities in both biological control and insecticide-treated greenhouses were acceptable to consumers. An average of 6.8 insecticide applications was applied to suppress whiteflies in chemical control greenhouses in this trial, compared to 1.7 in the biological control greenhouses. Use of biological control was 27 fold more expensive, costing $2.14 per plant compared to $0.08 for chemical control. Cost of biological control was inflated by three factors: (1) an incorrectly high estimate by one grower of number of plants per greenhouse, (2) an unusually long production period (23 weeks) for one grower, and (3) miscommunication with the insectary concerning manner of filling orders to compensate for reduced percentage of emergence of adult parasitoids from ordered parasitized nymphs. Control of these cost-inflating factors would allow some reduction in the cost of the use of this parasitoid, but not to levels competitive with current pesticides. This study is the first to demonstrate the ability of *E. eremicus* releases to suppress *T. vaporariorum* populations in commercial poinsettia crops and parasitism of *T. vaporariorum* by *E. eremicus* was 7.5-fold higher (ave. 24.8% parasitism of fourth instar nymphs in pooled seasonal samples) than that observed in *B. argentifolii* (ave. 3.3%).

Key Words: *Eretmocerus eremicus, Bemisia argentifolii*, *Trialeurodes vaporariorum* poinsettia, biological control, augmentative release, evaluation, cost, greenhouses

RESUMEN

Liberaciones de *Eretmocerus eremicus* Rose y Zolerowich (Hymenoptera: Aphelinidae) a razón de 3.0-7.5 hembras por planta por semana lograron un control efectivo de mosquita blanca en cuatro cultivos comerciales de nochebuena (*Euphorbia pulche-*

rrima Willd. ex Koltz.) de Massachusetts durante el otoño de 1996. En dos sitios, las poblaciones de mosquita blanca consistieron exclusivamente de la mosquita blanca de invernadero, *Trialeurodes vaporariorum* (Westwood), mientras que en los otros dos sitios las poblaciones fueron exclusivamente de mosquita blanca de la hoja plateada, *Bemisia argentifolii* Bellows and Perring. Los parasitoides fueron obtenidos de proveedores comerciales y monitoreados semanalmente para determinar la proporción de machos y hembras adultos recién emergidos, así como la tasa de emergencia de adultos. Las pupas producidas comercialmente fueron 48.1% (± 2.2 SE) hembras y tuvieron una tasa de emergencia de 58.1% (± 3.6 SE) bajo condiciones de invernadero. Al momento de su venta, plantas provenientes de los cuatro invernaderos de control biológico usados en este estudio tuvieron un promedio de 0.55 (± 0.28 SE) ninfas por hoja. En comparación, plantas protegidas con insecticidas tuvieron un promedio de 0.16 (± 0.09 SE) ninfas por hoja al momento de su venta en ocho locales comerciales. Las densidades finales de mosquita blanca encontradas tanto en los invernaderos de control biológico como en aquellos donde se emplearon insecticidas fueron aceptables a los consumidores. En promedio, 6.8 aplicaciones de insecticida fueron hechas para controlar a la mosquita blanca en los invernaderos de control químico usados en este estudio, comparado con 1.7 aplicaciones en los invernaderos de control biológico. El costo del control biológico fue 27 veces más caro que el del control químico ($2.14 vs. $0.08 por planta). El costo del control biológico resultó elevado debido a tres factores: (1) el cálculo erróneo (demasiado alto) por parte de un productor con respecto al número de plantas por invernadero, (2) un período demasiado largo de producción (23 semanas) en el caso de un productor, y (3) falta de comunicación con personal del insectario respecto a la manera de compensar el porcentaje reducido de emergencia de adultos parasitoides logrado por las ninfas parasitadas ordenadas. El costo del uso de parasitoides podría reducirse al corregir los errores mencionados, pero no lo suficiente para ser competitivo con el uso de insecticidas. Este estudio es el primero en demostrar la eficacia del parasitoide *E. eremicus* en el control de *T. vaporariorum* en cultivos comerciales de nochebuena. El estudio demostró que el parasitismo de *T. vaporariorum* por *E. eremicus* fué 7.5 veces más alto que el obtenido con *B. argentifolii* (parasitismo de 24.8% vs. 3.3% de ninfas de cuarto instar).

Silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring, (= the "B" strain of *Bemisia tabaci* [Gennadius]) and greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), (both Homoptera: Aleyrodidae) are important pests of poinsettia (*Euphorbia pulcherrima* Willd. ex Koltz.) in the United States (Helgesen & Tauber 1974, Byrne et al. 1990, Bellows et al. 1994). The parasitoids most extensively used for whitefly biological control in protected floricultural crops have been *Encarsia formosa* Gahan and *Eretmocerus eremicus* Rose and Zolnerowich (formerly given as *Eretmocerus* sp. nr. *californicus*) (both Hymenoptera: Aphelinidae) (Drost et al. 1996; Hoddle & Van Driesche 1996; Rose & Zolnerowich 1997; Hoddle et al. 1996, 1997ab, 1998abc; Hoddle & Van Driesche in press).

Previous trials in small, experimental greenhouses (holding 90 plants) suggested that a *Bemisia*-adapted strain of *E. formosa* (referred to as the Beltsville strain, Heinz & Parrella 1994) and *E. eremicus* had the potential to provide effective silverleaf whitefly control in poinsettia crops if released at rates of 1-3 females per plant per week (Hoddle et al. 1997ab, 1998a). Trials in commercial greenhouse poinsettia crops in 1995 in Massachusetts compared the efficacy of *E. eremicus* and the Beltsville strain of *E. formosa* at a release rate of 3 females per plant per week for each species. In both summer stock plants and fall Christmas crop plants, *E. eremicus* suppressed silverleaf whitefly better than the Beltsville strain of *E. formosa* (Hoddle and Van Driesche, 1999). Poinsettias from these 1995 trials were sufficiently free of whiteflies to

be acceptable to growers for use of cuttings from the summer crop (Hoddle & Van Driesche, 1999) and sale to retailers in the Christmas poinsettia market in the fall (Hoddle and Van Driesche, in press).

Here we report further results from commercial trials conducted in fall 1996 in Massachusetts in which four commercial poinsettia growers employed *E. eremicus* for control of whiteflies. The purpose of the trial was to assess the robustness of *E. eremicus* releases as a means of suppressing whiteflies in commercial poinsettia crops when applied to a wider variety of commercial conditions and when releases were made by growers. At each of four commercial greenhouse ranges, we measured the level of whitefly suppression achieved by releases *of E. eremicus* compared to whitefly populations treated chemically. At one study site, we made a further comparison to a caged whitefly population not subject to either biological or chemical control. The costs of biological control and chemical control were compared at all four locations.

Materials and Methods

Study Sites and Experimental Design

The study was conducted at four commercial greenhouse growers. Two growers were from the Connecticut River Valley in the western part of Massachusetts (Fairview Farms, Whately; Westover Greenhouses, Chicopee) and two were from eastern Massachusetts (Loosigian Farms, Methuen; Konjoian Greenhouses, Andover). The trial was conducted on the Christmas poinsettia crop between 3 July and 13 December 1996, with cropping periods varying from 17 to 23 weeks among sites. At each of the four locations, weekly observations were made in two greenhouses, one managed with biological control and one with insecticides. In the biological control greenhouses, our intent was to make weekly releases of 3 female *E. eremicus* per plant. In the chemical control greenhouses, the growers managed pests with pesticides. At 3 sites (Loosigian, Konjoian, and Westover), growers ordered parasitoids directly from commercial insectaries and made releases themselves. At one site (Fairview), we ordered and received parasitoids instead of the grower so we could assess the quality of weekly shipments in terms of number of parasitoid pupae shipped (compared to number ordered) and sex ratio of emerging adult parasitoids. At this site, we made releases and retrieved parasitoid exuviae weekly from release cups in greenhouses to determine the percentage emergence under greenhouse conditions. Greenhouse dimensions, names of poinsettia cultivars grown, numbers of plants and potting arrangements per greenhouse are given in Table 1. ("Plants" refers to independently rooted poinsettias; pots may contain one or several plants.)

To formally demonstrate, at least at one site, that whitefly populations on poinsettia increase sharply if left uncontrolled, a control cage was installed in the biological control greenhouse at Fairview Farms that received neither *E. eremicus* nor conventional insecticides for whitefly management. The control cage (153 cm long by 92 cm wide and 117 cm tall) was constructed of PVC pipe and covered with fine polyester screening (95 micron dia openings) capable of excluding entrance of whiteflies and parasitoids. The control cage contained 5 pots (20.3 cm), each with 3 poinsettia plants (total, 15 plants per cage). To initialize the caged whitefly population, we inspected all leaves on 100 plants from the greenhouse and chose plants that bore the number of whitefly nymphs and pupae needed to match the density of the whitefly population in the whole greenhouse as determined by a count of whiteflies on the potted cuttings at the start of the trial (see *Initial whitefly density*). Because initial whitefly densities at this site were very low, we augmented the silverleaf whitefly population in the biolog-

TABLE 1. GREENHOUSE TYPE, SIZE, PLANT NUMBER, POT NUMBER, AND POINSETTIA CULTIVARS IN TRIAL.

Site and treatment	Type	Dimensions	# Plants in greenhouse[1]	# Pots in greenhouse	Cultivars and potting dates[2]
Fairview biological control	plastic hoop	5m × 30m	1500 8/15/96 1021 12/6/96 902 12/12/96	500 (21.6 cm); three plants each	Freedom, 7 August
Fairview chemical	plastic hoop	5m × 30m	2448 for entire trial	612 (25.4 cm); four plants each	Freedom, 7 August
Konjoian biological control	glass	10m × 42m	2550 8/20/96 3193 9/17/96 2818 11/25/96 1633 12/3/96 345 2/10/96	625 (20.3 cm); three plants each; 1120 (15.2 cm); one plant each; 22 nine-plant hangers	Peter star, Freedom, V-14, Supjibi, 20 August
Konjoian chemical	glass	10m × 42m	3500 for entire trial	800 (10.2 cm); 500 (14 cm); 2200 (15.2 cm); all one plant each	Peter star, Freedom, V-14, Supjibi, 20 August
Loosigian biological control	plastic hoop	7m × 48m	1243 for entire trial	1243 (16.5 cm); one plant each	Red Sails, 13 August
Loosigian chemical	plastic hoop	7m × 48m	1200 for entire trial	1200 (16.5 cm); one plant each	Red Sails, 13 August
Westover biological control	glass	6m × 32m	2014 7/3/96 1331 12/4/96	160 (20.3 cm); three plants each; 256 ((30.5 cm); four plants each; 102 (38.1 cm); five plants each	Supjibi, Maren, Monet, V-17, V-14, Cortez Freedom, Peter Star, 3 July
Westover chemical	glass	15m × 61m	7800 for entire trial	2100 (17.8 cm); two plants each; 1200 (20.3 cm); three plants each	Supjibi, Maren, Monet, V-17, V-14, Cortez, Freedom, Peter Star, 3 July

[1]Earliest date gives initial number of plants. Pots were spaced initially at final densities. Subsequent dates reflect changes in number as crop was harvested.

[2]Sources of cuttings varied by variety and grower: Westover Greenhouse propagated V-14 and V-17 varieties from stock plants and purchased others as rooted cuttings; Fairview Farms purchased all plants as rooted cuttings; Loosigian Farms purchased unrooted cuttings; Konjoian Greenhouses propagated all varieties from stock plants.

ical control greenhouse using silverleaf whitefly-infested plants produced by using adult whiteflies from our laboratory colony of this species (see *Whitefly augmentation*). The numbers of whiteflies in the control cage were also augmented at the same rate so that they had the same starting density as the biological control greenhouse.

While control cages were not installed at the other three trial sites, we have shown in previous trials that silverleaf whitefly on poinsettia typically increases to high densities if not controlled (Hoddle & Van Driesche 1996; Hoddle et al. 1997ab, 1998a). No cage controls were included at sites that proved to be infested with greenhouse, rather than silverleaf, whitefly. Consequently control data showing unrestricted growth for that species in the absence of chemical or biological control were not collected in this trial. However, such growth has been observed in other trials (Helgesen & Tauber 1974, Rumei 1982).

During the trial we collected data on (1) the weekly numbers released, percentage emergence and sex ratio of *E. eremicus*, (2) the weekly whitefly densities in each greenhouse, (3) the species of whitefly present at each grower, (4) insecticide usage during crop production by each grower, and (5) the quality of plants at harvest (in terms of whitefly infestation).

Crop Management

Source of cuttings, potting dates, spacing, plant removals. Three of four greenhouses potted cuttings between 7 and 20 August. One location (Westover Greenhouses) potted on 3 July in order to produce large ("tree") poinsettias. Table 1 provides details on greenhouse type, size, numbers of plants, pot sizes, and cultivars.

Pesticide use. At three sites, the biological control greenhouse was treated only with fungicides and plant growth regulators. At one site, Konjoian Greenhouses, insecticides were sprayed on 23-30% of the plants in the biological control greenhouse. The infestation on these plants occurred because whitefly-infested plants from another greenhouse on the property were placed directly beneath the intake vent of the biological control greenhouse early in the cropping cycle, leading to a heavy, localized infestation on benches near the air intake fans. Plants sprayed with insecticides were excluded from sampling for the remainder of the trial.

Chemical and biological control greenhouses at all sites were treated with plant growth regulators and fungicides. Names and application dates of insecticides used to control foliar insects in chemical control greenhouses (and a portion of one biological control greenhouse) are presented in Table 2.

Parasitoid releases. Biological control greenhouses at all four sites received weekly releases of *E. eremicus* for whitefly control. The intended weekly release rate was 3 female parasitoids per plant. When plants were removed from biological control greenhouses for sale, numbers of parasitoids released per greenhouse were reduced accordingly. To avoid conflicts with parasitoids, yellow sticky cards (which are highly attractive to *E. eremicus*, Sanderson, unpub. data), used by growers to monitor whiteflies and fungus gnats, were not placed in any of the biological control greenhouses.

Whitefly Species Composition, Initial Density Estimate, and Augmentation

Whitefly species. Both *B. argentifolii* and *T. vaporariorum* infest poinsettia in Massachusetts. To determine the whitefly species present in each test greenhouse, ten heavily infested leaves were collected at each location in middle of the trial (mid-October). In the laboratory, all fourth instar nymphs, pupae and pupal cases were examined under a dissecting microscope and identified to species. Voucher specimens of

TABLE 2. APPLICATIONS OF INSECTICIDES MADE IN TRIAL FOR WHITEFLY CONTROL.

Grower	Greenhouse type	No. insecticide applications	Insecticides applied and application dates	Whitefly species present in greenhouse	Common chemical name
Fairview	biocontrol	0	None	*B. argentifolii*	
Fairview	chemical	1	Marathon 1%G (1% a.i.) (12 Sept.)	*B. argentifolii*	imidacloprid
Konjoian	biocontrol	7	Thiodan 50WP (50% a.i.) (on 12 benches) (19 Sept., 23 & 29 Oct.)[1]	*T. vaporariorum*	endosulfan
			Marathon 1%G (1% a.i.) (19 Sept., 6 Oct.)[2]		imidacloprid
			Orthene PT 1300 DS (3% a.i.) (on 12 benches) (23 & 29 Oct.)[1]		acephate
			Fulex Dithio (14% a.i.) (17 & 23 Nov.)		sulfotep
Konjoian	chemical	8	Thiodan 50WP (50% a.i.) (21 Aug. & 12 Sept., 29 Oct., 10 Nov.)	*T. vaporariorum*	endosulfan
			Avid 0.15EC (1.9% a.i.) (21 Aug., 10 Nov.)		abamectin
			PT 1300 (3% a.i.) (12 Sept., 29 Oct.)		acephate
			Vydate L (20% a.i.) (24 Sept., 1 Oct.)		oxymyl
			Fulex Dithio (14% a.i.) (16 & 23 Nov.)		sulfotep
Loosigian	biocontrol	0	None	*T. vaporariorum*	

[1]Thiodan and Orthene were applied to 30% of the plants in the biological control greenhouse.
[2]Marathon was applied to 23% of the plants in the biological control greenhouse.

TABLE 2. (CONTINUED) APPLICATIONS OF INSECTICIDES MADE IN TRIAL FOR WHITEFLY CONTROL.

Grower	Greenhouse type	No. insecticide applications	Insecticides applied and application dates	Whitefly species present in greenhouse	Common chemical name
Loosigian	chemical	8	Marathon 1%G (1% a.i.) (12 Sept.)	*T. vaporariorum*	imidacloprid
			Fulex Dithio (14% a.i.) (25 Sept., 17 & 21 Oct., 11 Nov.)		sulfotep
			Fulex Nicotine (14% a.i.) (20 Nov.)		nicotine
			Fulex Thiodan (14% a.i.) (2 & 13 Dec.)		endosulfan
Westover	biocontrol	0	None	*B. argentifolii*	
Westover	chemical	10	Azatin EC (3% a.i.) (9 & 16 Aug.)	*B. argentifolii*	azadirachtin
			Tame 2.4EC (33.6% a.i.) (9 & 16 Aug.)		fenpropathrin
			Attain PT 1800 TR (0.5% a.i.) (11 Sept., 3 Oct.)		bifenthrin
			Preclude TR (4.8% a.i.) (17 & 26 Sept.)		fenoxycarb
			Marathon 1%G (1% a.i.) (4 Oct.)		imidacloprid
			Talstar (7.9% a.i.) (28 Oct., 1, 8 & 14 Nov.)		bifenthrin
			Enstar II (65.1% a.i.) (28 Oct., 1, 8 & 14 Nov)		s-kinoprene

[1]Thiodan and Orthene were applied to 30% of the plants in the biological control greenhouse.
[2]Marathon was applied to 23% of the plants in the biological control greenhouse.

whiteflies were not retained as no opportunity exists for taxonomic confusion in our case. *Trialeurodes vaporariorum* is distinct in the context of greenhouse crops from all other whiteflies, and all *Bemisia* whiteflies in poinsettia greenhouse crops in North America are strain B of *B. tabaci* (= *B. argentifolii*), as the A strain was known only from outdoor crops and even there has disappeared over the last decade in North America, being replaced completely by the B strain.

Initial whitefly density. In order to determine if initial whitefly population densities in greenhouses designated as biological control greenhouses were within an acceptable range for management using parasitoids (considered by us to be 1.0 or fewer live nymphs, pupae and adults combined per cutting, for *B. argentifolii*, based on levels seen in our earlier trials, Hoddle et al. 1996, Hoddle and Van Driesche in press), population densities were estimated on cuttings at the time of potting. At each location, all nymphs, pupae, and adults on all leaves of 50 potted cuttings in the biological control greenhouse were counted within 1-2 days of the potting date (see Table 1), and numbers of leaves per cutting were recorded.

Whitefly augmentation. Because no whiteflies were seen on cuttings (n = 100) examined from the biological control greenhouse at one site (Fairview Farms), the whitefly population there had to be augmented by introducing whitefly-infested plants from our laboratory. Our intention was to add a number of immature whiteflies sufficient to bring the per plant density at this site up to the average value of the three other sites. To infest plants, we chose six uninfested poinsettia plants and used ventilated, clip-on leaf cages (2.5 cm dia) to enclose 4-5 pairs of whitefly adults over leaves for 2 days to produce eggs. We then counted the eggs produced and removed excess numbers. Infested plants each had three infested leaves; each infested leaf (after egg removal) bore an average of 105 *B. argentifolii* eggs (± 8.6 SE, n = 10 leaves counted). Infested plants were placed in the biological control greenhouse at Fairview Farms on 19 August. Initially, all infested leaf patches remained protected from attack by parasitoids within clip cages. One clip cage on each plant was removed on each of 19, 23, and 29 August, allowing for a gradual introduction of the whiteflies into the crop. A total of 1890 eggs (6 plants × 3 patches × 105 eggs per patch) were added to this greenhouse, which contained 1500 plants. We assumed 79% survival to the settled crawler stage (based on cohort survival data in Hoddle et al. 1998a), giving a projected augmented nymphal density of 1.0 nymph per plant, meeting our objective of a density comparable to the average density of the other three biological control greenhouses in the trial (1.05 nymphs per plant).

Parasitoid Sources, Application Methods, and Release Rates

The *E. eremicus* we used were purchased from commercial suppliers and shipped as parasitized *T. vaporariorum* fourth instar nymphs packed in sawdust, except for the material used at Fairview Farms. Sawdust was omitted from shipments send to our laboratory for use at this site in order to allow us to retrieve parasitized whiteflies for estimation of parasitoid number per unit weight, sex ratio, and percentage emergence. Over the course of the trial, parasitoids were obtained from two suppliers. From the start of the trial until 4 October, parasitoids were supplied by Beneficial Insectary, Inc. (14751 Oak Run Rd., Oak Run, CA 96069). This colony was discontinued mid-way through the trial, but the same population of *E. eremicus* was available from Koppert Biological Systems, Inc. in the Netherlands, and parasitoids from this source were used to complete the trial. Koppert's production of this species was initiated with the same material that had been used by Beneficial Insectaries (O. Minkenberg, pers. comm.), so the genetic composition of the parasitoids used in the trial was consistent throughout. Specimens from material sold by Koppert, Inc. as *E. californicus* (previ-

ous name for *E. eremicus*) were submitted for taxonomic confirmation to Michael Rose (specialist on the genera *Eretmocerus* and *Encarsia*, formerly of Texas A & M University) and were confirmed to be *E. eremicus*. Voucher specimens have been deposited in the insect collection of the University of California, Riverside campus**.**

Parasitoid pupae were shipped directly to three of the four participating growers because it was intended that processes used in the trial be as close to commercial as possible. Therefore, at three locations growers received parasitoid shipments and placed shipped material in release containers in greenhouses. These growers received parasitized fourth instar *T. vaporariorum* nymphs mixed with sawdust. This mixture was placed in styrofoam release cups (6 cm tall, 5.5 cm wide at bottom, 8.5 cm wide at top) that had the bottoms cut out and replaced with organdy (mesh 0.95 microns) to allow for drainage. Cups were attached 10 cm above the canopy to wooden stakes (50 cm long) placed in the potting media. In each biological control greenhouse, there were 15 release cups distributed evenly throughout the crop. Each week, growers emptied sawdust and any unemerged parasitoids from the previous week's release into pots of plants on benches where cups were located and then added the new material to the same cups. Watering was done so as to avoid wetting parasitoid pupae in release cups (either drip irrigation was used or workers were advised not to wet sawdust in release cups when hand watering).

To estimate numbers of parasitoids released, parasitoids for use at Fairview Farms were sent to our laboratory for subsampling before release. To estimate the number of parasitoids released, we measured the number of pupae per unit weight of material sent by the supplier, the weight of the shipment, the sex ratio of emerging adults, and the percentage of pupae from which parasitoids successfully emerged under greenhouse conditions.

Estimating number of E. eremicus pupae received from suppliers. Each week before taking parasitoid pupae to Fairview Farms to be released, we counted the number of live parasitoid pupae in each of ten 20 mg subsamples under a stereomicroscope at 25×. The average number of pupae per 20 mg was multiplied by 50 (to get the number per gram) and then by the weight (in g) of all pupae received to determine the total number of pupae actually shipped by the supplier in particular orders. The percentage deviation between this value and the number ordered was noted.

Estimating E. eremicus sex ratio. Each week, 200-300 parasitoid pupae from the shipment sent to our laboratory were placed in a petri dish in a growth chamber at 22°C and long day light regime (16:8 L:D) and held for emergence. One week after receipt, samples were frozen, and 15 groups of 10 adult parasitoids were examined at 50× with a stereomicroscope and their sex determined. Sexes were recognized based on the clubbed antennae of the female (Rose & Zolnerowich 1997).

Estimating E. eremicus emergence rate. Each week before adding new parasitoid pupae to release cups in the biological control greenhouse at Fairview Farm, whitefly nymphs with parasitoid exit holes and remaining dead nymphs in cups from the previous week were retrieved and returned to the laboratory, frozen, and used to estimate the parasitoid emergence rate. From the material returned to the laboratory from each week of the trial, 15 samples of 10 parasitoid "pupae" (comprised of whitefly nymphs containing dead parasitoid pupae and whitefly nymphal integuments with parasitoid emergence holes) were examined at 25× under a stereomicroscope, and classified as dead or emerged based on the presence of parasitoid emergence holes. The percent emergence was calculated as the number of whitefly nymphs with parasitoid emergence holes divided by the total number examined (nymphs containing dead parasitoid pupae plus whitefly nymphal integuments bearing parasitoid emergence holes).

Calculating release rates of E. eremicus. For one site (Fairview Farms) we used the above information on number of parasitoid pupae per unit weight, together with sex ratio and percent emergence, to adjust the number of parasitoid pupae actually released to achieve the intended release rate. At the other three sites, growers received shipments directly and made their own releases, and quality control checks were not made. At these sites, we estimated the number of parasitoid pupae that would be needed to achieve our intended release rate (3 females per plant per wk) by assuming a 50% female sex ratio and a 60% emergence rate. The sex ratio value was based on advice from the supplier and the emergence rate was based on quality control checks we made in greenhouse trials in 1995. Based on these assumptions, 10 parasitoid pupae per plant per week were ordered for each participating grower, with exact numbers being calculated from numbers of plants in each biological control greenhouse. Subsequent to the trial, we calculated the actual release rate achieved by reference to quality control data collected from samples taken for the Fairview Farms site.

Whitefly Population Sampling

Densities of whitefly life stages (adult whiteflies, live and dead nymphs and pupae) were estimated weekly throughout the cropping season by examining leaves on arbitrarily selected plants. At Westover Greenhouses, Konjoian Greenhouses, and Loosigian Farms, two arbitrarily selected mature leaves from each of the upper and lower halves of the plant from each of 30 arbitrarily selected plants (120 leaves total) in each greenhouse were inspected for whiteflies on each sample date.

Numbers of leaves examined in the biological control greenhouse at Fairview Farms differed from that of the other three sites because this greenhouse was also part of a separate, concurrent experiment with a more intense level of sampling. At Fairview Farms in the biological control greenhouse, three leaves (1 from the bottom third of the plant, 1 middle, and 1 top) on 90 plants (270 leaves total) were inspected. In the control cage in the biological control greenhouse at Fairview Farms, three leaves on each of eight plants were inspected in a similar manner, weekly. At Fairview Farms, the chemical control greenhouse was sampled for a shorter period than the biological control greenhouse. Three arbitrarily chosen leaves from each of 20 plants (60 leaves total) were inspected weekly, from 29 August to 13 November only. For figures in which whitefly densities are plotted on log scales, 0.001 was added to all counts to avoid zero values.

Measurement of Parasitoid-Caused Mortality

Whitefly nymphs killed by parasitoids through host feeding were included in counts of dead nymphs or pupae made to estimate densities (see above). Deaths from host feeding could not be distinguished from physiological death. Successful parasitism was scored by noting numbers of visibly parasitized fourth instar whitefly nymphs seen weekly on leaves on which whitefly stages were counted. Because parasitism was rare, weekly samples were not analyzed separately by date because of low sample sizes. Instead, season-long rates of parasitism were computed for each of the four biological control greenhouses by summing the number of visibly parasitized fourth instar whitefly nymphs across all sample dates. Parasitism was computed as the total number (A) of parasitized fourth instar whitefly nymphs summed across all dates within one location, divided by this same value (A) plus the summed value in the same samples of all whitefly pupae (B), (% parasitism = 100[A/ A +B]). Younger whitefly stages (various nymphs) were not included in the estimation of parasitism,

as these stages were too young for any parasitism they might have had to have become visible in samples. Parasitism rates were compared statistically between the combined samples of the two biological control greenhouses with *T. vaporariorum* and those of the two with *B. argentifolii.*

Whitefly Densities on Plants at Harvest

To compare the quality of plants in the trial to that of plants offered for sale in Massachusetts, we determined the densities of live nymphs, pupae, and adults on plants from the biological control and chemical control greenhouses and on poinsettia plants at 8 retail outlets in Massachusetts in December 1996. Numbers of whiteflies on plants at retail outlets were measured using a standardized market survey sampling protocol used previously in Massachusetts, in which six leaves (2 bottom, 2 middle and 2 top) on 15 arbitrarily selected plants were examined for live whitefly nymphs, pupae, or adults (Hoddle et al. 1997ab, 1998a).

Cost Analysis

To compare the costs of biological and chemical control, we computed the costs of parasitoids versus pesticides used for whitefly control in the biological control and chemical control greenhouses at each trial site. To compute the cost of chemical pest control, grower spray records were examined and all applications of materials to suppress whiteflies were noted. Using 1995 catalog prices for insecticides and label application rates and methods, we computed amounts and cost of insecticide applied in each application. Seasonal expenditures for pesticides were then summed and divided by the number of plants in each greenhouse to obtain a seasonal insecticide cost per plant. To compute the cost of parasitoids we used the 1996 commercial price of $11 per thousand pupae and an application rate of 10 pupae per plant (equal to 3 females per plant, based on an assumed 50/50 sex ratio and 60% emergence rate). Costs of labor for application were not considered for either chemicals or parasitoids (after Hoddle & Van Driesche 1996).

Statistical Analyses

Average seasonal values of parasitoid emergence rate, sex ratio, and release rate at Fairview Farms were compared to assumed or intended values with Student's t test. Densities of whitefly nymphs were compared between chemical and biological control greenhouses (and in one location, to whitefly nymphal densities in a control cage) using nested ANOVAs. A Chi Square test was used to compare rates of parasitism of greenhouse whitefly and silverleaf whitefly nymphs. This comparison was performed on data after pooling across all sample dates for the pair of locations with each whitefly species. A nested ANOVA was used to compare whitefly nymphal densities on leaves from the biological control and chemical control greenhouses to whitefly densities on leaves of plants offered for sale at retail outlets.

RESULTS

Crop Management and Pesticide Use

In the chemical control greenhouses, from 1 to 10 insecticide applications were made per greenhouse for whitefly control (avg. 6.8 ± 1.8 SE, Table 2), with an ave. of

8 applications against *T. vaporariorum* at two sites and 5.5 applications against *B. argentifolii* at the remaining two locations. In biological control greenhouses, three growers used no insecticides and one made 7 applications to a portion (about 30%) of the greenhouse (Table 2) to suppress whiteflies drawn in through the air intake vents.

Whitefly Species Composition, Initial Density, and Augmentation

Whitefly species. Of 216 nymphs and 404 pupal exuviae collected 17 October at Loosigian Farms and of 798 nymphs and 242 pupal exuviae collected on the same date at Konjoian Greenhouse, all were *T. vaporariorum*. In contrast, at Fairview Farms and Westover Greenhouse, all fourth instar nymphs and pupae seen in samples during the trial were *B. argentifolii*.

Initial whitefly density on potted cuttings. Mean numbers of live nymphs plus pupae per leaf (± SE) found in the initial count on poinsettia cuttings in the biological control greenhouses varied from 0.0 to 1.6 (Fairview Farms [0.0 initially, 1.0 after augmentation], Konjoian Greenhouses [1.6 ± 0.7], Loosigian Farms [1.4 ± 0.4], and Westover Greenhouse [0.14 ± 0.14]). Chemical control greenhouses at each site were filled with cuttings from the same sources as the biological control greenhouses.

Silverleaf whitefly levels at two sites (Fairview Farms and Westover Greenhouses) were considered suitable for use of biological control, based on previous trials in commercial greenhouses in Massachusetts (Hoddle & Van Driesche, in press). Potential for biological control of the greenhouse whitefly populations at Loosigian Farms and Konjoian Greenhouses could not be evaluated because no previous trials on biological control of this species on poinsettia had been run in Massachusetts.

Parasitoid Sex Ratio, Emergence, and Release Rates Achieved

Parasitoid sex ratio. The percentage of parasitoid pupae producing female parasitoids varied from 39 to 58% for 1500 insects examined from September to November (Fig. 1). The seasonal average, 48.1% (± 2.2 SE), did not differ statistically in a Student's t test from the assumed value (50%) used in calculating numbers of pupae for releases (t = -0.85, df = 9, $P > 0.05$)

Parasitoid emergence rate in greenhouse. The emergence rate in week one of the trial at the monitored site (Fairview Farms) was very low (16%) for unknown reasons. (Maximum daytime greenhouse temperatures were very high [36-43°C], but so were temperatures in several succeeding weeks in which emergence rates were higher.) In weeks 2-17, emergence rates varied from 37 to 75% (Fig. 2). The average emergence for weeks 2-17 was 60.7% (± 2.6 SE). This value did not differ statistically in a Student's t test from the assumed value (60%) used in calculating the release rate (t = 0.27, df = 15, $P > 0.05$).

Number of parasitoid pupae shipped by supplier versus number ordered. Important discrepancies occurred between numbers of parasitoids ordered and numbers received. At Fairview Farms, we calculated the number of parasitized nymphs to be placed in the greenhouse weekly ourselves and corrected for this discrepancy. At the other three locations, the supplier sent higher numbers of parasitized nymphs than ordered. Counts in our laboratory of numbers of parasitized nymphs averaged 264.6 (± 17.3 SE) per 20 mg (range 144-388). For ten shipments, numbers of pupae received from Koppert Biological Inc. were 201% of the number ordered (i.e., double), ranging from 127 to 365% of the desired number. The main identifiable reason for this excess was compensation by the supplier for non-emergence of, in their view, 30% of the shipped parasitoids. Subsequent to this trial we learned that Koppert views emergence of its product to average 70% and as a matter of policy, fills orders at 142% of the number requested to compensate.

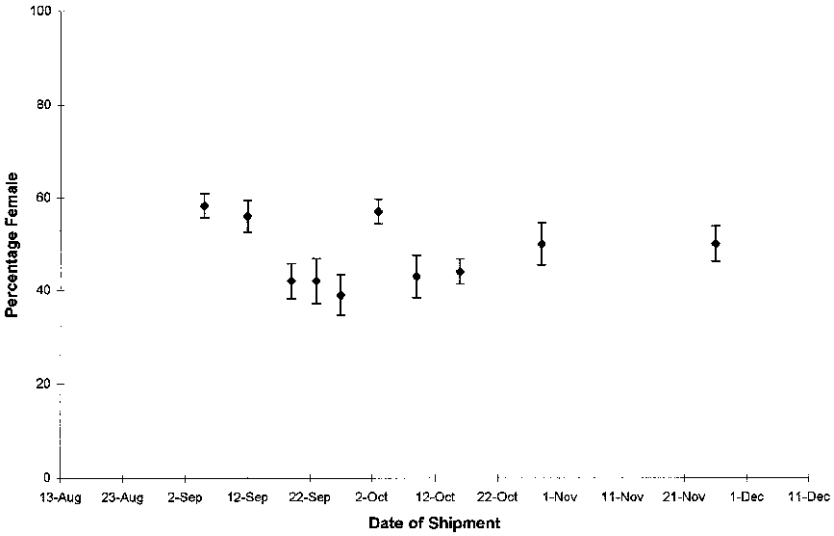

Fig. 1. Mean (± SE) percentage female of adult *Eretmocerus eremicus* emerging in the laboratory from material received weekly from insectaries supplying parasitoids for release in trial.

Actual parasitoid release rates. Release rates achieved at study sites varied because actual numbers shipped differed from numbers ordered (see above) and because, for particular dates, actual sex ratios or percent emergence differed from assumed values. At Fairview Farms, the average number of adult female parasitoids actually emerging into the crop per plant per week from parasitized nymphs was 2.92 (± 0.2 SE, range 0.60-4.15) (Table 3, Fig. 3). This rate did not differ statistically in a Student's t test from the intended release rate of 3.0 females per plant per week (t = -0.51, df = 1, $P > 0.05$).

Release rates at other greenhouses in the trial were estimated by using data on sex ratio and percentage emergence derived from the parasitoids shipped to us for use at Fairview Farms, and our estimate of the degree to which the supplier shipped more parasitized nymphs than ordered (which were calculated based on the ratio of number received to the number ordered for Fairview Farms). The supplier's over supply of parasitized nymphs to compensate for less than 100% emergence directly affected the release rate. Consequently, actual release rates (female parasitoid adults per plant per week) were 6.67 (± 0.87 SE) at Konjoian's Greenhouse, 4.47 (± 0.48 SE) at Loosigian Farms, and 4.72 (± 0.67 SE) at Westover Greenhouses.

Whitefly Population Monitoring

Fairview Farms. At Fairview Farms, only *B. argentifolii* was present. Whitefly density in the control cage increased steadily over the course of the trial, reaching 19.0 (± 4.6 SE) live nymphs per leaf by wk 18 (11 Dec.) (Fig. 4). Peak whitefly nymphal density in the control cage was 90 fold greater than that on uncaged plants in the biological control greenhouse, which did not exceed 0.2 (± 0.1 SE) nymphs per leaf (Fig. 5a).

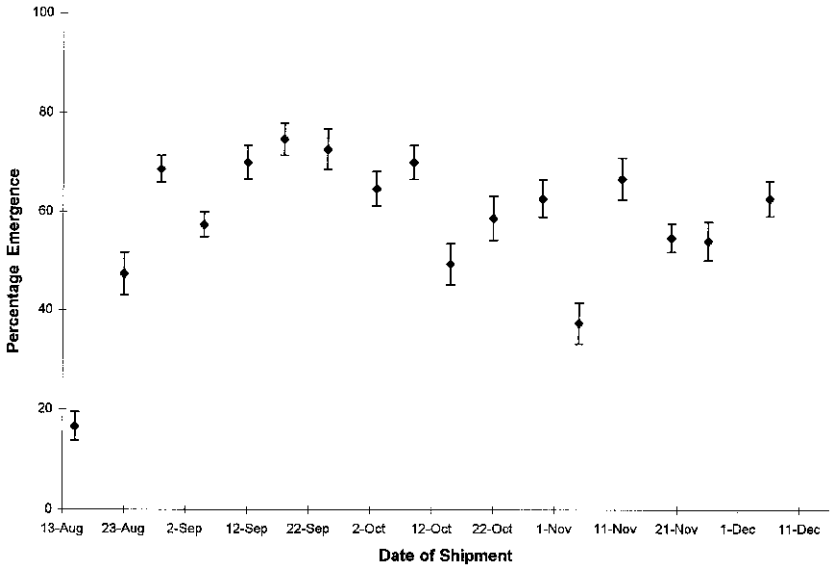

Fig. 2. Mean percentage (± SE) emergence of *Eretmocerus eremicus* after one week in the biological control greenhouse at Fairview Farms in Whately, MA.

Density of whitefly nymphs on uncaged plants in the biological control greenhouse was similar to that observed in the chemical control greenhouse, in which plants were treated with imidacloprid. Numbers of live pupae and adults were consistently below 0.04 per leaf (Fig 5 b, c).

Westover Greenhouses. At Westover Greenhouses, the grower produced a long season crop of extra large poinsettia plants that included poinsettia "trees" started 3 July (6 weeks earlier than the normal mid-August starting date for smaller poinsettias). The crop was infested exclusively with *B. argentifolii* and management problems in the chemical control greenhouse occurred, leading to a whitefly outbreak that reached 86.3 (± 20.8 SE) live nymphs per leaf on 3 October. Repeated applications of pesticides (Table 2) reduced this population to 0.47 (± 0.15 SE) nymphs per leaf by time of harvest (Fig. 6a).

In the biological control greenhouse, parasitoid releases consistently maintained whitefly densities below 1 live nymph per leaf until 21 November, with numbers then increasing to 1.31 (± 0.26 SE) by the time of harvest (Fig. 6a). Densities of live whitefly nymphs in the biological control greenhouse were consistently lower than those in the chemical control greenhouse between 31 July and 13 November. Numbers of live pupae and adults per leaf in the biological control greenhouse were consistently lower than those observed in the chemical control greenhouse until 30 October (Figs. 6 b, c).

Konjoian Greenhouses. At Konjoian Greenhouses, poinsettias were infested only with *T. vaporariorum*. Numbers of live nymphs per leaf in the portion of the biological control greenhouse not treated with insecticides exceeded 2 live nymphs per leaf on one sample occasion (2.8 nymphs on 1 October), but were at acceptable densities (1.03 ± 0.34 SE) at the time of sale (Fig. 7a).

TABLE 3. QUALITY CONTROL INFORMATION USED IN ESTIMATING ACTUAL RELEASE RATE *OF ERETMOCERUS EREMICUS* AT FAIRVIEW FARMS BIOLOGICAL CONTROL GREENHOUSE.

Release date	% female ($\bar{X}$ ± SE)	% emergence ($\bar{X}$ ± SE)	No. parasitized nymphs/20 mg[2] ($\bar{X}$ ± SE)	No. parasitized nymphs ordered	No. parasitized nymphs received[3]	Ratio oversupplied	No. plants in greenhouse	Estimated release rate (females per plant per week) ($\bar{X}$ ± SE)
16 Aug.	48 ± 1[1]	17 ± 3	144	14,895	11,232	0.75	1485	0
23 Aug.	48 ± 1[1]	47 ± 4	225	14,895	21,262	1.43	1485	0.80 ± 0.14
30 Aug.	48 ± 1[1]	69 ± 3	185	14,895	15,078	1.01	1485	2.28 ± 0.22
6 Sept.	58 ± 3	57 ± 3	219	14,895	16,717	1.12	1485	3.95 ± 0.22
12 Sept.	56 ± 3	70 ± 3	200	14,895	15,100	1.01	1485	3.22 ± 0.24
19 Sept.	42 ± 4	75 ± 3	293	14,895	27,982	1.88	1485	2.89 ± 0.30
26 Sept.	57 ± 3	73 ± 4	176	14,895	17,688	1.19	1485	2.92 ± 0.34
4 Oct.	43 ± 5	65 ± 4	351 ± 16	14,895	55,650	3.73	1485	4.17 ± 0.31
10 Oct.	44 ± 3	70 ± 3	354 ± 18	14,895	28,276	1.90	1485	2.79 ± 0.33
17 Oct.	42 ± 5	49 ± 4	275 ± 13	14,895	32,175	2.16	1485	3.09 ± 0.24
24 Oct.	50 ± 5	59 ± 5	373 ± 8	14,895	31,752	2.13	1485	2.08 ± 0.30
31 Oct.	48 ± 1[1]	63 ± 4	273 ± 14	14,895	25,389	1.71	1485	2.94 ± 0.35
7 Nov.	48 ± 1[1]	37 ± 4	234 ± 12	14,895	18,954	1.27	1485	3.04 ± 0.20
14 Nov.	48 ± 1[1]	67 ± 4	269 ± 12	14,895	20,427	1.37	1485	1.81 ± 0.21
21 Nov.	48 ± 1[1]	55 ± 3	388 ± 16	14,895	33,026	2.22	1485	3.23 ± 0.22

[1]For indicated weeks, data on % of pupae that yielded females were not collected. To compute the estimate of the release rate, we used the seasonal average for proportion female.
[2]For weeks 1-7, counts of pupae per 20 mg were supplied by the producer, with information on standard errors. For weeks 8-18, counts were made in our laboratory.
[3]Pupae received were estimated as total weight of pupae received times number of pupae counted in 10 subsamples of 20 mg each, times 50 (see materials and methods for details).
[4]Pupae shipped in sawdust this week, so quality control data were not obtained.
[5]Supplier changed as of 2 October.

TABLE 3. (CONTINUED) QUALITY CONTROL INFORMATION USED IN ESTIMATING ACTUAL RELEASE RATE *OF ERETMOCERUS EREMICUS* AT FAIRVIEW FARMS BIOLOGICAL CONTROL GREENHOUSE.

Release date	% female ($\bar{X}$ ± SE)	% emergence ($\bar{X}$ ± SE)	No. parasitized nymphs/20 mg[2] ($\bar{X}$ ± SE)	No. parasitized nymphs ordered	No. parasitized nymphs received[3]	Ratio oversupplied	No. plants in greenhouse	Estimated release rate (females per plant per week) ($\bar{X}$ ± SE)
27 Nov.	50 ± 4	54 ± 4	282 ± 7	14,895	29,134	1.96	1485	2.76 ± 0.26
5 Dec.	48 ± 1[1]	63 ± 04	259 ± 14	14,895	24,815	1.67	1021	2.57 ± 0.19
12 Dec.	No data[4]	No data[4]	No data[4]	14,895	No data		902	No data[4]

[1]For indicated weeks, data on % of pupae that yielded females were not collected. To compute the estimate of the release rate, we used the seasonal average for proportion female.
[2]For weeks 1-7, counts of pupae per 20 mg were supplied by the producer, with information on standard errors. For weeks 8-18, counts were made in our laboratory.
[3]Pupae received were estimated as total weight of pupae received times number of pupae counted in 10 subsamples of 20 mg each, times 50 (see materials and methods for details).
[4]Pupae shipped in sawdust this week, so quality control data were not obtained.
[5]Supplier changed as of 2 October.

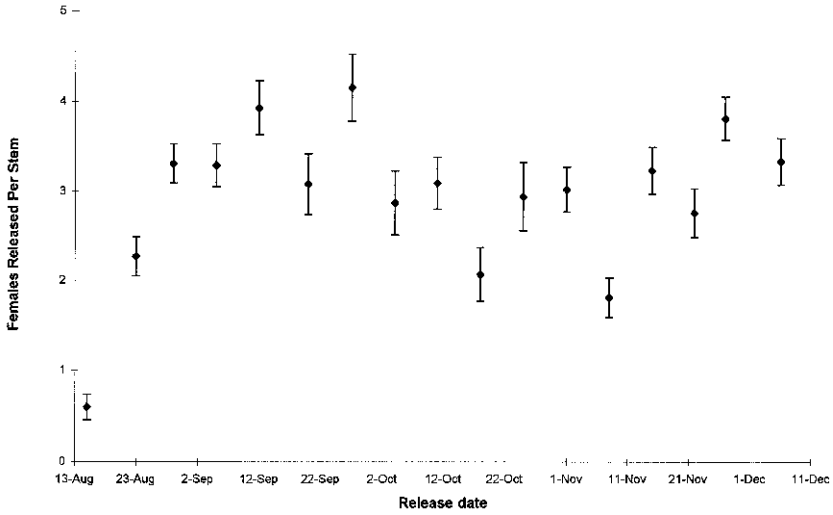

Fig. 3. Estimated mean (± SE) number of female *Eretmocerus eremicus* released per plant in the biological control greenhouse at Fairview Farms. (See Table 3 for calculations).

In the chemical control greenhouse, whitefly nymphal densities were similar to those in the biological control greenhouse until 12 November. After 12 November, nymphal densities remained lower in the chemical control greenhouse than in the biological control greenhouse through the end of the trial. Nymphal density was significantly lower in the chemical control greenhouse than in the biological control greenhouse on the last sample date before harvest (df = 1, F = 6.91, $P = 0.009$) (Fig. 7a). Pupal and adult counts in the biological control greenhouse (Fig. 7b, c) were lower than nymphal counts, but generally higher than counts of these stages in the chemical control greenhouse. Eight pesticide applications (Table 2) were made in the chemical control greenhouse, which reduced whitefly densities to 0.13 (± 0.05 SE) live nymphs per leaf at the time of sale (Fig. 7a).

Loosigian Farms. At Loosigian Farms, all whiteflies were *T. vaporariorum*. Numbers of live nymphs on the poinsettia crop in the biological control greenhouse exceeded 2 nymphs per leaf once, reaching 2.13 (± 1.02 SE) on 10 September (Fig. 8a). Densities of live nymphs on plants in the chemical control greenhouse reached 23.0 (± 7.6 SE) per leaf on 17 September, and eight pesticide applications (see Table 2) reduced numbers to 2.68 (± 1.0 SE), compared with 0.05 (± 0.03 SE) in the biological control greenhouse (Fig. 8a), at time of harvest. Nymphal densities in the biological control greenhouse were consistently lower than those in the chemical control greenhouse from 17 September through the end of the trial. At harvest, density of nymphs per leaf was significantly lower in the biological control greenhouse than in the chemical control greenhouse (df = 1, F = 12.08, $P = 0.0006$).

Numbers of live pupae and adults per leaf in the biological control greenhouse peaked at 0.08 (± 0.05 SE) on 19 November and 0.11 (± 0.05 SE) on 30 August, respectively (Figs. 8b, c). In contrast, in the chemical control greenhouse, numbers of live pupae reached 4.6 (± 1.50 SE) (on 12 November) and of adult whiteflies, 0.96 (± 0.22 SE) (on 15 October) (Figs. 8b, c).

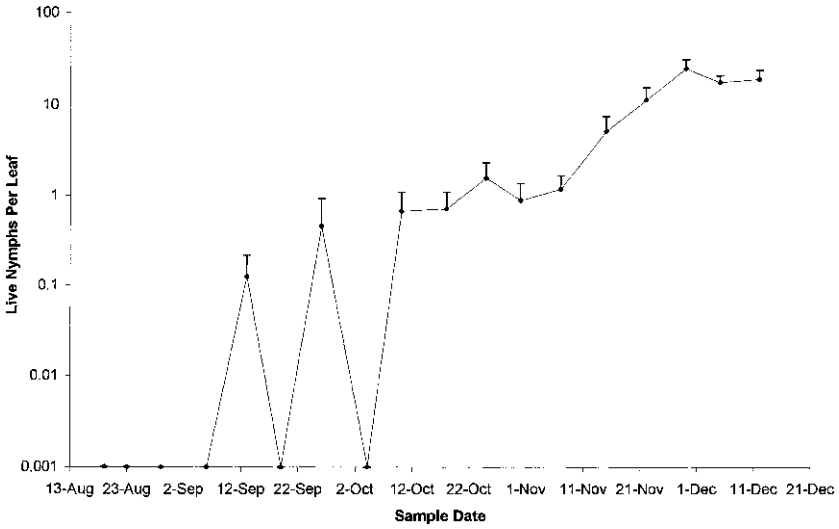

Fig. 4. Mean densities per leaf (± SE) of live *Bemisia argentifolii* nymphs in control cage at the biological control greenhouse at Fairview Farms.

Parasitoid-Caused Mortality

Numbers of dead nymphs on plants seen in whitefly density counts varied between locations and treatments. At Fairview Farms, chemical control was highly effective in suppressing whiteflies and dead nymphs were rarely detected. More dead nymphs were observed in the biological control greenhouse at this site, but numbers remained below 0.25 dead nymphs + pupae per leaf throughout the trial (Fig, 5d).

At Westover Greenhouses, where chemical control of whiteflies was ineffective until near the end of the trial, counts of dead whitefly nymphs in the chemical control greenhouse were high, exceeding 20 dead nymphs + pupae per leaf on some dates. In contrast, at this site in the biological control greenhouse, whitefly densities remained low and as a consequence, so did numbers of dead nymphs + pupae (Fig. 6d).

At Konjoian Greenhouses, numbers of live whitefly nymphs in the chemical and biological control greenhouses were similar on most sample dates (Fig. 7a), but numbers of dead nymphs + pupae were greater in the biological control greenhouse (Fig. 7d).

At Loosigian Farms, where densities of live nymphs in the chemical control greenhouse nearly always exceeded densities in the biological control greenhouse, so did densities of dead nymphs + pupae (Fig. 8d).

Parasitism, while rare in all four biological control greenhouses, was significantly higher ($\chi^2 = 22.27$, corrected for continuity; df = 1; $P < 0.005$) in the two greenhouses with *T. vaporariorum* populations (31.3% of 32 whitefly stages at Loosigian Farms and 18.4% of 228 whitefly stages at Konjoian Greenhouses) than at those locations with *B. argentifolii* (6.7% of 150 whitefly stages at Westover Greenhouses and no parasitism observed, of 50 whitefly stages at Fairview Farms).

End-of-Crop Whitefly Densities

At sale, plants produced in biological control greenhouses in this trial had 0.55 (± 0.28 SE) nymphs per leaf compared to 0.98 (± 0.36 SE) for the chemical control

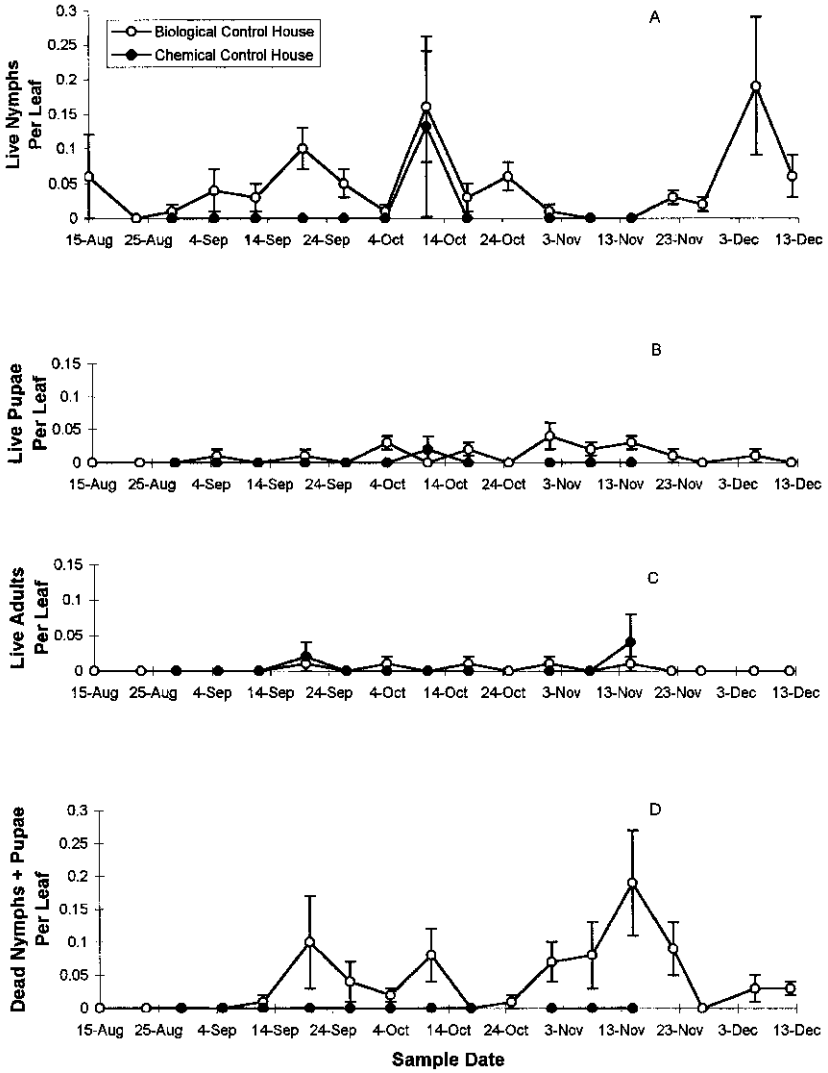

Fig. 5. Mean densities per leaf (± SE) at Fairview Farms greenhouses (in biological control and chemical control greenhouses) of *B. argentifolii* live nymphs (A), pupae (B), adults (C), and dead nymphs plus dead pupae (D).

houses at the test locations and 0.16 (± 0.09 SE) on poinsettias offered for sale at eight Massachusetts garden centers or shopping malls. A significant difference among these three treatments was detected using a nested ANOVA (df = 2, F = 10.63, P = 0.0001). Tukey's Studentized Range test indicated that nymphal densities in the biological control greenhouses did not differ from those in either the chemical control greenhouses in the test or the plants from retail outlets. However,

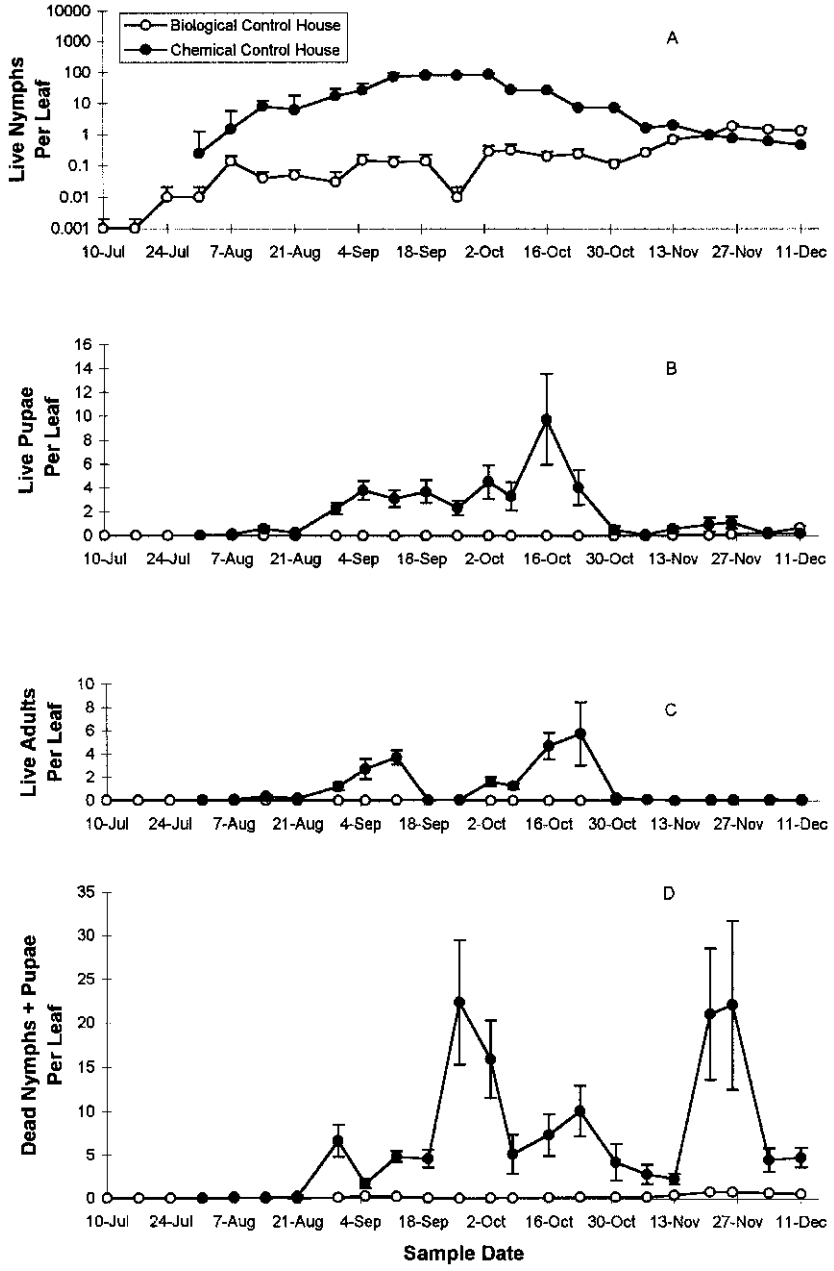

Fig. 6. Mean densities per leaf (± SE) at Westover Greenhouses (in biological control and chemical control greenhouses) of *B argentifolii* live nymphs (A), pupae (B), adults (C), and dead nymphs plus dead pupae (D).

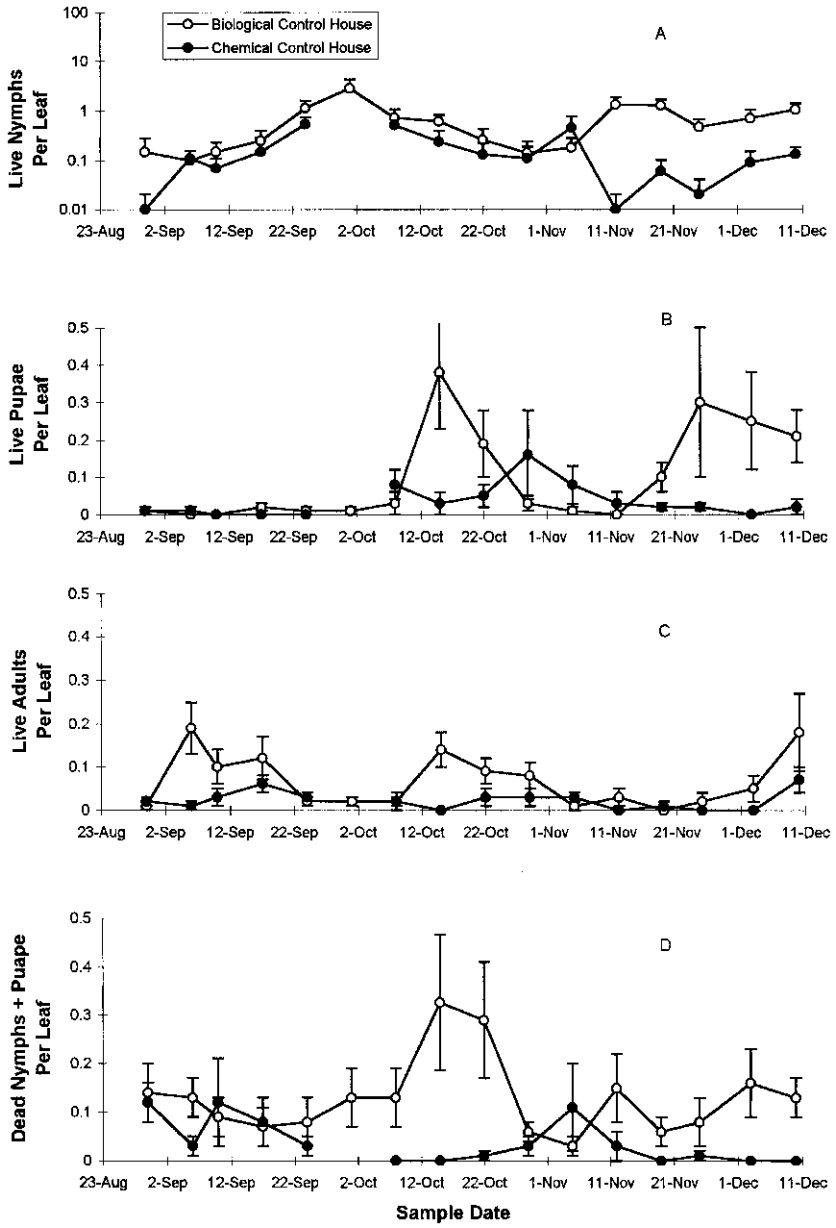

Fig. 7. Mean densities per leaf (± SE) at Konjoian Greenhouses (in biological control and chemical control greenhouses) of *T. vaporariorum* live nymphs (A), pupae (B), adults (C), and dead nymphs plus dead pupae (D). Data missing for chemical control greenhouse on 1 October due to pesticide application on sample date.

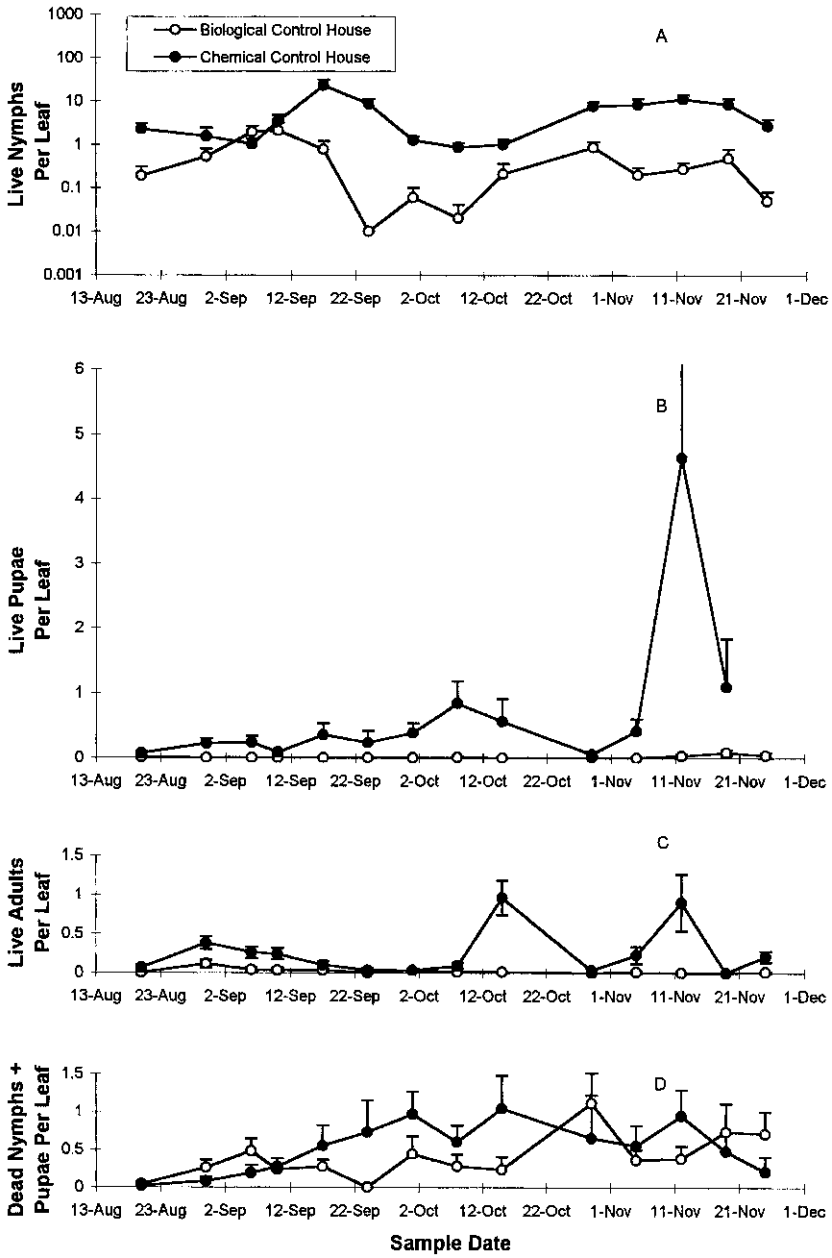

Fig. 8. Mean densities per leaf (± SE) at Loosigian Farms (in biological control and chemical control greenhouses) of *T. vaporariorum* live nymphs (A), pupae (B), adults (C), and dead nymphs plus dead pupae (D).

the chemical control greenhouses had higher nymphal densities than poinsettias from retail outlets.

Cost Analysis

Costs for whitefly control in chemical control greenhouses averaged $0.08 per plant (± $0.04 SE, range $0.02-0.15). Costs in biological control greenhouses averaged $2.14 (± $0. 15 SE, range $1.81-2.40) per plant. The average number of pesticide applications made for whitefly control was reduced 75% across all biological control greenhouses (ave. 1.7 applications) compared to usage in the chemical control greenhouses (ave. 6.8 applications). However, all insecticide use against whiteflies in biological control greenhouses occurred in one location, with no use of insecticides for whiteflies in the other three locations.

DISCUSSION

This trial assessed the efficacy of whitefly biological control in commercial poinsettia crops when management of *E. eremicus* releases was done solely by growers. *Eretmocerus eremicus* releases at rates used in this trial were effective at maintaining whitefly nymphal densities below 2 live nymphs or pupae per leaf at time of sale. At these levels, marketing of poinsettias in Massachusetts is not adversely affected by whiteflies, indicating that nymphal + pupal densities <2 do not exceed economic injury levels. This trial both extends the number of cases in which *E. eremicus* has been shown to suppress *B. argentifolii* on poinsettia and is the first to demonstrate the ability of *E. eremicus* to suppress *T. vaporariorum* on this crop.

The intended release rate in the biological control greenhouses was 3 female parasitoids per plant per week. It was assumed that parasitoids received from commercial suppliers would be 50% female and have 60% emergence under greenhouse conditions. Weekly assessments at one site (Fairview Farms) showed these assumptions to be correct. Use of only 15 release cups in greenhouses containing 1,200 to 3,200 plants (ave. of one release cup per 18 m^2 across all four biological control greenhouses) provided successful control of both whitely species.

Experience at the other three sites pointed out unforeseen difficulties in practical use of *E. eremicus*. First, growers received different numbers of parasitoid pupae than anticipated (based on numbers ordered) because the supplier over filled orders to compensate for reduced parasitoid emergence. Second, one grower (Konjoian) released more parasitoids than intended because fewer plants (3,193) were used to fill the biological control greenhouse at that site than were originally estimated (4,000). Third, grower practices affected the success of whitefly biological control at some sites. At two locations, plants used in the trial were infested with *T. vaporariorum* that appeared to have come from retail sales areas near where cuttings were rooted. At one site, composting of whitefly-infested plants near air intake vents allowed whiteflies to enter the biological control greenhouse, and insecticides were required to control the localized infestation within the biological control greenhouse. These events emphasize the need for biological control agents to be used in a proper IPM context to avoid such problems. Although plants actually treated with pesticide sprays were excluded from whitefly sampling, parasitoid mortality from contact with foliar residues on these plants may have reduced overall efficacy of biological control in this greenhouse.

Costs of biological control were 27 fold greater than costs of chemical control. Costs of chemical control in this trial ($0.08) were similar to those reported by Hoddle & Van Driesche (1996) in an earlier trial ($0.09) with *E. formosa* for control of *B. argentifolii*

on poinsettia. Costs of biological control in the trial reported here were higher ($2.14 per plant) than those in Hoddle & Van Driesche (1996), where cost was $1.02 per plant. In contrast to the Hoddle & Van Driesche (1996) trial with *E. formosa*, whitefly biological control with *E. eremicus* produced adequate pest suppression.

To be economically feasible, substantially lower release rates of *E. eremicus* will be required. Based on a subsequent trial in 1997 (Van Driesche et al., unpublished), release of as few as 1 adult parasitoid per plant per week should be able to provide whitefly control in commercial poinsettia crops if supplemented with limited use of insect growth regulators. Also, recognizing that the supplier provides additional parasitized nymphs in shipments to compensate for less than 100% emergence, ordering 2 parasitoid pupae per plant per week would be adequate to achieve this lower release rate. Cost for this low release rate would be $0.35 per plant for 16 weekly releases, just 16% of the total cost reported for *E. eremicus* in this trial.

Acknowledgment

We thank participating growers for their cooperation and the use of their greenhouses. We thank Beneficial Insectaries, Inc. and Koppert Biological Systems, Inc., and Dr. Oscar Minkenberg for providing *E. eremicus* to us free or at a reduced price. We thank the MA Department of Food and Agriculture (Agriculture Environmental Technology Grant), the Bedding Plant Foundation, and the MA IPM Program at the University of Massachusetts for financial support. Any opinions, findings, conclusions, or recommendations expressed in this article are those of the authors and do not necessarily reflect the views of the specific granting agencies.

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A NEW SPECIES OF *HADROSOMUS* (HEMIPTERA: HETEROPTERA: LYGAEIDAE: LYGAEINAE) FROM THE DOMINICAN REPUBLIC

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ABSTRACT

A new species of *Hadrosomus* A. Slater from Dominican Republic is described; a key to the known species is included and the dorsal view and parameres are illustrated.

Key Words: West Indies, Heteroptera, Lygaeinae, *Hadrosomus,* new species

RESUMEN

Se decribe una nueva especie del género *Hadrosomus* A. Slater, recolectada en República Dominicana y se incluye una clave para separar las especies conocidas; los parámeros y el ejemplar en vista dorsal son ilustrados.

In a revision of the Western Hemisphere Lygaeinae A. Slater (1992) recognized 22 genera, 7 subgenera, and 198 species. Each genus and subgenus is described or redescribed and a key to genera, subgenera and species is included. Line drawings of head, metapleuron, spermatheca, ovipositor, parameres, and aedeagus are provided, as well as a cladistic analysis of the genera.

One of the new taxa proposed by A. Slater was *Hadrosomus*, with three species: *H. confraternus* (Uhler) distributed from South-central México to southern Brasil, including the Dominican Republic and Trinidad, *H. teapensis* (Distant), the type species, apparently restricted to the southern half of México, and *H. corallipes* (Brailovsky) known only from Brasil.

This genus can be distinguished from other genera in the subfamily on the basis of the following characters: antennal segment I surpassing apex of tylus, eyes not produced, veins of clavus and corium lighter than surrounding areas, hemelytral membrane opaque, area behind callus without a series of four transverse impressions, posterior pronotal lobe higher mesally than at humeral angles, pronotal disc finely punctate, distinctly convex, with median carina obsolete, humeral angles orange, red or yellow, scutellum not swollen, impunctate, and with median carina distinct.

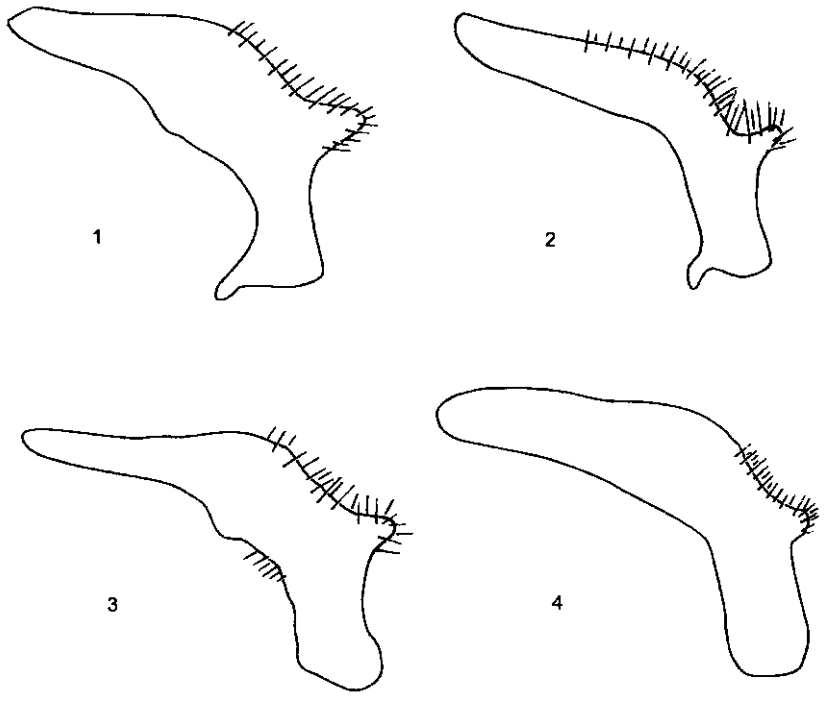
In *Torvochrimnus* (Brailovsky 1982) a closely related genus, the veins of clavus and corium are darker than surrounding areas and the humeral angles of the pronotum are dark brown to black.

In this paper we describe the fourth species of the genus, and the second species of *Hadrosomus* from the West Indies proper. This new species is described at this time to make the name available for the faunistic study of the Lygaeidae of the West Indies in progress by the senior author and J. A. Slater, University of Connecticut.

All measurements are in millimeters.

Hadrosomus nigrocoxalis Baranowski and Brailovsky**, New Species**
(Figs. 1-5)

Head orange dorsally. Following areas black to dark brown: antennal segments, tylus, frons, two lateral spots close to ocelli and connected by two irregular arms with darker frons, ocellar tubercle, and external edge of antenniferous tubercles. Pronotum chiefly dark brown with anterolateral margins including frontal and humeral angles, posterior margin, and a longitudinal median stripe orange; calli black; scutellum dark brown with a complete median orange longitudinal stripe; clavus and corium dark brown with claval and corial veins, costal and apical margin, claval suture and apical corial margin dark orange; connexival and abdominal segments bright orange with anterior margin of segment VII dark brown. Ventrally head orange; buccula pale yellow; rostral segments bright black; prosternum, mesosternum and metasternum black with posterior margin pale yellow; propleura, mesopleura and metapleura pale orange brown, with acetabulae, posterior margin of each segment, anterior margin of propleura and metathoracic peritreme pale yellow to pale orange yellow; propleura and mesopleura with shining black transverse stripe near to posterior margin; upper



Figs. 1-4. Parameres of *Hadrosomus* spp. 1, *H. nigrocoxalis* Baranowski and Brailovsky **New Species**; 2, *H. teapensis* (Distant); 3, *H. confraternus* (Uhler); 4, *H. corallipes* (Brailovsky).

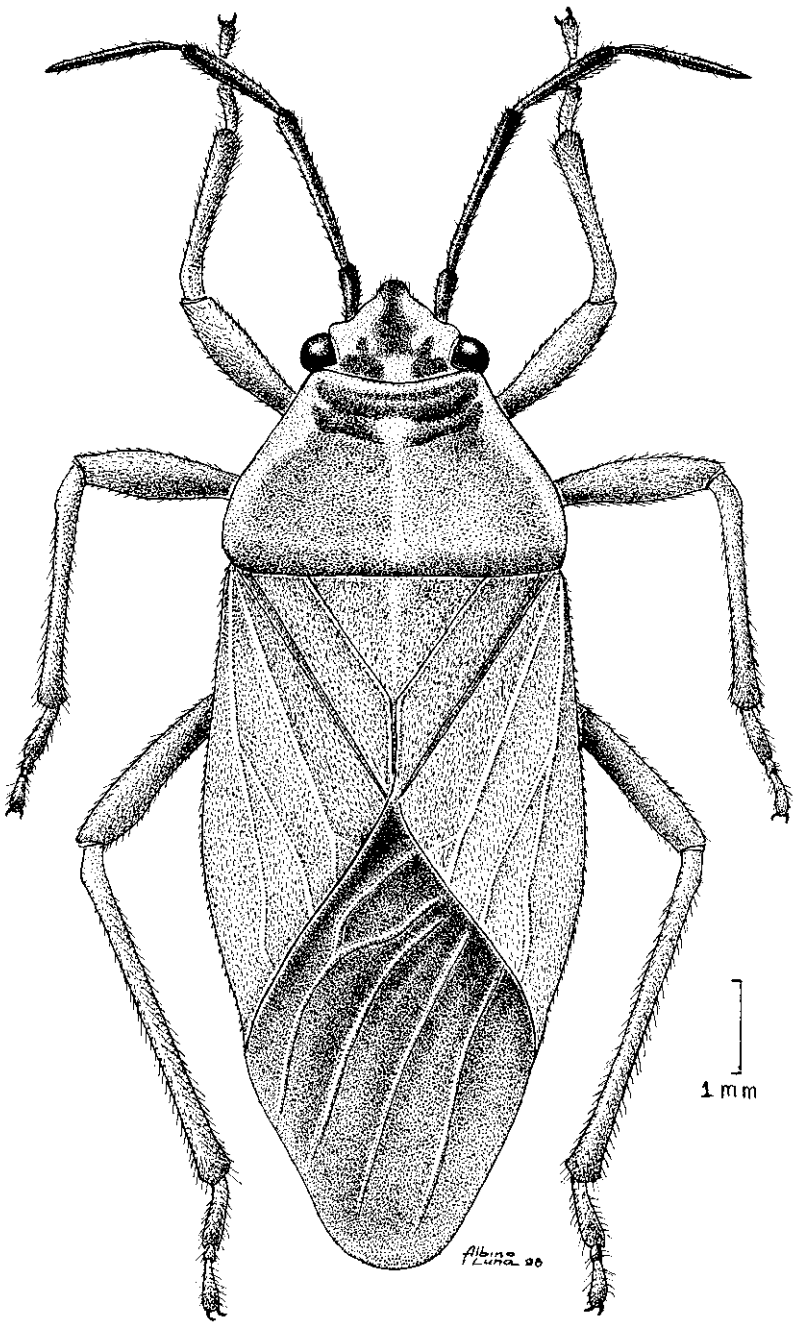


Fig. 5. *Hadrosomus nigrocoxalis* Baranowski and Brailovsky **New Species**.

margin of propleura, mesopleura and metapleura with a narrow shining black longitudinal stripe; coxae, tibiae and tarsi black; trochanters and femora dark orange hazel with apical third of femora black; abdominal sterna yellow, with pleural margin bright red orange to bright pink, and anterior border of each sternite and a narrow transverse stripe near the middle third and close to lateral sterna black; genital capsule dark brown with posteroventral margin pale orange hazel. Labium extending to anterior third of abdominal sternite IV. Paramere shank short, blade elongate and broad, posterior projection conical (Fig. 1).

Length head 1.33, width across eyes 1.80, interocular distance 1.20, interocellar distance 0.80, preocular distance 0.96. Length antennal segments: I, 0.52, II, 1.64, III, 1.45, IV, 1.55. Length pronotum 1.98, width across frontal angles 1.70, width across humeral angles 3.11. Length scutellum 1.24, width 1.39. Total body length 10.50.

Holotype. ♂ DOMINICAN REPUBLIC: Rio Chavon, 26-VIII-1997, R.M. Baranowski. In Florida State Collection of Arthropods.

Paratypes: 6 ♂♂ males, 6 ♀♀, same data as holotype. In R. M. Baranowski, J. A. Slater, and Instituto de Biología, Universidad Nacional Autónoma de México collections.

ETYMOLOGY. Named for its black coxae.

Color of females similar to holotype. Scutellum black with diffuse or very narrow median longitudinal orange stripe; connexival and abdominal segments VIII and IX bright orange red with two black discoidal spots on segment VIII; abdominal sterna III to VII pale yellow with or without pale green reflections, with pleural margin bright red orange, and anterior margin of each sternum black; gonocoxae I yellow with upper angle dark brown; parategite VIII and IX bright orange red.

Hadrosomus nigrocoxalis n.sp. like *H. confraternus* (Uhler) and *H. teapensis* (Distant) has the metathoracic peritreme yellow, the legs not entirely black, and the abdominal sterna mostly pale yellow. The new species is readily recognizable by the black coxae, on the other two species the coxae are yellow or orange hazel.

Hadrosomus nigrocoxalis like *H. confraternus* has the mesosternum and metasternum dark brown to black with the posterior margin yellow, and the abdominal sterna are yellow with anterior margin black, and pleural margins red to pink. The chief distinguishing features externally are the black frons and black coxae. In *H. confraternus* the head in dorsal view is predominantly yellow to orange, with only the tylus and ocellar tubercles black, and the coxae are yellow to orange hazel. In *H. teapensis* the mesosternum and metasternum are yellow, and the abdominal sterna yellow with anterior margin pale red and pleural margin yellow.

In *H. corallipes* (Brailovsky 1983) the other known species, the metathoracic peritreme is red to bright orange, the legs black, and the abdominal sterna black to red brown.

The parameres of the four known species are different (Figs. 1-4).

Key to Species of *Hadrosomus*

1. Abdominal sterna black to red brown; legs entirely black; metathoracic peritreme red to bright orange ..... *corallipes* (Brailovsky)

1'. Abdominal sterna mostly pale yellow; legs not entirely black; metathoracic peritreme yellow 2

2. Coxae black ..... *nigrocoxalis* n.sp.

2'. Coxae yellow to orange hazel 3

3. Abdominal pleural margins red to pink; head predominantly yellow to orange, with tylus black; mesosternum and metasternum black with posterior margin yellow..... *confraternus* (Uhler)

3'. Abdominal pleural margins yellow; head predominantly red, with tylus and irregular marks on frons and vertex black; mesosternum and metasternum yellow ..... *teapensis* (Distant)

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WEAK COMPETITION BETWEEN COASTAL INSECT HERBIVORES

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ABSTRACT

Related communities of four to seven insect herbivore species commonly feed on each of the coastal plant species *Borrichia frutescens* (L.), *Iva frutescens* (L.), and *I. imbricata* Walt. which grow on spoil islands in west-central Florida. Most stems of these host plant species show no evidence of herbivory or of actively feeding herbivores. At the scale of within *Iva* bushes or *Borrichia* patches on islands, there were significantly fewer co-occurrences of herbivores on individual stems or terminals than expected, suggesting competition is important on a small scale in this system. However, at the scale of between patches of host plants, that is, between islands, there were no negative correlations between herbivores which suggests that competition is unimportant

in influencing the distribution of these species at larger spatial scales. At large spatial scales, other phenomena such as host plant genotype or environmental (island) variability may be more important in influencing the distribution of herbivores.

Key Words: competition, co-occurrences, coastal plants, *Borrichia frutescens*, *Iva frutescens*, *Iva imbricata*, insect herbivores, Florida

RESUMEN

Comunidades de cuatro a siete especies de insectos herbívoros comúnmente se alimentan de las plantas costeras *Borrichia frutescens* (L.), *Iva frutescens* (L.) e *I. imbricata* Walt., las cuales crecen en islas ubicadas al oeste del centro de la Florida. La mayoría de los tallos de estas plantas huéspedes no muestran evidencia de actividad por parte de herbívoros. En plantas de *Iva* o en manchones de plantas de *Borrichia* se encontraron significativamente menos co-ocurrencias de herbívoros en tallos individuales o ramas terminales de lo esperado. Esto sugiere que la competencia es importante en pequeña escala dentro de este sistema. Sin embargo, a nivel de manchones de plantas huéspedes, es decir, entre islas, no se encontraron correlaciones negativas entre herbívoros, lo cual sugiere que en una escala espacial mayor, la competencia no influye de manera importante en la distribución de estas especies. Al nivel de escalas espaciales mayores, otros factores como el genotipo de la planta huésped o la variabilidad ambiental (isla) podrían influír de manera más importante sobre la distribución de herbívoros.

INTRODUCTION

The role of interspecific competition in ecological theory has changed through the years. Many studies in the 1970's viewed a lack of co-occurrences between possible competitors as a possible indicator of competition, reasoning that interspecific competition can cause negative associations (Strong 1982, Strong et al. 1984). In the early 1980s, phytophagous insects were seen as infrequent competitors possibly because their small size makes them especially vulnerable to predators which reduce population sizes to levels below which competition is important (Connell 1983). In the mid 1980s a series of experimental studies found that competition among herbivorous insects may be much more important than previously believed (Stiling and Strong 1984, Fritz et al, 1986, Faeth 1987, Crawley and Pattrasudhi 1988, Mopper et al. 1990, Moran and Whitham 1990, Damman 1993). By the mid 1990s enough evidence had accumulated to suggest that competition between phytophagous insects was probably as common as in other taxa, occurring in 76% of case studies (Denno et al. 1995). In spite of the increased recognition of interspecific competition, there remains relatively little progress in demonstrating where or when competition is likely to be important in insect communities (Denno et al. 1995). Is competition a strong enough phenomenon across all spatial scales to shape community structure and patterns of co-occurrence or is it only important at small scales and so weak that it cannot structure communities across broader geographic regions? Ricklefs and Schluter (1993) suggested that different ecological processes act on different scales and that interactions between species, such as competition and predation, would occur at relatively small scales. In support of this, extensive studies on the diversity of insects feeding on bracken revealed that competition was weak and occurred only at small scales (Lawton et al. 1993). Our study focuses on co-occurrences between insect herbivores attacking three species of coastal plants in west-central Florida: *Borrichia frutescens* (L.) de Candolle, *Iva frutescens* L. and *Iva imbricata* Walt. Here, lack of co-occurrence

is taken as a possible indication of interspecific competition. We first examine the extent of co-occurrences on a small scale, between bushes or patches of individual host plants, and then examine competition at a larger scale, between islands.

METHODS

The study system

A natural intracoastal waterway runs between the mainland and the barrier islands of many coastal states. To facilitate boat traffic, the U.S. Army Corps of Engineers often deepen these natural channels by dredging. Along the Florida coast, this dredge material was typically heaped together as small "spoil islands" that were placed adjacent to the main channel at regular intervals of about 0.5 kilometers. Such islands off the Pinellas County coast served as our study sites.

Most islands support some vegetation. Typically, they are overgrown by the invasive exotics Brazilian pepper and Australian pine in their centers, but a few palms may be present as well. Red, black and white mangrove, along with small patches of salt marsh cordgrass grow near the waterline. Between the waterline and the island centers, three other native plants can be relatively common: sea daisy, *Borrichia frutescens*, marsh elder, *Iva frutescens* and beach (or dune) elder, *Iva imbricata*. The phytophagous insect community on these hosts does not occur on any other plant species on these islands.

Islands usually have either one or two (rarely all three) of these host species. The three host plants do not commonly intermingle. *Borrichia* grows as clonal patches on saturated silty sands. *Iva frutescens* requires slightly higher elevations and prefers lower-salinity soils, often in stonier ground. *Iva imbricata* is most common on beaches or sand dunes and prefers islands with sandier soils (Barnett and Crewz 1990). Islands may or may not have all of these habitat types present, but if they do, these species tend to grow adjacent to one another, not interdispersed. Sometimes the *Iva* species may shade *Borrichia*, but only at the edge of the patch. The patchy nature of plant distribution between these islands mimics what occurs in mainland areas where patches of *Borrichia* and *Iva* are separated by salt pans, needle rush, salt-marsh cord grass or other vegetation (Stiling and Rossi 1994).

Insect herbivores

Borrichia frutescens, *I. frutescens* and *I. imbricata* have many genera of their insect herbivores in common (Table 1). The gall maker, *Asphondylia borrichiae* Rossi and Strong, exists as two races, one of which attacks *Borrichia* almost exclusively, and one, which we call *A.* sp nr *borrichiae*, which attacks *Iva* sp. (Rossi et. al. 1999) but which prefers *I. frutescens* (see also Rossi and Stiling 1995). Two species of *Pissonotus* planthoppers, *P. quadripustulatus* (Van Duzee) and *P. albovenosus* Osborn, suck the sap of leaves and stems. *Pissonotus quadripustulatus* feeds only on *B. frutescens*, while *P. albovenosus* feeds exclusively on the two *Iva* spp. with *Iva imbricata* the preferred host (Stiling and Rossi 1995). Another sap sucker, the aphid *Dactynotus* sp., feeds on *Iva* sp. but is most commonly found on *I. frutescens* (Ferguson and Stiling 1996). A related species which we call *Dactynotus* sp. green feeds on *Borrichia*. The third common sap sucker is a spittlebug, *Philaenus* sp., individuals of which are protected inside spittle masses. These are much more numerous on *I. imbricata* than on the other host species, *I. frutescens*. Cecidomyiid stem borers are common on both species of *Iva* but are not present on *Borrichia*. We noted a lepidopteran stem borer in *Borrichia*, but it was

much less common and we were unable to rear adults of this species. *Buccalatrix* leafminers leave characteristic thin, serpentine, mines on host leaves and are only present on *I. frutescens*. A seventh herbivore, an eriophydid mite, creates numerous leaf galls on *I. frutescens*, with up to 100 galls on a single leaf. Each gall contained up to 50 mites and some bushes are heavily infested. This was the most common herbivore on *I. frutescens*, but it was never found on the other two host plants.

There are two other broad categories of herbivores. The first is "other sap-sucking homopterans" which included *Carneocephala floridana* Ball, which is known to use *Borrichia* extensively in north Florida (Rossi and Strong 1991), the exotic cottony cushion scale, *Icerya purchasi* Maskell, and other scale insects. These other sap suckers are never common on most of the study islands. The other guild is the leaf chewers, and this group includes various grasshoppers, crickets, beetles, caterpillars and the stick insect, *Anisomorpa buprestiodes* (Stoll), but again these insects are rare and, on average, never infest more than 0.3% of the stems on any host plant species.

Censuses

On eight islands with *Borrichia*, eight with *I. imbricata* and 15 with *I. frutescens*, we counted the number of each species of insect occupying each stem on three sets of 30 stems, or ramets, in three areas of a *Borrichia* patch or three sets of 30 branches or terminals on each of three *I. frutescens* or *I. imbricata* bushes. Most insects were easily visible to the naked eye except stem borers, gall makers and spittle bugs. Density estimates of stem borers were assessed by counting exit holes on stems. Densities of gall makers and spittle bugs were assessed by counts of galls and spittle masses, respectively. Censuses were performed bi-monthly starting in February and ending in October in both 1992 and 1993 so as to encompass two years and multiple generations of insects. One partial data set, for *Borrichia* in February 1992 was lost. Presumed competition at the level of within islands on a patch of *Borrichia* or bush of *Iva* was assessed by comparisons of the presence, absence and co-occurrence of each species of herbivore on all stems combined for each plant species (Rathcke 1976). Statistical analyses were performed using X^2 tests, but species combinations were tested only where there was sufficient power to detect significant differences if they were present (Bultman and Faeth 1985). Competition at the level of between islands was assessed by correlating total abundance of each herbivore species, February 1992-October 1993, between islands.

Results

There are at least four common herbivores on the *Borrichia*/*I. frutescens*/*I. imbricata* community: the gall making fly *Asphondylia*, the sap sucking planthoppers *Pissonotus* spp., the sap sucking aphids, *Dactynotus* spp., and the stem boring fly *Neolasioptera* (Table 1). In addition, an eriophydid mite is common on *I. frutescens*, a sap sucking cercopid, *Philaenus* is present on *I. imbricata* and a leaf miner, *Buccalatrix*, occurs on *I. frutescens*. However, most stems on any one host plant exhibit no herbivores or signs of herbivory. The percentage of empty stems is, on average, 85.1% for *Borrichia*, 79.9% for *I. imbricata* and 65.1% for *I. frutescens*.

At the scale of a *Borrichia* patch or *Iva* bush, there were many fewer co-occurrences of herbivores together on individual stems than expected (Tables 2-4). On *Borrichia* the co- occurrence of the gall maker *Asphondylia* and the sap sucking *Pissonotus* was not significantly different than expected, but the co-occurrences of the two sap suckers, *Pissonotus* and *Dactynotus* were low, and approached statistical sig-

TABLE 1. HERBIVORES OF *BORRICHIA FRUTESCENS*, *IVA FRUTESCENS* AND *IVA IMBRICATA*, BASED ON SAMPLES OF 7200 RAMETS PER ISLAND DURING 1992 AND 1993.

Herbivore	Type of herbivore	Percent of stems infested		
		B. frutescens	*I. frutescens*	*I. imbricata*
Asphondylia borrichiae	stem galler	3.3	0	0
Asphondylia sp nr *borrichiae*		0	6.3	2.1
Pissonotus quadripustulatus	planthopper	9.3	0	0
Pissonotus albovenosus		0	3.8	9.3
Dactynotus sp brown	aphid	0	4.9	1.3
sp green		1.8	0	0
Neolasioptera	stem borer	0	3.6	5.5
Buccalatrix sp	leaf miner	0	1.2	0
Phinaenus	spittlebug	0	0.1	1.1
eriophydid mite	leaf galler	0	20.7	0
other homopterans	sap suckers	0.1	0.4	0.3
various spp	leaf chewers	0.2	0.3	0.2

nificance (P = 0.06). For *Iva imbricata*, *P. albovenosus* and *Dactynotus* co-occurred less frequently than expected, but the sap sucking spittle bug, *Philaenus*, did not occur less frequently with *P. albovenosus* than expected. The stem borer *Neolasioptera* co-occurred relatively infrequently with galls of *Asphondylia* sp. nr *borrichiae* (P = 0.082) and this result was not entirely unexpected as stem boring often kills the apical meristem above the bored portion of the stem. Thus, the presence of *Neolasioptera* may

TABLE 2. CO-OCCURRENCES OF HERBIVORES ON 6900 *BORRICHIA FRUTESCENS*.

Herbivore Species			X^2	P
	Pissonotus quadripustulatus			
Asphondylia borrichiae	Present	Absent		
Present	16	209	1.10	0.294
Absent	628	6047		
	Dactynotus sp			
Pissonotus quadripustulatus	Present	Absent		
Present	5	639	3.58	0.06
Absent	119	6137		

TABLE 3. CO-OCCURRENCE OF HERBIVORES ON 7200 *IVA IMBRICATA* STEMS.

Herbivore species			X^2	P
	Pissonotus albovenosus			
Asphondylia sp nr *borrichiae*	Present	Absent		
Present	3	150	9.194	0.002
Absent	670	6377		
	Neolasioptera			
Asphondylia sp nr *borrichiae*	Present	Absent		
Present	5	148	3.024	0.082
Absent	394	6655		
	Neolasioptera			
Pissonotus albovenosus	Present	Absent		
Present	3	670	35.76	<0.001
Absent	396	6131		
	Dactynotus sp			
Pissonotus albovenosus	Present	Absent		
Present	2	671	5.124	0.024
Absent	93	6434		
	Philaenus sp			
Pissonotus albovenosus	Present	Absent		
Present	11	662	1.851	0.174
Absent	69	6458		

prevent *Asphondylia* galls from developing, because they occur only on the apical meristems. Few co-occurrences were also noticed between *Neolasioptera* and *P. albovenosus* and between *Asphondylia* and *P. albovenosus*. For *Iva frutescens*, co-occurrences were significantly less than expected for every combination of insect herbivores tested, except those involving the eriophydid mite, and even here there was a significant lack of co-occurrences with the sap sucker *P. albovenosus* and a marginally significant lack (P = 0.065) with the sap sucker *Dactynotus* sp brown. At the larger scale of between islands there were no significant negative correlations between species abundances (Table 5). Similar results were observed when the correlations used total insect abundance instead of proportion of stems infected.

DISCUSSION

There are several conclusions from the present study. The first is that the occupancy of stems of *Borrichia frutescens*, *Iva frutescens*, and *Iva imbricata* is low, with the majority of stems having no herbivores. Interestingly, Root and Cappuccino (1992) also found low herbivore loads on goldenrod (*Solidago*) in New York, where the entire fauna weighed <1% of the leaf mass. Why stem occupancy rates are so low in our system remains a mystery. It was, therefore, a surprise that we found so few co-occurrences at the scale of a *Borrichia* patch and at the scale of individual bushes for *I.*

TABLE 4. CO-OCCURRENCE OF HERBIVORES ON 13500 *I. FRUTESCENS* STEMS.

Herbivore species			X^2	P
	Pissonotus albovenosus			
Asphondylia sp nr *borrichiae*	Present	Absent		
Present	3	847	26.92	<0.001
Absent	488	12162		
	Neolasioptera sp			
Asphondylia sp nr *borrichiae*	Present	Absent		
Present	10	840	16.07	<0.001
Absent	499	12151		
	Dactynotus sp			
Asphondylia sp nr *borrichiae*	Present	Absent		
Present	22	828	10.08	0.001
Absent	644	12016		
	Eriophydid mite			
Asphondylia sp nr *borrichiae*	Present	Absent		
Present	163	687	1.299	0.254
Absent	2641	10009		
	Neolasioptera sp			
Pissonotus albovenosus	Present	Absent		
Present	3	488	13.13	<0.001
Absent	506	12503		
	Dactynotus sp			
Pissonotus albovenosus	Present	Absent		
Present	6	485	14.15	<0.001
Absent	660	12349		
	Eriophydid mite			
Pissonotus albovenosus	Present	Absent		
Present	37	454	53.40	<0.001
Absent	2767	10242		
	Dactynotus sp			
Neolasioptera sp	Present	Absent		
Present	6	503	15.08	<0.001
Absent	660	12331		
	Eriophydid mite			
Neolasioptera sp	Present	Absent		
Present	120	389	2.355	0.125
Absent	2684	10307		
	Eriophydid mite			
Dactynotus sp	Present	Absent		
Present	119	547	3.403	0.065
Absent	2685	10149		

TABLE 5. PEARSON CORRELATIONS OF HERBIVORE DENSITIES (PROPORTION OF INFESTED STEMS) BETWEEN NATURAL PATCHES OF *B. FRUTESCENS* (N = 8), *I. FRUTESCENS* (N = 15) AND *I. IMBRICATA* (N = 8) DURING 1992/93 * = SIGNIFICANT AT $P < 0.05$.

Plant species	Herbivore species				
B. frutescens	*A. borrichiae*	*P. quadripustulatus*			
P. quadripustulatus	-0.371				
Dactynotus sp	-0.129	-0.329			
I. frutescens	*A.* sp. nr. *borrichiae*	*P. albovenosus*	*Dactynotus* sp	*Buccalatrix* sp	*Neolasioptera* sp
P. albovenosus	-0.282				
Dactynotus sp	-0.209	-0.395			
Buccalatrix sp	0.377	-0.131	-0.325		
Neolasioptera	-0.262	-0.507	-0.310	0.451	
Eriophydid	0.236	-0.289	0.140	0.303	0.438
I. imbricata	*A.* sp. nr. *borrichiae*	*P. albovenosus*	*Dactynotus* sp	*Neolasioptera* sp	
P. albovenosus	-0.386				
Dactynotus sp	-0.389	-0.339			
Neolasioptera sp	-0.311	-0.182	0.216		
Philaenus sp	-0.215	0.486	0.042	0.101	

frutescens and *I. imbricata*. Taking all host plant species together, co- occurrences were significantly lower ($P < 0.05$) in ten pairwise comparisons, marginally significantly lower ($0.05 > P < 0.10$) in three cases and non-significant ($P > 0.10$) in four cases. However, even in the non-significant cases the trend was towards fewer co-occurrences than expected. It is instructive to realize that while a lack of co-occurrences could indicate competition in this system, lack of interspecific association could also be caused by other factors such as differential attractiveness to certain stems by certain herbivore species. These methodological problems probably helped push competition studies towards experimental manipulations in the 1980s and beyond. However, the lack of co-occurrences is at least consistent with the idea that competition may be occurring at the spatial scale of between bushes or patches. Some of the competitive interactions at this scale may actually be amensalism (Lawton and Hassell 1981). For example, stem borers and gall makers do not commonly co-occur probably because the stem borer makes the stem unsuitable for the gall maker, not vice-versa. However, without detailed experimental studies of the effect of each species on the other, the exact ratio of amensalism to competition in this community remains difficult to assess.

Although presumed competition appeared frequently on a small scale in this community, as evidenced by virtue of the lack of species co-occurrences, it does not appear strong enough to shape distribution patterns of herbivores between islands. There were no significant negative correlations between herbivores between *Borrichia* patches or *Iva* bushes between islands. Our previous reciprocal transplant experiments, involving plants of different genotype between islands, have shown that host plant genotype and environmental variation both play major roles in shaping the distribution patterns of insects between islands (Stiling and Rossi 1995, 1996). Environmental and genetic variation between islands is probably so great that it swamps any effect of competition on the distribution of insect herbivores. Only when both genotype and environmental variation are minimized, as on small individual bushes, can the relatively small effects of competition be seen. Thus, in general, our results support the ideas of Ricklefs and Schluter (1993) that ecological phenomenon may operate only at certain scales and that the effects of competition operate primarily at small spatial scales.

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SOCIAL WASPS (HYMENOPTERA: VESPIDAE) TRAPPED WITH ACETIC ACID AND ISOBUTANOL

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ABSTRACT

The combination of acetic acid and isobutanol is attractive to different species of Vespidae in different areas of the United States. In Washington, the blend was attractive to workers and queens of *Vespula pensylvanica* (Saussure), *Vespula germanica* (F.), and workers of *Dolichovespula maculata* (L.). In Maryland, these chemicals were attractive to worker *Vespula maculifrons* (Buysson), worker *V. germanica*, worker *Vespula squamosa* (Drury), worker *D. maculata*, worker *Vespa crabro* L., and female *Polistes dominulus* F. In Oklahoma, the blend was attractive to worker *V. maculifrons*, worker *V. squamosa*, female *Polistes fuscatus* (F.), and *Polistes annularis* (L.). Several species were weakly attracted to acetic acid alone; *V. maculifrons* and *D. maculata* in Maryland, and *V. squamosa*, *V. maculifrons*, *P. fuscatus*, *P. perplexus*, and *P. annularis* in Oklahoma. Queens of *V. germanica* in Washington, workers of *V. maculifrons* in Maryland, as well as workers of *V. squamosa* and *V. maculifrons* in Oklahoma were weakly attracted to isobutanol alone.

Key Words: Vespidae, wasps, lures, attractants, traps, acetic acid, isobutanol

RESUMEN

La combinación de ácido acético e isobutanol atrae a diferentes especies de Vespidae en áreas distintas de los Estados Unidos. En el estado de Washington la mezcla atrajo a trabajadores y reinas de *Vespula pensylvanica* (Saussure), *Vespula germanica* (F.) y trabajadores de *Dolichovespula maculata* (L.). En el estado de Maryland, estos químicos fueron atrayentes a trabajadores de *Vespula maculifrons* (Bysson), *V. germanica*, *V. squamosa*, *D. maculata* y *V. cabro*, así como a hembras de *Polistes dominulus* F. En el estado de Oklahoma, la mezcla atrajo a trabajadores de *V. maculfrons* y *V. squamosa*, así como a hembras de *Polistes fuscatus* (F.) y de *Polistes annularis* (L.). Varias especies fueron atraídas de manera leve al ácido acético solo: *V. maculifrons* y *D. maculata* en Maryland y *V. squamosa*, *V. maculifrons*, *P. fuscatus*, *P. perplexus* y *P. annularis* en Oklahoma. Reinas de *V. germanica* en Washington, trabajadores de *V. maculifrons* en Maryland, así como trabajadores de *V. squamosa* y *V. maculifrons* en Oklahoma, fueron atraídos de manera ligera al isobutanol solo.

Chemical attractants are valuable management tools for pest insects, including many social wasps, and yet are not available for use for many pest species of Vespidae. A wide variety of food baits are attractive to some yellowjacket species (*Vespula*) (Spurr 1995, 1996), indicating strong chemotactic responses of wasps to food materials. Heptyl butyrate and octyl butyrate are strongly attractive to the western yellowjacket *V. pen-*

sylvanica (Saussure) and to *Vespula atropilosa* (Sladen) (Davis et al. 1969, 1972), but are only weakly attractive to other North American vespids (Grothaus et al. 1973, Howell et al. 1974, Sharp and James 1979). More effective chemical attractants are needed for other pestiferous species, such as the eastern yellowjacket *Vespula maculifrons* (Buysson), the southern yellowjacket *Vespula squamosa* (Drury), and some species of *Polistes*.

The combination of acetic acid and isobutanol is attractive to some species of social wasps and is useful as a bait for traps (Landolt 1998, 1999). Workers of *V. pensylvanica* and workers of the German yellowjacket, *Vespula germanica* (F.), as well as females and males of the golden paper wasp, *Polistes aurifer* Saussure, were captured in traps baited with this combination of chemicals in Yakima County, Washington (Landolt 1998). This chemical blend is probably a feeding attractant because the compounds were isolated from fermented molasses solutions which are attractive to many insects (Frost 1926, Ditman and Cory 1933, Landolt 1995), including Vespidae (Thomas 1960). The combination of acetic acid and isobutanol is the first chemical attractant useful for trapping *V. germanica* (Landolt 1998) and the first chemical attractant for any species of *Polistes* (Landolt 1999).

We report here a series of field tests to determine what species of social wasps are attracted to acetic acid and isobutanol. We expect that many social wasp species could be attracted to these compounds when foraging for carbohydrate foods. If this hypothesis is correct, the combination of acetic acid and isobutanol can be used as an attractant for a greater number of pest species over a broad geographic range.

Materials and Methods

All experiments were conducted with the Trappit Dome Trap (Agrisense, Fresno, CA). This is a plastic trap similar in shape to the glass McPhail trap (Newell 1936) commonly used for flies. The trap entrance is in the bottom of the trap, the top half is clear, and the bottom half is opaque and yellow in color. Traps contained 150-200 ml of a drowning solution comprised of water, clay, detergent, and food dyes (Landolt 1998). Acetic acid, when tested as an attractant, was added to the drowning solution at 0.5% by volume. Isobutanol (1 ml) was dispensed from a 2 ml polyethylene cap mounted on a pin at the top of the inside of the trap. It is assumed that the isobutanol was released through the walls of the cap.

Each experiment involved the comparison of 4 treatments; an unbaited control, 0.5% acetic acid in the drowning solution, 1 ml of isobutanol in the polyethylene cap, and the combination of 0.5% acetic acid in the drowning solution and 1 ml of isobutanol in a polyethylene cap. A randomized complete block design was used, with the 4 treatments included in each block. Traps were checked 1-3 times per week, with traps moved one position each time traps were checked. The drowning solution was replaced weekly and polyethylene caps were replaced monthly in experiments lasting longer than 1 month. This experiment was conducted in 4 different geographic areas, selected to target a variety of species of Vespidae.

The first location was in Yakima County, Washington, conducted in April and May of 1998. This time and area was selected to determine if queens of *V. pensylvanica* and *V. germanica* respond to acetic acid and isobutanol. Previous studies targeted workers and were conducted from mid to late summer when queens were not foraging (Landolt 1998). Traps were set up at 5 sites near Yakima on 22 April 1998. Four of these sites were in apple orchards and one was in a suburban yard. Traps were placed in trees at about 2 m height. Traps were checked weekly and were maintained until 26 May 1998.

The second location was the USDA-ARS Beltsville Agricultural Research Center in Beltsville, Prince George's Co., Maryland. This location was selected to determine if

workers of *V. maculifrons* and other *Polistes* species are attracted to acetic acid and isobutanol. Six blocks of traps were set up on the grounds of the Center on 4 August 1998. Two blocks were placed in a windbreak of holly trees (*Ilex* sp.), and 4 blocks were positioned along the borders of woodlots comprised primarily of deciduous hardwood trees. Traps were maintained until 18 August 1998 and were checked 2-3 times per week.

The third location was in western Washington. A trapping site was selected on the grounds of the Washington State University Agricultural Experiment Station at Puyallup, Pierce Co., Washington. This site was selected to determine if workers of *Vespula vulgaris* L., the common yellowjacket, are attracted to the combination of acetic acid and isobutanol. Four blocks of traps were set up on 25 August 1998, on ornamental plantings of trees and shrubs. Traps were about 5 m apart within blocks, and blocks were more than 30 m apart. Traps were checked weekly and were maintained until 14 October 1998.

The fourth location was in Tulsa, Oklahoma. Trapping sites were at a residence and in 4 suburban parks. This location was selected to determine if workers of *V. maculifrons* and *V. squamosa* and several species of *Polistes* present in that area are attracted to acetic acid and isobutanol. Six blocks of traps were set up on 8 August 1998 in trees and shrubs in ornamental plantings and along fence lines. Traps were checked weekly and maintained until 18 November 1998.

Data were analyzed by Wilcoxon signed rank test, with a significance limit at $p \leq 0.05$. Data were analyzed for each wasp species trapped at each site separately. For all species and all locations, data were excluded for dates on which no wasps were captured with any of the treatments.

Results

At the Yakima County location, significant numbers of queens of *V. pensylvanica* were captured in traps baited with the combination of acetic acid and isobutanol. Although small numbers of *V. pensylvanica* queens were captured in traps baited with acetic acid and in traps baited with isobutanol, these were not significantly greater than numbers captured in unbaited traps (Table 1). Eighty-six *V. pensylvanica* queens were captured in this test. Numbers of queens of *V. germanica* captured in traps baited with isobutanol and in traps baited with acetic acid with isobutanol (combination) were significantly greater than in unbaited traps (Table 1). There was no significant difference, however, between numbers of queens of *V. germanica* captured in traps baited with isobutanol versus the combination of acetic acid with isobutanol, despite the higher numbers in the traps baited with the combination of acetic acid and isobutanol. A total of 102 *V. germanica* queens were captured in this test. Twenty-seven *P. aurifer* were also captured in this test, but these numbers were insufficient for statistical comparisons.

In the test at the Beltsville, Maryland location, 232 *V. maculifrons* workers, 31 *V. squamosa* workers, 68 *V. germanica* workers, 6 *Vespula flavopilosa* (Jacobson) workers, 22 *Vespa crabro* L. (European hornet) workers, and 38 *Dolichovespula maculata* (L.) (bald-faced hornet) workers, were captured in traps, in addition to 23 *Polistes dominulus* (Christ), 10 *Polistes fuscatus* (F.), 1 *Polistes exclamans* Vierick, and 3 *Polistes metricus* Say females. One male of *P. dominulus* was also captured in a trap. Numbers of wasps captured were suitable for statistical comparisons (exhibited significant differences among treatments) for *V. maculifrons*, *V. squamosa*, *V. germanica*, *V. crabro*, *D. maculata*, and *P. dominulus* (Table 1). *Vespula maculifrons* workers were captured in significant numbers in traps baited with acetic acid, isobutanol, and the combination of acetic acid and isobutanol, with the greatest captures in traps baited

TABLE 1. MEAN (± SE) NUMBERS OF FEMALE SOCIAL WASPS CAPTURED PER TRAP PER CHECK AT 4 LOCATIONS, IN TRAPS BAITED WITH WATER (CONTROL), ACETIC ACID, ISOBUTANOL, AND ACETIC ACID WITH ISOBUTANOL (COMBINATION).[1]

	Control	Acetic acid	Isobutanol	Combination
WA, Yakima Co.				
V. pensylvanica queens	0.3 ± 0.3b	1.3 ± 0.8b	0.9 ± 0.5b	6.1 ± 1.0a
V. germanica queens	0.2 ± 0.1b	0.1 ± 0.1b	3.4 ± 0.6a	5.3 ± 1.4a
MD, Beltsville				
V. maculifrons workers	0.0 ± 0.0c	0.2 ± 0.1b	0.3 ± 0.2b	7.2 ± 2.0a
V. germanica workers	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	2.2 ± 1.0a
V. squamosa workers	0.0 ± 0.0b	0.0 ± 0.0b	0.1 ± 0.1b	0.9 ± 0.3a
D. maculata workers	0.0 ± 0.0c	0.4 ± 0.2b	0.0 ± 0.0c	0.9 ± 0.4a
V. crabro workers	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	0.7 ± 0.3a
P. dominulus	0.0 + 0.0b	0.0 + 0.0b	0.0 + 0.0b	0.9 + 0.2a
WA, Pierce Co.				
V. pensylvanica	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	2.4 ± 0.5a
V. germanica	0.0 ± 0.0b	0.1 ± 0.1b	0.0 ± 0.0b	0.8 ± 0.2a
D. maculata	0.0 ± 0.0c	1.3 ± 0.5b	0.1 ± 0.1c	4.0 ± 1.2a
OK, Tulsa				
V. squamosa	0.0 ± 0.0c	1.7 ± 0.5b	2.7 ± 1.2b	14.4 ± 3.8a
V. maculifrons	0.0 ± 0.0d	2.8 ± 0.7b	1.5 ± 1.1c	12.1 ± 2.7a
P. fuscatus	0.0 ± 0.0c	3.8 ± 2.3b	0.1 ± 0.1c	9.7 ± 4.3a
P. perplexus	0.0 ± 0.0b	2.4 ± 0.9a	0.1 ± 0.1b	2.1 ± 0.5a
P. annularis	0.1 ± 0.1b	1.2 ± 0.5b	0.0 ± 0.0b	1.6 ± 0.9a

[1]Means within a row followed by a different letter are significantly different by Wilcoxon signed rank test at $p < 0.05$.

with the combination of acetic acid and isobutanol. *Vespula germanica* and *V. crabro* workers were captured in significant numbers only in traps baited with the combination of acetic acid and isobutanol. The greatest captures of *D. maculata* were also in traps baited with the combination of acetic acid and isobutanol, but numbers in traps baited with acetic acid alone were also significantly greater than in unbaited traps. Females of the paper wasp *P. dominulus* were captured in significant numbers only in traps baited with the combination of acetic acid and isobutanol.

In the test at the western Washington location in Puyallup, 20 *V. pensylvanica* workers, 27 *V. germanica* workers, 2 *V. vulgaris* workers, and 130 *D. maculata* workers were captured in traps. Numbers of *V. pensylvanica* and *V. germanica* workers captured in traps baited with the combination of acetic acid and isobutanol were significantly greater than in unbaited traps (Table 1). Numbers of *D. maculata* captured in traps baited with acetic acid were significantly greater than in unbaited traps, but numbers in traps baited with the combination of chemicals were significantly greater than in either unbaited traps or traps baited with acetic acid (Table 1).

In the test at the Tulsa, Oklahoma area, 581 *V. squamosa* workers, 809 *V. maculifrons* workers, and 150 *P. fuscatus*, 112 *Polistes perplexus* Cresson, 33 *Polistes annu-*

laris (L.), and 12 *P. metricus* paper wasps were captured in traps over the 12 week trapping period. Numbers of *V. maculifrons* and *V. squamosa* yellowjackets captured in traps baited with acetic acid alone, isobutanol alone, and the combination of acetic acid and isobutanol were significantly greater than in unbaited traps (Table 1). However, for both species of yellowjackets, the numbers captured in traps baited with the combination of acetic acid and isobutanol were significantly greater than the numbers captured in traps baited either with acetic acid or with isobutanol. Significant numbers of *P. fuscatus* paper wasps were captured in traps baited with acetic acid or in traps baited with the combination of acetic acid and isobutanol (Table 1). The numbers of *P. fuscatus* paper wasps captured in traps baited with the combination of acetic acid and isobutanol were significantly higher than in traps baited with acetic acid alone. Significant numbers of *P. perplexus* paper wasps were captured in traps baited with acetic acid or with the combination of acetic acid and isobutanol (Table 1). For this species, there was no difference between numbers of wasps captured in traps baited with acetic acid alone or with acetic acid and isobutanol in combination. Despite the low numbers captured in the experiment, numbers of *P. annularis* captured in traps baited with the combination of acetic acid and isobutanol were significantly greater than in unbaited traps.

DISCUSSION

The results of these experiments demonstrate that a number of species of social wasps are attracted to the combination of acetic acid and isobutanol. The previous finding of attraction of worker *V. germanica* (Landolt 1998) to this blend was reconfirmed with the results of the tests in Beltsville, Maryland and Puyallup, Washington. Attraction of *V. maculifrons* and *V. squamosa* was demonstrated both in Maryland and Oklahoma. Attraction of *D. maculata* to the blend of chemicals was shown in Maryland and Puyallup, Washington, while *V. crabro* were trapped with the same chemicals in Maryland. *Polistes dominulus* was trapped with acetic acid and isobutanol in Maryland and *P. fuscatus* and *P. annularis* were trapped with the same chemicals in Oklahoma. This is a total of 5 species of yellowjackets (*Vespula*/*Dolichovespula*), one species of hornet (*Vespa*) and 4 species of paper wasps (*Polistes* spp) that are known to respond to this chemical attractant (Landolt 1998, 1999).

The lack of response of certain species is also of interest, although the reasons for a lack of captures of a given species are not determined. In Washington, *Vespula atropilosa* (Sladen) has not been captured in traps baited with acetic acid and isobutanol in significant numbers, despite a known population at the trapping locations. The aerial yellowjacket, *Dolichovespula arenaria* (F.), and *V. vulgaris* have not been captured in significant numbers in these trapping tests, despite their general distribution. However, neither of these two species has been known to be present at trapping sites during experiments, either in these tests or in previous experiments with these compounds (Landolt 1998). It is possible that these two species and others have not been captured because populations at trapping sites have been very low during the experiments. The responsiveness of species to this attractant may also reflect their sugar or carbohydrate foraging behavior, which for some species are well known. *Polistes fuscatus* and *P. annularis* stock cells of nests with concentrated sugars or honey (Rau 1928, Strassmann 1979).

A formulation dispensing acetic acid and isobutanol should be a useful lure for trapping most pestiferous species of Vespidae throughout North America and other areas of the world. In North America, *V. pensylvanica*, *V. maculifrons*, *V. germanica*, *V. vulgaris*, and *V. squamosa* are the most pestiferous because of their abundance, colony size, and foraging habits (Akre et al. 1980). *Vespula vulgaris* is the only major North American pest species that is not yet documented to be attracted to the combi-

nation of acetic acid and isobutanol. *Vespula germanica* is a major pest in Europe as well as many other areas of the globe where it has been introduced, including New Zealand, Tasmania, Australia, Chile, and Argentina (Edwards 1976). Following these results, it is expected that other pest species of Vespidae, particularly Palearctic Vespinae, are likely to be attracted to this chemical blend.

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EVALUATION OF TRAP TYPE AND COLOR FOR MONITORING *HYLOBIUS PALES* AND *PACHYLOBIUS PICIVORUS* IN FLORIDA

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ABSTRACT

The pyramid-shaped Tedders trap was evaluated in north Florida for capturing the root weevils, *Hylobius pales* (Herbst) and *Pachylobius picivorus* (Germar) (Coleoptera: Curculionidae). Weevil response to Tedders traps of several colors was compared to the Fatzinger stovepipe trap and a new traffic cone trap. Traps were baited with a 1:1 ratio of the attractants ethanol and turpentine. Black or brown Tedders traps were more effective than yellow or white traps. The Tedders trap and the cone trap were as good as or more effective and easier to use than the stovepipe trap for monitoring weevil adults. Tedders traps also captured many other species of forest insects.

Key Words: *Hylobius pales, Pachylobius picivorus*, Tedders trap, Root Weevils, *Pinus* spp.

RESUMEN

Se evaluó la efectividad de la trampa piramidal Tedders para capturar a los escarabajos de raíces, *Hylobius pales* (Herbst) y *Pachylobius picivorus* (Germar) (Coleptera: Curculionidae), en el norte de Florida. La respuesta de los escarabajos a trampas Tedders de distintos colores se comparó con la trampa tipo "stovepipe" y con la trampa de cono de tráfico. El atrayente utilizado consistió de una mezcla de metanol y terpentina (1:1). Trampas Tedders de color café o negro fueron más efectivas que las amarillas o blancas. Las trampas Tedders y de cono fueron tan o más efectivas y fáciles de usar que las tipo "stovepipe" para monitorear escarabajos adultos. Las trampas Tedders también capturaron una gran variedad de insectos del bosque.

The pales weevil, *Hylobius pales* (Herbst), and the pitch-eating weevil, *Pachylobius picivorus* (Germar), are important pests of new pine and Christmas-tree plantations throughout eastern North America (Fettig 1998, Rieske and Raffa 1991, Lynch 1984, Ciesla and Franklin 1965). Adult feeding on pine seedlings causes girdling damage to bark and twigs which can result in seedling mortality (Lynch 1984, Ciesla and Franklin 1965). Adult weevils of both species are attracted to fresh pine resin (Hertel 1970, Ciesla and Franklin 1965). Eggs are laid on tree roots and weevil larvae feed in the roots of recently burned, damaged or cut pine stumps (Fox and Hill 1973). When sites are replanted before weevils emerge and disperse, emerging adults feed on the pine seedlings.

Sampling techniques for these weevils have used radial discs cut from fresh pine (Ciesla and Franklin 1965), freshly-cut pine bolts (Taylor and Franklin 1970), and traps baited with ethanol and/or turpentine: modified bounce-column, stovepipe traps

(Clements and Williams 1981, Fatzinger 1985, Phillips et al. 1988), PVC pitfall traps (Hunt and Raffa 1991, Fettig and Salom 1998) and pit traps (Fettig and Salom 1998). Fettig and Salom (1998) used both host material and a 5:1 ethanol:turpentine mixture in the pit trap.

Thomas and Hertel (1969) reported that pales weevils could detect hosts up to 6 m away by olfaction. Fatzinger (1985) and Fatzinger et al. (1987) reported that in Florida ethanol and turpentine attracted both root weevil species to a baited stovepipe trap modified after the bounce-column trap of Clements and Williams (1981). Siegfried (1987) found that turpentine was more attractive than specific terpenes from turpentine when tested individually. Phillips et al. (1988), using a stovepipe trap, showed that *P. picivorus* was attracted to turpentine, but was unaffected by ethanol. *H. pales* displayed greatest attraction to ethanol and turpentine when released side by side or as a 1:1 mixture from one dispenser (Phillips et al. 1988). However, Fettig et al. (1998) reported that both sexes of *H. pales* responded in highest numbers to a 5:1 mixture of ethanol:turpentine. Rieske and Raffa (1991) reported that within each species males and females of *H. pales* and *P. picivorus* responded similarly to individual ethanol-turpentine ratios, however, *P. picivorus* response across all tested bait ratios deviated significantly from 1:1.

Fatzinger (1985) reported that a black stovepipe trap baited with a 1:1 ethanol:turpentine mixture caught higher numbers of weevils than a trap with a white stovepipe. However, unbaited traps collected no forest Coleoptera (Fatzinger 1985). Hunt and Raffa (1991) in Wisconsin compared white, black and green pitfall traps made of PVC with a 45 cm above-ground silhouette and baited with ethanol and turpentine. White traps caught more weevils than black and green traps. Rieske and Raffa (1991) tested different release ratios (1:10, 1:5, 1:1, 5:1, 10:1, 75:1) of ethanol and turpentine in pitfall traps and found that pales weevil responded best to a ethanol:turpentine ratio of 5:1 and greater, while pitch-eating weevils responded in higher numbers to the 5:1 and 10:1 ratios. Fettig and Salom (1998) used white PVC traps modeled after traps of Tilles et al. (1985) baited with a mixture of 5:1 ethanol:turpentine and pit traps baited with natural host material and a 5:1 ethanol:turpentine mixture to determine the relationship between trap catch and seedling damage by *H. pales* in Virginia Christmas tree plantations. Fettig and Salom (1998) reported that the PVC trap was not as accurate as the pit trap in predicting *H. pales* abundance and phenology, therefore, they recommended use of the pit trap for monitoring *H. pales* in Virginia Christmas tree plantations. Fettig and Salom (1998) also found no effect of trap rotation on trap catch of *H. pales*.

Despite the successful collection of weevils in the stovepipe traps (Fatzinger 1985), the PVC pitfall trap (Hunt and Raffa 1991, Rieske and Raffa 1993) and the pit trap (Fettig and Salom 1998), weevil response behavior to traps is not fully understood and all traps do not accurately indicate weevil population dynamics (Fettig and Salom 1998). Improvements are needed to increase ease of use and trapping efficiency and accuracy. Further understanding of the relative functions of visual and odor cues in weevil trap response is needed. Traps with different designs may enable investigation of different weevil behaviors. Stovepipe traps require continuous labor and water-hauling to maintain supplies of soapy water. Through time they become full of debris and algae. PVC traps are placed in the ground and their efficacy is negatively impacted in Florida's sandy soils by rain and armadillos (this study). Many observed differences in trap response with different methods exist between experiments from the northern and southern U.S. (Phillips et al. 1988, Rieske and Raffa 1991). Collections of *H. pales* and *P. picivorus* in unbaited pyramidal traps (Tedders and Wood 1994, Tedders et al. 1996) (named the Tedders trap in Sherman and Mizell (1995)) in peach orchards and other non-pine habitats led to the experiments reported herein.

This study reports a series of experiments in north Florida under different site and harvesting conditions to evaluate the Tedders trap in different colors in comparison to the stovepipe trap (Fatzinger 1985) and other potential trap designs for their use in determining weevil behavior and for monitoring the dynamics in populations of *H. pales* and *P. picivorus*.

Materials and Methods

Tedders traps (Tedders and Wood 1994) modified by adding a bait dispenser were used in all experiments. Traps were painted with either Ace® acrylic flat latex house paint (brown = 159A214, white = 103A200, black = 103A105) or Glidden® alkyd industrial formula, 4540 safety yellow. Stovepipe traps were as described by Fatzinger (1985). Cone traps were modified 90 cm (height) traffic cones (SEC+ Safety Equipment CO., Jacksonville, FL 32216) painted black with a collection top (boll weevil trap top) similar to the Tedders trap. A triangle of masonite tightly fitting the boll weevil trap top's bottom interior and attached into a saw kerf in a dowel which snugly fitted into the cone's hollow tip held the collection top in place. Traps in each site were placed 10-12 m apart (Thomas and Hertel 1969) on a transect in a completely random design. Baits were dispensed from a 250 ml plastic bottle fitted with a dental wick and filled with a 1:1 mixture of 95% ethanol and turpentine (Parks Pure Gum Turpentine, Parks Corporation, Somerset, MA 02726) (Fatzinger 1985). Bottles were placed in a circular wire frame so as to fit over the top of the Tedders and cone traps. They were placed about 10 cm from the trap top and eluted 0.52 gms ± 0.13/h (mean ± SE) of the ethanol:turpentine attractant. Elution rate was determined by weighing a filled dispenser each hour for several days under a variety of sunlight, cloud and humidity conditions.

Traps were checked 1-3 times per week and the number of *H. pales* and *P. picivorus* were recorded and removed. For analysis, weevil counts were converted to the number of weevils per trap per day by species. Data from all experiments were analyzed by analysis of variance using Proc GLM procedures of SAS (SAS Institute 1998). Due to the large number of zero counts, weevil counts were transformed before analysis by taking the square root of the counts + 1; non-transformed means are reported. When significant treatment differences were indicated, means were separated by Duncan's New Multiple Range Test (P = 0.05) (SAS 1998, Proc GLM) because of the unequal treatment replication.

Experiment A. Tedders traps of three colors. Tedders traps were placed in an approximately 4 ha mixed pine-hardwood forest located near Monticello, Florida from 25 June-17 December 1993. Sawtimber-sized loblolly pines, *Pinus taeda* (L.), had been harvested from the site in March-April 1993 leaving pine stumps and slash among 50-70 percent remaining hardwoods. Three to seven replicates of white, brown and black Tedders traps were tested. One trap of each color was not baited and served as a control for the odor effects. Bait position was rotated randomly among traps at each visit so that a different trap, one of each color, remained without bait during each period.

Experiment B. Tedders traps of four colors. Three replicates each of white, yellow, brown and black Tedders traps were placed 10-12 m apart in a completely random design in a mixed pine-hardwood location on the North Florida Research and Education Center at Monticello, Florida from 21 February-16 April 1994. No harvesting had occurred in this location which was adjacent to an open field on one side. Traps were placed in the forest along a north-south transect. Two traps of each color were baited as described above and one was left unbaited. Bait dispensers were shifted so as to change the location of the unbaited trap at each visit.

Experiment C. Tedders trap colors, the stovepipe and cone traps. The location was an approximately 15 ha clearcut of loblolly pine in Jefferson County near Monticello, Florida. All traps were deployed from 2 April-26 August 1994. Tedders traps of yellow, white, brown and black were compared to the stovepipe trap (Fatzinger 1985) and one cone trap. Three replicates of each Tedders trap type, two stovepipe traps and the cone trap were placed along a transect 10-12 m apart in a completely random design. Traps were baited as described above. The two stovepipe traps and the cone trap were baited continuously, but one of each colored Tedders traps was left unbaited. Baits were shifted at each visit to the previously-unbaited trap. Data are presented for the baited traps only. Other insects found in the traps were collected and recorded to family, genus or species when a determination could be made.

Experiment D. Tedders trap colors and stovepipe trap. This location was a recently-harvested, mixed pine-hardwood site near Lloyd, Florida. A timber harvest had removed the loblolly pine sawtimber from the site leaving about 70% of the remaining area covered with mixed hardwood species, pine slash/stumps and harvest trails. From 27 August-15 December 1994, 3 replicates of brown, black, yellow and white Tedders traps and 2 replicates of the stovepipe trap were placed about 10-12 m apart in a completely random design along a east-west transect. All traps were baited as described above.

Experiment E. Tedders trap colors and two sizes, stovepipe trap and combinations of both. This location was a 20 ha clearcut of about 25 year old loblolly pine near Monticello, Florida. Trapping was conducted from 10 May-15 July 1996. Tedders traps, (2 replicates each of black, white, yellow, a half-size (60 cm) yellow (cut from bottom half of the Tedders trap), a regular stovepipe trap, and the stovepipe bottom—wading pool—containing a black or white Tedders trap. All traps were baited and checked as described above. The stovepipe traps modified with Tedders traps caught weevils in the water and in the typical Tedders trap top.

Experiment F. Black Tedders trap, stovepipe and cone trap. This location was an approximately 20-year-old loblolly pine stand of about 5 ha that had been thinned and harvested in corridors. Remaining trees were in groups of 5 rows of trees separated by bare ground and slash residue where the 5 rows of trees had been removed. The site was harvested in March-April. Trapping was conducted from 13 May-3 November 1997. Two replicates of a 3 × 3 Latin Square design were used with traps placed 50 m apart. The stovepipe trap, the black Tedders trap and the black cone trap were tested. All traps were baited as described above.

RESULTS

Experiment A. Seventy-six *H. pales* (65/11, baited/unbaited) and 70 *P. picivorus* (65/5) were captured at this location (Table 1). There was no significant difference between trap colors for either weevil species (*H. pales*, $F_{(3,470)} = 0.36$, $P = 0.78$; *P. picivorus*, $F_{(3,470)} = 1.18$, $P = 0.32$). Weevil abundance patterns indicated a peak in July similar to that reported by Fatzinger (1985) (Fig. 1).

Experiment B. Fifty one *H. pales* (46/5, baited/unbaited) and 5 *P. picivorus* (baited) were captured in 12 traps during the 55 days of the experiment (Table 1). The black traps caught 25 *H. pales*, twice as many as any other color, but too low for statistical significance ($F_{(3, 255)} = 1.2$, $P = 0.31$).

Experiment C. Sixty-nine *H. pales* (66/3, baited/unbaited) and 184 *P. picivorus* (172/12, baited/unbaited) were captured (Table 1) during the 5 month trapping period. Significant differences in trap captures were detected for both species: *H. pales*, $F_{(5,248)} = 3.05$, $P = 0.01$; *P. picivorus*, $F_{(5,248)} = 6.67$, $P= 0.0001$. For *H. pales,* the one cone trap captured 13 weevils (0.13 ± 0.05, mean weevils/trap/day ± 1 standard error), greater

TABLE 1. THE TOTAL NUMBER OF *HYLOBIUS PALES* (H. P.) AND *PACHYLOBIUS PICIVORUS* (P. P.) WEEVILS CAUGHT IN EACH STUDY SITE IN EACH TRAP TYPE. MEAN NUMBERS PER TRAP PER DAY ARE STATED IN THE TEXT. CAPTURES IN SITES A AND B WERE NOT SIGNIFICANTLY DIFFERENT AMONG TREATMENTS.

	Exp. A		Exp. B		Exp. C		Exp. D		Exp. E		Exp. F	
	H. P.	P. P.	H. P.	P. P.	H. P.	P. P.	H. P.	P. P.	H. P.	P. P.	H. P.	P. P.
Treatment	Trap Totals[1]		Trap Totals[1]		Trap Totals[2]		Trap Totals		Trap Totals		Trap Totals	
Tedders Brown	17	11	3	0	18B[3]	31B	38A	4				
Tedders Black	36	25	25	3	14B	41B	22AB	2	9AB	25	112A	177A
Tedders Yellow	17	27	11	0	7B	29B	6B	0	4ABC	13		
Tedders White	6	7	12	2	4B	1C	16B	2	0C	12		
Stovepipe					10B	52A	9B	3	11A	31	19C	31C
Cone					13A	18B					78B	98B
Yellow Half-size									4ABC	13		
Stovepipe + White Tedders									1BC	27		
Stovepipe + Black Tedders									9ABC	28		

[1]Totals for baited and unbaited since no treatment differences are present.
[2]Totals for baited traps only.
[3]Number totals in columns not followed by the same letter have means which are significantly different.

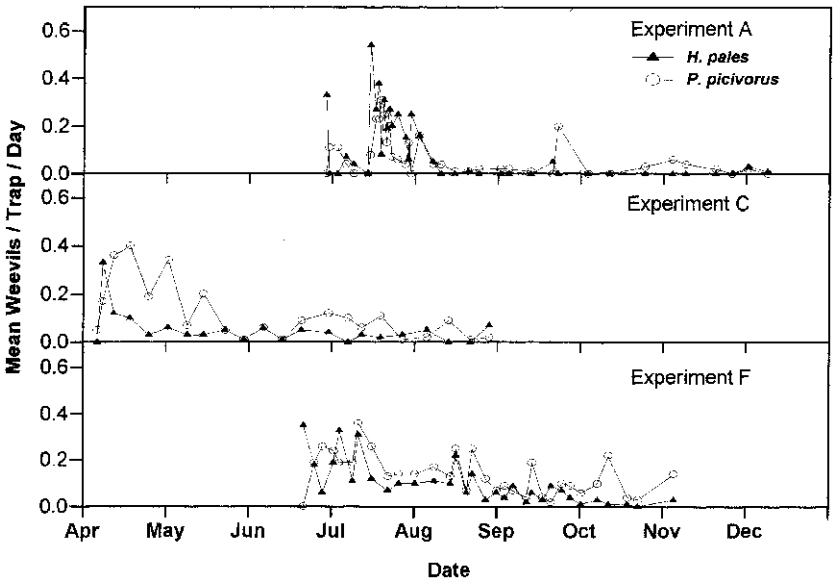

Fig. 1. Mean number of *Hylobius pales* and *Pachylobius picivorus* weevils per trap per day from experiments A, C, and F. Means were computed from total catch from all traps in each of these experiments.

than twice as many per trap per day as the other traps (brown - 0.06 ± 0.02, black - 0.05 ± 0.03, stovepipe - 0.05 ± 0.02, yellow - 0.03 ± 0.01, white - 0.01 ± 0.01) which had two replications. For *P. picivorus,* the pool trap captured significantly more weevils per trap per day (0.27 ± 0.07) (total = 52) and the white (0.01 ± 0.01) (total = 1) Tedders trap captured significantly less than the other trap types, P = 0.05 (Table 1). Seasonal abundance of weevils differed (Fig. 1) from the patterns observed by Fatzinger (1985). All of the traps captured numerous other wood-inhabiting insects commonly associated with conifers or slash residue as observed by Fatzinger (1985) as well as miscellaneous other species. One or more species of Cerambycidae, Buprestidae, Cleridae, Trogositidae, Siricidae, Mordellidae, Lycidae, Scarabaeidae, Elateridae, Tenebrionidae and Silphidae were commonly captured in the traps, often in large numbers.

Experiment D. Ninety-one *H. pales* and 11 *P. picivorus* were captured during the 89-day fall trapping period. The low numbers of *P. picivorus* did not respond significantly to trap color or type ($F_{(4, 266)} = 1.25$, P = 0.29). *H. pales* did respond significantly ($F_{(4, 266)} = 4.18$, P = 0.0027) to trap type with the highest response to the brown ((total = 38) 0.64 ± 0.13) and black ((total = 22) 0.39 ± 0.13) Tedders traps (Table 1).

Experiment E. Thirty eight *H. pales* and 149 *P. picivorus* were captured by traps from 10 May-15 July 1996. No significant differences were observed in the response of *P. picivorus* to the traps ($F_{(6, 231)} = 1.59$, P = 0.15). However, the stovepipe and modified stovepipe traps, along with the black Tedders trap, captured more than twice as many as the yellow and white Tedders traps (Table 1). The modified stovepipe traps, which were wading pools containing soapy water with Tedders traps in place of the stovepipe, enabled weevils to be captured in the bottom water and in the Tedders' top as weevils landed on the trap and walked upwards. *P. picivorus* were captured in

equal numbers in the top and bottom of the traps: the black traps captured 16 in the top and 12 in the water while the white traps captured 12 in the top and 15 in the water. This result indicated that some weevils land and walk on the "bounce column" when it is a Tedders trap and as reported by Fatzinger (1985). Capture of *H. pales* was low in this location, but significant differences in trap response were evident ($F_{(6, 231)}$ = 2.91, P = 0.009). White traps captured the lowest number (Table 1).

Experiment F. A total of 730 weevils was captured in this site in the 12 traps from May-November 1997. Technical difficulties precluded the accurate species identification of the first 215 captured weevils. Therefore, the data from the 515 weevils (209 *H. pales* and 306 *P. picivorus*) correctly identified to species were analyzed and reported. Significant differences in trap catch were detected for *H. pales* ($F_{(2, 566)}$ = 15.89, P = 0.0001) and for *P. picivorus* ($F_{(2, 566)}$ = 18.33, P = 0.0001). For both species, *H. pales* (total = 112) (0.15 ± 0.02/trap/day), *P. picivorus* (total = 177) (0.23 ± 0.03/trap/day), the Tedders trap caught significantly higher numbers than the cone trap (*H. pales* (total = 78) 0.12 ± 0.02 /trap/day, *P. picivorus* (total = 98) 0.13 ± 0.02/trap/day), which was significantly higher than the stovepipe trap (*H. pales* (total = 19) 0.03 ± 0.01/trap/day, *P. picivorus* (total = 31) 0.05 ± 0.05/trap/day) (Table 1). Trap catch as an indication of seasonal abundance of both weevil species was similar to the variable patterns observed by Fatzinger (1985) (Fig. 1). Unlike the findings of Fettig and Salom (1998) all three traps indicated similar seasonal abundance patterns (data not shown).

Discussion

The PVC pitfall trap (Tilles 1985, Rieske and Raffa 1991, Fettig and Salom 1998, Fettig et al. 1998) was evaluated in a preliminary test and was determined to be very inefficient in Florida's sandy soils. Even light rain events splashed sand onto the trap closing all the entrance holes. Armadillos often disturbed the traps by digging around them. Therefore, PVC traps were judged unacceptable for use in Florida's sandy soil and rain conditions and were not tested further.

Tedders traps were tested from 1993-1997 during most seasons of the year and in a variety of site types to provide weevils for study under a range of conditions and population levels. Using trap response to determine the effects of harvest practices on weevil populations was not an objective of this study. Populations of the two weevil species detected and presumably present in the test locations varied from low to high. Fatzinger (1985) using higher numbers of the stovepipe traps during 1980-1981 in Baker and Union County, Florida, captured much higher numbers of weevils (7,393 *H. pales* and 2490 *P. picivorus*), but also reported marked differences in numbers of both species of weevils captured in 1980 and 1981. Populations of weevils are likely affected by site characteristics such as the density of stumps available for colonization, time of year of harvest as it affects stump suitability, and weather following harvest which would affect the ability of weevils to colonize available food material.

In comparison to the stovepipe trap, the Tedders trap can be moved more easily, but it does require time and effort. Fettig and Salom (1998) indicated that position of traps had no significant impact on trap catch of *H. pales* in PVC traps. In these tests we moved the baits instead of the traps to eliminate any potential positional effects. However, in hindsight this appears unnecessary, but did indicate positive weevil response to unbaited traps.

We used a 1:1 ratio of ethanol:turpentine after Fatzinger (1985) and Phillips et al. (1988), because Fatzinger (1985) was the standard trap for comparison. We did not determine the components or ratio of the components of the turpentine because Siegfried (1987) reported that turpentine was more attractive to these weevils than the individual constituents. All traps were baited with the same ethanol:turpentine at-

tractant and dispensers so that the volatiles released from all traps should have been equivalent. Evaluating attractant ratios and the potential for differential response by *P. picivorus* (Rieske and Raffa 1991) was not an objective of this study, but merits testing with the Tedders trap.

While odor cues serve as the primary attraction, it is clear that visual cues are also important in weevil behavior (see below) and deserve more research. Unlike in previous studies, both weevil species (*H. pales* 19, *P. picivorus* 17) were captured in unbaited traps of every color (total all tests: brown 15, black 6, yellow 11, white 4) in every test, as well as in open fields away from pine hosts (in other experiments). We observed a significantly higher response to darker colors in most tests, however, the yellow and white traps also caught both weevil species. Fatzinger (1985) reported that a black stovepipe captured statistically significant higher numbers of weevils than a white stovepipe (8.3 vs 7.2/trap/3 days), although the numbers were very close. Hunt and Raffa (1991) reported capturing significantly higher numbers of weevils in white as opposed to black or green PVC pitfall traps. Weevils are clearly responsive to visual cues and perhaps traps of any color present dark silhouettes under certain light conditions that mimic tree trunks (Tedders et al. 1996). Fettig and Salom (1998) reported aggregation of weevils at the base of tree stumps.

Fatzinger (1985) used the stovepipe in the trap as a "bounce column", implying that weevils fly into the stovepipe and bounce into the water trap below. However, weevils land and walk on the vertically projecting parts of traps (Fatzinger 1985). We occasionally observed weevils on the traps, and caught equal numbers of weevils in the Tedders and the water when the Tedders trap was substituted for the stovepipe in the stovepipe trap (Exp. F.). This observation, combined with the trap catch in unbaited Tedders traps, further indicates the importance of visual cues in weevil behavior. This behavior likely also explains the difference in trap captures between the cone and the Tedders trap (Exp. F, Table 1). While the cone does provide a visible surface for weevils to land on, the round flat surface allows walking in any direction and the opportunity to fly away. With the Tedders trap, the perpendicular orientation of the four vanes and the 62° angle of the planar edges are such that, once insects land on the trap, they are arrested and have a high probability of walking upwards. This phenomenon has been observed with other weevils and phytophagous stink bugs (Mizell and Tedders 1996).

Weevils that are attracted by odors to the vicinity of a trap without landing on the trap would be excluded from the stovepipe trap, but not the Tedders, PVC pitfall, pit or the cone traps. The PVC pitfall traps with 46 cm of PVC above ground used by Hunt and Raffa (1991) would also allow weevils that oriented to trap odor and then visually to silhouettes to land, walk upwards and fly away without entering the trap. This perhaps explains why these traps did not collect root weevils without attractive baits. Rieske and Raffa (1991) modified the PVC trap such that only 6 cm were above ground to simulate a stump image which probably directed the weevils more towards the capturing area of the trap.

In this study we did not evaluate the effect of Tedders trap height except in Exp. E. with the yellow color. The half-size 61 cm (2') trap and the full size 122 cm (4') traps each caught the same number of both species of weevils (Table 1). This warrants more research because smaller traps would cost less and weevils may use visual cues to land on traps. Moreover, this suggests that the quality (effect on weevil behavior and the trap's ability to capture these landing/walking weevils) is also important in determining trap efficiency and in accurately comparing trap color effects. However, the ability to detect the results from this behavior by trapping will depend on trap design. PVC pitfall or pit traps would not capture the weevils landing on the above ground portion of the trap that could possibly walk or fly away and not enter the trap.

The Tedders trap captured many other species of tree-colonizing insects and their associates. Fatzinger (1985) used the stovepipe trap to collect black turpentine beetles, *Dendroctonus terebrans* (Olivier) and *Ips* spp. The Tedders trap did not collect these species in these tests. Fatzinger (1985) also caught *Monochamus titillator* (F.) and *M. carolinensis* (Olivier), Cerambycidae, in large numbers. The Tedders trap also caught large numbers of these species along with several species of Pentatomidae, Reduviidae, Buprestidae, Cleridae, Elateridae, Scarabaeidae, Chrysomelidae, Nitidulidae, Mordellidae, Trogositidae, Siricidae, Tenebrionidae, Lycidae and Silphidae. In addition, we have caught over 75 other species of Curculionidae, including many important agricultural pests, in the Tedders trap in a variety of habitats (R. Mizell, W. Tedders and C. O'Brien 1993-1998, unpublished data). Use of the Tedders trap as a detection and monitoring tool for these species should be further investigated.

Tedders traps and the experiments in these tests are the first trapping methods that provide an indication of root weevil behavior in response to color and trap surface and a means to fully exploit weevil flight and walking behavior together. Unbaited Tedders traps often trap weevils in low numbers in areas without host plants. Root weevils respond to host odors as simulated by ethanol:turpentine as primary attractants. Comparing the trap qualities in the results from Experiment F indicate that these weevils secondarily respond to visual cues provided by a trap. However, they may land on the trap and walk, fall down, fly away or perhaps they may land short of the trap and walk towards the odor source. The stovepipe trap would capture weevils that land and/or hit the trap and fall; it would not capture weevils that land, walk up and fly away, nor would it capture weevils that land away from the trap and walk to the odor source. The cone trap can capture weevils behaving in any manner, but apparently loses efficiency (relative to the Tedders trap) by not arresting weevils that land and then directing them exclusively vertically into the capturing top. The Tedders trap exploits all of these weevil behaviors and indicates that a black or dark colored trap may provide the best trap efficiency for *H. pales* and *P. picivorus*.

In comparison to the standard stovepipe trap, the Tedders trap is cheaper to make and easier to use. While the species collected in both traps overlap, the two traps do not collect all the same species. Further research with the Tedders trap is necessary to determine weevil response to ethanol:turpentine ratios and to determine if any relationship exists between trap capture and seedling damage. The differential response to trap color by weevils in Wisconsin (Rieske and Raffa 1991) and weevils in the Southeast (Fatzinger 1985, this study) remains to be fully explained.

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AVOCADO MOTH (LEPIDOPTERA: STENOMIDAE) DAMAGE IN TWO AVOCADO CULTIVARS

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ABSTRACT

Avocado moth, *Stenoma catenifer* (Wals.), damages the avocado, *Persea americana* Mill. Two cultivars, Beatriz and Margarida, were assessed during the fruit development period. The progression of fruit damaged was different in the two cultivars. The incidence of *S. catenifer* fruit damage at the beginning of fruit development was higher in Beatriz (72.1%) than in Margarida (28.4%). However, the differences in damaged fruit decreased between cultivars over the season. The number of borer holes per fruit was also higher throughout the season in Beatriz than in Margarida, as indicated on the first (3.99 and 1.41, respectively, on day 8) and last (13.35 and 6.08, respectively, on day 133) observation date. Percent fallen fruits were initially the same (2.00 and 0.38%, respectively, on day 8), but significantly higher in Beatriz at the end of the season (97.19 and 81.60%, respectively, on day 133). Margarida was less damaged than Beatriz, as evidenced by percent damaged fruits, but mainly in the earlier assessments. The use of Beatriz as a trap plant in avocado orchards is discussed.

Key Words: Insecta, plant resistance, phenology, trap cropping

RESUMO

Avaliou-se os danos causados pela broca dos frutos *Stenoma catenifer* (Wals.) nos cultivares Beatriz e Margarida de abacate durante o período de desenvolvimento dos frutos. A progressão de frutos danificados foi diferente nos dois cultivares. No início da infestação, verificou-se que este percentual foi maior no cultivar Beatriz (72,1%) do que no Margarida (28,4%). Entretanto, a diferença de suscetibilidade entre os cultivares diminuiu gradativamente durante a safra. O número de orifícios por fruto foi maior durante a safra no cultivar Beatriz do que no Margarida, na primeira (3,99 e 1,41, respectivamente, no dia 8) e na última avaliação (13,35 e 6,08, respectivamente, no dia 133). A percentagem de frutos caídos foi inicialmente a mesma (2,00 e 0,38%, respectivamente, no dia 8), mas significativamente maior no Beatriz no final da safra (97,19 e 81,60%, respectivamente, no dia 133). O cultivar Margarida foi menos danificado do que o Beatriz, como evidenciou-se pelo percentual de frutos danificados, principalmente nas primeiras avaliações. Discute-se a utilização do Beatriz como planta armadilha nos pomares.

Several species of Lepidoptera are considered as pests of avocado, *Persea americana* Mill., fruit, including *Boarmia selenaria* Schiffermuller (Geometridae) (Wysoki & Jong 1989, Meisner et al. 1990) and *Cryptoblabes gnidiella* (Millière) (Pyralidae) (Wysoki & Jong 1989, Anshelevich et al. 1993) in Israel; *Sabulodes aegrotata* (Guenee) (Geometridae) (Bailey & Olsen 1990a, 1990b) and *Amorbia cuneana* (Walsingham)

(Tortricidae) (Bailey & Olsen 1990a) in California. In Latin America, the avocado moth, *Stenoma catenifer* (Walsingham) (Stenomidae), is the most serious pest of avocado and is widely distributed (Medina 1978, Gaillard 1987). Costa Lima (1945) first reported the avocado moth as a pest in Brazil, and since then it has been reported throughout Brazil (Medina 1978). The moth lays eggs on fruits. Larvae bore pulp and seeds and pupation occurs in the soil. Incubation, larval and pupal developmental time were reported as 16.0, 15.3 and 10.6 days, respectively, and mean number of eggs per female was 164 (26 ± 1°C; 60 ± 10% rh and 14 h L:10 h D photoperiod) in Margarida cultivar (Hohmann & Meneguim 1993).

The damage to avocado can cause total production loss (Hohmann & Meneguim 1993). Because there is concern about the introduction of this species into the United States (Wolfenbarger & Colburn 1979), fruit importation has been limited from countries where the pest occurs (Koller 1982).

Natural enemies could be a key management tactic used to control pest species in avocado orchards. Thus, the development and deployment of pest management tactics that do not destroy natural enemy populations are desirable (Bailey & Olsen 1990a). Pheromones (Bailey & Olsen 1990b, Anshelevich et al. 1993), biological control with egg parasitoids *Trichogramma* spp. (Wysoki & Jong 1989, Bailey & Olsen 1990b), *Trichogramma pretiosum* Riley and *T. annulata* de Santis (Hohmann & Meneguim 1993) and microbial control with *Bacillus thuringiensis* (Berl.) (Izhar et al. 1979, Meisner et al. 1990) are examples of non-aggressive control strategies that could be used to conserve natural enemy populations.

Although *T. pretiosum* Riley and *T. annulata* de Santis (Hohmann & Meneguim 1993) have been reported in avocado moth eggs, only chemical control of avocado moth in avocado orchards has been studied thus far (Santos et al., 1996, unpublished). Producers use chemical insecticides to control *S. catenifer* in avocado orchards (ca. 6 sprayings of organophosphates, carbamates, or pyrethroids) without knowledge of the susceptibility of different cultivars to this pest. The objective of this study was to compare avocado moth damage progression in two avocado cultivars during the season.

Material and Methods

The avocado cultivars, Margarida and Beatriz, were assessed for avocado moth damage in a five-year-old commercial orchard in Londrina (latitude 23°19'S, longitude 51°12'W), Paraná State, Southern Brazil, between February and June 1996. The orchard consisted of 90% Margarida and 10% Beatriz. The Margarida cultivar is produced in the fallow of other cultivars in orchards in the southern and southeastern regions of Brazil, and thus has a high commercial value. Producers interplant 10 to 20% Beatriz cv. plants in Margarida orchards as pollinizers. Avocado plants have protogyny (Fehr 1987) and cultivars are divided into two groups according differences in pollinization (Vithanage 1990). Margarida represents one group in which the pistil matures before the anther, with no synchronization in the maturity of the female and male reproductive organs. The pistil is viable in the afternoon while pollen of the same flower is viable in the morning of the following day. In a second group, which includes Beatriz, the pistil is viable in the morning and pollen of the same flower in the afternoon of the following day. Both cultivars are late. Crop management was the same in cvs.

Fruit development was observed at the onset of fruiting period. The experiment was initiated when the first symptoms of pest attack were detected and terminated at harvest. Twenty-six plant pairs of each cultivar were randomly selected. Each pair of plants was considered a block. Ten fruits from each plant were randomly marked and observed at 8, 17, 38, 57, 73, 94, 114 and 133 days after experiment beginning. A ran-

domized block design was used with two treatments and 26 blocks. The following characteristics were assessed: percent damaged fruits (fruit was considered damaged if it contained one or more holes caused by the borer); percent fallen fruit and number of holes per fruit.

The mean value of each time period represents the accumulated values of the previous period for the variables. Thus, the data from the last assessment date represents the total damage throughout the observation period.

Regression lines were compared for the progression of avocado moth damage in the two cultivars (Snedecor and Cochran 1967). This procedure was applied only to percent damaged fruit, as this was the only variable for which the homogeneity of residual variances requirement was fulfilled. Data from the first and last observation periods were used to compare damage between the cultivars for the percent fallen fruit (χ^2test) and number of holes per fruit (analysis of variance and Tukey's studentized range test) (SAS Institute 1989).

Results

Progression of percent damaged fruit was different between two cultivars, and is shown by a significant difference by comparing the slopes or regression coefficients; b_1 = 0.21 and b_2 = 0.44, for Beatriz and Margarida, respectively (Table 1 and Fig. 1). Beatriz had a higher avocado moth infection than Margarida. The initial incidence of attack cultivars was also evident different by comparing the elevation of regression lines; a_1 = 72.1 and a_2 = 28.4, for Beatriz and Margarida, respectively (Fig. 1). The regression equations for Beatriz (Y_1 = 72.1 + 0.21 X) and Margarida (Y_2 = 28.4 + 0.44 X) explain the time variation in damaged fruit (Fig. 1). This may be better appreciated by the values of determination for the coefficient values of the regression lines, which reached R^2 = 0.74 in Beatriz and R^2 = 0.92 in Margarida. Margarida was less damaged than Beatriz initially but the difference between cultivars decreased because pest populations increased in the orchard during the growing season, causing comparable damage in both.

The number of holes per fruit was variable in both cultivars and increased through time (Fig 2). The regression equation for each cultivar (Y_3 = 6.50 + 0.06 X and Y_4 = 1.70 + 0.04 X for Beatriz and Margarida, respectively) showed low slope values. However, the slopes differed significantly from zero (b_3 = 0.06* and b_4 = 0.04* for Beatriz and Margarida, respectively). Beatriz showed higher numbers of holes per fruit (Table 2).

No significant (χ^2 = 2.8) difference was found between cultivars initially at the first assessment. However, cumulative percent fallen fruit was significantly (χ^2 = 36.1**) greater in Beatriz than Margarida. The percent fallen fruit increased in both culti-

Table 1. Summary of the F test of slopes of the linear regression of cumulative percent damaged fruits caused by the avocado moth, Stenoma catenifer, in Beatriz and Margarida cv. Londrina, Pr, Brazil 1996.

Analysis of Variance	Degrees of freedom	Square sum	Mean square	F
Equality of slopes	1	373.37	373.37	9.07**
Residual error	12	494.08	41.17	

**Significant at 1% level of probability.

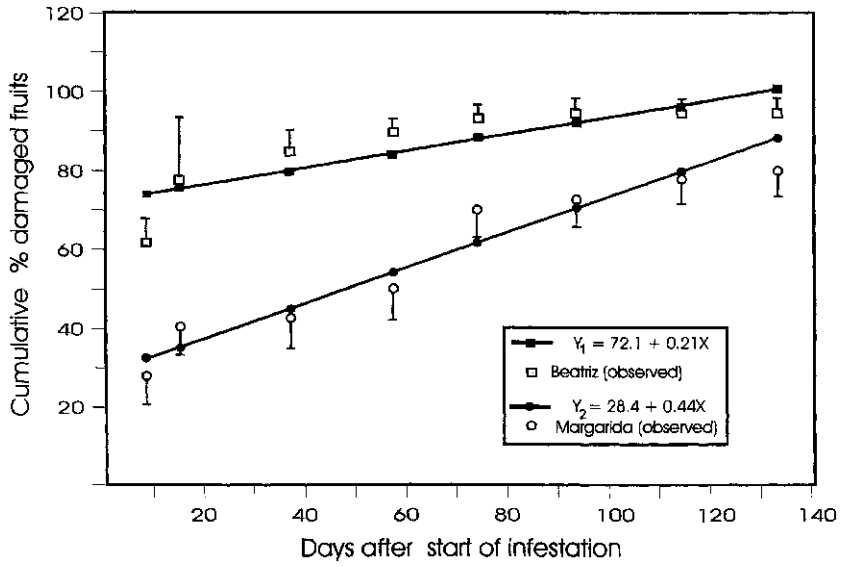

Fig. 1. Percent fruit damaged (mean S.E.) by *Stenoma catenifer* in Beatriz and Margarida avocado. Londrina, PR, Brazil, 1996.

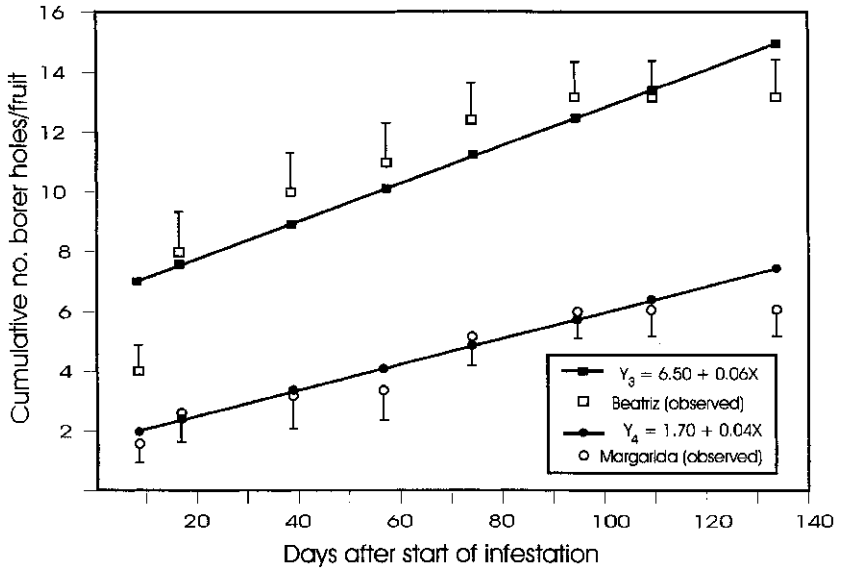

Fig. 2. *Stenoma catenifer* borer holes per fruit (mean S.E.) in Beatriz and Margarida avocado. Londrina, PR, Brazil, 1996.

TABLE 2. HOLES PER FRUIT (MEAN S.E.) IN THE AVOCADO CULTIVARS BEATRIZ AND MARGARIDA AT 8 AND 133 DAYS. LONDRINA, PR, BRAZIL, 1996.

	Holes per fruit[1]	
Cultivar	8 days	133 days
Beatriz	3.99 (0.63) a	13.35 (1.07) a
Margarida	1.41 (0.44) b	6.08 (0.83) b

[1]Means within the column followed by a different letter are significantly different ($P < 0.05$ Tukey's studentized range test).

vars, which is observed in the slope values ($Y_5 = 1.80 + 0.84$ X, Beatriz; and $Y_6 = 3.50 + 0.68$ X, Margarida) (Fig. 3). Accumulated moth damage to the fruit might influence the increase in fruit fall.

DISCUSSION

Gallo et al. (1988) proposed manual harvest and destruction of fallen fruit as a pest control strategy for the avocado moth. However, in the North of Paraná State, small farms predominate and they generally have small diversified orchards, including avocado, for their own consumption, with no pest and disease control. There is great genotypic diversity of avocado in these orchards, with plantings that flower at distinct times. Thus, there is an abundant food resource for the avocado moth all year.

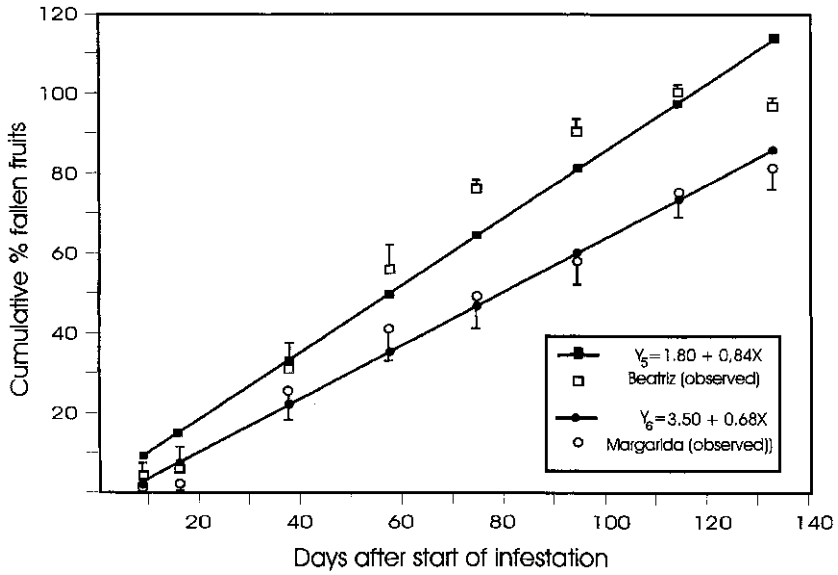

Fig. 3. Percent fallen fruit (mean S.E.) in Beatriz and Margarida avocado. Londrina, PR, Brazil, 1996.

Constant source of avocado moths originating in these small orchards makes manual harvesting ineffective in commercial orchards.

Margarida was less damaged by the avocado moth than Beatriz. Considering the progression of damage in the cultivars throughout the season, pest development in Beatriz contributed to the increased damage observed in Margarida at harvest. Pest control in a more susceptible trap crop (Beatriz) could potentially reduce final pest damage. Panda & Klush (1995) discussed the use of trap plants to manage pest populations in cropping systems, particularly in developing countries. Watson (1924) reported the use of *Crotalaria* spp. to attract green stink bugs, *Nezara viridula* (L.) in citrus orchards, while Nascimento et al. (1986) reported the use of *Cordia verbenacea* (Borraginaceae) to attract *Cratosomus* sp., also in citrus orchards. However, in practice, producers have not used these strategies because cultivation of plants with no economic value results in increased manual labor and management complexity, which makes adoption difficult. In the case of avocado, the plant used as a trap plant is already cultivated as a contrasting avocado pollinizer in orchards.

Spraying the most susceptible cultivar with more selective products could be elected instead of six insecticide applications area-wide, as proposed by Santos et al. (1996, unpublished). Hohmann & Meneguim (1993) reported up to 40% parasitism of avocado moth eggs by *T. pretiosum* and *T. annulata* in the North of Paraná. Parasitoids reared in the laboratory and released on the susceptible cultivars could be a suitable alternative to insecticide applications.

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TIMING AND DISTRIBUTION OF ATTACK BY THE BANANA WEEVIL (COLEOPTERA:CURCULIONIDAE) IN EAST AFRICAN HIGHLAND BANANA (*MUSA* SPP.)

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ABSTRACT

Timing and distribution of attack on East African highland banana (Musa AAA-EA) by the banana weevil, *Cosmopolites sordidus* (Germar), (Coleoptera: Curculionidae) was studied in a field trial at a farm 25 km NE of Kampala, Uganda. Weevils were released at three densities (5, 20 and 40 females per mat) in 324 m^2 banana plots (cv *Atwalira*) that had been established 18 months earlier and maintained relatively free of weevils. Two weeks after release, entire mats were removed and examined for weevil eggs and first instar larvae. At a density of 20 weevils per mat, oviposition oc-

curred on 25% of plants less than 6 six months old (suckers) with an average of three eggs (range 0-16) per infested plant. At the same time, 85% of flowered plants were attacked with mean oviposition of 15 eggs (range 0-41) per plant. An inverse relationship existed between weevil population density and eggs/female/plant. Five females per mat produced an average of 7.2 eggs per flowered plant, whereas 20 females produced 15 eggs per flowered plant and 40 females produced 12.5 eggs. This suggests the existence of density-dependent factors in weevil oviposition. Over 90% of the oviposition occurred in the base of the pseudostem, with the remaining eggs found in the corm and roots near the soil surface. However, in stands displaying high mat, (a condition in which part of the corm appears above the soil surface) more eggs were found on the corm than pseudostem.

Key Words: highland banana, banana weevil, *Cosmopolites sordidus*, high mat, oviposition

RESUMEN

Se estudió la época y distribución del ataque del barrenador del plátano, *Cosmopolites sordidus* (Germar), (Coleoptera: Curculionidae) al plátano de montaña de Africa del Este (Musa AAA-EA) en una plantación ubicada 25 km al NE de Kampala, Uganda. Se liberaron tres densidades de barrenadores (5, 20, y 40 hembras por mata) en lotes de 324 m^2 del cv. Atwalira plantados 18 meses antes y mantenidos relativamente libres de barrenadores. Dos semanas despues de liberar los barrenadores, se examinaron matas completas para determinar la presencia de huevecillos y larvas en primer instar. La densidad de 20 hembras/mata resultó en oviposición (0-16 huevecillos/planta) en 25% de plantas de menos de 6 meses de edad (chupones). El 85% de las plantas con floración fueron atacadas, encontrándose un promedio de 15 huevecillos/planta (rango 0-40 huevecillos/planta). Se encontró una relación inversa entre la densidad de población del barrenador y la cantidad de huevecillos/hembra/mata. La densidad de 5 hembras/mata resultó en un promedio de 7.2 huevecillos/planta florecida, mientras que 20 y 40 hembras/mata produjeron 15 y 12.5 huevecillos/planta florecida, respectivamete. Los resultados sugieren que el nivel de oviposición depende de la densidad de hembras. Mas del 90% de la oviposición ocurrió en la base del pseudotallo, mientras que el resto de los huevecillos se encontró en el cormo y raices cercanas a la superficie del suelo. Sin embargo, en aquellas plantas con cormos ubicados arriba de la superficie del suelo, se encontraron más huevecillos en el cormo que en el pseudotallo.

The banana weevil, *Cosmopolites sordidus* Germar, is a primary production constraint of highland cooking banana (*Musa* AAA-EA) in the Great Lakes region of eastern Africa (Gold et al. 1993; Bosch et al. 1995). Weevil larvae bore into the corm and the lower pseudostem causing mortality of suckers, through snapping and toppling (Wright 1977, Bosch et al. 1995, Rukazambuga 1996). Larvae also interfere with root initiation (Shillingford 1988). Damage is usually greater in ratoon crops (Mitchell 1980, Rukazambuga 1996, Gold 1998) and sustained attack over several crop cycles may prolong maturation rates and reduce yield by up to 60% (Rukazambuga 1996).

All of the indices developed for weevil assessment (Mitchell 1978, Taylor 1991, Gold et al. 1994) evaluate cumulative larval damage in corm residues soon after harvest. None of these methods discern timing of attack. There may be critical developmental periods when plant sensitivity to weevil damage is heightened. If so, two plants displaying similar levels of weevil damage at harvest may differ in yield loss if attack occurred at dissimilar times. Thus, it is critical to gain insight into the timing of weevil attack under natural conditions as a first step towards understanding dam-

age thresholds. At present, no information is available on oviposition preferences for different host phenological stages.

Research results suggest that no single control strategy is likely to provide complete control for banana weevil (Gold 1998). Therefore, a broad integrated pest management (IPM) approach encompassing major components of pest control and plant resistance mechanisms might provide the best chance for success in controlling this pest (Gold 1998). Information on timing and location of weevil attack and vulnerable stages will be essential to the development of any IPM program.

Classical biological control of banana weevil in Africa may be possible. The banana weevil evolved in southeast Asia and is not considered a pest in much of its area of origin (Neuenschwander 1988, Gold 1998). This suggests that natural enemies may be important in the control of the weevil in Asia. Based on the weevil's biology, Neuenschwander (1988) suggests the egg stage may be most vulnerable to natural enemies. Of particular interest would be the possible existence of egg parasitoids. Efficacy of egg parasitoids, in turn, would be affected by egg density, oviposition sites, and exposure of eggs. For example, eggs placed above the soil surface should be more vulnerable to natural enemies than those underground. The objectives of this study were to establish timing of banana weevil attack, and spatial and temporal egg distribution in highland banana plants under field conditions.

Materials and Methods

Site Description

The research was conducted in field trials at Sendusu Farm (0°32' N, 1260 m.a.s.l.) of the International Institute of Tropical Agriculture (IITA) and at the Kawanda Research Station (0°19' N, 1195 m.a.s.l.). Both sites have two rainy seasons (March-May and Sept.-Nov.), with an average precipitation of 1,219 mm per year. Daily mean temperature is 21°C at both sites.

Sendusu trial—timing of weevil attack

The research was carried out in an 18-month-old banana plantation (24 plots of 36 plants each) at Sendusu farm, established in July 1993. Plots consisted of six rows of six mats (cv *Atwalira*, AAA-EA) spaced at 3 m with 20 m grass alleys to minimize weevil movement between plots. The trial was established in a fallow field with no history of recent banana production. Suckers were pared and hot water-treated before planting to remove immature weevil immature stages, which are the main source of infestation in new plantations. At the time of this study, experimental plots contained 25-36 mats with three to seven plants per mat. Plants were characterized as (1) "peeper" (1-3 mo), (2) "maiden suckers" (4-6 mo), (3) "pre-flowered" (7-9 mo), (4) "flowered" and (5) "residues" (standing post-harvest plants). Desuckering was not undertaken for a month prior to weevil release to prevent plant injury. Timing of banana weevil attack, in relation to growth stage, was studied by destructively sampling entire banana mats and determining egg numbers and density on plants at different phenological stages.

Weevil Release and Sampling

Mature weevils were collected from pseudostem traps in farmers' fields in Masaka district (120 km SW of Kampala) and maintained on corm pieces in the IITA entomology laboratory at the Kawanda Research Station for two weeks. Female weevils were

released into plots at densities of 5, 20, or 40 females per mat. Each treatment was replicated twice. The weevils were released during the evening of 1 February 1995 into shallow holes around the base of each mat.

Data from previous trials at the same site suggest that banana weevil movement between plots was limited. In one study, for example, more than 15,000 weevils were marked to identify plot of release. Over a three year period, fewer than 3% of marked weevils captured in pseudostem traps were recovered from plots other than those in which they had been initially released (Gold & Night, unpubl.). Therefore, the number of released weevils which may have moved between plots during the relatively brief period of our study was likely to have been very low. The experiment was repeated in June 1995 using similar treatments and replication numbers.

Sampling commenced two weeks after weevil release and lasted for a three week period during which all mats were sampled. Mats were selected in random order, uprooted in their entirety, and separated into plants grouped by phenological stage. Plant girth at the collar (i.e., junction of pseudostem and corm) and the depth of the collar relative to the soil surface were recorded for each plant. All plants on a mat were sampled.

Since weevil oviposition is relatively low, both eggs and first instar larvae (i.e., < 1.5 mm head capsule width) were counted. Field observations suggested that first instar larvae did not move more than a few cm from eclosion sites. Preliminary observations suggested that few eggs were found more than 10 cm from the plant collar. Therefore, the roots were first inspected for eggs after which the first 10 cm of corm and the first 20 cm of pseudostem (relative to the collar) were gently pared to expose immature weevil stages. The number and location (i.e., root, corm pseudostem, distance from soil surface) of all eggs and first instar larvae were then recorded.

Kawanda trial—influence of high mat on egg distribution

The effect of high mat on weevil egg distribution was studied in an established field trial at the Kawanda Research Station. The trial was planted in November 1991 and consisted of 24 adjacent plots (i.e., no alleys) containing five rows of five plants in a 3 m × 3 m arrangement. Treatments included (1) continuous intercropping with finger millet; (2) control with neither intercrop nor soil amendments; (3) manure placed in planting holes; (4) manure plus continual grass mulching. Weevils were released at a mean rate of 10 males and 10 females per mat in August 1992 and remained high throughout the entire trial (Rukazambuga, 1996).

Egg and first instar larval distribution were studied during the fourth ratoon (April 1996) in the manure plus mulch plots. This treatment was selected because it supported the highest densities of weevil adults (Rukazambuga, 1996) and >60% of the plants had developed high mat. Existing field populations of weevils were used. At the time of sampling, weevil density, using mark and recapture methods (Southwood, 1978), was estimated at a mean density of 30 weevils/mat.

Sampling

Destructive sampling was undertaken on flowered plants. This stage displayed a greater degree of high mat than younger plants and supported the highest levels of weevil eggs. Plants were categorized as "high mat" if the corm appeared above the soil surface or "normal" if the corm was totally covered by soil. Six plants of each category were uprooted in each of the six mulched plots. Distribution of eggs and first instar larvae were recorded with respect to plant location (i.e., root, corm, pseudostem) and position (above or below) relative to the soil surface.

Data analysis included border plants since host stage preferences were likely to be independent of mat location. Egg and first instar larval numbers were combined; hereafter, "egg" refers to these combined values. Chi square analysis indicated that oviposition levels and egg distribution trends were similar for the February and June sampling periods; therefore, analyses (ANOVA) were conducted on pooled data. To stabilize the variance, data on oviposition were transformed to $\log_{10}(x + 1)$. Egg density was estimated as (1) number per plant for each banana stage; (2) total numbers per stage; and (3) numbers per unit pseudostem surface area (i.e., 100 cm^2) presented to gravid females. Surface area was estimated for the first 10 cm of pseudostem (where most oviposition occurred) by treating this section as a cylinder (i.e., girth × 10 cm). Standing post harvest plants on mats are referred to as crop residues and considered as a plant stage in the results.

Oviposition on different host phenological stages was compared through analysis of variance procedures (General Linear Model under SAS) for 1) egg number per plant; 2) egg number per plot and 3) egg density per unit surface area. Presented means are adjusted based on least square means procedure in SAS and compared using standard error. Oviposition per female under field conditions was calculated for the different treatments. Categorical mode regression analysis in SAS was used to determine the probability of a given plant stage being associated with oviposition

A T-test was used to compare the effect of high versus low mat on oviposition. Within each mat condition, egg placement on the corm versus the pseudostem was compared using a matched pair T-test. Egg location relative to the soil surface was estimated as the percentage of total eggs that were encountered above or below the soil surface.

Results

Sendusu trial—Timing of attack

Plants in trial plots were desuckered on a periodic basis such that peepers and maiden suckers were two to three times as abundant as flowered plants at the time of study (Table 1). At each of the three tested pest densities, banana weevils oviposited on all stages of the host plant including crop residues (Table 1). Weevils displayed a preference for older, larger plants with pre-flowered or flowered stages being utilized two to four times more than maiden suckers or peepers (Table 1).

Oviposition was highest on flowered plants and crop residues at all weevil densities (Table 2). Egg number per flowered plant was 2 to 2.4 times that of pre-flowered plants and 8 to 20 times that of peepers and maiden suckers. Adjusting for differential plant number per mat, 10-12% of oviposition occurred on peepers and maiden suckers, 27-34% on pre-flowered plants, 22-37% on flowered plants and 19-32% on crop residues (Table 3).

Egg distribution appeared to be affected by both stage preference and availability. For example, egg number per 100 cm^2 of plant was greatest on crop residues (Table 2) although a higher percentage of total oviposition was on the more abundant pre-flowered plants (Table 3).

Analysis of host plant association with oviposition using categorical mode regression gave probabilities less than 0.5 for peepers and maiden suckers. Pre-flowering plants were associated with an oviposition probability of 0.77, flowered plants with a probability of 0.79 and crop residues with a probability of 0.6. Peepers and maiden suckers carried a negative sign which was an indication of very low association with egg presence.

TABLE 1. EAST AFRICAN HIGHLAND BANANA (*MUSA* AAA-EA) UTILIZATION FOR OVIPOSITION AT THREE DENSITIES OF BANANA WEEVIL FEMALES IN A 2 YEAR OLD BANANA STAND AT SENDUSU RESEARCH FARM, NAMULONGE, UGANDA.

	5		20		40 ♀/mat	
Stage	No./plot	% utilized	No./plot	% utilized	No./plot	% utilized
Peeper	48	21	58	26	54	24
Maiden sucker	26	35	69	36	47	51
Pre-flowered	36	81	53	81	62	77
Flowered	18	78	27	93	17	94
Crop residues	15	67	23	92	25	100

Effect of Weevil Density

Fewest eggs were found following release of 5 females weevils per mat. However, increasing weevil density from 20 to 40 females per mat did not result in corresponding increases in oviposition. Thus treatment means at the two weevil densities were not significantly different (Table 4). Increasing weevil density per mat had little effect on the percentage of plants attacked (Table 1), while egg density per plant (Table 2) and egg number per plot (Table 3) increased only until 20 weevils per mat. Weevil density had a quadratic ($F = 23.66, P < 0.01$) influence on oviposition.

There was a treatment-stage interaction ($F = 3.24, P < .01$) that suggested the number of eggs encountered in different host stages at five females per mat were limited by weevil number (Table 5). Since plant size was similar across treatments, egg density per unit surface area followed the same trends as eggs per plant.

Weevils produced more eggs per female at lower densities. Oviposition averaged 1.4 eggs/female/week at a weevil release density of five females per mat, 0.8 eggs/female/week at a density of 20 females per mat, and 0.5 eggs/female/week at a density of 40 females per mat.

TABLE 2. DISTRIBUTION OF BANANA WEEVIL EGGS PER PLANT IN A 2 YEAR OLD BANANA STAND AT SENDUSU RESEARCH FARM, NAMULONGE, UGANDA (LSMEANS ± SE).

Stage	Eggs	Log_{10} (eggs+1)	Eggs/100cm^2
Peeper	0.6	0.11 ± 0.03	0.16 ± 0.09
Maiden sucker	1.2	0.22 ± 0.03	0.24 ± 0.09
Preflowered	4.5	0.57 ± 0.03	0.75 ± 0.09
Flowered	11.6	0.93 ± 0.04	1.74 ± 0.14
Crop residues	10.1	0.82 ± 0.04	1.93 ± 0.14
F value		108.01**	49.13**

**$P < 0.01$; df = 4, 577.

TABLE 3. DISTRIBUTION OF BANANA WEEVIL EGGS PER PLOT IN A 2 YEAR OLD BANANA STAND AT SENDUSU RESEARCH FARM, NAMULONGE, UGANDA.

	Banana Weevil Eggs/Plot		
Stage	5	20	40 ♀/mat
Peeper	9	12	23
Maiden sucker	8	49	36
Preflowered	61	154	160
Flowered	63	202	107
Crop residues	35	151	158

Oviposition Sites

On a mat basis, 95% of the oviposition was in the pseudostem, 4% in the corm and 1% in roots (Table 6). Weevil density did not affect egg location. On peepers and suckers oviposition never occurred in the roots while only 1 egg was found in the root system of a pre-flowered plant. Most oviposition on the pseudostem was <5 cm above the collar with eggs rarely encountered >15 cm above the plant collar. Oviposition on the corm was usually within five cm from the collar.

In this trial, the collar was, on average, 10 cm below the soil surface for all plant stages. Eggs in peepers and suckers were most commonly found 0-5 cm below the soil surface and rarely above ground (Table 7). In plants more than six months old, oviposition ranged from 10 cm below to 10 cm above the soil surface. Older plants with the collar near the soil surface supported significant above-ground oviposition. As a result, at least 37% of the eggs in flowered plants and crop residues were found close enough to the soil surface to be accessible to natural enemies.

Kawanda trial—Effect of high mat on oviposition

Plants with high mat received more eggs (28.0) than plants without high mat (17.4) ($T = 2.8$; $P < 0.01$). On plants with high mat, more eggs were placed on the corm

TABLE 4. EFFECT OF ADULT BANANA WEEVIL DENSITY ON INTENSITY OF OVIPOSITION PER PLANT IN A 2 YEAR OLD BANANA STAND AT SENDUSU RESEARCH FARM, NAMULONGE, UGANDA (LSMEANS ± SE FOR TRANSFORMED VALUES).

	Eggs per plant		
Weevils/mat	Eggs	Log_{10} (eggs + 1) ± SE	Eggs/100cm^2 ± SE
5	3.19	0.38 ± 0.03	0.57 ± 0.09
20	7.16	0.61 ± 0.03	1.29 ± 0.08
40	6.57	0.59 ± 0.03	1.03 ± 0.09
F value		19.11**	16.23**

** $P < 0.01$; df = 2, 577.

TABLE 5. INFLUENCE OF ADULT BANANA WEEVIL DENSITY AND PLANT PHENOLOGICAL STAGES ON OVIPOSITION PER PLANT IN A 2 YEAR OLD BANANA STAND AT SENDUSU RESEARCH FARM, NAMULONGE, UGANDA (LS MEANS ± SE FOR TRANSFORMED VALUES).

	Eggs per plant					
Stage	5[1]	Log_{10} (eggs + 1)	20[1]	Log_{10} (eggs + 1)	40[1]	Log_{10} (eggs + 1)
Peeper	0.3	0.1 ± 0.05	0.4	0.1 ± 0.04	0.9	0.1 ± 0.05
Maiden suckers	0.6	0.2 ± 0.07	1.6	0.2 ± 0.04	1.6	0.3 ± 0.05
Preflowered	3.3	0.5 ± 0.06	5.8	0.6 ± 0.05	5.3	0.6 ± 0.04
Flowered	7.2	0.7 ± 0.08	15.0	1.0 ± 0.07	12.5	1.0 ± 0.08
Crop residues	4.4	0.5 ± 0.09	13.1	1.0 ± 0.07	12.7	1.0 ± 0.07

[1]Female weevils/mat.

(17.3) than on the pseudostem (10.6) (matched pair T-test 2.6; $P < .01$). By contrast, plants with normal mat had only 33% of the eggs on the corm (5.8) and 67% on the pseudostem (11.6) (matched pair t test 2.8; $P < 0.01$).

DISCUSSION

Plant age was an important factor in determining the number of eggs encountered. Older (i.e., flowered) plants received more eggs than other plant stages. Additionally, egg density per unit surface area of the plant was greater on older plants suggesting that oviposition was not based on random encounter with hosts. Instead, flowered plants were either more easily located or accepted at higher levels than peepers, suckers and pre-flowered plants. Standing crop residues also attracted high levels of oviposition.

TABLE 6. BANANA WEEVIL OVIPOSITION SITES IN A 2 YEAR OLD BANANA STAND AT SENDUSU RESEARCH FARM, NAMULONGE, UGANDA (EGGS PER 10 PLANTS).

	Pseudostem		Corm		
	Distance from collar of				
Plant stage	6-15cm	0-5cm	0-5cm	6-15	Roots
Peeper	0.8	2.2	0	0	0
Maiden sucker	2.9	2.4	0.6	0	0
Preflowered	20.7	29.5	2.9	0.1	0.1
Flowered	50.9	93.4	7.8	0.2	2.9
Crop residues	42.1	69.2	8.8	0	2.9

F value 20.99**; for plant stage- site interaction.
**P < 0.01; df = 16, 1199.
Standard errors: Peeper = 3.5; Maiden sucker = 3.3; Preflowered = 3.4; Flowered = 5.4; Crop Residues = 5.5.

TABLE 7. DISTRIBUTION OF BANANA WEEVIL EGGS IN RELATION TO THE SOIL SURFACE IN A 2 YEAR OLD BANANA STAND AT SENDUSU RESEARCH FARM, NAMULONGE, UGANDA.

	Egg site		
	Soil surface		Paired T-test
Plant stage	Below	Above	T - value
Peeper	0.14	0	2.11*
Maiden sucker	0.15	0.02	2.30*
Preflowered	4.13	2.00	4.71**
Flowered	9.88	5.83	5.39**
Crop residues	9.34	5.55	7.44**

*$P < 0.05$.
**$P < 0.01$; df = 2, 577.

Standing crop residues supported higher egg densities than growing plants although numbers of eggs encountered per plant suggested diminishing levels with time after harvest. The results in this study contrast with those of Gold & Bagabe (1994) in Uganda and our observations in Indonesia where heavy weevil attack was observed on prostrate corms and pseudostems, while little damage was observed on standing (i.e., uncut) residues.

Close examination of banana plants revealed small scars on all plant stages which may have been oviposition chambers or signs of exploratory feeding and in older plants, eggs or first instar larvae were commonly found in or around these scars. Although similar scars were common in peepers and maiden suckers, they rarely contained eggs. This suggests that host plant acceptance may be more important than host plant location in determining egg distribution across different aged plants. If this is true, it remains unclear whether or not host acceptance is related to oviposition stimulants or deterrents.

Although weevil oviposition on peepers and suckers was low, such plants are still highly vulnerable to weevil damage. In many cases, weevil larvae pass from the mother plant into followers through a shared corm. In a heavily infested weevil trial at Kawanda, we observed this type of attack on 46% of suckers. Such attack causes poor sucker growth, early plant death, and contamination of planting material, which is the primary source of infestation of new stands.

The cause of high mat in cooking banana is unclear. In West Africa, high mat in plantain is believed to reflect general plant stress, including low soil fertility and high pest pressure (Swennen 1984). In Uganda, high mat is most common in aging plantations. In this study, corm exposure above the ground increased susceptibility to weevil attack. This would further exacerbate overall plant stress and would likely hasten plantation decline.

Observed egg densities in our study of 0.5-1.4 eggs per female per week suggest that oviposition in the field may be considerably less than that obtained in the laboratory. Differences between our results and laboratory studies might be explained by emigration of adults, failure to detect eggs or reduced fecundity under field conditions. Follow-up studies suggested that weevil emigration was limited (Gold et al. unpubl.). Similarly, we believe that our examination for eggs was quite thorough and that we detected a high percentage of the eggs in study plots.

Thus, it appears that banana weevil fecundity is lower in the field than under laboratory conditions. Oviposition also seems to be affected by density dependent factors (i.e., reduced oviposition per female at higher weevil densities) In our study, total oviposition was similar in plots with 20 versus 40 females per mat. This might help explain why damage estimates may be similar in farms with disparate populations of adult weevils (Gold et al.1997).

The data suggest that banana weevils do not achieve their oviposition potential under field conditions. Density dependent factors may further limit fecundity in highly infested fields. Such reduced fecundity at high densities may contribute to the slow population build-up commonly observed in banana weevil and may also explain the poor relationship observed between weevil adult densities and damage (Rukazambuga 1996; Gold et al. 1997).

ACKNOWLEDGMENTS

Paul Speijer and Daniel Rukazambuga assisted in problem definition and proposal development. Advice on data analysis was given by S. Nokoe. Funding was provided by the Rockefeller Foundation through IITA.

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BOOK REVIEW

HILL, D. S. 1997. The Economic Importance of Insects. Chapman & Hall; London. x + 395 p. ISBN 0-412-49800-6. Hardback. $148.95.

In this book, Hill provides an innovative approach to the treatment of economic entomology. His approach is to provide worldwide taxonomic coverage of economically important insects (and mites but not slugs or snails), with the taxa aggregated under several major pest categories: medical, veterinary, household and stored product, agriculture, and forestry. Each of the major economically important families is discussed briefly. In most cases, specific genera or species are given as examples, accompanied by a few words on geographic range and nature of injury. Chapters on beneficial insects, characteristics of pests, and pest management tactics are also included.

Worldwide coverage of any topic is a difficult undertaking, particularly considering the diversity of insects. However, Hill has admirably identified most of the important taxa. Possibly due to the breadth of the topic, however, precious little text is devoted to any pest or pest group. This book is exceptionally well illustrated with line drawings and black and white photographs showing pests and damage. As an introduction to the taxa causing damage, this book is unsurpassed.

In the introductory section, Hill indicated that an alternative title for this book could be "An introduction to applied entomology," so I tried to envision using this book for an applied entomology course. Perhaps if plant science students were to receive only a single entomology course as part of their curriculum, and there was a strong desire to blend taxonomy with economic entomology, this would serve as a useful text. However, the pest management section is fairly limited, and might need to be supplemented. For example, it would have been appropriate to discuss bait formulations within the pest management section or under the discussion on grasshoppers or cutworms, but it appears nowhere. On a positive note, the treatment of beneficial insects is unusually good.

The traditional economic entomology book focuses on local pests, an unsatisfactory approach for international students, but this book provides a holistic view that will make students from Asia and Africa particularly happy. I believe that most American institutions would want to supplement the reading with local extension material so students would be better equipped to deal with local problems, but this is easy to accomplish. Also, because the text is so taxonomically oriented, a key to the major orders and families, accompanied by laboratory exercises on use of the keys, might be an essential and useful part of a course.

I detected relatively few errors in this book, though of course there are a few factual problems. For example, *Epicauta* beetles are the major blister beetle pests in temperate areas of North America as well as tropical (p. 181); the fruit industry of Florida is worth considerably more than $180 million (p. 357); and though Colorado potato beetle is the major pest of potatoes in many areas of North America and Europe, it is not "the main pest worldwide" (p. 185). Also, there are differences of opinion, such as whether eradication of a pest "should not be done unless really necessary, for the ecological consequences cannot always be predicted." Are the consequences of not eradicating a pest any more predictable? I think not.

On the whole, this book is an excellent addition to the small selection of economic entomology texts available for student use, offering a refreshing, non-chemically oriented view of pests. Though relatively costly, this book should appeal to some instruc-

tors, and may prove to be a useful mechanism to demonstrate the importance of taxonomy to students who otherwise might fail to appreciate its utility.

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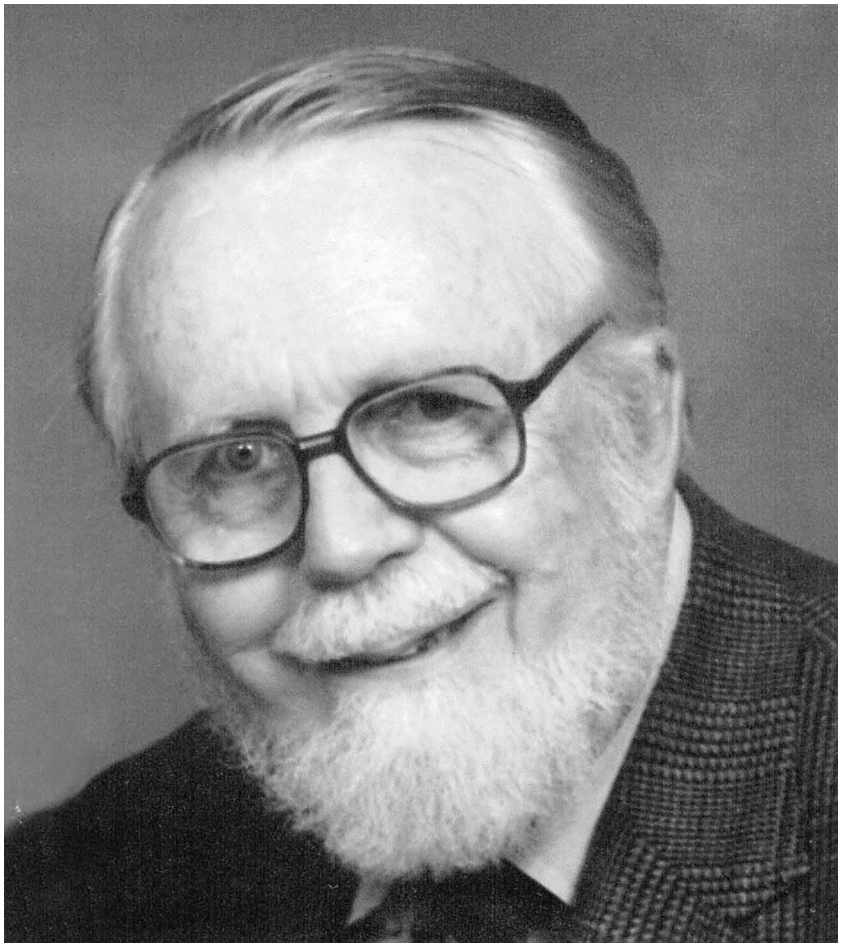
IN MEMORIUM

ROSS HAROLD ARNETT, JR.
1919-1999



Ross Harold Arnett, Jr., a retired Professor, and founder of the Coleopterist's Bulletin, died on July 16, 1999 at his home in Gainesville, Florida.

Ross was born on April 13, 1919 in Medina, New York. His interest in natural history began at the Medina High School, where he graduated in 1938. He attended Cornell University at Ithaca, N.Y., and took courses from Robert Matheson, J. Chester Bradley, W.T.M. Forbes and others. During his sophomore year at Cornell he was given a work desk in one of the graduate student "labs." His interest in insects centered on beetles, and eventually he started a revision of the Nearctic Silphidae. He re-

ceived his Bachelor of Science degree in 1942. He married Mary Ennis, a high school sweetheart on February 16, 1942. After graduation, he took over the job I and my wife held at the New York State Conservation Department, studying the stomach contents of game birds.

In July 1942, he entered the U.S. Army as a private, and was sent to Lowry Air Force Base, studying the Sperry bombsight. He then was sent to the Avon Park Bombing Range in Florida, to survey and control mosquitoes on the range. He then was sent to Panama to teach mosquito taxonomy at the Army School of Malariology. In October 1945 he was discharged as a Technical Sargent, and reentered Cornell as a graduate student. He majored in Medical Entomology under Robert Matheson, and minored in Aquatic Botany under Walter Muenscher. He received his Masters degree in 1946.

For his doctorate, he returned to his original interest in beetles, and started on a revision of the North American Oedemeridae. He finished his Ph.D. in 1948. In the meantime he started the Coleopterist's Bulletin (1947), which he edited for a number of years.

On July 1 1948, Ross and family moved to Arlington, Virginia, and started to work as a beetle taxonomist for the USDA, assigned to the U.S. National Museum, Smithsonian Institution. He missed the academic life, and in August of 1954, he moved to Fairport, N.Y. where he became the Head of the Department of Biology at Saint John Fisher College. By this time his family increased to eight children. In the Fall of 1958, he returned to Washington, D.C. to accept a position at Catholic University of America. In 3½ years he was promoted to full professor and head of the department. He finished the beetle book "Beetles of the United States" in 1963.

In 1966 he received an offer to go to Purdue University to teach insect systematics. The family moved to Lafayette, Indiana. He took a leave of absence to take a three year appointment as a Henry L. Beadel Fellow, at the Tall Timbers Research Station near Tallahassee, Florida. He resigned from Purdue University and in 1973 accepted a teaching position at Siena College, Loudonville, N.Y. In 1979, Ross and Mary decided to strike out on their own. From the income from the "Guide to the Insects" that he and Richard Jacques wrote, they had enough income for a while. Working at this home in Kinderhook, N.Y., he published "The Naturalists' Directory". A short while after, he moved to Baltimore, Maryland, where he worked on his new book "American Insects." In 1982, the family moved to Gainesville, Florida, where he formed a company called Flora and Fauna Publications, which was later purchased by E.J. Brill Publishers, and Ross was retained as an editor. In 1985, Ross and Bob Woodruff organized and incorporated a not-for-profit foundation, "The Center for Systematic Entomology". A new journal, "Insecta Mundi" became the official journal for CSE. In 1989, Brill decided to drop biology, and so Ross was out of a job. He then formed Sandhill Crane Press and was back in publishing. In 1994 he sold his stock of books to St. Lucie Press. He then devoted his time, along with Norville Downie to writing "The Beetles of Northeastern North America". Before his illness, he was working on "American Beetles" A handbook of the beetles of North America, North of Mexico".

Ross was a prolific writer, a superb taxonomist, a good travel companion, and a great friend.

Ross is survived by his wife Mary and eight children and numerous grandchildren.

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PRESIDENTIAL ADDRESS

80TH ANNUAL MEETING OF THE FLORIDA ENTOMOLOGICAL SOCIETY

DAVID G. HALL

It is a privilege and honor to stand before you today as President of the Florida Entomological Society and to open our 80th Annual Meeting. As you know, I accepted the presidential gavel prematurely last fall when newly-installed President Everett Mitchell had to step down due to a serious health problem.

Dr. Mitchell's health had been improving to the point that he planned to attend our annual meeting this year. Everett informed me last week that his doctors wanted to put him in the hospital for further treatments, preventing him from attending our meeting. I am happy to report that Everett's attitude is very positive. I know you will keep him in your prayers.

When I took over this office last fall, Everett had already organized much of what needed to be done, making my job fairly easy—and I got out of the president-elect's responsibility of putting together this year's technical program. That burden shifted to Dr. Joe Funderburk, and he has done a fine job.

Dr. Mitchell once referred to the office of FES President as a coveted position. I certainly agree with Dr. Mitchell. After all, ours is without question one of the finest entomological organizations in the world.

FES is unique in many respects.

Our journal, the *Florida Entomologist*, is one of the most-respected entomological research publications in the U.S. and currently the only entomology journal on the Internet (thank you, Dr. Tom Walker). All major university libraries subscribe to our journal, and it has most fittingly been dubbed "An International Journal for the Americas."

Our Society's Annual Meetings feature excellent scientific presentations and bring internationally acclaimed scientists together each year. We offer the prestigious "Pioneer Lectures" like those you will hear this morning by Dr. Knipling and Mr. Baumhover. In general, FES members share a special camaraderie, and our once-every-five year Caribbean Conference has expanded our base.

At the heart of FES is education, the sharing of information pertaining to arthropods. But our Society's role in education goes beyond the sharing of information through our journal and meetings.

Each year, we encourage students of entomology to present papers at the annual meeting, and the caliber of these student presentations is almost always outstanding (I'll see you at the student paper session on Wednesday). We also offer annual travel grants and mini-grants to students, and two student appointees serve each year on the Society's Executive Committee with full voting privileges.

Another example of our commitment to education is FES support of science fairs. For the second year in a row, Gary Leibee and Moh Ling Kok-Yokomi served as judges to select the best projects in entomology at the Florida State Science and Engineering Fair. Vicky Buckles won the Senior Special Award for her project entitled 'Can the Pattern of *Leucauge venusto* Webs be Used to Indicate Environmental Contamination?' Amanda Rebecca Zeiler won the Junior Special Award for her project "Which Color or Pattern Attracts the Most Insects?' These winners will be present on Wednesday with their projects. Please go by and welcome them.

FES interest and active involvement has increased with respect to educating the general public about entomology. For example, for the second year in a row, FES members participated in the Annual Insect Encounters Exhibition at the Florida State Fair in Tampa. This large exhibit of live arthropods was extremely popular among fair-goers. In particular, I commend Mary Jo Hayes for her leadership in this exhibition.

As another example of our Society's interest in educating the general public, we recently worked with the Department of Entomology & Nematology at the University of Florida to develop an informative poster about insects for primary school students. Many of the posters have been sent to county school districts for distribution among classrooms in Florida.

Each year FES offers an award for an outstanding elementary or high school teacher promoting entomology. This year's award-winning teacher will be honored Wednesday evening at our banquet.

Our Society has been on the right track with respect to education, and we must continue our endeavors in this arena. After all, entomological problems continue to affect our welfare, and by educating each other and the public about these problems, we stand a better chance defeating insects like the medfly, the Formosan termite, the West Indian weevil *Diaprepes,* and the brown citrus aphid. Through education, we stand a better chance of helping the general public implement true IPM programs.

Our excellent journal, our annual meetings, and our commitment to education - these are some of the reasons entomologists like Dr. Mitchell and myself hold so much respect for the Florida Entomological Society. It has truly been an honor for me to have served as President, and I thank you for the privilege.

EDITED MINUTES OF THE 80TH ANNUAL MEETING, FLORIDA ENTOMOLOGICAL SOCIETY

The 1996-97 Annual Business Meeting was called to order by President David Hall at 5:40 p.m., August 5, 1997, at the Adam's Mark Hotel, Daytona Beach, Florida. There were 44 members in attendance. Approval of minutes from the 1996 business meeting held at the Sheraton Sand Key, published in the *Florida Entomologist* 80(1): 105-111, was motioned by Russ Mizell, seconded by Abe White, and unanimously accepted. Final reports from standing committees of the Society were presented. Outgoing President Hall handed the gavel over to incoming President Joe Funderburk. The first 1997-98 Executive Committee meeting was tentatively scheduled to be held September 11, at 10:00 a.m. in Gainesville. The meeting adjourned at 6:50 p.m.

REPORT OF THE BUSINESS MANAGER
JANUARY 1, 1996 TO DECEMBER 31,1996

INCOME:	
Operating Income	
Membership Dues	8,675.00
Subscriptions	7,632.00
Annual Meeting	10,725.00
Miscellaneous	221.64
Total Operating Income	27,253.64
Other Income—Interest Income	3,041.54
Total Income	30,295.18
EXPENSES	
Business Manager Salary	11,693.24
Editor Salary	1,876.95
Other Labor	795.68
Office Expenses	290.99
Postage	354.80
Grants/Scholarships	2,500.00
Journal Printing	1,435.25
Newsletter Expenses	105.98
Editing	1,554.59
Miscellaneous	48.35
Dues and Subscriptions	112.50
Bank Charges	312.38
Student Activities	700.00
Refunds	175.00
Licenses and Permits	61.25
Honors and Awards	302.65
Annual Meeting	10,492.17
Total Expenses	32,811.78
NET INCOME	-2,516.60

TERESA DUCHENE, BUSINESS MANAGER

STANDING COMMITTEE REPORTS

Report of Publications Committee

A total of 629 pages were published in Volume 79 (1996) including: Two Symposia with a total of 15 papers, 45 research reports, 16 scientific notes, 7 book reviews, one In Memoriam, the First Pioneer Lecture Award, the Minutes of the 1995 Annual Meeting and Articles of Incorporation and Revised Bylaws of the Florida Entomological Society. RICHARD BARANOWSKI (CHAIRMAN)

Report of Public Relations Committee

During 1997, the Public Relations Committee began a new procedure of outreach to non-FES members. We were able to submit an announcement of the meeting so that the Bulletin of the Entomological Society of America could list it. This was accomplished just in time to get an announcement in the final issue before the meeting. Also, we constructed a quarter-page ad for the *American Entomologist.* This also was finalized just in time for the issue that shipped about three weeks ahead of the meeting. Apparently, there was positive response, as Dr. Funderburk received additional inquiries from non-members outside of Florida seeking additional information on the 1997 program. Our plans for 1998 include early development of information release through these two conduits, and to announce the FES website address when it becomes available. NANCY EPSKY, HEATHER DILLON, RICHARD J. BRENNER (CHAIRMAN)

Report of Program Committee

The annual program for the Eightieth Annual Meeting of the Florida Entomological Society consisted of 85 oral papers including 48 symposia papers, 12 student competition papers, and 25 submitted papers. Additionally, there were 8 poster papers, a termite workshop and the Pioneer Lecture (E. F. Knipling and A. Baumhover). Symposia topics at the meeting were: Behavioral Ecology; Systematics; *Diaprepes abbreviatus;* urban entomology; and IPM-compatible insecticides. The Presidential Address was given by David Hall. Six full-page advertisements were included in the final printed program, generating $660 to cover costs of printing and mailing. J. FUNDERBURK (CHAIRMAN)

Report of Local Arrangements Committee

The Eightieth Annual Meeting of the Florida Entomological Society was held at the Adam's Mark Hotel in Daytona Beach, FL. There were 158 registrants, 26 of whom were students. A total of 184 attended the banquet. J. SIVINSKI (CHAIRMAN)

Report of 1997 Meeting Site Committee

Keeping in mind that even-year FES annual meetings have traditionally been held on the west coast of Florida, several resort hotels on the Gulf were investigated as potential 1998 meeting sites. These included the Don CeSar in St. Petersburg, the Ritz Carlton in Naples, the Sundial Beach Resort un Sanibel Island, South Seas Plantation on Captiva Island, and Hawk's Cay near Marathon in the Keys.

The Sundial Resort was selected as the 1998 meeting site, to be held August 3-6. The Sundial is located on the Sanibel beach, with 5 large pools and parking very near their 1 or 2 bedroom suites. The main part of the hotel is centrally located and includes several restaurants and an in-house store/deli/gift shop. The Sundial has

locked in all banquet, food and libation prices quoted. The basic room rate will be $95, with 20 executive rooms each for $89 on a first-come-first-serve basis; these room rates include all housecleaning and bellmen tips. The hotel is going to provide a complimentary 1-hour cocktail party which will probably be held as part of our Tuesday evening social. Audio visual equipment will be provided at no additional cost. A contract for the convention was signed and a mandatory $1,000 deposit was given to the hotel—this deposit will be subtracted from the master account at the end of the meeting.

D. G. HALL (CHAIRMAN)

REPORT OF HONORS AND AWARDS COMMITTEE

This year the Florida Entomological Society is proud to recognize and honor 21 individuals for their achievements and contributions to the discipline of entomology and to the Society.

Entomologist-of-the-Year: Everett R. Mitchell

Dr. Everett R. Mitchell is Research Leader for the Behavior and Biological Control research Group, USI)A, ARS, Center for Medical, Agricultural, and Veterinary Entomology, Gainesville, Florida. The creativity and originality in research in the area of behavioral ecology conducted over 25 years by Everett can best be illustrated by the following examples. Everett developed methods necessary for the extraction, isolation, and evaluation of sex pheromones, pheromone mimics, and sex attractant inhibitors for economically important insect groups including *Heliothis, Spodoptera,* and several looper species, among others. Everett also developed practical pheromone delivery systems and trapping devices for several important insect pests which are currently used in the US and elsewhere in basic studies on insect olfaction, reproduction, and behavior, and programs to survey or control crop insect pests. He has formulated the multi-chemical concept of mating control in insect pests via permeation of the atmosphere through the simultaneous application of two or more disruptant chemicals, and subsequently demonstrated the feasibility of this concept against fall armyworm and corn earworm in corn and cabbage looper and diamondback moth in cabbage. Everett also has developed methods for assessing the impact of mating disruptive chemicals on parasitoids of fall and beet armyworms and diamondback moth. He used pheromones to characterize the diurnal behavior of crop insect pests and to determine the seasonality and fluctuations throughout their range. Based upon these data, he proposed a program for managing migrant pests such as armyworms and loopers through imposition of area wide control measures in their overwintering environment. Everett then led a program that identified native parasitoids that exert the greatest impact on fall armyworm in its overwintering refuge. He also conceived, initiated, and directed a program to isolate plant allelochemicals that attract lepidopterous pests to plants and that influence oviposition behavior upon arrival. He also proposed that plant allelochemicals might be the causative agents responsible for inducing the 'impulse to migrate' in many insect species. Everett and his team discovered that *Heliothis* moths are attracted to volatiles from several species of host plants and proposed that attractant chemicals from plants could be admixed with sex pheromones and pesticides, i. e., so-called attracticide baits, to enhance detection, survey, and prediction techniques and possibly for direct control through attract and kill technology. He recently devised a management strategy for diamondback moth using plantings of collards in and around cabbage fields to 'trap' moths coming in from the outside. Naturally occurring parasitoid populations developing in the collards are supplemented with periodic releases of insectary-reared parasitoids. Developing parasitoid populations 'spill' over into the adjacent cabbage where they attack diamond-

back moth larvae. Everett has unselfishly trained graduate students, postdoctural scientists, and visiting scholars, and served the Society while carrying out a research program of distinction. Clearly, Everett has made outstanding contributions to the knowledge of the behavior and management of lepidopterous pests of importance to Florida, to the nation, and worldwide. The Florida Entomological Society proudly presents the Entomologist-of-the-Year Award for 1997 to Dr. Everett R. Mitchell.

Achievement Award for Research: David F. Williams

Dr. David F. Williams of the USDA-ARS-MAVERL, Gainesville, Florida is world renowned for both stable fly and fire ant biology and control. He developed the Williams Stable Fly Trap in the early 70s, which is still the standard for evaluating stable fly populations. David developed the bait systems currently used for imported fire ant control throughout the U. S. His scientific achievements have resulted in technology transfers that have had a tremendous impact on our nation's citizens by reducing the use of pesticide sprays and dusts to control ants, replacing them with baits that do not harm the environment. David's research has been published in more than 150 refereed scientific publications and ten book chapters. He has given more than 300 formal presentations at scientific meetings. His current research is in biological control of urban pest ants and imported fire ants. David has in just two short years made some major discoveries, such as the presence of a microsporidian disease in fire ant populations throughout the southeastern U.S., something that had been looked for more than fifty years by numerous scientists but never recognized. For these contributions to science of entomology the Florida Entomological Society presents the 1997 Achievement Award for Research to Dr. David F. Williams.

Achievement Award for Extension: Joseph L. Knapp

Dr. Joseph L. Knapp of the University of Florida's Citrus Research and Education Center, Lake Alfred, Florida has provided outstanding leadership in the Citrus IPM program for the past 20 years in Florida. He has drawn upon research and technology generated in IFAS and elsewhere, and, if information was not available. conducted the necessary research and applied these data on all classes of pests of Florida citrus. Joe serves as an authoritative source of information on IFAS citrus pest management and IPM research and development for other state, federal, and international agencies. He developed an exemplary program that addresses the most urgent issues of pest management facing the Florida citrus industry. Related pesticide issues dealing with farm worker safety, environmental protection, groundwater contamination and food safety are also factored into the program. Effective response to emergencies (like citrus canker and imported fruitflies) has been essential to his highly successful program. Joe has authored three book chapters, eight refereed and 71 nonrefereed publications, examples of which are the Florida Citrus Integrated Pest and Crop Management Handbook and the Florida Citrus Pest Management Guide which are considered standards for Florida and worldwide citrus production. For these outstanding accomplishments the Florida Entomological Society presents Dr. Joseph L. Knapp with the 1997 Achievement Award for Extension.

Achievement Award for Industry: Dean Remick

Dean Remick has worked in Florida for A. Duda & Sons since 1980, and is currently Manager for crop research and development for their Florida Operations. Dean has been a catalyst for cooperation between growers, chemical industry representatives and IFAS researchers. He was instrumental in the development and adoption of a number of IPM programs on Florida crops, most notably that for control of *Liriomyza* leafminers. Through his efforts, IFAS and industry researchers alike have re-

ceived the cooperation and help of A. Duda & Sons growers in the production and maintenance of test plots, application of test chemicals, and numerous other areas. As a result, many new pest problems have been addressed quickly and effectively. Dean has served the Florida Entomological Society on a number of committees and is currently active in the Florida Fruit and Vegetable Association. He serves on industry advisory committees for both the Department of Entomology and Nematology at the University of Florida and the Everglades Research and Education Center. For his achievements and contributions to Florida agriculture the Florida Entomological Society presents Dean Remick with the 1997 Achievement Award for Industry.

Achievement Award for Team Research: Marjorie A. Hoy and Ru Nguyen

The introduction of citrus leaf miner into Florida in 1993 put the industry into panic, and the impact on foliage production was dramatic. Insecticides were pretty ineffective and potentially disruptive to existing biocontrol programs. Dr. Marjorie A. Hoy of the University of Florida's Department of Entomology and Nematology identified cooperators in Australia, went there to collect parasitoids, and shipped them to Dr. Ru Nguyen of Florida's Department of Plant Industry. They worked together on culture and screening, and then distribution. Marjorie and the DPI staff got approval from USDA to make parasite releases in remarkably short time. With the help of UF and industry cooperators around the state the parasitoids were quickly distributed and established, providing high levels of suppression. Within 3 years the insect has been relegated to minor pest status. This is a remarkable classical biological control success story that demonstrates what good planning and teamwork can do for the Florida citrus industry. Thus, the Florida Entomological Society is proudly presents Dr. Marjorie Hoy and Dr. Ru Nguyen with the 1997 Achievement Award for Team Research.

Achievement Award for Education (K-12): Liana Glanville

Liana Glanville is an exceptionally talented kindergarten teacher who participated in Dr. Donald W. Hall's grant-funded 1994 ecology summer science institute. She also took a 3 credit hour course entitled "Entomology for Elementary School Teachers" from Dr. Hall. Liana has approached the especially challenging task of teaching kindergarten children about science by incorporating both indoor and outdoor hands-on insect activities that introduce students to basic ecological concepts. She has gathered a wide array of insect teaching resources and created some of her own materials for teaching insect biology to these young students. Examples of her teaching include an exercise on ant food preferences and one on microhabitats of insects using pine cones. For her creativity and commitment to education, the Florida Entomological Society proudly presents Liana Glanville with the 1997 Achievement Award for Education (K-12).

Achievement Award for Higher Education: Jerry F. Butler

Dr. Jerry F. Butler of the University of Florida's Department of Entomology and Nematology has been described as one of the most effective faculty members in training graduate students. He has chaired or co-chaired 22 M.S. and 15 Ph.D. committees. As a testimonial to his effectiveness, his students have been very effective at finding jobs and have had successful careers. Jerry has participated for many years in the teaching program at U. F. by assuming responsibility for 50% of the graduate level medical and veterinary entomology courses. More recently, due to the tremendous growth of the undergraduate program in entomology at U. F., he has taken responsibility for teaching multiple sections of the undergraduate medical and veterinary entomology courses. Jerry and the Teaching Assistants he supervises have done an

outstanding job of giving students a quality learning experience in this important field. For his success and dedication in teaching the science of entomology, the Florida Entomological Society presents Dr. Jerry F. Butler with the 1997 Achievement Award for Higher Education.

Presidential Recognition Award: Thomas J. Walker

The Florida Entomological Society recognizes Dr. Thomas J. Walker for exemplary service to the Society and contributions to the profession of entomology for his vision, leadership, and devotion in the publication of the Florida Entomologist on the Internet.

Presidential Recognition Award: Rudolf H. Scheffrahn

The Florida Entomological Society recognizes Dr. Rudolf H. Scheffrahn for exemplary service to the Society and the profession of entomology for arranging and conducting the termite identification workshops at the annual meetings of the Society.

Presidential Recognition Award: David G. Hall

The Society recognizes our outgoing president, Dr. David G. Hall, for outstanding dedicated service as President of the Florida Entomological Society for 1997, culminating in the 80th Annual Meeting.

Recognition of the President: David G. Hall

The Society recognizes our outgoing president, Dr. David G. Hall, for outstanding dedicated service as President of the Florida Entomological Society for 1997, culminating in the 80th Annual Meeting.

Certificates of Appreciation:

Moh Leng Kok-Yokomi for outstanding service to the Society as a Florida Entomological Society Special Awards Judge at the 42nd State Science and Engineering Fair of Florida.

Gary L. Leibee for outstanding service to the Society as a Florida Entomological Society Special Awards Judge at the 42nd State Science and Engineering Fair of Florida.

Clay Scherer for outstanding service to the Florida Entomological Society and the profession of entomology as Student Member of the Executive Committee of the Society.

Lois Wood for outstanding service as Co-Editor of the Newsletter of the Florida Entomological Society.

Nancy Epsky for outstanding service as Co-Editor of the Newsletter of the Florida Entomological Society.

Alan C. Bartlett for outstanding service to the Florida Entomological Society and the profession of entomology as Associate Editor of the Florida Entomologist.

Michael K Hennessey for outstanding service to the Florida Entomological Society and the profession of entomology as Associate Editor of the Florida Entomologist.

Joseph E. Funderburk for exemplary service as Chairman of the Program Committee for the 80th Annual Meeting.

John M. Sivinski for exemplary service as Chairman of the Local Arrangements Committee for the 80th Annual Meeting.

Certificates of Achievement:

Amanda Rebecca Zeiler of Richmond Heights Junior High School, Miami, Florida as the recipient of the Florida Entomological Society Special Award in the Junior Section of the 42nd State Science and Engineering Fair of Florida for her project titled

Which color or pattern attracts the most insects. Amanda's project also won Second Place in the Zoology category at the SSEFF. Amanda received $100 cash and an invitation to the 805' Annual Meeting of the Florida Entomological Society.

Vicky P. Buckles of Palatka High School, Palatka, Florida for outstanding achievement as the recipient of the 1997 Florida Entomological Society Special Award in the Senior Section *of* the 42nd State Science and Engineering Fair of Florida for her project titled *Can the pattern of the* Leucauge venusto *webs be used to indicate environmental contamination.* Vicky's project also won Third Place in the Zoology category at the SSEFF. Vicky received $100 cash and an invitation to the 805' Annual Meeting of the Florida Entomological Society.

F. A. JOHNSON, F. W. HOWARD, G. L. LEIBEE (CHAIRMAN)

REPORT OF RESOLUTIONS COMMITTEE

Resolution No. 1:

WHEREAS the 80th Annual Meeting of the Florida Entomological Society at Adam's Mark Daytona Beach Hotel, Daytona, Florida, has enjoyed outstanding facilities and hospitality which immensely contributed to the success of the meeting,

AND WHEREAS Katherine Travis, City Commissioner, generously gave her time and effort to welcome the Society to the city of Daytona, at the opening of our 80th Annual Meeting,

THEREFORE, BE IT RESOLVED that the Secretary of the Society be instructed to forward a copy of the resolution to Mary Ortiz, Director of Sales, Adam's Mark Hotels and Resorts.

Resolution No. 2:

WHEREAS John Sivinski and the Local Arrangements Committee have provided excellent organization and facilities for the 80th Annual Meeting of the Society,

AND WHEREAS Joe E. Funderburk and the Program Committee have prepared a well-balanced, high quality program for the Society's meeting,

AND WHEREAS the speakers who presented papers, both invited and submitted, shared their outstanding work and ideas with our Society,

AND WHEREAS excellent and timely symposia and workshops were organized by J. Días, J. Eger, J. H. Frank, L. Peterson, R. F. Scheffrahn, J. Sivinski, P. Stansly, and E. Thoms,

AND WHEREAS the committee on Student Activities encouraged excellent student participation in, and contributions to, our Annual Meeting,

THEREFORE BE IT RESOLVED that the Society expresses its deepest appreciation to these individuals.

Resolution No. 3:

WHEREAS Presidents David Hall and Everett R. Mitchell and other members of the Executive Committee have provided our Society with dedicated leadership and invaluable service,

AND WHEREAS Teresa DuChene has done an outstanding job as Business Manager,

AND WHEREAS Richard Baranowski and the Associate Editors of Florida Entomologist have done an exceptional job in maintaining the highest standards for the Society's journal,

AND WHEREAS Lois Wood and Nancy Epsky have excelled in the production of the informative and timely newsletter for the Society,

AND WHEREAS members of other committees and individuals have generously contributed their time and efforts to the Society this past year,

THEREFORE BE IT RESOLVED that the Society commends these individuals and expresses its appreciation for their service to the Society and to the Science of Entomology.

Resolution No. 4.

WHEREAS members of the industry continue to provide much needed financial support to the Society by way of Sustaining Memberships, advertising in the program, support for the journal and numerous other Society functions,

THEREFORE BE IT RESOLVED that the Society hereby expresses its appreciation to these groups. R. SPRENKEL, R. DUNCAN (CHAIRMAN)

REPORT OF FISCAL COMMITTEE

On April 30, 1997, two members of the fiscal committee (Susan Webb and Richard Mankin) met with accountant Robert Respess to discuss procedures for optimizing committee oversight of the Society's financial records. He made the following recommendations:

1. Compare current and previous year statements, looking for major differences. Determine reasons for such differences.
2. Compare income and expense statements with the budget, identifying any problem areas.
3. Pick a month or two at random and match receipts with records of disbursements. Potential items of concern might be checks made to cash, and checks to unfamiliar persons or businesses.
4. The potential for mismanagement is reduced if income is received and recorded by someone other than the person writing checks or if two persons are required to sign checks. Also, the society may wish to impose restrictions on how excess operating funds are spent.

Susan Webb and Richard Mankin presented the accountant's recommendations to the Executive Committee on May 1, and afterwards conducted the annual inspection of the Society financial records with the business manager, Teresa DuChene. No irregularities were found in the records, but a question arose about an apparent 50% decline in the number of memberships between 1995 and 1996. This question will be resolved before the next business meeting.

After discussing the accountant's recommendations with the business manager, the fiscal committee determined that the proposed changes in income collection and check writing procedures would be difficult to implement. The committee does not recommend their adoption. The business manager agreed to begin furnishing quarterly reports to the fiscal committee. Next year she will include comparisons of expenses and income with the budget and with the previous year.

Robert Respess, an accountant who has worked with FES before, is willing to put together a procedure for the annual examination of the financial records of the Society by the Fiscal Committee. This should alleviate the some of the frustration and confusion felt by members of this committee in the past and will ensure that this important task gets done properly. Respess estimates a cost of not much more than $100. The committee would like to meet with him after looking over the procedure he develops. This will result in some additional cost, but we expect that it will take no more than an hour of his time. The Committee requests approval to proceed with this course of action.

We also recommend that, as soon a.s we have made a final decision on a bank, we put one-third of our excess operating funds in a 6-month certificate of deposit, one-third in a 12-month CD, and one-third in an 18-month CD with at least an annual review to evaluate the results and make changes as needed.

RICHARD MANKIN, SUSAN WEBB (CHAIRMAN)

REPORT OF STUDENT ACTIVITIES COMMITTEE

Nine applications were received for the 10 minigrants available. The committee found that all requests were valid and awarded $100 each to Divina Amalin, Julieta Brambila, Yasmin Cardoza, Andy Rasmussen, Dina Richman, Clay Scherer, Alonso Suazo Calix, Christopher Tipping, and Marco Toapanta.

Seven applications were received for travel grants, six for the Florida Entomological Society meeting in Daytona, and one for the Southeastern Branch meeting *of* the Entomological Society of America in Asheville, NC in March 1997. The committee awarded $125 each to: Divina Amalin, Julieta Brambila, Denise Johanowicz, Dini Miller, Andy Rasmussen, Dina Richman, and Juan Villanueva-Jiménez.

Thirteen applications were received for three $500 scholarships. The committee chose three winners despite great difficulty in picking only three from so many well-qualified and deserving applicants. Those receiving scholarships were: Juan Villanueva-Jiménez, Andy Rasmussen and Wendy Meyer. The committee expressed dissatisfaction with the current scholarship criteria and judging sheet. The guidelines for application and the criteria for judging the John Henry Comstock award of the ESA are well outlined and may be less ambiguous than the guidelines and criteria FES currently uses. The drawback to the Comstock guidelines is that preparing packages and judging the packages would be more time consuming than with our current system. The committee will discuss this issue further.

Twelve students competed in the Student Paper competition at the annual meeting. The winners were: Clay Scherer (1st place, $150 award), Dina Richman (2nd place, $125 award), and Juan Villanueva-Jiménez (3rd place, $100 award).

M. HUBBARD, P. NICHOLS, G. HU, H. MCAUSLANE (CHAIRMAN)

AD HOC COMMITTEE REPORTS

REPORT OF COMPUTER RESOURCES COMMITTEE

Florida Entomologist *on WWW continued and improved*

The permanent Web posting of concurrent electronic reprints for all articles published in Florida Entomologist was continued with the cost of $2.40 per page taken from page charges. A major improvement in access was accomplished by posting articles in plain text as well as PDF format. The text files allow search robots, such as those of AltaVista, to index every word in every article. Posting text files began with the June 1996 issue, but only recently have AltaVista robots been induced to index them. If the current system continues to work, full text files of earlier electronically page made issues should be posted-namely, June 1994 to March 1996. [AltaVista has always indexed all words in the tables of contents of Web-posted issues of *Florida Entomologist*. Thus articles in all posted issues can be found by searching with AltaVista for words in the tables of contents, such as names of authors and words in titles.]

Tables of contents made available by e-mail

Sanford Porter volunteered to develop and service a mailing list of those who wish to receive the table of contents by e-mail each time a new issue of *Florida Ento-*

mologist is posted on WWW. He began with the Dec. 1996 issue and has continued with the March and June 1997 issues.

Analysis of subscription trends begun

Library subscriptions may decline if librarians decide that their clients no longer need access to centrally printed issues and bound volumes of *Florida Entomologist.* If this occurs, the Society may wish to change its publication policies. Among possible changes are these: (1) Increase page charges, to compensate for lost subscription revenue. (2) Delay posting of e-reprints for 6 to 18 months, to discourage libraries from dropping their subscriptions. (3) Cease central printing, to substantially reduce publishing costs. However, data provided by Teresa DuChene showed that from 1994 to 1996 institutional subscriptions to *Florida Entomologist* increased from 185 to 190. This 3% increase can be compared with decreases of 12 and 8% for *Journal of Economic Entomology* and *Annals of the Entomological Society of America* for the same three-year period. This analysis of subscription trends will be updated annually.

Back issues of Florida Entomologist *posted on WWW*

At the 16 Jan. 1997 Executive Committee meeting, Tom Walker reported that the $250 appropriated by the Executive Committee to establish the cost of putting back issues of *Florida Entomologist* had been used to hire Phoebe Wilson at $7 per hour. In 36 hours she made PDF files of all articles in the March 1994 and December 1993 issues and HTML files of the two tables of contents. These issues are now on line. She perfected techniques as she worked, and though the two pilot issues cost $0.75 per page to put on line, she can now make $7 per hour by charging $0.65 per page. This means that additional recent back issues can be put on line for about $100 each.

Sponsors for posting issues to be sought

At the 1 May 1997 Executive Committee meeting, Tom Walker presented this plan for putting additional back issues of the *Florida Entomologist* on line:

* For $100, a donor could sponsor an issue and be named and have a hyperlink on the Web table of contents tor that issue. [Some issues would actually cost more than $100 and some less, but this would average out over the first 5 or 10 years of back issues. Eventually the cost per issue would become much less than $100 because earlier issues are much smaller than more recent ones.]
* The initial appeal would go to Sustaining Members and would solicit sponsorship of whole issues.
* A follow-up appeal would be made to authors of articles already on the Internet. These would be asked to give $25 or more to sponsor a quarter issue or more.
* Donors would be credited not only at the tables of contents of issues they sponsored, but also in the Newsletter and in the Society's home page.
* As money is received, issues would be put online starting at Vol. 76, No. 3 (Sep. 1993) and working backward. Only if a sponsor requested a particular back issue would an issue be posted out of sequence.
* Only whole issues would be put on line.

The Executive Committee approved asking Sustaining Members to sponsor issues. The Committee liked the suggestion that the soliciting letter also announce a new, free benefit-namely, that Sustaining Members can hyperlink to sites of their

choosing from their names in the list of Sustaining Members posted on the home pages of the *Florida Entomologist* and the Florida Entomological Society.

In June, Tom Walker asked JSTOR, a nonprofit organization that puts back runs of journals on the Web with full-text indexing, whether they would be interested in doing *Florida Entomologist* for $0.65 per page or less. In July they reported they were behind with other commitments and that their costs were five times greater than the $0.39 per page reported in *Scientific American.*

In late July, Tom Walker sent David Hall a draft of a letter to Sustaining Members announcing their free-hyperlink benefit and soliciting sponsorship of a back issue of *Florida Entomologist.*

Florida Entomological Society home page established

During the year Dick Sprenkel and Jaw-Ching Liu accumulated and organized materials to go on a home page for the Florida Entomological Society, and they found a place for it on the IFAS VAX at http://gnv.ifas.ufl.edu/fes/. Last week, Julia Porter, daughter of Sanford Porter, volunteered to convert the accumulated materials to HTML files and to link them in a logical fashion. On 1 August 1997, the initial version of the FES home page went on the Web. The Society should either find a volunteer to improve and maintain its home page or hire someone to do it. Phoebe Wilson, who maintains several University of Florida Web pages and who did the pilot work on posting back issues of *Florida Entomologist,* is available for $7 per hour.

SANFORD PORTER, RICHARD K. SPRENKEL, JAW-CHING LIU (LEO),
THOMAS J. WALKER, (CHAIRMAN)

REPORT OF PIONEER LECTURE COMMITTEE

Dr. E. F. Knipling, former Director of the Entomology Research Division, Agricultural Research Service and Science Advisor to the ARS Administrator was unanimously elected as the second Lecturer for the Pioneer Lecture Awards Series.

The Screwworm Team that led the successful campaign to eradicate the screwworm fly from Florida was the Committee choice as the second Honoree for the Pioneer Lecture Awards Series.

H. A. DENMARK, D. H. HABECK, A. G. SELHIME, D. F. WILLIAMS, L. M. WRIGH,
C. W. MCCOY, (CHAIRMAN).

EXECUTIVE COMMITTEE MEETINGS
1996-97

October 31, 1996—Gainesville
January 16, 1997—Lake Alfred
May 1, 1997—Gainesville
August 5, 1997—Daytona Beach

These minutes of the 80th Annual Meeting of the Florida Entomological Society were reviewed and accepted by the 1997-98 Executive Committee on September 24, 1998.

JOHN M. PETTI, SECRETARY

PRESIDENTIAL ADDRESS

81ST ANNUAL MEETING OF THE FLORIDA ENTOMOLOGICAL SOCIETY

JOE FUNDERBURK

For over a century, Florida entomologists have made outstanding contributions to entomology as a discipline as well as the livelihood of all citizens of Florida through industry, teaching, research, and service. The Pioneer Lecture Award was begun three years ago as a way of recognizing individuals who were Pioneers of Florida entomology. J. R.Watson was the recipient of the first Pioneer Award. He was a hard-working natural historian despite his responsibilities in economic entomology and administration. As I understand it, his work on thrips was a spare-time interest; yet, he described 101 species. He collected and preserved many thrips, and Dr. Laurence Mound, this year's Pioneer Lecturer, has spent much of the last two weeks sorting and cataloguing the type specimens in the Watson collection housed at the Florida State Collection of Arthropods. Dr. Knipling was the recipient of the second Pioneer Award for eradicating the screwworm from the USA. We are meeting on Sanibel island where the screwworm fly was successfully eradicated in their first experimental trial. This year's Pioneer Awardee is Wilmon Newell. We could not invite someone who knew the man, because the events took place over 50 years ago. He planned and coordinated the first eradication of the Mediterranean fruit fly. He had outstanding abilities as a scientist and administrator, and was honest and dignified in dealing with the politics surrounding the effort. We can only wonder about the impacts on Florida if he had not succeeded.

The Florida Entomological Society has a core membership of entomologists from Florida. This membership is composed of student and professional entomologists with diverse interests and backgrounds. But, our membership is also composed of many scientists from outside Florida. We have a large number of papers in our program authored by scientists from across the USA and other countries. One of the most enjoyable aspects of this meeting is the wide diversity in entomological subjects of the papers. I thank John Sivinski, the symposium organizers, and all the paper presenters for such an outstanding program.

The Florida Entomological Society publishes the *Florida Entomologist*. It is a very high quality journal with scientists from all over the world publishing research papers. A couple of times this year I was called and told that an administrator had questioned the scientific worthiness of publishing in the Journal. One administrator asked where it was "ranked". Finally I went to the University of Florida library to see where it is ranked, and found that it ranked very well with a high impact factor and citation half-life. The journal is roughly equivalent to many well-known international journals such as *Journal of the Australian Entomological Society, Canadian Entomologist, Entomophaga, European Journal of Entomology,* and *Journal of Insect Behavior.* The journal is rated much higher than regional journals such as *The Journal of Entomological Science, Southwest Entomologist, Pan-Pacific Entomologist, Great Lakes Entomologist*, and *The Journal of the Kansas Entomological Society.* The Society voted a few years ago not to change the name of the *Florida Entomologist*. And probably this is a correct decision as it has a proud legacy and is the journal of the Florida Entomological Society. The Society has every reason to be proud of the quality of the journal that it publishes.

The *Florida Entomologist* is accessible and searchable without cost to all Web users. In fact, it was the first entomology journal to put new issues on line. This year the Society decided to put all back issues on line. This was paid for by industry and the University of Florida. Included on the home page of our new web site is a search engine that finds any article. Our objectives as stated in our by-laws are to promote entomology as a science and a profession, to encourage research relative to insects and related arthropods in Florida, to distribute and publicize knowledge pertaining to insects and related arthropods, and to publish the *Florida Entomologist*. Publishing scientific journals has turned into business, and we are making profits on the *Florida Entomologist*. However, the Society is clearly focused on its mission. Unlike most Societies, the Florida Entomological Society is grass-roots and relies most heavily on the intellectual and technical contributions of the members. The Florida Entomological Society is proving to be highly adaptable in a time of rapid change. I encourage the Society to focus on its objectives, rely on volunteers wherever possible, and provide efficient, good service to its members as well as the public in general. No one can predict the future, and who knows the fate of many professional societies. However, I think that our approach is best. The Florida Entomological Society regular membership grew 10% this year, student membership grew 30%, sustaining membership grew 22%, and subscription/institutional membership grew 6%. Despite improving membership service, the Society made several business-related changes to reduce the cost of operating the Society. The Society is in excellent financial condition.

The Florida Entomological Society developed an excellent web site this year. Teresa DuChene our Business Manager is now mailing forms to members asking for new information needed to improve the Society's database. Please return it immediately or e-mail Teresa the information. It will help the Society to improve service and operate more efficiently.

I have owned a butterfly net from my earliest recollections, and I know many of you have carried a butterfly net on occasion. The general public may still view entomologists as eccentric and maybe a little crazy. I think entomologists may be fairly accused of doing a poor job informing the public about entomological issues. I have never encouraged as your President the Society to engage in politics, but we do need to educate the public so informed decisions can be made. The web site is already a great link with public and private institutions providing excellent entomological information over the Web. Our Web site is a great start, but it is just the beginning. Please contribute your knowledge and creativity to improve it for the purpose of informing the public about entomology.

The Florida Entomological Society has a proud legacy and is a great scientific society. I am humbled to be the President. I implore you to take an active part in selecting your leadership for future's sake. And lastly, serving the Society is vital to its future.

EDITED MINUTES OF THE 81ST ANNUAL MEETING, FLORIDA ENTOMOLOGICAL SOCIETY

The 1997-98 Annual Business Meeting was called to order by President Funderburk at 5:15 p.m., August 4, 1998, at the Sundial Beach Resort, Sanibel Island, Florida. There were 42 members in attendance. David Hall filled in as Secretary for John Petti who could not attend the meeting. The 1996-97 Annual Business Meeting Minutes from the Eightieth Annual Meeting held in Daytona could not be approved because the minutes had not yet been printed in the *Florida Entomologist.* Final reports from standing committees of the Society were presented. Out-going President Funderburk handed the gavel over to incoming President John Sivinski. The first 1998-99 Executive Committee meeting was tentatively scheduled to be held September 24 at 1:00 p.m. in Gainesville. No further business was discussed. The meeting adjourned at 6:20 p.m.

REPORT OF THE BUSINESS MANAGER
JANUARY 1, 1997 TO DECEMBER 31, 1997

INCOME:	
Operating Income	
Membership Dues	14,900.00
Subscriptions	5,890.00
Annual Meeting	12,345.00
Miscellaneous	629.71
Total Operating Income	33,764.71
Other Income—Interest Income	5,216.63
Total Income	38,981.34
EXPENSES	
Business Manager Salary	9,166.66
Editor Salary	3,182.72
Office Expenses	1,094.59
Telephone Expenses	677.16
Postage	672.94
Grants/Scholarships	2,775.00
Journal Printing	1,773.29
Newsletter Expenses	259.39
Editing	312.76
Miscellaneous	100.00
Accounting Fee	400.00
Consulting Fee	1,000.00
Dues and Subscriptions	118.75
Bank Charges	15.30
Student Activities	2,150.00
Annual Meeting	19,713.45
Income Tax	1,449.74
Total Expenses	44,861.75
NET INCOME	-5,880.41

TERESA DUCHENE, BUSINESS MANAGER

STANDING COMMITTEE REPORTS

Report of Publications Committee

A total of 499 pages were published in Volume 80 (1997) including: One Symposium with a total of 6 papers, 40 research reports, 5 scientific notes, 15 book reviews, the Minutes of the 1996 Annual Meeting and two errata. One hundred and four research reports and scientific notes were received for publication in 1997. Sixty six have been published, 8 rejected and 30 remain in the peer review process. Dr. Sanford Porter and Dr. Joseph Knapp resigned as Associate Editors and Dr. F. W. Howard and Dr. A. Wheeler have been appointed as Associate Editors.

RICHARD BARANOWSKI (CHAIRMAN)

Report of Public Relations Committee

Our goals this year were to provide timely information on the Florida Entomological Society—particularly regarding the Annual Meeting—to non-FES members to increase our visibility to other professional entomologists, and to the public in general. A announcement of our Annual Meeting was prepared and submitted in January for the Newsletter of the Entomological Society of America. This announcement runs free of charge until the date of the event. A quarter-page advertisement was published in the spring issue of ESA's American Entomologist, announcing the FES Annual Meeting. This ad included a list of symposia, the ant identification workshop, the Pioneer Lecturer, and the FES website address. Finally, in the week preceding the Anual Meeting, e-mail announcements were sent to some major newspapers in Florida. These announcements provided the location and date of the meeting, described symposia topics, provided a link to the FES website, indicated that the entire scientific program could be browsed on the web, and offered the assistance of the Public Relations chairperson in arranging any interviews or in providing additional information.

NANCY EPSKY, HEATHER DILLON, RICHARD J. BRENNER (CHAIRMAN)

Report of Program Committee

The annual program for the Eighty-First Annual Meeting of the Florida Entomological Society consisted of symposia entitled: Behavioral Ecology; Transferring Biointensive Pest Management Technologies; Insects Education and School IPM; Opportunities for Area-Wide Pest Management; and Systematics. In addition there was a Pest Ant Identification Workshop. There were three sessions of regular submitted papers on the topics of Medical & Urban Entomology, Agricultural Entomology, and Ecology & Biocontrol. The poster session included the student winners of the 1998 State Science and Engineering Fair of Florida FES Award. The Pioneer Lecture honoring Wilmon Newell was presented by Lawrence Mound and the Presidential Address was given by Joe Funderburk.

J. SIVINSKI (CHAIRMAN)

Report of Local Arrangements Committee

The Eighty-first Annual Meeting of the Florida Entomological Society was held August 3-6 at the Sundial Beach Resort Hotel in Sanibel Island, FL. A block of 90 rooms were held for pre-registration at the Sundial for the rates of $95.00 for a 1 Bedroom Suite, $165 for a 2 Bedroom Suite and $210 for a 2 Bedroom Suite with Den. Twenty (20) Executive Suites at $89 were available. The society was granted one (1) complimentary room night for each 50 room nights sold. The final determination of complimentary room nights by the hotel to the Society was 5.

A block of 90 rooms were reserved and 97 rooms were reported taken at the Sundial Beach Resort and another 16 rooms were referred to their Sister Hotel, The Sanibel Inn, for overflow. The absolute breakdown for number rooms paid and for which nights was not available at this writing.

The total number of registrants at the conference was 188 Society members and non-members, including 28 student members, 38 spouses/guests and 29 attending the ant workshop.

The Society Reception was co-sponsored by the Hotel and the Society and was very well attended. The Hotel sponsored the first hour of open bar and the Society sponsored the second hour of open bar as well as the mixture of hors d'oeuvres. Appreciation to the Industry Sponsors of the Society that contributed to this event goes to:

AgrEvo Environmental Health	American Cyanamid Co.
Dow AgroSciences LLC	DuPont
Elf Altochem N.A.	Florahome Pest Control, Inc.
Helena Chemical Co.	Monsanto
Novartis Crop Protection	Rhone-Poulenc Sedagri
Thermo Trilogy Corporation	The Scotts Company, Southeastern R&D
Uniroyal Chemical	Zeneca Ag Products

The Awards Banquet Buffet was guaranteed for 150 places and actually served 149 at a negotiated price of $35.00/plate, inclusive of tax & tip. At the time of registration, conferees were asked to confirm their intention to attend the banquet. Tickets for the banquet were distributed to those planning on attending (spouse/guest tickets were priced at $30) and were collected at the door. This greatly facilitated arriving at the guarantee number as well as accounting for the number of dinners actually served.

The newly initiated Student Luncheon with the Pioneer Awards Lecturer, Dr. L. A. Mound, was sponsored by Dow AgroSciences. A total of 19 lunches were served including Dr. Mound and 18 students. The students were given a lunch ticket at time of registration and these were collected as they went through the luncheon buffet line to account for the number served. This lunch was an astounding success by the account of the students, and it is recommended that it be made a regular program feature.

The Past-Presidents breakfast was set for 25 places and was attended by 6 Past-Presidents and 4 guests. It is recommended that the number of place settings provided for be significantly reduced for next year.

Most of the Audio Visual equipment, and the poster boards were provided by the hotel at minimal cost and worked out very well. Two slide scanners were provided by the University of Florida, Quincy. L. G. PETERSON (CHAIRMAN)

REPORT OF 1999 MEETING SITE / CARIBBEAN CONFERENCE COMMITTEES

The site selection representatives for the Florida Entomological Society—Teresa DuChene (Business Manager), Lance Peterson (Vice-President)—visited the prospective 1999 meeting sites in Puerto Rico during June 10th-14th to inspect the three sites offering favorable facilities and room rates. The Caribe Hilton was selected as the site for the 1999 Caribbean Conference of the Florida Entomological Society. This hotel is located near the popular Condado shopping and dining area in San Juan and is close to the Old San Juan historical district. The hotel also has a fine beach, a 17-acre garden, two fresh water swimming pools, several restaurants and good meeting facilities. The meeting dates are set for July 25-19. The standard room rate will be $115. The committee feels the site offers our membership the opportunity for another interesting and memorable Caribbean Conference. Information on the Caribe Hilton and on

activities in Puerto Rico were made available to members at the 1998 Annual Meeting at Sanibel. H. FRANK, J. KNAPP, J. PEÑA, A. WHITE (CHAIRMAN)

REPORT OF MEMBERSHIP COMMITTEE

As of August 3, 1998, we have 367 regular, 72 student, 44 sustaining, and 182 subscription/institutional members. These numbers represented a 10% increase in regular memberships and a 36% increase in student memberships over 1996-97. The committee sent letters to department heads at all biology-oriented departments at all Florida colleges and universities inviting memberships. Half-page ads (free) were placed in the two state trade magazines (PCO and Advantage) associated with the pest control industry. Another free ad was scheduled to appear in "Wingbeats", the official newsletter of the Florida Mosquito Control Assn. A set of guidelines for the Membership Committee was compiled and turned into the Executive Committee.

CLAY SCHERER AND PHIL KOEHLER (CO-CHAIRMEN)

REPORT OF HONORS AND AWARDS COMMITTEE

This year the Florida Entomological Society is proud to recognize and honor 29 individuals for their achievements and contributions to the discipline of entomology and to the Society.

Entomologist-of-the-Year: John L. Capinera

As Chairman of the Department of Entomology and Nematology, University of Florida, John L. Capinera has administrative responsibility for the research, teaching, and extension functions of 31 faculty and approximately 100 undergraduate and 75 graduate students in Gainesville. He also provides disciplinary support for 41 faculty at the research and education centers statewide and represents entomology to state agencies, commodity groups, and the general public. His visionary leadership has resulted in significant enhancement of the research, teaching, and extension functions of our large and complex department. Notably, John has been a leader in encouraging the use of technology (e.g., teaching on the World Wide Web and initiating development of a "Featured Creatures" Web site to serve as an information base on insects for extension and the citizens of Florida). He took faculty development leave to learn more about the extension function of the department. He has also established an industry advisory group to assist the department in being more responsive to the needs of the state. In addition to his administrative responsibilities, John has conducted important grant-funded research in the biological control of vegetable insects and served as major advisor to seven graduate students during the last five years. For his leadership role in entomology throughout the State of Florida, the Florida Entomological Society proudly presents the Entomologist-of-the-Year Award for 1998 to John L. Capinera.

Achievement Award for Research: Dov Borovsky

Dov Borovsky has been studying the physiology of blood feeding by mosquitoes at the Florida Medical Entomology Lab at Vero Beach, Florida. He identified the hormone that regulated digestion in mosquitoes. He was able to clone this hormone and, with the help of William O. Dawson at the Citrus Research and Education Center at Lake Alfred, Florida, use tomato mosaic virus to produce the hormone. Further, he has been able to insert the hormone into *Clorella* algae, which allows not only for propagation but protection from degradation. The patents have been purchased and the product is under the early stages of commercial development. This is a nice in-

stance of how fundamental research can translate into useable products, and likely will result in an entirely new class of insecticides. For these contributions to the science of entomology, the Florida Entomological Society proudly presents the 1998 Achievement Award for Research to Dov Borovsky.

Achievement Award for Extension: John L. Capinera

John L. Capinera took a sabbatical during 1997 to conduct working visits to many of the county extension offices and research and education centers throughout Florida. The purpose of his sabbatical was to gain firsthand knowledge of the strengths and weaknesses of the extension system in Florida, and to improve communication between county extension and the main campus. During his sabbatical he recognized that many county extension agents do not have entomological backgrounds, yet are frequently required to answer entomological questions. Therefore, he established a web page, "Featured Creatures" (GNV.IFAS.UFL.EDU/~INSECT/), for callers. He has continued his involvement with county extension and recently conducted a workshop for master gardeners on insect identification. His commitment and dedication to improving extension entomology greatly benefits the people of Florida. For these outstanding accomplishments, the Florida Entomological Society proudly presents John L. Capinera with the 1998 Achievement Award for Extension.

Achievement Award for Industry: J. B. (Buster) Pratt

Buster has been instrumental over the last five years in assisting the citrus, sugarcane, ornamental and nursery industries fight one of the most important insect pests in the State of Florida, the weevil, *Diaprepes abbreviatus*. Stimulated by the site of citrus groves in central Florida that were dying out due to the weevil, Buster has led the State's fight against the weevil problem. Buster formed the growers' *Diaprepes* Task Force, a group endorsed by the State of Florida through the Office of the Commissioner of Agriculture. Through the Task Force, Buster has devoted countless hours helping growers understand the *Diaprepes* problem and encouraging research entomologists to find solutions. He has worked hard to help University and Governmental administrators understand the economic importance of the weevil. During 1996, Buster and his Task Force campaigned for increased USDA funding toward research on the weevil problem and, as a result, the Federal House Appropriations Committee directed an additional $400,000 annually toward finding a solution to the weevil problem. He has held numerous meetings, workshops, and field days to bring growers, researchers and administrators together to discuss this important pest. For his efforts and dedication in the fight against *Diaprepes abbreviatus*, the Florida Entomological Society proudly presents Buster Pratt with the 1998 Achievement Award for Industry.

Achievement Award for Team Research: Marinus van de Vrie, James F. Price, and Gordon C. DeCou

Marinus van de Vrie, James F. Price, and Gordon C. DeCou were responsible for developing and implementing a biological control program for the management of spider mites on strawberries. The program is based upon scouting, timed releases of predaceous mites, and applications of selective pesticides. During the 1997-98 season, about 13% (800 acres) of the strawberry acreage was under biological control. Another 13% of the acreage was scouted but not under biological control. Without the efforts of this team, no strawberries would be scouted or under biological control. For their significant contributions to the advancement of IPM for strawberries, the Florida Entomological Society proudly presents Marinus van de Vrie, James F. Price, and Gordon C. DeCou with the 1998 Achievement Award for Team Research.

Achievement Award for Education (K-12): Vicki Crisp

Vicki Crisp was a participant in Dr. Donald W. Hall's 1996 NSF-sponsored summer science institute in insect field biology for middle school teachers. Vicki was transferred out of the traditional classroom setting by the Putnam County School Board to her current position as Project Coordinator for the Northeast Florida Educational Consortium. In this capacity, she trains teachers from 19 north Florida counties to teach environmental biology. She also conducts summer science workshops for K-12 children.

Vicki utilizes hands-on insect activities in many of her workshops with both teachers and children. Vicki has been extremely effective in the education of both science teachers and students of north Florida in entomology and environmental education. For her creativity and commitment to education, the Florida Entomological Society proudly presents Vicki Crisp with the 1998 Achievement Award for Education (K-12).

Achievement Award for Higher Education: Paul M. Choate

Paul M. Choate has made major contributions toward the education of 100 undergraduate majors and many of the graduate students in the Department of Entomology and Nematology at the University of Florida. Although it is not part of his job description, he has voluntarily taken responsibility for teaching laboratory sections of both the Principles of Entomology and Insect Classification courses. This has required many hours in addition to his normal assigned responsibilities. He has worked hard to develop laboratory exercises that teach not only content (i.e., facts) but also challenge the students to think. For his dedication and excellent teaching contributions to the profession of entomology, the Florida Entomological Society proudly presents Paul M. Choate with the 1998 Achievement Award for Higher Education.

Presidential Recognition Award: Patrick Greany

The Florida Entomological Society recognizes Patrick Greany for leadership and devotion in the development of the Florida Entomological Society website.

Presidential Recognition Award: Thomas J. Walker

The Florida Entomological Society recognizes Thomas J. Walker for leadership and devotion in the publication of all issues of Florida Entomologist on the Internet.

Presidential Recognition Award: Ellen M. Thoms

The Florida Entomological Society recognizes Ellen M. Thoms for development of the Florida Entomological Society operating guidelines.

Presidential Recognition Award: Joseph E. Eger

The Florida Entomological Society recognizes Joseph E. Eger for development of the Florida Entomological Society operating guidelines.

Presidential Recognition Award: Clayton W. McCoy, Jr.

The Florida Entomological Society recognizes Clayton W. McCoy, Jr. for leadership and devotion in launching the Pioneer Lecture Award.

Recognition of the President: Joseph E. Funderburk

The Society recognizes our outgoing president, Joseph E. Funderburk, for outstanding dedicated service as President of the Florida Entomological Society for 1998, culminating in the 81st Annual Meeting.

Certificates of Appreciation:

Moh Leng Kok-Yokomi for outstanding service to the benefit of the Society and the profession of entomology as Special Awards Judge for the 43rd Annual State Science and Engineering Fair of Florida.

Ellen M. Thoms for outstanding service to the benefit of the Society and the profession of entomology as Special Awards Judge for the 43rd Annual State Science and Engineering Fair of Florida.

Joseph E. Eger for outstanding service to the benefit of the Society and the profession of entomology as Special Awards Judge for the 43rd Annual State Science and Engineering Fair of Florida.

Andrew K. Rasmussen for outstanding service to the benefit of the Society and profession of entomology as Student Member of the Executive Committee.

Christopher Tipping for outstanding service to the benefit of the Society and profession of entomology as Student Member of the Executive Committee.

Lois Wood for outstanding service as Co-Editor of the Newsletter of the Florida Entomological Society.

Nancy Epsky for outstanding service as Co-Editor of the Newsletter of the Florida Entomological Society.

Joseph L. Knapp for outstanding service to the benefit of the Society and profession of entomology as Associate Editor of the Florida Entomologist.

Sanford D. Porter for outstanding service to the benefit of the Society and profession of entomology as Associate Editor of the Florida Entomologist.

John M. Sivinski for exemplary service as Chairman of the Program Committee for the 81st Annual Meeting of the Florida Entomological Society.

Lance G. Peterson for exemplary service as Chairman of the Local Arrangements Committee for the 81st Annual Meeting of the Florida Entomological Society.

Guangye Hu for outstanding service to the benefit of the Society and the profession of entomology as Chairman of the Student Activities Committee.

Jerome A. Hogsette for outstanding service to the Society as Chairman of the Committee for Tax Exempt Status.

Mary Jo Hayes for outstanding service to the benefit of the Society and the profession of entomology as Secretary of Florida Entomological Society.

John M. Petti for outstanding service to the benefit of the Society and the profession of entomology as Secretary of the Florida Entomological Society.

Joseph E. Funderburk for his leadership in guiding the Florida Entomological Society "on-line."

Certificates of Achievement:

Stephanie M. Dodson of St. Michael Lutheran, Fort Myers, Florida for outstanding achievement as recipient of the 1998 Florida Entomological Society Special Award in the Junior Section of the 43rd State Science and Engineering Fair of Florida for her project *How to please the bees*. Stephanie's project also won Second Place in the Behavioral and Social Sciences category at the SSEFF. Stephanie received $100 in cash and an invitation to the 81st Annual Meeting of the Florida Entomological Society.

Vicky P. Buckles of Palatka High School, Palatka, Florida for outstanding achievement as recipient of the 1998 Florida Entomological Society Special Award in the Senior Section of the 43rd State Science and Engineering Fair of Florida for her project *Can the pattern of* Leucauge venusta *webs be used to indicate environmental contamination: phase III*. Vicky's project also won First Place in the Zoology category at the SSEFF. Vicky received $100 in cash and an invitation to the 81st Annual Meeting of the Florida Entomological Society. F. A. JOHNSON, F. W. HOWARD, G. L. LEIBEE (CHAIRMAN)

REPORT OF NOMINATIONS COMMITTEE

The Nominating Committee submitted the following slate of nominees for 1998-99 FES offices:

President:	John Sivinski
President-Elect:	Lance Peterson
Secretary	John Petti
Vice-President	Pat Greany
	Dan Wojcik
Executive Committee Member at Large:	Jim Carpenter
	Julie Stavisky

There were a total of 47 ballots returned from FES members. John Sivinski was elected President, Lance Peterson was elected President-Elect, John Petti was elected Secretary, Pat Greany was elected Vice-President, and Julie Stavisky was elected Executive Committee Member at Large. The Nominating Committee expresses appreciation to all the candidates for their willingness to serve. DAVID G. HALL (CHAIRMAN)

REPORT OF RESOLUTIONS COMMITTEE

Resolution No. 1:

WHEREAS the 81st Annual Meeting of the Florida Entomological Society at Sundial Beach Resort, Sanibel Island, Florida, has enjoyed outstanding facilities and hospitality which immensely contributed to the success of the meeting,

AND WHEREAS Lance Peterson generously gave his time and effort to welcome the Society to the city of Sanibel Island, at the opening of our 81st Annual Meeting,

THEREFORE, BE IT RESOLVED that the Secretary of the Society be instructed to forward a copy of the resolution to Stephanie Stevens , Manager of Catering and Conference Services, Sundial Beach Resort.

Resolution No. 2:

WHEREAS Lance Peterson and the Local Arrangements Committee have provided excellent organization and facilities for the 81st Annual Meeting of the Society,

AND WHEREAS John Sivinski and the Program Committee have prepared a well-balanced, high quality program for the Society's meeting,

AND WHEREAS the speakers who presented papers, both invited and submitted, shared their outstanding work and ideas with our Society,

AND WHEREAS excellent and timely symposia and workshops were organized by R. Brenner, H. Browning, J. Carpenter, L. Davis, J. Eger, Jr., P. Greany, and J. Sivinski,

AND WHEREAS the committee on Student Activities encouraged excellent student participation in, and contributions to, our Annual Meeting,

THEREFORE BE IT RESOLVED that the Society expresses its deepest appreciation to these individuals.

Resolution No. 3:

WHEREAS President Joe Funderburk and other members of the Executive Committee have provided our Society with dedicated leadership and invaluable service,

AND WHEREAS Teresa DuChene has done an outstanding job as Business Manager,

AND WHEREAS Richard Baranowski and the Associate Editors of Florida Entomologist have done an exceptional job in maintaining the highest standards for the Society's journal,

AND WHEREAS Lois Wood and Nancy Epsky have excelled in the production of the informative and timely newsletter for the Society,

AND WHEREAS Pat Greany, Richard Mankin and Tom Walker graciously spent so much of their time designing and implementing the Society's new Internet Web Page,

AND WHEREAS members of other committees and individuals have generously contributed their time and efforts to the Society this past year,

THEREFORE BE IT RESOLVED that the Society commends these individuals and expresses its appreciation for their service to the Society and to the Science of Entomology.

Resolution No. 4:

WHEREAS members of the industry continue to provide much needed financial support to the Society by way of Sustaining Memberships, advertising in the program, support for the journal and numerous other Society functions,

THEREFORE BE IT RESOLVED that the Society hereby expresses its appreciation to these groups. R. SPRENKEL, R. DUNCAN (CHAIRMAN)

REPORT OF FISCAL COMMITTEE

The Fiscal Committee met on April 29 and July 6, 1998 in Gainesville to examine the financial records of the Society for the 1997 fiscal year. The records were found to be in order. We do recommend, however, that documentation for all disbursements be on file, especially for reimbursements of the travel expenses of symposium speakers. The committee suggests that all those being reimbursed should submit original receipts to the Business Manager before receiving a check. The committee thanks the Business Manager, Teresa DuChene, for her cooperation, excellent record-keeping, and sound advice. ROB MEAGHER, JOHN ALTOM, SUSAN WEBB (CHAIRMAN)

REPORT OF STUDENT ACTIVITIES COMMITTEE

Travel grants of $187 each to attend the 1997 Entomological Society of America Annual Meeting in Nashville were awarded to: Denise Johanowicz, Dina Richman, Alonso Suazo-Calix, Juan A. Villanueva-Jimenez, Yasmin J. Cardoza and Tim McCoy. Fifteen applications were received for 1998 Florida Entomological Society Annual Meeting travel grants. The committee found that all travel grant requests were valid and recommended that each student be awarded $100. The awardees were: Juan Alvarez (canceled), Divina Amalin, Deanna Branscome, Jerry Gahlhoff, Hazel Levy, Timothy McCoy, Wendy Meyer, Thomas Powell, Andrew Rasmussen, Dina Richman, Lois Swoboda (canceled), Chris Tipping, Marco Toapanta (canceled), Barbara Vasquez and Yong Zeng.

Fourteen applications were received for 10 minigrants. The committee chose 10 winners and awarded $100 each to: Deanna Branscome, Marco Toapanta, Paul Tinerella, Juan Alvarez, Divina Amalin, Jerry Gahlhoff, Chris Tipping, Timothy McCoy, Yong Zeng and Heather Dillon.

Twelve applications were received for the three $500 scholarships. The committee chose three winners despite great difficulty in picking only three from so many well-qualified and deserving applicants. Those receiving scholarships were: Juan Manuel Alvarez, Wendy L. Meyer and Chris Tipping.

Fourteen papers were judged for the Student Paper competition. The winners were: Dina Richman (3rd place), Barbara Vasquez (2nd place) and Dini Miller (1st place).

Heather McAuslane had twin babies and was unable to judge the student award applications and paper competition. Robert Meagher was chosen as her substitute. Jorge Peña was not able to judge the paper presentations, and John Sivinski was chosen as his substitute. H. MCAUSLANE, J. PEÑA, E. MCCORD, G. HU (CHAIRMAN)

REPORT OF LONG RANGE PLANNING COMMITTEE

The long range planning committee suggests that the following issues need to be addressed by the Executive Committee and where pertinent the Society at large.

1. The duties and function of the Long Range Planning Committee (LRP) should be examined and redefined as necessary. The committee suggests that the LRP be assigned the task of planning for the Caribbean Basin Meetings. This could be addressed in several ways: by having a regular LRP committee and having the ad hoc meeting committee members as automatic special members of LRP; or selecting as LRP committee members people interested in developing the off-shore meetings.

2. The FES should revisit the issue of being a Society and having a journal "for the Americas". Are the present activities and ties to Entomologists in the Caribbean Basin and beyond appropriate and effective or should we change current practices and polices? We ask specifically if our journal publications are appropriately representing "the Americas" and if the Society is effectively fostering the entomology profession and practices off-shore? We observe that the threat of invasive species to Florida from Caribbean countries is one area where it is imperative that we interact with Caribbean scientists.

3. It has been suggested that the timeliness, quality and unusually reflective nature of the symposium presentations (relative to normal scientific discourse) warrant more formal publication in addition to the program title and abstracts. We suggest that the web site might be an appropriate venue for this and suggest that a standard web site subject area and form be developed for those presenters who would be willing to summarize their thoughts for extra-society consumption.

RUSS MIZELL (CHAIRMAN)

AD HOC COMMITTEE REPORTS

REPORT OF NEWSLETTER COMMITTEE

The Newsletter of the Florida Entomological Society is scheduled to appear four times a year, usually during the months of February/March, May/June, August/September, and November/December, to coordinate reporting of Society business conducted at quarterly Executive Committee meetings. At the time this report was written, three Newsletters had been organized and distributed during 1998: the Jan-

uary issue (Volume 12, #4), March issue (Volume 13, #1), and June issue (Volume 13, #2). These were mailed out to members. The Newsletter now appears on the Internet on the Society's Home Page (www.flaentsoc.org). The aforementioned issues as well as March, June and September 1997 issues (Volume 12, #s 1, 2 and 3) are available as PDF files that can be downloaded. While the Newsletter serves as an important role in informing the general membership of the business and activities of the Society and its members, the practicality of sending hard copies (approximately 600) through the mail will need to be addressed in the near future. The editors foresee increases in printing and mailing costs since the University of Florida is changing policies that will directly affect the IFAS print shop and mail room, facilities FES depends on for their respective services. Inclusion of certain items in the Newsletter, for example the minutes of the Executive Committee Meetings, will also need to be discussed in light of the feasibility of posting such information on the Home Page.

NANCY EPSKY, LOIS WOOD (CO-CHAIRMEN)

REPORT OF COMPUTER RESOURCES COMMITTEE

The Computer Resources Committee is pleased to announce the successful development of a new, comprehensive FES website that is essentially a "one-stop-shop" for information pertaining to most of the society's activities. This was accomplished with the cooperation and assistance of the FES Board, Dr. Tom Walker, the Newsletter Editors, and the Public Relations and Program Committees. A commercial website development firm, Colony One Online, was employed to do the actual HTML programming. The site can be found at www.flaentsoc.org. Dr. Richard Mankin has agreed to serve as the webmaster for the site. P. GREANY (CHAIRMAN)

REPORT OF PIONEER LECTURE COMMITTEE

Dr. Wilmon Newell, former Plant Commissioner (1915), Dean of the College of Agriculture, Director of the Florida Agricultural Experiment Station and the Agricultural Extension Division, was unanimously elected as the third Honoree for the Pioneer Lecture Awards Series.

Dr. Laurence Mound, former Deputy Keeper, Department of Entomology (Senior Principal Scientific Officer) (1975) was the choice of the Committee to give the Lecture. J. FUNDERBURK, J. LLOYD, N. LEPPLA, J. SIVINSKI, D. HABECK, C. MCCOY, A. SELHIME, H. DENMARK (CHAIRMAN)

REPORT OF EDUCATION COMMITTEE

The principal activity of the committee during 1997-98 was to organize the entomology exhibit at the State Fair in Tampa, held February 5-16, 1998. Participants were Florida Department of Agriculture, University of Florida, U.S. Department of Agriculture—ARS, and the Florida Mosquito Control Association. The committee will solicit participation from USDA—APHIS next year because invasive organisms are such a timely topic. Also, planning has begun for a poster to replace the popular "Insects - Friend or Foe" poster, which is out of print. The theme will be Insects Unique to Florida. We could use some suggestions on insects to feature, accompanied by photographs and text as well as on ways to finance the new poster. A number of educational computer links were submitted for inclusion on the FES website.

W. DIXON, R. MANKIN, B WOJECK, B. KELLY, L. CUTTS, J. STEWART, M. REEVES, D. HABECK, G. BUCKINGHAM, J. CAPINERA (CHAIRMAN)

Report of Operating Guidelines Committee

The Operating Guidelines Committee completed the initial draft of the Florida Entomological Society Operating Guidelines. The document contains at least preliminary guidelines for almost all of the officers and committees currently operating in the Society. The committee would like to thank President Joe Funderburk and the other 1997-98 officers and committee chairs for their cooperation in assembling these guidelines. The final document contained 131 pages and 25 copies were produced for the incoming officers and committee chairs. The cost of producing these copies was $292.23. D. G. Hall, E. M. Thoms, (Co-Chair), J. E. Eger, Jr. (Co-Chair)

Report of Sustaining Membership Committee

The committee met in Lake Alfred, FL and composed letters for solicitation of new sustaining members and renewal for existing members, for solicitation of monetary support for the FES Annual Mixer, and for support of student scholarships and grants. Over 70 companies or businesses were contacted. The current 43 sustaining memberships were listed in the 1998 program. A total of 14 sustaining members contributed to the FES Annual mixer and the number providing financial support for student scholarships was 9. E. McCord, J. Knapp, K. Griffith (Chairman)

Report of Historical and Necrology Committee

The Historical and Necrology Committee is an ad hoc committee of our Society but might be worthy of being a standing committee. Any FES member who has an interest in joining and working with this committee is welcome to become a member. The year 1996 was really the first year that this committee was up and running. The committee set up a historical photo display at the 1996 annual meeting on Sand Key in Clearwater. The display included photographs of several groups of FES officers during the 1st and 2nd decades of the history of the society. More recent groupings of FES officers, honored members and the like were also displayed. Particularly showcased were Scholarship Program recipients, and other photos and memorabilia that illustrated FES outreach commitment efforts to expand the roles of minorities and women in FES, as well as in entomology in general. Future displays will be presented periodically and will be based on themes chosen the committee. Other future endeavors based on the FES archival photo collection could include such efforts as note card or memo pad production for sale to our members. With respect to necrology, we plan to designate a primary member, as well as a back-up member, responsible for receiving and keeping/developing records of FES members recently deceased. Either of two present members, Howard V. Weems or Susan Broda, would be responsible for reading the memorial list of names at the FES annual meetings. Anyone at this present meting who is aware of FES members whose names were not read at the 1996 Annual Meeting at Daytona Beach, as well as others deceased more recently, please contact either of these two members during the meeting. We on the Committee thank everyone for their assistance in this matter. In conclusion, the Historical and Necrology Committee plans to meet as a group once annually the FES annual meetings. Contacts between the various committee members will be made via telephone or correspondence throughout the intervening year.

H. V. Weems, F. W. Mead, S. Broda-Hydorn (Chairman)

EXECUTIVE COMMITTEE MEETINGS
1997-98

September 11, 1997—Gainesville
December 4, 1997—Gainesville
May 7, 1998—Gainesville
August 3, 1998—Sanibel Island

These minutes of the 81st Annual Meeting of the Florida Entomological Society were reviewed and accepted by the 1998-99 Executive Committee on December 1, 1998. JOHN M. PETTI, SECRETARY

PHOTOGRAPHS FROM THE 81ST ANNUAL MEETING OF THE FLORIDA ENTOMOLOGICAL SOCIETY AUGUST 3-6, 1998 SANIBEL ISLAND

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Fig. 1. Outgoing President Joe Funderburk presents the gavel to incoming President John Sivinski (left).

Fig. 2. President Sivinski presents the Past President's Award to Joe Funderburk in recognition of his outstanding dedicated service as FES President for 1998.

Fig. 3. Tom Walker receives a Presidential Recognition Award for his leadership and devotion in the publication of all back issues of the *Florida Entomologist* on the Internet.

Fig. 4. Joe Eger and Ellen Thoms (not shown) receive Presidential Recognition Awards for development of the Florida Entomological Society Operating Guidelines.

Fig. 5. Pat Greany receives a Presidential Recognition Award for his leadership and devotion in the development of the Florida Entomological Society website.

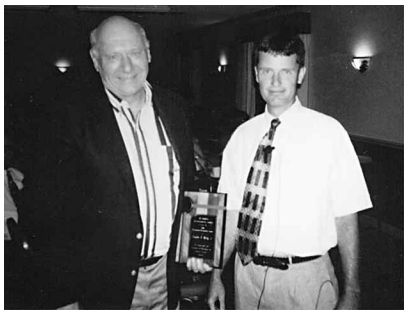

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Fig. 6. Clay McCoy receives a Presidential Recognition Award for his leadership and devotion in launching the Pioneer Lecture Award.

Fig. 7. John Capinera is presented with the 1998 Entomologist-of-the Year Award for his leadership role in entomology throughout the State of Florida.

Fig. 8. J. B. (Buster) Pratt receives the 1998 Achievement Award for Industry for his efforts and dedication in the fight against *Diaprepes abbreviatus*.

Fig. 9. Marinus van de Vrie (left), James Price (not shown), and Gordon DeCou receive the 1998 Achievement Award for Team Research for their contributions to the advancement of IPM for strawberries.

Fig. 10. President Sivinski thanks Gary Leibee for his outstanding service to the Society as Chairman of the Honors and Awards Committee.

Fig. 11. Outgoing President Funderburk is awarded a Certificate of Appreciation for his leadership in guiding the Florida Entomological Society "on-line."

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Fig. 12. Lance Peterson receives a Certificate of Appreciation for exemplary service as Chairman of the Local Arrangements Committee for the 81st Annual Meeting.

Fig. 13. Certificates of Appreciation were awarded to Nancy Epsky (left) and Lois Wood for outstanding service as Co-Editors of the Newsletter of the FES.

Fig. 14. President Sivinski presents a Certificate of Achievement to Stephanie Dodson for winning the Junior Section of FES Special Awards at the 43rd State Science and Engineering Fair of Florida.

Fig. 15. Vicky Buckles receives a Certificate of Achievement for winning the Senior Section of FES Special Awards at the 43rd State Science and Engineering Fair of Florida.

Fig. 16. Dina Richman receives a $100 travel grant and wins 3rd place in the Student Paper Competition.

Fig. 17. Deanna Branscome is awarded one of ten $100 minigrants and receives a $100 travel grant.

All photographs courtesy of Frank Mead

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